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Request for Information on the National Spectrum Research and Development Plan

Cellular Telecommunications and Internet Association (CTIA)

Before the
NATIONAL SCIENCE FOUNDATION
NETWORKING AND INFORMATION TECHNOLOGY RESEARCH AND DEVELOPMENT NATIONAL COORDINATION OFFICE
Alexandria, VA 22314

In the Matter of	)
	)
Request for Information on the National Spectrum Research and Development Plan	)
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COMMENTS OF CTIA

CTIA[1] submits this response to the National Science Foundation ("NSF")'s Request for Information on establishing a national spectrum research and development plan ("R&D Plan").[2]

I. INTRODUCTION.

Spectrum R&D is critical to maintaining U.S. global leadership in wireless and enhancing use of spectrum for our nation's economic and national security. The commercial wireless industry has made substantial investments in technology advancements that improve spectrum utilization, enhance service quality, and lower deployment costs. Examples include spectrum refarming, massive multiple-input multiple-output technologies, carrier aggregation, RF front-end design, Open Radio Access Networks, network slicing, and artificial intelligence-enabled network management.[3] During the 4G decade alone, U.S. wireless providers increased their spectrum efficiency by a factor of 42, when measured on a MBs/MHz basis.[4]

These advances—the result of R&D investments—yield innovations and growth in the form of new products, services, and business models that benefit American consumers and U.S.

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[1] CTIA – The Wireless Association® ("CTIA") (www.ctia.org) represents the U.S. wireless communications industry and the companies throughout the mobile ecosystem that enable Americans to lead a 21st century connected life. The association's members include wireless providers, device manufacturers, suppliers as well as apps and content companies. CTIA vigorously advocates at all levels of government for policies that foster continued wireless innovation and investment. The association also coordinates the industry's voluntary best practices, hosts educational events that promote the wireless industry and co-produces the industry's leading wireless tradeshow. CTIA was founded in 1984 and is based in Washington, D.C.

[2] Request for Information on the National Spectrum Research and Development Plan, 89 Fed. Reg. 12871 (Feb. 20, 2024) ("R&D Plan RFI" or "RFI"). This document is approved for public dissemination. The document contains no business-proprietary or confidential information. Document contents may be reused by the government in the National Spectrum R&D Plan and associated documents without attribution.

[3] *See*, *e.g.*, Comments of CTIA, GN Docket No. 22-203, at 18-25 (filed July 1, 2022).

[4] *Smarter and More Efficient: How America's Wireless Industry Maximizes Its Spectrum*, CTIA (July 2019), https://www.ctia.org/news/smarter-and-more-efficient-how-americas-wireless-industry-maximizes-its-spectrum.

enterprises alike. Among others, this includes new competitive broadband options through 5G Home and localized industrial and manufacturing use cases, along with new consumer-oriented sectors such as ride sharing and third-party food and grocery delivery. The U.S. wireless industry is also advancing our national security through innovation and wide-area deployments, both by enabling use of next-generation commercial technologies and networks to support federal missions and by supporting prototyping and testbeds for use of advanced wireless technologies at military installations.

As NSF develops the R&D Plan, we urge it to apply three guiding principles: orient spectrum research toward improving private sector investment and commercially viable deployment; ensure all potential spectrum research areas are explored, including commercial access for full-power spectrum; and promote equitable transparency and access to technical information in stakeholder engagements. These principles will help ensure that R&D will improve lives, enhance our economy, help the nation maintain its global standing while enhancing national security, especially relative to competitors like China, and create well-paying U.S. jobs.

Today, there is an immediate need to evaluate federal spectrum use, transparently with federal and non-federal stakeholders, to better understand opportunities for more intensive and efficient operations. The R&D Plan can help improve spectrum decision making by adding important context about the capacity needs of federal users, operation of federal missions in other countries, and proven sharing techniques.

The U.S. will be able to maintain its leadership role in spectrum only if R&D efforts are connected to marketplace realities—on the commercial front, if the R&D Plan is out of sync with the speed of business, or strays too far into "industrial policy," our nation risks smothering commercial innovation and growth. NSF should strive to avoid arbitrary limitations in terms of vision, scope, or policies in the R&D Plan that could keep the U.S. from achieving vital national goals, and it should pull from lessons learned from prior spectrum evaluations in the process.

