

# National Science Foundation

## Electromagnetic Spectrum Management

AAAC Meeting

January 26, 2021

Jonathan Williams  
Ashley (Zauderer) VanderLey  
David Morris

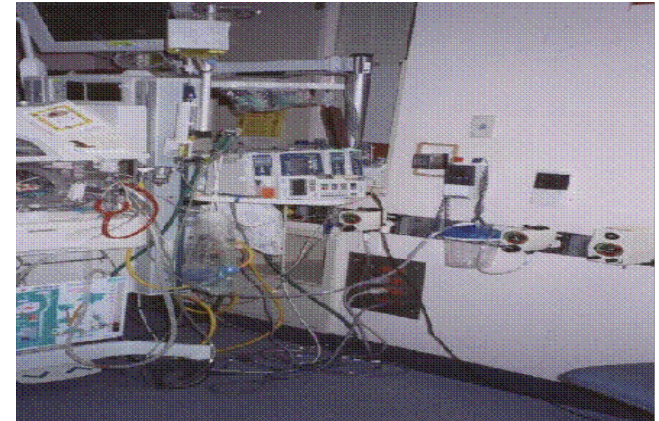
**NSF's Spectrum Innovation Initiative**

*... enabling Industries of the Future*



# Then...

*25 years ago*





# ...and now



## *Advanced Wireless networks are the enabler*

- WiFi, Bluetooth
- 3G → 4G → and (upcoming) 5G

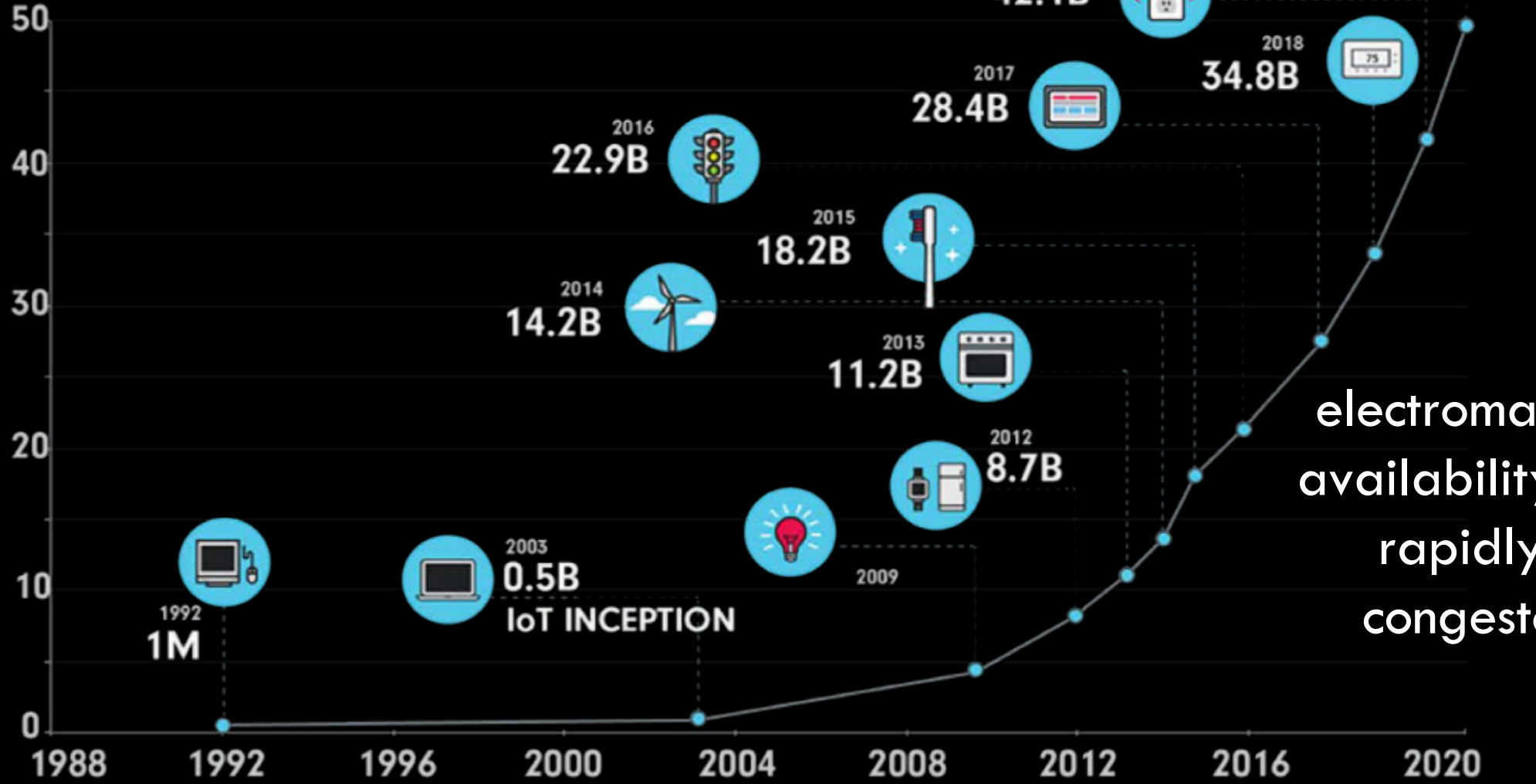
## *Rapid growth in connected devices\**

