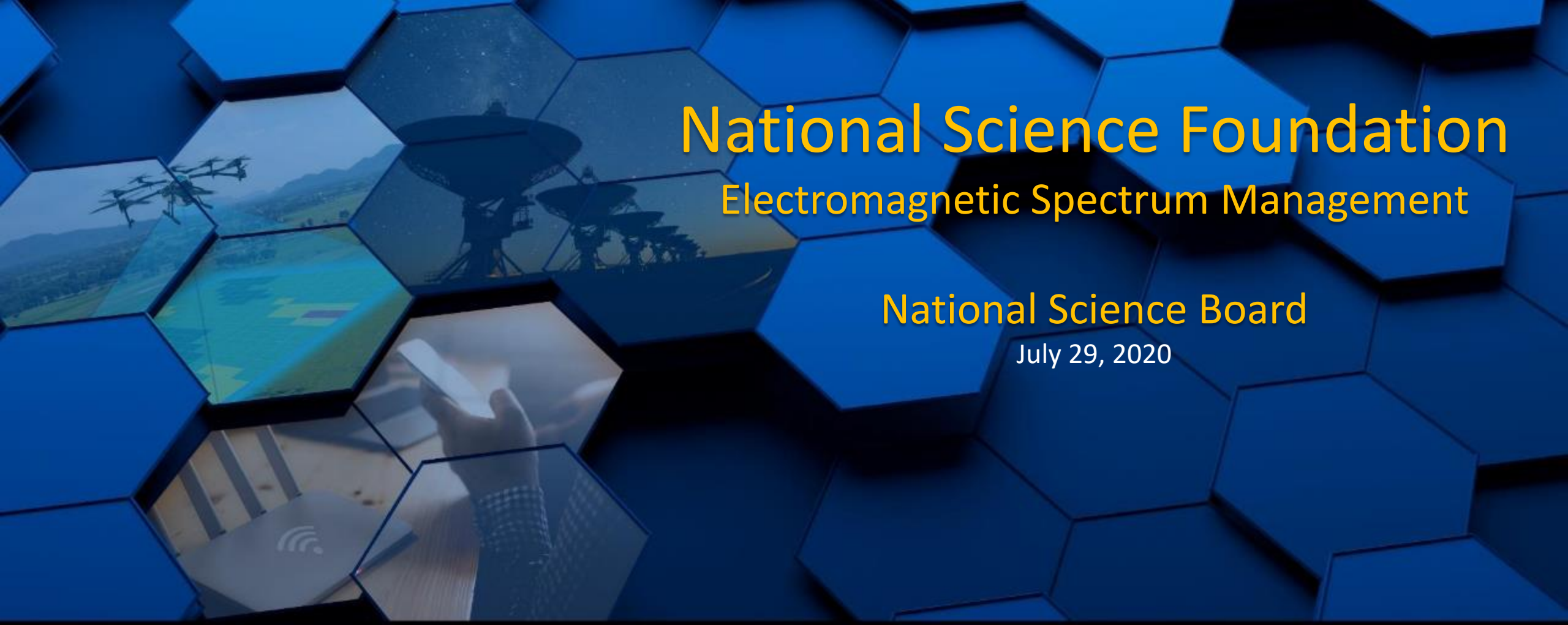


National Science Foundation

Electromagnetic Spectrum Management

National Science Board

July 29, 2020

NSF's Spectrum Innovation Initiative

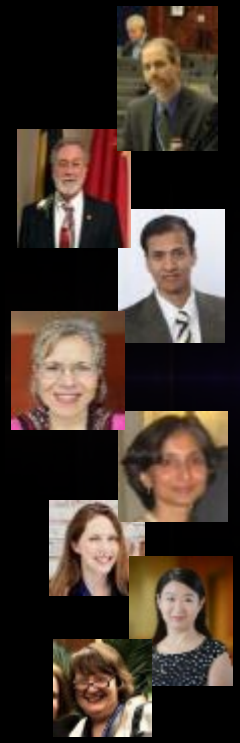
and

NSF's Advanced Wireless Research Programs

… enabling Industries of the Future

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*
Ashley Zauderer	*MPS/AST, ESM Unit*
Li Yang	*EHR*
Nancy Lutz	*SBE*

Jim Ulvestad — *Chief Officer for Research Facilities, Office of the Director*

<u>SII Working Group Members:</u>

Lisa Winter (GEO)

Jenshan Lin (ENG)

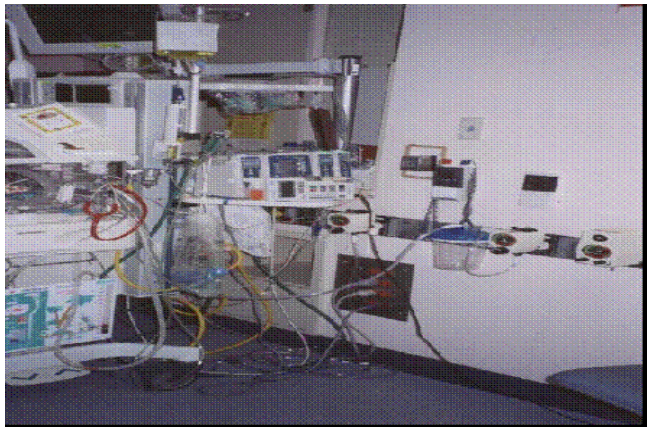
Alex Sprintson (CISE)

Mohammod Ali (ENG)

Larry Goldberg (ENG)

Then…

25 years ago



…and now

Advanced Wireless networks are the enabler

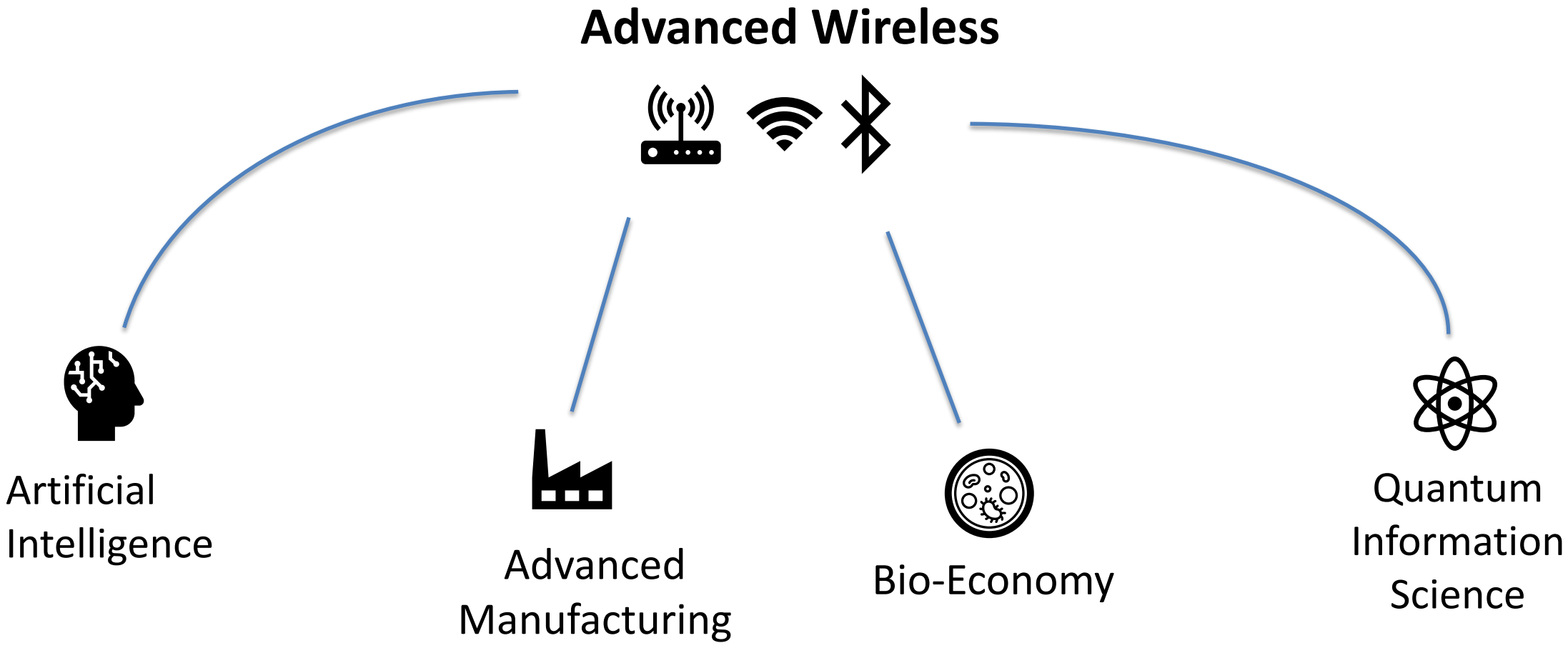
- WiFi, Bluetooth
- 3G → 4G → and (upcoming) 5G