Finally, as the National Spectrum Strategy ("Strategy") sets out, there is an immediate need to make additional mid-band spectrum available for commercial use,[5] which will support expanded and enhanced mobile and fixed wireless broadband and is necessary for progress on

[5] *See National Spectrum Strategy*, The White House, at 6-7 (Nov. 13, 2023) ("Strategy").

Open RAN and other network and technology innovations. R&D is, naturally, a longer-term initiative, and it should not slow progress on high-priority spectrum bands under near-term evaluation as part of the Strategy's spectrum pipeline.[6]

II. U.S. GLOBAL LEADERSHIP IN WIRELESS AND THE U.S. WIRELESS ECONOMY ARE BUILT ON FULL-POWER, WIDE-AREA COMMERCIAL NETWORKS WITH PREDICTABLE ACCESS, AND THE R&D PLAN SHOULD EXPLORE WAYS TO ADVANCE SUCH OPPORTUNITIES.

The U.S. relies on full-power spectrum to support wide-area commercial deployments that promote innovation and bring the benefits of new technologies to all Americans—it is the foundation of the wireless ecosystem.[7] It would be imprudent to ignore this reality as NSF launches the R&D Plan. There are multiple actions the R&D Plan can initiate to meet this grand challenge.[8]

A. The R&D Plan Should Promote Research on Enhancing Opportunities for Full-Power, Wide-Area Spectrum Use.

CTIA agrees with the RFI that strategies for conducting research must "ensure[] that all essential spectrum research areas are sufficiently explored," which should include access for additional full-power spectrum, and must recognize that economic factors are relevant to identifying priority areas for spectrum R&D.[9] This comports with the President's directive that the Strategy underlying the R&D Plan include "plans to optimize United States spectrum management" by considering the benefits of exclusive-use licensing as a spectrum access model.[10] And it is consistent with the Strategy's Implementation Plan, which calls for spectrum modeling that includes consideration of economic factors associated with spectrum allocation.[11]

Licensed, full-power spectrum offers the predictable access required for the massive investment necessary to deploy wide-area networks on the scale needed for new wireless

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[6] *See* Comments of CTIA on Implementation of the Strategy, at 12-18 (filed Jan. 2, 2024), https://www.ctia.org/positions/documents/nss-implementation-plan-rfi-comments-of-ctia ("CTIA Strategy Implementation Comments").

[7] *Id*. at 5-12; *see also* Comments of CTIA, Docket No. NTIA-2023-0003, at 11-14 (filed Apr. 17, 2023), https://www.ctia.org/positions/documents/comments-of-ctia-before-ntia-in-the-matter-of-development-of-a-national-spectrum-strategy ("CTIA Strategy Comments").

[8] *See* R&D Plan RFI, 89 Fed. Reg. at 12872, Question 3.

[9] *Id*. at Questions 1, 2.

[10] *See Memorandum on Modernizing United States Spectrum Policy and Establishing a National Spectrum Strategy*, The White House, at Sec. 3(c) (Nov. 13, 2023).

[11] *See National Spectrum Strategy Implementation Plan*, NTIA, at 12, Outcome 2.2(a) (Mar. 12, 2024) ("Strategy Implementation Plan").

innovations such as 5G Home broadband.[12] The U.S. wireless industry is at the forefront of the nation's economic success, with licensed, full-power spectrum contributing more than $5 trillion to the U.S. economy in the last decade, and providers investing a historic $39 billion in 2022 alone on network capacity and coverage expansion.[13] Yet a deficit of licensed spectrum exists as compared to other nations' commitment to licensed use.[14] Absent action to make additional full-power spectrum available for commercial use, this deficit could impede innovation, upend the ability to meet consumer and enterprise demands, and impair non-federal mission-critical use cases such as public safety and critical infrastructure uses, which rely on commercial networks and require predictable, secure spectrum access. It would also hinder the ability of secure, licensed spectrum deployments to support federal missions, including defense capabilities.[15]

Additionally, while NSF seeks input on a definition of "dynamic spectrum sharing" ("DSS"), it should promote research opportunities for proven sharing techniques. Specifically, it should recognize "spectrum sharing" more broadly for R&D purposes and define it to include repacking, relocation, and compression, which can enable full-power, wide-area deployments.[16]

B. NSF Should Explore Efficient Utilization to Enhance Spectrum Opportunities.

The RFI highlights the need for strategies that consider spectrum utilization, efficiency, and resilience.[17] In this regard, and consistent with the approach outlined in the Strategy's spectrum band studies,[18] the R&D Plan should study new means to advance the proven strategies of repacking, relocation, and compression, which have enabled shared commercial access to federal spectrum while enhancing the federal mission. Indeed, there is a long tradition of making

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[12] *See, e.g.*, CTIA Strategy Implementation Comments at 19; CTIA Strategy Comments at 19-21.

