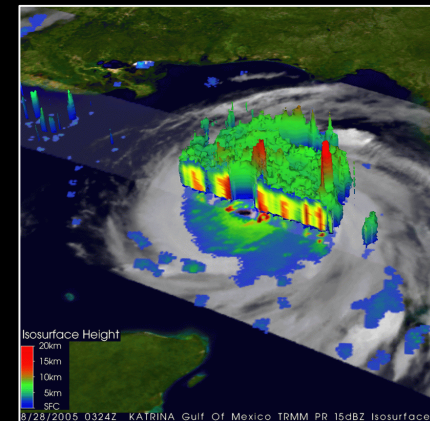


# Committee on Radio Frequencies Recent Activities

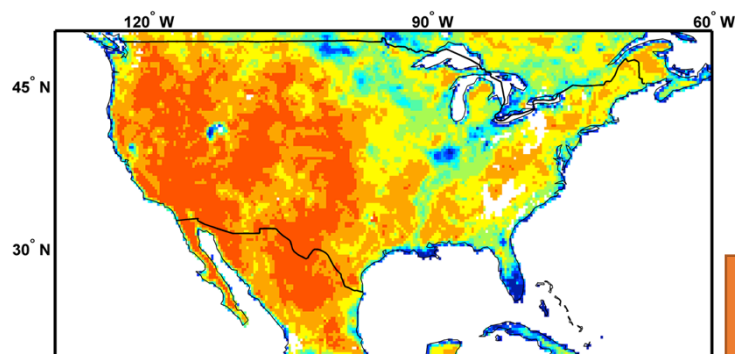
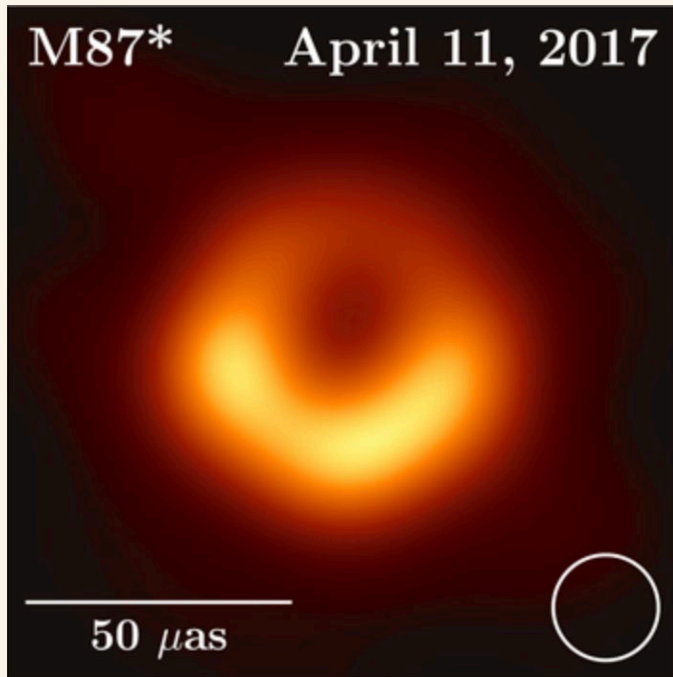
Joint meeting of the Board on Physics and Astronomy and Space  
Studies Board

November 17, 2020

Nathaniel Livesey, Chair of CORF  
Scott Paine, Vice Chair of CORF



## Scientific Use of the Radio Spectrum



- Radio frequencies have played a vital role in scientific discovery, as witnessed by Nobel Prizes awarded to Radio Astronomers, and to the IPCC, whose efforts were informed by passive microwave observations
- “Radio Astronomy Service” (RAS): origins and evolution of the Universe; chemistry and formation of stars and solar systems; matter in extreme environments; gravitational radiation; solar activity
- “Earth Exploration Satellite Service” (EESS): a critical tool for predicting weather and investigating climate change. Satellites provide data on issues including food, transportation, energy, and national security
- Together, these activities represents billions of dollars in federal investment in numerous satellites and radio observatories – each of which are national assets

Upper: EHT image of M87 black hole at 230 GHz.  
Lower: Soil moisture (1–10 July 2013) at 1.41 GHz.

## Spectrum Management and Policy

- The radio spectrum is shared between commercial, governmental, and scientific users (the latter both “passive” and “active”)
- Radio regulations are codified both internationally (by the International Telecommunication Union, ITU) and domestically (by the Federal Communications Commission, FCC, and the National Telecommunications and Information Administration, NTIA)
  - Much of the ITU work is focused on “World Radiocommunication Conferences” WRCs, held roughly every four years (next is WRC-23)
- There is an ever-increasing commercial demand for and usage of radio frequencies, driven in part by recent advances in telecommunications technologies
  - The 2021 FCC auction of 3.70–3.98 GHz raised \$81.1 billion!
  - (By contrast, NOAA estimates \$3 trillion of the US economy is weather-sensitive, and \$35 billion in annual economic benefits from weather forecasting\*)
- This increases the need for spectrum sharing and coordination
  - The passive use of the spectrum is under an ever-growing threat
  - It is difficult to reverse regulations and recover spectrum when passive services are negatively impacted

\* <https://www.noaa.gov/weather> and <https://www.performance.noaa.gov/economics/>

# UNITED STATES FREQUENCY ALLOCATIONS

## THE RADIO SPECTRUM

**RADIO SERVICES COLOR LEGEND**

AERONAUTICAL MOBILE	INTERSATELLITE	RADIO ASTRONOMY
AERONAUTICAL MOBILE SATELLITE	LAND MOBILE	RADIO DETERMINATION SATELLITE
AERONAUTICAL RADIOLOCATION	LAND MOBILE SATELLITE	RADIOLOCATION
AMATEUR	MARITIME MOBILE	RADIOLOCATION SATELLITE
AMATEUR SATELLITE	MARITIME MOBILE SATELLITE	RADIOSOUNDING
BROADCASTING	MARITIME RADIOLOCATION	RADIOSOUNDING 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**

