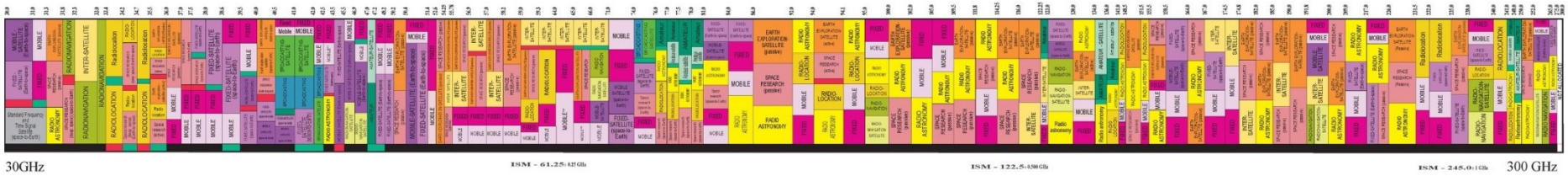
National Science Foundation

Electromagnetic Spectrum Management
Division of Astronomical Sciences



January 23, 2020

Report to the Astronomy and Astrophysics Advisory Committee (AAAC)

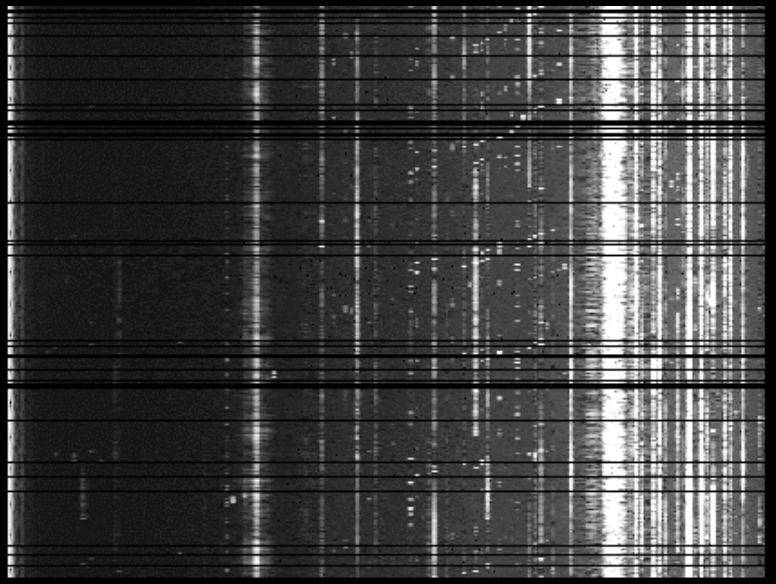
The 2020s:
A decade with
new opportunities

Credit: LSST

Credit: almaobservatory.org

The 2020s:
A decade with
new opportunities
and
new challenges

optical interference



radio interference

AAAC 2018 report

Report of the Astronomy and Astrophysics Advisory Committee

March 15, 2018

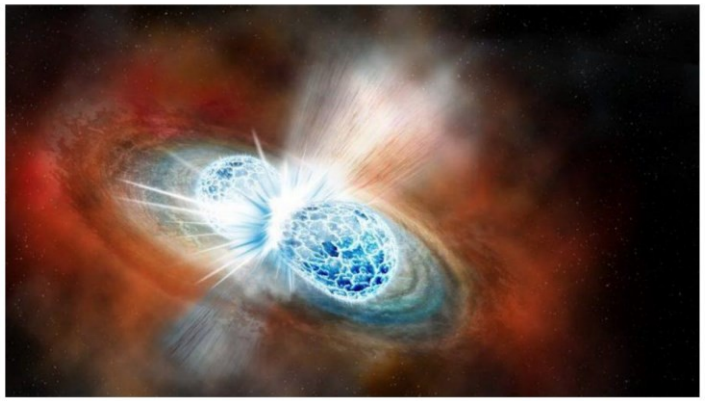
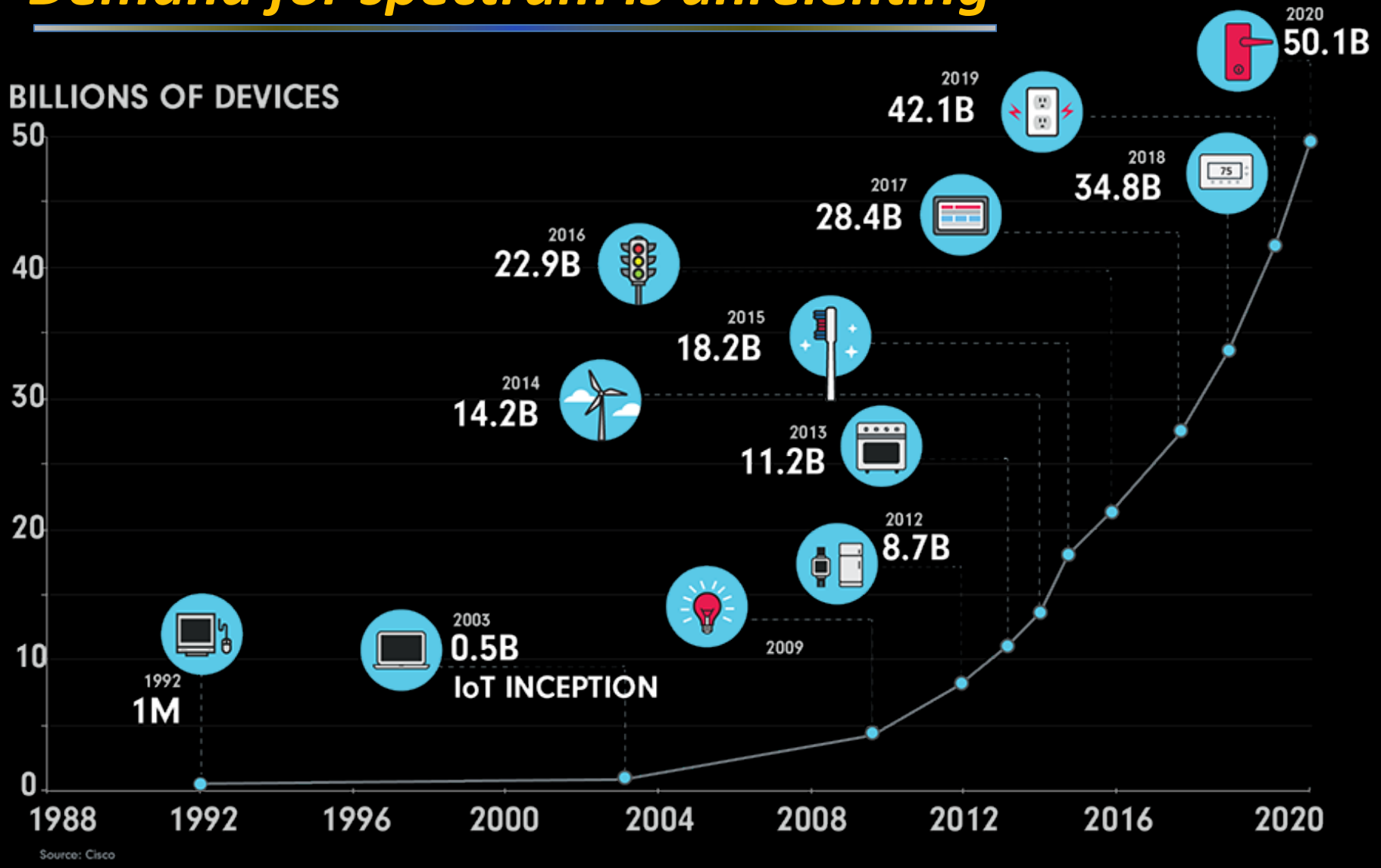


Image credit: Robin Dienel courtesy of the Carnegie Institution of Science.

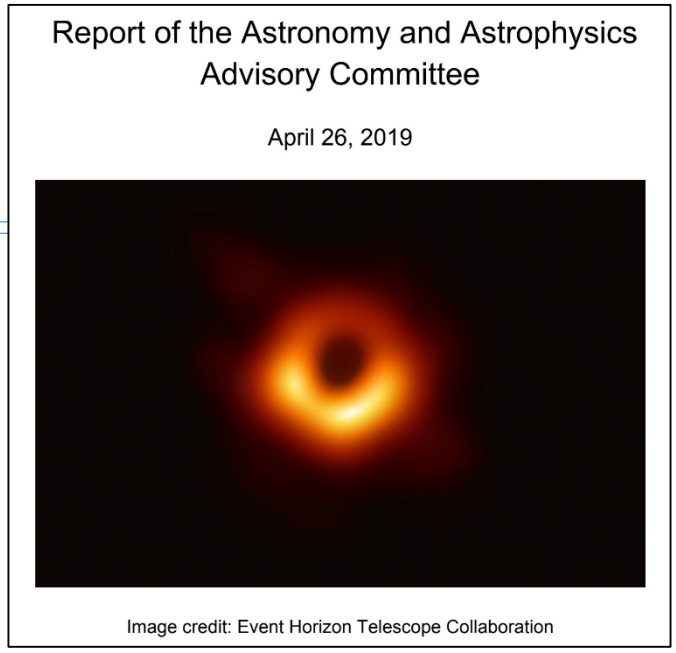
…the original protected frequency regions have been eroded both from external challenges, as well as significant out-of-band emission from competing sources and harmonics overlapping with key astronomical lines.

