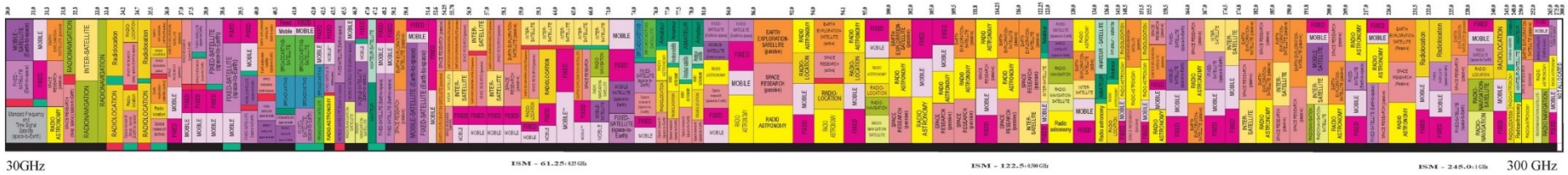
National Science Foundation

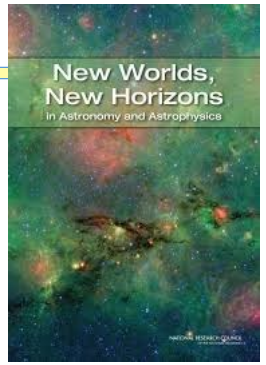
Electromagnetic Spectrum Management
Division of Astronomical Sciences



February 25, 2019

Report to the Astronomy and Astrophysics Advisory Committee (AAAC)

Relevant NRC reports

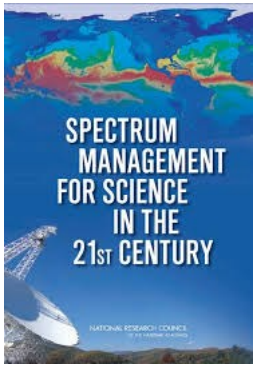


I. ***New Worlds, New Horizons in Astronomy & Astrophysics*** (NRC 2010)

- Science is impacted by spectrum management, but no specific mention outside of ESM budget

II. ***Spectrum management for Science in the 21st Century*** (NRC 2010)

- Multiple explicit recommendations; see Summary Intro (pages 1 - 5)



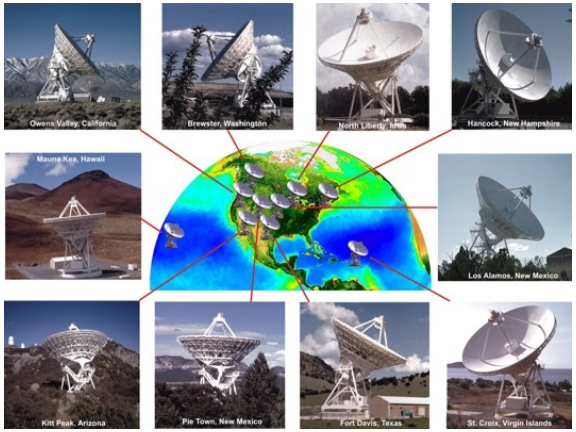
What is Spectrum Management and Why is it Vital to Enabling Cutting-Edge Astronomical Science?

NSF-funded Astronomy research relies on access to electromagnetic spectrum

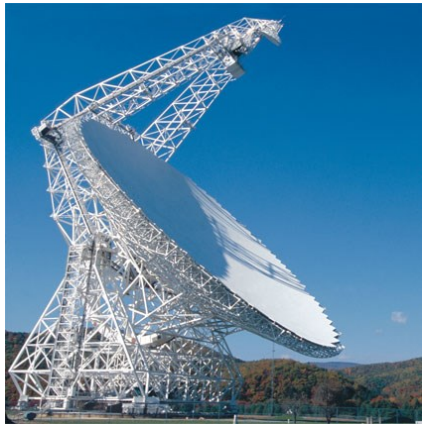
ESM resides in MPS/AST because historically spectrum usage has been focused primarily around the needs of a few large facilities and the National Radio Quiet Zone.