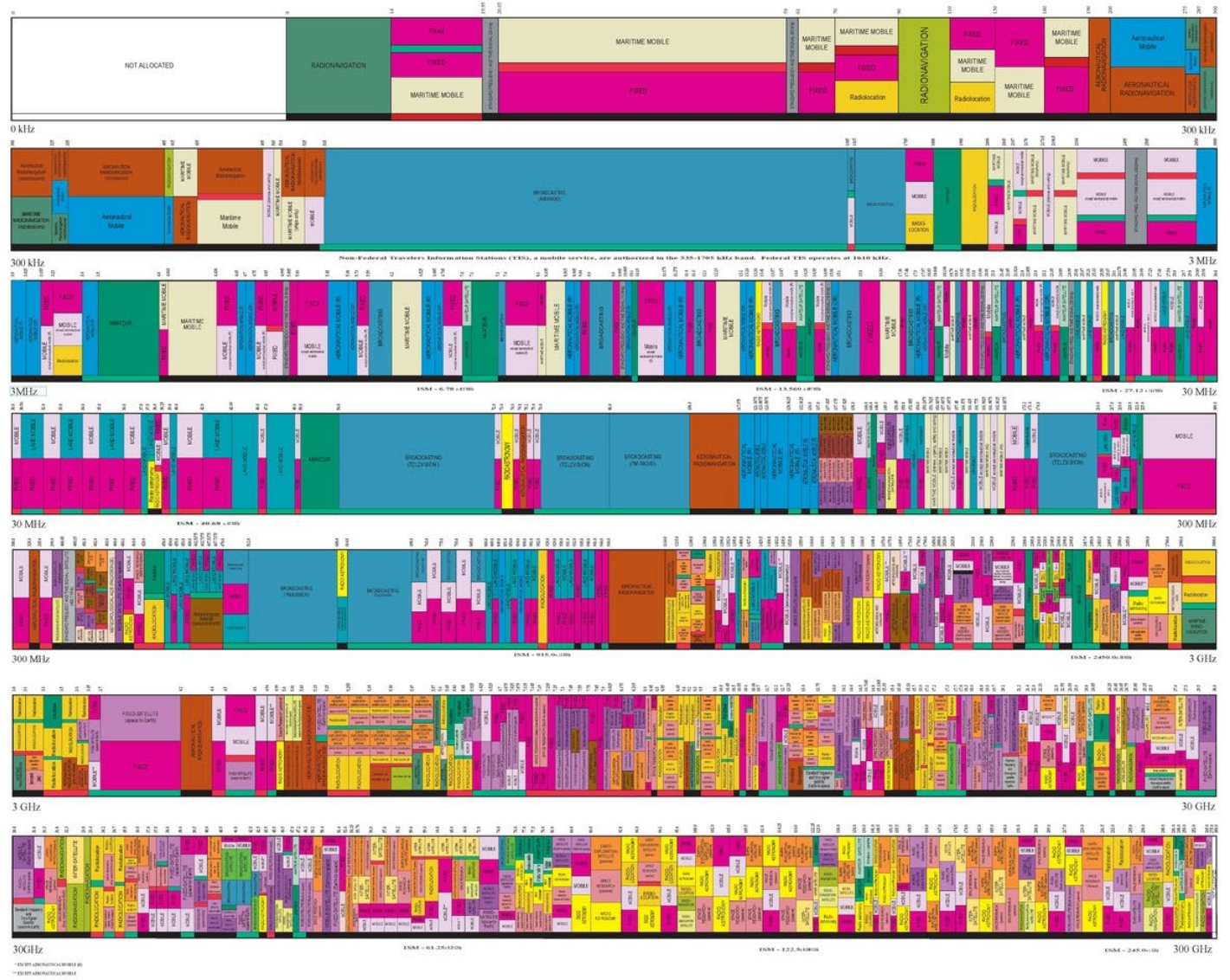
FEDERAL INCLUSIVE	FEDERAL/NONFEDERAL SHARED
NONFEDERAL INCLUSIVE	

**ALLOCATION USAGE DESIGNATION**

SERVICE	EXAMPLE	DESCRIPTION
Primary	Fixed	Capital Letter
Secondary	Mobile	1st Capital with lower case letter

The chart is a public information product of the Federal Communications Commission (FCC) and the NTIA. It is not a substitute for the actual rules and regulations of the FCC and the NTIA. For more information, visit [www.fcc.gov](http://www.fcc.gov) or [www.ntia.gov](http://www.ntia.gov).

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



PLEASE NOTE: THE ALLOCATIONS OF THE SPECTRUM SHOWN IN THIS CHART ARE SUBJECT TO CHANGE WITHOUT NOTICE TO THE USER OF THE SPECTRUM AS DETERMINED BY THE FCC.

## Roles of CORF

- CORF represents interests of U.S. researchers using radio frequencies: both radio astronomers and Earth scientists
- CORF coordinates the views of U.S. scientists and acts as a channel to represent their interests
- We recommend requirements and limits necessary to protect scientific use of the radio spectrum from interference
  - This is largely through filing comments in public proceedings of Federal Communications Commission (FCC)
  - Comments are drafted by CORF and its legal counsel, then reviewed per standard NAS protocols and approved and signed by the NAS President
- CORF also performs specific studies, maintains a Handbook and conducts various forms of outreach to scientists and industry
- CORF is funded by NSF and NASA



## Membership of CORF

### Committee Members

Nathaniel Livesey, JPL (Chair) – EESS

Scott Paine, CfA (Vice Chair) – RAS

Nancy Baker, NRL – EESS

Laura Chomiuk, Michigan State – RAS

Dara Entekhabi, MIT – EESS

Phil Erickson, Haystack Observatory – EESS

Kelsey Johnson, U Virginia – RAS

Christopher Kidd, GSFC/UMD – EESS

Karen Masters, Haverford – RAS

Mahta Moghaddam, USC – EESS

Frank Schinzel, NRAO – RAS

### Consultants

Darrel Emerson, Ariz., retd. – RAS

Tomas Gergely, NSF, retd. – RAS

Paul Feldman, Esq., Fletcher, Heald and  
Hildreth – Legal counsel

### Staff

Colleen Hartman, Director, Space, Physics,  
and Aeronautics

Greg Mack, Senior Program Officer

Neeraj Gorkhaly, Linda Walker

## Recent CORF FCC Filings

- Four filings in 2020
  - TV Channel 37: Impacts to RAS – May
  - 6 GHz: Unlicensed Devices – June
  - 70/80/90 GHz: Airborne Internet NPRM – August
  - 4.9 GHz: 7<sup>th</sup> FNPRM on public safety band use – November
- Two filings and two in progress for 2021 thus far
  - 23.6 GHz: Implications of international Mobile (i.e., 5G) – June
  - 57 GHz: New approvals for short-range devices – September
  - 4.9 GHz: 8<sup>th</sup> FNPRM on public safety use – Signed today
  - 70/80/90 GHz: Airborne Internet revisit – November

## 70/80/90 GHz for Commercial Aircraft

- FCC solicited comments on use of 70/80/90 GHz bands to provide internet to commercial aircraft via – ground-to-air, air-to-ground, and air-to-air links
- CORF opposed use of the 80 GHz band (81–86 GHz) for downlinks and for aircraft-to-aircraft transmission
- CORF noted the need for guard bands to protect EESS from Out of Band Emissions (OOBE) at 86–92 GHz (an “All Emissions Prohibited” band).
- CORF also recommended updating OOBE limits to match those in ITU-R Res. 750.
- CORF further recommended an active tracking system be employed to null emissions in direction of orbiting EESS sensors
- A subsequent FCC Public Notice solicited further inputs, particularly related to use of High Altitude Platform Stations (HAPS – stratospheric balloons/airships)
- We plan a brief note stating our same concerns apply equally to these other platforms



