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Conference Outcomes Report

Resolving Interference Conflicts among "Highest and Best" Uses of the Radio Spectrum

October 7–8, 2022
Boulder, CO

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In Gratitude

Special thanks to the Silicon Flatirons team—Brad Bernthal, Sara Schnittgrund, Shannon Sturgeon, Christine McCloskey, Katherine Koebel, and Nate Mariotti—for helping host and organize this conference.

Published February 15, 2023

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II. Introduction

As the importance and demand for access to the radio spectrum ("spectrum") continues to increase, identifying the "highest and best" uses of spectrum looms ever larger in the minds of regulators and stakeholders. This increasing focus is due in part to the reality that spectrum allocation decisions are often mired in extended and recurring fights that delay the implementation of new uses and technologies. To foster productive discussions among a wide variety of stakeholders about why these challenges occur and what can be done to remedy them, the Silicon Flatirons Center for Law, Technology, and Entrepreneurship at the University of Colorado Law School held a conference October 7 and 8, 2022. The conference built off the work of Silicon Flatirons' Spectrum Policy Roundtable in March 2022[1] and convened stakeholders from a diverse range of commercial, academic, technical, and regulatory backgrounds to explore the policy, legal, institutional, technical, economic, and social conflicts that arise when multiple interests angle for the same spectrum resources.

> ***"The fact that we have spectrum conflicts – as frustrating as some of them can be – is not itself a sign that something is wrong; it's how we manage them that matters."***
>
> ***—Austin Bonner***

Day One of the conference began with a keynote speech by Austin Bonner of the White House Office of Science and Technology Policy. Bonner's remarks focused on solutions to spectrum conflicts, which she stressed are always inevitable where there are many competing uses, but need not always be intractable. Her suggestions included institutionalizing the conflict-resolution process, enhancing spectrum research and development, creating a common technical manual for Federal users, and investing in human capital to maintain a qualified and competent workforce. The morning continued with a panel focused on the "root causes" of interference conflicts (Topic 1). A second panel convened to address the technical, economic, and regulatory solutions to interference conflicts (Topic 2). Following lunch,

[1] Silicon Flatirons' March 2022 Roundtable was held in Washington, D.C. At the Roundtable, many knowledgeable and well-respected spectrum experts with technical, policy, and commercial backgrounds came together to identify key challenges facing spectrum management. Particular challenges identified by the participants included identifying common language and vocabulary across the field; fostering mutual trust, respect, and collaboration; and "applying advanced technology to enable a future of dynamic spectrum sharing." One of the specific goals of this conference was to address these identified challenges and develop concrete recommendations to resolve them. *See* STACEY WEBER, SILICON FLATIRONS CENTER, RESOLVING INTERFERENCE CONFLICTS AMONG "HIGHEST AND BEST" USES OF RADIO SPECTRUM 3 (2022), https://siliconflatirons.org/wp-content/uploads/2022/07/FY22-Spectrum-Policy-Roundtable-Ouctomes-Report.pdf.

breakout sessions convened on each panel topic to develop recommendations on issues raised during the panels.

The second day of the conference opened with a keynote speech from Thomas Rondeau, Principal Director of FutureG/5G at the Department of Defense Office of the Undersecretary of Defense for Research and Engineering. Rondeau explored the incentives and considerations that decision-makers use to craft spectrum policy. Following the keynote, a panel composed of the breakout-room moderators and student rapporteurs presented and then analyzed the recommendations developed in the Day One breakout rooms. The panel discussion highlighted the critical importance—and difficulty—of developing high-level spectrum management strategy tied to discrete, tangible methods and goals. Finally, the conference wrapped up with a panel of breakout room participants who presented critiques and expansions on the recommendations.

Ultimately, participants agreed that tinkering at the margins—as opposed to wholesale reform-was the preferred approach to adapting spectrum management policy to modern challenges. Themes along these margins included greater stakeholder inclusion, revamped knowledge-gathering strategies, and appropriate congressional involvement. The conversation was undergirded by consensus on the need for more basic data about interference conflicts and spectrum users' operating environments. The data discussion also led to compelling questions about what type of data parties could agree was relevant to characterizing interference disputes. When the groups convened, there was agreement that overlap between the two approaches could be fruitful. Participants in the Topic 2 discussion inquired how institutional policy might support paradigm-shifting technological development, while those from Topic 2 pushed for more coordination and collaboration in research efforts.

The discussion highlighted the notion that there are no discrete solutions to spectrum conflicts; rather, an "all-of-the-above" approach is often best. The policy group recommended a new two-step approach to spectrum allocation: the governing spectrum agencies—the Federal Communications Commission (FCC) and the National Telecommunication and Information Administration (NTIA)—should co-create stakeholder-informed and science-based reports, which they could present to Congress as the final decision-maker to determine which approaches are most in line with the needs of the government, industry, and—most importantly—the American people. The technology group recommended that risk-informed interference analysis become the basis for making spectrum policy decisions.

This report is organized in seven sections. Sections 2 and 3 provide summaries and analyses of the conference's two keynote speeches. Sections 4 and 5 present the panel and breakout discussions for topics 1 (root causes, the policy conversation) and 2 (technical, economic,

and regulatory solutions—the technical conversation). Section 6 presents the panel discussion of the breakout recommendations. Section 7 summarizes the discussion of the wrap-up panel session. Finally, the Section 8 presents a summary and conclusions.

III. Day One Keynote: Austin Bonner

> ***"However acute some of today's hot topics in spectrum may seem, our basic situation is not all that different from the spectrum use challenges of the last hundred years."***
>
> ***—Austin Bonner***

Day One of the conference opened with a keynote address from Austin Bonner, Assistant Director for Spectrum & Telecom Policy at the White House Office of Science and Technology Policy (OSTP).[2] Bonner began her remarks by emphasizing the importance of getting spectrum policy right, given that it is a critical resource with impacts on all facets of modern life. Many of the Biden Administration's policies—such as providing cheaper services for low-income Americans to get online to providing telemedicine, from better extreme weather forecasting to developing better and faster defense systems—implicate spectrum. Therefore, there is a need for a spectrum policy that can respond to those needs promptly and efficiently.

Bonner acknowledged that, where there are many competing uses for a critical public resource like spectrum, conflicts are bound to happen, but that resolving those conflicts fairly and efficiently is an essential part of the policy process. Citing Peter Tenhula's roundtable presentation,[3] she specifically noted that policymakers have had to grapple with two competing roles since the first development of spectrum policy: (1) preventing interference while (2) simultaneously encouraging "the larger and more effective use" of the radio spectrum.[4] In other words, there has always been tension between the needs of existing users and new entrants, and hence there is also a need to mediate the conflicts arising out of that tension.

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[2] OSTP was founded in 1976 by Congress to provide guidance to the President on everything science and technology related "to advance health, prosperity, security, environmental quality, and justice for all Americans." The main goals of the OSTP Tech Team, as stated by Assistant Director Bonner in her keynote, are to ensure that: "(a) government has the tech capacity to effectively deliver its programs and services; (b) policy is informed by tech expertise; and (c) America continues to lead the world in values-driven technological research and innovation." OSTP as a team has relations with many different governmental agencies such as the Federal Communications Commission (FCC), the National Telecommunication and Information Administration (NTIA), the Office of Management and Budget (OMB), and other stakeholders such as Non-Governmental Organizations (NGOs), academia and the technology industry. Austin Bonner, Assistant Director for Spectrum & Telecom Pol'y, White House Off. of Sci. and Tech. Pol'y, Day One Keynote Address at the Silicon Flatirons 2022 Spectrum Policy Initiative Conference 2 (Oct. 6, 2022) [hereinafter Bonner Keynote] (transcript available on Silicon Flatirons website, siliconflatirons.org); for more on OSTP, *see Office of Science and Technology Policy*, THE WHITE HOUSE, https://www.whitehouse.gov/ostp/.

[3] *See* WEBER, *supra* note 1, at 5–7.

[4] Bonner Keynote, *supra* note 2, at 3.

Bonner stressed the high stakes of getting such management decisions right, especially given the downstream effects of every new spectrum decision in a world that is increasingly interconnected and because consumer demand for spectrum-dependent innovations has exploded. To contextualize, she provided some statistical data:

> *Cisco predicts that Internet of Things devices will, at a total of 14.7 billion of them, account for half of all global networked devices by 2023.*[5] *By 2023, Americans are also expected to have an average of 13.6 devices and connections per person*[6]*… Last month, CTIA released its latest annual survey of key wireless trends.*[7] *And they found [1.25x] growth in mobile traffic in [from 2020 to 2021].*[8] *For a longer-term perspective, mobile data traffic in 2021 was more than 100 times bigger than it was in 2010 when President Obama signed his first spectrum Presidential Memorandum.*[9] *Demand for Wi-Fi is just as explosive. Globally, the number of Wi-Fi hotspots will grow fourfold in just the years between 2018 and 2023.*[10]

All that data represents the pressure exerted on the spectrum resource by the explosion in consumer use. Governmental entities at the federal and state level, she added, are just as eager as commercial users to take advantage of wireless innovations that will advance their missions.

Bonner likened the "highest and best" uses of the radio spectrum to that of the real estate industry: mid-rise buildings that formerly covered the Manhattan landscape were considered ideal until the emergence of air-conditioning and elevators, which paved the way for high-rise buildings and thus expanded the boundaries of the highest and best uses of property (and increased the value of those high-rise buildings). Just as circumstances changed for the highest and best uses of property, they do for other resources, too—including spectrum. This fact is especially true in the modern age where rapid technological advancements make change and adaptation imperative. As such, Bonner warned, we should not fool ourselves into thinking that the work of resolving spectrum conflicts will ever be finished.

To the contrary, Bonner argued that parties should embrace the fact that changes occur. No technology stays state-of-the-art forever. Anticipating change does not eliminate the need to raise efficiency standards, to make necessary investments for infrastructure, or to

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[5] CISCO, CISCO ANNUAL INTERNET REPORT (2018–2023) 8 (2020), https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.pdf.
[6] *Id.* at 6.
[7] *See* CTIA, 2022 ANNUAL SURVEY HIGHLIGHTS (Sept. 13, 2022), https://api.ctia.org/wp-content/uploads/2022/09/2022-Annual-Survey.pdf.
[8] *Id.* at 4.
[9] *Id.*
[10] CISCO, *supra* note 5, at 2.

upgrade existing infrastructure. Since spectrum offers enormous economic, social, public safety, and national security benefits, there is a need to be precise but adaptable when it comes to spectrum policy.