- 1 million in 1992 → 5 billion in 2008
- 50 billion in 2020



\*Cisco Annual Internet Report, 2020

# BILLIONS OF DEVICES



Demands for electromagnetic spectrum availability are increasing rapidly in an already-congested environment

Fonte: Cisco





# UNITED STATES FREQUENCY ALLOCATIONS

## THE RADIO SPECTRUM

**RADIO SERVICES COLOR LEGEND**

VOICED SERVICE	UNALLOCATED	AIRBORNE MOBILE
AIRBORNE MOBILE (SATELLITE)	LAND MOBILE	AIRBORNE MOBILE (SATELLITE)
AIRBORNE MOBILE (SATELLITE)	LAND MOBILE (SATELLITE)	UNALLOCATED
MARITIME	MARITIME MOBILE	AIRBORNE MOBILE (SATELLITE)
MARITIME MOBILE (SATELLITE)	MARITIME MOBILE (SATELLITE)	UNALLOCATED
UNALLOCATED	MARITIME MOBILE (SATELLITE)	AIRBORNE MOBILE (SATELLITE)
AIRBORNE MOBILE (SATELLITE)	AIRBORNE MOBILE (SATELLITE)	UNALLOCATED
AIRBORNE MOBILE (SATELLITE)	AIRBORNE MOBILE (SATELLITE)	UNALLOCATED
UNALLOCATED	UNALLOCATED	SPECIALIZED SERVICE (SATELLITE)
UNALLOCATED	UNALLOCATED	SPECIALIZED SERVICE (SATELLITE)

**ACTIVITY CODE**

PRIMARY SERVICE    FEDERAL RESERVE

UNALLOCATED

**ALLOCATION USAGE DESIGNATION**

<b>SERVICE</b>	<b>CLASS</b>	<b>USE</b>
Plan	FSS	Earth station
Station	MS	Land mobile station

The above table provides a summary of the frequency allocations in the United States. It is not intended to be a substitute for the Federal Communications Commission's (FCC) rules and regulations. For more information, please refer to the FCC's website at [www.fcc.gov](http://www.fcc.gov). This is a preliminary document and is subject to change without notice.

**NTIA**  
U.S. DEPARTMENT OF COMMERCE  
National Telecommunications and Information Administration  
Office of Spectrum Management  
JANUARY 2016



Image Credit: [www.ntia.doc.gov](http://www.ntia.doc.gov)





# Science applications share the spectrum with many other users



Figure Credit: <https://techcrunch.com/2016/02/05/new-air-force-satellites-launched-to-improve-gps/>



	FIXED	MOBILE	RADIOLOCATION	1330.0
	FIXED	MOBILE **	Fixed-satellite (Earth-to-space)	1390.0
	FIXED	MOBILE **		1392.0
	FIXED	MOBILE **		1395.0
	LAND MOBILE (medical telemetry and medical telecommand)			1400.0
	EARTH EXPLORATION - SATELLITE (passive)	<b>RADIO ASTRONOMY</b>	SPACE RESEARCH (passive)	1427.0
	LAND MOBILE (medical telemetry and medical telecommand)	LAND MOBILE (telemetry and telecommand)	Fixed (telemetry)	1429.5
	FIXED (telemetry and telecommand)	LAND MOBILE (telemetry & telecommand)		1429.5
	FIXED (telemetry and telecommand)	LAND MOBILE (telemetry & telecommand)	Fixed-satellite (space-to-Earth)	1430.0
	FIXED	MOBILE **		1432.0
	MOBILE (aeronautical telemetry)			1435.0
	MOBILE SATELLITE (space-to-Earth)			1525.0
	RADIONAVIGATION-SATELLITE (space-to-Earth)(space-to-space)	AERONAUTICAL RADIONAVIGATION		1559.0
	RADIO DETERMINATION-SATELLITE (Earth-to-space)	AERONAUTICAL RADIONAVIGATION	MOBILE SATELLITE (Earth-to-space)	1610.0
	<b>RADIO ASTRONOMY</b>	RADIO DETERMINATION-SATELLITE (Earth-to-space)	AERONAUTICAL RADIONAVIGATION	1610.6
	MOBILE-SATELLITE (space-to-Earth)	RADIO DETERMINATION-SATELLITE (Earth-to-space)	AERONAUTICAL RADIONAVIGATION	1613.8

**Frequency Allocations: 1390 – 1614 MHz**



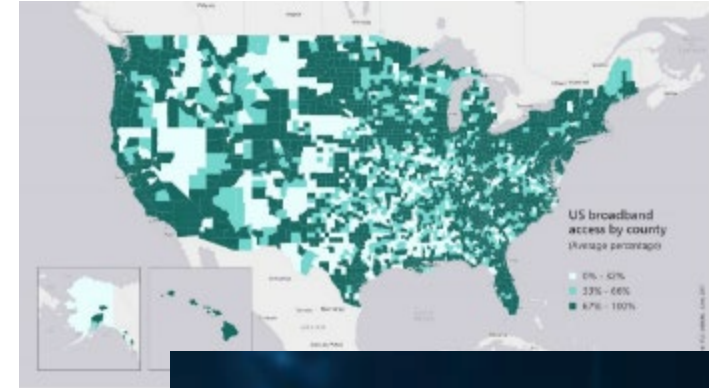
# Challenges include:

**Commercial** - Providing cellular and broadband internet coverage in rural areas

**Public Safety** - Interference to communications for emergency first responders

**National Security** - Congested usage for the DoD (e.g., 5G, radars) requiring flexibility

**Science** - Many scientific uses of the spectrum are passive (listen only) and extremely sensitive to interference



## THE 5G ECOSYSTEM: RISKS & OPPORTUNITIES FOR DoD

DEFENSE INNOVATION BOARD

April 2019



# NSF-supported research relies on access to the electromagnetic spectrum and catalyzes its efficient usage

## *Passive – “listen only”*



- GPS Radio Occultation
- Radio Astronomy
- Geodesy

## *Active – “transmit”*



- Wi-Fi, Bluetooth, Television Whitespaces, Millimeter Wave/ TeraHertz Bands
- Research Drones, Cubesats
- Radar



## Two Sides to the Spectrum Coin

### *Spectrum for basic research*

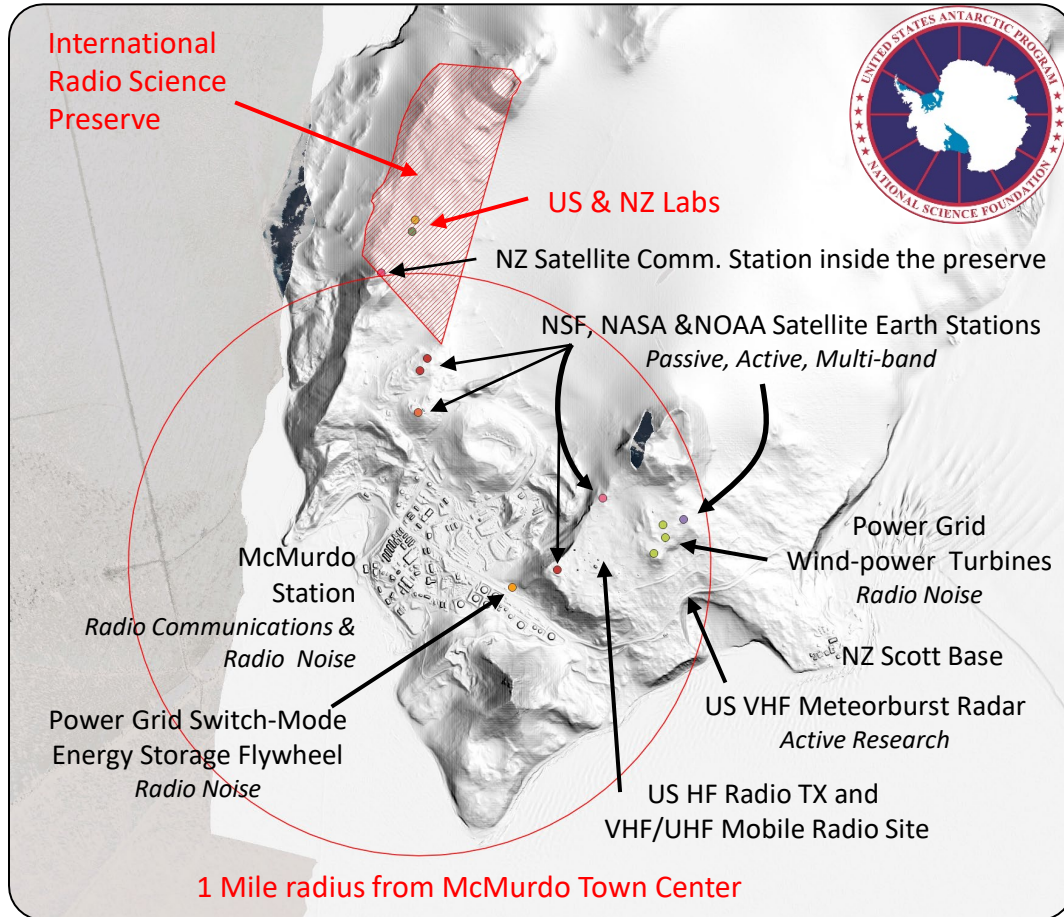
Radio quiet environment is critical for scientific observations, such as Cosmic Microwave Background experiments at the South Pole.



### *Spectrum for communications and operations*

Access to the spectrum for communications is essential for many operations, both for logistical purposes and for relaying data.

