Before the
National Telecommunications and Information Administration
Washington, D.C. 20230

In the Matter of	)	
	)	
Development of a	)	Docket No. 230308–0068
National Spectrum Strategy	)	NTIA–2023–0003
	)	

COMMENTS THE
INSTITUTE FOR THE WIRELESS INTERNET OF THINGS
AT NORTHEASTERN UNIVERSITY

SUMMARY

Northeastern University's Institute for the Wireless Internet of Things is please to file these comments to NTIA's RFC on National Spectrum Strategy. We have limited our comments to issues we feel we have special competence in as shown in the table below:

	Issues								
Pillar	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	•	•			•			•	•
2					•				
3					•				

WIOT BACKGROUND

Researchers and students at Northeastern University's Institute for the Wireless Internet of Things (WIoT) envision a future in which people and their environment are wirelessly connected by a continuum of AI-powered devices and networks, from driverless cars and search-and-rescue drones swarms to implantable medical devices and smart cities. The Institute is home to world-leading expertise, facilities, and technologies dedicated to making wireless communications exponentially faster, more energy efficient, and more secure.

WIoT's research priorities are artificial intelligence and machine learning for wireless systems, 5G and 6G wireless systems, IoT business models for tomorrow's industries, smart and connected implantable medical devices, smart cities and oceans, and unmanned aerial vehicles for civil and national defense.

Pillar #1 – A Spectrum Pipeline to Ensure U.S. Leadership in Spectrum-Based Technologies Issue 1 & 2

WIoT agrees with the comments of the mmWave Coalition, which it is a member of, on the need for a contiguous block of spectrum in 100-200 GHz with a bandwidth at least 30 GHz wide for an alternative for fiber optic links in circumstances where fiber installation is too expensive, not timely enough for unelected needs or in cases of emergency restoration of telecom networks when it is too dangerous to repair or replace fiber links. WIoT is developing sub-THz approaches to provide 1 Tb/s links to offer this alternative for cellular backhaul/fronthaul and for other terrestrial networks. Since the largest present contiguous Fixed service allocation below 200 GHz is only 12.5 GHz wide, larger contiguous blocks will require some sharing with passive satellite spectrum protected by RR 5.340 and US246. However, WRC-2000 Res. 731[1] – proposed in the US inputs to that conference - provides for a process to consider such sharing.

Pillar #1 – A Spectrum Pipeline to Ensure U.S. Leadership in Spectrum-Based Technologies Issue 5

This issue asks

> "Are there changes the government should make to its current spectrum management processes to better promote important national goals in the short, medium, and long term without jeopardizing current government missions?"

[1] https://www.itu.int/net/ITU-R/conferences/docs/ties/res-731-en.pdf

Little is publicly available about the NTIA certification of spectrum support for federal systems. From the 2022 Edition of OMB Circular No. A -11 Section 31.11 the following text can be found:

> "The value of radio spectrum should be taken into consideration when requesting funding for new or modified spectrum-dependent systems. When replacing systems, agencies should consider improvements in spectrum "efficiency" and "effectiveness" compared to the prior system. Agencies should also consider whether there are any non-spectrum dependent or commercial alternatives to meet mission/operational requirements, or whether using an existing or alternative Federal system to meet the capability requirement."[2]

WIoT suggests that NTIA and OMB should consider modifying this provision to explicitly address additionally the issue of spectrum sharing between federal government/"G" and nonfederal government/"NG"[3] users as a factor to be considered before NTIA grants certification of spectrum support for federal systems under the terms of Circular A-11 early in the develop cycle of new federal radio systems. Experience has shown time after time that trying to share with a radio system design without sharing in mind is challenging to impossible.[4] Moreover, spectrum sharing issues arise when *reactive* rather than *proactive* approaches are employed in spectrum sharing. Consequently, consideration early in the design process can facilitate sharing options, particularly if potential NG shares could be involved in considering design and architecture options. While this might be difficult in systems with classified design features, like military radars, it may well be practical in systems with unclassified technology, or in which the classified features are not key aspects of the physical layer of the system design, or in which limitations to access to specific frequency band do not impact the system mission itself.