[13] *See* CTIA Strategy Comments at 11-14.

[14] *See id*. at 8.

[15] *See*, *e.g.*, *Modernizing Communications for the Air and Space Forces*, AT&T BLOG (Mar. 8, 2023), https://about.att.com/blogs/2023/5g-buckley-space-force-base.html; *5G and technological innovation help the Department of Defense explore new frontiers*, VERIZON (Sept. 2021), https://papers.govtech.com/Moving-to-Agile-100758.html/5G-and-Technological-Innovation-Help-the-Department-of-Defense-Explore-New-Frontiers-139930.html; Press Release, T-Mobile, *T-Mobile and Oceus Team Up to Bring 5G Advanced Network Solutions to U.S. Government* (June 14, 2022), https://www.t-mobile.com/news/business/t-mobile-and-oceus-team-up-to-bring-5g-advanced-network-solutions-to-u-s-government.

[16] *See* R&D Plan RFI, 89 Fed. Reg. at 12872, Question 7.

[17] *Id*. at Question 2.

[18] *See* Strategy Implementation Plan at 6, Outcome 1.2(a); *id*. at A-3 (stating the lower 3 GHz and 7/8 GHz spectrum sharing analyses will include various spectrum management mechanisms, including "spectrum sharing, repacking, relocation, and compression of Federal systems, as well as co-existence via variations in frequency usage, operating locations, time of use, and power levels–for both the Federal and commercial systems") (citations omitted).

spectrum available for shared use under pre-defined or static sharing mechanisms that leverage auction revenues to pay for relocation, repacking, compression, or upgrading federal incumbent users as appropriate, while providing predictable commercial access.[19] Information will be necessary to optimize any coexistence requirements to ensure predictable access to the spectrum.

More efficient federal use will further enable these sharing strategies, and as a first step the R&D Plan should promote evaluation of whether federal agencies are making efficient use of spectrum and help identify the capacity needs of federal users. Ever-increasing spectral efficiency has been a hallmark of licensed users,[20] spurred in part by the unyielding incentive to maximize the return on their investments in spectrum acquisition via auctions. Given the lack of such market incentives among federal users, NSF should encourage research into actual federal spectrum usage, not just allocations, as the Implementation Plan directs.[21] As the Strategy highlights, "[d]ata about current real-world usage, the purpose and type of use (active or passive), as well as occupancy in the time, frequency, and geography domains, is needed as the basis for assessing the potential for increased capacity."[22] Stakeholders need to know where incumbents are located and when and how they are operating. Information on how much bandwidth is required for federal operations, as opposed to how much spectrum they occupy, is an important step. As are technical specifics such as transmit power, duty cycles, antenna and pulse characteristics, and interference margin and mitigation capabilities, which can inform discussion of co-channel and adjacent-channel protection criteria and coexistence.[23]

At the same time, CTIA recognizes that federal users may require evolving spectrum access to meet mission objectives, but a baseline understanding of their current spectrum use is critical to informing future discussions regarding our nation's airwaves. NSF has an opportunity here to promote the collection of such information, which can be populated into a comprehensive system to better facilitate spectrum access for commercial and federal operations alike.

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[19] *See* CTIA Strategy Comments at 21-27.

[20] *See supra* at 1 and n.4.

[21] *See* Strategy Implementation Plan at 8, Outcome 1.3(a); *see also id*. at 4-6, Outcomes 1.1(a), (b); *id*. at 15, Outcome 3.1(a).

[22] Strategy at 12.

[23] *See* CTIA Strategy Implementation Comments at 20-23; *see also* NTIA Commerce Spectrum Management Advisory Committee ("CSMAC"), *Spectrum Efficiency Subcommittee Report*, at 4, 11 (July 2018), https://www.ntia.gov/sites/default/files/publications/csmac_spectrum_efficiency_subcommittee_report_0.pdf ("CSMAC 2018 Spectrum Efficiency Report").