*Rapid growth in connected devices**

- 1 million in 1992 → 5 billion in 2008
- <u>50 billion in 2020</u>

*Cisco Annual Internet Report, 2020

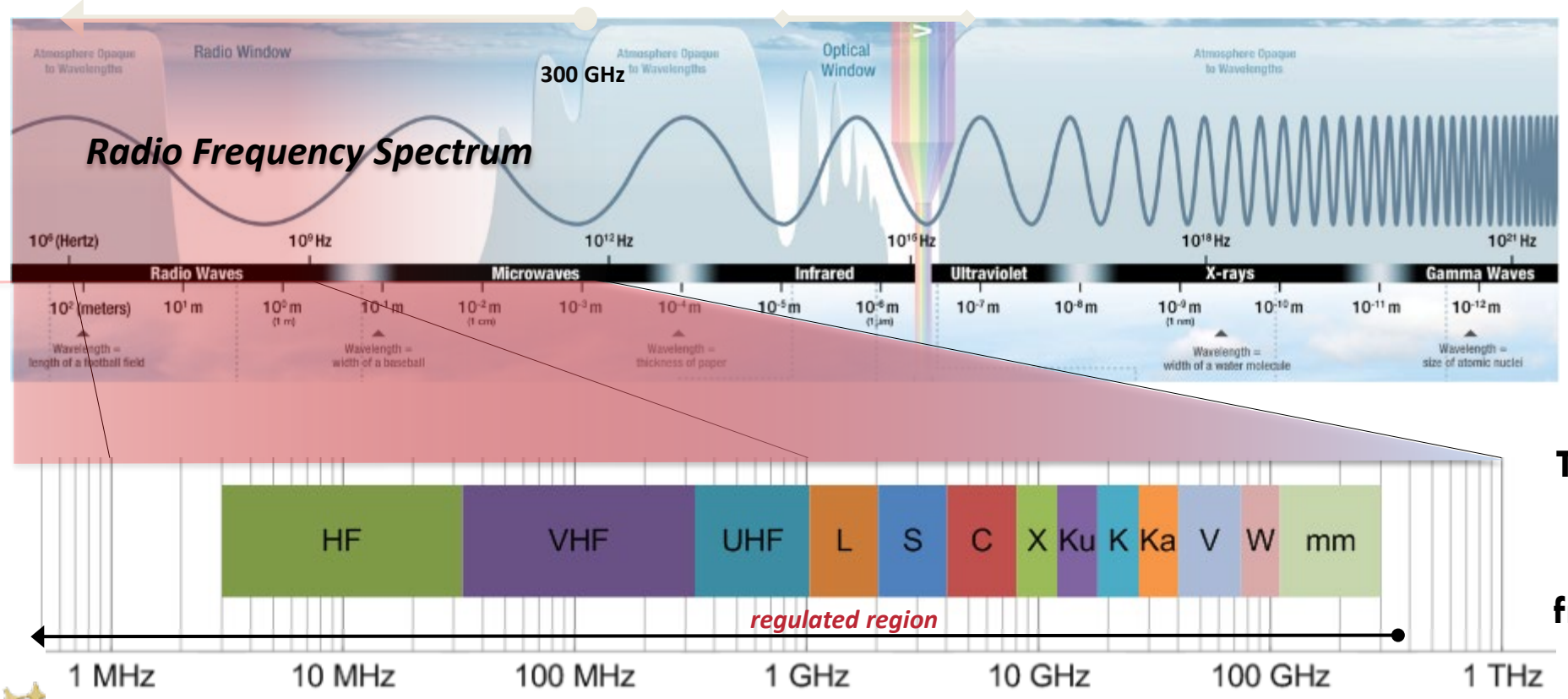
Components of Industries of the Future



What is the "spectrum"?

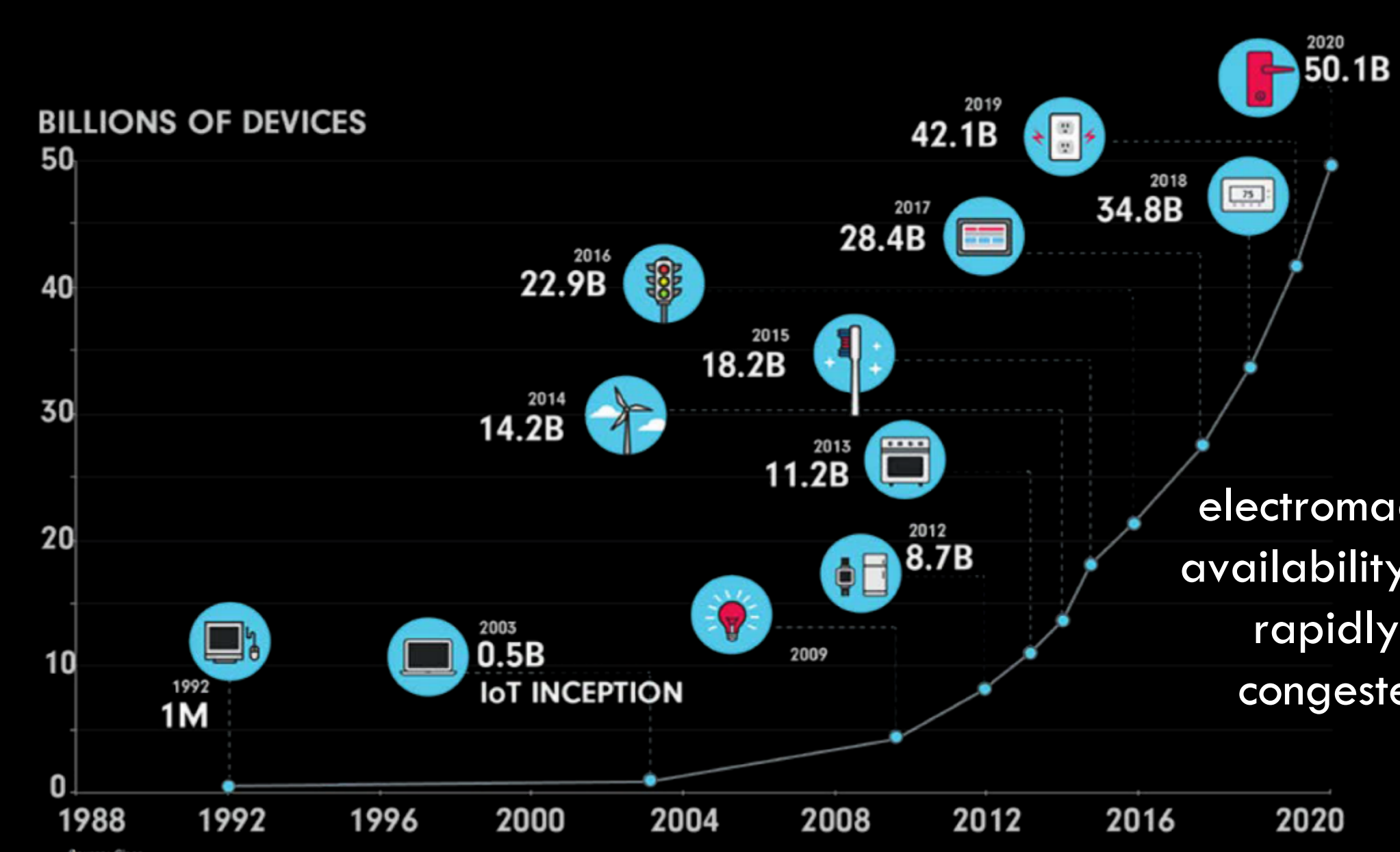
Scientists and Engineers use the entire electromagnetic spectrum