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[2] Office of Management and Budget, CIRCULAR NO. A–11,PREPARATION, SUBMISSION, AND EXECUTION OF THE BUDGET, AUGUST 2022, at Section 31.11

[3] NG users' spectrum use is regulated by FCC pursuant to 47 USC § 301

[4] M. J. Marcus, "CR: Cooperative Radio or Confrontational Radio," 2007 2nd IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks, Dublin, Ireland, 2007, pp. 208-211, doi: 10.1109/DYSPAN.2007.34.

For example, in the case of next-generation environmental satellites with passive sensors operating in RR 5.340/US246 bands, NTIA could request that the system proponent engage with a dialogue with potential sharers of the band under the provisions of WRC-2000 Res. 731 on issues such as orbit selection, coordination of orbit position with other passive satellites, antenna beamwidth, and antenna pointing direction relative to the motion of the satellite to see if changes from a base design might enhance sharing potential without important impact on satellite performance.

NTIA could also use the A-11 certification process to review whether the system proponent adequately considered the possibility of including incumbent informing capability (IIC) in the system design.

In the next section we discuss another concept that would be helpful.

Pillar #1 Item 8

> This item asks:
> "What incentives or policies may encourage or facilitate the pursuit of more robust federal and non-federal spectrum sharing arrangements, including in mid-band and other high priority/demand spectrum? For example, does the current process for reimbursement of relocation or sharing costs adequately incentivize the study or analysis of spectrum frequencies for potential repurposing? Are there market-based, system-performance based or other approaches that would make it easier for federal agencies to share or make spectrum available while maintaining federal missions? At the same time, what mechanisms should be considered to meet some of the current and future federal mission requirements by enabling new spectrum access opportunities in non-federal bands, including on an "as needed" or opportunistic basis?

The use of the word "incentives" in the first sentence is unclear here. We presume that NTIA is using "incentive" in the context of NG spectrum users regulated by FCC not for G users subject to NTIA's jurisdiction pursuant to 47 USC 902(b)(2)(K) -

> "The authority to establish policies concerning spectrum assignments and use by radio stations belonging to and operated by the United States."

While it is important for NTIA to strive for consensus among G users, almost all G spectrum users are Executive Branch agencies[5] and the search for consensus should not necessarily give individual agencies veto power over NTIA's actions on G spectrum use. We note that GSA has parallel responsibility for federal real property and property rentals by federal agencies. There may be advantages of reviewing GSA's relationship with agencies in the real property area and emulating aspects in NTIA's 902(b)(2)(K) role

Another example in the federal government policy to encourage private firms to cooperate in making their assets available for federal use is the management of the Civil Reserve Air Fleet/CRAF[6], a program under which

> "(t)he airlines contractually pledge aircraft to the various segments of CRAF, ready for activation when needed. To provide incentives for civil carriers to commit aircraft to the CRAF program and to assure the United States of adequate airlift reserves, the government makes peacetime DOD airlift business available to civilian airlines that offer aircraft to the CRAF."

Under a concept parallel to CRAF, NTIA could pay NG spectrum licensees to include design features in their systems that allow more efficient government sharing of spectrum in time of high demand for G spectrum use. We note a parallel may be the 1970s "Protected Communications Zone"/PCZ program[7] under which the Executive Branch "minimize(d) opportunities for intercept (by Soviet/Bloc installations of concern in major cities) of both government and major private firm communications" by paying major carriers to modify their

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[5] FCC's internal spectrum use and the US Capitol Police are examples of other agencies that use spectrum that are not in the Executive Branch

[6] https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104583/civil-reserve-air-fleet/

[7] Foreign Relations of the United States, 1969–1976, Volume XXXV, National Security Policy, 1973–1976 , National Security Decision Memorandum 296, May 23, 1975 https://history.state.gov/historicaldocuments/frus1969-76v35/d177

microwave equipment in Washington DC are to make it more difficult to intercept. (NTIA was involved in the PCZ program at that time.)

Pillar #1 Item 9

This item asks:

> "How do allocations and varying spectrum access and governance models in the U.S. compare with actions in other nations, especially those vying to lead in terrestrial and space-based communications and technologies? How should the U.S. think about international harmonization and allocation disparities in developing the National Spectrum Strategy?"