Arecibo Observatory, Puerto Rico

Very Large Array, NM



Very Long Baseline Array

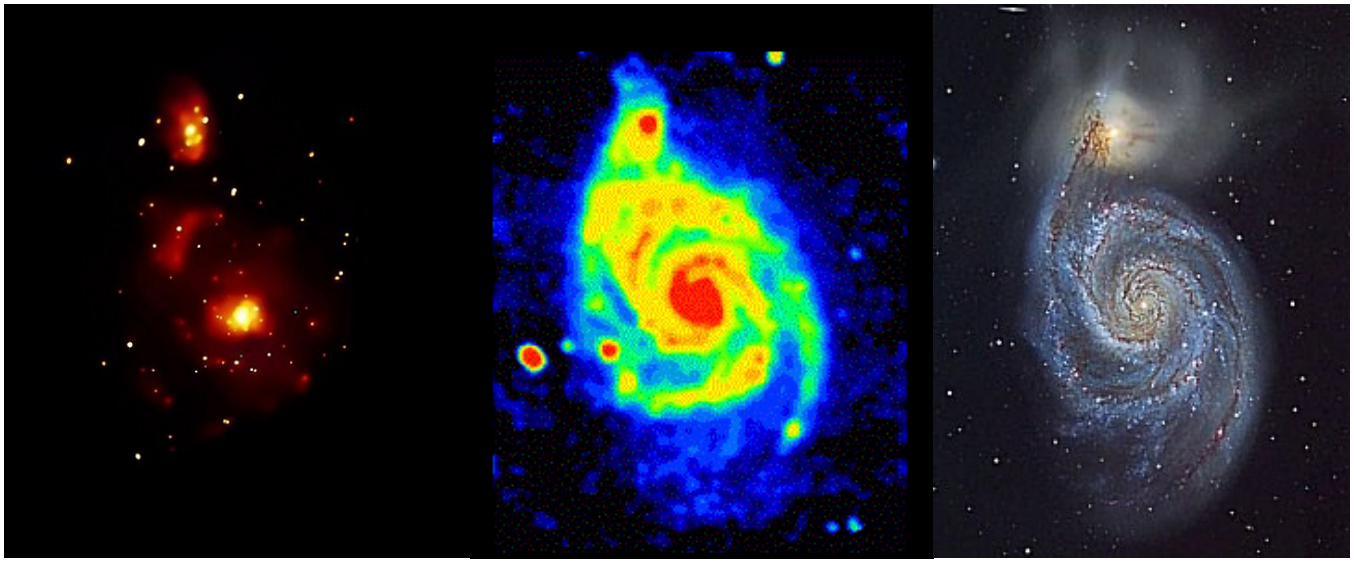


Green Bank Observatory
National Radio Quiet Zone

Importance of EM Access

- AST sciences are <u>fundamentally dependent on the detection of light across the full EM spectrum</u> (AAAC report, March 2017)

- "The observations exploited the large collecting area of the GBT and the power of a recently developed high-speed digital signal processor. In general, such measurements *<u>depend critically on access to wide swaths of the electromagnetic spectrum free of interference.</u>*" (p. 10, AAAC report 2010 - 2011)



M51 in X-ray, radio, and visible light (Image Credit: http://coolcosmos.ipac.caltech.edu/)

