Making Data Available for National Spectrum Management: Workshop Report

National Institute of Standards and Technology Boulder Laboratories

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Prepared By

Wireless Spectrum R&D
Interagency Working Group

of the

Networking and Information Technology
Research and Development Program

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Executive Summary

On May 3-4, 2023, the Networking and Information Technology Research and Development Program Wireless Spectrum Research & Development Interagency Working Group (NITRD WSRD IWG) held a workshop titled *Making Data Available for National Spectrum Management*. The objectives of the workshop were the following:

- Identify challenges associated with obtaining, disseminating, and using data about spectrum to support policy making, operations, and research and development (R&D) with applications to spectrum sharing and optimization through improved analysis, modeling, and prediction.
- Discuss ideas for resolution of these challenges through the action of researchers, industry, agencies, regulators, and/or legislators with potential inputs to R&D agency prioritization and the National Spectrum Strategy.

It had been almost a decade since the previous WSRD IWG workshop on spectrum data, *Understanding the Spectrum Environment: Data and Monitoring to Improve Spectrum Utilization,* held August 2014. The May 2023 workshop sought to refresh the R&D recommendations generated by that workshop and to investigate new requirements driven by changes such as the rise of artificial intelligence and machine learning technologies.

Between the end of the workshop and the completion of this report, additional emphasis on the need for R&D related to data for national spectrum management came with the publication of the National Spectrum Strategy[1] in October 2023. Collection and use of trustworthy data is a theme throughout the National Spectrum Strategy, appearing as a key component of all the strategic objectives under Pillar One of the strategy, “A Spectrum Pipeline to Ensure U.S. Leadership in Advanced and Emerging Technologies,” and Pillar Two, “Collaborative Long-Term Planning to Support the Nation’s Evolving Spectrum Needs.”

Key takeaways of the Workshop included:

- Top most wanted spectrum data sets
  - Spectrum occupancy data
  - Interference events and impacts reports
  - Model validation data, in particular propagation measurements
  - Others including RF noise, device information, deployment information, and spectrum sharing information
- Guiding principles for spectrum data management and stewardship
- Next steps for WSRD IWG

Introduction

The WSRD workshop, Making Data Available for National Spectrum Management, was held on May 3-4, 2023 at the National Institutes of Standards and Technology (NIST) laboratory in Boulder, Colorado. In this context, the word spectrum refers to the radio frequency portion of the

[1] The White House. (2023, November). *National Spectrum Strategy.* https://www.ntia.gov/sites/default/files/publications/national_spectrum_strategy_final.pdf

electromagnetic spectrum. The video recording is available at WSRD Workshop: Making Data Available for National Spectrum Management | NIST.[2]

One objective of this workshop was to identify challenges associated with obtaining, disseminating, and using data about spectrum to support policy making, operations, and R&D with applications to spectrum sharing and optimization through improved analysis as well as modeling and prediction. Other objectives included discussing ideas for resolution of these challenges through the action of researchers, industry, agencies, regulators, and/or legislators with potential inputs to R&D agency prioritization and the National Spectrum Strategy.

The following items motivated members of the WSRD IWG to plan and execute the workshop:

- WSRD IWG discussions regarding privacy challenges for spectrum monitoring/data collection.
- The desire to maximize results of data collected through agency spectrum-related programs (e.g., Spectrum Innovation Initiative,[3] SWIFT,[4] PAWR,[5] SC2,[6] etc.)
- Perceived need to build on the results of the 2022 RF Data Factory Workshop.[7]
- Conclusion of 2019 WSRD Workshop Report (Artificial Intelligence & Wireless Spectrum: Opportunities and Challenges):[8]
  - "… The specific methods for measuring and collecting data that will be needed to effectively implement [machine learning] ML techniques is an important research area. Collection, processing, and storage issues to support ML techniques may also be a challenge. Challenges notwithstanding, fueled by the ability to track, collect, and leverage enormous amounts of data, advances in [artificial intelligence] AI show great promise for improving and automating the spectrum management systems that wireless communication networks depend upon."
- WSRD FY 2024 strategic priorities (updated periodically):[9]
  - Strategic priority 3: Increase the overall utilization of the electromagnetic spectrum through better systems and mechanisms for spectrum and interference management, sensing, sharing, monitoring, control, prediction, adaptation, and protection.
  - Strategic priority 4: Develop trustworthy measurement-based data-driven algorithms, analytics, and models to inform system design, spectrum policy and management.
  - The principle of making decisions based on evidence, driven by the best available science, and accurate and precise data.

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[2] NIST. (2023, May). *WSRD Workshop: Making Data Available for National Spectrum Management.* https://www.nist.gov/news-events/events/2023/05/wsrd-workshop-making-data-available-national-spectrum-management

[3] NSF. (2021, January). *Spectrum Innovation Initiative: National Radio Dynamic Zones (NRDZ).* https://new.nsf.gov/funding/opportunities/nrdz-spectrum-innovation-initiative-national-radio-dynamic-zones/505788/nsf21-558

[4] NSF. (2020, January). *NSF 20-537: Spectrum and Wireless Innovation enabled by Future Technologies (SWIFT).* https://new.nsf.gov/funding/opportunities/swift-spectrum-wireless-innovation-enabled-future-technologies/505774/nsf20-537/solicitation

[5] Platforms for Advanced Wireless Research (PAWR). https://advancedwireless.org/

[6] DARPA. *SC2: Spectrum Collaboration Challenge*. https://www.darpa.mil/research/programs/spectrum-collaboration-challenge

[7] NSF. (2022, June). *RF DataFactory.* *https://workshop.rfdatafactory.com/program*

[8] NITRD. (2020, November). *Artificial Intelligence & Wireless Spectrum: Opportunities and Challenges.* https://www.nitrd.gov/pubs/AI-WirelessSpectrum-2019WorkshopReport.pdf

[9] NITRD. *Wireless Spectrum Research and Development*. https://www.nitrd.gov/coordination-areas/wsrd/

- Support data-driven processes for long-term spectrum planning that increase transparency into current and future federal and non-federal spectrum use, and that anticipate and enable technological advances to facilitate spectrum access.

Welcome from WSRD Co-chair

Mike DiFrancisco, National Telecommunications and Information Administration (NTIA) Office of Spectrum Management, welcomed participants and reviewed the agenda and workshop objectives. He described the panel sessions and said that the first panel will address the big questions to think about throughout the entire workshop to help spur discussion during the final session: what are the most wanted spectrum data sets for each area (policy making, spectrum management and operations, R&D), and what are the most important data characteristics for each area? He encouraged participants to sign up for tours of the NIST and NTIA labs.

Welcome from NITRD Subcommittee Co-chair

Kamie Roberts, former director of the NITRD National Coordination Office (NCO), provided some context on NITRD and the WSRD IWG. She said that NITRD is a multiagency program that promotes innovations in pivotal emerging technologies to ensure the U.S. maintains its leadership in information technology (IT). For the past three decades, NITRD has been at the frontier of computing, networking, data, and software that has led to many breakthroughs, from weather modeling to agriculture, from clean energy to advancing the understanding of human diseases like COVID-19. IT is everything, everywhere all at once.