The bifurcation of spectrum policy between the President and FCC dates to the Radio Act of 1927[8] and was preceded by the creation by several agencies of the Interdepartment Radio Advisory Committee[9] in March 1923 without either statutory or presidential authorization, to fill a power vacuum that existed at that time in spectrum policy under outdated legislation. In virtually every other country spectrum policy is more unified. The closest bifurcation is in the United Kingdom but is rarely discussed. The main UK regulator Ofcom actually has no authority over government spectrum use.[10] The rarely mentioned UK Spectrum Board coordinates national spectrum policy between Ofcom and national agencies:

> "Effective cross-government coordination is critical to ensure government interests are aligned and trade-offs in government spectrum decisions are properly considered. DSIT has overarching responsibility for spectrum policy and strategy across government. The main cross-government governance forum is the **UK Spectrum Board** which provides a forum for strategic level discussion and cross-Whitehall coordination on spectrum-related matters. We are in the process of updating the Memorandum of Understanding (MOU) which outlines both Ofcom's engagement with the Spectrum Board and its representation

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[8] Public Law 69-632, February 23, 1927
https://babel.hathitrust.org/cgi/pt?id=uc1.$b45924&view=1up&seq=204

[9] R. H. Coase , The Interdepartment Radio Advisory Committee, T*he Journal of Law & Economics,* Vol. *5* (Oct., 1962), pp. 17-47

[10] T. Lavender and W. Webb, "Division of Responsibility in U.K. Spectrum Management," in *IEEE Wireless Communications*, vol. 29, no. 3, pp. 8-9, June 2022,
https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9857811

> of UK interests in international spectrum bodies (under the direction made by the Secretary of State) to ensure it reflects the current arrangements."[11] (Emphasis added)

But after nearly a century of spectrum policy bifurcation in the US, congressional support for the needed legislation to change it is unlikely. Most key NG spectrum users seem opposed to a unified system that would give G spectrum users a larger role. Similarly, many large federal agencies are opposed to a greater role of NG influence on G spectrum matters.

The 2012 PCAST spectrum report[12] recommended "Re-involving the White House" at a higher level, stating

> "Various groups in the White House have a stake in the President's agenda regarding spectrum: OMB in allocating funds for spectrum efficiency improvements; the Office of Science and Technology Policy (OSTP) on general spectrum policy; the National Security Staff (NSS) regarding spectrum's role in the maintenance and improvement of national security; and the NEC on the importance of spectrum for innovation and economic growth. PCAST proposes that these four groups come together to formalize a White House Spectrum Management Team (SMT) that would work with the NTIA Administrator to bolster NTIA authority and execute the President's agenda. We recommend that the White House Chief Technology Officer (CTO) take a leadership role, working in concert with the Deputy CTO for Telecommunications, and that representation from the NSS, the OMB, and the NEC be at a similarly senior level."

While there was some attention to this recommendation at that time and it was only partially implemented. It may be a good time to consider it again in view of recent G/NG spectrum policy controversies.

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[11] (UK) Department for Science, Innovation & Technology Policy paper, Spectrum statement, 11 April 2023 https://www.gov.uk/government/publications/spectrum-statement/spectrum-statement

[12] Executive Office of the President, President's Council of Advisors on Science and Technology, Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth, July 2012 at p. 53 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf

Pillar 2 Long-Term Spectrum Planning Item #5

> This item asks:
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> "Are additional spectrum-focused engagements beyond those already established today (e.g., FCC's Technical Advisory Committee (TAC),2 NTIA's Commerce Spectrum Management Advisory Committee (CSMAC) and NTIA's annual Spectrum Policy Symposium) needed to improve trust, transparency, and communication among the federal government, industry, and other stakeholders (including Tribal Nations) and why? What would be the scope of such engagements, how would they be structured, and why would establishing new engagements be preferable to expanding the use of existing models? If existing models are sufficient, how (if needed) should FCC and NTIA maximize their usefulness or leverage their contributions to enhance and improve coordination?"