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

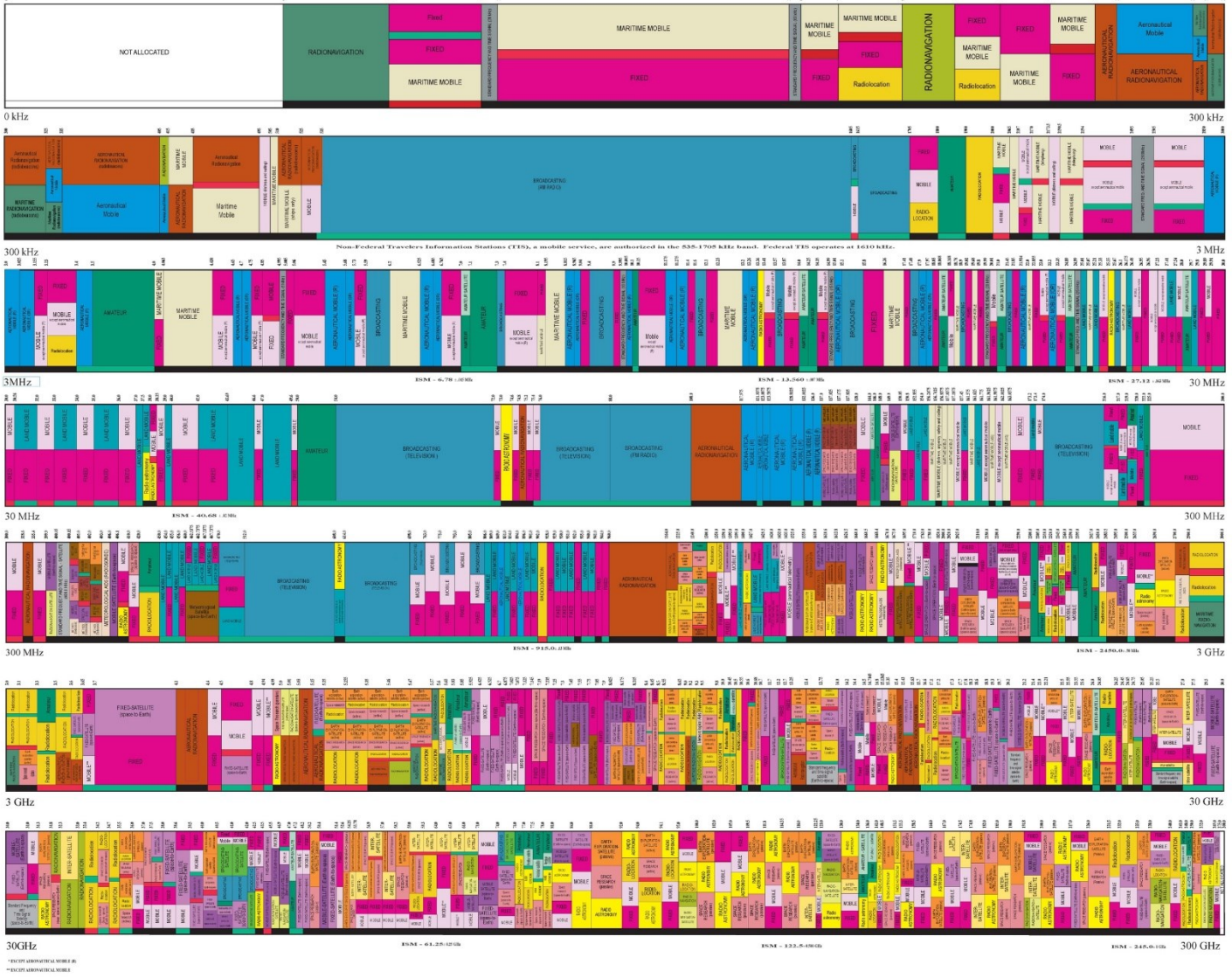
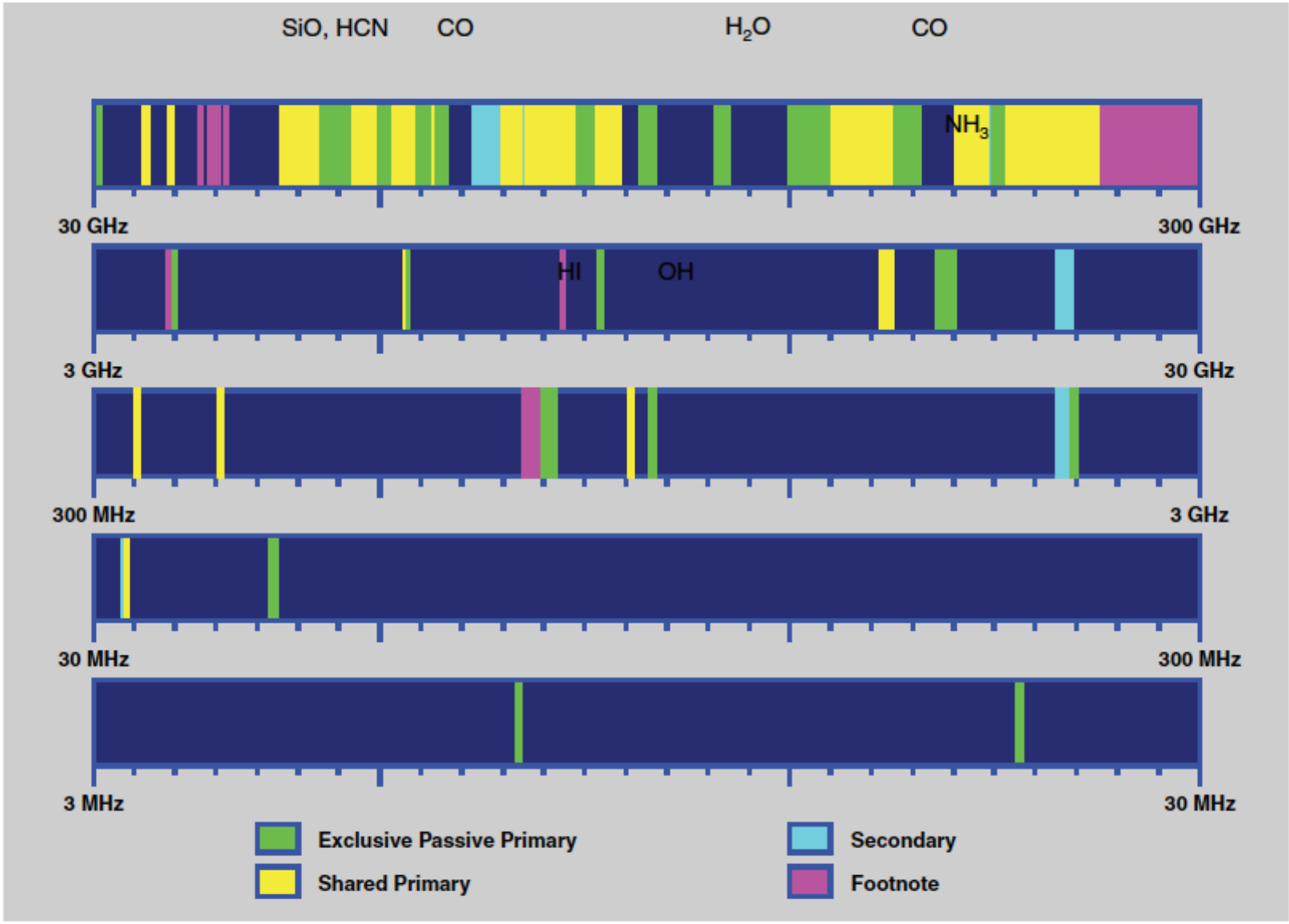


