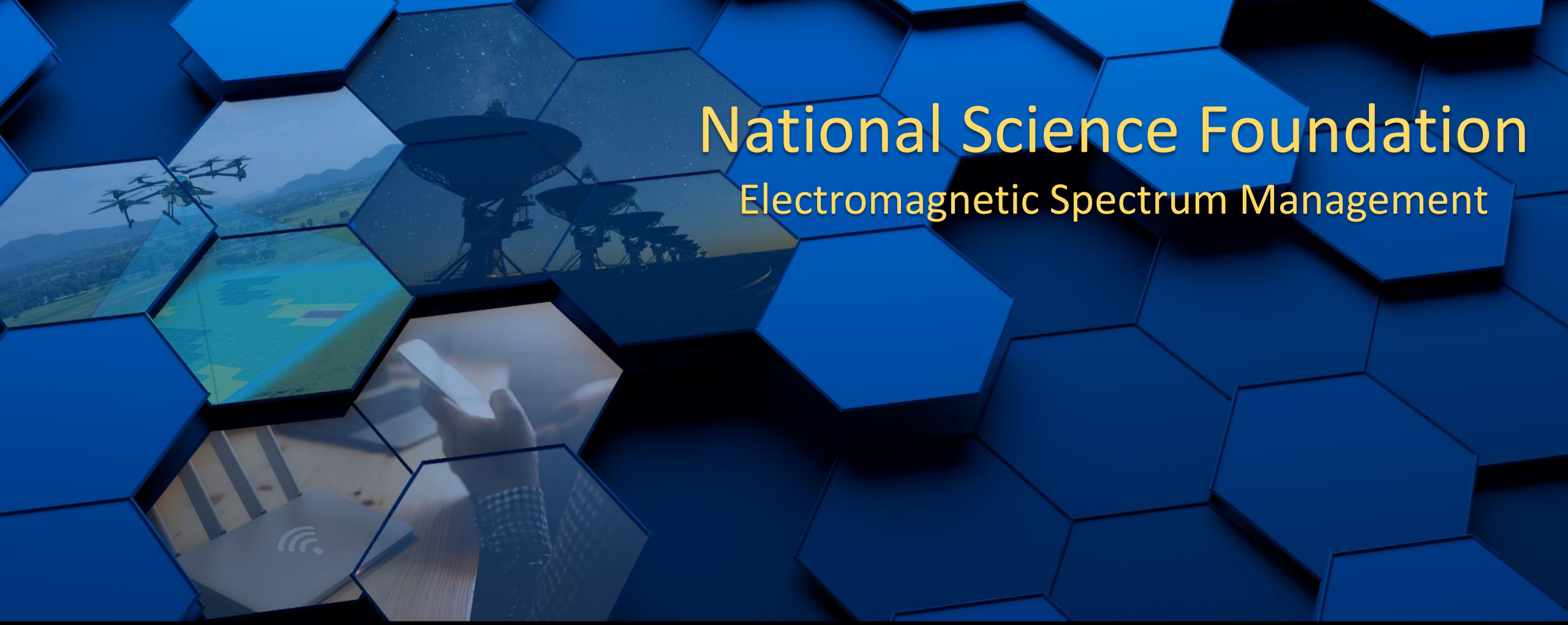

National Science Foundation

Electromagnetic Spectrum Management

May 20, 2021

Report to the Committee on Radio Frequencies
National Academy of Sciences

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Jonathan Williams - *jonwilli@nsf.gov*

Overview

1. NSF Spectrum Management – Changes
2. NSF Goals and Initiatives
3. Advisory process / Astronomy Decadal
4. Domestic Issues
5. International issues - ITU
6. Open Questions for CORF / NSF priorities