Ms. Roberts expressed her excitement at this first WSRD in-person workshop since the AI and Wireless Spectrum workshop in 2019, before COVID. She said one of the takeaways from that event was that advances in AI show great promise for improving and automating the spectrum management systems that wireless communication networks depend upon, but AI advances are fueled by the ability to track, collect, and leverage enormous amounts of data. In the subsequent years, the WSRD IWG has discussed privacy challenges for spectrum monitoring and data collection and maximizing results of data collected through agency spectrum-related programs. These discussions were the main motivation for this workshop, in addition to the desire to build on the results of the 2022 RF Data Factory Workshop on Radio Frequency Dataset Generation, Access, and Sharing.

Keynote Presentations

The workshop opened with a series of keynotes to set the stage for the discussion sessions to follow.

1: Perspectives on Data for National Spectrum Management and Implications to National Spectrum Strategy

Matt Pearl, National Security Council Executive Office of the President, provided comprehensive remarks about the need to use data effectively and responsibly and the importance to the management of our use of spectrum. Mr. Pearl discussed the critical importance of considering the use of data in spectrum management in 5G & 6G, which are transformative technologies, and present substantial opportunities for economic (energy, transportation, water, agriculture, etc.) prosperity and are critical to national security.

Mr. Pearl described how spectrum management is a critical element of making spectrum available for innovation. The use of spectrum is critically important because it is a finite resource. There is a need to figure out how existing users continue to coexist without interfering with each other.

Mr. Pearl described the two main tools for making spectrum available for new services: repacking/relocating and sharing. He noted that both tools require data and that sharing requires continuous exchange of data/information, possibly with obfuscation to protect sensitive operational information. He said that currently, limited data is available to support spectrum sharing operations and that we need to overcome the data gap. He noted that the Federal Communications Commission (FCC), NTIA, and Department of Defense (DOD) encourage dynamic spectrum sharing to manage interference for federal and non-federal users.

Mr. Pearl described the Citizen Broadband Radio Service (CBRS) at 3.5 GHz as one of few examples where data is being exchanged to support spectrum sharing. Mr. Pearl described the recent Institute for Telecommunication Sciences (ITS) report[10] describing the use of CBRS based on measurements and aggregated data provided by CBRS Spectrum Access System (SAS) administrators as a prime example of transparent data collection. He cited the ITS research and report as an example of evidence-based policy making.

Mr. Pearl said that thoughtful policies on collecting data will be critical going forward and described the administration's effort to develop a National Spectrum Strategy. He said that policies on how to obtain data to support spectrum management may prove to be a critical component. He described one effort underway within the Administration to provide real time data on spectrum use: NTIA's Incumbent Informing Capability (IIC), a mechanism to dynamically share spectrum in a given band between incumbent federal users and new entrants. He noted that the President's FY24 budget includes a request to fund this effort.

Mr. Pearl discussed the challenging issue of how to address privacy in the collection and use of data to support spectrum management. He said that lessons still need to be learned. He said that we must ensure the data the federal government collects minimizes risks to privacy and to federal operations. There are always tradeoffs and costs when collecting data. We need to collect and retain only what we need to achieve spectrum management goals. Mr. Pearl reiterated that the stakes are very high; we have been a leader in the development of wireless communications technology and need to maintain that leadership in collaboration with like-minded allies, while upholding our principles and values, including protection and privacy implicated by the collection of data.

2: Overview of the NIST Privacy Framework

Dylan Gilbert, NIST, described the NIST Privacy Framework,[11] a tool for improving privacy through enterprise risk management. He described the Privacy Framework as a risk-based framework building on the NIST Cybersecurity Framework.[12] The Privacy Framework includes five sub-categories: Identify, Govern, Control, Communicate, and Protect.

Mr. Gilbert described the Privacy Framework and provided some thoughts on its application to data for spectrum management. His observations included the following points:

[10] NTIA. (2023, May). *An Analysis of Aggregate CBRS SAS Data from April 2021 to January 2023.* https://its.ntia.gov/publications/download/TR-23-567.pdf

[11] NIST. *Privacy Framework.* https://www.nist.gov/privacy-framework

[12] NIST. *Cybersecurity Framework.* https://www.nist.gov/cyberframework

- Anonymizing can be tricky if there are other data sets that in combination would cause the data to be de-anonymized.
- Spectrum logic must be simple, and technology must be agnostic, if policymakers want relatively friction-free uptake.
- People contribute when they know why they are being asked to contribute. Crowdsourcing alleviates government burdens in bandwidth, data collection, data publishing, data storage, etc.
  - Enterprise risk management already does this on many levels.
  - Collection, chain of custody, storage, and secure disposal best practices.
  - Can include sales and revenues to justify defense and “Spectrum Management”
- Private databases are integral to commercial advantage. Controlling them is natural, but counterproductive to societal advancement in understanding.
- Access is integral to innovation.
  - Cybersecurity is insufficient for privacy.
  - Privacy allows bad actors to hide under privacy statutes.
  - Both access and privacy are required for the system to remain open and drive innovation.
  - There must be fair and amicable definitions delineated for spectrum management.

3: Spectrum Use and Planning

Joel Taubenblatt, FCC Wireless Telecommunications Bureau (WTB), provided perspectives on spectrum use and planning. He said that there are more questions than answers. He described data that FCC collects from licensees and noted that we might need to track more data:

- Equipment authorization system.
- Different data requirements for different licensed services.
- Generally, more data required for less flexible licenses.
- Geographic licenses – do not require location information for each transmitter.
- Additional data is needed for particular proceedings – he gave some specific examples of data requirements for the recent C-band proceeding.

Mr. Taubenblatt noted that FCC does not collect real-time usage data. He made the following observations on data collection:

- Third party database systems can be a source of much data (CBRS SAS and automated frequency coordination (AFC) 6 GHz database examples).
- Crowd sourcing should possibly be considered.
- Transparency of data/access to data is an important consideration.

Mr. Taubenblatt said that efficient use of spectrum will require evolution of spectrum policy to make more spectrum available.

4: Observations on Data for Federal Spectrum Management & IT Modernization

Alan Rosner, NTIA, described the commerce data strategy that guides and impacts the spectrum IT modernization effort:

- Govern and manage data as a strategic asset.
- Enable more efficient data access and management.
- Promote appropriate data use and access.

- Cultivate a modern data skills workforce.
- Coordinate collaborative data innovation.

Mr. Rosner described NTIA's IT modernization goals:

- Strengthen security - enhance the security of NTIA spectrum IT systems to ensure their continued availability for essential federal missions, and to protect spectrum data from unauthorized release and improper modification.
- Modernize IT platform, including application stack: improve the enhance-ability and scalability of NTIA spectrum IT systems, and provide the IT foundation for future spectrum capabilities.
- Enhance spectrum analyses: provide capabilities that execute more accurate, trusted and repeatable spectrum analyses to improve federal spectrum use efficiency.
- Streamline spectrum processes, improve timeliness, reduce level of effort, and increase transparency of federal spectrum processes.
- Improve accessibility, interoperability, and comprehensiveness of spectrum data.

Mr. Rosner provided closing observations for workshop participants to consider:

- Data underpins everything in IT modernization. To achieve our goals, we must use the data we have better.
- Data has a significant cost: there is a cost to collect, maintain, and secure it.
- In many cases the data we hold is not ours. We must respect that in how we use it; need to ensure it is appropriately secured.
- Data also has significant value often beyond its intended purpose.
- Data needs to be maintained, or it is at risk of becoming obsolete. Need to establish data management processes.
- Data needs to be interoperable so it can be exchanged.