Image Credit: www.ntia.doc.gov



Radio Astronomy Frequency Allocations in the United States

Frequency Usage Takeaways

- **Protected frequency bands include most important identified spectral lines for studying the local universe (e.g. HI, CO, OH masers), but doppler-shifted lines from sources further away in the Universe fall into non-protected bands. Frequencies used for observation are often non-interchangeable, and much observation is done opportunistically.**

Epoch of Reionization

HI: 21 cm -> 1.5 m

Freq ~ 1420 MHz -> 200 MHz

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

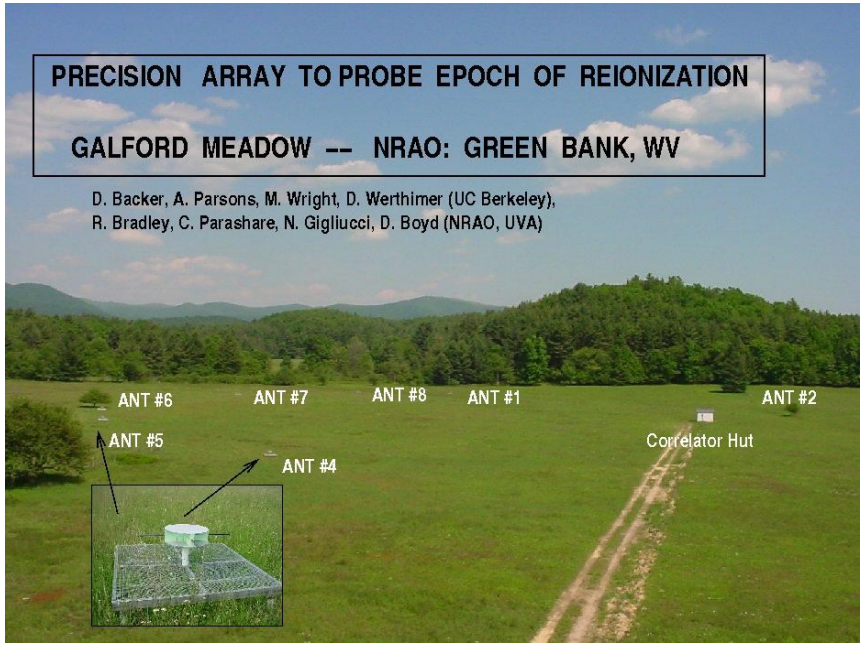


Image Credit: w.astro.berkeley.edu

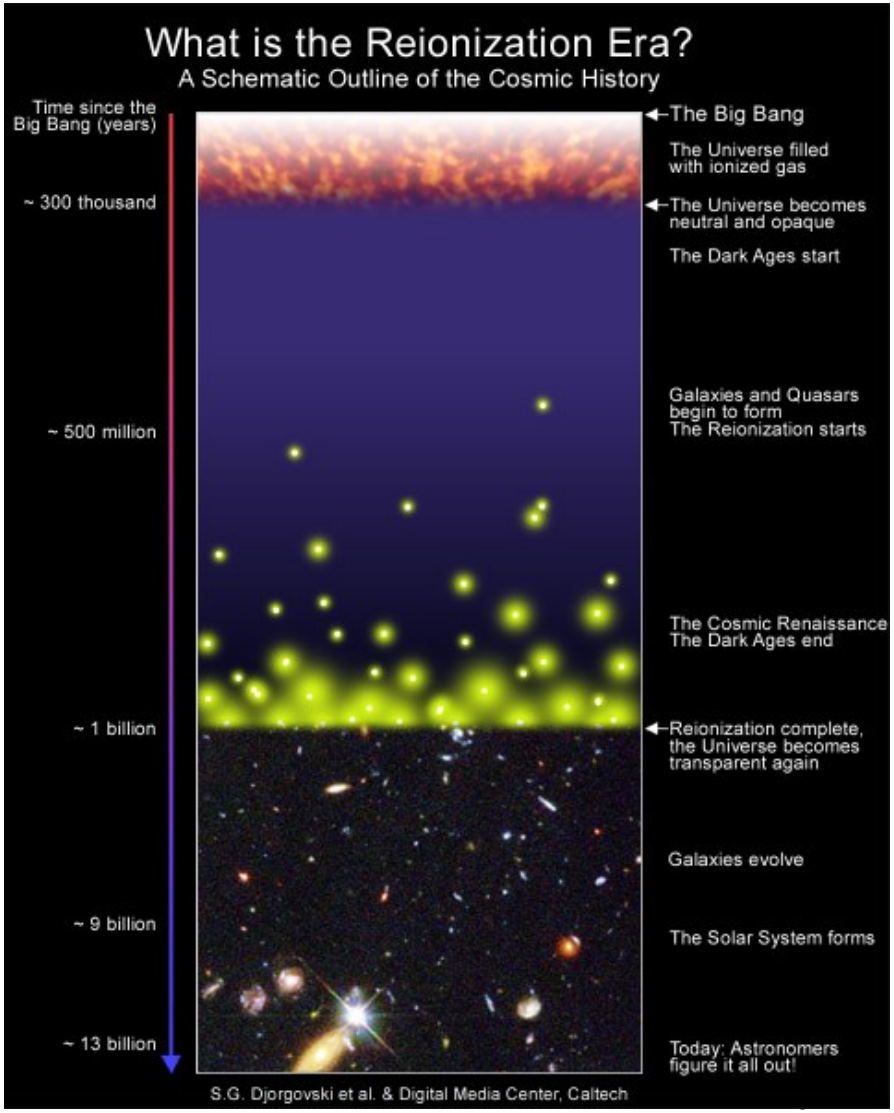


Image Credit: Djorgovski et al. (Caltech); www.haystack.mit.edu

AST Frequency Usage Takeaways

- **Protected frequency bands include most important identified spectral lines for studying the local universe (e.g. HI, CO, OH masers), but doppler-shifted lines from sources further away in the Universe fall into non-protected bands. Frequencies used for observation are often non-interchangeable, and much observation is done opportunistically.**

- **It is imperative that the increasing demands for spectrum take into consideration the challenges to scientific progress and NSF appreciates efforts to coordinate and to limit out-of-band emissions; Astronomy observations also include continuum emission (thermal, non-thermal).**