NSF Spectrum Team

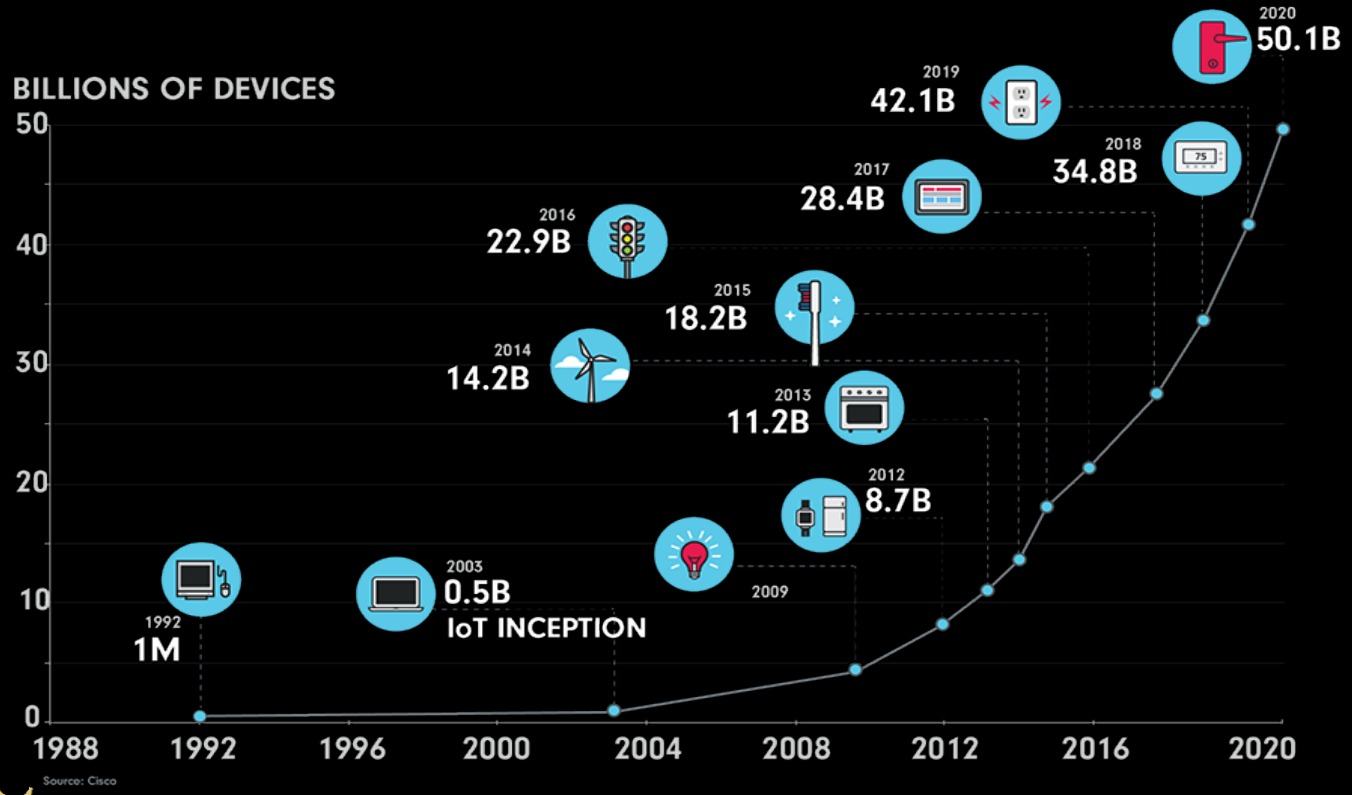
Ashley VanderLey, Senior Advisor for Facilities, MPS/AST

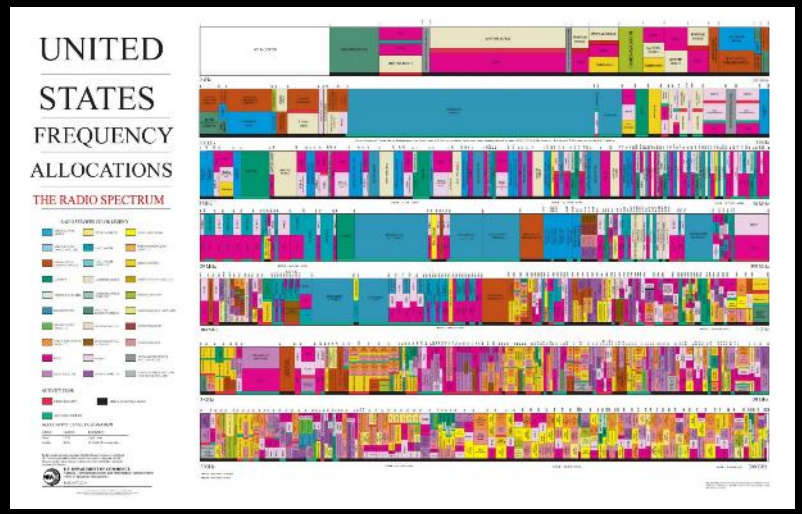
Jonathan Williams, Program Officer, MPS/AST

David Morris, AAAS STP Fellow, MPS/AST

John Chapin, Special Advisor for Spectrum, MPS/AST

Demands for electromagnetic spectrum use are increasing rapidly in a congested environment