- ***Some portions*** of the spectrum are managed via international and national laws and regulations



Terminology used with portions of the radio frequency domain

Slide Credit: NASA



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

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

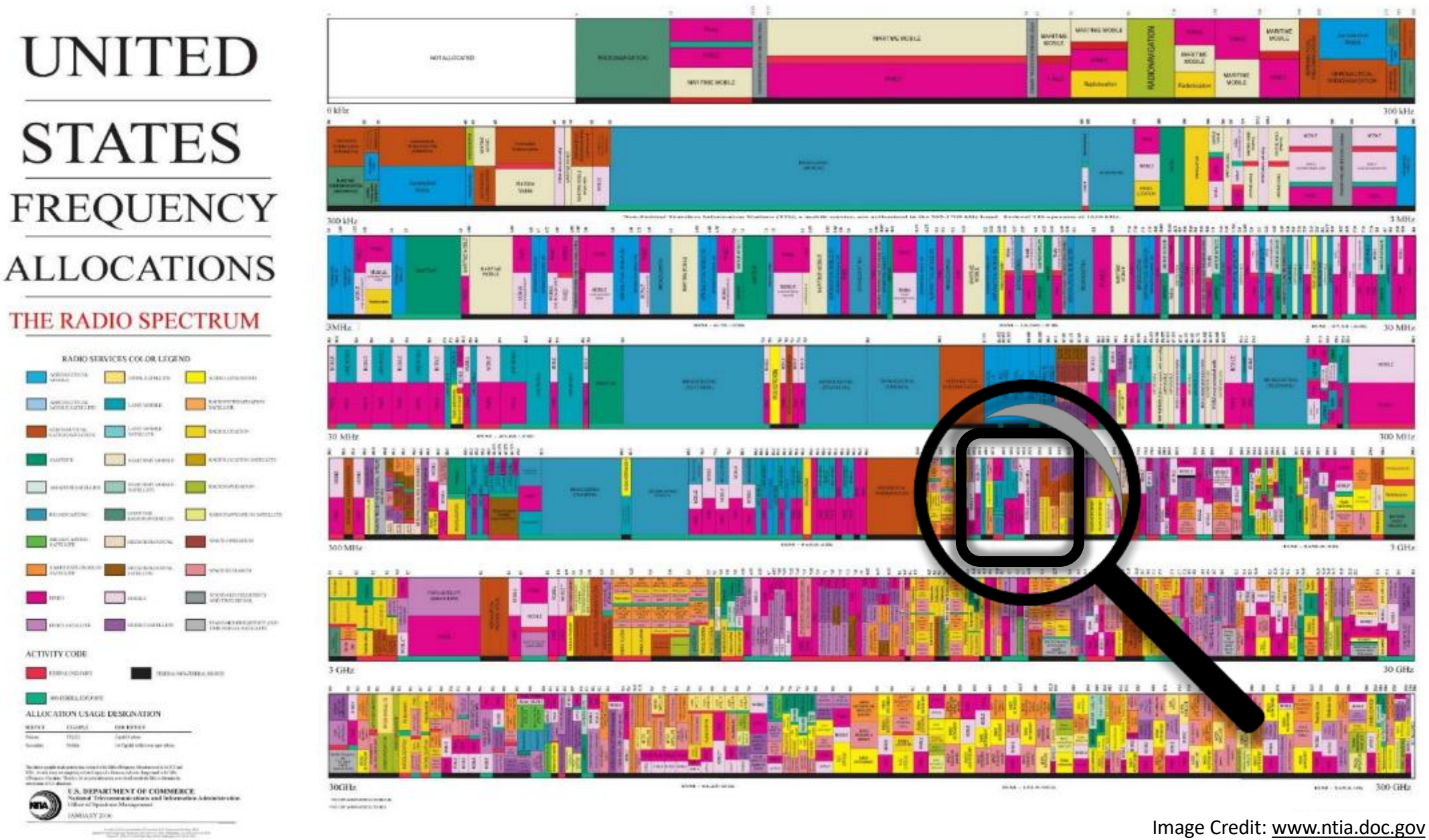


Image Credit: www.ntia.doc.gov

Science applications share the spectrum with many other users

GPS

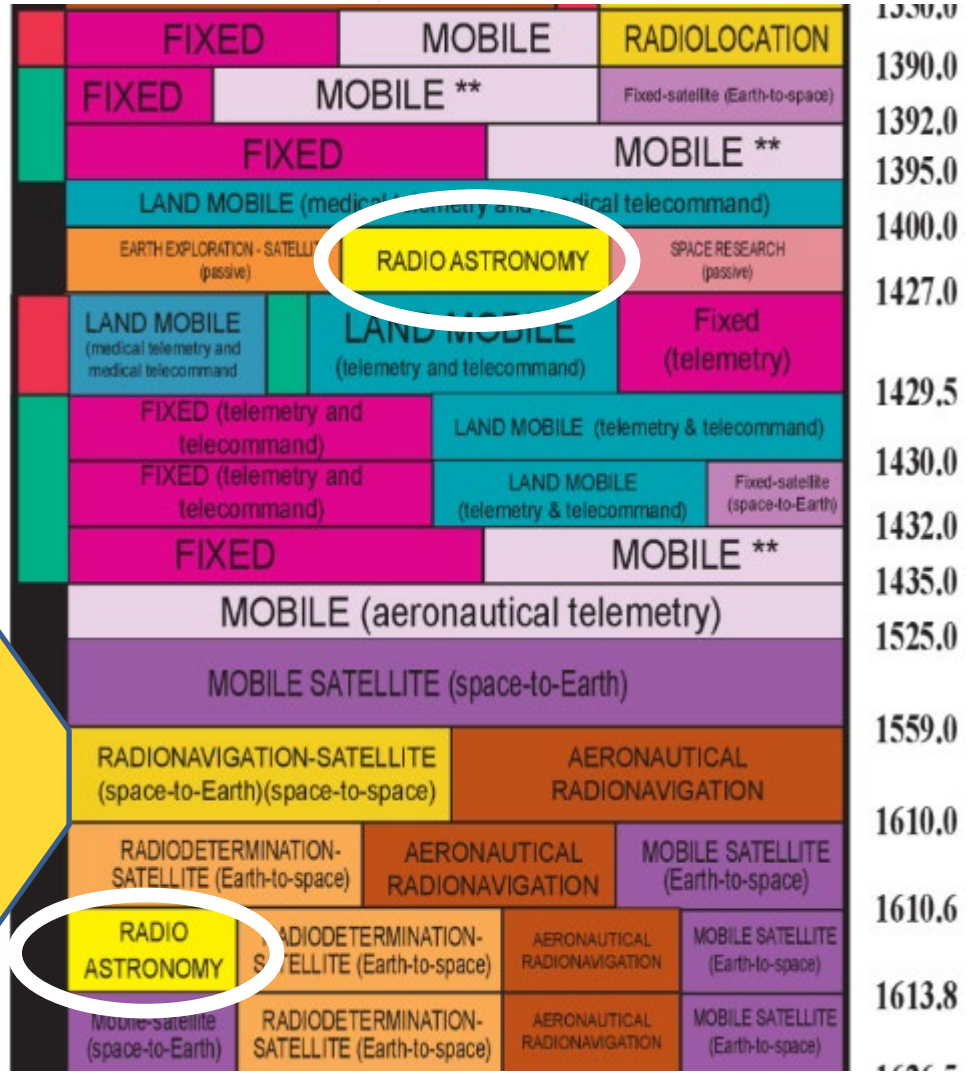


Figure Credit: https://techcrunch.com/2016/02/05/new-air-force-satellites-launched-to-improve-gps/

Frequency Allocations: 1390 – 1614 MHz

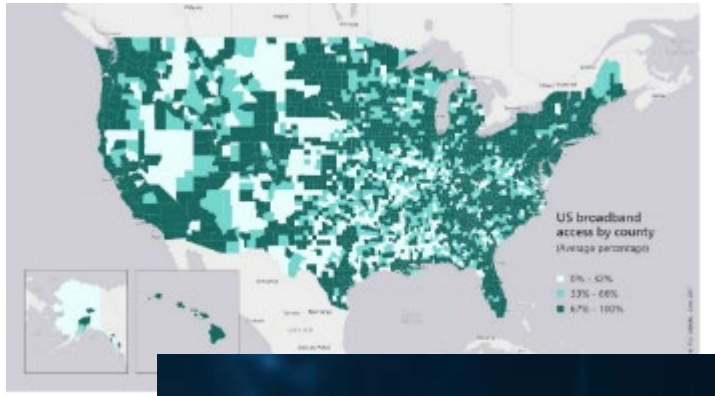
Challenges include:

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



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