Concept for dynamic ground-to-air,  
air-to-ground, air-to-air internet links

## 23.6 GHz for 5G Mobile Phones

- In 2017 the FCC auctioned the band from 24.25–24.45 GHz for 5G use
- The associated OOB limits were inconsistent with protecting 23.6–24.0 GHz EESS (column and near-surface water vapor) and RAS ( $\text{NH}_3$ ) observations
- The FCC urged international confirmation of such limits, but WRC-19 adopted stricter limits (though not as strict as those advocated by, for example, WMO)
- In 2021, the FCC requested comments on US implementation of WRC-19 limits
- CORF responded with details on the importance of the 23.6–24.0 GHz band to Earth science and radio astronomy, urging that the WRC-19 limits be implemented as expediently as possible while arguing that they may still ultimately prove insufficient in some circumstances
- In an unusual move, the NTIA (that manages federal government spectrum usage) submitted a response on behalf of NASA and NOAA urging speedy implementation of the limits, with strong procedures for addressing violations

## Protection of EESS From 57–64 GHz Active Sensing

- The 57–59.3 GHz (Oxygen) band is essential for temperature sounding
- However, atmospheric opacity is sufficient to shield spaceborne observations from ground-based emissions
- There has been increased use of this band for short-range active devices (unattended infants in cars, lawn mowers, building surveys)
- In 2021, the FCC released a notice outlining plans to loosen current limits for such devices (citing prior approvals on a case-by-case basis)
- The FCC noted no plans for increased airborne usage at this time (some limited airborne use has previously been approved)
- CORF filed comments stressing the importance of these bands and their extreme sensitivity to airborne emissions
- CORF further noted shortcomings in prior analyses from industry that underestimated absorption from aircraft windows
- Once again, NASA/NOAA/NTIA submitted their own filing urging caution in allowing new emitters in this band (both airborne and ground-based)

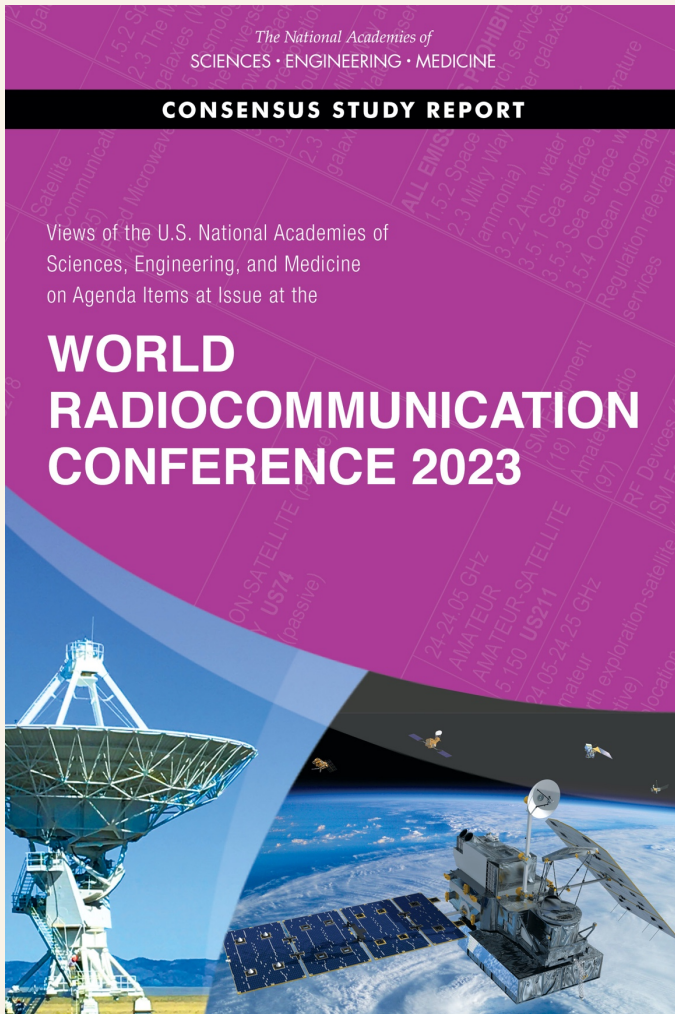
## CORF at the International Level

- ITU-R Study Groups (and Working Parties) are well into the study cycle for WRC-23
- SG 1: Spectrum Management
  - WP 1A: Spectrum Engineering Techniques
- SG 3: Radiowave Propagation
  - Multiple working groups, but usually meeting in plenary
- SG 4: Satellite Services
- SG 5: Terrestrial Services
- SG 6: Broadcasting Services
- SG 7: Science Services
  - WP 7C: Earth Remote Sensing Systems
  - WP 7D: Radio Astronomy

## CORF at the International Level (cont.)

- WP 7C – Earth Remote Sensing
  - CORF members are participating in US WP 7C
  - Numerous NASA/NOAA representatives on US Delegation
- WP 7D – Radio Astronomy
  - CORF members are participating in US WP 7D
  - CORF has sent one of its consultants to ITU WP 7D for many decades; more recently, sending its former Chair as well
  - In this virtual world, more people are participating in the international meetings. This led to a disproportionate presence and influence of industry representation on the US WP 7D delegations during 2020
  - Recognizing this, Liese van Zee (prior CORF chair) urged more participation by RAS scientists. This has worked well (plan for in person meetings TBD)
    - Multiple US delegates (CORF members and others)
    - Valuable US-originated reports being developed (documentation of the EHT, low-frequency arrays, bolometers, and threats posed by harmonics)

# CORF Activities: WRC-23 Views Report



- Separate consensus committee
- Represents input from US scientists regarding agenda items at the World Radiocommunication Conference 2023 (WRC-23), and preliminary items for the WRC-27 agenda
- Decisions at the WRCs lead to international regulations under the ITU
- Multiple agenda items with potentially significant impact to RAS/EESS
  - NASA and NSF (and FCC) heavily involved
- More than 250 downloads from the National Academies Press since its June 2021 release
- Report briefed to NSF, NASA, and staffers from House Science Committee

## Follow up to WRC-23 Views Report

Letter from chair and ranking member  
of house science committee to OSTP.

5 November 2021

November 5, 2021

The Honorable Eric Lander  
Director, U.S. Office of Science and Technology Policy  
Science Advisor to the President  
1650 Pennsylvania Avenue NW  
Washington, DC 20502

Dear Director Lander,

As you know, scientific research across natural science disciplines, including astronomy, climate science, and other Earth and environmental sciences, all depend upon the radio-frequency spectrum for active and passive remote sensing and other methods of data collection. As demand for spectrum for mobile applications has increased drastically in recent years, spectrum-dependent scientific fields and operational functions such as weather forecasting are facing increasing threats to their spectrum equities, including bands coordinated domestically and internationally, due to harmful interference. Both privately- and federally-funded research and operational weather radioastronomy activities within the National Oceanic and Atmospheric Administration, due to the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF).<sup>1,2,3</sup>

Due to these concerns, we respectfully request that the National Academies of Sciences, Engineering, and Technology (PCAST) prepare a report on the access and quality for science and operations of the United States government and operations of the National Telecommunications and Information Administration (NTIA) spectrum.