The original protected frequencies do not include emission lines that have become increasingly important as astrophysical diagnostics since the 1970's, nor do the protected frequencies encompass known lines that are redshifted out of the protected bands.

Demand for spectrum is unrelenting



2019 AAAC report



Finding (12): Competing interests continue to provide a severe and unrelenting threat to astronomers' ability to detect electromagnetic signals from space. Without clean access to these wavelengths, the ability of astronomers to obtain fundamental knowledge about the universe is profoundly impaired. This is particularly important as time-variable astronomy gains visibility (for example in detecting gravitational wave counterparts or other multi-messenger astronomy activities). Mobile and transient noise sources form a large and growing threat.

Finding (13): The resources currently available to the NSF and NASA are not sufficient to protect essential astronomical wavelengths in an arena of competing commercial interests with deep financial support and professional lobbyists.

Epoch of Reionization

HI: 21 cm -> 1.5 m

Freq ~ 1420 MHz -> 200 MHz

$$1 + z = \frac{f_{\text{emit}}}{f_{\text{obsv}}}$$

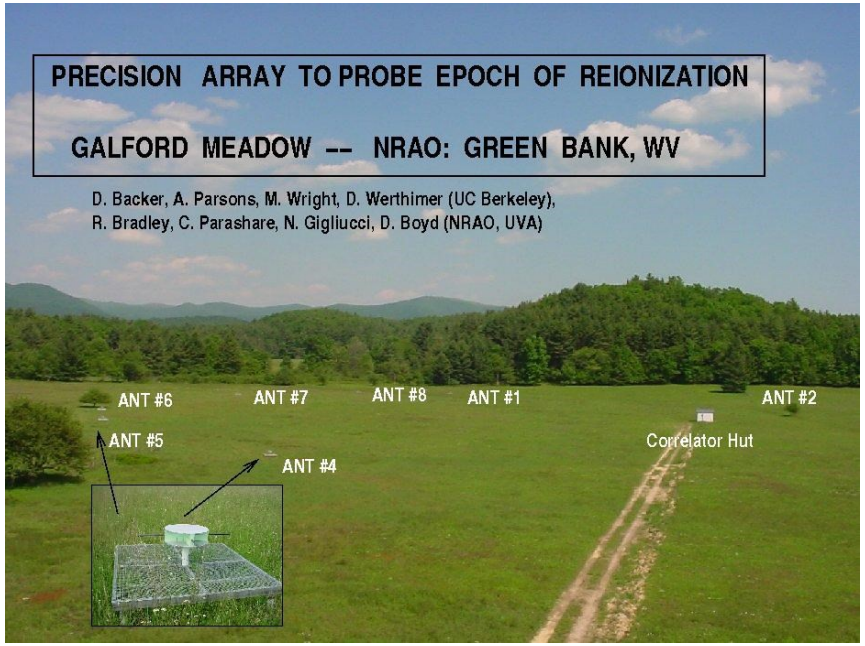


Image Credit: w.astro.berkeley.edu

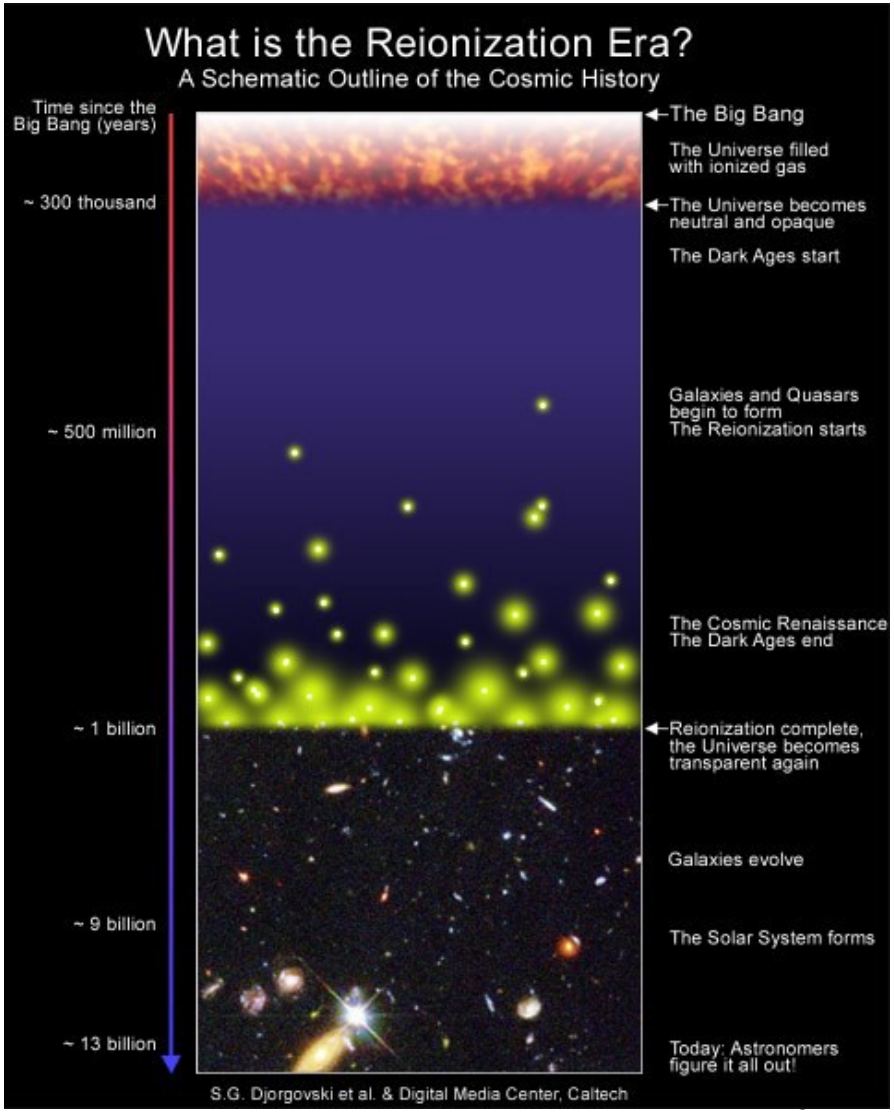


Image Credit: Djorgovski et al. (Caltech); www.haystack.mit.edu

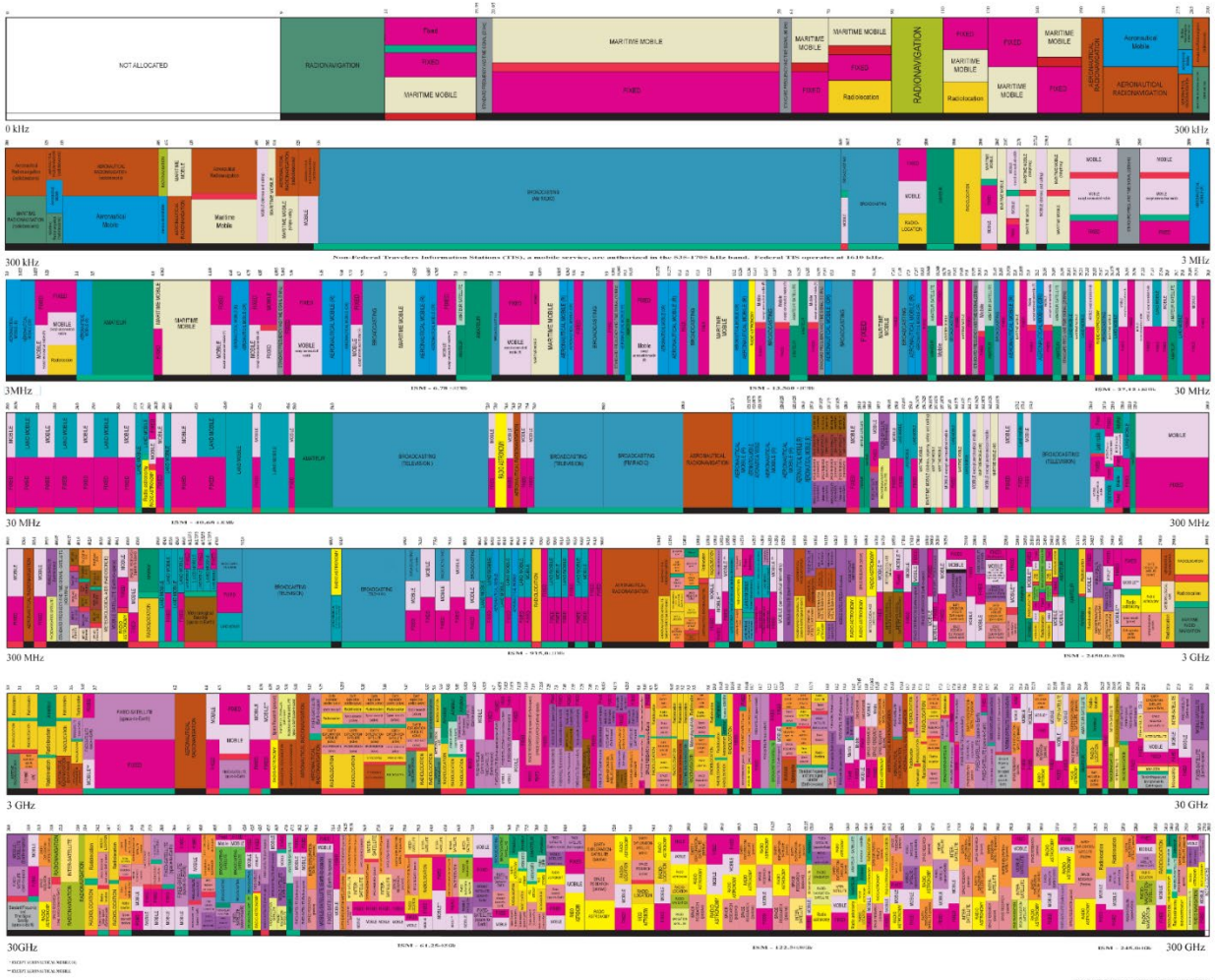
UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