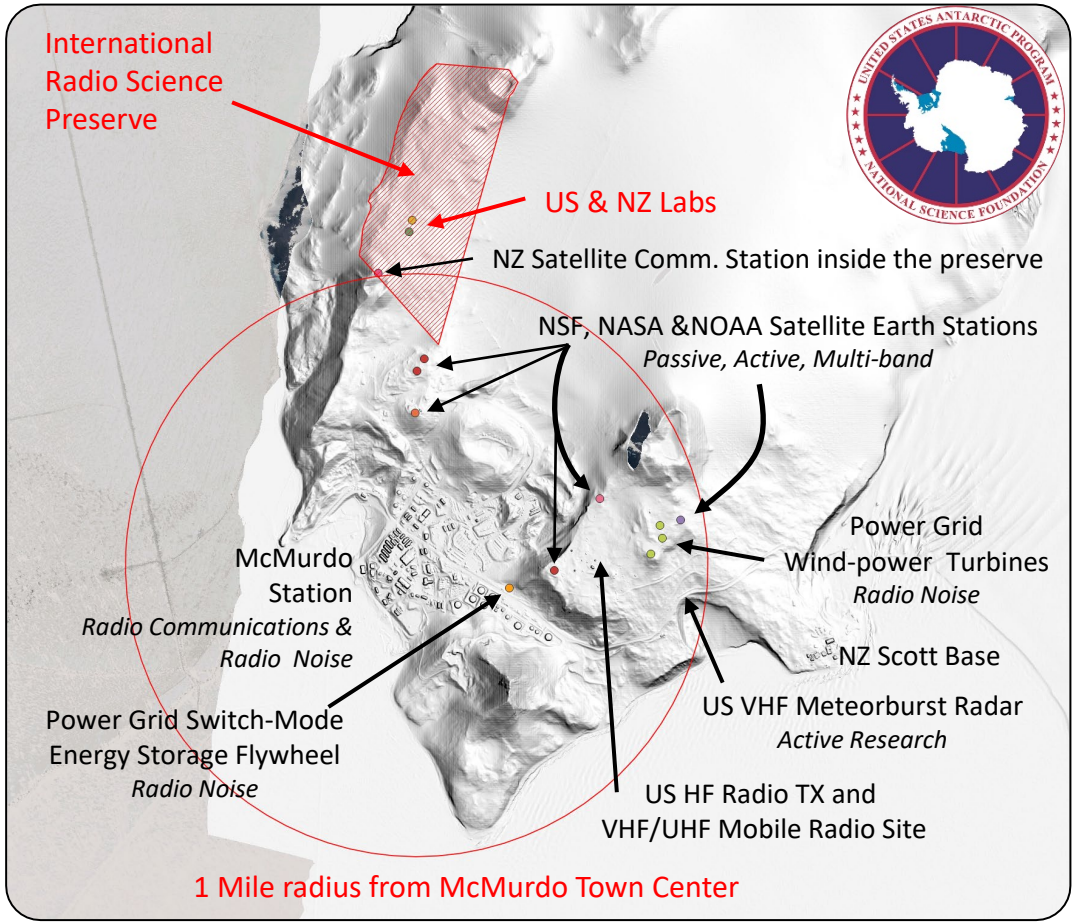
Spectrum for basic research

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 Representative Activities

Federal Communications Commission

- **Domestically** – to the National Telecommunications and Information Administration (NTIA); coordinate with the FCC, commercial companies, and other Federal Agencies

- **Internationally** – serve on U.S. Delegations to the international preparatory meetings leading to the World Radiocommunication Conference

NSF develops positions based on *input from scientific community* including National Academies Committee on Radio Frequencies, Advisory Committees (NSF, PCAST)

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

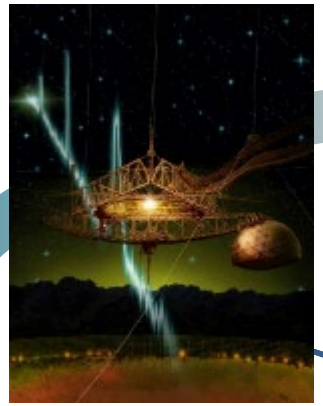
Spectrum Innovation Initiative (2020)

