



Repurposing Government Spectrum for Licensed Commercial Use:

A Win-Win for Wireless Providers
and Federal Agencies

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Executive Summary

The federal government is the United States' largest spectrum user. This is no surprise given the multitude of federal missions, from defending the nation to air traffic control to everyday agency communications. Federal communications systems, however, often rely on decades-old wireless technologies, have limited capabilities, and are less spectrally efficient.

However, the demand for licensed spectrum to power commercial wireless networks keeps growing. While U.S. wireless providers have invested hundreds of billions to build more cell sites and more efficiently use their existing spectrum resources, more licensed spectrum is needed, particularly to unleash the full power of 5G networks and ensure a strong foundation for the 5G economy over the next decade.

At first blush, this may appear to create an intractable conflict between federal agencies and the commercial wireless industry. Fortunately, more than 15 years ago, policymakers identified a way to create win-win outcomes: transition federal spectrum to commercial wireless use while making federal users whole with comparable—and often enhanced—wireless systems so federal missions remain well served.

The Commercial Spectrum Enhancement Act of 2004 created a forward-looking spectrum clearing and reallocation framework. This law was instrumental in converting several bands of spectrum previously used by federal agencies to commercial use, like the AWS-1 and AWS-3 bands, that were crucial in establishing U.S. 4G global leadership.

At the same time, federal agencies used revenues from these spectrum auctions to upgrade and modernize their communications systems. For instance, as part of the AWS-1 and AWS-3 auctions, the Spectrum Relocation Fund has already transferred nearly \$4.6B to federal agencies to upgrade their systems using other spectrum—funding that enables transitions to modern, state-of-the-art digital systems, IP-based technologies, and fiber, thus improving communications efficiencies and capabilities.¹

This paper explores the win-win outcomes that flowed from two efforts—AWS-1 and AWS-3—that repurposed federal spectrum for commercial use thanks to CSEA mechanisms, while looking forward to the lower 3 GHz opportunity to unlock additional similar benefits for federal agencies and the wireless industry.

The CSEA's Spectrum Relocation Fund Makes Auctions of Federal Spectrum a Win-Win

In the early 1990s, policymakers identified a U.S. spectrum management quandary: lots of spectrum allocated to the U.S. government, often used inefficiently; and a growing demand to identify additional spectrum bands to support the growing commercial wireless market. Lawmakers sought a framework to repurpose government-held spectrum for commercial use.

Congress initially sought to pave the way in 1999 by allowing auction winners to negotiate with federal agencies to determine the costs and timeline for relocating federal systems from the newly licensed bands.² Although this was a significant step forward, the approach proved unworkable as auction bidders had no upfront knowledge of the relocation costs or timelines, let alone a framework to avoid potential holdout or free rider issues.³

To address these issues and to advance the clearing of federal spectrum for commercial use, Congress enacted the Commercial Spectrum Enhancement Act (CSEA) in 2004.⁵ Specifically, the CSEA:

- 1. Created the Spectrum Relocation Fund (SRF).** The SRF, funded by auction revenues, serves as a centralized and streamlined mechanism for federal agencies to defray the costs associated with relocating to new bands or alternative technologies.
- 2. Provided Greater Certainty for Federal Users and Wireless Providers.** Federal agencies now had to provide estimated relocation costs and a timeline to accomplish the relocation, providing certainty on the timeline for making the spectrum available for commercial use.⁶
- 3. Ensured Agencies Received Sufficient Funds for Relocating.** Total cash proceeds from any auction of federal spectrum had to amount to at least 110 percent of the total estimated costs for relocating federal agencies.⁷

In its original form, the SRF was considerably more restrictive in the types of activities that agencies were allowed to receive funding for in the process of repurposing federal spectrum. But as demand for wireless services continued to grow and the focus on federal spectrum repurposing intensified, Congress modified the SRF to provide more flexibility to federal agencies:

- In 2012, the Spectrum Act required NTIA to identify additional federal spectrum that could be repurposed, allowed SRF payments for sharing solutions as well as relocation, and permitted agencies to access the SRF for planning and system upgrades;⁸
- In 2015, the Spectrum Pipeline Act added an additional requirement for NTIA to coordinate with the FCC to bring federally-held spectrum to the commercial marketplace. It also allowed SRF payments to fund federal agency research and development and related planning activities that have the potential to result in an auction of federal spectrum;⁹ and
- In 2017, the MOBILE NOW Act further updated the SRF to accelerate federal clearing by transferring SRF funds to agencies immediately after an auction is completed rather than after the actual deposit of auction proceeds into the SRF.¹⁰

Taken together, it is clear that Congress believes that the CSEA framework is an important spectrum management tool that should enable stakeholders to identify opportunities for federal spectrum repurposing and for the SRF to streamline funding for the clearing process.¹¹



The [SRF] process allows for the consolidation of Federal spectrum use, with budgetary benefit resulting from spectrum auction proceeds, economic benefit resulting from new consumer wireless services, and agency benefit through the procurement of new communications systems.”