*"...WRC23 will consider specific Agenda items which have potential impact on spectrum used for radio astronomy and remote sensing. The National Academies Committee on Radio frequencies (CORF) has already convened to assess each agenda item and consider their potential effects on current and future radio frequency science applications. CORF issued a report on those items in late September..."*

<sup>1</sup> <https://www.nationalacademies.org/~/media/Files/Reports/2021/08/21210801main.pdf>

<sup>2</sup> <https://www.nationalacademies.org/~/media/Files/Reports/2021/08/21210801main.pdf>

<sup>3</sup> <https://www.nationalacademies.org/~/media/Files/Reports/2021/08/21210801main.pdf>



This report is dedicated to the memory of Gail Skofronick-Jackson (1963–2021), whose deep dedication to advancing Earth science and mentoring current and future scientists and engineers serves as an inspiration to all.

## Views on WRC-23 Agenda Items

- 1.2 International Mobile Telecommunication (IMT, cell phones) at 3.3–3.4, 3.6–3.8, 6.425–7.125, and 10.0–10.5 GHz
- 1.4 High Altitude Platforms (HAPS) as IMT (cell phone) Base Stations (HIBS) below 2.7 GHz
- 1.5 Review 470–960 MHz in Region 1
- 1.8 Fixed Satellite Services (FSS) and unmanned aircraft (10–15 GHz, 19.7–20.2 GHz, 29.5–30 GHz)
- 1.9 Aeronautical mobile in HF bands (adjacent to RAS at 13.36–13.41 MHz)
- 1.10 Aeronautical mobile at 15.4–15.7 and 22–22.1 GHz
- 1.11 Maritime distress services (1610–1626.5 MHz and 2483.5–2500 MHz)
- 1.12 EESS (active) radar sounders at 45 MHz
- 1.13 Space Research Services at 14.8–15.35 GHz
- 1.14 EESS (passive) at 231.5–252 GHz
- 1.15 Geostationary Earth Stations in Motion (GSO-ESMIS) at 12.75–13.25 GHz

And more. See the next slide

## WRC-23 Agenda Items (cont.) and WRC-27 Items

- 1.16 nGSO-ESIMs at 17.7–18.6, 18.8–19.3, and 19.7–20.2 GHz, and others
- 1.17 Inter-satellite links at 18.1–18.6 GHz, 18.8–20.2 GHz, and others
- 1.19 Fixed Satellite Services (FSS, space-to-Earth) at 17.3–17.7 GHz in Region 2
- 9.1 Topic A: Space Weather
- 9.1 Topic B: Amateur Service at 1240–1300 MHz
- 9.1 Topic C: Mobile use (IMT, cell phones) in bands allocated to Fixed services
- 9.1 Topic D: Protection of EESS (passive) at 36–37 GHz

### WRC-27 Preliminary Agenda Items:

WRC-27 2.8 and 2.9 (1330–1350 MHz; 1610.6–1613.8 MHz; 1660–1670 MHz)

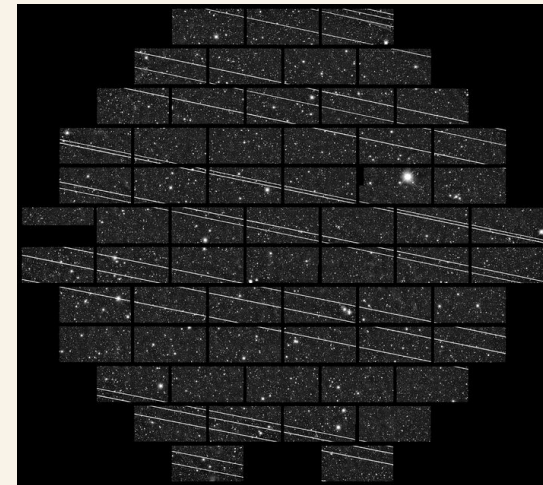
WRC-27 2.2 and 2.3 (37.5–51.4 GHz)

WRC-27 2.4, 2.5, and 2.7 (71–76 and 81–86 GHz)

WRC-27 2.1 (231.5–275 GHz; 275–700 GHz)

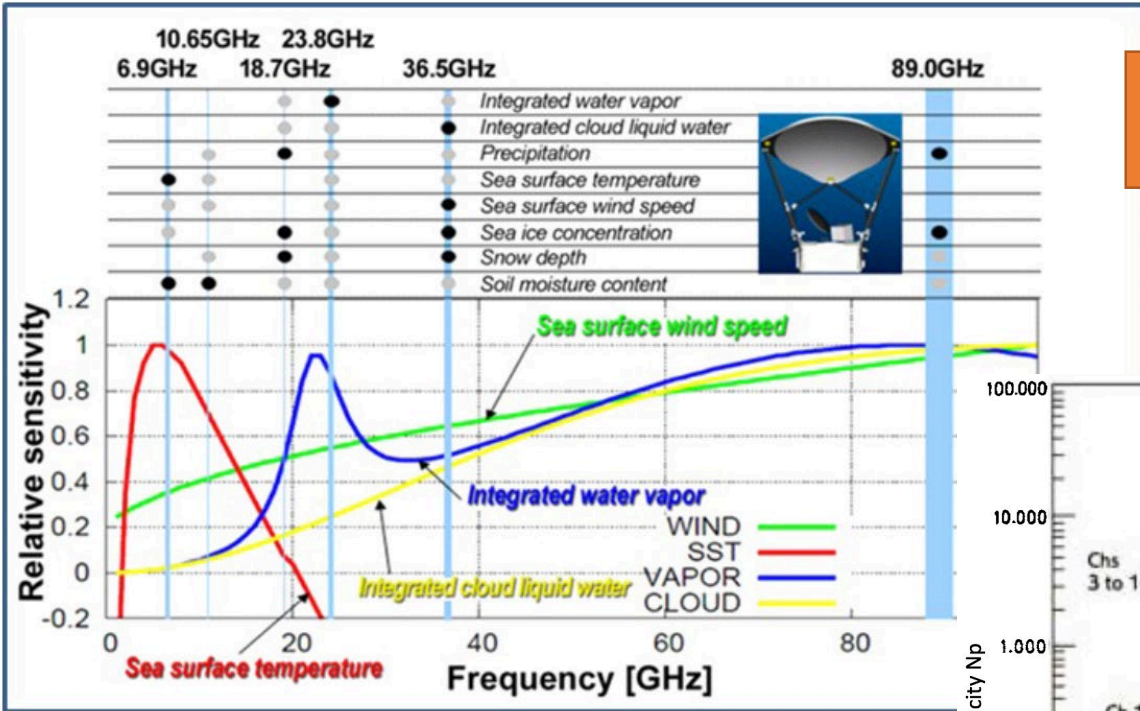
## Other “Hot Button” Issues

- Constellations with thousands of satellites
- National Radio Dynamic Zones
  - Dynamic spectrum sharing for the ngVLA?
- NSF Spectrum Innovation Initiative program
  - Recent selection of “Spectrum X” consortium includes participation by current and previous CORF members
- Spectrum Management
  - Next generation of leaders
- Threats to “all emissions prohibited” restrictions  $> 95$  GHz
  - We are resisting efforts from industry to undermine/revise the “All emissions prohibited” restrictions on passive bands in the region of the spectrum above 95 GHz
  - These efforts started within the US process, but have moved to the international arena (and the FCC are full-throated in their support)