In order to do a better job of managing spectrum conflicts through a sustainable system that incentivizes stakeholders to engage with established processes (rather than attempt to circumvent them), Bonner proposed the following recommendations:

1. Institutionalize the conflict-resolution process. One problem frequently identified by stakeholders is the gap between the way that spectrum management is supposed to work on paper and how it functions in practice. To resolve this issue, the government must "institutionalize a trustworthy, predictable process for managing change in spectrum allocations and for resolving disputes."[11]

   To this end, one important step taken by the Biden Administration is the recent Memorandum of Understanding (MOU) between the FCC and NTIA.[12] Together, these agencies are responsible for managing the country's spectrum resources in the public interest, so there is a presumption of cooperation. However, Bonner noted that "operationalizing that cooperation [does not] happen by accident."[13] The new MOU sets out procedures for regular coordination and for ensuring that Federal considerations get to the right place in the process, which sends an important signal to agencies that care about coordination.[14] Of course, she stressed, the MOU alone is not enough: all stakeholders need to be given proper notice and an adequate opportunity to be heard.

2. Enhance spectrum research and development. Innovation can be created through initiatives such as SpectrumX that bring together industry, academia, and government stakeholders to solve spectrum conflicts.[15] The Institute for Telecommunications Sciences (ITS, the research and engineering laboratory for NTIA), addresses other federal agencies' spectrum research needs via Interagency Agreements and directly collaborates with industry and

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[11] Bonner Keynote, *supra* note 2, at 5. This was also one of the recommendations that arose from the breakout sessions, which are discussed in more detail in Section 5.
[12] *See generally* Memorandum of Understanding Between the FCC and NTIA (Aug. 2, 2022), https://docs.fcc.gov/public/attachments/DOC-385867A1.pdf.
[13] Bonner Keynote, *supra* note 2, at 5.
[14] *See* Memorandum of Understanding Between the FCC and NTIA, *supra* note 12.
[15] SpectrumX is a Spectrum Innovation Initiative Center funded by a grant from the National Science Foundation. Their mission is "to become a trusted resource within the spectrum ecosystem offering objective, long-term and innovative policy and technical contributions through collaborative, inclusive and integrative education and research activities."For more, *see About*, SPECTRUMX, https://www.spectrumx.org/about/.

academia.[16] These multilateral relationships are incredibly important, particularly for adding capacity, depth, and resources for the many agencies that need reliable spectrum research but are not in the spectrum management business themselves. As an example of the benefits of such research and collaboration, Bonner suggested the Fast Track Citizens Broadband Radio System (CBRS) exclusion zones. Solid research and testing reduced the zones by 77 percent, allowing CBRS to benefit millions more people—and make a compelling commercial case.[17]

Bonner explained that expanding capacity and adding resources at places like ITS could help resolve spectrum conflicts in two key ways. First, it would generate trustworthy data that can help definitively resolve issues arising from competing claims on interference and guide agencies and other stakeholders to base their assertions on more trustworthy facts. Second, adding more research and development (R&D) capacity would lead to more innovation that then would create new options for policymakers, such as new sharing modalities.

3. Develop a common technical manual for Federal users. Bonner stressed the need for a common handbook that would provide consistent and fact-based standards for all Federal users. She stated that the technical studies she had to work through during her time at the FCC often seemed to conflict with one another, further cementing her belief in the need for a common standards manual containing evidence-based decisions guided by the best available science and data.

4. Pave the way for a qualified and competent workforce. Expertise in the area of spectrum management is essential and the path to that expertise, she argued, is a long path of

> ***"In the fields of science, technology, engineering, and mathematics - fields that are critical to our prosperity, security, and health - our history is filled with examples of how America's ability to attract global talent has spurred path-breaking innovation."***
>
> ***—Austin Bonner***

[16] For more about the Institute for Telecommunications Sciences, *see ITS: The Nation's Spectrum and Communications Lab*, NTIA, https://its.ntia.gov/about-its/its-the-nation-s-spectrum-and-communications-lab/.
[17] *See* E. DROCELLA ET AL., NTIA, 3.5 GHZ EXCLUSION ZONE ANALYSES AND METHODOLOGY, (2015), https://its.ntia.gov/umbraco/surface/download/publication?reportNumber=TR-15-517r1.pdf.

education, training, and mentorship. In that vein, she continued, the Biden Administration has recognized the importance of Science, Technology, Engineering and Mathematics (STEM) skills and, under the guidance of the National Science and Technology Council (NSTC), seeks to achieve three overarching goals: build strong foundations for STEM literacy; increase diversity, equity, and inclusion in STEM; and prepare the STEM workforce for the future.[18] Achieving these goals will position the U.S. as the global leader in STEM literacy, innovation, and employment. She drew attention to the Aspen Institute's *Toward a National Spectrum Strategy*,[19] which advocates for education programs for non-engineering staff to make them fluent in the latest technical developments in spectrum management. She also added that attracting global talent to the U.S. would augment these efforts.

Finally, after outlining these recommendations, Bonner stressed the need for strong and values-driven leadership that can cut through institutional conflict, keep the focus on shared values, and bring conflicting parties to a reliable space for negotiation as an idea that would prevent spectrum conflicts from growing into institutional conflicts that make future spectrum challenges even harder to address.

[18] *See generally* OSTP, PROGRESS REPORT ON THE IMPLEMENTATION OF THE FEDERAL STEM EDUCATION STRATEGIC PLAN (Dec. 2021), https://www.whitehouse.gov/wp-content/uploads/2022/01/2021-CoSTEM-Progress-Report-OSTP.pdf.
[19] *See Toward a National Spectrum Strategy*, ASPEN INST. (Sept. 15, 2022), https://www.aspeninstitute.org/publications/toward-a-national-spectrum-strategy/.

IV. Day Two Keynote: Thomas Rondeau

Day Two kicked off with a keynote address from Thomas Rondeau, the Principal Director for FutureG/5G, United States Department of Defense (DOD), Office of the Undersecretary of Defense for Research & Engineering (OUSD(R&E)).[20] Director Rondeau focused his speech on spectrum policy, incentives, and decision-makers.

> ***"'… love of liberty means guarding every resource that makes freedom possible. From the sanctity of our families, and the wealth of our soil, to the genius of our scientists.' [Quote from Eisenhower's inaugural speech] And I love the fact that he put the scientist in there because I suddenly feel like he's speaking to me."***
>
> ***—Thomas Rondeau***

Rondeau stated that the clarity of mission—here, supporting national defense—drives the decisions he makes and pushes technology forward. Referring to Eisenhower's National Interstate and Defense Highways Act of 1956,[21] which created the interstate highway system, Rondeau drew attention to the fact that even in building a highway system, defense was at the forefront of the decision-makers' minds. He emphasized that the things that are going to keep us safe and successful as a country are interrelated, such as the building of the highway system that involved safety, economics, and national security concerns wrapped up together.

Rondeau then gave an overview of the 5G Initiative.[22] Congress gave the responsibility for the project to the DOD, which in turn announced a $600 million investment in award contracts.[23] At the time, this was the largest single public investment in 5G technology.[24] The goal of this investment was to incentivize 5G as well as to make the U.S. more competitive globally. The Initiative has since rolled out 5G installations at sixteen military bases across the U.S., creating test beds and infrastructure for use in experiments and in developing new

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[20] For more about the FutureG/5G Program and the Office of the Undersecretary of Defense for Research and Engineering, *see Critical Technology Areas*, OUSD(R&E), https://www.cto.mil/usdre-strat-vision-critical-tech-areas/.
[21] *See* National Interstate and Defense Highways Act of 1956, 70 Stat. 374 et seq. (1956).
[22] For more on the 5G initiative, *see generally Advancing 5G Communications for America's Warfighters*, OUSD(R&E), https://www.cto.mil/5g/.
[23] *See* Press Release, DOD, DOD Announces $600 Million for 5G Experimentation and Testing at Five Installations (Oct. 8, 2020), https://www.defense.gov/News/Releases/Release/Article/2376743/dod-announces-600-million-for-5g-experimentation-and-testing-at-five-installati/.
[24] *Id.*

applications.[25] While the focus was on the military (specifically on new warfighting applications), Rondeau stressed that the Initiative has always had a dual use in mind that also encompasses commercial applications and markets. After all, Rondeau noted, the DOD's investment in 5G is and will remain dwarfed by that of private industry.

Rondeau drew attention to his belief that open architectures and virtualization are important because breaking open some of these architectures is the way to create a new space for innovation and security. Open, transparent, and secure technologies, which would enable better understanding and monitoring of what goes on inside networks and devices, are essential components of modern systems. But those goals must be balanced with goals such as data privacy, constituting competing objectives. He stated that the U.S. has offloaded some aspects of virtualization, specifically manufacturing technologies to other countries. However, the U.S. is particularly competent at software and services, so managing this technology space is one of the Initiative's focus areas. He also noted that security covers a wide range of issues from cybersecurity to supply chain to the threat of radio frequency (RF) attacks. Securing 5G then, Rondeau offered, is a multi-layered task that needs to take all threats and interference into account.

> ***"[P]eople say we need to secure 5G. How are you going to secure 5G? And unfortunately, that is the question at hand, but it's the wrong question because if you really go down into it, you can never secure something. You can make things more secure."***
>
> ***—Thomas Rondeau***

Rondeau's presentation also highlighted another exciting area of interest: zero trust architecture (ZTA), which is a process and a set of protocols that can be put in place to strengthen the security of 5G.[26] He stated that he is working closely with the DOD's Chief Information Office on this topic. Mindful of the nuances in this area, Rondeau posed the question of how the DOD should be engaged in the standards bodies without coming off as too heavy-handed, given the importance of international interagency collaboration.

Rondeau then talked about the 5G experiments being conducted across 16 different bases in the U.S. He added that each experiment location was chosen for different reasons and covered different

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[25] Thomas Rondeau, Day Two Keynote Presentation at the Silicon Flatirons 2022 Spectrum Policy Initiative Conference (Oct. 7, 2022) (redacted presentation slides available on the Silicon Flatirons website, siliconflatirons.org).
[26] For more detail on ZTA, *see* SCOTT ROSE ET AL., NIST, ZERO TRUST ARCHITECTURE, (2020), https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-207.pdf.

geographies, and that all military services—Army, Navy, Air Force, Marine Corps, and Joint Bases—were involved. One important application being pursued in these experiments is smart warehousing logistics. Logistics, Rondeau joked, may be boring when talking about military strategy, but is also the key to winning wars.