—White House Executive Office of the President/OMB, October 2008⁴

AWS-1 Case Study: The Launch of CSEA and Transitioning Federal Users to New, Updated Systems

The 2006 AWS-1 auction, which paired government-held spectrum in the 1710-1755 MHz band with spectrum in the 2110-2155 MHz band, was the first time the U.S. government applied CSEA, and it stands as a significant milestone in the success of repurposing federal spectrum.

The 2006 auction and a follow-on AWS-1 auction generated \$13.7 billion in winning bids,¹² at a federal relocation cost of \$1.55 billion.¹³ That's an ROI of more than 775%, which doesn't even include the resulting economic benefits (jobs, GDP) from commercial deployment of that spectrum.

Challenges Overcome in the 1710-1755 MHz band. Transitioning federal operations from this spectrum required the relocation of 12 federal agencies from the 1710-1755 MHz band. All told, the band contained 1,990 NTIA-issued federal frequency assignments, ranging from fixed microwave systems used to transmit voice and data signals from one site to another to more specialized law enforcement video and surveillance systems and mobile aeronautical systems.¹⁴

Benefits to Federal Agencies. While specific transition plans varied by agency, many used this spectrum repurposing as an opportunity to transition from legacy analog systems to new digital systems and IP-based technologies, improving communications efficiencies and capabilities.¹⁵

- The Department of Agriculture's (USDA) Forest Service, for instance, used the opportunity to upgrade to its radio control functions, replacing its existing radio systems with next-generation data radio technologies using Radio over Internet Protocol (RoIP).¹⁶ New, IP-based radio technology allowed for seamless interoperability between USDA and other Internet-capable systems, provide faster and more efficient transmissions, and data delivery guarantees. USDA was able to upgrade its technology with enhanced functionality at a lower operational cost to the agency.¹⁷
- Within the Department of Energy, the Southwestern Power Administration was able to transition its legacy analog microwave communications to a new digital backbone or to new digital microwave systems.¹⁸ Similarly, systems within the Western Area Power Administration (WAPA) replaced 767 miles of radio with fiber, allowing WAPA to benefit from new technology, avoid areas of high congestion due to existing spectrum usage, and eliminate interference concerns.¹⁹
- The Department of Interior's Bureau of Reclamation (Reclamation) was also able to benefit from the AWS-1 auction, replacing analog microwave systems with digital microwave on alternative frequencies.²⁰ Upgrading these systems provided Reclamation with enhanced capabilities such as remote monitoring, converging multiple voice gateways, the ability to transfer data at much higher rates and reliability, and higher encryption levels.²¹ Similarly, the Department of Interior's National Park Service replaced existing analog microwave systems with digital microwave technology to provide more reliable, efficient, and versatile communications systems.²²
- Some agencies, such as the Department of the Treasury and the Navy, were able to use transition funding to relocate their systems to alternate frequency bands such as the 7 GHz and 8 GHz bands. And the National Aeronautics and Space Administration's (NASA), for example, was able to leverage commercial off-the-shelf equipment to relocate its video surveillance and air to ground video telemetry systems, meeting the continued needs of the agency and reallocating valuable spectrum to commercial use.²³

Today, all twelve federal agencies have ceased operations in the 1710-1755 band so that commercial wireless providers are able to use the spectrum without interference from government operations, with 10 having completed their relocation processes and met their operational needs either by relocating to new frequency assignments or transitioning to an alternative technology.²⁴

Throughout the transition process, OMB and NTIA worked to ensure that federal agencies were able to successfully implement their transition plans and address any unforeseen challenges. For instance, as part of this process, in 2005, the Executive Branch provided Congress and the FCC with a \$936 million estimate for relocating federal users out of the band. As federal agencies worked through clearing and relocation, that number grew, with total cumulative outlays of \$1.36 billion transferred from the SRF to federal users as reported in 2019.²⁵