# GEO US Antarctic Program McMurdo Station Case Study



- Tension between general rise of industrial noise/spectrum use and the active/passive radio sciences
- Requires new methods of harmonization, coordination, and resiliency



# NSF's response to new spectrum challenges

1-2 full-time  
spectrum  
managers  
(1970s)

*Focus on radio astronomy -> broaden to consider all NSF interests and optical/IR impacts*

Spectrum research:  
"Advanced  
Wireless" (1997)

*Individual research programs -> platforms -> external partnerships*

NSF-wide ESM  
Coordination  
Group formed  
(2018)

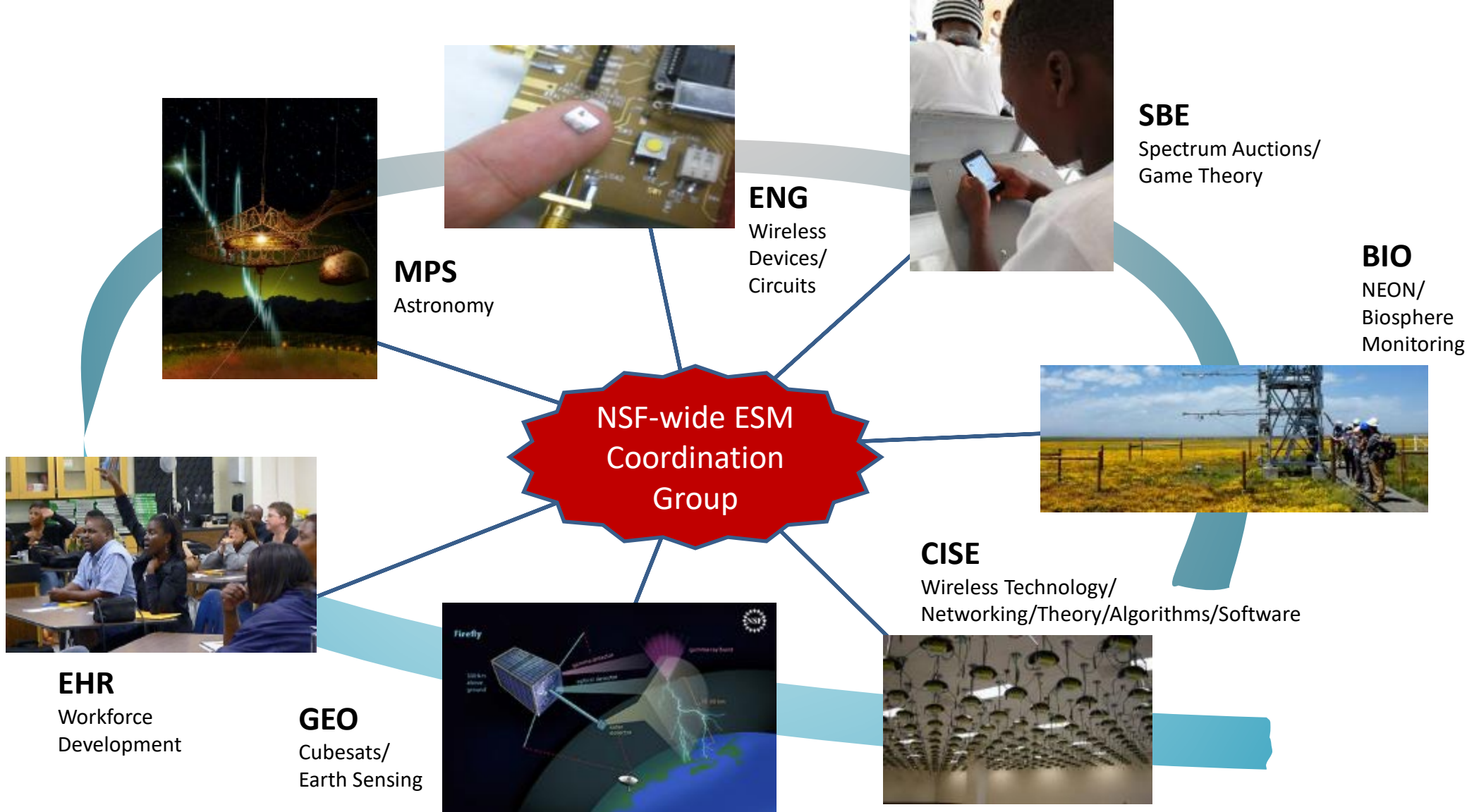
*NSF-wide collaboration*

Spectrum  
Innovation  
Initiative  
(2020)

Presidential Memorandum on  
Developing a Sustainable  
Spectrum Strategy for America's  
Future