Another area of research could be the extent of inter-agency sharing that is occurring within federal allocations, as well as opportunities for greater government-to-government sharing to free up bandwidth for commercial use.[24] Research should also be encouraged regarding whether mission requirements can be met by migrating functions from federal systems to commercial networks or other mediums such as fiber, as the Implementation Plan directs.[25]

The R&D Plan should also promote research on federal receiver performance in targeted bands.[26] This enhanced understanding would provide meaningful information for future reallocations, including as the interference environment evolves, safeguard against approaches that may unnecessarily inhibit other potential uses in a band, and better ensure affected parties disclose relevant information before spectrum policy decisions are made.[27]

Finally, the R&D Plan should leverage resources within the FCC and NTIA's Institute for Telecommunication Sciences to facilitate the U.S. Government's understanding of 5G and future wireless technologies for purposes of evaluating bands and coordination with federal users. This will enable more refined conversations about the practical realities of wireless broadband deployment, which can better inform discussions on spectrum repurposing and sharing.

C. The R&D Plan Should Promote Transparency in Spectrum Evaluations to Facilitate Informed and Effective Spectrum Sharing and Coordination.

The R&D Plan should promote development of information sharing policies for use during spectrum investigations, as effective policies can only be achieved when all interested stakeholders can meaningfully engage in and benefit from the discussion.[28] A variety of spectrum stakeholders, including the Department of Defense ("DoD") and industries, will be seeking access to information to enable shared use. Unfortunately, history has shown there is likely to be an imbalance in terms of which stakeholders receive access to relevant data—in particular, to sensitive or classified information. In the context of the Partnering to Advance Trusted and Holistic Spectrum Solutions ("PATHSS") Task Group and Emerging Mid-Band

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[24] *See* CSMAC 2018 Spectrum Efficiency Report at 11.

[25] *See* Strategy Implementation Plan at 5-6, Outcome 1.1(b); *see also* Department of Defense Research & Engineering Enterprise, FutureG Office, https://rt.cto.mil/futureg-home/ (last visited Mar. 18, 2024).

[26] *See*, *e.g.*, Strategy Implementation Plan at 16, Outcome 3.1(c).

[27] *See* Comments of CTIA, ET Docket No. 22-137, at 10 (filed June 27, 2022); *see also* Expanding America's Leadership in Wireless Innovation, 78 Fed. Reg. 37431, 37434, Sec. 5 (June 14, 2013) (strongly encouraging the FCC to develop a program of performance criteria for radio receivers and requiring NTIA to provide information regarding federal receiver standards and agency practices to facilitate the same).

[28] *See*, *e.g.*, Strategy Implementation Plan at 8, Outcome 1.3(a); *id*. at 10-11, Outcome 2.1(a).

Radar Spectrum Sharing ("EMBRSS") initiative, for instance, coexistence dialogue and discussions of accommodating federal and commercial users were constrained and would have been enhanced if there had been additional transparency on the inputs and assumptions being modeled, including the domestic usage and expected service life of the relevant DoD systems.

As the National Security Telecommunications Advisory Committee ("NSTAC") stated: "Incumbent federal systems users should be as transparent as possible to enable meaningful evaluation of the spectrum for commercial use."[29] The R&D Plan should facilitate development of a mechanism for all relevant stakeholders to meaningfully engage with usage, testbed, and technical data. This could build off and enhance solutions used in the PATHSS/EMBRSS and Advanced Wireless Services processes for classified and controlled unclassified information.[30]

The R&D Plan should also promote development of a roadmap for *ex ante* coordination processes that are transparent and that hold both new entrants and incumbent federal operators accountable for the commitments that are made and relied on regarding spectrum repurposing and sharing. Such initiatives should not, however, duplicate any principles for spectrum management/coordination developed by NTIA and the Interagency Spectrum Advisory Council.

D. NSF Should Explore Global Harmonization and International Coexistence with Military Radars to Inform Domestic Policy Considerations.