5: Insights on Policy and Regulatory Issues that may Shape the Future of Spectrum Monitoring

Dale Hatfield, CU Boulder & Silicon Flatirons, provided his insights on policy and regulatory issues that may affect data for spectrum management. He described FCC activities regarding receiver performance and highlighted the critical need to understand through measurement the increase in background noise from new technology and systems. He gave the example of noise generation from switching noise for recharging car batteries. He said that we need a system to measure that will locate, classify and respond to noise generation to support enforcement. He also noted that I/Q measurements may be needed to improve spectrum policy.

6: Technical Keynote Linking Data Collection, Storage, Dissemination, and Operations

Dr. John Chapin, National Science Foundation (NSF) and WSRD co-chair, set the stage for the upcoming technical panel sessions on data requirements for spectrum, constraints and policy issues, spectrum data collection, and spectrum data storage and dissemination.

Dr. Chapin provided some ideas on the nature and scope of data needed for spectrum management:

- Spectrum usage data

- Tx/Rx masks for sensitivity
- Contact info for licensees
- Spectrum access requests
- Interference reports
- Deployment counts and locations

Dr. Chapin provided the following spectrum usage data types:

- I/Q data
- Power spectral density maps
- User types/IDs by band
- Bands in use by receivers
- Directional 3D maps

Dr. Chapin provided the following spectrum usage data sources:

- Spectrum monitoring
- Crowdsourced
- Economic indicators
- Transmitter or receiver telemetry

Dr. Chapin said that a variety of data needs, data types, and data sources contribute to effective spectrum management decisions. He highlighted the issue of massive data sets and suggested that there may need to be processing at the source based on requirements for operations, policy, and R&D. He noted the privacy issue and said that bulk storage should not retain privacy sensitive data.

Dr. Chapin described spectrum operations as nested control loops with data collection, analysis, storage and distribution needing to occur in the context of interacting feedback loops involving multiple control, action, and monitoring entities. He discussed other notable issues:

- Organizational issues: federation, governance, funding
  - Autonomous entities collect data, control its storage and use
  - Challenges include emergent behavior, inter-entity interfaces
- Easy evolution–spectrum data systems need to be built and organized to evolve over time
  - Collect and store data on collection, analysis, storage, distribution processes and systems
  - Enable incremental change, side-by-side testing
- Various user requirements
  - Interference control–requires fast information
  - Regulatory enforcement–requires trusted details
  - Policy making–requires accurate overview

Dr. Chapin concluded by noting that spectrum management is evolving. Past technical constraints determined today's spectrum management, but the constraints have changed and new challenges abound.

Sessions

After the keynote presentations, the Workshop included five discussion sessions: Requirements Perspectives, Constraints and Policy Issues, Spectrum Data Collection, Spectrum Data Storage and Dissemination, and Summary of Challenges and Ideas for Resolution. Each session began with a panel, followed by an audience discussion.

1: Requirements Perspectives

The objective of Session 1 was to identify the top five "most wanted" spectrum data sets and their characteristics for policy making, spectrum management and operations, and R&D.

Panel:

- Tom Rondeau, DOD Office of the Under Secretary of Defense for Research and Engineering (OUSD) (R&E) (moderator)
- Lisa Guess, Cradlepoint-Ericsson
- Charles Cooper, NTIA
- Joel Taubenblatt, FCC WTB
- Steve Ellingson, Virginia Tech

Dr. Rondeau asked the panelists a series of general questions related to the objectives and followed up with the specific questions below. His general questions included:

- Why is data important?
- What do you hope to use it for?
- What do you think should come out of this panel/this workshop?

The key takeaways from these general questions included the following:

- The cost to acquire and maintain data is a major factor and concern.
- Data accuracy and the need to cross-check data across multiple sources are critical, as is the need for defined metrics for spectrum occupancy.
- The multi-dimensional nature of data for different spectrum services (radio astronomy, broadband communications, radio navigation, etc.) and across broad frequency bands need to be understood and addressed.
- Receiver performance and ability to deal with noise in receivers is a key issue.
- A CBRS paper[13] provides an example of the type of data that can be acquired and how longitudinal data over many years can be collected and applied to decision making.
- A panelist recommended that we should define desirable characteristics of spectrum data, and provided the following candidate list for consideration:
    - Standard format (or at least lossless conversion with a standard format)
        - "Zoomable" time-frequency resolution
        - Complete and extensible metadata
    - Absolute power density calibration with known uncertainty
    - Sensitivity to ITU RA.769 thresholds (note that other, more stringent, application-specific criteria often apply)
    - Resolution: 1 kHz x 1 ms desired, 100 kHz x 1 ms required
    - Sensitivity to sub-microsecond pulses without bandwidth smearing as a separate mode. Even better: raw digitizer output
    - Triggerable Nyquist-rate buffering
    - Spatial covariance/wavelength-scale averaging
    - Full Stokes, but at least unambiguous description of antenna polarization

[13] NTIA. (2023, May). *An Analysis of Aggregate CBRS SAS Data from April 2021 to January 2023.* https://its.ntia.gov/publications/download/TR-23-567.pdf

  - Localization (or at least discrimination) in azimuth and elevation: where did it come from?
- The same panelist also said that we should be cognizant of potential shortfalls or issues with spectrum datasets that are very important considerations about monitoring systems, such as:
  - Unknown, uncertain, incorrect sensitivity
    - Receiver temperature not reported, uncertain, or incorrect
    - Oversimplifying antenna characteristics, especially gain, impedance, and polarization
    - Not present or incorrect power density calibration
  - Unaddressed spurious, linearity, reciprocal mixing
  - Failure to linearly average over wavelength-scale fading
  - Failure to account for fading in space and time domains
  - Bursty signals obscured by bandwidth smearing

Dr. Rondeau asked how to create the right schema for our data sets. Can we use large language models to help tease out the ontologies for spectrum data? The key takeaways from these questions included the following:

- Spectrum data standards need an extensible meta data format. Additional data should be allowed without breaking the standard and data sets should be hierarchical.
- Data sets should include:
  - System design information
  - Performance information with ranges (typical vs max)
  - Deployment and use information in time, location and frequency (transmitters and receivers)
- FCC's broadband data collection activity provides some experience on the range of data sources and various ways of validating the data. One challenge is assessing the relative value of data.
- A suggestion to use ML to identify problems with data sets.

Dr. Rondeau asked about the concept of synthetic data sets and whether they are useful or not. When do models become useful? How do we compare synthetic data sets to the real world? The key takeaways from these questions included the following:

- Models can become useful if they can help identify what is causing harmful interference.
- Models are instruments and should be commissioned like instruments that are validated by testing. One can envision a set of tests that could validate synthetic data sets to some degree.
- It is important to have cross-checks across multiple data sets.

The key takeaways during the audience Q&A included the following:

- Policies are created based on the best knowledge we have at the time the policies are written, but after that we do not adjust. How can we create a system to adjust policies over time?
- Data needs to be tied to applications and functions; the most critical data for different applications is different. A process and criteria are needed for determining what data is preserved. One criterion is that the data needs provenance.

- The regulators from NTIA and FCC were asked about the decisions they make and how data informs those decisions vs. other avenues to inform decisions (legislation, private desires, etc.)
  - The FCC is always looking for ways to increase the use of spectrum. The information to achieve that objective is obtained through the open rule-making process.
  - NTIA has two broad decision-making categories:
    - Making sure new assignments will not result in harmful interference.
    - Spectrum repurposing analysis that is driven from executive or legislative branch direction.