AST Frequency Usage Takeaways

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.**

AST Frequency Usage Takeaways

Image credit: NASA

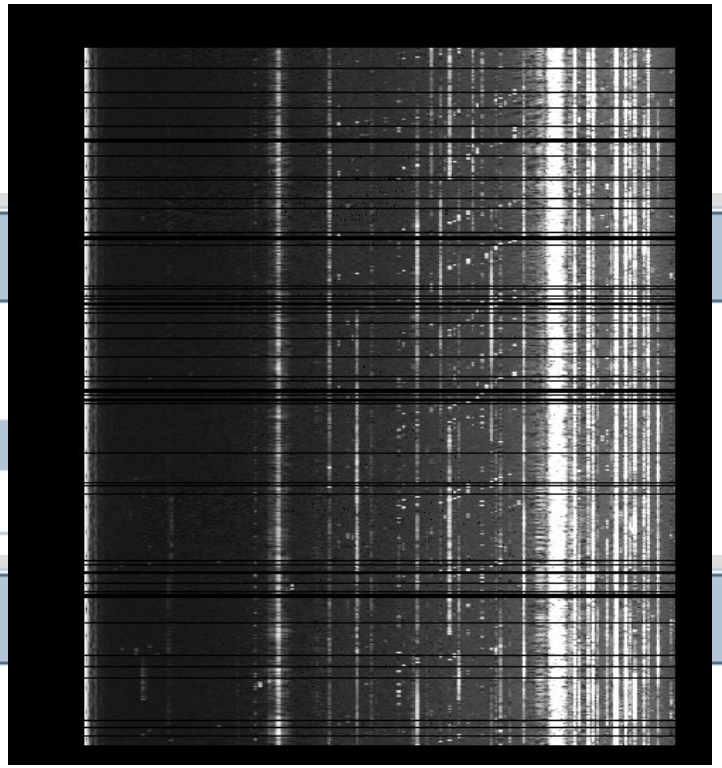
- **<u>Space observations are not "safe"</u>… for example JWST currently plans to use a Ka-band downlink (X band is saturated, not enough throughput in S-band downlinks)**

Table 1: Overall EVLA Performance Goals			
Parameter	VLA	EVLA	Factor
Continuum Sensitivity (1-σ, 9 hr)	10 μJy	1 μJy	10
Maximum BW in each polarization	0.1 GHz	8 GHz	80
Log (Frequency Coverage over 1–50 GHz)	22%	100%	5

Table and Image Credit: NRAO

What is coming…

- Constellations of thousands of satellites (20-50 GHz regime) such that from any location you would always "see" at least one, preferably (in mind of satellite providers) up to 3 or 4 satellites
- Mobile telecommunications
- High Altitude Platform Systems



RFI at K-Band (18-26.5 GHz)

by Emmanuel Momjian — last modified Jul 07, 2011

Frequency (MHz)	Description	Origin	Classification
17800-20200	Satellite downlink	Clarke Belt	continuous

RFI at Ka-Band (26.5-40 GHz)

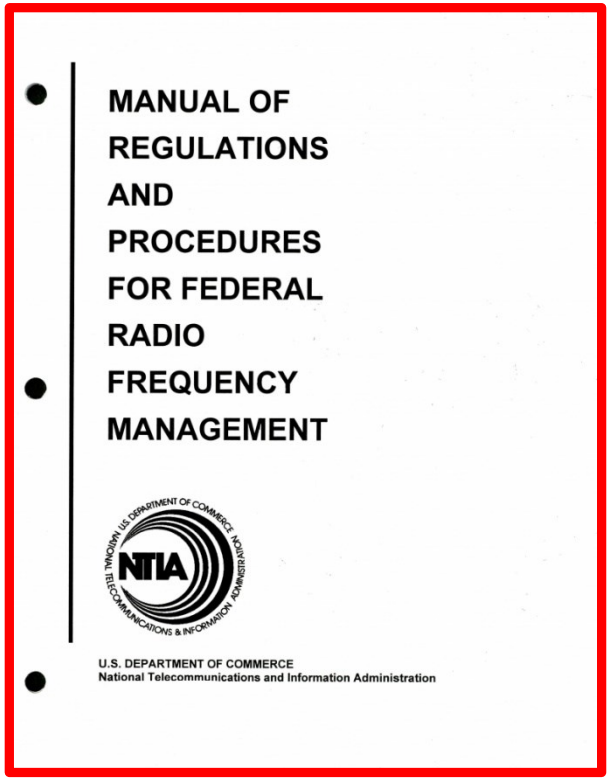
by Emmanuel Momjian — last modified Mar 15, 2013 by Heidi Medlin

Frequency (MHz)	Description	Origin	Classification	Spectrum
29500-30000	local Wildblue VSAT	Local residences	Intermittent	
34875	Internal (June 2 to Oct. 8, 2010)	Antenna EA10	Continuous	plot
36286	Internal (June 2 to Oct. 8, 2010)	Antenna EA10	Continuous	plot

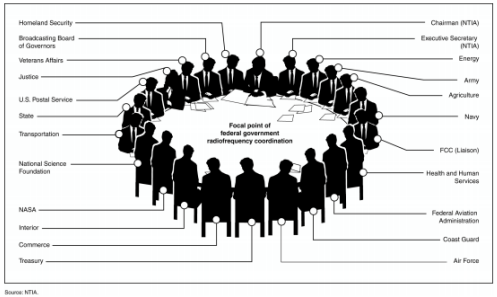
https://science.nrao.edu/facilities/vla/observing/RFI

Allocations and Coordination

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



NSF ESM Unit Activities



Source: NTIA.