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



UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND

AERONAUTICAL MOBILE	INTER-SATELLITE	RADIO ASTRONOMY
AERONAUTICAL MOBILE SATELLITE	LAND MOBILE	RADIODETERMINATION SATELLITE
AERONAUTICAL RADIONAVIGATION	LAND MOBILE SATELLITE	RADIOLOCATION
AMATEUR	MARITIME MOBILE	RADIOLOCATION SATELLITE
AMATEUR SATELLITE	MARITIME MOBILE SATELLITE	RADIONAVIGATION
BROADCASTING	MARITIME RADIONAVIGATION	RADIONAVIGATION SATELLITE
BROADCASTING SATELLITE	METEOROLOGICAL	SPACE OPERATION
EARTH EXPLORATION SATELLITE	METEOROLOGICAL SATELLITE	SPACE RESEARCH
FIXED	MOBILE	STANDARD FREQUENCY AND TIME SIGNAL
FIXED SATELLITE	MOBILE SATELLITE	STANDARD FREQUENCY AND TIME SIGNAL SATELLITE

ACTIVITY CODE

FEDERAL EXCLUSIVE	FEDERAL/NON-FEDERAL SHARED
NON-FEDERAL EXCLUSIVE	

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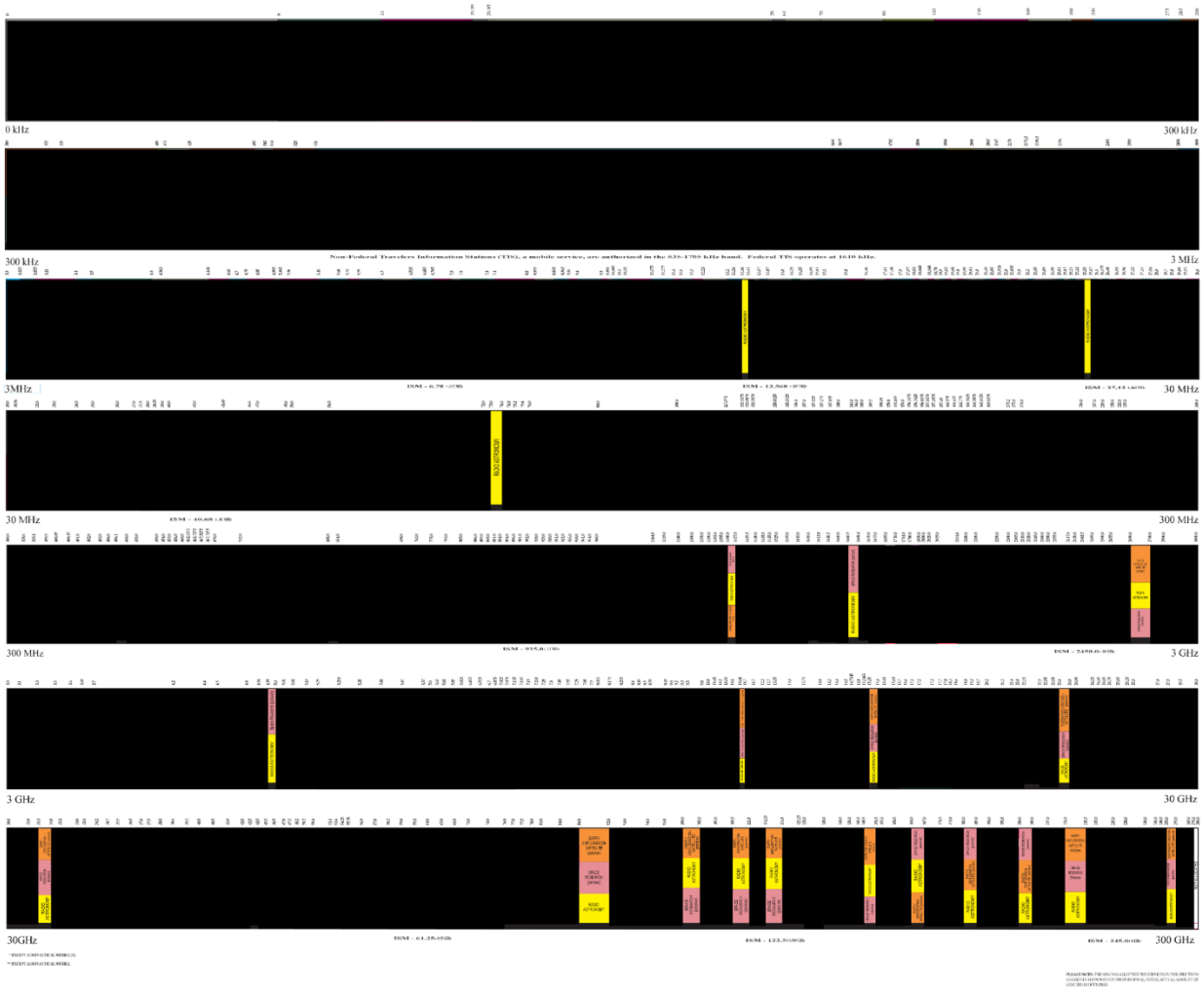

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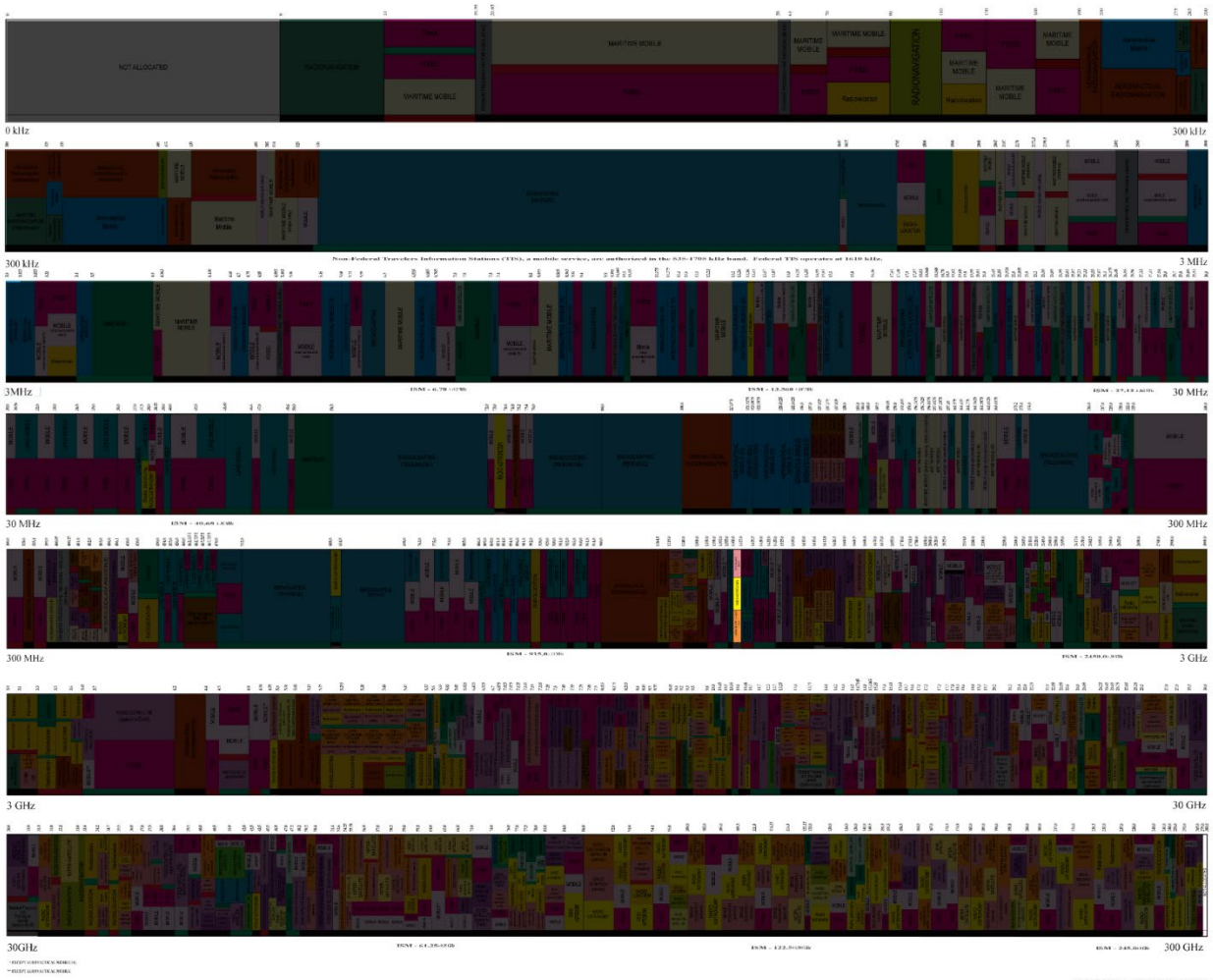