2: Constraints and Policy Issues

The objective of Session 2 was to discuss and assess legal, policy, and privacy constraints and how they can be overcome while supporting the needs of policy making, spectrum management and operations, and R&D. Topics discussed included operational security issues for agency operations and for key spectrum dependent functions – health care, transportation, etc.

Panel:

- Derek Khlopin, NTIA (moderator)
- Martin Doczkat, FCC
- Lisa Guess, Cradlepoint-Ericsson
- Martin Weiss, University of Pittsburgh
- Mark Walker, CableLabs

Derek Khlopin asked Dr. Martin Weiss to present some concepts and questions that the panel reflected on.

Dr. Weisse said that data architectures should be measured against the Findable; Accessible; Interoperable; Reusable (FAIR) principles, but before we gather data, we should address the Collective Benefit; Authority to control; Responsibility to engage; Ethics (CARE) principles. The key takeaways from the panel and the audience reflecting on the legal, policy, and privacy constraints and operational security issues included the following:

- Data is needed to support policy development (as discussed in Session 1)
  - The need is most acute for bands where the potential for changes to the rules is most likely (e.g., the bands called out for study in the National Spectrum Strategy.)
  - Evidence-based policy making is a key criterion for FCC and NTIA going forward (both separately and together).
    - One open question is how to get the data to make those policy decisions.
  - The more we have and know about systems (e.g., improvements to the equipment certification program) the more we can apply evidence-based policy making.
  - Spectrum use information on incumbent services is needed for any band to support evidence-based policy making.
- Creating incentives for sharing spectrum data is a fundamental challenge that needs to be addressed (note that this issue has been highlighted as a research area in the National Spectrum R&D Plan).
  - How do we create a marketplace so that the holders of data gain something by giving it up?
- Security and privacy have different constraints depending on the entity and their role (government, industry, academia). For example:

  - Espionage is a concern of research organizations.
  - Manufacturers have private networks for their suppliers.
  - Health care has unique privacy and security challenges.
  - Defense operational security is an issue that will necessarily constrain data to support spectrum sharing.
- Privacy is situation specific. To achieve privacy related to spectrum data collection, we need to be able to define ahead of time what the data can be used for. One needs to have a purpose for collecting data. Cannot collect info on the American public without identifying the purpose and notifying the people who the data is about.
  - There is a tension between the FAIR principles focused on sharing data and using it for new purposes vs. the principle that data should only be collected for a defined purpose. How to use data for something new if the collection was motivated by a specific goal?
    - This open question needs to be addressed via policy or guidance.
  - Also need to pay attention to data security, protecting the data from inappropriate use.
- The group discussed the merits of the data collection and reporting approaches used by ITS as reflected in the recent CBRS report.[14]
  - The report confirms positive signs that CBRS is something that users are getting value and it is valuable to have such an objective report.
  - The growth of CBRS deployments over time builds the case for future shared bands. Not every band is suitable for the same type of analysis, but we should try to do similar objective analysis of band usage.
  - The report is a good example of what you can do with more and better data.
- The data necessary to process a claim of harmful interference needs to be defined.
- Innovation in how to use data to support future policy development is needed.
- Tribal communities have a variety of interests, including deploying their own networks and having rights to spectrum.

3: Spectrum Data Collection

The objective of Session 3 was to consider how to collect spectrum data in a way that is affordable, scalable, trustworthy, power-efficient, useful, legal, respects privacy concerns, and that meets the needs of policy, operational, and R&D users.

Panel:

- Melissa Midzor, National Advanced Spectrum and Communications Test Network, NIST (co-moderator)
- Michael Cotton, Institute for Telecommunication Sciences, NTIA (co-moderator)
- Won Namgoong, University of Albany
- Kobus van der Merwe, POWDER testbed, University of Utah
- Gregory Wagner, Defense Spectrum Organization, Defense Information Systems Agency
- Andrew Clegg, Google
- Jenifer Alvarez, Aurora Insight, Maxar
- Brian Jordan, Aerospace Corporation

[14] NTIA. (2023, May). An Analysis of Aggregate CBRS SAS Data from April 2021 to January 2023. https://its.ntia.gov/publications/download/TR-23-567.pdf

Each panelist gave a briefing on their individual projects and perspectives, followed by an open discussion of challenges and opportunities. The key takeaways were the following:

Data on spectrum occupancy and usage:

- Deployment of a dedicated wide-area terrestrial spectrum monitoring network would be cost prohibitive. Even if lower-cost hardware is used, the labor, real estate, and maintenance remain unaffordable, while trends such as 5G deployment using directional antennas require increasingly dense measurements for proper characterization.
- An effective overall spectrum data collection solution should combine land, air, and space-based sensing. Small satellites ("cubesats") in low earth orbit have proven capable of providing useful global data.
- Scalability is at odds with quality/precision of data.
    - Scalability goals encourage generic collection methods. However, collection methods normally must be matched to the use cases for the collected data, e.g. proper measurement sensitivity, antenna configuration, and data reduction pipeline to assure the information of interest is available in the output.
    - Scalability goals require adaptive reduction of data resolution, since detailed collection everywhere is not affordable.
- R&D towards generally applicable metadata standards is essential.
    - In the absence of a dedicated wide-area monitoring network, data used for any particular decision will likely come from multiple providers.
    - The metadata must document information like sensitivity, antenna configuration, and calibration that enable potential consumers to determine whether the data set can be used for their application.
    - R&D on methods or devices that spectrum sensor operators could use to easily create accurate metadata documentation would be valuable, as would methods to make metadata tagging at the point of collection universal.
- Since multiple entities will contribute data used for decision making, R&D towards RF engineering and signal processing best practices that can be widely implemented to raise the quality of collected data would be useful.
- Software-defined radio technology (SDR) is promising.
    - SDR enables one device to perform different spectrum monitoring activities matched to different data use cases.
    - SDR enables integrating spectrum sensing into devices deployed for other purposes, such as communications systems.
    - A key open R&D challenge is to provide sufficient dynamic range in the analog front end to make a multi-function SDR into an effective sensor. High dynamic range is required because spectrum sensing requires the capability to observe weak signals that are near strong ones.
- Spectrum sensing measurements often include unidentifiable signals. R&D is needed to improve interpretation of spectrum measurements.
- R&D should be performed to assess the synergies between incumbent informing mechanisms and spectrum monitoring mechanisms. Combining both approaches is likely to lead to better spectrum efficiency and access robustness than using either alone.

Data to improve propagation, behavior, and band models:

- Measurement data to improve propagation and behavior models is vital to support technology development and system deployment. Collecting this data is an important R&D activity.
- Propagation model improvement is valuable because current imprecise models lead to conservative decision making for safety. Bad propagation models consume spectrum just like poorly designed receivers consume spectrum, by excluding transmissions that would otherwise be permissible.
- Regulatory information on allocations, assignments, and emissions masks is insufficient for design or deployment decisions. Measurement data is essential to build band models that reflect actual usage, deployment, and system behavior, including effects like out-of-band emissions.
- The amount of measurement required to build a behavior model for a transmitter or system is going up significantly, driven by new capabilities like antenna directivity and by cognitive control mechanisms that change behavior based environmental factors such as usage patterns and weather.

Legal and privacy issues:

- Spectrum sensing from space wasn't considered when current regulations were established. The technology and systems have run ahead. It is desirable to establish policies to ensure that U.S. national interest is protected.
- R&D should be done on methods to use incumbent informing mechanisms for privacy and operational security protection, not just for interference prevention. For example, incumbent informing mechanisms could enable the DOD to request that spectrum sensors near a test or training facility switch to a low-resolution mode when sensitive operations happen.