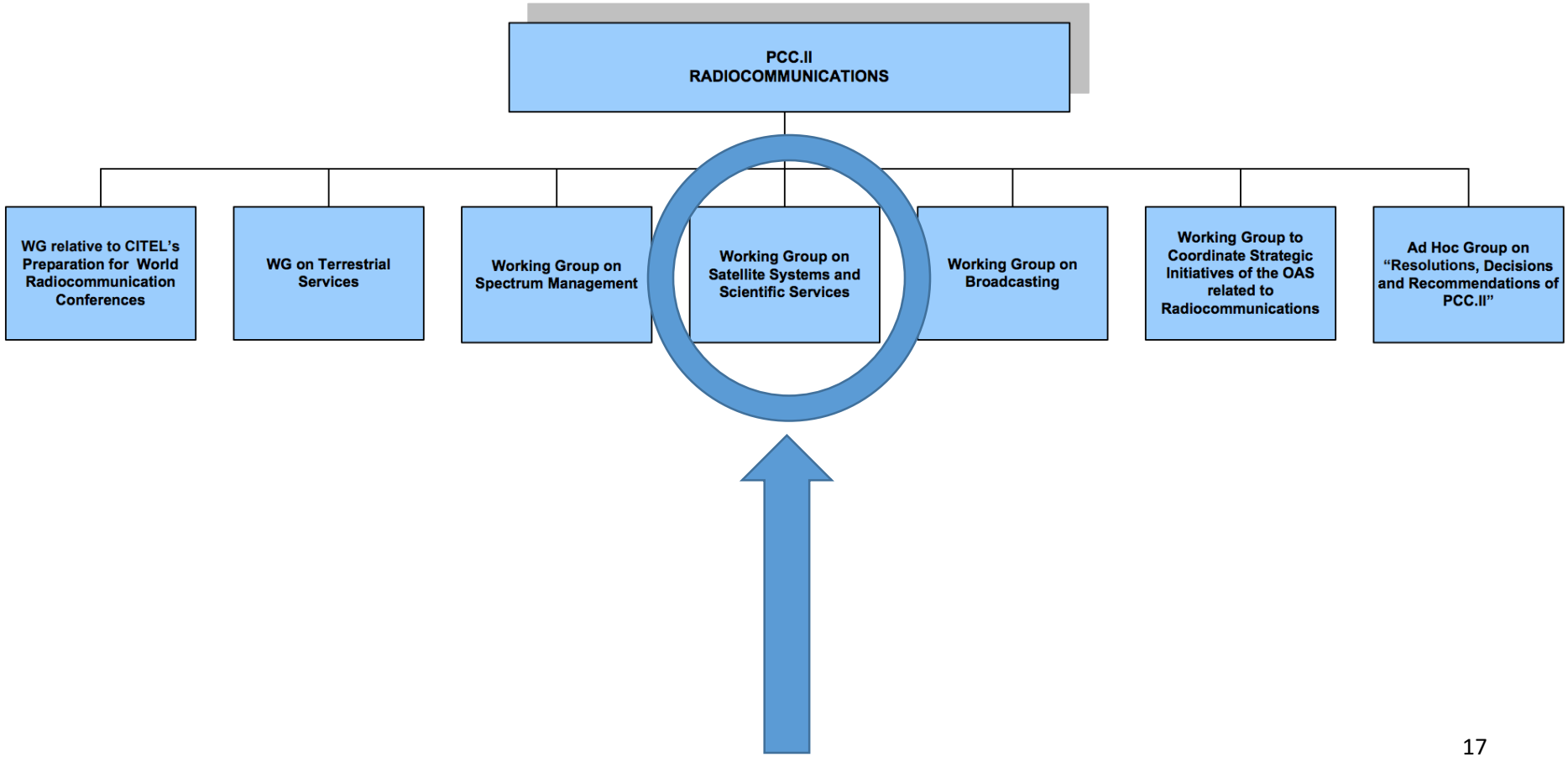
- Represent NSF as a Federal Agency to the National Telecommunications and Information Administration
  - 10 subcommittees including
    - IRAC
    - FAS (NRQZ coordination)