UNITED STATES FREQUENCY ALLOCATIONS

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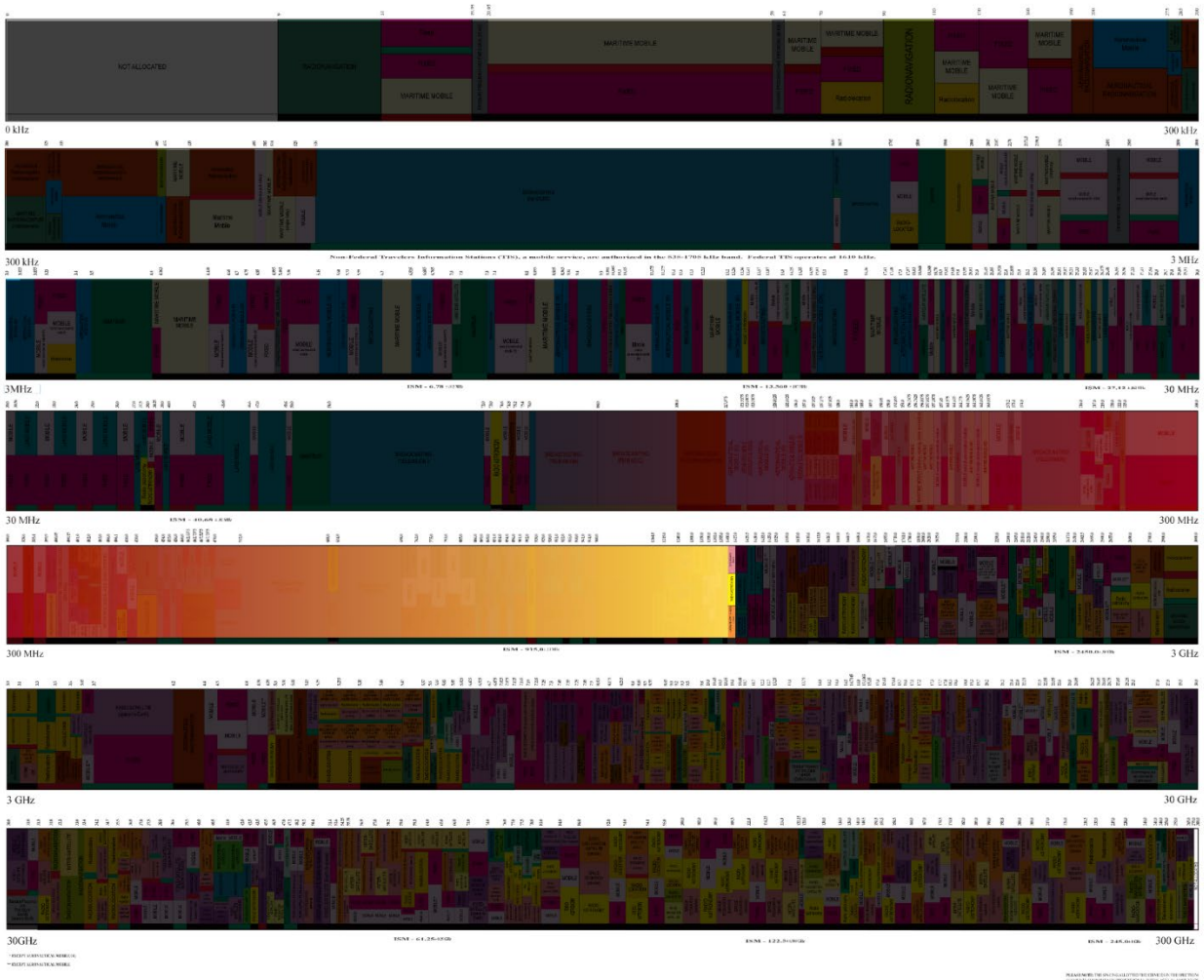
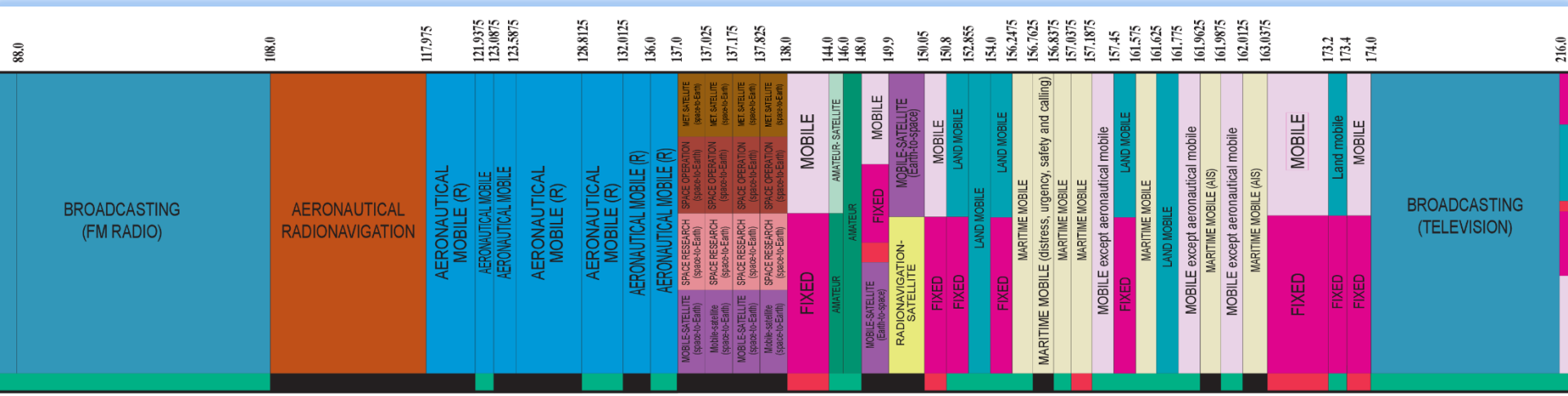
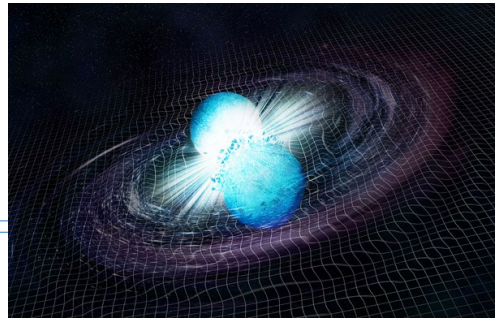


Epoch of Reionization



Importance of EM Access



10 uJy at 3 GHz ~2 weeks

2 GHz BW (~1.4 GHZ after RFI excision)

<50 MHz is RAS primary

VLA Observation September 7, 2017

GW170817

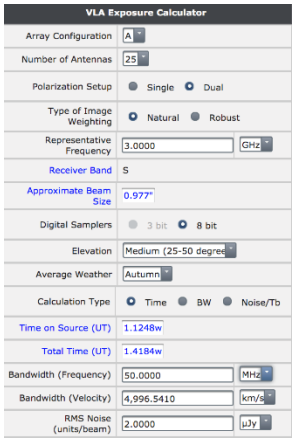
Image Credits: Hallinan et al., Science (16 Oct 2017)