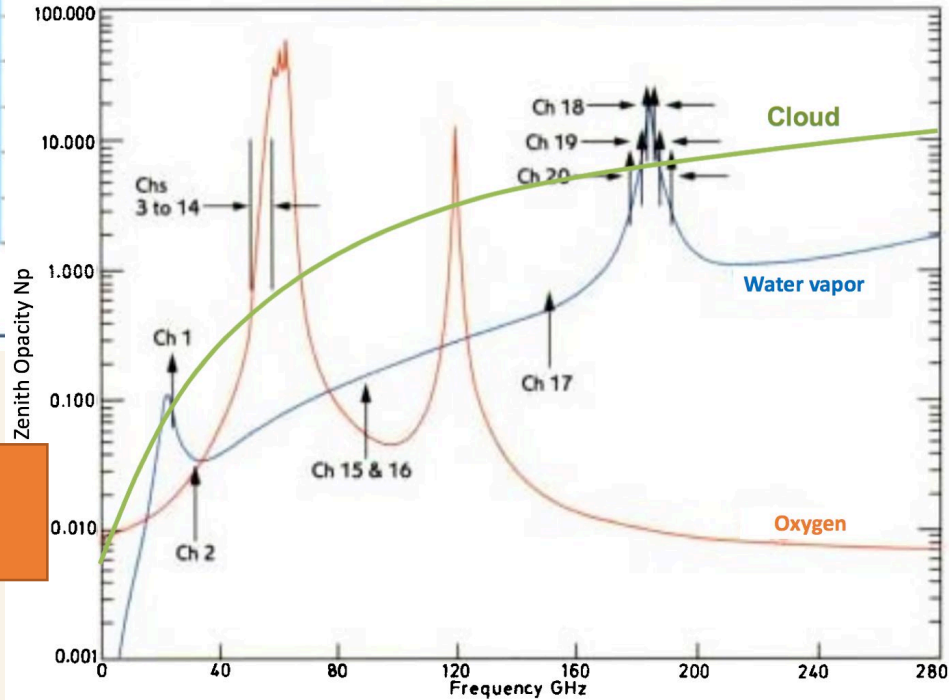


# EESS (passive) as a System

Advanced Scanning Radiometer 2 (AMSR2) onboard GCOM-W1



Advanced Microwave Sounding Unit (AMSU) on NOAA-15, NOAA-16, and NOAA-17.



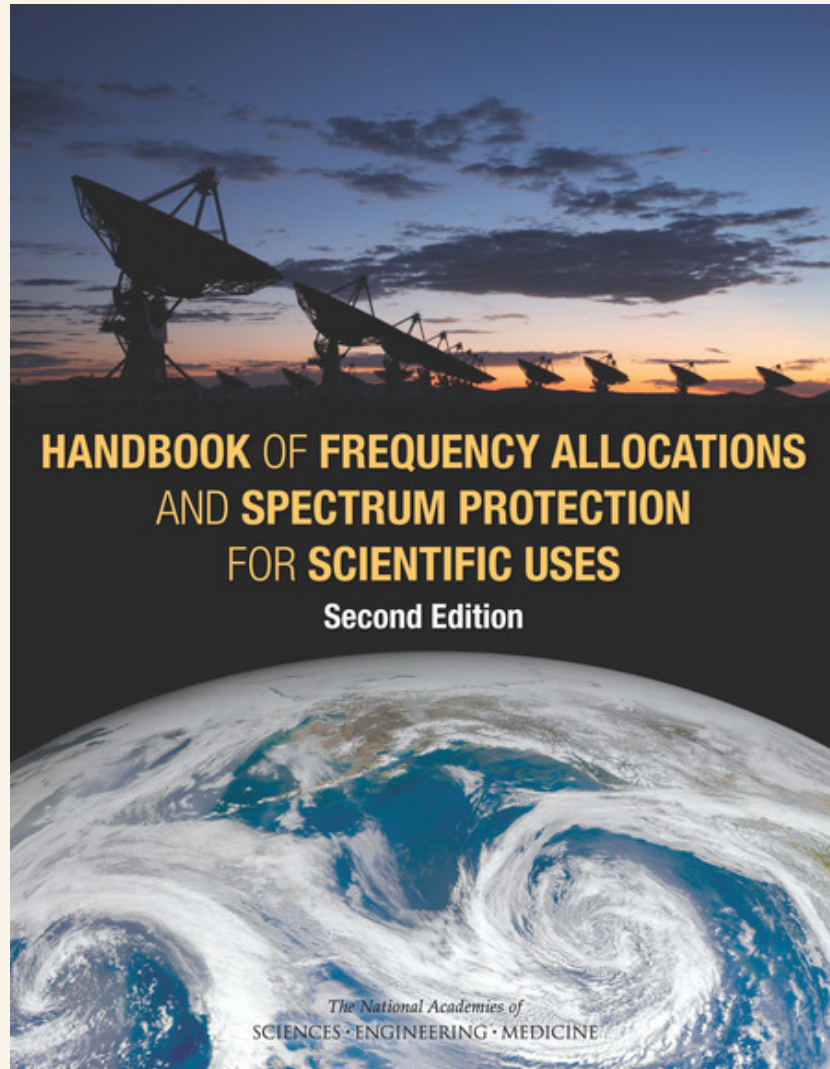
## CORF Activities: Meetings

- Spring meeting: May 2021 (Virtual)
  - Met with government stakeholders and representatives of national and international committees.
- Fall meeting: September/October 2021 (Virtual)
  - Invited talks on timely science within RAS and EESS
  - Discussions with NIST learning about their testing program
- Many teleconferences