4: Spectrum Data Storage and Dissemination

The objective of Session 4 was to consider how to make spectrum data broadly available to support policy making, operations, and R&D. Topics discussed included how to control access, how to pay for a data storage and distribution infrastructure, how to govern the infrastructure to maximize benefits and prevent misuse, how to achieve the necessary goals while reducing the storage of privacy-sensitive data, and how to label data.

Panel:

- Kaushik Chowdhury, Northeastern University (moderator)
- Nada Golmie, Communications Technology Laboratory, NIST
- Doug Boulware, Institute for Telecommunications Sciences, NTIA
- Monisha Ghosh, SpectrumX and Notre Dame University
- Keith Gremban, Silicon Flatirons and University of Colorado, Boulder

Each panelist gave a briefing on their individual projects and perspectives, followed by an open discussion of challenges and opportunities. The key takeaways were the following:

- Policy making, operations, and R&D have significantly different requirements that will likely require distinct solutions for spectrum data storage and dissemination. At a high level, the FAIR principles are key to making the solutions useful.

- Requirements and planning for spectrum data for R&D uses may be facilitated by leveraging a general framework NIST has developed, the Research Data Framework[15] (RDaF). The RDaF is a tool that aims to help shape the future of open data access and research data management.
- The storage and distribution ecosystem should be structured in a way that the software tools consumers can use to interpret the data are stored, distributed, and evolved by the community along with the data sets; and that complementary data sets such as terrain, building, and foliage data are linked to and findable with the spectrum data that they affect. These goals should guide R&D efforts on prototype storage and distribution solutions and on interfaces and standards supporting the evolving spectrum data ecosystem.
- Spectrum analyses appear to be substantially improved by higher quality complementary data, e.g., 1m vs 5m resolution data on terrain and buildings. R&D should be done to quantify this improvement and assess whether investment in making the higher quality data available to the spectrum community is appropriate.
- Spectrum monitoring data sets are large and will exceed the capacity of any affordable data storage system. Therefore, R&D is needed on data reduction methods that preserve information needed downstream.
- Significant data sets already exist as commercial products that empower sophisticated planning and decision tools. However, the data and tools may not be available to researchers and government users due to their high cost. Also, there is a lack of mechanisms that would attest to the quality and accuracy of the commercial data, making it difficult to use for critical policy decisions.
- Cataloging stored spectrum data for effective access is an important R&D problem. Success depends on adopting a “librarian mindset.” Private sector or nonprofit/open-source catalogs of spectrum data are a valuable complement to governmental efforts. One current example is the NextG channel model alliance. A nascent open-source project is SpectrumWiki.[16]
- Many of the key questions facing policy makers depend on characterizing statistically rare events, e.g., how often usage of a band approaches the worst-case scenario for interference. Data reduction, storage and distribution methods must be designed to enable making grounded estimates at the edge of statistical validity.
- AI/ML could play a valuable role in helping sift through available data sets to find information needed to answer an analytic question. R&D on AI/ML techniques should proceed in parallel with R&D on metadata, labels, and data access approaches to assure they work well together.

5: Summary of Challenges and Ideas for Resolution

The agenda for Session 5 was the following:

- Document the top “most wanted” spectrum data sets.
  - In Session 1, panelists gave their opinions.
  - In Session 5, workshop participants sought to achieve consensus.
- Discuss and document challenges and ideas for resolution of the challenges.

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[15] NIST. (2023, June). *NIST’s Research Data Framework*. https://www.federalregister.gov/documents/2023/06/06/2023-11916/nists-research-data-framework

[16] *SpectrumWiki*. https://www.spectrumwiki.com/Index.aspx

- Discuss what should be included in the National Spectrum Strategy to address data-driven processes for long-term spectrum planning.

The session was chaired by Keith Gremban of Silicon Flatirons and the University of Colorado, Boulder. The session included extensive discussion involving all workshop participants.

The group discussed several ideas for the National Spectrum Strategy but did not come to consensus. Key agreements in the session regarding the agenda items were the following:

Top "most wanted" spectrum data sets

Spectrum Occupancy

Spectrum occupancy data sets describe spectrum usage, normally indexed by spectrum band and by geography. Some current occupancy data sets report only signal power levels, while others classify observed signals or extract internals to provide additional information such as operator or traffic analysis.

Receive-only services like passive sensors also use spectrum, in the sense that they exclude others from transmission at certain times and places. Spectrum occupancy data sets that properly account for receive-only spectrum usage—for example, through recording data streams provided by the sensors showing when they are active, what directions they face, and which frequency ranges are actively being used—are desired.

Occupancy data sets of two types are needed: data sets that cover multiple bands over time as seen from one or a few locations, and data sets that cover one or a few bands over time as seen simultaneously from many locations. The second type of occupancy data set is rare today due to the high cost of collection; however, it is important for analyzing how occupancy changes over time correlate geographically.

Additional notes on this desired dataset:

- Measured occupancy often diverges from, and thus cannot be replaced by, datasets based on regulatory assignments and licenses.
- Detailed occupancy measurements start from collecting raw signal samples, also known as I/Q data. Storing I/Q data would be valuable because it can be analyzed in the future to extract occupancy information that was not of interest during the initial experiment. Unfortunately, stored I/Q data can be analyzed with receiver algorithms to extract audio/video information, message contents, or application data, which in some cases may compromise privacy or proprietary data. This makes it challenging to store or share I/Q data. I/Q data sets should be converted to privacy-protecting representations that still support extracting occupancy information that was not of interest during the initial experiment. The science of such representations is not well understood and should be researched.
- The importance of spectrum occupancy data was reflected in an FCC Notice of Inquiry[17] on Advancing Understanding of Non-Federal Spectrum Usage published after the workshop.[18]

Interference event reports and impact reports

[17] FCC. (2023, August). *Notice of Inquiry*. https://docs.fcc.gov/public/attachments/FCC-23-63A1.pdf

[18] FCC. (2023, August). *FCC Launches Technical Inquiry Into Spectrum Usage Data*. https://www.fcc.gov/document/spectrum-usage-noi

Interference event reports describe events where undesired signal energy in a band rises above expected or permissible thresholds; they include information such as location of the measurement, duration of the power excursion, and measured characteristics of the undesired signal.

Impact reports quantify how interference events impact the performance of the victim system or the mission of its user.

These two types of reports are needed, in part, to help evaluate the technical rules selected for each band. In particular, policy makers need to know whether there is too much or too little protection margin to validate the many assumptions used to develop the rules, and to guide changes that can improve spectrum efficiency or interference protection.

Model validation data, especially propagation measurements

Spectrum planning and control tasks including engineering, system design, band planning, and operational decisions depend on models including propagation models, mission models, environmental models, receiver models, and aggregate interference models, among many others. The limitations of these models, their inaccuracies, and debates about their scope and applicability impair spectrum policy decision making and operations. Datasets that assist in validating and improving these models are needed.

Although these data sets are typically used for R&D to improve the models, it would be equally valid to use them to support policy and operations decision making due to the high impact expected in those areas from improving the above models.

Additional notes on this desired dataset:

- Propagation data is particularly important due to the fundamental role of propagation predictions in many aspects of spectrum decision making, control, and analysis.
- Propagation data measured out to long distances and under troposcatter conditions is highly desired, because current propagation models underpredict loss at long distances and thus limit spectrum availability when sharing.
- High precision data sounders are needed to obtain high fidelity propagation data to improve models. The idea of a central repository of equipment that could be borrowed was floated.