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

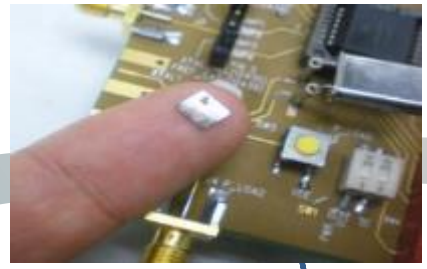
NSF Spectrum Goals:

Innovate and *Secure*

Spectrum Connections Across NSF



MPS
Astronomy



ENG
Wireless Devices/ Circuits

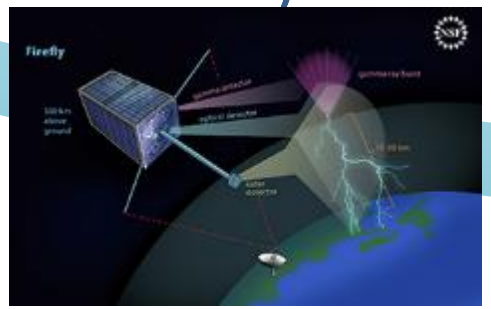
SBE
Spectrum Auctions/ Game Theory

BIO
NEON/ Biosphere Monitoring

NSF-wide ESM Coordination Group

EHR
Workforce Development

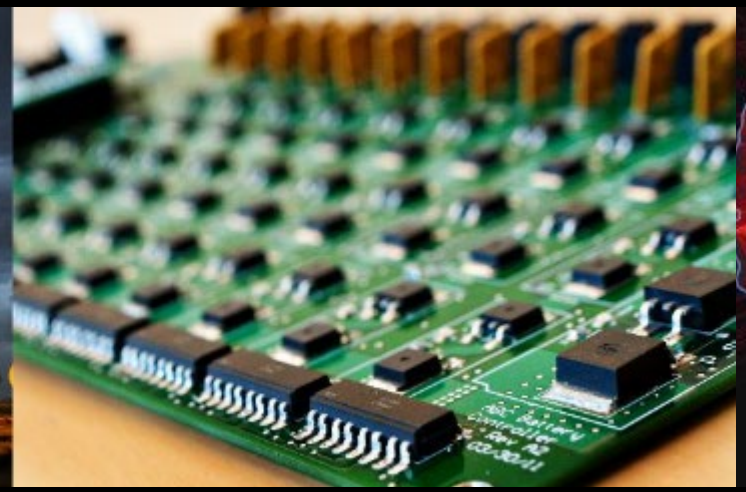
GEO
Cubesats/ Earth Sensing



CISE
Wireless Technology/ Networking/Theory/Algorithms/Software

NSF's Spectrum Innovation Initiative

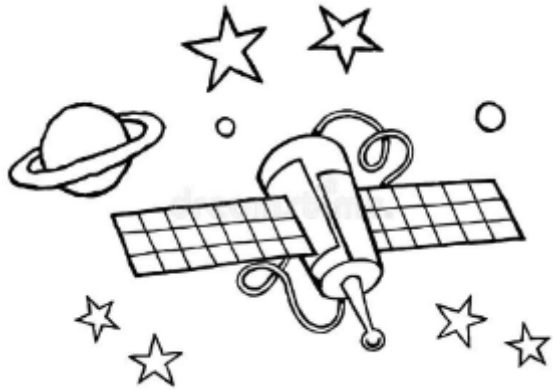
Cross-Directorate, housed in MPS Office of Multidisciplinary Affairs (OMA)
(via a stewardship model similar to NSF Big Ideas)

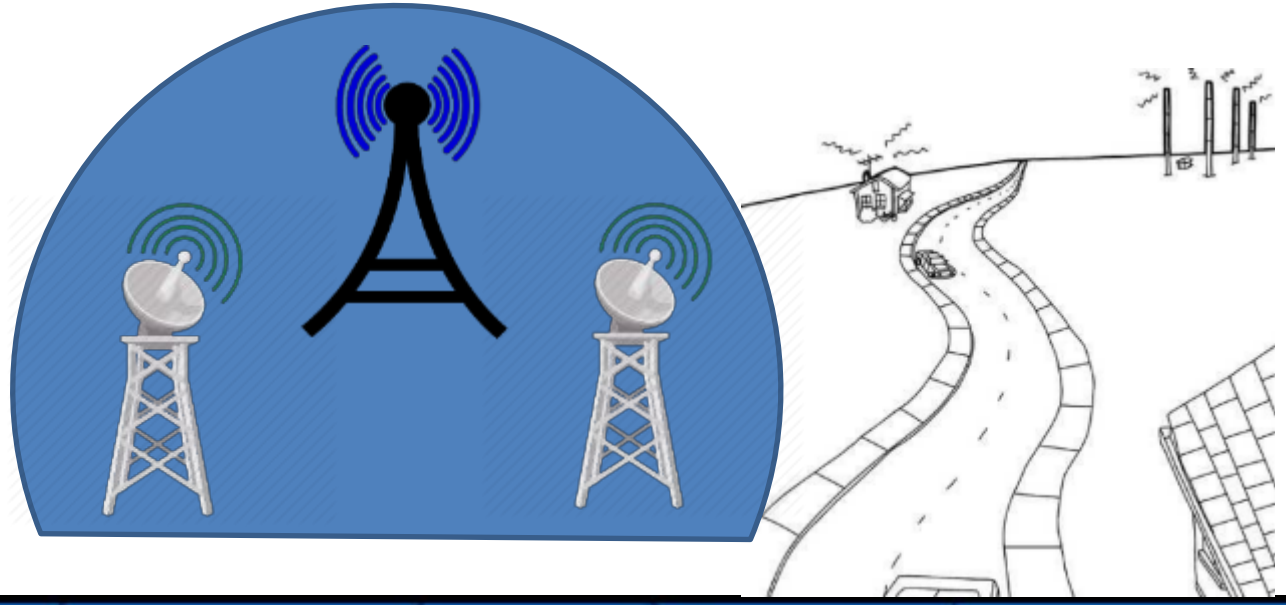



I. National Radio Dynamic Zone
II. National Center for Wireless Spectrum Research
III. Spectrum Research Integrative Activities
IV. Education and Workforce Development

National Radio Dynamic Zone

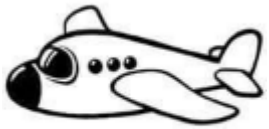
Wireless testing “in” the zone does not interfere with users of spectrum outside