Clearing and Auctioning AWS-1 Spectrum Boosted U.S. 4G Leadership and Funded Key Congressional Priorities. With the CSEA framework in place, the wireless industry gained access to a key spectrum band for commercial service and federal agencies benefited from significant upgrades to their communications systems made possible only by an auction of repurposed federally-held spectrum. The AWS-1 band was a critical spectrum auction that fueled investment in 4G and helped the U.S. gain first mover advantage as 4G networks began rolling out a few years later. Indeed, the introduction of AWS-1 increased U.S. GDP by \$48.6 billion from 2011 to 2014.²⁶

AWS-3 Case Study: Clearing and Close Industry-Government Coordination Enabling Commercial Use

CSEA mechanisms also played a key role in the highest grossing spectrum auction in U.S. history. In 2014-2015, the FCC auctioned two federal spectrum bands (1695-1710 MHz and 1755-1780 MHz), along with the 2155-2180 MHz band, bringing in \$41.3 billion in revenue. With total federal relocation costs of \$5.1 billion,²⁷ that's an ROI of more than 700%.

Transitioning federal operations from the two government bands required the relocation of ~16 federal agencies and more than 100 federal wireless systems.²⁸ All told, these bands contained over 200 systems or programs that qualified for transition funding as a result of the AWS-3 auction, ranging from NOAA microwave operations and Department of Defense (DoD) air combat training to DHS video operations and DOJ robotics systems.²⁹

The 1695-1710 MHz and 1755-1780 MHz bands presented particular relocation challenges due to the heavy incumbent government usage, but close coordination—greatly enhanced by CSEA-driven collaboration and processes—between federal and commercial stakeholders made this effort a success. And, due to the flexibility provided by Congress in the 2012 Spectrum Act, federal agencies were able to recover costs stemming from the planning actions they took to enable this valuable spectrum to be shared or relocated and to recover pre-auction costs to further effectuate a smooth transition.³⁰

Challenges Overcome in the 1695-1710 MHz band. In this spectrum, federal government operations included a meteorological space-to-earth satellite service that receives and disseminates critical weather data.³¹

NTIA determined that relocation for exclusive non-federal use was not possible, so industry and federal users worked together to identify a solution to accommodate both federal and commercial interests.³² Industry suggested that wireless broadband operations could coexist with smaller and more flexible protection zones,³³ and NTIA, federal incumbents, and the wireless industry collaborated on a web-based portal that contains a database solution to better coordinate spectrum use.³⁴

Challenges Overcome in the 1755-1780 MHz band. The 1755-1780 MHz band was home to a wide variety of federal operations, including microwave links, unmanned aircraft systems, and video surveillance. Although NTIA determined that most federal operations in the band could be relocated to other bands or alternative technologies,³⁷ transitioning some of these—such as satellite and radio systems operated by DoD—would have been cost prohibitive.³⁸

To solve this problem, industry and government collaborated to determine commercial operations could co-exist with satellite systems through the use of protection zones in small, discrete locations.³⁹

Benefits to Federal Agencies. Various federal users in these bands have already transitioned systems out of the spectrum. So far, cumulative outlays for the 1695-1710 MHz band are \$148 million and \$1.527 billion for the 1755-1780 MHz band. Federal agencies continue to access SRF funds as they work towards final clearing or sharing arrangements.⁴⁰ For instance, once completed in 2026, DoD is expected to receive \$3.468 billion and the Department of Justice is expected to receive over \$1.1 billion.⁴¹

As with the AWS-1 auction, federal users were able to benefit from the AWS-3 auction by capitalizing on cost efficiencies and upgrades to new technology. For example, the National Weather Service accessed new technology by replacing microwave links in the 1755-1780 MHz bands with commercially-leased bandwidth. Similarly, the Army relocated microwave systems into the 7 and 8 GHz bands to enable highly mobile ground and airborne DoD systems to utilize the 1780-1850 MHz band. And the Navy updated legacy ship radio to new technology radios.⁴²

Agencies also leveraged relocation funding to realize both equipment and spectral efficiencies. The Department of Homeland Security (DHS) relocated systems to other spectrum bands utilized by law enforcement agencies for similar purposes, allowing for an increased sharing of equipment and technologies.⁴³ DHS also consolidated its management of video operations using mesh technologies that allowed for increased spectrum reuse and a reduction of the agency’s total spectrum footprint.⁴⁴