Other datasets

Additional datasets discussed as high priorities were measurements or repositories of:

- RF noise, both anthropogenic and natural
- Device information such as transmit/receive filter masks, transmit power, and receive sensitivity
- Deployment information such as device counts, locations, and operator/owner contact information
- Spectrum sharing information such as geographic and temporal occupancy of a shared band by each user class, e.g., primary, protected, general.

Challenges and Resolution

The session considered the FAIR data practices goals raised in Session 2. Participants extended these to FAIREST to highlight the key best practices for management and stewardship of spectrum data.

- Findable
- Accurate (note difference from FAIR in which A stands for Accessible)
- Interoperable
- Reusable
- Error checked (cross checked or validated automatically)
- Secure (immutable)
- Trustworthy/traceable (zero trust environment)

The group focused its discussion on the second goal, accuracy of data.

- All data sets have bias.
    - Document the intended use before collection.
    - Document all aspects of the data collection to enable determining whether the data set is usable for new purposes discovered after collection.
- Data that is inaccurate is worse than no data.
    - Draw on NIST as a leader in measurement science for data collection.
    - Use signals of opportunity as a calibration source across datasets. Benefits of signals of opportunity include:
        - Everybody has access.
        - These signals are at a place and intensity that doesn't change.
        - They also help to validate geolocation of sensors.
    - Cross-check data sources to detect faked data.

Valuable lessons in how to achieve FAIREST for spectrum data can be found in testbed activities such as NSF PAWR platforms, and in consortia context like the NextG Channel Model Alliance, both of which supply data gathered from multiple sources to multiple user bases.

Conclusion

This workshop aimed to identify challenges associated with obtaining, disseminating, and using data about spectrum to support policy making, operations, and research and development (R&D) with applications to spectrum sharing and optimization through improved analysis, modeling, and prediction. The attendees, who represented a wide range of sectors and backgrounds, weighed in on the most wanted spectrum data sets, which included spectrum occupancy data, interference events and impacts reports, model validation data, etc. They also discussed the guiding principles for spectrum data management and stewardship, which resulted in the creation of a new acronym, FAIREST (Findable, Accurate, Interoperable, Reusable, Error checked, Secure, and Trustworthy or Traceable), to represent the desired principles for spectrum data management and stewardship. Going forward, the WSRD IWG will continue to explore these topics through active engagement, collaboration, and partnerships among industry, academia, and the federal government.

Speaker Bios

All speakers participated in this workshop while affiliated with the listed organizations.

Jennifer Alvarez, Maxar/Aurora Insight

Jennifer Alvarez is the Director of RF Innovation at Maxar RF Solutions after the acquisition of her venture-backed startup, Aurora Insight Inc. She leads Maxar's initiatives in RF sensing. Her roles include developing innovative technologies, architecting cost-effective and high-performance systems, and creating business opportunities and markets for RF data collected from land, air, and space. Her 30-year career as an engineer and as an executive has given her a wide range of experiences across technology, team building, and running a business. She holds nine patents and has a bachelor's degree in electrical and electronics engineering from the University of Texas at Austin, and a master's degree in electrical engineering from the University of Texas at San Antonio.

Doug Boulware, NTIA ITS

Doug Boulware joined ITS in 2017 and has served as the project leader and senior software engineer for the Propagation Modeling Website and senior software engineer for the Spectrum Characterization Occupancy Sensing spectrum monitoring system. Prior to joining ITS, Mr. Boulware conducted research and developed software for 15 years in support of the DOD as both a private contractor and government employee. Mr. Boulware holds a bachelor's degree in computer science from Hamilton College and a master's degree in computer science from Syracuse University.

John Chapin, NSF

Dr. John Chapin is Special Advisor for Spectrum at the National Science Foundation, a role in which he serves as program officer in the Electromagnetic Spectrum Unit of the Division of Astronomical Sciences and advisor on strategic spectrum issues to NSF leadership. Previously, Dr. Chapin has served as a DARPA Program Manager, Vice President at Advanced Technologies for Roberson and Associates, Chief Scientist at TV Band Service, LLC, CTO at Vanu, Inc., and Assistant Professor in the EE and CS department of MIT. Dr. Chapin holds a Ph.D. in computer science from Stanford University.

Kaushik Chowdhury, Northeastern University

Dr. Kaushik Chowdhury is a Professor and Associate Chair of Research in the Electrical and Computer Engineering Department of Northeastern University. His expertise and research interests lie in wireless cognitive radio ad hoc networks, resource allocation in wireless multimedia sensor networks, and bio-medical applications of sensors. Dr. Chowdhury holds a Ph.D. in electrical and computer engineering from Georgia Institute of Technology.

Andy Clegg, Google

Dr. Andy Clegg is the Spectrum Engineering Lead for Google. Prior to joining Google, he served from 2003–2013 as the electromagnetic spectrum manager for NSF. At NSF, he founded the Enhancing Access to the Radio Spectrum (EARS) program, a $50 million research program dedicated to funding academic and small business research focused on improving spectrum efficiency and access. Prior to NSF, he was a Lead Member of Technical Staff at what is now AT&T Mobility, and senior engineer at Comsearch. Dr. Clegg holds a Ph.D. in radio astronomy and electrical engineering from Cornell University.

Charles Cooper, NTIA

Charles Cooper is Associate Administrator in NTIA's Office of Spectrum Management. He leads the agency's work on national and international spectrum policy issues and oversees spectrum management efforts for federal agencies. He is responsible for frequency assignment and certification, as well as other strategic planning functions including development of innovation approaches to spectrum sharing. Before joining NTIA in July 2019, Cooper was the Enforcement Bureau Field Director at FCC, where he managed the nationwide enforcement of spectrum interference affecting public safety communications, FCC licensees, and federal agencies.

Mike Cotton, NTIA ITS

Mike Cotton is the Division Chief of the Telecommunications Theory Division. He joined NTIA/ITS in 1992. He has been involved in a broad range of research topics including applied electromagnetics, atmospheric effects on radio wave propagation, radio channel measurement and theory, interference effects on digital receivers, ultrawideband technologies, spectrum sharing with federal systems, and spectrum occupancy measurements.

Mike DiFrancisco, NTIA OSM

Mike DiFrancisco serves as a senior technical advisor in NTIA's Office of Spectrum Management. In this role he acts as co-chair of the WSRD IWG, tracks and monitors advances in spectrum-related technologies, develops plans to establish the IIC and supports implementation plans for the National Spectrum Strategy. He is also Chief Engineer at the Virginia Tech Applied Research Corporation (VT-ARC) where he focuses on research and testing related to wireless technology and provides technical oversight and quality control on the corporation's project lifecycle, including IR&D. Prior to joining VT-ARC, Mr. DiFrancisco was a Principal in Booz Allen Hamilton's Cyber Technology Center of Excellence. Mr. DiFrancisco received a bachelor's degree in electrical engineering from Pennsylvania State University and a master's degree in electrical engineering (communications) from George Washington University.

Martin Doczkat, FCC

Martin Doczkat is the Chief of the Technical Analysis Branch in the Office of Engineering and Technology at the FCC. Prior to joining the FCC, he provided consulting engineering services to various FCC licensees, including broadcasters. He is a member of the Institute of Electrical and Electronics Engineers as well as an active participant in many of their subordinate organizations. He is a United States member of International Electrotechnical Commission Technical Committee 106, a member of the Association of Federal Communications Consulting Engineers, and a licensed professional engineer in the District of Columbia. He holds a bachelor's degree in electrical engineering from Pennsylvania State University and two master's degrees in systems engineering and electrical engineering from George Washington University.