The R&D Plan should promote research on the benefits of spectrum harmonization and economies of scale for wireless equipment. Harmonizing spectrum for substantially similar use worldwide helps minimize the threat of other countries seeking to dominate bands for 5G and beyond, while benefitting consumers through economies of scale in infrastructure, devices, and chipsets. It is thus in our national interest to participate in global spectrum harmonization, rather than having the U.S. on a spectrum island.[31] Failing to leverage global allocations leads to lost innovation and productivity and higher costs, which put at risk the estimated $200 billion in economic benefits that spectrum harmonization can bring to the U.S. over the next decade.[32]

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[29] Letter from Scott Charney, NSTAC Chair, to President Joseph R. Biden, at 5 (2024), https://www.cisa.gov/sites/default/files/2024-02/2024.02.26-DRAFT_NSTAC_Letter_to_the_President_on_Dynamic_Spectrum_Sharing-508c.pdf ("NSTAC Letter"); Howard Buskirk, *NSTAC: Balance Industry and Federal Interests in Spectrum Strategy*, COMM. DAILY (Mar. 8, 2024).

[30] *See* CTIA Strategy Implementation Comments at 24; *see also* Strategy Implementation Plan at 8, Outcome 1.3(a).

[31] *See* CTIA Strategy Implementation Comments at 15; CTIA Strategy Comments at 31-32; NSTAC Letter at 8; *see also* Strategy Implementation Plan at 16, Outcome 3.1(e).

[32] *Advancing US Wireless Excellence: The Case for Global Spectrum Harmonization*, ACCENTURE, at 8 (Feb. 2024), https://www.ctia.org/news/advancing-u-s-wireless-excellence-the-case-for-global-spectrum-harmonization.

In this regard, research would be useful on the demonstrated ability of dozens of nations to deploy 5G without compromising military radar systems, including the type utilized by DoD in the U.S. and abroad, for example in the 3 GHz band.[33] Such information would be beneficial to discussions on the transition of similar spectrum here in the U.S. and could inform opportunities for upgrades to, or replacement of, outdated federal equipment to better support defense missions while enabling commercial access.

III. IN STUDYING DSS, THE R&D PLAN SHOULD INCORPORATE LESSONS LEARNED AND RECOGNIZE CHALLENGES.

Novel spectrum sharing technologies are worthy of exploration, and the "technical demonstration platform" envisioned by the Strategy may prove informative for future spectrum repurposing discussions. The R&D Plan should acknowledge, however, that DSS is, at present, a potential complement to commercial, full-power, exclusive-use licensing, not a replacement.

Additionally, as NSF explores strategies for DSS R&D, it should ensure any DSS testbeds are not conducted in mid-band frequencies identified for near-term study. If NSF believes a testbed is appropriate for the bands identified in the Strategy for near-term use, it should consider testing in the 37.0-37.6 GHz band and in the non-3GPP standardized portion of the lower 3 GHz band (*i.e.*, 3.1-3.3 GHz).

The R&D Plan should recognize that DSS need only include sharing across a single dimension (*e.g.*, geography, frequency, time, power) at one time. In this way, R&D strategies can consider the widest array of options and focus on a broad range of spectrum access needs, including full-power opportunities, even as DSS is explored. To that end, DSS should be viewed more broadly than any single implementation, such as the Citizens Broadband Radio Service ("CBRS"). Rather, it should be defined as a sharing mechanism that allows for spectrum access to the same frequency band by two dissimilar spectrum users that varies in near-real time across one or more other dimensions of spectrum use: geography, frequency, time, or power. Such definition should be revisited over time as the landscape evolves.

In any research on DSS, NSF should acknowledge and seek not to replicate the various challenges that have erupted in early spectrums sharing experiments, consistent with the

[33] The n77 and n78 bands from 3.3-3.8/4.2 GHz are being used by nearly 50 countries for 5G, many of which have U.S. or allied radar systems that coexist or will need to coexist in the future with widely deployed 5G networks. *See Successful Military Radar and 5G Coexistence in the Lower 3 GHz Band: Evidence from Around the World*, CTIA (Aug. 15, 2023), https://www.ctia.org/news/successful-military-radar-and-5g-coexistence-in-the-lower-3-ghz-band-evidence-from-around-the-world.

Implementation Plan's call for assessing past spectrum allocation challenges and successes.[34] We identify three key issues below.