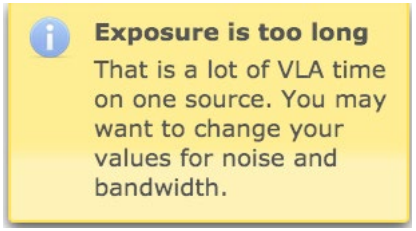
To achieve 2 uJy RMS
requires integration time on source of:

2 GHz bandwidth:
5.5 hours

1.4 GHz bandwidth:
6 hours

50 MHz bandwidth:
185 hours (more than one week)



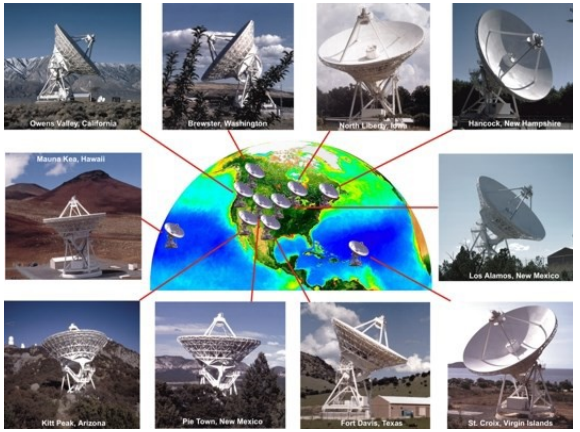


NSF-funded Astronomy research relies on access to electromagnetic spectrum

ESM resides in MPS/AST because historically spectrum usage has been focused primarily around the needs of a few large facilities and the National Radio Quiet Zone.

Arecibo Observatory, Puerto Rico

Very Large Array, NM



Very Long Baseline Array

Green Bank Observatory
National Radio Quiet Zone

Domestic and International Impact

Image credit: almaobservatory.org

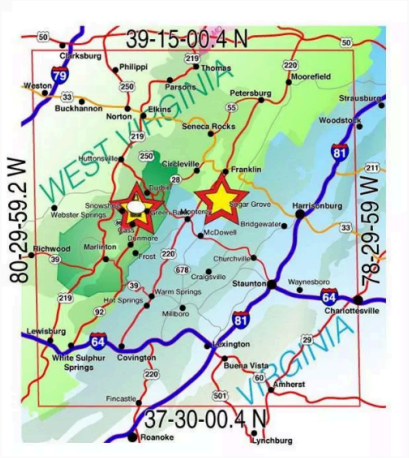
- **The United States has significant scientific assets / large facilities outside of its national borders.**

- **Observatories tend to be in geographically remote sites, but radio emission from moving emitters: car radars, satellites and high altitude delivery systems will be an increasing challenge.**

National Radio Quiet Zone

- **NRQZ (established 1958) needs updated protections from airborne transmitters; other radio telescopes need also need newly established coordination zones.**

- **We need new quiet/coordination zones for coordinating access to wider bandwidths for the VLA, Arecibo, VLBA, ALMA and other facilities**



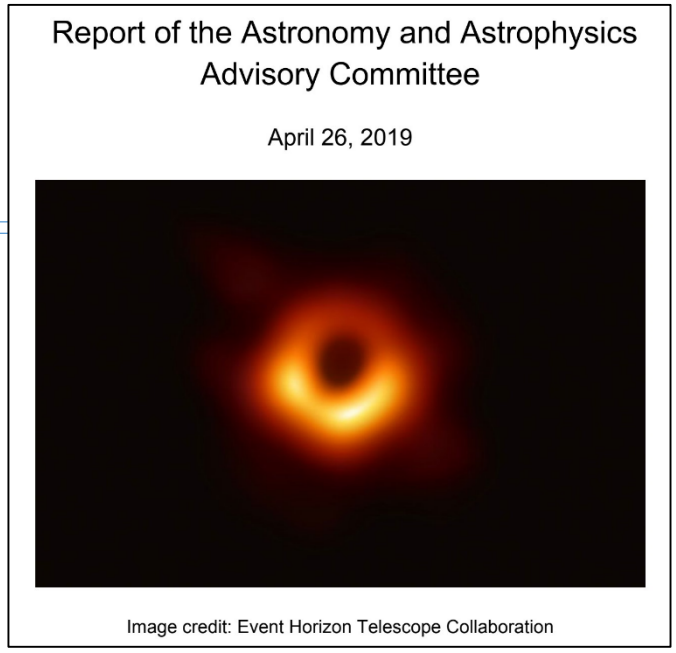
Credit: Green Bank Observatory

Description

The National Radio Quiet Zone (NRQZ) was established by the Federal Communications Commission (FCC) in Docket No. 11745 (November 19, 1958) and by the Interdepartment Radio Advisory Committee (IRAC) in Document 3867/2 (March 26, 1958) to minimize possible harmful interference to the National Radio Astronomy Observatory (NRAO) in Green Bank, WV and the radio receiving facilities for the United States Navy in Sugar Grove, WV. The NRQZ is bounded by NAD-83 meridians of longitude at 78d 29m 59.0s W and 80d 29m 59.2s W and latitudes of 37d 30m 0.4s N and 39d 15m 0.4s N, and encloses a land area of approximately 13,000 square miles near the state border between Virginia and West Virginia.

Credit: NRAO

2019 AAAC report

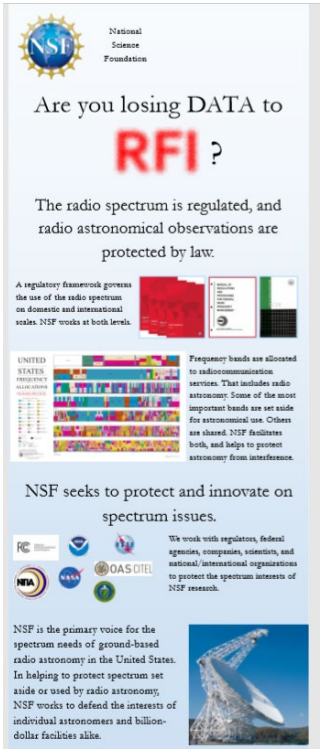


Recommendation (14): Given their common interests in access to the spectrum, NASA and NSF should enhance their collaboration with each other and with other groups, including international agencies and commercial interests, to protect the accessibility of essential astronomical wavelengths to researchers.

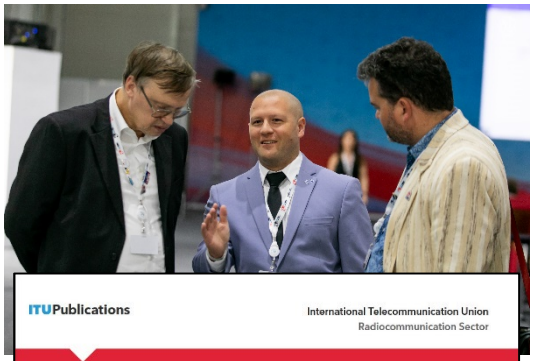
Recommendation (15): Efforts, ideally coordinated with all three agencies, should be made to increase awareness of spectrum management issues among astronomers, the general public, and government agencies. Possible agents for meeting this recommendation might include the NSF-funded national facilities for operations at radio and optical wavelengths. Efforts to engage and coordinate with other international agencies should continue.

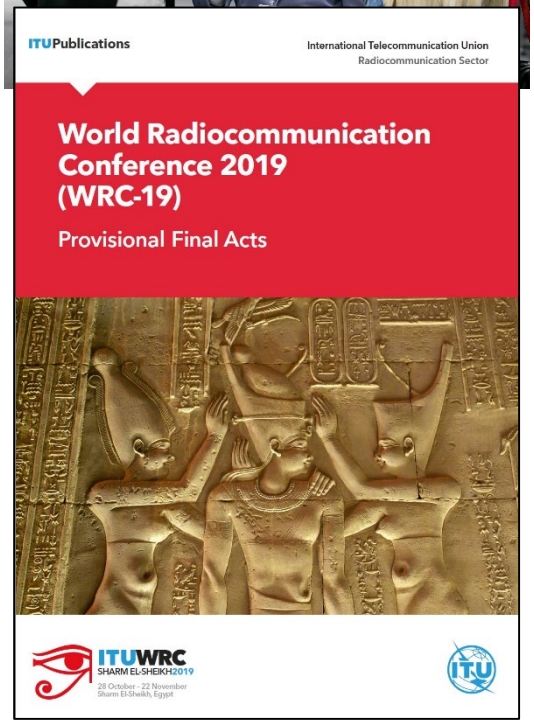
ESM Office Actions

I. ***Outreach - Presented at the AAS 235th meeting***
II. ***Ongoing regular meetings with NASA and NOAA***
III. *Represented U.S. scientific interests at the World Radio Conference 2019, beginning WRC-23 prep cycle*
IV. *Stepping into a role to consider the optical impacts from satellites as well as the radio impacts*
V. *NSF-wide Coordination Group*