Steve Ellingson, Virginia Tech

Dr. Steve Ellingson is an Associate Professor at Virginia Tech. His research interests focus on antennas & propagation, applied signal processing, and RF instrumentation. His work on instrumentation includes antennas, RF electronics, digital signal processing, and software for systems with unusual or extreme requirements. Prior to his faculty position at Virginia Tech, he has served as a Research Scientist at the Ohio State University ElectroScience Laboratory, a Senior Systems Engineer at Raytheon, a Senior Consultant at Booz-Allen & Hamilton, and a Captain in the U.S. Army. Dr. Ellingson holds a PhD in electrical engineering from The Ohio State University.

Monisha Ghosh, Notre Dame University/Spectrum X

Dr. Monisha Ghosh is a Professor at the University of Notre Dame and the Spectrum X Policy Outreach Director. Prior to this role, she served as the Chief Technology Officer at the FCC. Monisha previously served at NSF as a rotating Program Director (IPA) within the Directorate of Computer & Information Science and Engineering, where she managed wireless networking research. From 2015 to 2021, she also was a Research Professor at the University of Chicago. She previously worked in industrial research and development at Interdigital, Philips Research, and Bell Laboratories on wireless systems such as the HDTV broadcast standard, cable standardization, and cognitive radio for the TV White Spaces. Dr. Ghosh holds a Ph.D. in electrical engineering from the University of Southern California.

Dylan Gilbert, NIST

Dylan Gilbert is a Privacy Policy Advisor with the Privacy Engineering Program at NIST, U.S. Department of Commerce. In this role, he advances the development of privacy engineering and risk management processes with a focus on the Privacy Framework and emerging technologies. Prior to joining NIST, he was Policy Counsel at Public Knowledge where he led and developed all aspects of the organization’s privacy advocacy.

Nada Golmie, NIST CTL

Dr. Nada Golmie has been a research engineer at NIST since 1993. From 2014 to 2022, she served as the chief for the Wireless Networks Division in the Communications Technology Laboratory. She leads several projects related to the modeling and evaluation of future generation wireless systems and protocols and serves as the NextG Channel Model Alliance chair. Dr. Golmie received her Ph.D. in computer science from the University of Maryland at College Park.

Keith Gremban, CU Boulder/Silicon Flatirons

Dr. Keith Gremban is a Research Professor in the Smead Aerospace Engineering Sciences Department and Co-director of the Silicon Flatirons Spectrum Policy Initiative. Keith joined CU Boulder in November 2019 as research faculty in the Technology, CyberSecurity, and Policy program, which was dissolved in June 2020. Keith spent over 30 years in the defense industry as a software architect and systems engineer, where he led research and engineering efforts in robotics, command-and-control systems, and tactical communications. In 2011, Keith joined DARPA as a Program Manager in the Strategic Technologies Office, where he was responsible for a portfolio of programs in wireless communications and electronic warfare. In 2015, Keith became the Director of the Institute for Telecommunication Sciences in Boulder, which is the research and engineering laboratory of NTIA. Dr. Gremban received a Ph.D. in computer science from Carnegie Mellon University.

Lisa Guess, Cradlepoint-Ericsson

Lisa Guess is the Senior Vice President of Global Sales Engineering at Cradlepoint. Prior to this position, Lisa was Vice President of Systems Engineering at Juniper Networks, providing leadership and driving the technology vision for the Enterprise and Service Provider sectors. Lisa has been a member of the FCC Technical Advisory Committee since 2015 and is a co-chair of the FCC’s AI working group.

Dale Hatfield, CU Boulder & Silicon Flatirons

Dale Hatfield is currently an Executive Fellow at the Silicon Flatirons Center for Law, Technology, and Entrepreneurship and an Adjunct Professor in the Interdisciplinary Telecommunications

Program - both at the University of Colorado at Boulder. Prior to joining the University of Colorado, Hatfield was the Chief of the Office of Engineering and Technology at the FCC and, immediately before that, he was Chief Technologist at the Agency. He has over fifty years of experience in telecommunications policy and regulation, spectrum management and related areas.

Brian Jordan, Aerospace Corporation

Brian Jordan is a Senior Project Leader at The Aerospace Corporation. He joined Aerospace in 2014, where he provides spectrum policy expertise to multiple government customers and Aerospace's Center for Space Policy and Strategy. Prior to joining Aerospace, he served over 27 years in the U.S. Air Force, retiring in the grade of colonel. His military career included assignments as Chairman of the North Atlantic Treaty Organization's Military Frequency Group, Commander of the Air Force Spectrum Management Office, and as a Senior Spectrum Policy Analyst in the Office of the Secretary of Defense. He has been involved in the development of spectrum strategies, spectrum legislation, the Advanced Wireless Services 3 spectrum reallocation, the 3.45 – 3.55 GHz spectrum reallocation, and multiple ongoing Federal Communications Commission proceedings.

Derek Khlopin, NTIA

Derek Khlopin is Deputy Associate Administrator in NTIA's Office of Spectrum Management (OSM). Derek leads spectrum management efforts for the federal agencies, NTIA coordination groups such as IRAC and PPSG, and spectrum policy initiatives. He has been with NTIA since 2015 as a Senior Advisor to the Assistant Secretary and NTIA Administrator, spending most of his time collaborating with OSM and ITS. More recently, he added to his responsibilities as Acting Chief of SAID. Prior to joining NTIA, he spent most of his career in the private sector after a start at the FCC. Khlopin holds a J.D. from the Catholic University of America Columbus School of Law and a certificate from its Law and Technology Institute.

Melissa Midzor, NIST

Dr. Melissa Midzor leads the Spectrum Technology and Research Division at NIST, developing innovative measurement methods and tools to promote novel and efficient use of spectrum through improved access, sharing, atmospheric sensing and precision timing. Prior to NIST, Midzor served as the division director for Electronic Warfare Integrated Laboratories at Naval Air Systems Command. She also served for two years in the Assistant to the Secretary of Defense Research and Engineering Electronic Warfare and Countermeasures Office. Dr. Midzor holds a Ph.D. in physics from the California Institute of Technology.

Won Namgoong, University of Albany

Dr. Won Namgoong joined the University at Albany in the fall of 2018. Previously, he was with the University of Texas at Dallas, the University of Southern California, and Atheros Communications in California. He has served on the editorial boards of the IEEE Transactions on Circuits and Systems I – Regular Papers, the Journal of Signal Processing Systems, and the IEEE Transactions on Circuits and Systems II – Express Briefs. He is a recipient of the NSF Faculty CAREER Award. His research interests are in signal processing/communication systems and RF/analog circuits with particular focus on DSP-assisted analog/RF circuits and systems. Dr. Namgoong holds a Ph.D. in electrical engineering from Stanford University.

Matt Pearl, EOP, NSC

Matt Pearl is the Director for Emerging Technology at the National Security Council with their cyber directorate. Prior to this position, he was Associate Bureau Chief at the FCC in the Wireless Telecommunications Bureau of the Bureau Chief. In his FCC duties, he contributed to the development of policy and rules governing wireless spectrum and auctions, including rules to facilitate the rapid, widespread deployment of communications services. Previously, Matthew worked as a Legal Advisor in the Office of the Bureau Chief and as an Honors Attorney in the Bureau's Broadband Division. He earned his J.D. at Yale Law School.