"[I]f you've been on one Navy ship, you've been on exactly one Navy ship. Every one of them is different. The infrastructure is different, the build-out is different,"[27] Rondeau said while drawing attention to the critical role of getting those different ships tied into the enterprise infrastructure. Taking advantage of 5G and putting it into practice with these unique ships is as exciting as it is critical for the US to continue to lead the world in innovation.

5G, to Rondeau, means more bandwidth, higher data rates, lower latency, greater connectivity and density of the devices, a local edge computing model, and the network slicing all combined together. Each of these elements have been done before individually, but never all together. As an example of these combinations, Rondeau discussed Augmented Reality / Virtual Reality (AR/VR) because these two capabilities require both high bandwidth and low latency. He asked the audience to consider how to use an AR/VR system for an operational training environment, such as by converting an ordinary room into a beachhead that soldiers could storm.

As another example of the need for high bandwidth, Rondeau brought up the F-35 fighter. The F35 is one of the most impressive sensor platforms in the world because, on each individual mission, the aircraft often pulls more data from its environment than the DOD can manage.[28] Downloading and processing the vast amounts of information it collects and then using that information to manage whatever threats might exist on the next mission is critical. These threats might include electronic targets, radar systems, and other spectrum-based systems. Dealing in a timely manner with the gigabytes of data involved highlights the need for the extremely high bandwidth promised by 5G technologies.

Camp Pendleton (Expeditionary Advanced Base Operations, or EABO) was a third example that Rondeau gave that involves all kinds of spectrum-related issues. EABO essentially involves Marines hopping from island to island carrying out their missions without being targetable.[29] EABO requires the ability to ramp up comms, mobile

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[27] Silicon Flatirons, 2022 Spectrum Policy Initiative Conference Transcript 67 (2022), https://siliconflatirons.org/wp-content/uploads/2022/12/Transcript_2022-10-07_Spectrum-Conference.pdf [hereinafter Conference Transcript].
[28] For more about the F-35's sensors, *see* Nick Zazulia, *F-35 Data Fusion: How the Smartest Fighter Shares What it Sees*, AVIATION TODAY (Sept. 4, 2018), https://www.aviationtoday.com/2018/09/04/f-35-data-fusion/.
[29] *See Expeditionary Advanced Base Operations (EABO)*, U.S. MARINES (Aug. 2, 2021), https://www.marines.mil/News/News-Display/Article/2708120/expeditionary-advanced-

base defense systems, sensors, and perception of the world around the operation. All these actions historically required days, but ideally need to be executed within minutes and require highly reliable, multiply-connected devices that are all communicating and using that spectrum—a stress-test for DOD use of 5G.

Rondeau reiterated the importance of communication in a safe, fast, and secure manner that enables rapid understanding of what happens in the field, such as at the US military bases across the globe, and enables a rapid response. In other words, managing critical communication traffic in both directions constitutes a vital spectrum policy goal. Rondeau drew attention to the importance of deploying private networks for internal communications that are integrated with the enterprise and stated that this was probably the most difficult part of his portfolio. He also added that non-terrestrial networks are becoming a key component of future-generation technologies of which DOD wants to be at the forefront.

Rondeau referenced the innovation space for the internet in the 1980's and 1990's to emphasize his belief in the need for creating an open space and technology base for innovation and new ideas in 5G and beyond. He stated that transferring that kind of creative energy to the wireless networking world could have immense benefits and that his Deputy Principal Director, Amanda Toman, has been pushing on open interfaces, working in particular with Open Radio Access Network (O-RAN).[30] Studying interfaces and connecting different vendor devices could pave the way for a well-built system.

When the Defense Advanced Research Projects Agency (DARPA) and OUSD(R&E) collaborated on defining what they wanted to do with 5G, Rondeau said, they worked together to find projects to create open source technologies, open source software, and to create innovation space. The advantage of open-sourcing the software stack that goes on top of the hardware, he continued, is that it gives us more insight and more ability to observe what's happening in there, which then enables us to create better technologies and more secure systems.

Rondeau mentioned the Multisite OPS-5G Joint Independent Testing Option (MOJITO)[31] as an exciting possibility to put open source cores in multiple installations of the 16 military experimentation bases across the United States. He argued that "if we can actually connect all of these together through these cores, have multiple cores, but all

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base-operations-eabo/#:~:text=Expeditionary%20Advanced%20Base%20Operations%20is,inshore%20within%20a%20contested%20or.

[30] For more about O-RAN, *see* O-RAN ALL., https://www.o-ran.org/.

[31] For more on MOJITO, *see* DARPA Presentation on "Open Programmable Secure 5G (OPS-5G) Overview and Use Cases (Mar. 31, 2021), https://wiki.onap.org/download/attachments/92999805/Linux%20Foundation%20Use%20Case.pdf?version=1&modificationDate=1617200355000&api=v2.

actually jointly networked together, we can start scaling our experiments that can represent real data, real traffic, and real problems in the real world," thus opening up exciting new capabilities.[32]

Rondeau concluded by re-emphasizing that DOD needs to figure out how to use 5G. DOD has been successful in pushing the technology and incentivizing commercial companies. Next year and beyond, he hoped, should really show some exciting new capabilities.

[32] Conference Transcript, *supra* note 27, at 72.

V. Topic 1: Root Causes of Interference

> ***"So I'll raise this as a provocative question: is part of the problem we have - one of our root causes - that we no longer have final answers in spectrum policy?"***
> ***—David Redl***

One of spectrum management's most pervasive and vexatious challenges is resolving conflicts arising out of interference between users—whether commercial, federal, scientific, or otherwise. The wildly varying mission-dependent needs of spectrum users mandate treatment of interference issues at all stages of the process and must be created to comport with policy, legal, and societal perspectives. The importance of developing solutions to interference issues spawned the first central topic of the conference: identifying and addressing the "root causes" of interference conflicts.

To kick off the discussion on root causes, David Redl, Founder and Chief Executive Officer (CEO) of Salt Point Strategies[33] and former Assistant Secretary for Communications and Information at the U.S. Department of Commerce and NTIA Administrator, led a panel of four field experts representing several unique stakeholder perspectives. After the panelists teased out many of the key points of interest, the conference proceeded to a breakout session under the "Chatham House Rule,"[34] where the panelists, invited participants, and the audience engaged in a free-form discussion about the themes and ideas of the panel. By the end of the breakout session, the group identified several key recommendations that they felt were most appropriate to address the issue of root causes.

Silicon Flatirons' February Spectrum Policy Roundtable identified "institutional conflict"—primarily between the FCC and NTIA—as both a cause and a product of spectrum conflict.[35] The roundtable noted the lack of common understandings of many key topics such as harmful interference, efficiency, and effectiveness. Currently, each individual stakeholder (whether government, scientific, or commercial) is often only sensitive to its own mission-driven understanding of these topics; moreover, the FCC and NTIA are often only sensitive to their own

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33 For more about Salt Point Strategies, *see What We Do*, Salt Point Strategies, https://www.saltpointstrategies.com/#whatwedo.
34 Chatham House Rule mandates anonymity of the participants in the discussion to encourage the trusted and uncensored flow of information within the group. All content may be shared out, but no identities can be attached. As such, the breakout sessions were not recorded and all discussion of breakout-room content in this report will be unattributed. *See Chatham House Rule*, CHATHAM HOUSE, https://www.chathamhouse.org/about-us/chatham-house-rule#:~:text=The%20Rule%20reads%20as%20follows,other%20participant%2C%20may%20be%20revealed.
35 WEBER, *supra* note 1, at 10.

constituents' concerns, yet are tasked with joint responsibility for administration over different parts of spectrum.[36] The development of methods to reconcile these institutional conflicts was a fundamental concern of the roundtable and formed the basis of the root causes topic at the conference.

Panel Discussion

> ***"When I say 'efficiency,' I'm not saying 'reduce the effectiveness of your mission,' I'm just saying 'might there be a way that you can achieve your mission—maybe even better—but using a smaller spectrum footprint.'"***
>
> ***—Tom Power***

In keeping with the theme, Redl kicked off the root causes panel discussion with a question that struck straight at the heart of the issue of disparate understandings: "what," he asked, "do you consider harmful interference when you're looking at new uses?"[37] Panelists' answers immediately revealed the scope of the issue. For example, Jordan Gerth of the National Oceanic and Atmospheric Administration (NOAA)[38] noted that some in the weather science community "feel that all interference is harmful" because of the need for the "highest quality observations" from their sensitive equipment to provide the "best weather forecast possible."[39] By contrast, Lockheed Martin's[40] Jennifer Warren and CTIA's[41] Tom Power highlighted the need for a mission-driven, case-by-case approach because "there is no one-size-fits-all" solution.[42] Striking the middle ground, Greg Guice of Public Knowledge[43] emphasized the difference between "harmful" interference and "actionable" interference; that is, interference that is sufficient to spur conflict and remediation efforts between parties (perhaps involving the agencies along the way).[44]

These three perspectives on the issue of harmful interference highlighted the key concern of the panel that the lack of a common understanding—or perhaps stakeholders' unwillingness to anticipate or accept alternative understandings—was often one of the primary factors

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[36] *Id.*
[37] Conference Transcript, *supra* note 27, at 15.
[38] For more about NOAA, *see About our agency*, NOAA, https://www.noaa.gov/about-our-agency.
[39] Conference Transcript, *supra* note 27, at 15.
[40] For more about Lockheed Martin, *see About Lockheed Martin*, LOCKHEED MARTIN, https://www.lockheedmartin.com/en-us/who-we-are.html.
[41] For more about CTIA, *see Our Mission*, CTIA, https://www.ctia.org/about-ctia/our-mission.
[42] Conference Transcript, *supra* note 27, at 18.
[43] For more about Public Knowledge, *see About Us*, PUB. KNOWLEDGE, https://publicknowledge.org/about-us/.
[44] Conference Transcript, *supra* note 27, at 16.

leading to late-stage and highly-publicized interference battles such as L-Band and C-Band.[45] Panelists noted that one common reason for differing levels of interference tolerance for certain types of stakeholders is a result of outdated technologies. However, whereas some stakeholders—such as many commercial entities—are incentivized to adopt new technologies as they come, others prefer to wait until they can guarantee that their systems are "technologically mature."[46] For example, Warren noted that the DOD and government contractors "don't want to be replacing systems that aren't a technology readiness level of a 9" when matters of national security are at stake.[47]

The questions surrounding the adoption of technology also drew out another area of inter-stakeholder misunderstanding: measuring efficiency and effectiveness. Power called for a definition of efficiency that focused on concrete measurements of spectrum usage: "when I say 'efficiency,' I'm not saying 'reduce the effectiveness of your mission,' I'm just saying 'might there be a way that you can achieve your mission—maybe even better—but using a smaller spectrum footprint."[48] Warren expressed disagreement, highlighting the fact that the correlation between efficiency and a smaller spectrum footprint isn't always accurate or appropriate. In fact, she argued, this lack of correlation is one of the primary reasons that spectrum sharing has become more prevalent in recent years. Redl queried whether certain "externalities" such as privacy or national security have become ingrained in our assessment of efficiency. While panelists suggested not, they left open for discussion whether those externalities should be brought into the fold to capture a broader idea of efficiency than that currently considered by commercial entities and, often, Congress.

