Wireless Innovation Forum WInnComm 2021
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Current NSF Spectrum Science Activities
&
A Spectrum Monitoring Challenge

National Science Foundation ESM Unit (MPS/AST)
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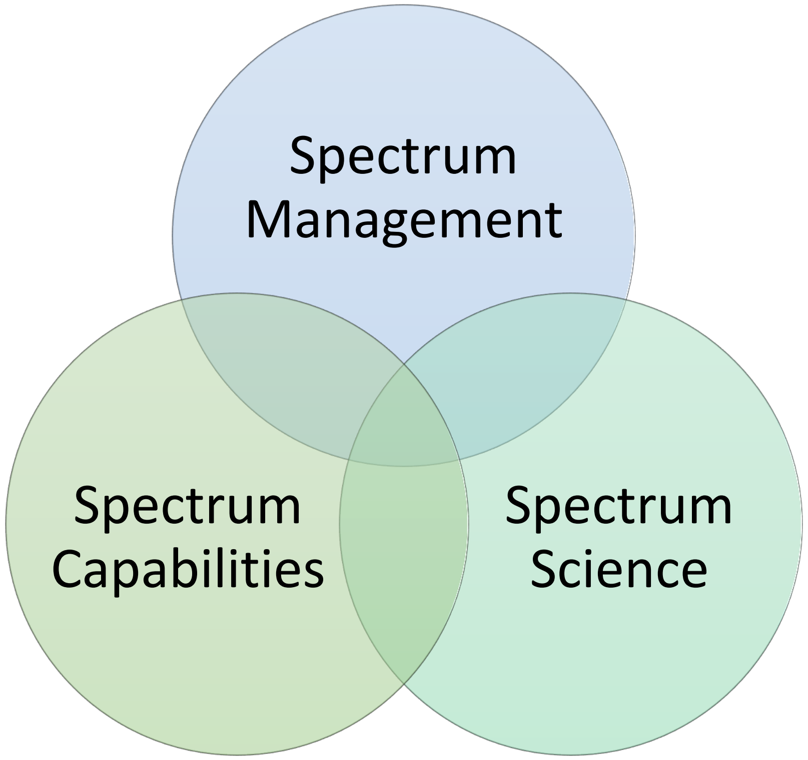
Categories of NSF work in the radio spectrum

Activities and investments that ensure spectrum is available for use



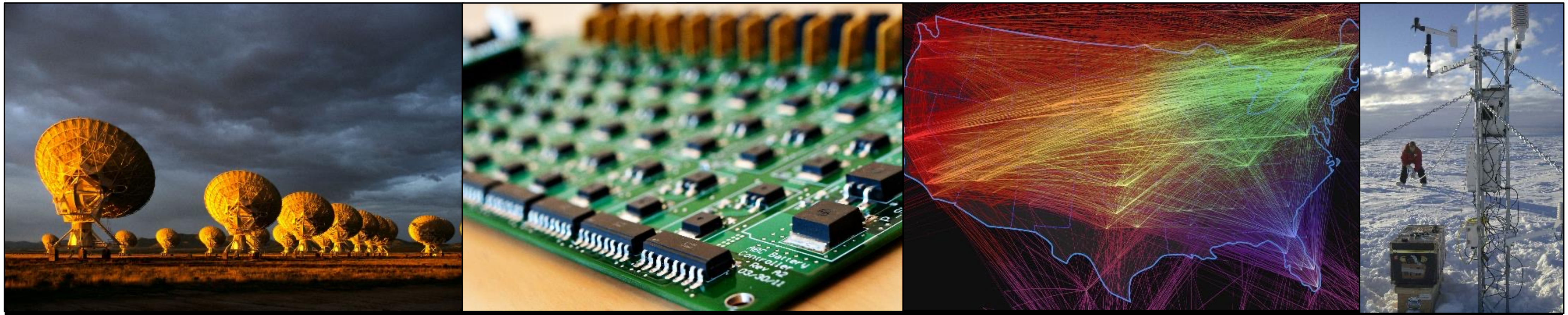
Activities and investments that use the radio spectrum

Astronomy
Advanced Wireless
Geosciences
Climate Change
Biosphere Monitoring
Wireless Devices/Circuits
Economic Theory
…

Spectrum management: the operational activity of planning and managing spectrum use
Spectrum capabilities: devices and techniques enabling a system to operate in multiple bands or in constrained or shared spectrum
Spectrum science: the basic and applied understanding of resource management of the electromagnetic spectrum