## CORF Activities: Outreach

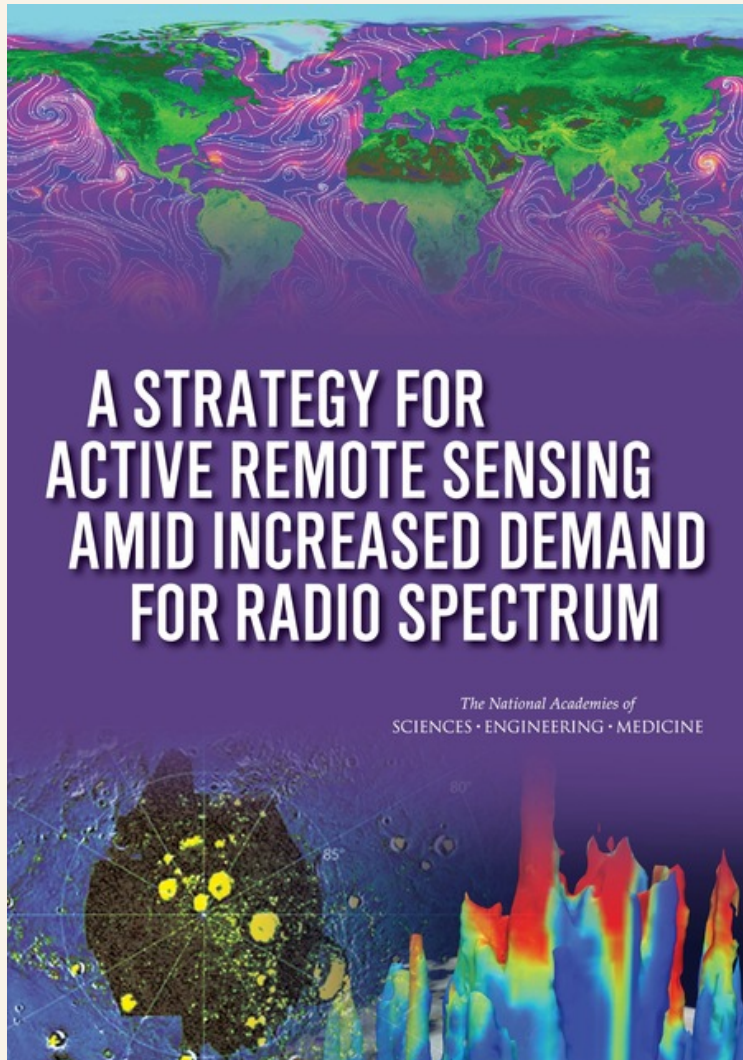
- Participation with other groups around the world.
  - ITU-SG7; Working Parties – 7C (EESS), 7D (RAS), WP 1A, SG 3
  - IUCAF, CRAF, etc. – primarily RAS
  - IEEE-GRSS – Frequency Allocation Technical Committee
  - AMS – Radio Frequency Allocations Committee
- Presentations at professional meetings.
  - Panel discussion as part of NSF Spectrum Innovation Initiative
  - Presentation at meeting of the Wireless Innovation Forum (Nathaniel)
- CORF-related
  - Follow up on briefing to house science committee staffers (Nathaniel)

## CORF Activities: Publications



- Major rewrite of previous edition.
- Comprehensive resource for scientists, engineers, and spectrum managers. Detailed information including a description of regulatory bodies, a discussion of the relevant scientific background, a list of science spectrum allocations in the United States, and an analysis of spectrum protection issues for RAS and EESS.
- More than 4700 downloads from the National Academies Press!!

## CORF Activities: Publications (cont.)



- Addresses management issues between active services' demand for greater spectrum use and passive users' need for quiet spectrum.
- Recommendations provide a pathway for putting in place the regulatory mechanisms and associated supporting research activities necessary to meet the demands of both users.
- Nearly 3200 downloads!

## Future CORF Activities

- Engage more frequently with FCC Commissioners and Staff
- Continue responding to FCC actions
- Educate Congressional staff regarding scientific use of the radio spectrum
- Engage in international spectrum management, particularly in regards to US facilities located abroad
- Continue to engage international scientists
  - Guest speakers at CORF meetings



## Want to Learn More? We Have a Brochure!

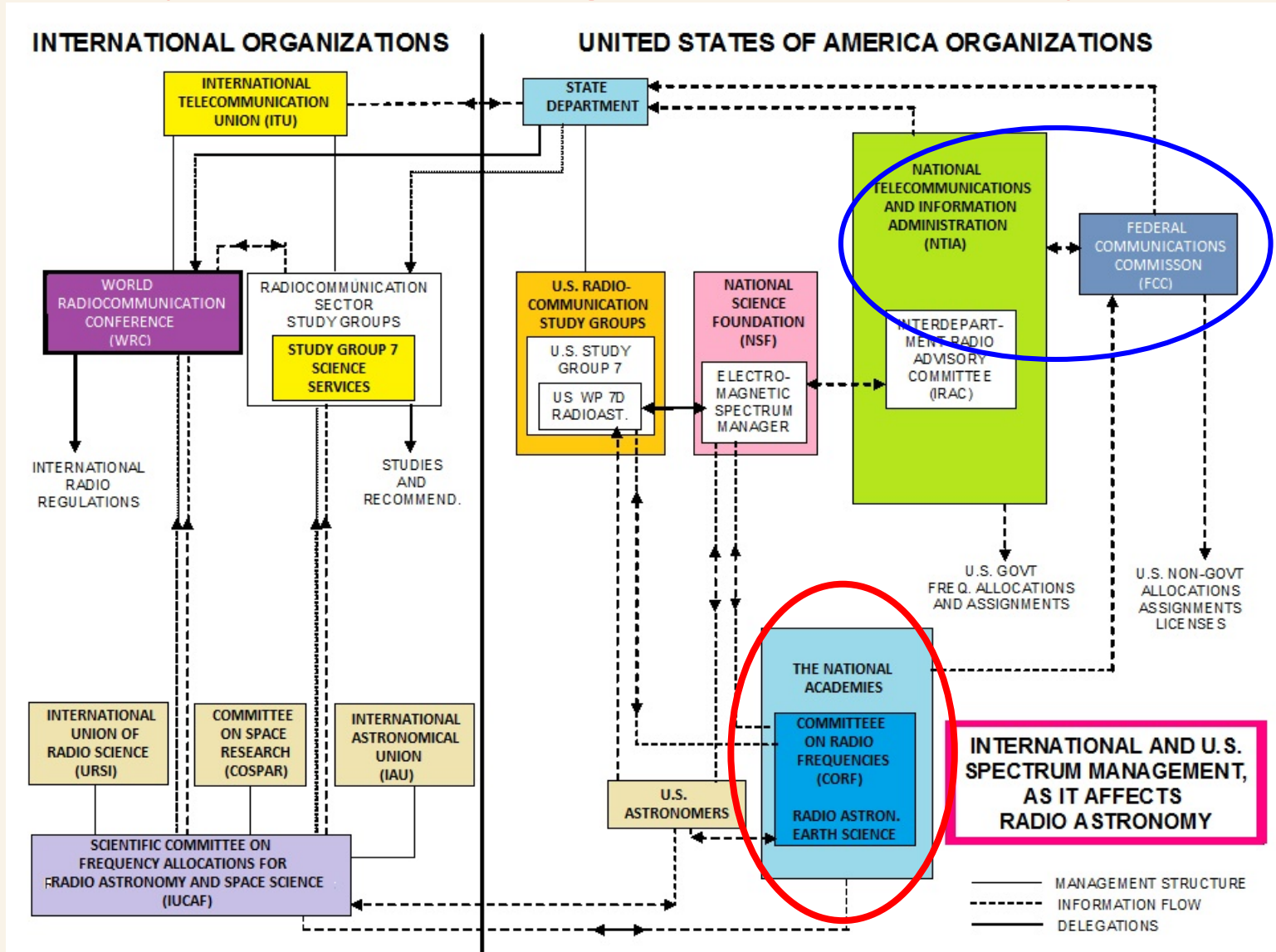
### COMMITTEE ON RADIO FREQUENCIES (CORF)

Summarizes key aspects of spectrum management for the protection of RAS and EESS (passive)