# Spectrum Connections Across NSF





# NSF ESM Coordination Group

- Formed March 2018
- Includes NSF input across all Directorates



**Jonathan Williams**

*Chair, MPS/AST, ESM Unit*



**Patrick Smith**

*GEO/OPP*



**Thyaga Nandagopal**

*CISE/CCF*



**Carmiña Londoño**

*ENG/ECCS*



**Mangala Sharma**

*GEO/AGS*



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*MPS/AST, ESM Unit*



**Li Yang**

*EHR*



**Nancy Lutz**

*SBE*



**Jim Ulvestad**

*Chief Officer for Research Facilities,  
Office of the Director*

## SII Working Group Members:

**Lisa Winter (GEO)**

**Jenshan Lin (ENG)**

**Alex Sprintson (CISE)**

**Mohammad Ali (ENG)**

**Larry Goldberg (ENG)**



## **NSF Spectrum Goals:**

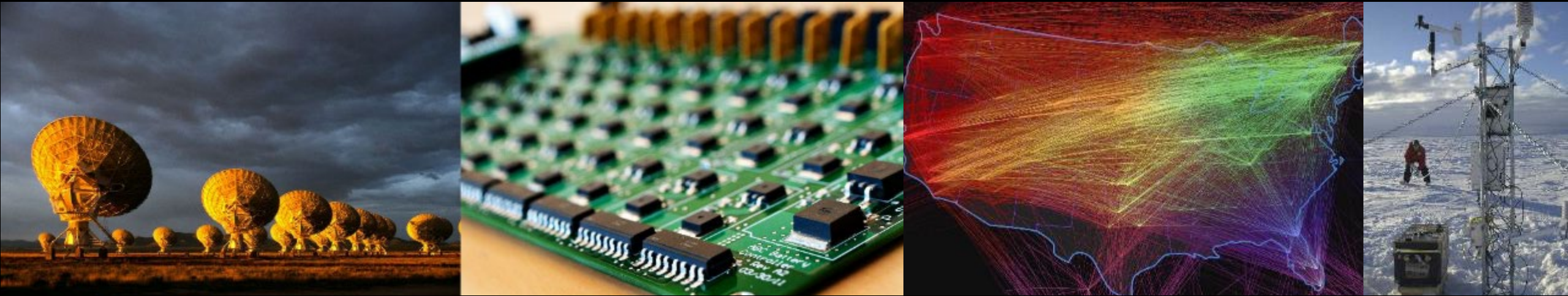
***Innovate and Secure***





# NSF's Spectrum Innovation Initiative

*Cross-Directorate, housed in MPS Office of Multidisciplinary Affairs (OMA)  
(via a stewardship model similar to NSF Big Ideas)*

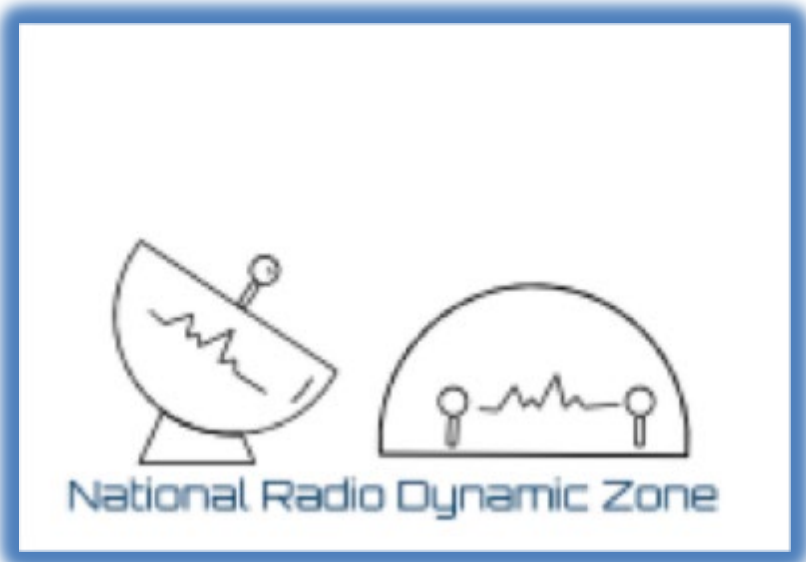


I. National Radio Dynamic Zone

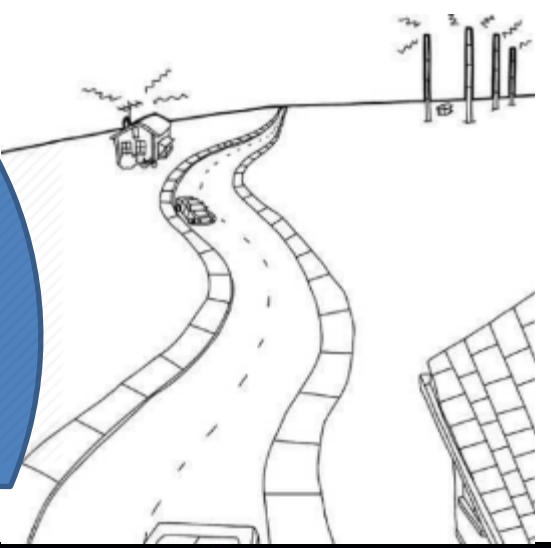
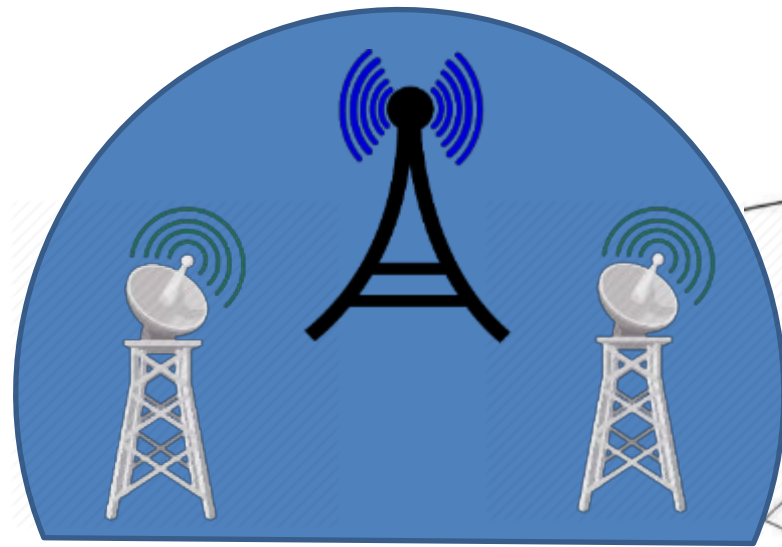
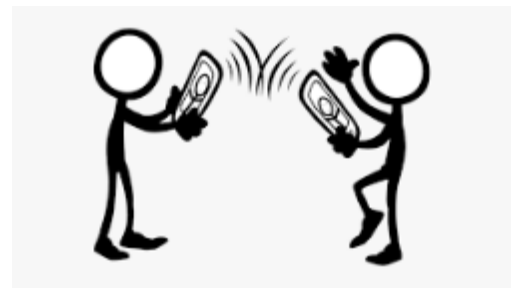
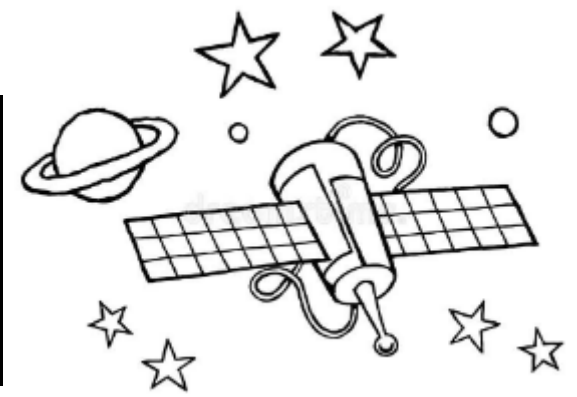
II. National Center for Wireless Spectrum Research