World Radiocommunication Conference

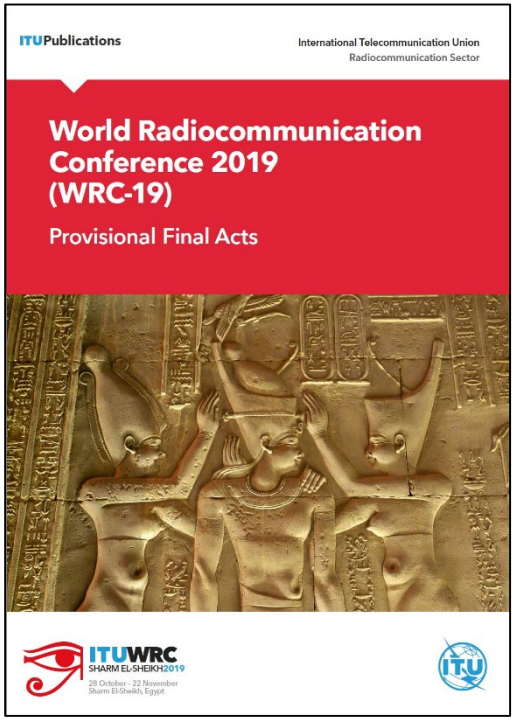




- Treaty conference convened every four years
- Just completed; held in Egypt, Oct-Nov, 2019

World Radiocommunication Conference

- Astronomy outcomes at WRC-19:
  - 275 – 450 GHz protections for RAS from FSS/LMR
  - Protection of 1610-1613 MHz
  - Language for development of a recommendation for protection of RAS sites from 5G (especially at 24 and 42 GHz)
  - RAS protections from HAPS (coordination distances required)
  - Still ambiguous how RAS limits are treated from out-of-band emissions from nearby services



World Radiocommunication Conference Key WRC-2019 Outcomes

- IMT (Mobile Broadband)
  - Identification in 24.25-27.25 GHz, 37-43.5 GHz
    - In-band and adjacent to radio astronomy frequencies
    - Further ITU documentation for protection to be developed
  - Modifications to numerous country footnotes adding IMT identification
- High-altitude platforms
  - Identification in 21.4-22 GHz, 24.25-25.24 GHz, 31-31.3 GHz, 38-39.5 GHz
  - Significant protections for radio astronomy (more strict than Recommendation ITU-R RA.739-2
- 275-450 GHz terrestrial operation
  - 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz identified for land-mobile and fixed service applications
  - Means to protect radio astronomy assets indicated as necessary

World Radiocommunication Conference Key WRC-2019 Outcomes

- GMDSS identification for Iridium system (1616-1626 MHz)
  - Out of band interference from Iridium system into OH maser band (1610-1613 MHz) noted for more than two decades
  - Significant discussion at WRC-19 revolved around resolving ongoing interference situation
- End result:
  - GMDSS operation allowed in frequency band 1621.35-1626 GHz
  - Restrictions on out-of-band emissions greatly strengthened
  - Radio astronomy limits incorporated into the radio regulations for emissions into the OH maser band
  - Several loopholes in compliance were fixed

World Radiocommunication Conference WRC-23 Agenda

- The most challenging issues from a radio astronomy perspective were redirected to the WRC-27 agenda
- Issues of interest on WRC-23 agenda:
  - IMT (Mobile Broadband) in 3300-3400 MHz, 3600-3800 MHz, 6425-7 025 MHz, 7025-7125 MHz and 10.0-10.5 GHz
  - Use of high-altitude platforms for provision of IMT services in 694-960 MHz, 1710-1885 MHz, 2500-2690 MHz
  - Sub-orbital vehicles (frequencies to be determined; of interest to NASA)
  - More GMDSS
  - Upgrade of SRS allocation in 14.8-15.35 GHz
  - Review of frequency allocations for EESS (passive) in the frequency range 231.5-252 GHz
  - Space weather sensors

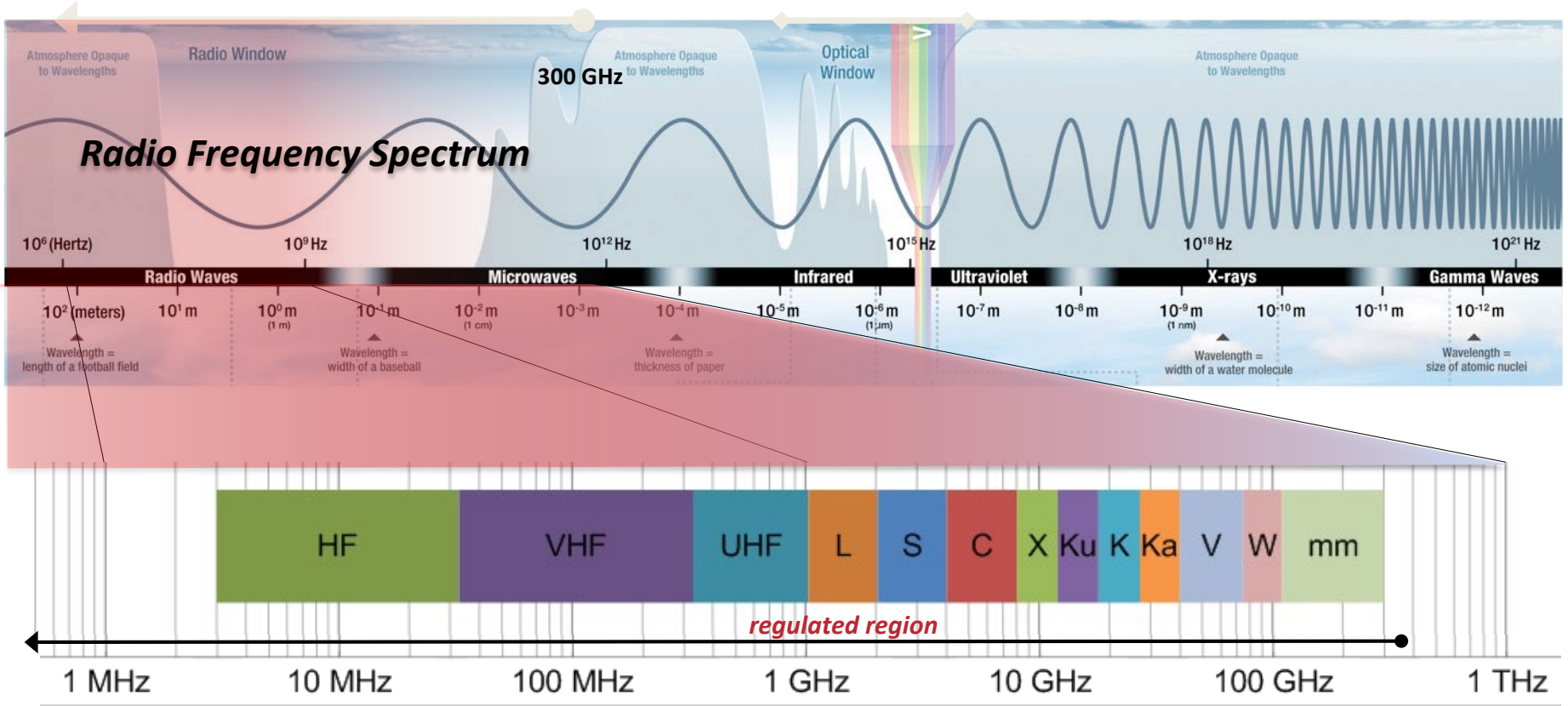
World Radiocommunication Conference WRC-27 Agenda

- Approaching cautiously; these issues may never be studied
- Items of concern:
  - New allocations and identifications to the radiolocation service in 275-700 GHz
  - ESIMs in 37.5-39.5 GHz (space-to-Earth), 40.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space)
  - Fixed satellite service allocations in 43.5-45.5 GHz, 71-76 GHz, 81-86 GHz
  - Space-to-space inter-satellite links in 1525-1544 MHz, 1545-1559 MHz, 1610-1645.5, 1646.5-1660.5 MHz, and 2483.5-2500 MHz
  - IMT studies in 1300-1350 MHz

Scientists use *the entire spectrum* but only *8.3 kHz to 275 GHz is regulated*:

- ***Radio Frequency Spectrum***: **frequency region of the EM Spectrum that is managed via international and national laws and regulations**

- **Limited regulations in the near-infrared and optical region (e.g., laser coordination & safety standards)**