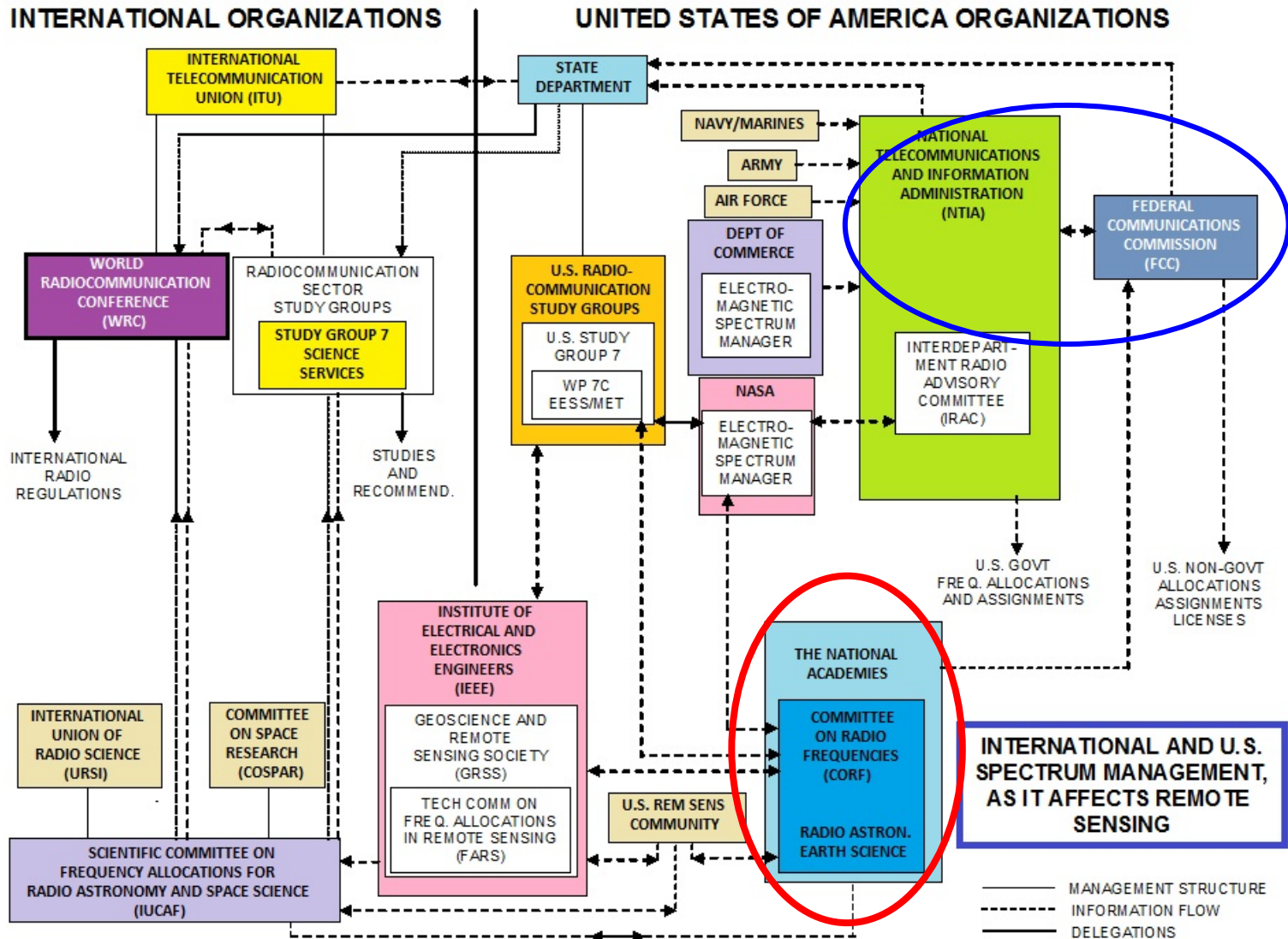


Backup material

# Spectrum Management and Policy



# Spectrum Management and Policy



## CORF Priorities

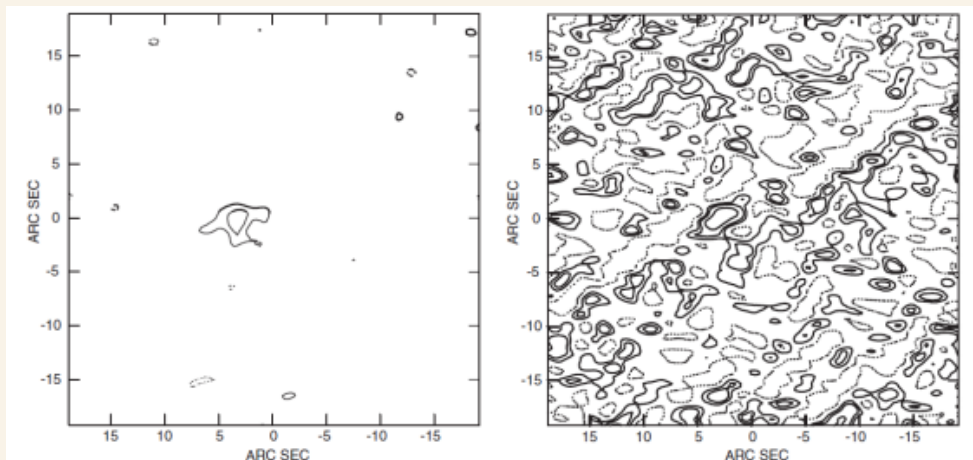
- Protect RR 5.340 and US246 bands from direct transmission (“all emissions prohibited”)
- Protect RR 5.149 and US342 bands from direct transmission (“all practicable steps”)
- Compatibility of sharing\* for co-primary and secondary allocations
- Protect above from out-of-band emission (OOBE) and spurious emission due to adjacent allocations or harmonics

\* Sharing is often ok for RAS with Fixed Services and FSS (Earth-to-space) with geographic separation; sharing is often ok for EESS with FSS (space-to-Earth) and/or temporal separation. Airborne services are problematic for both EESS and RAS.

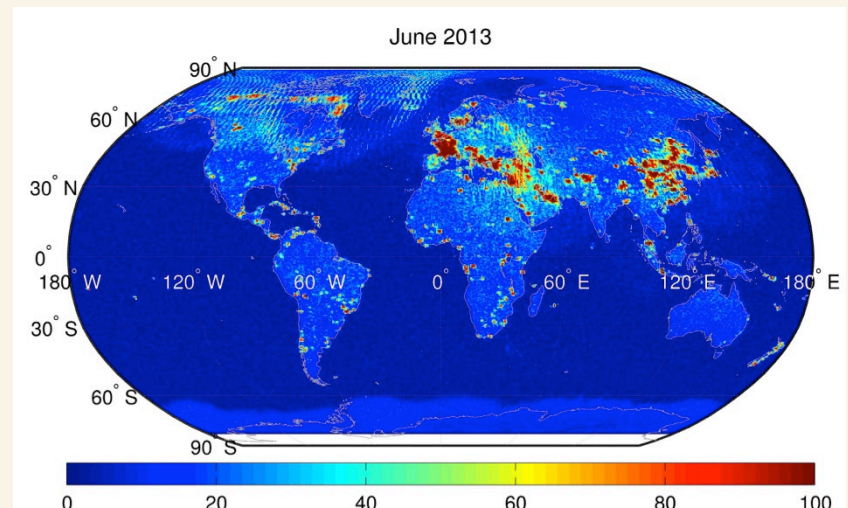
## High Sensitivity of Receivers and Interference

- Radio telescopes have large antennas and low noise receivers to detect faint astronomical signals – 1% of one-billionth of one-billionth of a watt ( $10^{-20}$  W) !!
- Both RAS and EESS observations are vulnerable to in-band emissions and out-of-band and spurious emissions from users of neighboring bands, all contributing to Radio Frequency Interference (RFI).