First, it is widely recognized that the CBRS framework has a number of limitations and has resulted in over-protection of federal incumbents in the band.[35] Indeed, NTIA has directed that further study of the 3.1-3.45 GHz band will address these shortcomings, highlighting that the effort for this band will focus on achievable outcomes that "substantially improve the efficiency of spectrum use as compared with current approaches to [DSS] (such as the [CBRS]) by leveraging new technologies and capabilities."[36] NSF should pursue realistic modeling assumptions as necessary to ensure federal incumbent systems are adequately, but not overly, protected by new commercial systems that share the same frequency band. Among other things, the following solutions could serve as a guide: (1) allowing use of clutter data, where appropriate; (2) relaxing highly conservative federal incumbent protection reliability, thereby making more spectrum available for commercial use without jeopardizing federal operations; (3) removing aggregate interference coordination calculations, which have been shown to be unnecessary and complex to efficiently implement in dynamic environments; and (4) more timely releasing spectrum after incumbent cessation of use.

Second, modeling and coordination areas must be grounded in real-world measurements and realistic system capabilities. For instance, measurements of commercial wireless systems show significant attenuation is provided by terrain, clutter, the curvature of the earth, antenna pointing, and time occupancy, but these and other factors were not accurately represented in the prior CBRS or PATHSS/EMBRSS processes. Incumbent systems are also often equipped with interference avoidance and rejection capabilities, which were likewise not considered in the PATHSS/EMBRSS or CBRS modeling. Moreover, the "whisper zones" around each CBRS Environmental Sensing Capability ("ESC") sensor cause CBRS devices to be shut down or operated at much lower power levels, a problem that is compounded by having multiple ESC providers. The CBRS and PATHSS/EMBRSS incumbent protection approaches also did not consider realistic operational settings, network laydowns, and capabilities of incumbent systems.

[34] *See* Strategy Implementation Plan at 12, Outcome 2.2(b).

[35] *See*, *e.g.*, NTIA, CSMAC, *Report of Subcommittee on CBRS*, at 6, 8, 10-11, 16-17 (Dec. 2023).

[36] Strategy Implementation Plan at 19, Outcome 3.2(f).

Third, the R&D Plan should promote robust, commercially viable service. The lack of investment in the CBRS band, as demonstrated by the low level of deployment and public statements to investors, underscores the need for spectrum access models that are scalable and incent necessary investment in large-scale spectrum use, with technical rules including full-power base stations to better align with the coverage of similar spectrum bands.[37] NSF correctly recognizes the importance of these considerations in seeking to ensure R&D projects consider economic, market, and business concerns and models,[38] and the R&D Plan should reflect this objective, consistent with the Strategy, Implementation Plan, and NSF's Directorate for Technology, Innovation and Partnerships.[39] To that end, certain guardrails should be established with any DSS regime developed to ensure commercially viable utilization of the relevant spectrum band by both incumbents and new licensees, including: (1) ensuring access for full-power licensed use; (2) establishing predictable times and/or geographies in which the spectrum can be utilized on an ongoing basis; (3) examining a full range of interference mitigation techniques and not just on/off spectrum access control or transmission power limitations; and (4) using defined co-channel and adjacent-channel interference environments to incorporate in network design and operation.

Finally, NSF should consider guidance on the use of modeling assumptions that play an important role in spectrum sharing proceedings, such as the 6 GHz band. These modeling assumptions could include, for example, building entry loss (including where real-world transmission testing is conducted inside a building), line-of-sight field testing, antenna orientations, bandwidth sizes, duty cycles, and activity factors.

IV. CONCLUSION.

CTIA and its members look forward to working with NSF and the U.S. Government to advance spectrum R&D efforts and the Strategy writ large. By taking steps as discussed herein, NSF can lay the foundation for research initiatives that promote investment and deployment, enhance transparency, and support the holistic needs of all users of our nation's airwaves.

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[37] *See*, *e.g.*, CTIA Strategy Comments at 28-30; Letter from Umair Javed, Senior Vice President, CTIA, to Scott Blake Harris, Senior Spectrum Advisor, NTIA, at 14-16 (dated Jan. 30, 2024) ("CTIA Strategy Implementation Reply Letter").

[38] *See* R&D Plan RFI, 89 Fed. Reg. at 12872, Question 3.

[39] *See* CTIA Strategy Implementation Reply Letter at 6-7; Strategy Implementation Plan at 15-16, Outcomes 3.1(b), (d); *see also* About TIP, NSF, https://new.nsf.gov/tip/about-tip (last visited Mar. 18, 2024).

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