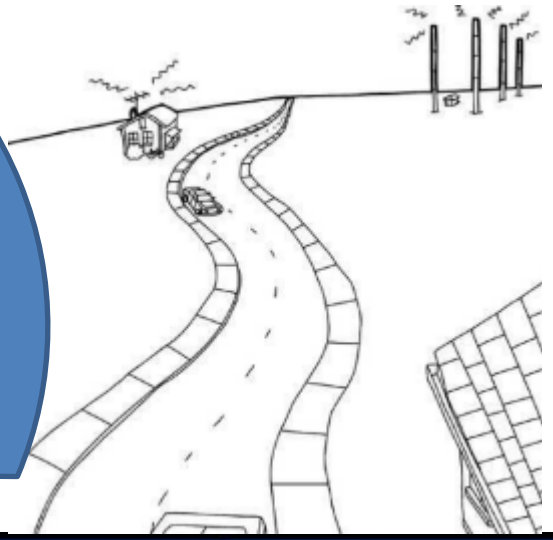




National Radio Dynamic Zone

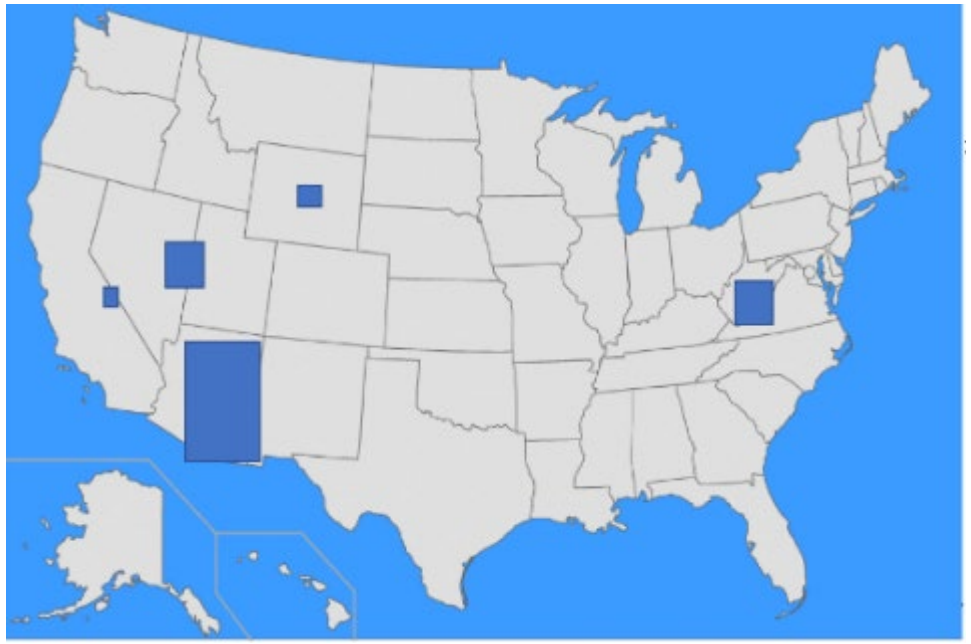
Spectrum users “outside” the zone do not interfere with passive users in the zone





National Radio Dynamic Zones (NRDZ)

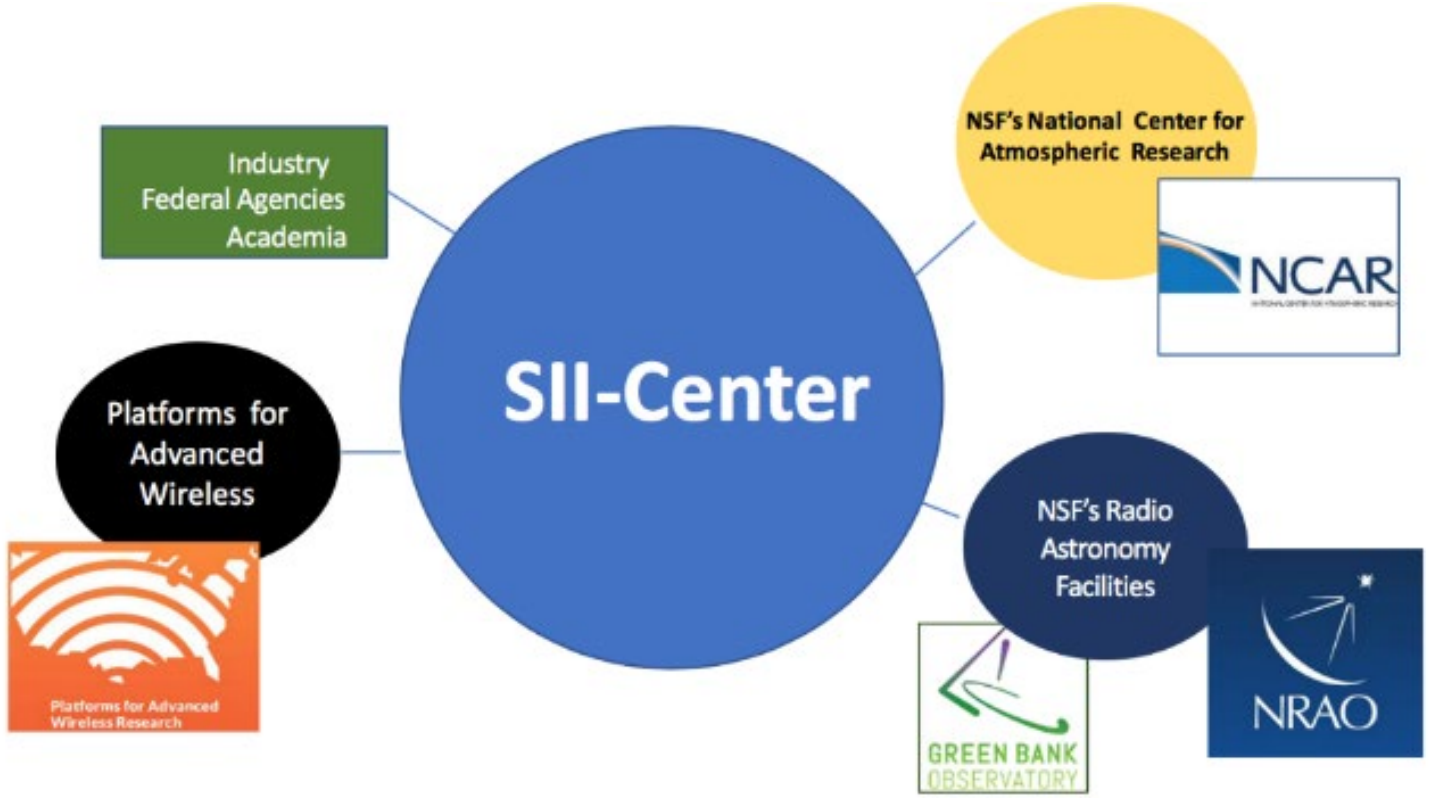
- Pilot innovative approaches for transmission/reception at various frequencies of interest
- Cognitive machine-to-machine frequency coordination leading to dynamic allocation and improved efficiency



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

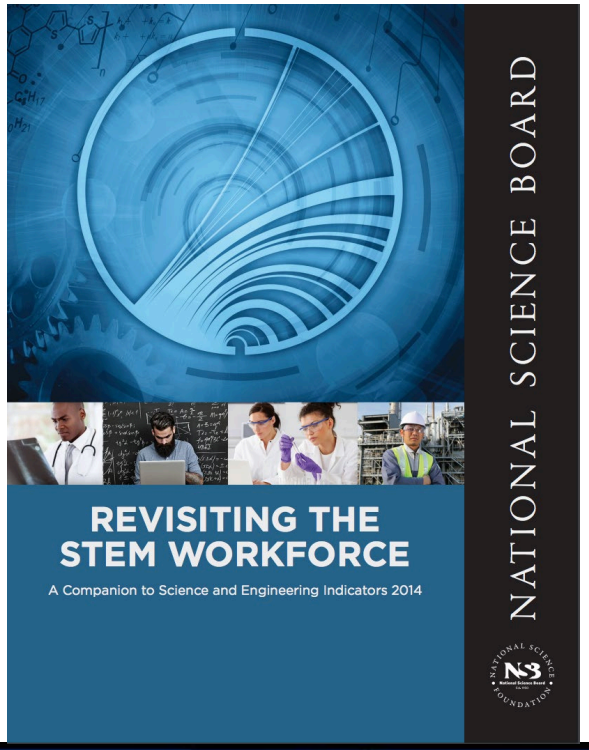


National Center for Wireless Spectrum Research (SII-Center)