Discussion surrounding the reasons for common areas of misunderstanding led to the identification of another key root cause: disparate timelines for spectrum-dependent systems. Redl noted that "you've got satellite missions that are in the tens of years. You've got the [Congressional Budget Office (CBO)] looking at ten years, and you've got the wireless industry iterating multiple times in a decade."[49] Redl pointed to the discussion on receiver standards as a salient example of the impacts of these disparate timelines. Running with the

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[45] For more detail on the C-Band "fiasco" (approximately the range between 4 GHz and 8 GHz), *see* Peter Elkind, *Inside the Government Fiasco That Nearly Closed the U.S. Air System*, PROPUBLICA (May 26, 2022, 5:00 AM), https://www.propublica.org/article/fcc-faa-5g-planes-trump-biden. For more on the L-Band issue (especially 1.5 GHz to 1.6 GHz), *see* Chris Gibbs, *LightSquared rebrands as Ligado Networks but spectrum plans remain cloudy*, FIERCE WIRELESS (Feb. 9, 2016, 6:56 PM), https://www.fiercewireless.com/wireless/lightsquared-rebrands-as-ligado-networks-but-spectrum-plans-remain-cloudy.

[46] Conference Transcript, *supra* note 27, at 19.

[47] *Id.*

[48] *Id.* at 31.

[49] *Id.* at 20; see also *Budget and Economic Data*, CBO, https://www.cbo.gov/data/budget-economic-data (noting default 10-year budget projections).

example, Guice emphasized the importance of determining what parties actually need and deserve protection, which requires the early disclosure of information and implementation of incentives for parties to "put their cards on the table."[50] For her part, Warren called back to the C-Band proceeding to highlight that addressing issues early in the process requires more than stakeholders presenting their technical concerns to the agencies—it also requires the agencies to grapple with the issues that are brought before them, rather than "punt[ing]" them when they are inconvenient.[51]

The back and forth between Guice and Warren spurred a second line of inquiry: how can stakeholders be brought together around the table? Warren pointed to the United Kingdom's spectrum regulator, Ofcom,[52] as an example of a system where the central authority manages to bring all parties together to air out all positions before developing a course of action. But Redl questioned whether the U.S.'s dual-agency system prevents the presence of a "final arbiter" for spectrum policy.[53] Guice felt that the agencies have become somewhat hobbled by their multiple mandates and constituencies and expressed that "it is a real shame that regulatees go to their regulator and get them to go to their congressional members and rough people up through that process."[54] Power noted that part of what leads to that scenario—at least on the commercial front—is the information imbalance between government entities and commercial entities: "it's sort of a black box. [The commercial sector doesn't] know what's going on behind the curtain" because the agencies typically go through NTIA, which then filters their various concerns into one united, but often opaque, federal position.[55] Yet, the panelists also expressed hesitation with the idea of Congress having an unfettered say, given its comparative lack of expertise and emphasis on CBO scoring for spectrum allocations.

One final root cause identified during the panel was the unbalanced role of engineering in spectrum management decisions. Panelists universally agreed that the number of engineers at the agencies themselves was inadequate; often, the agencies end up relying on their stakeholders to provide technical proposals. But, Redl stressed, "as long as we…have engineers who [are given] different sets of premises [by their stakeholder employers] and are told 'go defend this as the ground truth that is infallible,' I don't think that we're going to get to the point where engineers are respected in the process the way

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[50] Conference Transcript, *supra* note 27, at 21.
[51] *Id.*
[52] For more about Ofcom, *see About Ofcom*, OFCOM, https://www.ofcom.org.uk/about-ofcom.
[53] Conference Transcript, *supra* note 27, at 22.
[54] *Id.*
[55] *Id.* at 28.

they should be."[56] The agencies, then, must develop incentives to draw in engineering talent to push back against biased stakeholder models to restore faith in the technical underpinnings of spectrum management.

As the panel wrapped up, four key root causes had emerged ripe for further discussion in the breakout session: (1) a lack of common vocabularies surrounding interference thresholds, efficiency, and the lack of cohesive timelines utilized across entities and sectors; (2) the importance of aligning incentives for stakeholders and regulators to participate candidly; (3) the absence of consistent multi-stakeholder groups; and (4) the roles of leaders—both in policy and engineering—in driving specific, goal-oriented procedures. Nonetheless, the panelists expressed hope that, despite its failings, the U.S.'s bifurcated spectrum management system could continue to produce balanced and forward-looking outcomes.

Breakout Session

With many of the key issues teed up by the panel, the panelists and interested audience members reconvened for further discussion on the topic in a breakout session. As mentioned earlier, the breakout session proceeded under the Chatham House Rule, meaning that no quotes are attributed to any specific speaker. The candid discussion fostered by the Chatham House approach yielded several actionable recommendations that were later presented and analyzed on Day 2 of the conference.

David Redl reprised his role as moderator, accompanied by student rapporteurs Graham Stevenson and Sean Harms. Redl kicked off the breakout session with the question that had eluded the panelists: should the division of authority between the FCC and NTIA be completely overhauled? This question teased out a concern shared by many in the group as to whether NTIA is empowered with sufficient authority to carry out its mission to be the spectrum representative of the other federal agencies and, even if it does, whether NTIA uses that authority to effectively convey its concerns to the FCC. Participants widely perceived NTIA as being the front for the "national" (or, more accurately, the federal agencies') interests and the FCC as the representative of the "public" (or, perhaps in reality, the private industry) interest. Additionally, while the participants were pleased with recent efforts to increase information sharing between the agencies (such as the MOU), they cited the historical lack of information sharing as a significant barrier to productive dual regulation.

[56] *Id.* at 35.

Stemming from their recognition of the agencies as representatives of these different constituencies, the participants questioned whether the White House—perhaps through the OSTP—could serve as an arbiter. But this idea quickly fizzled; participants feared that the executive branch might be too driven by politics to serve as an appropriate check. Congress was also initially dismissed, given its comparative lack of expertise and focus on fiscal concerns rather than the mission-driven concerns of government and scientific users. Frustrated with the options of alternatives at home, participants turned abroad to look for other governance examples. Ofcom (mentioned during the panel) and the International Telecommunication Union (ITU)[57] processes were both held up as possible examples due to their forums' abilities to incentivize open discussion and constructive, multi-stakeholder problem-solving.

> ***"as long as we…have engineers who [are given] different sets of premises [by their stakeholder employers] and are told 'go defend this as the ground truth that is infallible,' I don't think that we're going to get to the point where engineers are respected in the process the way they should be."***
>
> ***—David Redl***

In fact, the concept of multi-stakeholder groups proved quite popular among the participants. They redirected their focus back to the U.S., holding up the Commerce Spectrum Management Advisory Committee (CSMAC)[58] and the more recent Partnering to Advance Trusted and Holistic Spectrum Solutions (PATHSS)[59] processes as examples of productive multi-stakeholder discussions. However, one participant cited the difference in outcome between Advanced Wireless Services (AWS-3)[60] and C-Band to highlight the fact that multi-stakeholder discussions are only useful when the parties involved are properly incentivized to participate. Another participant agreed, observing that these efforts often fail when one powerful party—such as an incumbent—has little incentive to make concessions for the "greater good." Participants also recalled that some of the comparative success of AWS-3 could be attributed to involvement from OSTP and a wide variety of sectors.

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[57] For more about the ITU, *see About International Telecommunication Union*, ITU, https://www.itu.int/en/about/Pages/default.aspx.
[58] For more about the CSMAC, *see CSMAC*, NTIA, https://ntia.gov/category/csmac.
[59] For more about PATHSS, *see* Anne Keeney, *National Spectrum Consortium Launches PATHSS Task Group to Explore 5G Spectrum Sharing,* BUSINESS WIRE (Oct. 27, 2021, 6:00 AM), https://www.businesswire.com/news/home/20211027005267/en/National-Spectrum-Consortium-Launches-PATHSS-Task-Group-to-Explore-5G-Spectrum-Sharing.
[60] For more about AWS-3, *see Auction 97: Advanced Wireless Services (AWS-3): Fact Sheet*, FCC, https://www.fcc.gov/auction/97/factsheet.

The discussions surrounding the importance of multi-stakeholder groups also bled into a conversation about the role of leaders in the process. Like the panelists, breakout participants lamented the lack of engineers in the agencies. Nonetheless, they felt that strong leadership at the agencies could overcome some of the engineering dominance of their constituents. Leaders—free to pursue their goals—could incentivize the pursuit of informal interaction between the agencies that participants felt was crucial to overcoming some of the information gaps between the FCC and NTIA. Participants also felt that it was important for stakeholders to approach each other directly, especially across commercial and government lines.

After a brief break, the session reconvened to distill the discussion into a few actionable recommendations. Notably, where the participants had earlier dismissed Congress's role, they now began to revisit its potential as a mediator and final arbiter in the process (or at least parts of the process). The participants remarked upon the Supreme Court's recent trend of decreased deference to agencies,[61] recognizing that it could lead to a greater role for Congress regardless of the participants' feelings about Congress's (lack of) expertise. One participant noted that Congress's fiscal focus could be important to balance the lack of such considerations on NTIA's end; another mentioned that, on the technical front, Congress's fact-finding efforts were incredibly effective in the passage of the Telecommunications Act of 1996.[62] Based largely on their recognition of the inevitability of Congress's role, the participants eventually generated the recommendations outlined in the next section.