On this issue WIoT supports the 2018 recommendation of IEEE-USA, the US membership of the major technical society in the electronics field. IEEE-USA included in its position statement on Improving US Spectrum Policy Deliberations the creating a new joint FCC/NTIA advisory committee of independent technical experts in radio technology and spectrum management. It stated

> "FCC and NTIA should supplement their existing Technological Advisory Council (TAC) and Commerce Spectrum Management Advisory Committee (CSMAC), which consist mainly of representatives of major communications firms, with a new advisory committee that serves both agencies and focuses on independent review of options for resolving spectrum conflicts and identifying outdated policies. The new group should be modeled on the EPA Science Advisory Board and the NRC Advisory Committee on Reactor Safeguards and members should have the necessary security clearances to deal with issues involving classified federal government spectrum users, if so requested.
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> Both FCC's TAC and NTIA's CSMAC have been implemented with members who are in most cases representatives of affected parties. While this representation is beneficial in many cases -- in reviewing what affected parties want and how they might be impacted by possible decisions -- it does not give the agencies all the options that are possible with today's and future technologies. FCC has never even asked the TAC to recommend or evaluate options on pending docketed proceedings. On the NTIA side, the CSMAC charter has no provisions for classified deliberations showing that NTIA is not using it for reviewing pending government/federal spectrum policy matters.

FCC and NTIA should supplement the existing committees with a new advisory committee patterned after the prestigious committees that serve NRC and EPA consisting of distinguished members without immediate conflicts (e.g., academics and retirees who have agreed to limit their consulting activities, in exchange for payment as special government employees). A committee that advises both agencies will be a cost-effective way to make sure both are presented with technological policy options, and that their impacts have been evaluated in an objective fashion. The FCC commissioners and the NTIA administrator can then combine this input with more subjective factors in making national interest determinations and policy decisions."[13]

Pillar #3 – Unprecedented Spectrum Access and Management through Technology Development Item #5

This item asks

"What other technologies and methodologies are currently being, or should be, researched and pursued that innovate in real-time dynamic spectrum sharing, particularly technologies that may not rely on databases?

WIoT suggests that NTIA require new system designs that need A-11 certification to include consideration of signal/modulation design features that facilitate the use of "cyclostationary detectors"[14] in NG systems that may try to share spectrum without interference. Cyclostationary detectors are systems that can detect the presence of a format of know signal structure at a much weaker signal strength than the signal can be demodulated at an acceptable error rate. While this seems contradictory, it is possible because the intended receiver must make thousands or millions of decisions/second at a low error rate to demodulate the signal. A detector only has to make one decision: is the signal of known format present or not. Thus the integration time of such as detector compared to the time/bit is a *processing gain* that can be very large

[13] IEEE-USA, POSITION STATEMENT, "Improving U.S. Spectrum Policy Deliberations"
3 October 2018)

[14] W. A. Gardner, "Signal interception: a unifying theoretical framework for feature detection," in *IEEE Transactions on Communications*, vol. 36, no. 8, pp. 897-906, Aug. 1988, doi: 10.1109/26.3769.

allowing a detection levels 10-30 dB or more lower than the usable signal level for acceptable error rate.

Technical literature has considered the use of cyclostationary detectors in cognitive radio systems[15] but it has not been a topic in spectrum policy discussions. We urge NTIA to review with NSF and other funders of federal R&D of increasing the priority of this research topic for use in implementing sharing without relying on databases. We also urge NTIA to consider including this in the A-11 certification process for systems where the ability to detect transmissions is not a security issue and covertness is not an issue. If some federal systems could include in their signal design features that facilitate detection of the presence of such signals at very low signal levels with modest equipment, then the cases where listen-before-talk detectors could be used for short range spectrum sharing could be increased without creating complex real time data bases.

Furthermore, WIoT recommends the NTIA requires new system designs that need A-11 certification the implementation of Artificial Intelligence and Machine Learning (AI/ML) techniques to achieve spectrum awareness and thus facilitate spectrum sharing and optimization across time, space and frequency over large spectrum bands[16]. Traditional techniques for spectrum sensing are based on energy detection over sub-bands of interest, which cannot deliver