- **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



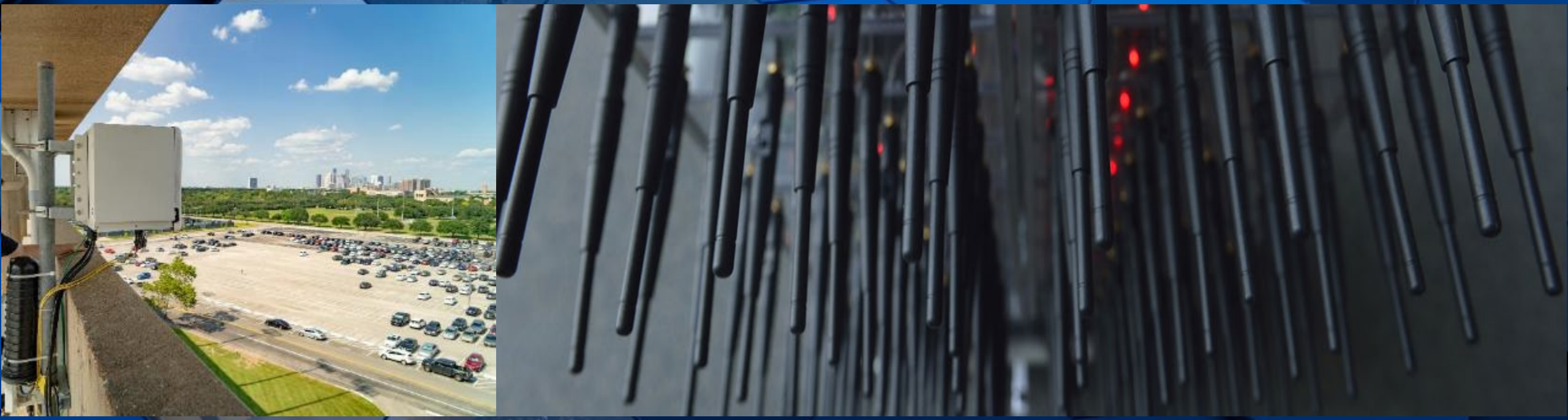


Image Credit: Jeff Fitlow/Rice University

NSF's Advanced Wireless Research Programs

Advanced Wireless Research: 5G and Beyond

Benefits to all:

- Affordable and equitable high-speed broadband
- New applications - enabled by ultra-low-latency communications, better positioning accuracy

Build on recent successes:

- Today's early 5G networks built on outcomes from NSF-funded research
  - Spectrum sharing, higher-frequency (millimeter-wave) use, software-defined networks
- Research community that is engaged and primed to innovate

Building Blocks

Electromagnetic spectrum expansion

- Learn to use more frequencies

Increased spectrum efficiency (higher data-speeds/Hz)

- Use these frequencies better

Switch from hardware-heavy to software-heavy network

- Adapt faster

Novel uses of wireless

- New application domains

NSF Investments in Advanced Wireless

Foundational R&D

- Core research programs
- Multi-Directorate research programs
- Partnerships (*DARPA, Intel, PAWR Industry Consortium*)
- National Center for Wireless Spectrum Research

Testing infrastructure

- Platforms for Advanced Wireless Research (PAWR)
- National Radio Dynamic Zone

R&D Coordination

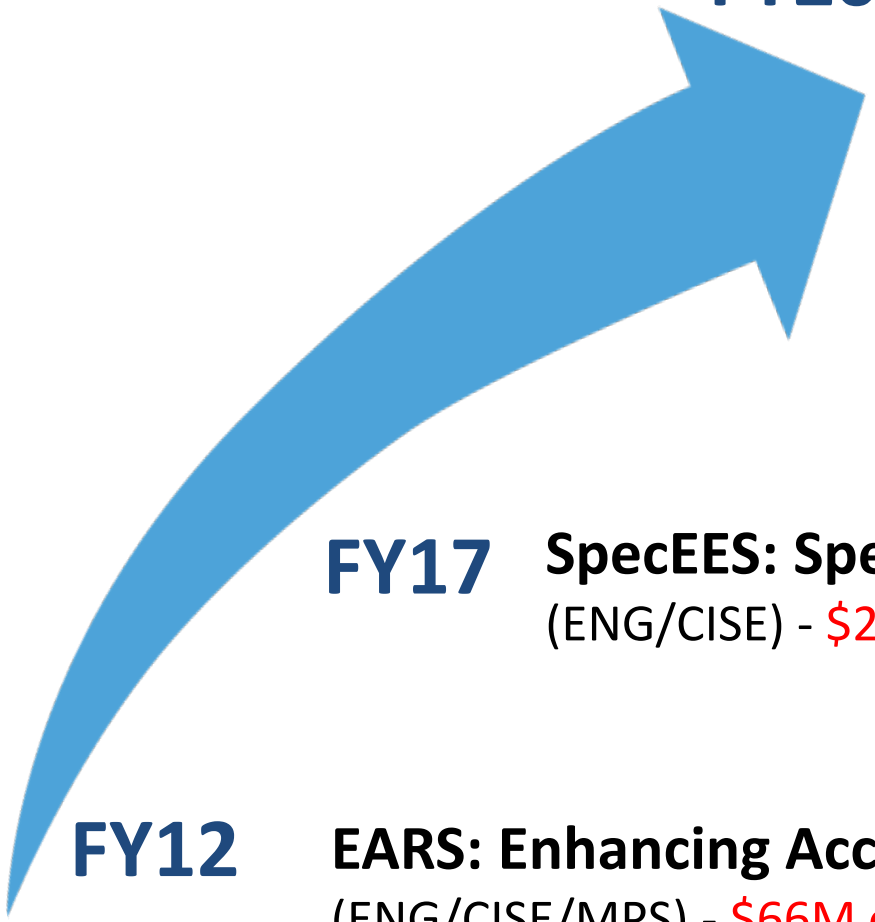
- Wireless Spectrum R&D Interagency Working Group (WSRD IWG)

Education and Workforce Development

- SII-Center

$60M annually, on average

Multi-Directorate Spectrum R&D Programs



FY20

SWIFT: Spectrum and Wireless Innovation enabled by Future Technologies
(ENG/CISE/MPS/GEO) - $12M in FY20

MLWiNS: NSF/Intel Machine Learning for Wireless Networks and Systems
(CISE/ENG/Intel) - $9M in FY20

FY17

SpecEES: Spectrum Efficiency, Energy Efficiency and Security
(ENG/CISE) - $29M over 3 years

FY12

EARS: Enhancing Access to the Radio Spectrum
(ENG/CISE/MPS) - $66M over 5 years

Platforms for Advanced Wireless Research (PAWR)