Recommendations

Over the course of the panel and ensuing breakout session, the participants synthesized several recommendations to address the root causes of interference conflicts that they had identified. Participants developed these recommendations after concluding that the bifurcated spectrum management system, while flawed, worked more often than not and was worthy of continuation. They also recognized that the vast majority of interference conflicts stem not from existing spectrum environments, but from new, repurposed spectrum allocations. Finally, they placed great emphasis on the issue of disparate timelines for spectrum use-cases that are often not well shared or received by other stakeholders and disagreement over what

[61] For more about the Supreme Court's recent administrative state jurisprudence (specifically the "major questions" doctrine), *see generally, e.g.*, W. Virginia v. Env't Prot. Agency, 142 S.Ct. 2587, 213 L.Ed.2d 896 (2022); Food & Drug Admin. v. Brown & Williamson Tobacco Corp., 529 U.S. 120, 120 S.Ct. 1291, 146 L.Ed.2d 121 (2000); MCI Telecomms. Corp. v. Am. Tel. & Tel. Co., 512 U.S. 218, 114 S.Ct. 2223, 129 L.Ed.2d 182 (1994).

[62] *See, e.g.*, S. REP. NO. 104-23 (1995) (Committee Rep.); H.R. REP. NO. 104-458 (1996) (Conf. Rep.) (reports describing Congress' fact-finding efforts for the Telecommunications Act of 1996).

constitutes "efficient" or "effective" use of spectrum. To combat these issues, the root causes participants proposed the following recommendations:[63]

1. Implement an "inclusive, iterative process" of preparing new spectrum allocations that would heighten Congressional involvement to reduce the likelihood of outside interference or uninformed decision-making on Congress's part. This process was born of the recognition that Congress is the one entity involved that is beholden to all stakeholders and is often the court of last resort despite its comparative lack of expertise. To ensure that Congress' inevitable involvement is informed, then, the recommended process would involve the development of a joint report from the FCC and NTIA for each proposed allocation that would force the agencies to distill the views of all of their constituents and compromise to present a united front for easy implementation by Congress.

2. All participants agreed that they should focus on identifying the most "efficient" use of the available spectrum, although there was lingering disagreement on exactly how that efficiency would be defined. Nonetheless, participants did agree that the reports should investigate whether the "capabilities of a government system or platform [can] meet its mission more effectively through spectrally efficient improvements or components."[64] Perhaps reflecting concerns about taking too narrow a definition of efficiency, participants also stressed that Congress should be asked to expand its considerations beyond mere revenue generation. Furthermore, participants felt that the continued use of multi-stakeholder discussions such as CSMAC and PATHSS could foster the development of material to be used in these reports.

Once developed, these recommendations were presented by panelists on Day 2 of the conference alongside the recommendations from the second topic. After each side presented their recommendations, a new discussion was opened to put the topics in conversation to draw out the final takeaways from the conference. Before diving into these final takeaways, the recap and analysis of the second topic is presented in the following section.

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[63] Silicon Flatirons, 2022 Spectrum Policy Initiatives Conference: Recommendations Outbriefs from Breakout Discussions: Actions or Next Steps 2–4 (Oct. 8, 2022) (available on the Silicon Flatirons website, siliconflatirons.org).
[64] Conference Transcript, *supra* note 27, at 81.

VI. Topic 2: Technical, Economic, and Regulatory Solutions

Even once root causes of interference can be identified, finding solutions to those conflicts that stakeholders can agree upon is a daunting task. As multifarious and complex as root causes can be, so too can solutions that properly reflect the interests of all stakeholders in a way that is justifiable and affords each spectrum user an appropriate process. To tackle this challenge head-on, the second central topic of the conference focused on developing technical, economic, and regulatory solutions to interference conflicts.

> ***"We need to identify and fund risk reduction studies, with more emphasis on the technical side. We do a good job with the initial modeling to understand where the issues are, but there's a lot that can be done on the technical side."***
>
> ***—Melissa Midzor***

The treatment of the solutions topic began with a panel led by Nick Laneman, Founding Director of the Wireless Institute at the University of Notre Dame[65] and Center Director for SpectrumX. This panel consisted of four experts representing different scientific, regulatory, and commercial interests in spectrum management. The panel format provided panelists opportunities to answer questions that illuminated some of the challenges and questions posed when finding solutions to spectrum interference conflicts. As with root causes, the second group then proceeded to a breakout session under the Chatham House Rule to further explore topics discussed in the panel and draft actionable recommendations towards finding solutions to spectrum interference disputes.

Panel Discussion

Laneman kicked off the panel by asking the group to explore the framing of the panel: will solutions be technical, economic, regulatory, or some combination of all three? Panelists broadly agreed that addressing interference conflicts necessarily implicates an all-of-the-above approach, with each sphere of spectrum policy working in unison to address interference conflicts. Derek Khlopin of the NTIA expressed his understanding that in "an ideal world, [solutions are] technical" but that the real world requires a recognition of the economic and regulatory forces that influence and push technical solutions to market.[66] Al Gasiewski, Professor of Electrical, Computer,

[65] For more about the Wireless Institute, *see About the Institute*, WIRELESS INSTITUTE, https://wireless.nd.edu/about/.
[66] Conference Transcript, *supra* note 27, at 38.

and Energy Engineering at the University of Colorado Boulder,[67] agreed with the idea that all three components are necessary to develop solutions and was particularly concerned with the ways that economic and regulatory forces enable successful technological development. He stressed, however, that engineering development is not always a predictable process; rather, it often proceeds stochastically, where the probability of important developments can be improved by economic and regulatory pressure, but are rarely guaranteed.

Jennifer Manner, Senior Vice President of Regulatory Affairs at EchoStar Corporation,[68] emphasized the importance of having a technical basis for regulatory and economic decisions before those decisions are made. Specifically, Manner pointed to the FCC's authorization of Lynk's satellite direct-to-cell service, without a technical study completed investigating interference concerns beforehand.[69] Melissa Midzor, Division Chief for Spectrum Technology & Research at National Institute of Standards and Technology (NIST)[70] emphasized that not only do regulatory, economic, and technical solutions need to be equally utilized, but that advocates for each approach should "be in the room together"—a similar sentiment to that expressed by participants in the root causes discussion.[71] This joint approach to problem-solving helps to move along the conversation and helps ameliorate the conflict that Manner noted, where technical concerns aren't reflected at the beginning of the process.

Moving the panel forward, Laneman offered up a provocative question: if a participant were the "ruler for a day" for the FCC and NTIA, what changes would they make in spectrum management to mitigate or prevent harmful interference issues, particularly the headline grabbing conflicts of recent infamy?[72] This question sparked debate amongst the panelists as to what steps could be taken to promote better cooperation amongst agencies, particularly the FCC and NTIA, to help address these disputes. Khlopin expressed that a return to a model similar to the FCC's former "negotiated rulemaking" process, where all interested stakeholders are "[locked] in the proverbial room" to come up with "a framework or guideline

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[67] For more about the University of Colorado's engineering department, *see About Us*, UNIV. OF COLO. BOULDER COLL. OF ENG. AND APPLIED SCI., https://www.colorado.edu/engineering/about.
[68] For more about EchoStar, *see About EchoStar*, ECHOSTAR, https://www.echostar.com/company/about-echostar.
[69] For more on this, *see Aga*Monica Alleven, *Lynk acquires FCC license for commercial satellite-to-phone service*, G (Sept. 19, 2022, 1:08 PM), https://www.fiercewireless.com/wireless/lynk-acquires-fcc-license-commercial-satellite-phone-service#:~:text=The%20company%20on%20Friday%20announced,way%20for%20universal%20mobile%20connectivity.
[70] For more about NIST, *see About NIST*, NIST, https://www.nist.gov/about-nist.
[71] Conference Transcript, *supra* note 27, at 40.
[72] *Id.* at 41.

document" for guiding best practices in technical analysis, might prove fruitful in giving a consistent avenue to address these disputes.[73] Others emphasized the value of coming to agreement on methods for statistical analysis, creating and utilizing propagation models, and developing a binding framework to guide various processes. Manner, however, expressed concern that the negotiated rulemaking model, in her experience, was an arduous process whose return would scarcely be welcomed by those who had experienced it.

Gasiewski took Laneman's open-ended question in a different direction, suggesting that a valuable step would be to widen the net from which to pull in talent to help solve these problems. He emphasized the extremely interconnected nature of the global community and expressed that the right people to solve spectrum conflicts—be they engineers, regulators, or others—might only be found abroad and we should take advantage of the ease of connecting across the globe to source the right talent.

For other panelists, the importance of up-front technical studies before decisions are made remained a central issue. Noting the importance of the technical side of the tripartite framing for the solutions discussion, Midzor added that "we need to identify and fund risk reduction studies with more emphasis on the technical side. We do a good job with the initial modeling to understand where the issues are, but there's a lot that can be done on the technical side."[74] Laneman took a more holistic approach as "ruler for a day," suggesting the establishment of some kind of binding national spectrum plan. In support, he pointed to the success of the National Broadband Plan (NBP)[75] and the President's Council of Advisors on Science and Technology (PCAST) Report[76] as holistic documents that led to high levels of spectrum deployment.

The next question broached one of the biggest variables in effective spectrum management: establishing useful incentive structures that push users toward finding solutions to spectrum disputes. Panelists broadly agreed that incentives can be challenging to properly calibrate since indirect pushes on spectrum use, particularly in the context of finding actionable solutions. Spectrum sharing took center stage as a method of incentivizing users to find solutions to spectrum interference disputes. Midzor pointed to the DOD's experience in developing effective sharing solutions for operating in crowded spectrum environments without exclusive licensing. Laneman shared this

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[73] *Id.* at 42.
[74] *Id.* at 41–42.
[75] *See generally* FEDERAL COMMUNICATIONS COMMISSION, NATIONAL BROADBAND PLAN (2010), https://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf.
[76] *See generally* EXECUTIVE OFFICE OF THE PRESIDENT, REPORT TO THE PRESIDENT: REALIZING THE FULL POTENTIAL OF GOVERNMENT-HELD SPECTRUM TO SPUR ECONOMIC GROWTH (July 2012), https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf.

enthusiasm for utilizing the defense industry's experience in spectrum sharing, noting that if those technologies could find their way into commercial settings (with respect given to national security limitations), they could play an important role in enabling and incentivizing more efficient spectrum use. Midzor also noted that the development of a methodology that clearly identifies what "fair co-existence" entails for spectrum users is another step that would incentivize effective spectrum sharing.[77]

Continuing on the topic of spectrum sharing, Khlopin identified the fact that the exclusive use license, a prominent feature in U.S. spectrum management, itself dis-incentivizes users from efficient spectrum use. However, he noted that the expansion of spectrum use—and consequent shrinking of usable spectrum—provides a natural push towards incentivizing more efficient use that avoids interference conflicts. But Manner expressed some discontent with the idea of incentive structures as an avenue for pursuing more efficient spectrum use and reducing conflicts, noting that some bands where users are required to share are put under inordinately restrictive terms. Instead, she felt that self-interest is often the most effective motivator for spectrum users and that only incentives with proper technical backing should be employed to avoid the problematic anti-competitive behavior that is typically the logical outgrowth for self-interested actors.