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[15] J. Lunden, V. Koivunen, A. Huttunen and H. V. Poor, "Spectrum Sensing in Cognitive Radios Based on Multiple Cyclic Frequencies," *2007 2nd International Conference on Cognitive Radio Oriented Wireless Networks and Communications*, Orlando, FL, USA, 2007, pp. 37-43, doi: 10.1109/CROWNCOM.2007.4549769.
Y. L. Zhang, Q. Y. Zhang and T. Melodia, "A frequency-domain entropy-based detector for robust spectrum sensing in cognitive radio networks," in *IEEE Communications Letters*, vol. 14, no. 6, pp. 533-535, June 2010, doi: 10.1109/LCOMM.2010.06.091954.
[16] Jagannath, Jithin, Nicholas Polosky, Anu Jagannath, Francesco Restuccia, and Tommaso Melodia. "Machine learning for wireless communications in the Internet of Things: A comprehensive survey." *Ad Hoc Networks* 93 (2019): 101913.

in-depth real-time spectrum knowledge[17]. For example, an *N*-point Fast Fourier Transform (FFT) can be used to obtain a measurement of the spectral occupancy across bandwidth *B* with bandwidth resolution of *B/N* Hz. However, these and similar techniques fail to recognize *who, when, where* and *how* the spectrum is being utilized. In stark contrast, recent work by WIOT researchers has shown that AI/ML techniques can effectively and efficiently solve complex problems such as bandwidth detection[18], modulation recognition[19], detection of polarization, direction-of-arrival and beam identification[20], radio identification[21], and even detection of a particular wireless standard (e.g., a 5G NR waveform or Wi-Fi signal) without the need of complex, explicit feature extraction operations[22]. Ultimately, this will allow the implementation of sophisticated database-free spectrum access policies where some technologies have priorities over others.[23] As for cyclostationary detectors, we urge NTIA to consider coordinating with other federal agencies to substantially increase R&D funding for this research topic.

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[17] Uvaydov, Daniel, Salvatore D'Oro, Francesco Restuccia, and Tommaso Melodia. "Deepsense: Fast wideband spectrum sensing through real-time in-the-loop deep learning." In *IEEE INFOCOM 2021-IEEE Conference on Computer Communications*, pp. 1-10. IEEE, 2021.

[18] Hall, Jacob, Josep Miquel Jornet, Ngwe Thawdar, Tommaso Melodia, and Francesco Restuccia. "Deep Learning at the Physical Layer for Adaptive Terahertz Communications." *IEEE Transactions on Terahertz Science and Technology* 13, no. 2 (2023): 102-112.

[19] Restuccia, Francesco, and Tommaso Melodia. "PolymoRF: Polymorphic wireless receivers through physical-layer deep learning." In *Proceedings of the Twenty-First International Symposium on Theory, Algorithmic Foundations, and Protocol Design for Mobile Networks and Mobile Computing*, pp. 271-280. 2020.

[20] Polese, Michele, Francesco Restuccia, and Tommaso Melodia. "DeepBeam: Deep waveform learning for coordination-free beam management in mmWave networks." In Proceedings of the Twenty-second International Symposium on Theory, Algorithmic Foundations, and Protocol Design for Mobile Networks and Mobile Computing, pp. 61-70. 2021.

[21] Al-Shawabka, Amani, Francesco Restuccia, Salvatore D'Oro, Tong Jian, Bruno Costa Rendon, Nasim Soltani, Jennifer Dy, Stratis Ioannidis, Kaushik Chowdhury, and Tommaso Melodia. "Exposing the fingerprint: Dissecting the impact of the wireless channel on radio fingerprinting." In *IEEE INFOCOM 2020-IEEE Conference on Computer Communications*, pp. 646-655. IEEE, 2020.

[22] Restuccia, Francesco, and Tommaso Melodia. "Deep learning at the physical layer: System challenges and applications to 5G and beyond." *IEEE Communications Magazine* 58, no. 10 (2020): 58-64.

[23] Baldesi, Luca, Francesco Restuccia, and Tommaso Melodia. "ChARM: NextG spectrum sharing through data-driven real-time O-RAN dynamic control." In *IEEE INFOCOM 2022-IEEE Conference on Computer Communications*, pp. 240-249. IEEE, 2022.

CONCLUSIONS

WIoT has commented on several of the issues raised in the RFC and has raised possible new approaches ranging from procedural issues such as possibly broadening the use of the A-11 certification process to technical issues for sharing such as consideration of cyclostationary detectors and Artificial Intelligence and Machine Learning early in the design of new G systems. WIoT is interested in engaging with NTIA and G spectrum users on such topics in any way that NTIA feels is most constructive. We thank NTIA for this opportunity.

/s/

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