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)

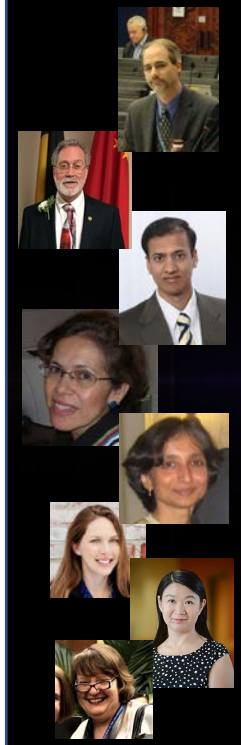
NSF-wide collaboration

Spectrum Innovation Initiative (2020)

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

NSF 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 VanderLey	*MPS/AST, ESM Unit*
Li Yang	*EHR*
Nancy Lutz	*SBE*

Contributing POs:

Lisa Winter (GEO)

Murat Torlak (ENG)

Alex Sprintson (CISE)

Mohammod Ali (ENG)

Larry Goldberg (CISE)

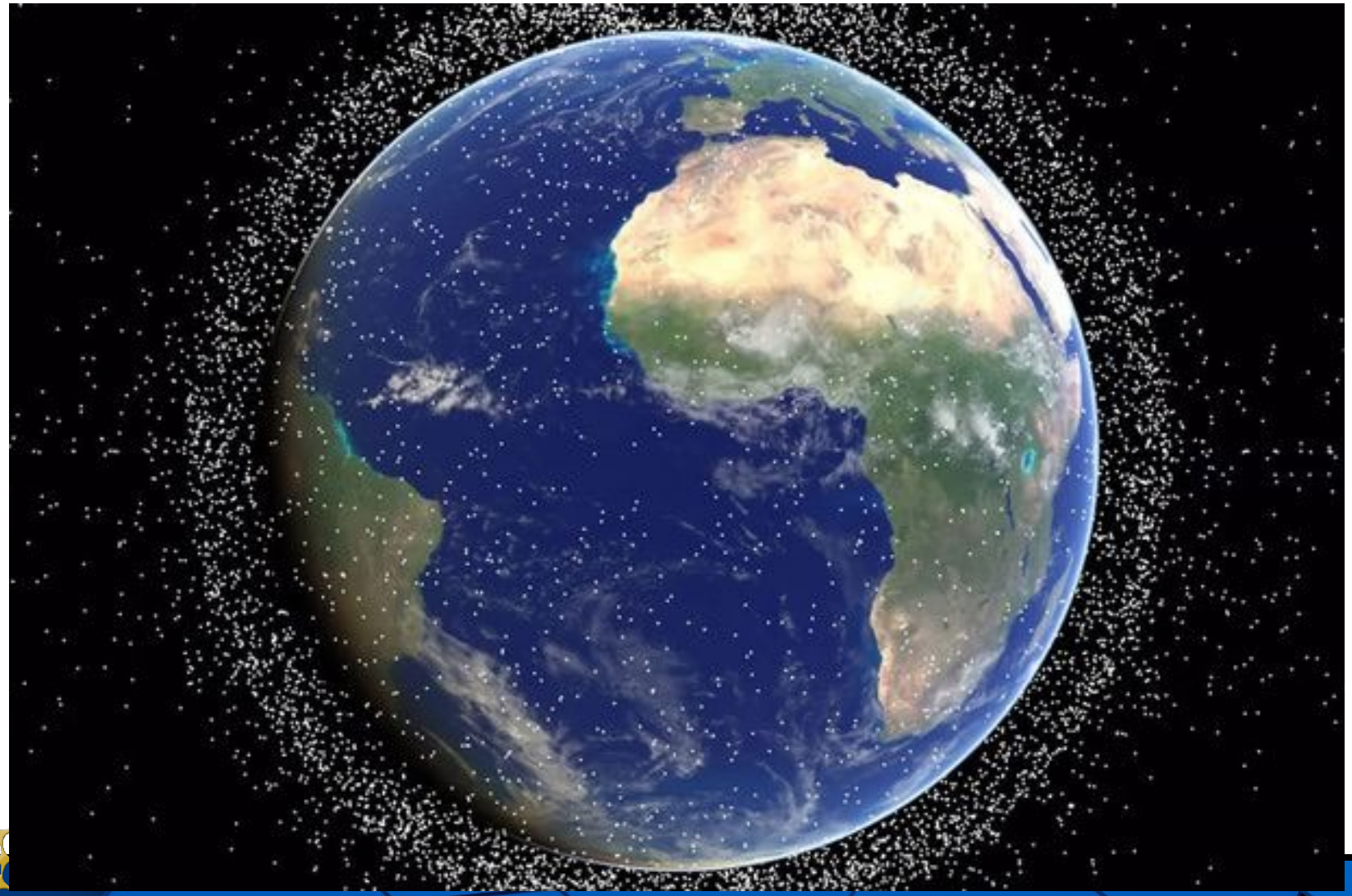
John Chapin (MPS)

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

Satellites and Optical

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!