III. Spectrum Research Integrative Activities

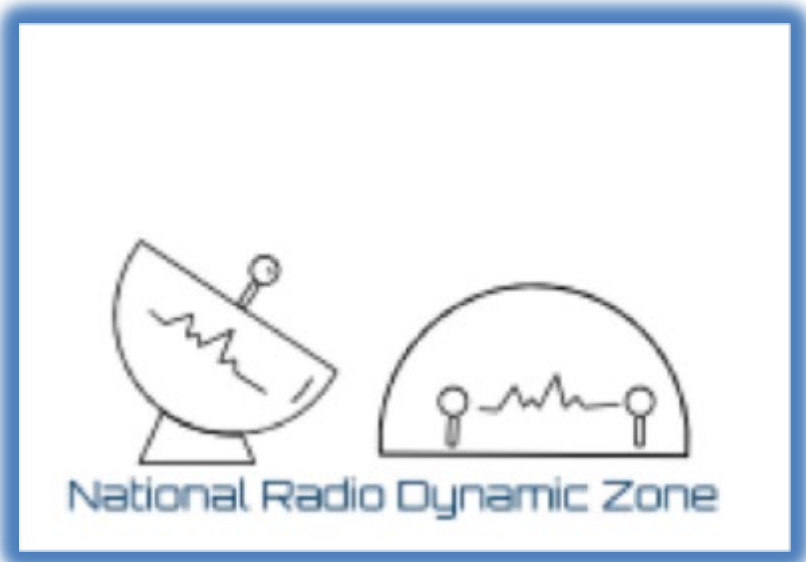
IV. Education and Workforce Development



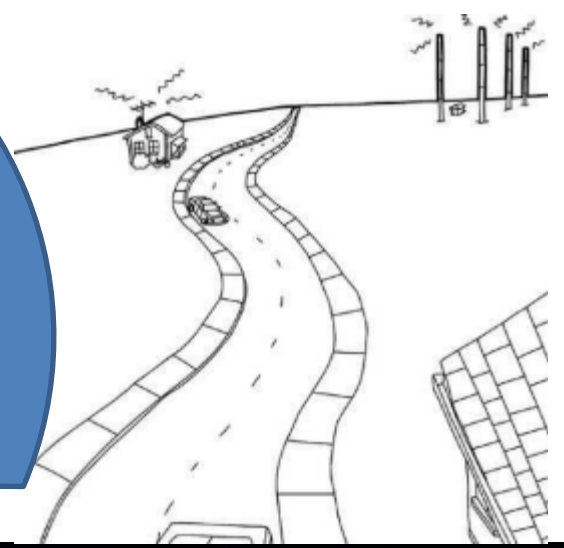
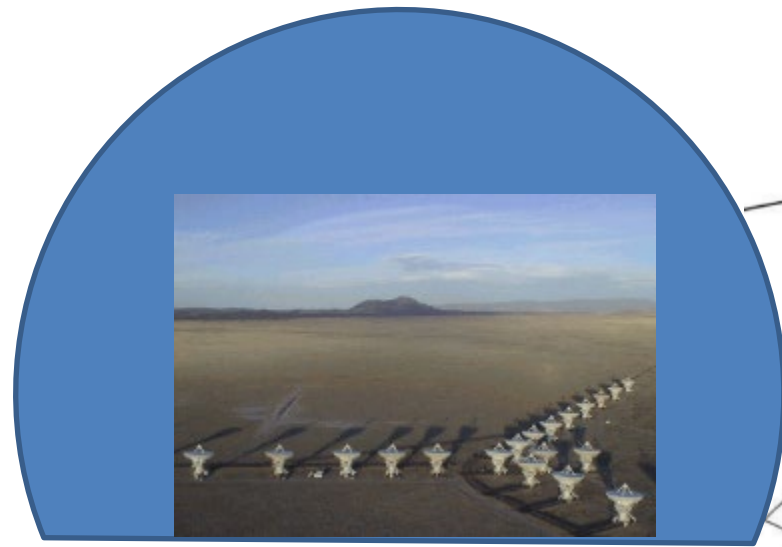
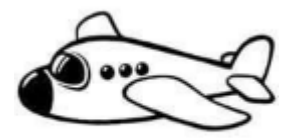
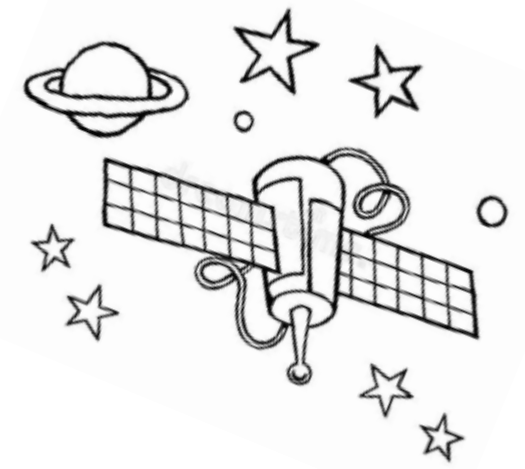
Wireless testing "in" the zone does not interfere with users of spectrum outside





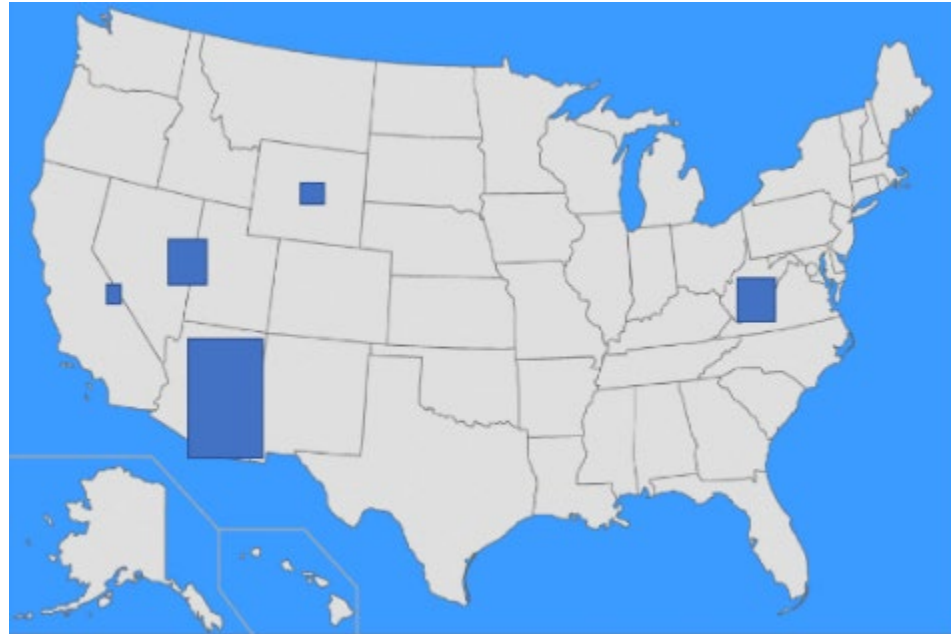


Spectrum users "outside" the zone do not interfere with passive users in the zone