And the Department of Energy’s Bonneville Power Administration used auction proceeds to fund a transition from a microwave point-to-point system to newer, digital microwave technology or fiber.⁴⁵ Similarly, the Department of Housing and Urban Development was also able to replace antiquated microwave equipment with Internet Protocol-based systems.⁴⁶

Clearing and Auctioning AWS-3 Spectrum Boosted U.S. 4G Leadership and Funded Key Congressional Priorities. Meanwhile, wireless providers have moved quickly to turn on mobile service that leverages this spectrum.⁴⁷ Within two years of the auction, AT&T, T-Mobile, and Verizon had already begun to deploy on their AWS-3 spectrum.⁴⁸



The launch of this streamlined method for the coordination of spectrum sharing between federal and non-federal users represents a significant advance towards facilitating expanded commercial use of the spectrum while ensuring federal agencies continue to have access to the airwaves they need to perform critical functions for the American people.”

—NTIA³⁵



Bipartisan Praise for AWS-3 Government/ Industry Efforts³⁶

“The AWS-3 auction has been a historic success ... [and] will help us fund the national priorities identified by Congress [and] help broaden the American platform for wireless innovation.”

—Then FCC Commissioner
Ajit Pai

“Today marks a key milestone in U.S. spectrum policy. The success of the AWS-3 auction ... has [] shown that it is possible to work together on a bipartisan basis and across agencies to free up spectrum and shows a path forward for making more spectrum available for innovation commercial use.”

—Sen. Brian Schatz

In addition to these airwaves boosting consumers' wireless experience, the auction revenues were used to fund the nation's public safety broadband network, reduce the federal deficit, and deploy NG911 technologies.

The mutual benefits to the American wireless consumer and federal government agencies of clearing and auctioning spectrum can provide valuable spectrum for mobile broadband and preserve and advance important federal missions.⁴⁹

The Next Federal Spectrum Opportunity: The Lower 3 GHz Band

Policymakers have identified the next major opportunity to create more win-win outcomes for federal agencies and the U.S. wireless industry: the lower 3 GHz band. This band is highly valuable given it is adjacent to the 3.5 GHz band and, coupled with the FCC's repurposing a portion of the C-band (3.7-4.0 GHz) for terrestrial wireless use, would provide a sizable swath of mid-band spectrum for 5G. Indeed, many other countries are allocating spectrum in the lower 3 GHz band for commercial 5G services.

In January, NTIA published a report on the upper 100 megahertz, the 3.45-3.55 GHz band⁵⁰, and in July published a report on the full band, noting that the agency is "working ... to determine if, when, and where, and at what cost incumbents can relocate from spectrum in [[the full]] band".⁵¹

Clearing—as opposed to sharing—the Lower 3 GHz would allow the wireless industry to unlock the full potential of this critical mid-band spectrum. Sharing necessarily creates trade-offs by restricting what, when, or where services, infrastructure, or capital can be deployed. And sharing, while appropriate on occasion, decreases the value of auctioned spectrum by restricting use, lowering auction revenue, increasing costs necessary to avoid interference, and, most importantly, limiting the type or quality of allowable services that could be deployed.⁵²

In turn, this risks undermining the certainty to commercial users who will deploy 5G services in this spectrum, benefits to consumers who would otherwise gain access to more robust 5G networks, and the ability of auction proceeds to sufficiently replenish the SRF so that federal agencies can use to upgrade their communications systems and continue to meet their missions.

Industry, NTIA, and the FCC working together presents a significant opportunity to ensure that cleared, licensed spectrum in the Lower 3 GHz band is made available for commercial use under a 5G-friendly framework that enables federal system upgrades as well.⁵³