Credit: University of Southampton

Also:

- Mobile telecommunications

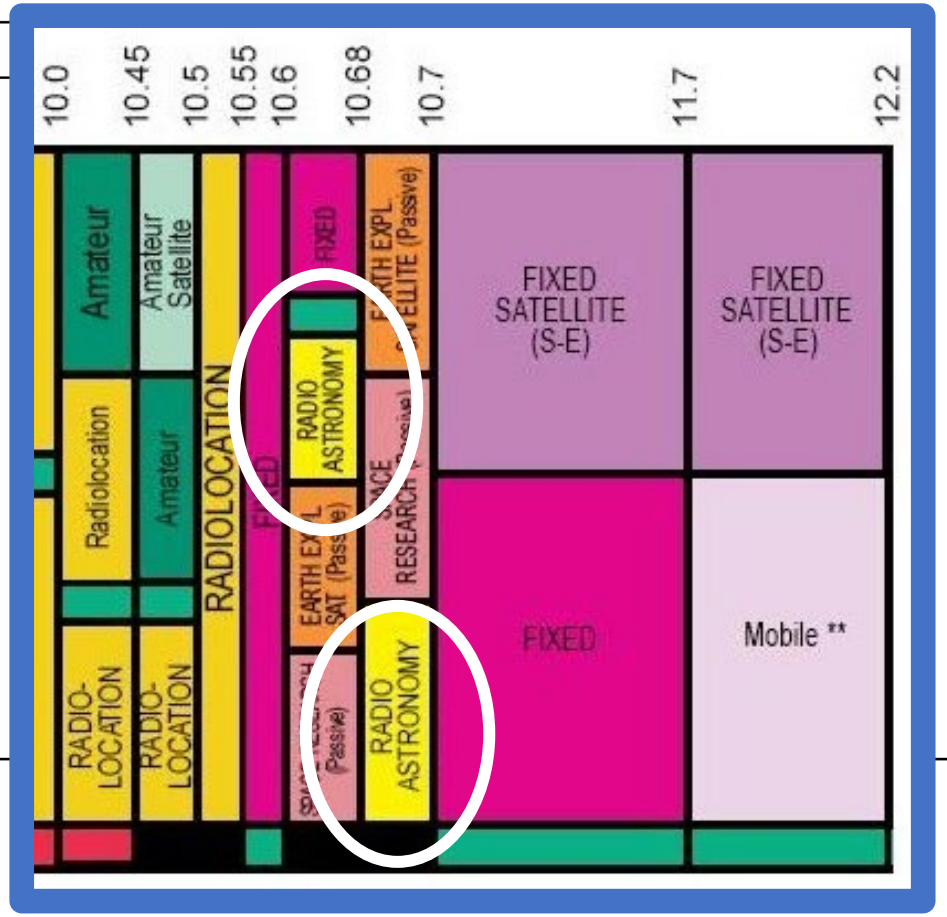
- High Altitude Platform Systems

Radio Astronomy protections at 10.6 GHz

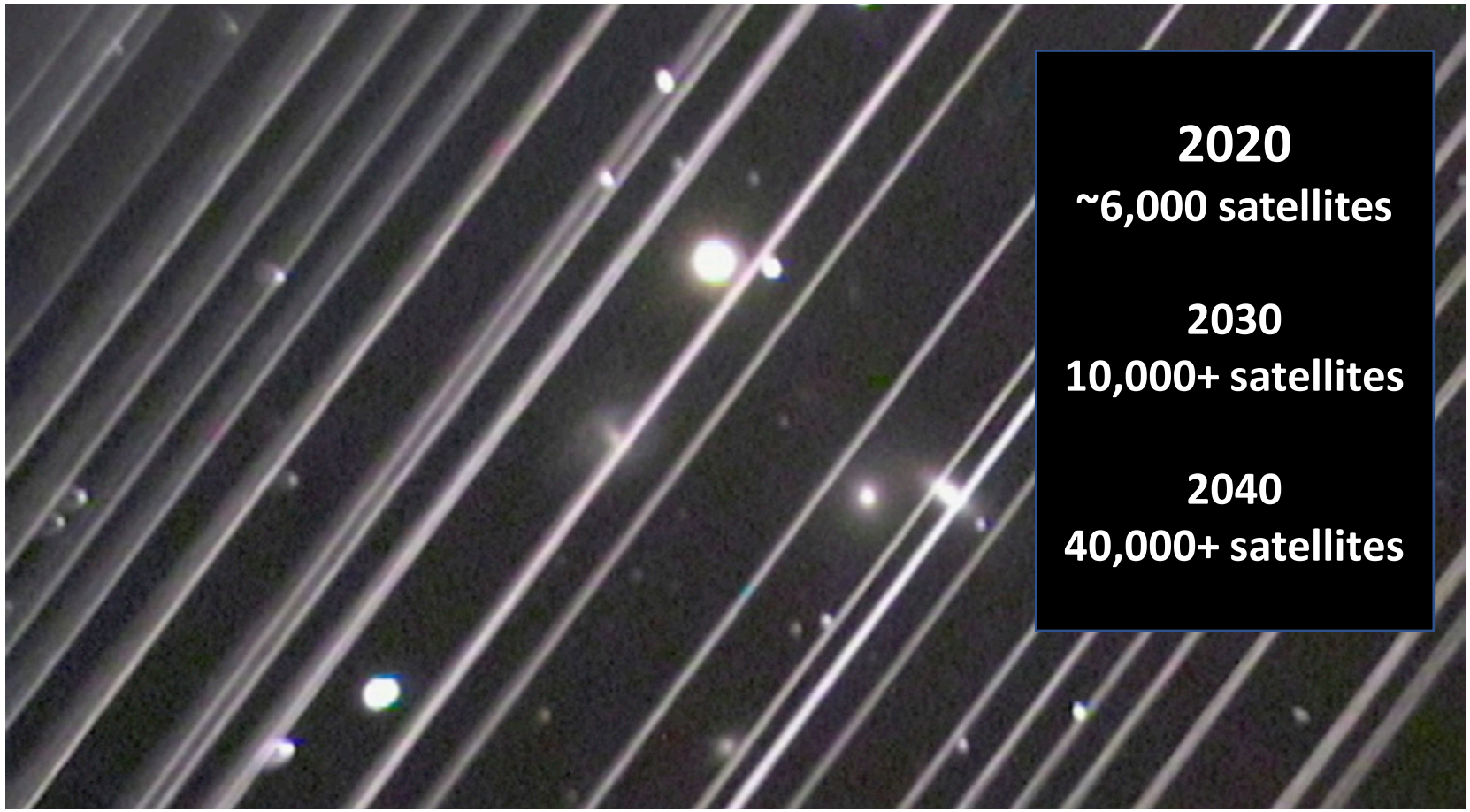
US131 In the band 10.7-11.7 GHz, non-geostationary satellite orbit licensees in the fixed-satellite service (space-to-Earth), prior to commencing operations, shall coordinate with the following radio astronomy observatories to achieve a mutually acceptable agreement regarding the protection of the radio telescope facilities operating in the band 10.6-10.7 GHz:

Observatory
Arecibo Observatory, PR…….....
Green Bank Telescope (GBT), WV…..…...
Very Large Array (VLA), Socorro, NM…..…
Very Long Baseline Array (VLBA) Stations:
Brewster, WA……..…
Fort Davis, TX……..…
Hancock, NH…….....
Kitt Peak, AZ…….....
Los Alamos, NM…….....
Mauna Kea, HI…….....
North Liberty, IA……...
Owens Valley, CA…….....