# National Radio Dynamic Zones (NRDZ)

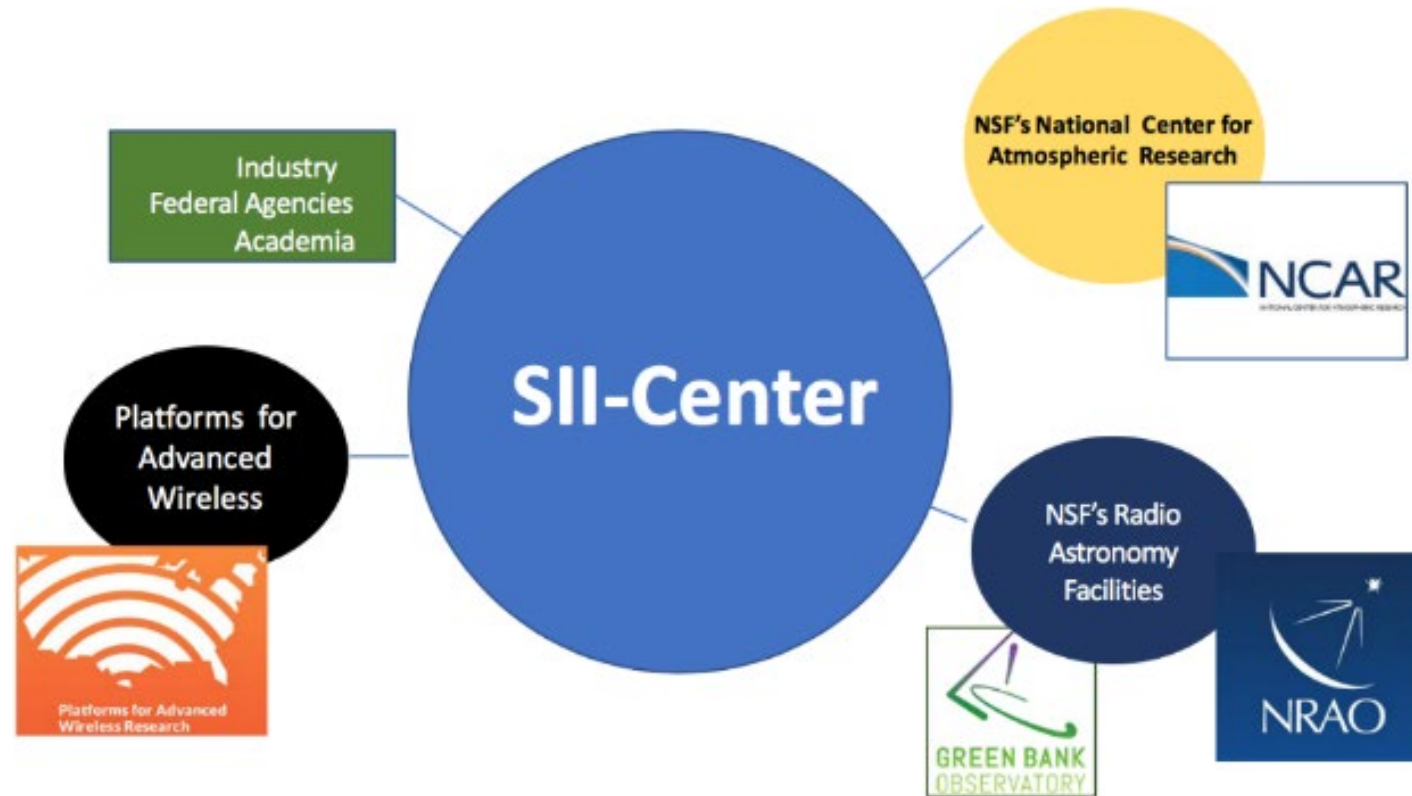
- Pilot innovative approaches for transmission/reception at various frequencies of interest
- Cognitive machine-to-machine frequency coordination leading to dynamic allocation and improved efficiency



See Dear Colleague Letter [NSF 20-079](#)

# National Center for Wireless Spectrum Research (SII-Center)

- Multidisciplinary groups of scientists and engineers with a common vision to address nationwide challenges in wireless spectrum research



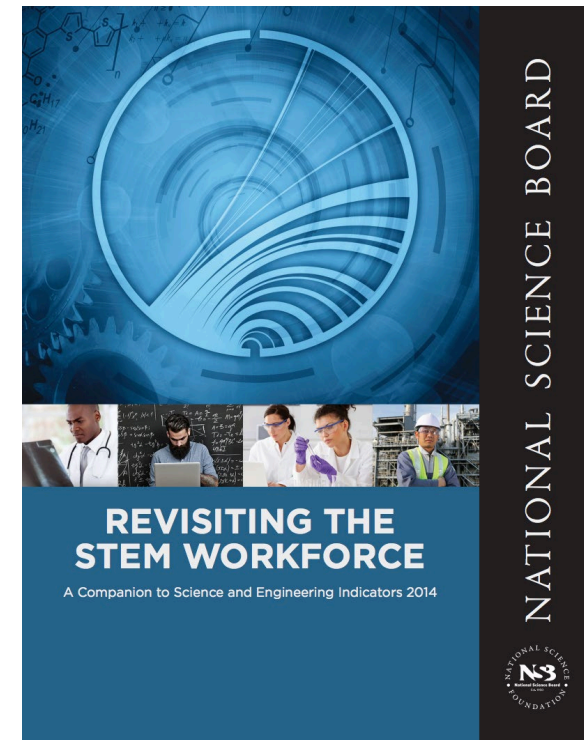


# National Center for Wireless Spectrum Research (SII-Center)

- **Grow the spectrum workforce in support of industries of the future**

The demands on the workforce in spectrum management and wireless technologies are challenging, **requiring an interdisciplinary skill set.** Along with research, innovation, and collaboration, a key goal of the SII-Center is the **creation of education, training, and workforce development programs.**

- Expose trainees to open questions and challenges in wireless spectrum research in collaboration with national laboratories, industry and international partners
- Innovate in educational curricula and pedagogy reflecting the complexity of spectrum research and facilitate its replication by other institutions



Invest in R&D to contribute innovative solutions to the advanced wireless and spectrum challenges facing the Nation:

Innovate and Secure



# Contact information

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## Learn More

*Spectrum Innovation Initiative Program Page:*  
[https://nsf.gov/mps/oma/spectrum\\_innovation\\_initiative.jsp](https://nsf.gov/mps/oma/spectrum_innovation_initiative.jsp)