Out of Band Emissions (OOBE) from Iridium Satellite

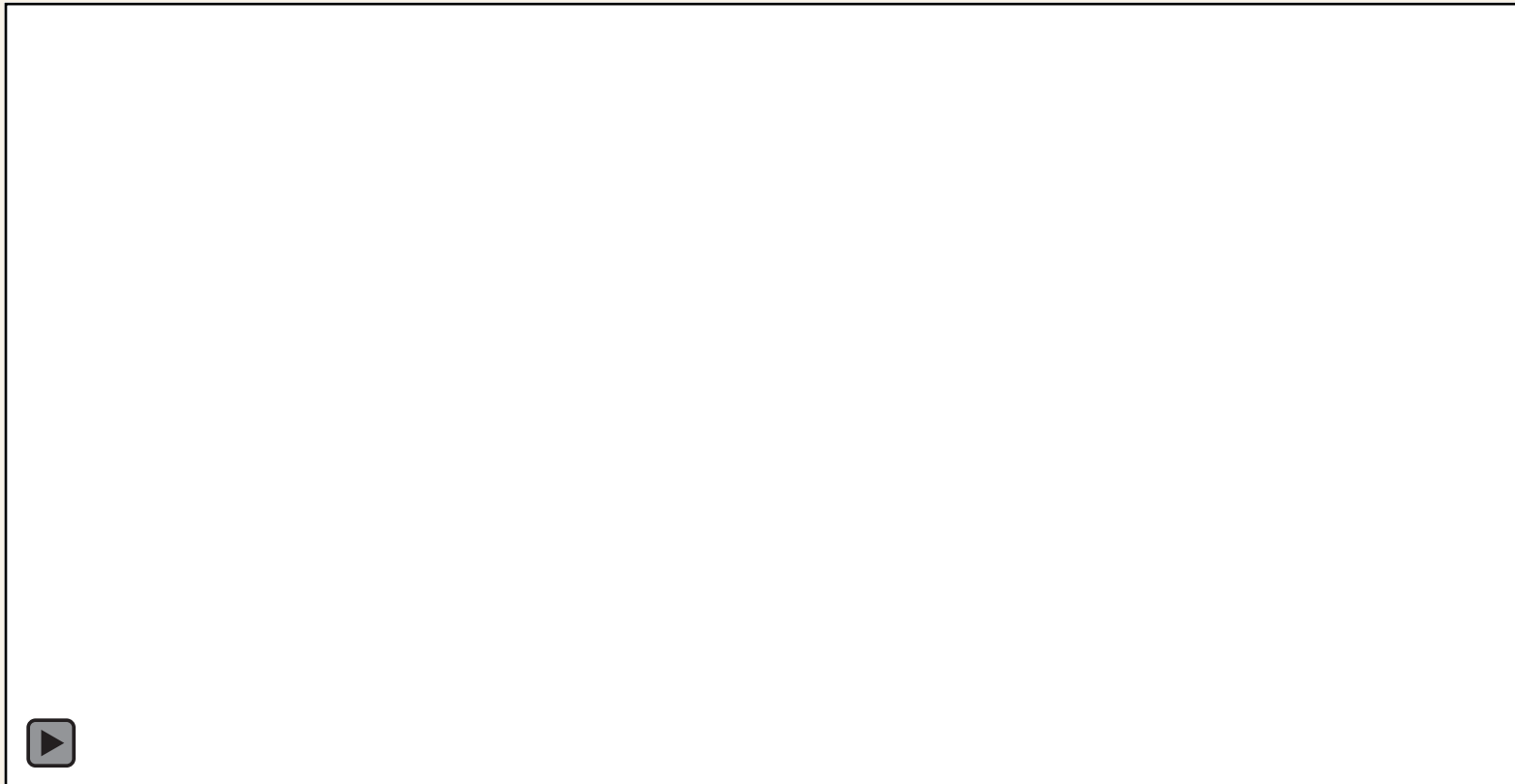


Percentage of spaceborne L-band (1.4 GHz) observations flagged as contaminated by RFI



# Radio Frequency Interference

RFI limits the utility of an observation, generates erroneous scientific results, and damages instruments – for both RAS and EESS



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## Why the Interest in High Radio Frequencies?

- 5G technologies are pushing to higher frequencies in order to provide sufficient bandwidth
  - New spectrum allocations allow higher data rates per user
  - Narrow beams and atmospheric attenuation allow more users of the same frequency allocation
- Concerns for CORF:
  - Technology developed in the US will almost certainly be used elsewhere, including Chile (location of ALMA)
  - However, rationale for FCC filings are based on facilities located in the United States
  - As mm and sub-mm astronomy facilities in the US close, it becomes more difficult to object to FCC frequency allocations in the mm and sub-mm (including the ALMA bands) based on RAS

## Recall 2019 Petition for Rulemaking Regarding US 246

- CORF opposed the petition to the FCC by the mmWave Coalition with a proposal to modify US 246 to allow emissions in the U.S. in relevant bands above 95 GHz:
  - Modification was requested because current US 246 bands prohibit broad bandwidth (> 30 GHz) allocations above 95 GHz, other than the 116 – 148.5 GHz band, of course
  - For context, US 246 bands are 18.4% of 95 – 275 GHz allocations in the US, but only 2.2% below 24 GHz
  - Phrased as being in the interests of protecting the passive services
  - Proposed protection at the level of ITU-R RS.2017, ITU-R RS.1858, ITU-R RA.517, ITU-R RA.611, ITU-R RA.769-2, ITU-R RA.1031
- **However, *actual* relevant ITU-R standard is RR 5.340:**
  - Although Article 4.4 indicates that Administrations can make assignments at variance to the International Table of Frequency Allocations, the process is essentially forbidden for assignments that would go counter to RR 5.340

## US WP1A: Initiate Compatibility Studies for RR 5.340 and other passive-only bands above 71 GHz

- Latching onto a recent revision of ITU-R Res. 731 as justification, documents were drafted in US WP1A to initiate compatibility studies for active use of the passive bands above 71 GHz
- ITU-R Res 731 (Rev. WRC-19) is under purview of WP1A because it involves potential studies by many different WPs and was revised at WRC-19 to include studies above 275 GHz, as per WRC-19 AI 1.15
- Original draft document included statements suggesting that if the current FS technology is found to be incompatible with passive use, adjustments will be made until they are compatible. **This is an existential threat to the concept of passive-use only bands**
- Sent to national review as a non-consensus document
- After contentious discussion, US document includes Liaison Statements to WP 5A, 5C, 7B, 7C, and 7D requesting technical information on emerging technologies in these bands