National Science Foundation's Future Spectrum Requirements: https://www.nsf.gov/mps/ast/NSF_Future_Spectrum_Requirements_Report_2019-08-27.pdf

Spectrum Innovation Initiative (SII)



I. National Radio Dynamic Zones

II. National Center for Wireless Spectrum Research

III. Spectrum Integrative Activities

IV. Education and Workforce Development

- Includes all NSF directorates, plus FCC & NTIA via Memorandum of Agreement
- Launched FY20
- $17m/yr dedicated funding focused on spectrum

Spectrum Innovation Initiative: National Radio Dynamic Zones (SII-NRDZ)

- At-scale test beds for Spectrum Science
  - Pilot new spectrum sharing techniques
    - Experimentation
    - Validation
    - Demonstration

- Small initial investigations in FY20-21
  - total ~$10M funding

- Program solicitation anticipated FY22

Most-suggested Broader Impact goals for SII-NRDZ

Near Term

Enhance spectrum access for existing facilities and uses

- Wireless research facilities
- Radio astronomy observatories
- Satellite-borne terrestrial environmental and space research

Mid Term

Enable wider use of spectrum sharing

- Overcome technical barriers to approval
- Provide reusable components and tools

Long Term

Build trust in spectrum sharing

Accelerate wireless and spectrum management innovation

- Establish national facility for at-scale research & experimentation

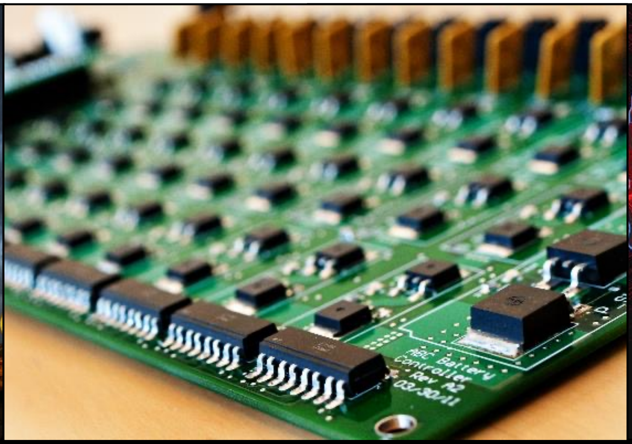
More information on SII-NRDZ

- NSF SII home page
  - https://nsf.gov/mps/oma/spectrum_innovation_initiative.jsp

- Researcher-led community meetings
  - Event recordings available at https://www.cs.albany.edu/nrdz-ra/

- Webinars on NRDZ concepts for Radio Astronomy and for Wireless Research & Experimentation
  - 2 webinars, date TBD (sometime between January and April 2022)
  - Briefings by PIs of ongoing NRDZ projects funded by NSF in FY20 and FY21
    - recent project results
    - what a NRDZ for a radio astronomy or wireless test site might look like
    - benefits, challenges, requirements

Spectrum Innovation Initiative (SII)

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Multi-Directorate R&D Programs in Spectrum Science

FY20 **SWIFT: Spectrum and Wireless Innovation enabled by Future Technologies**

- Coexistence of active radio services and passive services (e.g. astronomy)
- Interference mitigation
- Efficient spectrum utilization

MLWiNS: NSF/Intel Machine Learning for Wireless Networks and Systems

- ML-based Spectrum Monitoring and Analysis
  - Real-time ML Tools for RF Spectrum Sensing and Channel Characterization
  - Learning-enabled Improved Coexistence
  - ML-based Dynamic Protocol Selection

FY17 **SpecEES: Spectrum Efficiency, Energy Efficiency and Security**

FY12 **EARS: Enhancing Access to the Radio Spectrum**

Resilient & Intelligent NextG Systems

RINGS

- $40m investment
  - resilient, secure, and intelligent next generation wireless systems
- Public-private partnership
  - NSF, DOD, NIST, Apple, Google, Nokia, Qualcomm, …
- Includes improving performance in shared or constrained spectrum
- Benefits for all:
  - Better broadband performance in shared or constrained spectrum
    → reduced demand for exclusive, clean spectrum
    → enhanced spectrum access for all other uses

Extracts from solicitation

Novel spectrum management technologies: NextG network systems will need to support evolving spectrum-use constraints.