Endnotes

1. See Wilbur L. Ross and Diane Rinaldo, U.S. Dept. of Commerce and NTIA, *Commercial Spectrum Enhancement Act (CSEA) Annual Progress Report for 2018*, at IA-3, IIC-1, IIE-2 (Oct. 2019), https://www.ntia.doc.gov/files/ntia/publications/3397-ntia_2018_csea_report102819final.pdf (2018 CSEA Report).
2. H.R. Rep No. 108-137, at 7 (2003) (House CSEA Report).
3. *Id.*
4. Spectrum Relocation Fund Guidance, Executive Office of the President, Office of Management and Budget (Oct. 14, 2008), <https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/memoranda/2009/m09-01.pdf>.
5. Commercial Spectrum Enhancement Act, Pub. L. No. 108-494, 118 Stat. 3986, 3991 (2004) (CSEA).
6. House CSEA Report at 7.
7. CSEA § 203(b).
8. Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, § 6701(a)(1)(D), 126 Stat. 156, 245 (2012), codified at 47 U.S.C. § 923(g)(3)(A), (B)(ii). (Spectrum Act).
9. Bipartisan Budget Act of 2015, Pub. L. No. 114-74, § 1005, (2015), codified at 47 U.S.C. § 928(g).
10. Consolidated Appropriations Act of 2018, Pub. L. No. 115-141, § 613, 132 Stat. 348, 1109 (2018), codified at 47 U.S.C. § 928(e)(1).
11. CTIA, *The Benefits of Spectrum Auctions for Wireless Consumers, Providers, and Federal Agencies* (Apr. 2019), <https://api.ctia.org/wp-content/uploads/2019/03/The-Benefits-of-Spectrum-Auctions-for-Wireless-Consumers-Providers-and-Federal-Agencies.pdf>.
12. See 2018 CSEA Report at I-1.
13. See OMB, *Commercial Spectrum Enhancement Act: Report to Congress on Agency Plans for Spectrum Relocation Funds* (Feb. 16, 2007), https://www.ntia.doc.gov/files/ntia/publications/ombspectrumrelocationcongressionalnotification_final.pdf (2007 OMB CSEA Report); 2018 CSEA Report at I-2.
14. See 2018 CSEA Report at I-1.
15. See *id.* at 6, 20, 30-31, 37-38.
16. See *id.* at 9.
17. See *id.*
18. See *id.* at 21.
19. See *id.* at 22-23.
20. See *id.* at 30.
21. See *id.*
22. See *id.*
23. See *id.* at 39.
24. See 2018 CSEA Report at I-1.
25. See Wilbur L. Ross and Douglas W. Kinkoph, US Dept. of Commerce and NTIA, *CSEA Annual Progress Report for 2019*, at I-2 (June 2020), https://www.ntia.doc.gov/files/ntia/publications/ntia_2019_csea_report_june_2020.pdf (2019 CSEA Report).
26. Recon Analytics, *The Impact of 10 MHz of Wireless Licensed Spectrum*, at 1 (Dec. 2015), <http://www.ctia.org/docs/default-source/default-document-library/for-every-10-mhz.pdf>.
27. The total estimated relocation and sharing costs for the 1695-1710 MHz band were \$527.1 million and the total estimated relocation and sharing costs for the 1755-1780 MHz band were \$4.576 billion. 2018 CSEA Report at II-1.
28. 2018 CSEA Report.
29. See *id.*
30. See 2019 CSEA Report at 1.
31. See Letter from Lawrence E. Strickling, Assistant Secretary for Communications and Information, to John D. Rockefeller IV, Chairman, Senate Committee on Commerce, Science, and Transportation at 1 (June 4, 2014) (Strickling Letter). https://www.ntia.doc.gov/files/ntia/publications/ntia_notice_to_congress_per_47_usc_923j_re_1695_and_1755_sharing_final_06-04-2014.pdf.
32. See *id.*
33. See *id.* at 2 (“Industry commenters subsequently urged further evaluation that could potentially reduce the impact of such exclusion zones to make the band more attractive and useful for wireless broadband operations.”).
34. See NTIA, *Portal Opens for AWS-3 Spectrum Coordination*, (Nov. 2015), <https://www.ntia.doc.gov/blog/2015/portal-opens-aws-3-spectrum-sharing-coordination> (NTIA Portal Opens). Although government satellite services retained a primary allocation in this band, it is limited to 27 protection zones across the country within which federal operations are protected from harmful interference. See Strickling Letter at 3; 47 C.F.R. § 27.1134(c).
35. *Portal Opens for AWS-3 Spectrum Sharing Coordination*, National Telecommunications and Information Administration, U.S. Department of Commerce (Nov. 16, 2015), <https://www.ntia.doc.gov/blog/2015/portal-opens-aws-3-spectrum-sharing-coordination>.
36. John Eggerton, *Washington Hails Success of AWS-3 Auction*, *Broadcasting+Cable* (Jan. 29, 2015), <https://www.nexttv.com/news/washington-hails-success-aws-3-auction-137541>.
37. See Strickling Letter at 3.