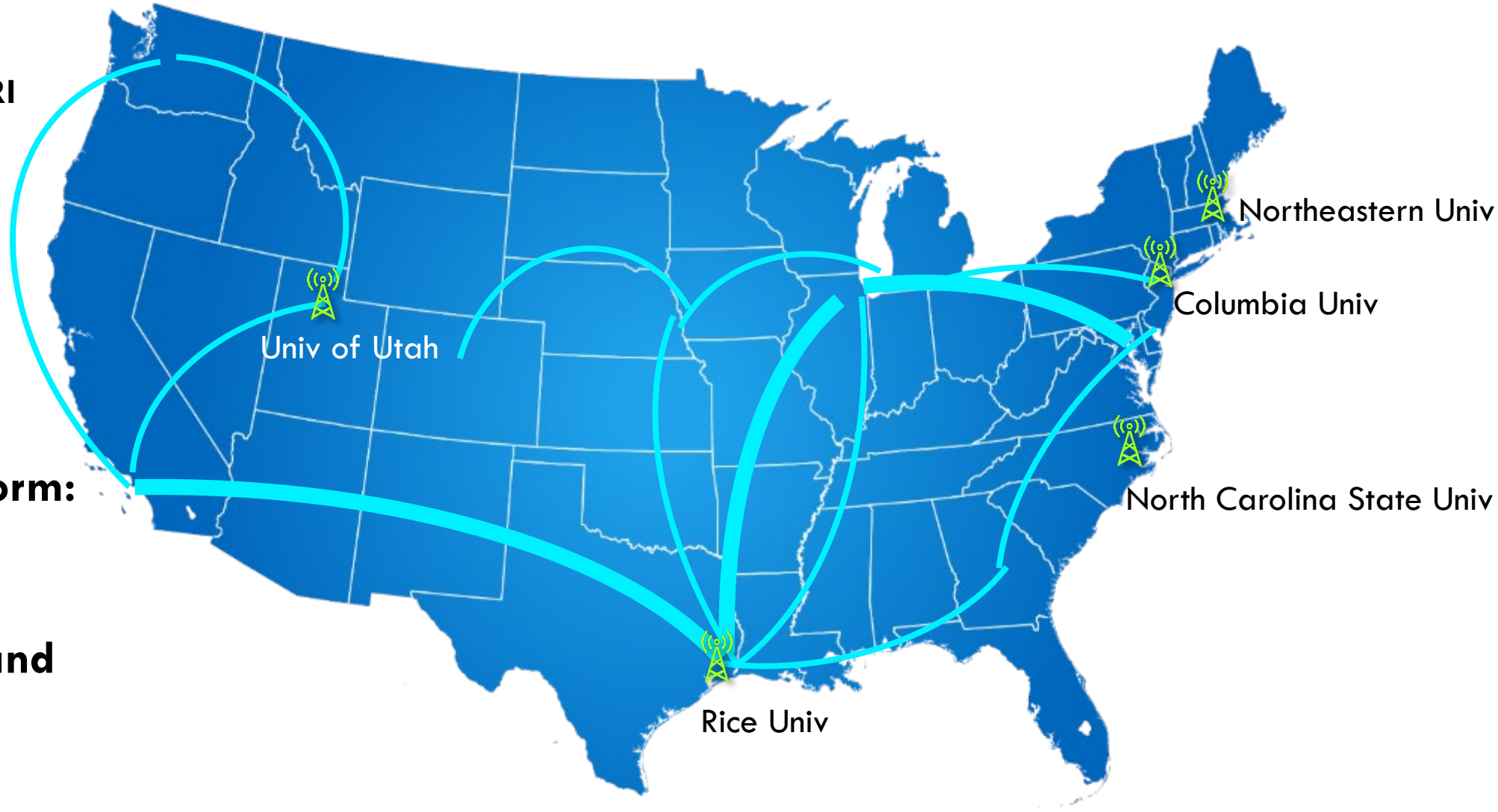
Programmable, Open Access, Remotely Operable (http://beyond5g.org)

$50M NSF investment (with 1:1 matching from 34-member industry consortium)

Advanced Wireless Testbeds

FABRIC Mid-Scale RI

PAWR Testbeds



Rural Wireless Broadband Platform: Spring 2021

NRDZ: location and timing TBD

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

<u>Innovate and Secure</u>

Contact information

NSF Electromagnetic Spectrum Management Office:

esm@nsf.gov

Contacts:

- ***BIO – Robert Fleischmann***
- ***CISE – Thyaga Nandagopal***
- ***EHR – Li Yang***
- ***ENG – Carmiña Londoño***
- ***GEO – Pat Smith***
- ***MPS – Ashley Zauderer, Jonathan Williams***
- ***SBE – Nancy Lutz***

Learn More

Advanced Wireless Program Page:
https://www.nsf.gov/cise/advancedwireless/

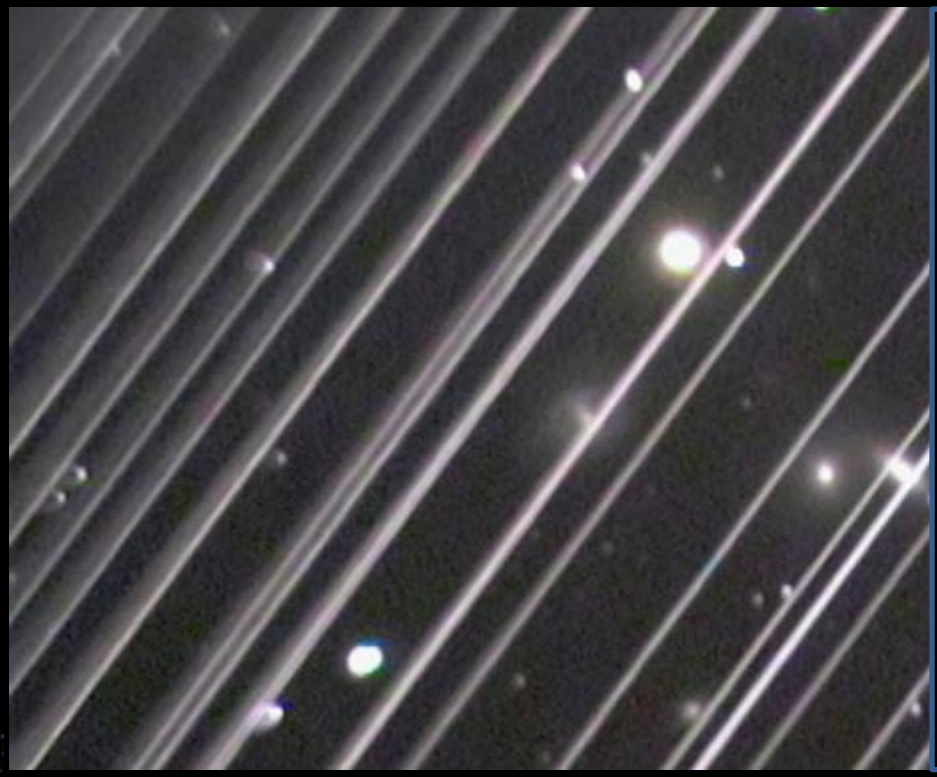
Spectrum Innovation Initiative Program Page:
https://nsf.gov/mps/oma/spectrum_innovation_initiative.jsp

Backup slides

Extended Role of ESM Office to Optical Wavelengths

Under leadership of
- Ralph Gaume, AST Division Director

Working with NSF's NOIRlab and the Vera Rubin Observatory to mitigate impacts to NSF optical ground-based science



2020
~6,000 satellites

2030
10,000+ satellites

2040
40,000+ satellites

Optical image of NGC 5353/4 galaxy group (25 May 2019)

Image Credit: Victoria Girgis / Lowell Observatory
https://www.iau.org/public/images/detail/ann19035a/