Moving on, Laneman refocused the group on a post-facto question: in cases of unavoidable interference, how can we best assess the relative value of competing spectrum uses? Despite the overwhelming push for more spectrum for the deployment of 5G commercial services, panelists unanimously agreed on the importance of recognizing the value of spectrum uses that may not carry the dollar signs of commercial mid-band spectrum.[78] In particular, Gasiewski honed in on the importance of environmental remote sensing not only for critical weather prediction services but for gathering information for climate sciences. A sentiment permeated the group that pure financial assessment failed to capture critical externalities impacting the valuation of different service, and the essential role regulators play in ensuring economic forces did not take absolute precedence in determining the best uses of spectrum.

The panel then transitioned to a topic of recent import, namely, receiver performance and the potential role that updated receivers could play in resolving spectrum conflicts. The panelists unanimously supported the premise that receiver standards, while not a panacea,

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[77] Conference Transcript, *supra* note 27, at 45.
[78] Mid-band spectrum is often considered the "beachfront property" of frequencies ranges being considered for commercial use, due to particular characteristics of the frequencies such as favorable combinations of propagation characteristics and data rates.

played an important role in finding solutions to interference conflicts. Midzor—referencing Laneman's earlier question about avoiding high-profile interference conflicts such as the 5G/C-Band dispute—noted that receiver standards would have helped to mitigate the damage of these conflicts. Another thread touched on by multiple panelists was that the normative value of signaling that receiver standards are being considered helps to push manufacturers and spectrum users to more thoughtfully consider their spectrum use and avoid interference at the receiver end. Manner offered a mitigating concern: any receiver standards adopted by regulators would have to consider a phased-in approach, particularly for satellite systems where equipment life cycles are longer than in other contexts.

Manner's comments offered a natural segue into the group's final question: how do regulators keep up with industries where the products evolve faster than the regulatory environment? The discussion highlighted a consistent thread throughout the rest of the panel—balancing the need, and perhaps desire, of regulators and users to move quickly and secure more spectrum for use against the need to have technical support for spectrum decisions before they are made. Multiple panelists touched on the importance of flexibility in adjusting approaches in response to technological development and humility in acknowledging that previous decisions may need to be revisited. To illustrating the tension between acting fast and waiting for requisite studies, Khlopin noted that, in past disputes, the regulators had demonstrated an ability to look back and revise rules to mitigate interference conflicts arising after allocation decisions had already been made. Given the rapidity of technological advancement, it was often better to adopt this approach rather than make no decision at all. Laneman likened Khlopin's example to the iterative approach of agile software development.

At last, closing thoughts for the day's panel were provided by Midzor, who echoed the need to be flexible when assessing past decisions and reemphasized that more data at all stages of the spectrum management process is critical to resolving conflicts.

Breakout Session

After the panel, the panelists and audience transitioned to discuss the topic in a separate breakout session under the Chatham House Rule with the objective of offering actionable recommendations for resolving interference conflicts.

Nick Laneman moderated again, accompanied by student rapporteurs Jackson McNeal and Xelef Botan. Laneman opened the group's discussion by reprising the idea of a national spectrum plan, asking the group what ingredients would be necessary for a successful national plan. The opening suggestion—one that would reflect a repeated emphasis on definitional clarity—was to define objectives for a

hypothetical plan. Members of the group agreed that a foundational step would be the identification of means to encompass the societal effects of spectrum allocation decisions. Participants looked toward a recurring touchstone for the idea of a national spectrum plan. Specifically, participants took note of the plan's inventorying of the spectrum as an approach toward forward-looking management that could prove fruitful.

As the discussion progressed, inputs flowed from the broad idea of accounting spectrum to a more grounded analysis of the specifics of implementation. The breakout group acknowledged that most spectrum is already spoken for, so forward-looking discussions of spectrum "inventory" are really discussions about who gets to keep the spectrum allocated to them and who will lose their spectrum. One participant, attempting to forecast this allocation dilemma, stated bluntly that if decision makers try to guess who should get to keep that spectrum and who should lose it ten years from now, they will guess wrong. The group broadly agreed with this notion and further expressed consensus that, with respect to national strategy, the focus should be on changing the regulatory and incentive structure to encourage more efficient spectrum use and the development of technology facilitating that objective rather than dictating preferred technologies and ousting those that do not fit the preference.

Another ingredient of a national spectrum strategy that garnered broad group support was rigorous and focused data collection around all aspects of spectrum management. Naturally, the first focus was on defining interference itself. Group members had a difficult time agreeing on exactly what metrics should be considered given the preponderance of unique and disparate spectrum use cases and potential interference conflicts. There was general agreement, however, that a framework for addressing harmful interference could help identify what data was needed to address disputes. Participants agreed that even without standardizing what data should be collected in assessing and resolving disputes, standardizing the process by which these disputes were handled could be enormously beneficial by introducing much-needed stability into the spectrum management process.

Moving from interference conflicts themselves, the group debated what data was needed to assess "highest and best" uses. As during the panel, there was general agreement that economic analysis fails to fully capture the benefits of certain services. One idea that met general assent was that spectrum is in many cases a local resource: the valuation of a particular use necessarily varies from locality to locality. Mirroring the group's agreement that the regulatory structure should not attempt to "guess" the best use ten years down the line, the participants questioned whether a hypothetical national plan should even attempt to determine the best uses of spectrum.

As the discussion progressed, the participants began to express skepticism towards the viability of a holistic, cohesive national plan. Recognizing this hesitancy, Laneman moved the discussion to focus specifically on challenges of such a plan. Once again, participants expressed apprehension at the idea of even attempting to determine "highest and best" uses. Many agreed with the notion that in any attempt to nail down a single definition, the plan would need to contain protection against monopolization by powerful economic entities, such as the commercial wireless industry. In this vein, some members of the group urged for the consultation of technologists to obtain an understanding of the direction of the industry and what technologies needed to be given the space to grow and expand in a national spectrum plan. Another challenge was that the very idea of a "national" spectrum plan misses the crucial notion that spectrum policy is inherently a global issue. Not only does the United States policy influence North American neighbors, but satellite policy necessarily implicates the ITU and other global bodies. The group widely agreed that at minimum, regional harmonization—with Canada and Mexico—was critical to any successful implementation of a national spectrum plan.

Leaving the discussion on national spectrum strategy with fewer answers than questions, Laneman focused the breakout group on a narrower subject to close: what are five things that research organizations such as SpectrumX should focus on? One avenue the group generally agreed on was a focus on research into new sharing and incentive structures. Acknowledging that the auction system relied upon by the U.S. often forces federal agencies to make efficient budgetary decisions rather than efficient spectrum decisions, the group felt that an entity such as SpectrumX was uniquely situated to serve as a "watchdog" for these decisions: analyzing them with an objective lens focused on spectral efficiency and identifying opportunities where federal decisions could lead to a more spectrally efficient outcome with minimal added cost. Another participant suggested that SpectrumX might be well suited to researching new ways of measuring receiver impact, in support of the outstanding Notice of Inquiry on receiver standards.[79] Outside of specific suggestions for SpectrumX, there was widespread agreement in the group that it was important to retain a focus on making sure the work from the project did not remain purely academic and translated into tangible results in industry.

[79] Published April 21, 2022, the FCC's NOI "Promoting Efficient Use of Spectrum through Improved Receiver Interference Immunity Performance" has reopened discussions into the role receiver performance requirements and incentives may play in spectrum management. *See generally* In the Matter of Promoting Efficient Use of Spectrum through Improved Receiver Interference Immunity Performance, Notice of Inquiry, 87 Fed. Reg. 29248 (May 13, 2022), https://www.fcc.gov/document/fcc-launches-proceeding-promoting-receiver-performance-0.

Recommendations

Following a brief break, Laneman focused on the idea of tangible results to push the group to identify actionable recommendations for presentation at the breakout panel, which are captured below. The discussion of actionable recommendations considerably narrowed the focus of the group, asking participants to identify the who, how, what, why, when, and cost of their recommendations:[80]

1. Develop more, better, and varied RF propagation models. Participants identified that this goal would require the participation of ITS, the National Science Foundation (NSF), and NIST. These models should reflect both reactive and predictive considerations and need to identify potential future conflicts and be able to help resolve ongoing interference disputes.

2. Develop a harmful interference framework. NIST was named as the primary driver of this recommendation, and much like the RF models, the group agreed that the framework needed to be both forward-looking and retrospective; capable of being applied when moving spectral users to new spectrum, and for resolving interference conflicts on the back end.

3. Assess, create, and characterize the impact of interference mitigation technologies—for example, multiple input, multiple output (MIMO)81 technology—to be developed by the research community in conjunction with industry testing organizations, research organizations, and academic communities.

4. With almost unanimous support— convince the FCC to adopt risk-informed interference analysis. The participants pointed in particular to the C-Band fiasco as evidence of the need for this new measure.

5. Looking back to the breakout's SpectrumX discussion, the group endorsed a specific recommendation that SpectrumX should focus on developing new incentives for spectrum-sharing solutions.

[80] Silicon Flatirons, *supra* note 63, at 5–7.
[81] For more about MIMO, *see* Eva Webster, *MIMO (multiple input, multiple output)*, TECHTARGET (Mar. 2021), https://www.techtarget.com/searchmobilecomputing/definition/MIMO.

VII. Panel 3: Recommendations Outbrief

On Day 2, the conference reconvened for a third panel, moderated by Peter Tenhula, Senior Fellow of the Spectrum Policy Initiative at Silicon Flatirons, where the two breakout session facilitators presented their groups' recommendations and provided feedback on each other's proposals. This panel consisted of David Redl and Nick Laneman, supported by Colorado Law students Graham Stevenson (root causes) and Jackson McNeal (solutions). This section will briefly recap the general findings of the breakout groups before exploring the discussion stemming from the groups' separate recommendations.

Redl and Stevenson reported that participants in the root causes breakout session (Topic 1) agreed that the bifurcated regulatory system currently employed by the United States, while not without flaws, generally worked well. While adjustments were needed, Topic 1 participants felt that there was no compelling reason to reinvent the wheel. Further, the group agreed that the operating assumption for all stakeholders should be that more spectrum is always needed. With that assumption in hand, disparate timelines of various users and stakeholders posed a challenge that could be solved by bringing spectrum disputes up earlier in the process and with more information. Finally, the group found that addressing root causes would necessarily require a Congressionally-led approach, combined with empirical joint reports from the NTIA and FCC.