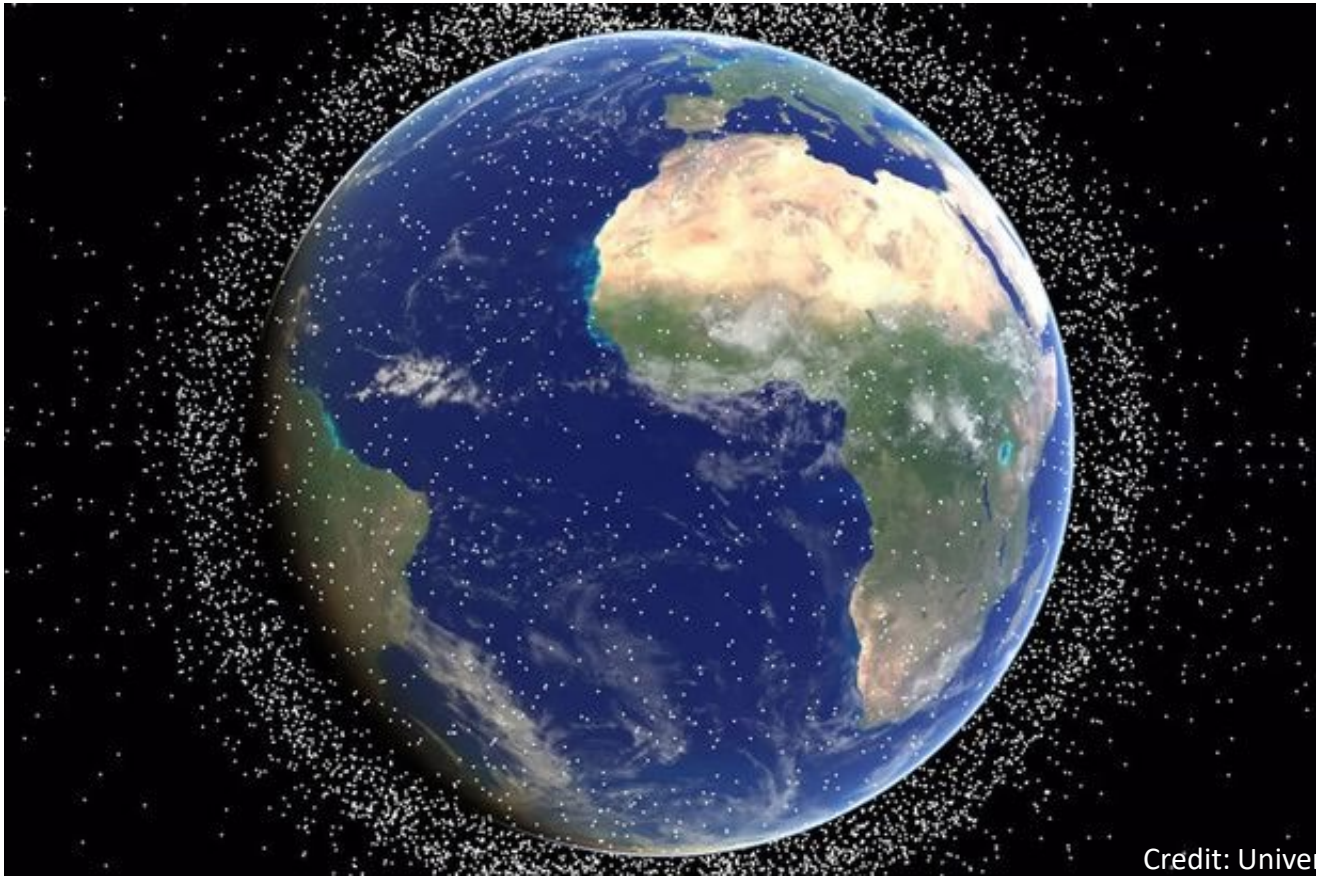


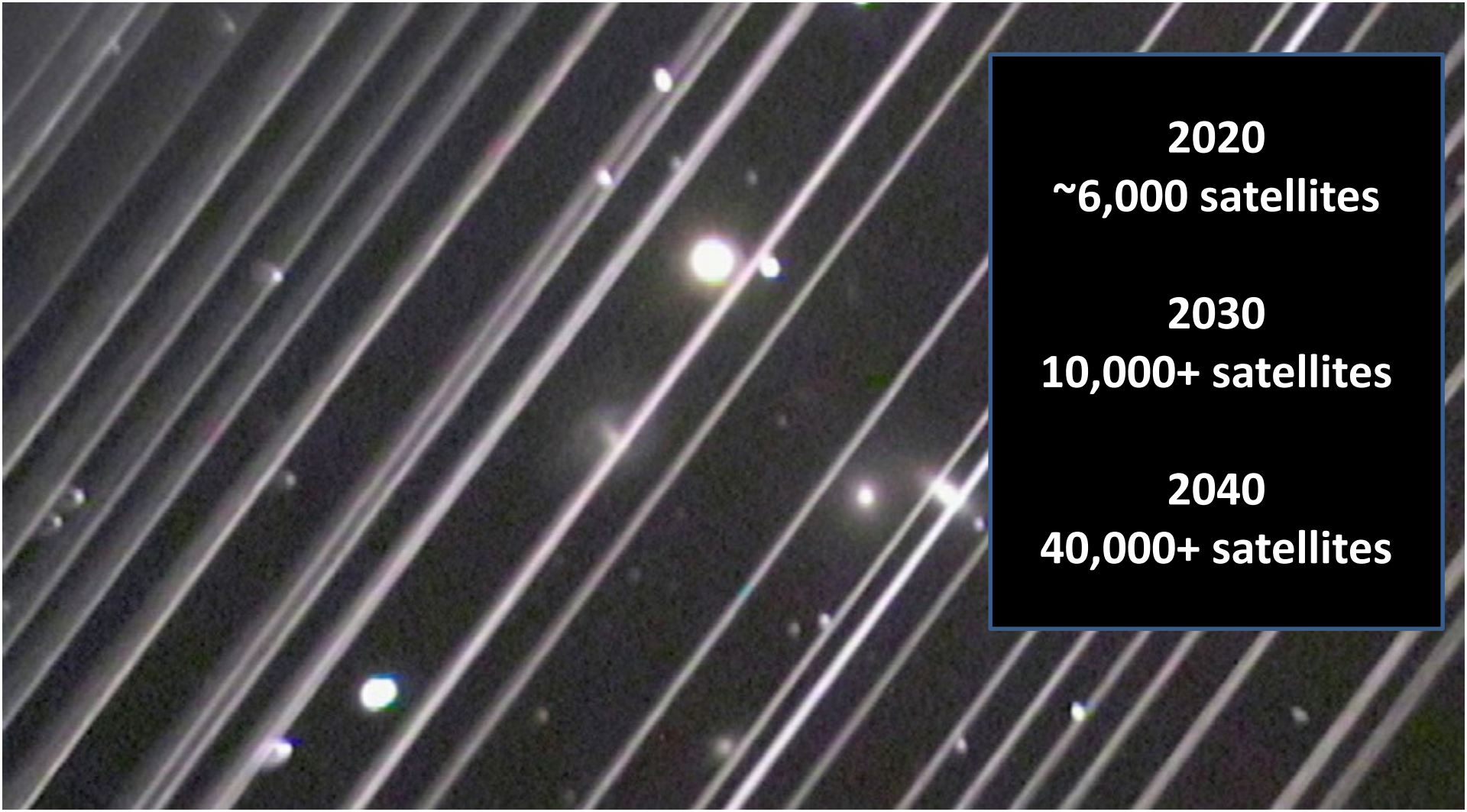
Terminology used with portions of the radio frequency domain

Slide Credit: NASA

What is coming?

- Constellations of thousands of NGSO satellites (10-50+ GHz transmitters) such that from any location you would always “see” at least one and up to 3 or 4 satellites or more!
- Mobile telecommunications (5G, IMT)
- High altitude platform systems





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/

Summary

- **Keep protected <u>allocations</u> as RFI-free as possible**
  - *Emissions may be prohibited at certain frequencies, out-of-band emissions can still be problematic*
    - *New challenges above the regulated regime (above 275 GHz, into optical)*

- **Utilize technology developments and advancements to <u>increase</u> spectrum availability, esp. in strategic geographic locations**
  - *Research in RFI excision techniques and receiver technology*
  - *Astronomy needs enhanced ESM geographical protections*
    – a new coordinated quiet zone for the upcoming decade (VLA has no quiet zone, NRQZ in WV does not protect from airborne emitters)

- **<u>Coordination</u> – internal at NSF and external stakeholders**
  - *Spectrum sharing*
  - *Costs must be considered; resources required for dynamic sharing*

- **Educational opportunity - Increased awareness of the spectrum as a finite resource**

Questions?