- New multi-band/multi-radio network designs, leveraging licensed/shared/ unlicensed spectrum
- Advanced spectrum sensing, coordination and adaptation
- Spectrum-aware systems to meet extreme performance requirements

Platforms for Advanced Wireless Research (PAWR)

- Testbeds for wireless research: SDR, MIMO, Drones, Rural/Agriculture
- Programmable, Open Access, Remotely Operable: https://advancedwireless.org/
- $50M NSF investment (with 1:1 matching from 34-member industry consortium)

A Spectrum Monitoring Challenge

A longer version of this content was presented at Gnu Radio conference 9/22/2021

Talk starts 32 minutes after start of recording (https://youtu.be/2s940fttDco?t=1920)

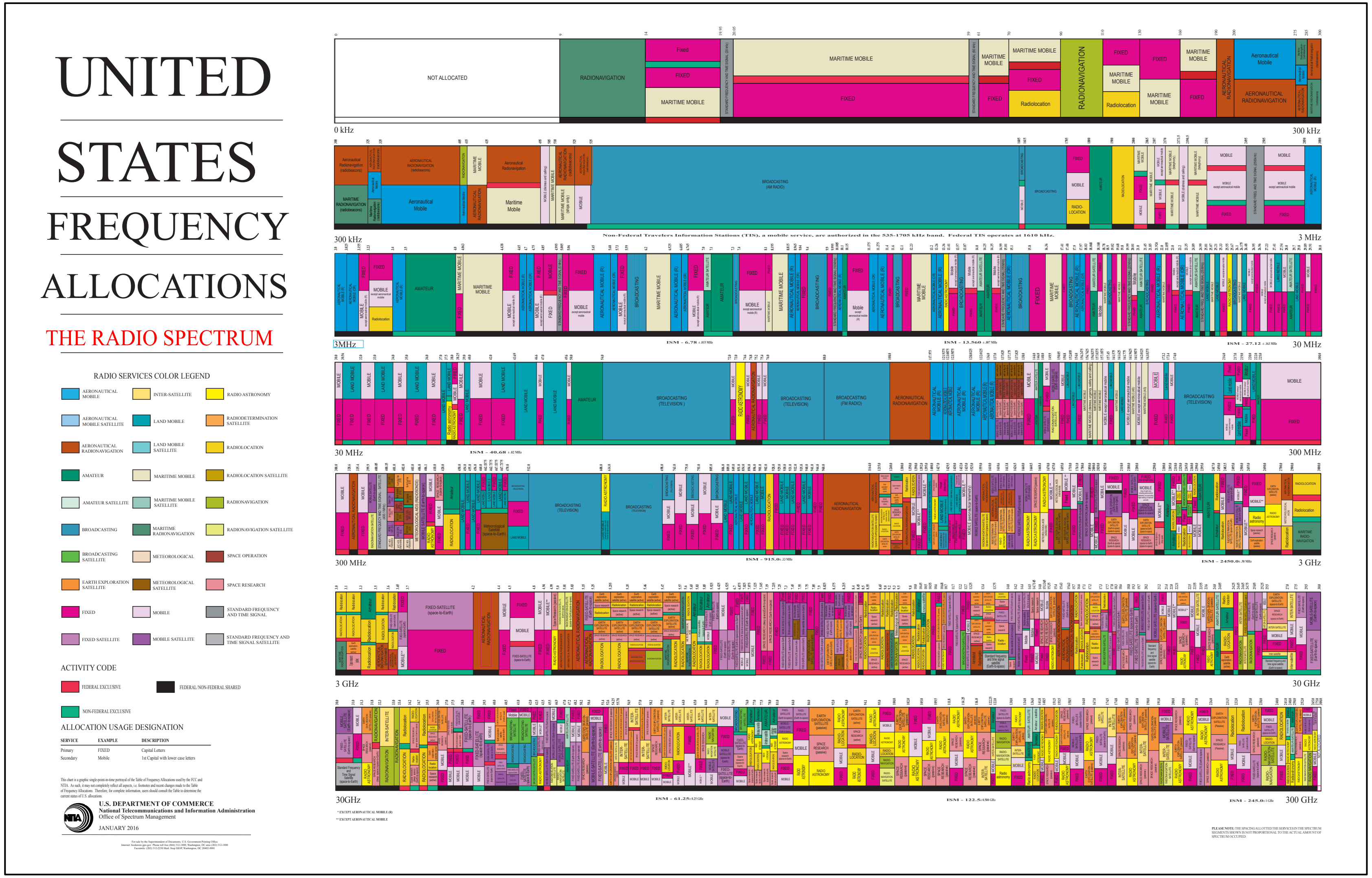
Interference Management

- Formal definition
  - The activities and processes executed to enhance electromagnetic compatibility and prevent, prepare for, respond to, and recover from electromagnetic interference[1]