Laneman and McNeal reported that much of the discussion in the Technical, Regulatory, and Economic breakout session (Topic 2) focused on finding technical solutions and methods of structuring regulatory and economic forces to support developing the technology necessary to resolve interference disputes. Further, the group consistently found that more data, such as more sophisticated RF propagation and interference modeling, was necessary to appropriately address interference conflicts. Finally, incentive discussions weighed heavily in the breakout session, leading to a general consensus that they played an important role in resolving conflicts but had to be wielded carefully.

Tenhula then opened the analysis by noting the more technically-oriented recommendations of Topic 2, compared to the more policy- and legislatively-oriented solutions of Topic 1. Following this thread, Redl shared his observation that Topic 1 seemed to focus more on collaboration between governmental and nongovernmental entities, whereas Topic 2's recommendations evinced more of a preference toward private-sector technological development. Laneman partially disputed this assertion, noting that many of Topic 2's solutions—while potentially involving private sector technical development—focused on how to get regulatory forces to help bring these developments into industry. Laneman pointed to the Semiconductor Research

Corporation (SRC) as an example of a public-private partnership that has been successful and a model that could potentially be emulated in the spectrum context.[82] This example highlighted a recurring theme of Topic 2's discussion that contrasted with the more process-oriented approach of Topic 1: the opportunities to approach R&D policy from new and previously unexplored directions.

> ***"It's one thing to come up with a disruptive technology, whether it's in a government lab or an academic lab or even the 'Bell Labs' of the world, it's another thing to transition it and that's where the industry—the market, the business mechanisms—have to pull that technology into the standards. And so some of these pretty innovative public-private partnerships have been making a significant investment, [hence the mention] of the SRC…materials and devices, they're doing a lot in collaboration with a number of the big foundries and DARPA to fund university research."***
>
> ***—Nick Laneman***

Redl and Laneman's exchange set up one of the overarching themes for the panel: harmonizing procedural and systemic strategy in spectrum management with tangible and discrete solutions. Redl highlighted Topic 1's focus on ex-ante procedural means for addressing root causes and contrasted it with Topic 2's focus on ex-post technical solutions for demonstrable interference. Laneman took the procedural approach to developing technical solutions, inquiring how policy can orient towards incentivizing coordination and strategic research roadmaps in research and development. In particular, he saw policy as an important tool to avoid duplicative effort in R&D.

In part, Redl saw increased collaboration between the FCC and NTIA necessary to craft their joint report as a useful tool for promoting coordination by forcing each agency to connect with its "core constituenc[y]" to glean what requests are truly essential and, more importantly, the reasons underlying those requests.[83] While acknowledging that such a report could result in fundamentally different conclusions, Redl nonetheless saw value in getting the two agencies to engage and presenting their findings to Congress,

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[82] For more about the Semiconductor Research Corporation, *see About*, SEMICONDUCTOR RSCH. CORP., https://www.src.org/about/.
[83] Conference Transcript, *supra* note 27, at 90.

however potentially disparate those findings might be. He emphasized the holistic nature of such an approach and that it would be necessarily forward-looking.

Redl's proposal led to a more extended discussion regarding Congress's role in spectrum policy; as Redl had previously noted, discussion of the role of Congress was notably absent in Topic 2's breakout discussion. McNeal, citing his experience as a congressional staffer, agreed with the notion that Congress has to be heavily involved in any major spectrum policy decisions. Redl—also a former congressional staffer—expanded on the concern, admitting that, while Congress "isn't perfect…we're not going to stop the fact that Congress is going to have a strong role in spectrum policy."[84] To that end, Redl queried whether it is "better to have Congress driving the train [than it is] to have them as the court of last resort for the aggrieved spectrum user," and emphasized that Topic 1's participants concluded that yes, it was, and that Congress should be "engaged from 'go.'"[85] The panelists felt that Topic 1's proposal could accomplish this goal by remedying the aspect with which Congress struggles most: the scientific and technical underpinnings essential for effective spectrum policy. The iterative process described in the recommendation could also reduce the bias injected into the process by CBO scoring, which often ignores non-economic elements that do not fit the CBO's ten-year forecast.

Before wrapping up the panel, the panelists had a brief opportunity—prompted by an audience question—to discuss how their groups' recommendations might have avoided or mitigated the problematic outcomes of the C-Band and L-Band processes. Laneman suggested that increased testing and better reporting could have caused technical issues to surface earlier. Redl agreed but noted that the results would actually need to be shared with the appropriate parties to have a real impact. They agreed that in combination, the recommendations provided by both groups could jointly provide a clear protocol for identifying, surfacing, and remedying interference issues at the outset.

[84] *Id.* at 91.
[85] *Id.*

VIII. Panel 4: Wrap-Up

Finally, a fourth panel convened to close out the conference, consisting of two participants from each of the breakout groups who reflected on the recommendations presented during the third panel. Julius Knapp, former Chief of Engineering and Technology at the FCC, and Jonathan Williams, Program Director for Electromagnetic Spectrum Management at the NSF,[86] represented Topic 1, while David Goldman, Director of Satellite Policy at SpaceX,[87] and Paul Kolodzy of Kolodzy Consulting[88] represented Topic 2. The panel was moderated by Anna Gomez, recently retired from the law firm Wiley Rein[89] and former Deputy Assistant Secretary for Communications and Information and Deputy NTIA Administrator.

While the panelists generally applauded the recommendations presented in the third panel, they also raised the concern that many of the themes appeared to focus on re-litigating past interference conflicts. Panelists argued that technological advances and the changing nature of spectrum environments may soon render these past battle lines inconsequential. The panel thus advocated for more forward-looking policies that would be capable of addressing future uses. This focus on the future was balanced with the broader understanding that when policy makers have tried to predict the future, they have predicted incorrectly. Panelists argued the solution would be to focus not on prescriptive solutions, but on purposefully creating incentive structures that would encourage collaboration across the industry.

In his opening reflection on the breakout room recommendations, Goldman zeroed in on the discussion of the panel's focus on forward looking policies: "I think that there's a lot of fighting the last war that's going on [and] you know what fight they were talking about when they came up with these bullet points."[90] Goldman found this theme to be problematic since the trends he sees indicate the traditional assumptions and "battle lines" in spectrum disputes are changing with the introduction of new technologies and uses.[91] He and other panelists described the reorganization of the spectrum landscape, noting particularly the blurring of the lines between terrestrial and

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[86] For more about Electromagnetic Spectrum Management and the National Science Foundation, *see Electromagnetic Spectrum Management (ESM)*, NSF, https://beta.nsf.gov/funding/opportunities/electromagnetic-spectrum-management-esm.
[87] For more about SpaceX and Starlink, *see* SPACEX, https://www.spacex.com/mission/; Starlink, https://www.starlink.com/.
[88] For more about Kolodzy Consulting, *see* KOLODZY CONSULTING, https://kolodzy.com/.
[89] For more about Wiley, *see* WILEY, https://www.wiley.law/.
[90] Conference Transcript, *supra* note 27, at 104.
[91] *Id.*

satellite connectivity and the increasing trend of federal applications using commercial 5G among others.

Building off the theme of future conflicts looking different from those in the past, Knapp highlighted the contrast between tracking past and modern interference conflicts. Reflecting that "for years and years, it was like here's the source, here's the victim receiver. And we're going to have one path," Knapp contrasted that simplistic version of interference with the complications that are common today.[92] He specifically highlighted technology such as adaptive antennas on transmitters with variable power levels and the new focus on out-of-band interference resulting from the massive increase in the number of devices transmitting at one time. In general, Knapp concluded, the spectrum environment is more complicated than it used to be. As a result, the solutions for resolving interference conflicts can no longer rely on the methods employed when conflicts were simpler.

Panelists balanced the concern about the changing landscape with the understanding that prescriptive regulation of the spectrum environment has never worked in the past, as Goldman said, "you look back and we get it wrong every time we try to guess."[93] With that qualification in mind, the conversation focused not on how to prescribe future uses and regulatory regimes, but on how to incentivize spectrum being put to its "highest and best" use, specifically through increased collaboration and spectrum sharing.

Panelists expressed agreement that the existing structures largely fail to incentivize productive behaviors and often actively lead to behaviors that undermine ideals, such as "squatting"[94] or refusal by incumbents to come to the negotiating table as new uses or sharing are proposed. When incumbents do participate in negotiations, they are incentivized to advocate for worst-case interference analyses and to argue against the introduction of spectrum sharing in new bands or for overly restrictive interference protections. Kolodzy highlighted that embracing risk-informed analysis over such worst-case scenarios would facilitate sharing.[95]

Similarly, David Goldman described the lack of clear rules governing shared satellite spectrum as a "cage match" where each user is incentivized to exclude other users from sharing agreements and to claim as much spectrum for themselves as they can.[96] This no-holds-

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[92] *Id.* at 114.
[93] *Id.* at 105.
[94] Squatting is a colloquial term typically used to refer to a situation where a party holds a license (or a collection of licenses) for a certain band of spectrum but does not actually make productive use of those licenses and thus allows the spectrum to remain unutilized.
[95] For most systems, the worst-case-scenario is extremely rare. Thus, relying on such scenarios would be overly conservative and result in wasting opportunities to share spectrum.
[96] Conference Transcript, *supra* note 27, at 105.

barred mentality presents incentives to encourage spectrum sharing or collaboration to find the highest and best use. Rather, it incentivizes all parties to amass as much spectrum as they can and squat on it to protect their future interests.

Moderator Anna Gomez, leaning on the example of a lack of early collaboration in the C-Band proceeding, raised the concern that incumbents' first reaction to studying the potential for sharing their spectrum is to resist. She noted that these incumbents typically argue that their limited resources should be devoted to their own mission, not to giving their spectrum away. This often leads them to respond, "I'm not going to help you take my spectrum. I'm not going to help you possibly interfere against me."[97] Goldman built on the idea, stating existing users are told to "come in now for a process to sit down. And if you interact with us and do everything really well, we won't hurt you that much."[98] When presented with this lose-lose situation, an incumbent's only incentive is to drag their feet and resist coming to the table to help find the "highest and best" use.

To summarize, the panelists found that existing incentives lead spectrum users to be doggedly territorial in guarding their existing spectrum, leaving little reason to come to the bargaining table to contribute their expertise towards finding a working solution that results in the spectrum being employed to the "highest and best" use. That said, Knapp and Williams did raise examples where the incentives have been structured to circumvent these problems.