Kamie Roberts, NITRD NCO

Kamie Roberts is the Director of the NCO for the NITRD Program. She is a computer scientist on detail to the NCO from NIST's Information Technology Laboratory, where she provided leadership to a wide range of programs, including IT standards, networking, health IT, big data, and future computing technologies. She leads NITRD to coordinate federal R&D in networking and IT with an enhanced focus on transitioning the results into use for the nation's benefit.

Tom Rondeau, DOD OUSD (R&E)

Dr. Tom Rondeau is the Principal Director for FutureG & 5G for the US DOD, serving in the Office of the Undersecretary of Defense for Research and Engineering (OUSD (R&E)). In these roles, Dr. Rondeau is responsible for guiding the DOD on research, funding, and execution of programs around warfighting capabilities using 5G and future generation wireless technologies. Prior to this role, Dr. Rondeau spent more than six years as a DARPA program manager, working on numerous technology areas to improve wireless networking and communications. Dr. Rondeau holds a Ph.D. in electrical engineering from Virginia Tech.

Alan Rosner, NTIA

Alan Rosner is the program manager for Spectrum National Security Systems Program at the NTIA Office of Spectrum Management. Previously Alan served as the Chief of the Spectrum Enterprise Services Branch in the Joint Spectrum Center (JSC), Defense Spectrum Organization (DSO) within DISA. He was the program manager for the Global Electromagnetic Spectrum Information System (GEMSIS) and Electromagnetic Battle Management (EMBM). Mr. Rosner was at DISA/DSO 2003-2022 in various technical capacities. He has significant experience in the management and development of software capabilities to enhance DOD's ability to operate and evolve their use of the electromagnetic spectrum. Prior to DISA he was a consulting engineer for 15 years working on engineering regulatory matters before the Federal Communications Commission and has been involved in numerous projects including high-definition television, digital radio, satellite earth stations, cellular, radio-frequency radiation exposure, land mobile and terrestrial microwave systems. Mr. Rosner has a bachelor's degree in electrical engineering (BSEE) from The Catholic University of America and is a Licensed Professional Engineer in the District of Columbia.

Joel Taubenblatt, FCC WTB

Joel Taubenblatt serves as the Bureau Chief of the Wireless Telecommunications Bureau of the Federal Communications Commission. Mr. Taubenblatt has held several leadership positions in the Bureau, including Deputy Bureau Chief, Chief of the Competition and Infrastructure Policy Division, and Chief of the Broadband Division. He received his J.D. from Duke University School of Law and two bachelor's degrees from the University of Pennsylvania, in Economics from the Wharton School and in English from the College of Arts and Sciences.

Kobus van der Merwe, University of Utah (POWDER)

Dr. Kobus van der Merwe is the Jay Lepreau Professor in the School of Computing at the University of Utah and a Director in the Flux Research Group. He is the PI and Director of the Platform for Open Wireless Data-driven Experimental Research (POWDER) project (one of the NSF PAWR platforms). He came to Utah in August 2012 after more than 14 years at AT&T Labs - Research in New Jersey. He has broad interest in networking systems research including network management, control and operation, mobile networking, network evolution, network security and cloud computing. He received his Ph.D. in computer science from the University of Cambridge.

Greg Wagner, DOD DISA DSO

Mr. Gregory C. Wagner is the Chief of DISA DSO's Strategic Planning Division. In addition to the AWS-3, CBRS, and 3.45 GHz sharing systems, his portfolio includes the AWS-3 Spectrum Sharing Test and Demonstration effort, electromagnetic spectrum enterprise architectures, electromagnetic spectrum data quality and data administration, and electromagnetic spectrum modeling and simulation.

Mark Walker, CableLabs

Mark Walker is Vice President, Technology Policy at CableLabs. He joined CableLabs in 2015 and now leads the Technology Policy group, which focuses on broadband policy, spectrum and wireless policy, cybersecurity and supply chain policy, and energy efficiency policy. Prior to joining CableLabs, Mark was the Deputy Chief in the Telecommunications Access Policy Division of the Federal Communications Commission that led the policy team for the E-rate Program. He holds a J.D. from the University of Colorado.

Martin Weiss, University of Pittsburgh

Dr. Martin Weiss is Professor in the Department of Informatics and Networked Systems in the School of Computing and Information at the University of Pittsburgh. He earned his Ph.D. in Engineering and Public Policy from Carnegie Mellon University. He earned a master's degree in computer, control, and information engineering from the University of Michigan and a bachelor's degree in electrical engineering from Northeastern University. His overall research theme is the analysis of situations where competing firms must cooperate technically; this has expressed itself in studying the standardization process, internet interconnection, and, most recently, radio spectrum sharing.

Abbreviations

5G	fifth-generation mobile networks
AI	artificial intelligence
CBRS	Citizen Broadband Radio Service
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DSA	dynamic spectrum access
DISA	Defense Information Systems Agency
FAIR	findable, accessible, interoperable, reusable
FAIREST	findable, accurate, interoperable, reusable, error checked, secure, trustworthy/traceable
FCC	Federal Communications Commission
IIC	Incumbent Informing Capability
IT	information technology
ITS	Institute for Telecommunication Sciences
IWG	interagency working group
ML	machine learning
NCO	National Coordination Office
NIST	National Institute for Standards and Technology
NITRD	Networking and Information Technology Research and Development
NSF	National Science Foundation
NSTC	National Science and Technology Council
NTIA	National Telecommunications and Information Administration
OUSD	Office of the Under Secretary of Defense
R&D	research and development
RDaF	research data framework
RF	radio frequency
SAS	spectrum access system
SC2	DARPA Spectrum Collaboration Competition
WSRD	Wireless Spectrum Research and Development
WTB	Wireless Telecommunications Bureau

Workshop Agenda

Wednesday, May 4, 2023

- 8:30 a.m. Keynote Session
- 10:45 a.m. Break
- 11:00 a.m. Session 1: Requirements Perspectives
- 12:30 p.m. Lunch
- 1:30 p.m. Tours of NIST and NTIA Boulder Labs
- 3:00 p.m. Session 2: Constraints and Policy Issues
- 5:30 p.m. Reception

Thursday, May 4, 2023

- 8:00 a.m. Session 3: Spectrum Data Collection
- 10:15 a.m. Break
- 10:30 a.m. Session 4: Spectrum Data Storage and Dissemination
- 12:30 p.m. Lunch
- 1:30 p.m. Tours of NIST and NTIA Boulder Labs
- 3:00 p.m. Session 5: Summary of Challenges and Ideas for Challenge Resolution
- 5:30 p.m. Adjourn

About the Authors

The NITRD Program is the Nation's primary source of federally funded coordination of pioneering IT R&D in computing, networking, and software. The multiagency NITRD Program, guided by the NITRD Subcommittee of the NSTC Committee on Science and Technology Enterprise, seeks to provide the R&D foundations for ensuring continued U.S. technological leadership and meeting the Nation's needs for advanced IT. More information is available at https://www.nitrd.gov.

The WSRD IWG consists of Federal agency representatives who coordinate spectrum-related research and development activities both across the Federal Government and with the private sector and academia. The WSRD Co-Chairs are John Chapin, NSF, and Mike DiFrancisco, NTIA. More information is available at https://www.nitrd.gov/coordination-areas/wsrd/.

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