- Simple definitions
  - Things you do to enable independent systems to use the radio spectrum without interfering with each other
  - The technical part of spectrum management

[1]Defense Spectrum Organization, “Emerging Spectrum Technology Concept for Interference Management Modernization,” v1.1, 23 March 2020

Traditional interference management: frequency licensing



Frequency allocation chart: NTIA

Opportunities for interference management innovation

- Past technical constraints determined today's approach
- The constraints have changed

Then	Now
Dumb devices	Storage and computing at all nodes
Standalone devices	Nodes connected to the internet or management point (some intermittently)
Fixed function devices	All behaviors flexible (firmware/software updates)
Fixed frequency devices	Increasingly multiband
Slow manual modeling	Able to run system model in real time (e.g. in the cloud)
Disconnected systems	Machine to machine coordination possible between neighboring systems
Limited data analysis	Big data and AI capabilities
Raw communications links	Error mitigation at higher layers
Omnidirectional antennas	Adaptive, steerable, smart antennas

Examples of potential interference management innovations

- Context sensitive rules
  - Based on current situation, not worst-case analysis
- Real-time negotiations among spectrum users
  - Jointly work out how to share a band *(first steps taken by DARPA SC2)*
  - Peer-to-peer payments for priority or exclusivity
- Intended interference + fast interference mitigation
  - Significant efficiency gains due to long-tailed distributions

These innovations all depend on spectrum monitoring

Spectrum monitoring will play a key role

Spectrum monitoring

Activity that provides trusted real-time data about spectrum use

1. Essential for many interference management innovations

2. Supports data-based policy and regulatory decisions

3. Increases trust that others will be protected from interference
   - Design errors in the sharing mechanisms
   - Software bugs, hardware faults, environmental anomalies
   - Careless or malicious actors

Trust is key for adoption of new interference management methods

Key challenges for future spectrum monitoring

- Systems
  - Massive data
  - 3D
  - Secure
  - Real-time streaming
- Capabilities
  - Classification
  - Identification
  - Localization
  - Effective in dense spectral environments
  - Effective if directional / MIMO
- Overall
  - Affordable when scaled up
  - Rapidly evolvable
- Regulatory
  - Trusted data
    - Provenance for measurements
    - Metadata – context, quality
  - Easy to use for decision making
- Legal
  - Privacy protection

Monitoring architecture 1 of 3

- Fixed function spectrum monitoring system (adjustable parameters)
- Measure spectrograms
- Geolocate strong signals on request

- Lacks key capabilities needed for future interference management
  - No classification
  - No identification
  - Data is not easy to use for regulatory decision making

Implemented by current commercial systems

Monitoring architecture 2 of 3

- Spectrum monitoring system with selectable processing functions
  - Functions activated on request
  - Function set is extensible by manufacturer
- Lacks key capabilities needed for future interference management
  - No waveform-specific signal processing
  - No consumer-specific functions
  - Not rapidly evolvable

IEEE SCOS, *Standard for Spectrum Characterization and Occupancy Sensing*, 802.15.22.3-2020
Open-source python reference implementation by NTIA/ITS is available

Monitoring architecture 3 of 3

- Virtualize the spectrum monitors
- Data consumers upload the edge processing functions they need
  - Platform manages compute / storing / sensing resources, similar to other VMs
- Key benefits
  - Rapid evolution of edge processing
    - Waveform-specific processing that keeps up with environment evolution
    - Meet specialized data needs of different consumers
  - Transparent to help assure privacy and promote public acceptance

Platform solution for virtualized spectrum monitors

- Platform should
  - Enable describing the edge processing functions at a high level
    - Hard to hide privacy violating code
  - Do signal processing once if shared by multiple active pipelines
    - Important for computational efficiency
  - Support a wide range of hardware
  - Leverage FPGAs, GPUs, and other non-traditional processing as available

Can WinnForum help standardize an effective platform for virtualized spectrum monitoring?

Thank you for your attention