Knapp contrasted the decade-long effort of developing the CBRS regime with other, more rushed, allocation proceedings. Of critical importance in CBRS was the FCC's commitment to getting both the military incumbents and unlicensed community to spend time hammering out the details before ever beginning an official proceeding with a Notice of Proposed Rulemaking. Williams described a similar sentiment about how the FCC can encourage more collaboration, warning regulators to "make sure that the process is constructed such that everybody knows that they're going to be listened to. They may not get what they want, but they're going to be heard."[99]

> ***"Come in now for a process to sit down. And if you interact with us and do everything really well, we won't hurt you that much."***
>
> ***—David Goldman***

Williams argued that the NSF, as a small agency focused on using spectrum for radio astronomy, is rarely prioritized in comparison to

[97] *Id.* at 108.
[98] *Id.* at 109.
[99] *Id.*

revenue generating uses. As a result, he frequently found that the industry is forced to collaborate and share spectrum "out of necessity."[100] This raised the question of what other structural forces can be adjusted to create a similar incentive to collaborate from the start.

Assessed as a whole, this panel's major takeaway was that the recommendations from the previous panel should be revised or built upon to create incentives for collaboration in finding the highest and best use of spectrum, increasing spectrum sharing, and better information sharing.

[100] *Id.*

IX. Conclusions

After two days of in-depth analysis of the root causes of and possible solutions to ever-growing interference challenges, at least one major point of agreement (among many) emerged: no solution, be it ex-ante or ex-post, or technical, regulatory, or economic, can work alone. In recognition of this, the conference elevated voices from a wide array of spectrum stakeholders to ensure that any recommendations that were developed would have the input of all impacted parties. Robust discussions surfaced that often challenged dominant assumptions about the framing of spectrum management challenges and the solutions to them.

Conference participants considered the resolution of spectrum interference conflicts through different technical, regulatory, and economic lenses, while also considering how to better address the root causes of interference disputes. Through the course of the conference, the collective analysis honed in on the notion that better solutions would necessarily be technically oriented, but that the research necessary to find those solutions must be holistically supported by economic and regulatory means. Additionally, incentive structures emerged as a controversial but potentially powerful economic tool for solving recurring interference conflicts. There was widespread assent that squashing spectrum disputes at the source would require greater collaboration and information sharing from spectrum stakeholders at the outset of any discussion and would also require greater legislative and institutional involvement in management decisions. There was also widespread agreement surrounding the need for more information, better information, and more effective mechanisms for sharing information earlier in the spectrum management process.

The first of two conference groups centered their discussion on the "root causes" of interference disputes. Primed by a panel discussion featuring voices from the scientific, commercial wireless, government, and satellite communities, the breakout group questioned the roles of the FCC, NTIA, and Congress—as well as their constituencies—in developing spectrum policies. While initially skeptical of any Congressional involvement, the group eventually came to the consensus that Congress, when properly informed, plays a valuable role as a final arbiter in the allocation process.

At the end of the conference, one key recommendation arose from Topic 1. The group proposed what they described as an "inclusive, iterative process" wherein Congress (when seeking to establish new allocations) would solicit a joint report from the FCC and NTIA outlining the agencies' combined view of the most "efficient" use for the spectrum at issue. The report would serve as Congress' guiding document for the allocation, thus forcing the agencies to solicit from

their respective constituencies the most compelling reasons for and against a certain course of action. These constituencies would be incentivized to air all of their grievances, lest their concerns be left out of the report. Moreover, even a "split" report reflecting fundamental disagreement between the agencies could prove valuable to Congress in that it might indicate an opportunity to revisit the proposed allocation altogether.

The solutions group's recommendations touched on the recurring refrain that sufficient data is crucial to effectively resolving interference disputes. In particular, the group identified the need for more, better, and varied RF propagation models. There was general agreement that properly characterizing the RF environment under current conditions is often challenging and that better modeling could resolve this issue. Of course, this recommendation was not provided without some skepticism that the cost to provide better modeling may outweigh the actual cost of the interference dispute, but most participants nonetheless recognized that the overall benefits were too great to ignore.

Reflecting the technical bent of Topic 2's discussion, participants also called for the assessment, creation, and characterization of the impact of interference mitigation technologies. Recognizing that some interference was inevitable, the group agreed that a clearer understanding of the capabilities of existing mitigation technology would help provide clarity as to what interference could be mitigated and what disputes would require more discrete action to resolve.

Additionally, Topic 2 panelists and breakout participants recognized that more data does not, in a vacuum, help to solve interference issues; rather, spectrum managers must have a framework for identifying and responding to disputes that promotes cooperation, clarity, and stability for stakeholders. There was broad consensus that the development of a framework for harmful interference—headed by the technical know-how of NIST—would help spectrum users have a consistent and repeatable set of guiding principles for characterizing interference disputes. Finally, the group was in rare unanimous agreement that the FCC should immediately stop considering worst-case interference analysis and instead focus on risk-informed analysis.

Of course, the questions presented and recommendations produced at the conference serve merely as a starting point for further work. The iterative, inclusive, and congressionally-centered approach suggested by the root causes group, combined with the promotion of public-private partnerships for research and development put forth by the solutions group certainly have promise. But many of the details naturally remain unaddressed and present unique and important opportunities for further research, discussion, development, and implementation.

On the topic of metrics and concepts, conference participants frequently advocated for regulators—both the agencies and Congress—to take a more skeptical view of stakeholder-provided data (given the propensity of stakeholders to present data most favorable to their position) and consider more holistic conceptions of ideas such as "efficiency," "highest and best use," and "harmful interference." Unfortunately, there is currently little consensus on what exactly these terms should capture, due in part to differing stakeholder priorities or the needs of certain spectrum use cases. As such, there continues to be a great need for research into methods of either standardizing vocabulary or finding creative solutions to bake in the nuances that currently exist.

Another area ripe for further work (and one that has recently become far more prevalent) is dynamic spectrum sharing (DSS).[101] As spectrum has become more crowded and users have become more advanced, the need for and ability to implement DSS have grown commensurately. But while the technology has progressed significantly, its adoption has—at least in some areas—been slow. The reasons for this slow adoption are myriad and have proven vexatious for regulators; thus, additional research is needed into methods for incentivizing increased spectrum sharing and ensuring that the legitimate concerns (such as national security) that have caused certain industries to balk at the idea are addressed.

Finally, a recurring concern expressed at the conference was the growing dearth of new engineering talent at the FCC and NTIA. Stakeholders from a variety of backgrounds agreed that this absence has forced the agencies to rely on outside engineering experts and exposes the agencies to the risk that their ability to perform their missions will continue to be slowed or even hampered. Conference participants noted that these absences are not necessarily found across the government; the National Aeronautics and Space Administration (NASA), for example, continues to ignite public interest and draw in new talent. While some ideas, such as increased pay, were floated to address the issue, many speakers agreed that creative solutions must be presented to ensure that the agencies remain able to effectively and efficiently serve their constituencies and the public.

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[101] For an explanation of DSS, *see Dynamic Spectrum Sharing: How It Works & Why It Matters*, CELONA (Oct. 14, 2020), https://www.celona.io/5g-lan/dynamic-spectrum-sharing-how-it-works-why-it-matters#:~:text=What%20Is%20Dynamic%20Spectrum%20Sharing,bandwidth%20based%20on%20user%20demand.

X. Participants

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XI. Acronyms

AR/VR, Augmented reality / virtual reality

AWS, Advanced Wireless Services

C-Band, radio frequencies ranging from 4.0 to 8.0 gigahertz

CBO, Congressional Budget Office

CBRS, Citizen's Broadband Radio System

CEO, Chief Executive Officer

CSMAC, Commerce Spectrum Management Advisory Committee

DARPA, Defense Advanced Research Projects Agency

DOD, Department of Defense

DSS, Dynamic spectrum sharing

EABO, Expeditionary Advanced Base Operations

FCC, Federal Communications Commission

ITS, Institute for Telecommunication Sciences

ITU, International Telecommunication Union

L-Band, radio frequencies ranging from 1.0 to 2.0 gigahertz

MIMO, Multiple input, multiple output

MOJITO, Multisite-Ops 5G Joint Independent Testing Option

MOU, Memorandum of Understanding

NASA, National Aeronautics and Space Adminstration

NBP, National Broadband Plan

NIST, National Institute of Standards and Technology

NOAA, National Oceanic and Atmospheric Administration

NSF, National Science Foundation

NSTC, National Science and Technology Council

NTIA, National Telecommunications and Information Administration

OSM, Office of Spectrum Management

OUSD(R&E), Office of the Undersecretary of Defense for Research and Engineering

PATHSS, Partnering to Advance Trusted and Holistic Spectrum Solutions

PCAST, President's Council of Advisors on Science and Technology

R&D, Research and development

RAN, Radio access network

RF, Radio frequency

STEM, Science, Technology, Engineering, and Mathematics

ZTA, Zero trust architecture

XII. About Silicon Flatirons Center

Mission

Silicon Flatirons' mission is to elevate the debate surrounding technology policy issues; support and enable entrepreneurship in the technology community; and inspire, prepare, and place students in these important areas. Learn more at siliconflatirons.org/about-us/.

Spectrum Policy Initiative

Spectrum policy dictates how, where, and when wireless services can be delivered to devices—and it has deep ramifications for the economy, scientific development, national security, personal enjoyment, and more. Since 2005, Silicon Flatirons has explored the intersection of policy and engineering in the heavily regulated and rapidly changing wireless services industry.

Silicon Flatirons convenes stakeholders and provides law and engineering students with a foundational understanding of spectrum policy. The Spectrum Policy Initiative engages a wide range of wireless industry professionals, radio engineering professionals, and spectrum policymakers from Colorado, Washington, D.C., and across the country.

Learn more about the Spectrum Policy Initiative and other Silicon Flatirons Initiatives at siliconflatirons.org/initiatives/.

Our Team

For more information about center leadership, faculty, staff, fellows, and advisory board, visit siliconflatirons.org/about-us/our-team/.

Our Supporters

Silicon Flatirons exists thanks to the generosity of our supporters and the strength of our community. We rely on their contributions to advance our mission to catalyze policymaking and innovation and to develop the next generation of tech lawyers, policy experts, and entrepreneurs.

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We promote thought leadership and intellectually honest discourse not only in our events, but in publications from our team, our roundtables, and scholars presenting at our conferences. See more at siliconflatirons.org/publications/.