OAS | CITEL

- 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, manage spectrum related grants portfolio (CORF, Enhancing Access to the Radio Spectrum Solicitation; EARS)

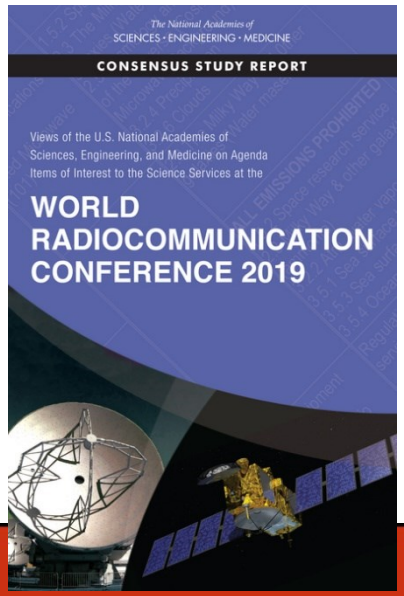
- Coordinate with other US Agencies, <u>could especially strengthen collaboration with DOE</u>

Federal Communications Commission

- Interface with commercial interests to advocate for their taking “practicable” steps to not cause interference to passive services

World Radiocommunication Conference

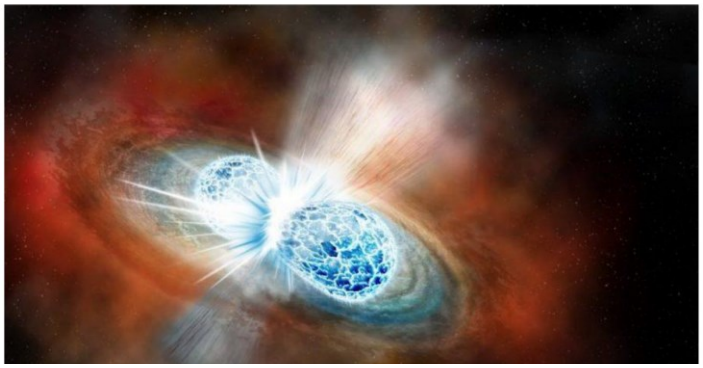
- Every Four years; where International Regulations are formulated; Treaty
- Issues of Concern for WRC19 include
  - Ka band (an important downlink for the JWST)
  - >275 GHz (including Radio Astronomy Protections)
  - High Altitude Platform Systems
  - NGSO/GSO increased allocations
  - Increased allocations for 5G worldwide above 20 GHz



2018 AAAC report

Report of the Astronomy and Astrophysics Advisory Committee

March 15, 2018



Finding: 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.

Recommendation: 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: 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.

Summary

- **Keep protected allocations as RFI-free as possible**
  - *Emissions may be prohibited at certain frequencies, out-of-band emissions can still be problematic*

- **Utilize technology developments and advancements to increase spectrum availability, esp. in strategic geographic locations**
  - *Research in RFI excision techniques and receiver technology*
  - *"National Radio Dynamic Zone" for 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)*

- **Coordination – internal at NSF and external stakeholders**
  - *Spectrum sharing*
  - *Costs must be considered; lacking resources*

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

Suggestions

- Continue and increase collaboration with other government agencies and coordination with NASA and DOE, but also NOAA and NTIA (esp. ITS Boulder lab for R&D)

- Increase collaborative efforts within NSF – noting that some of the R&D necessary for protecting astronomy may come from research from ENG or CISE, the Big Idea on Harnessing the Data Revolution (RFI monitoring and dynamic sharing can be a big data problem)

- Increased funding is necessary if facilities will tackle the RFI challenges; noting Presidential Memo and leadership in Spectrum R&D

- Increase geographic protections for the NRQZ from airborne emitters and create new National Radio Dynamic Zones to provide extra geographic protections for RAS and NASA Deep Space Network/TDRS stations

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 will includes representation from

- Mathematical and Physical Sciences
- Geosciences
- Computer and Information Science and Engineering
- Engineering
- Biological Sciences
- Office of the General Counsel
- Office of International Science and Engineering

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Questions?

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Thank you