Jonathan Williams jonwilli@nsf.gov

Ashley Zauderer bezauder@nsf.gov

Thank you

NSF Coordination Group on Electromagnetic Spectrum Management

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

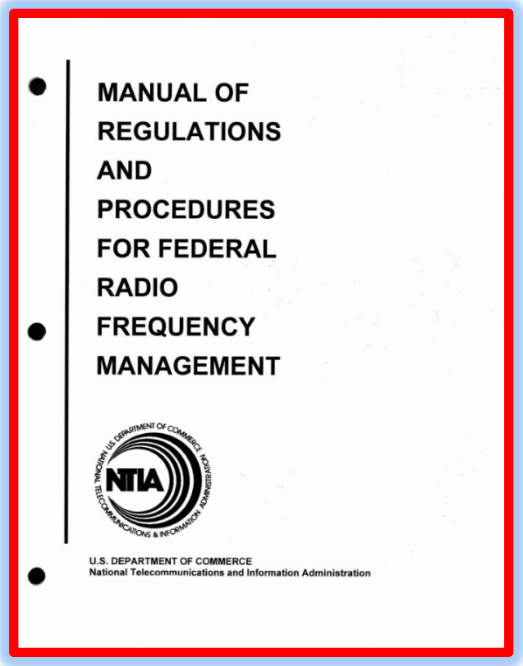
Jonathan Williams — **Coordination Group Chairman**

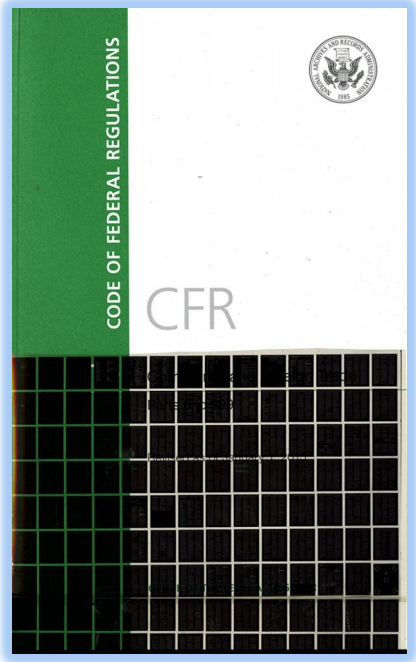
NSF Coordination Group includes representation from

- Mathematical and Physical Sciences
- Geosciences
- Computer and Information Science and Engineering
- Engineering
- Biological Sciences
- Social and Behavioral Sciences
- Education and Human Resources
- Office of the General Counsel
- Office of International Science and Engineering

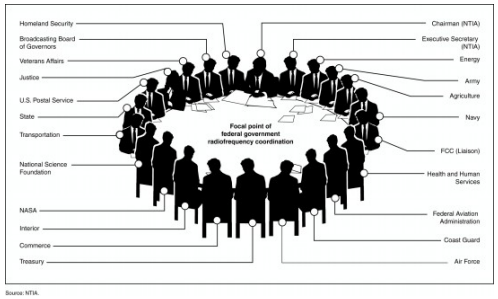
Allocations and Coordination

- Radio Regulations:
  - (1) International (ITU-R Radio Regulations; www.itu.int)
  - (2) Regional (bilateral agreements)
  - (3) National (USA: NTIA - www.ntia.doc.gov; FCC - www.fcc.gov)





NSF ESM Unit Activities

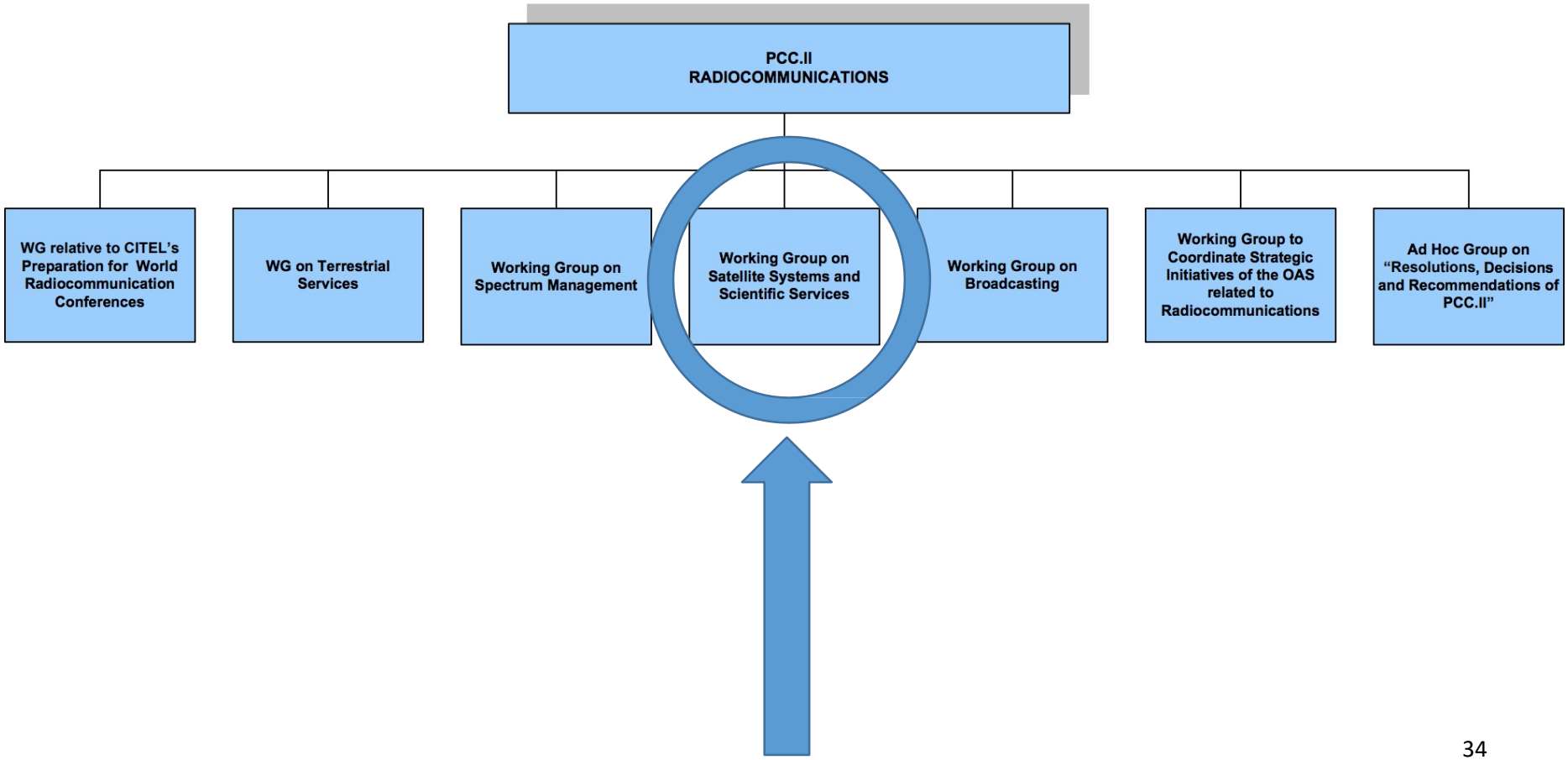


- Represent NSF as a Federal Agency to the National Telecommunications and Information Administration
  - 10 subcommittees including
    - IRAC
    - FAS (NRQZ coordination)

- Representation on official U.S. Delegations to the Inter-American Telecommunications Commission (CITEL) of the Organization of American States (OAS)

- Representation on official U.S. Delegations to the International Telecommunication Union's World Radiocommunication Conference (WRC 2019), including leading 7D – Radio Astronomy

OAS | CITEL


PCC.II
RADIOCOMMUNICATIONS
WG relative to CITEL's Preparation for World Radiocommunication Conferences
WG on Terrestrial Services
Working Group on Spectrum Management
Working Group on Satellite Systems and Scientific Services
Working Group on Broadcasting
Working Group to Coordinate Strategic Initiatives of the OAS related to Radiocommunications
Ad Hoc Group on "Resolutions, Decisions and Recommendations of PCC.II"

NSF ESM Unit Activities

- At NSF – Coordination with other Directorates and Divisions with spectrum needs, and manage spectrum related grants portfolio, including the National Academies of Sciences Committee on Radio Frequencies (CORF)
- Coordinate with other US Agencies, especially science agencies
- Interface with commercial interests to advocate for their taking "practicable" steps to not cause interference to passive services

JWST plans to use the Ka-band downlink…

Name:	Ka-Band Transmitter
Frequency:	25.9 GHz
Emission Designators:	56M0G1D, 28M0G1D, 14M0G1D
Service Directions:	• Space to Earth • Deep Space
Radio Services:	• Space Research
Station Classes:	• EH - Space Research (Space)
Earth Stations:	• Canberra (AUS) • Goldstone (CA) • Robledo de Chavela (E) (Madrid)
Asset Type:	Emitter
DBIU:	03/30/2021