38. See *id.*
39. See *id.*
40. See 2019 CSEA Report at II-2.
41. See *id.* at IIE-2.
42. DoD, Releasable Information, DOD\AR 1755-1780 (Rev. 1) (Sufficient), at 42 (Mar. 6, 2018), https://www.ntia.doc.gov/files/ntia/publications/releasable_dod_ar_1755-1780_rev-1_sufficient_10_26_2018.pdf; see also DoD, Releasable Information, DOD\N 1755-1780 (Rev. 4) (Sufficient), at 37 (Aug. 20, 2019), https://www.ntia.doc.gov/files/ntia/publications/releasable_dod_n_1755-1780_rev-4_sufficient_11_13_2019.pdf; Dept. of Commerce, Releasable Information, DOC\NOAA 1755-1780 (Rev. 1) (Sufficient), at 8 (May 1, 2018), https://www.ntia.doc.gov/files/ntia/publications/releasable_doc_noaa_1755-1780_rev-1_sufficient_10_26_2018.pdf.
43. DHS, Releasable Information, DHS\DHS 1755-1780 (Rev. 1) (Sufficient), at 96 (Oct. 27, 2017), https://www.ntia.doc.gov/files/ntia/publications/releasable_dhs_dhs_1755-1780_rev-1_sufficient_10_26_2018.pdf.
44. See *id.*
45. Dept. of Energy, Releasable Information, DOE\BPA 1755-1780 (Rev. 1) (Sufficient), at 7 (Mar. 11, 2019), https://www.ntia.doc.gov/files/ntia/publications/releasable_doe_bpa_1755-1780_rev-1_sufficient_11_13_2019.pdf.
46. HUD, Releasable Information, HUD\HUD 1755-1780 (Rev. 2) (Sufficient), at 8 (Mar. 12, 2018), https://www.ntia.doc.gov/files/ntia/publications/releasable_hud_hud_1755-1780_rev-2_sufficient_10_26_2018.pdf at p. 8.
47. See Colin Gibbs, *T-Mobile to begin lighting up AWS-3 Spectrum with launch of LG V20*, FierceWireless (Oct. 17, 2016), <https://www.fiercewireless.com/wireless/t-mobile-to-begin-to-light-up-aws-3-spectrum-launch-lg-v20>.
48. See Howard Buskirk, *Verizon Trims Customer Losses in Q1 But Only After Opening Unlimited Plan*, Communications Daily at 17 (Apr. 21, 2017); Colin Gibbs, *AT&T looks to deploy FirstNet, WCS and AWS spectrum as soon as this year*, FierceWireless (May 31, 2017) <https://www.fiercewireless.com/wireless/at-t-looks-to-deploy-firstnet-wcs-and-aws-spectrum-as-soon-as-year>.
49. Maj. Gen. Robert E. Wheeler (Ret), *Next Steps to Revolutionary Change of Spectrum Usage*, at 6 (May 24, 2017), <https://c4i.gmu.edu/wp-content/uploads/AFCEA-GMU-2017-Wheeler.pdf>.
50. Edward Drocella, Robert Sole, Nickolas LaSorte, *Technical Feasibility of Sharing Federal Spectrum with Future Commercial Operations in the 3450-3550 MHz Band*, NTIA Technical Report 20-546 (rel. Jan. 27, 2020) <https://www.its.blrdoc.gov/publications/download/TR-20-546.pdf>. The FCC has proposed to prepare the band for possible expanded commercial wireless use by removing existing non-federal secondary Radiolocation and Amateur allocations in the 3.3-3.55 GHz band and relocating incumbent non-federal operations out of the band. See *Facilitating Shared Use in the 3.1-3.55 GHz Band*, Notice of Proposed Rulemaking, 34 FCC Rcd 12662, 12662, ¶ 1 (2019).
51. NTIA, *Feasibility of Commercial Wireless Services Sharing with Federal Operations in the 3100-3550 MHz Band* (July 2020), https://www.ntia.doc.gov/files/ntia/publications/ntia_3100-3550_mhz_mobile_now_report_to_congress.pdf.
52. See *id.* at 13-21.
53. See Comments of CTIA, WT Docket No. 19-348, at 2 (filed Feb. 21, 2020).