United States (US) Footnotes



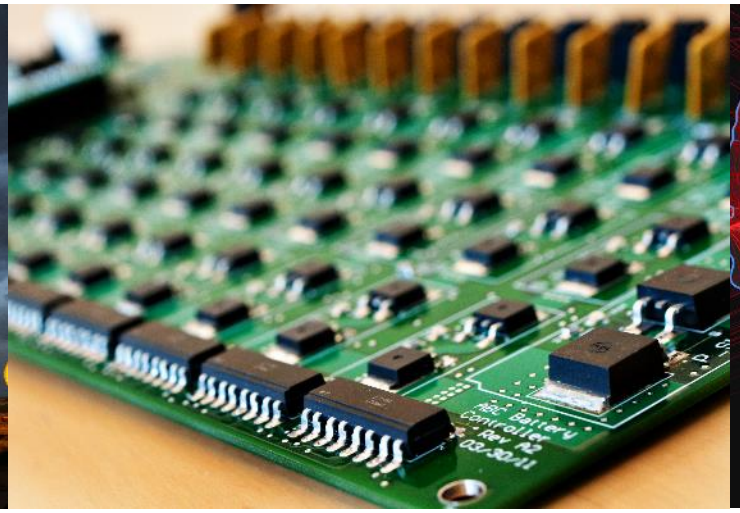
Extended Role of ESM Office to Optical Wavelengths



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/

NSF's Spectrum Innovation Initiative

Cross-Directorate, housed in MPS Office of Multidisciplinary Affairs (OMA)

NSF's Spectrum Innovation Initiative

https://nsf.gov/mps/oma/spectrum_innovation_initiative.jsp

- National Radio Dynamic Zones (NRDZ)
- National Center for Wireless Spectrum Research (SII-Center)
- Spectrum Research Integrative Activities
- Education and Workforce Development

National Radio Dynamic Zones (NRDZ)

National Radio Dynamic Zones (NRDZ)

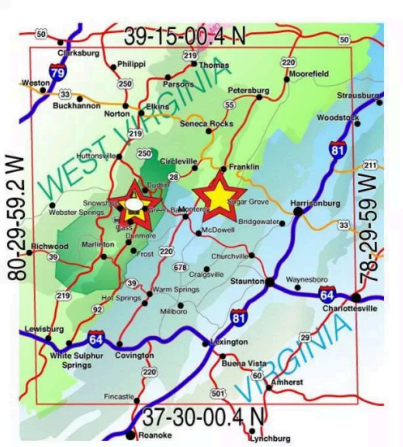
- Designate limited geographic areas to pilot innovative approaches in test beds
- RFI environmental sensing and waveform analysis (up to 115 GHz and beyond)
- Cognitive machine-to-machine frequency coordination leading to dynamic allocation and improved efficiency
- Bi-directional sharing / win-win

- See Dear Colleague Letter NSF 20-079
- For questions, email SII@nsf.gov

How do we do radio astronomy for the next decade and beyond?

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

- **We need a new "National Radio Dynamic Zone" for the VLA and other facilities**



Credit: Green Bank Observatory

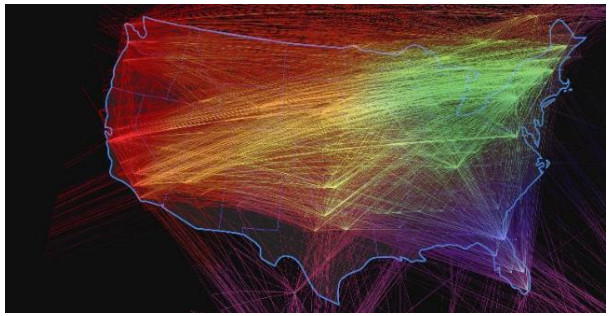
Description

The National Radio Quiet Zone (NRQZ) was established by the Federal Cor
No. 11745 (November 19, 1958) and by the Interdepartment Radio Advisory
(March 26, 1958) to minimize possible harmful interference to the National
Green Bank, WV and the radio receiving facilities for the United States Nav
bounded by NAD-83 meridians of longitude at 78d 29m 59.0s W and 80d
N and 39d 15m 0.4s N, and encloses a land area of approximately 13,000 s
Virginia and West Virginia.

Credit: NRAO

National Center for Wireless Spectrum Research

National Center for Wireless Spectrum Research (SII-Center)



- Connect spectrum researchers with the nationwide challenges and grow the spectrum workforce in support of industries of the future
- Multidisciplinary groups of scientists and engineers with a common vision to address basic research challenges in wireless spectrum research
- $5M/year for a Wireless Spectrum Research Center for five years, starting in FY21

- See Solicitation NSF 21-558

Industry
Federal Agencies
Academia

SII-Center

NSF's National Center for Atmospheric Research

Platforms for Advanced Wireless

Green Bank Observatory

NSF's National Radio Astronomy Observatory

Spectrum Research Integrative Activities

Spectrum Research Integrative Activities

- Promote and research the means for increased and more effective use of the spectrum for passive and active applications, especially activities of a cross-disciplinary nature;
- Many ongoing programs in NSF's Advanced Wireless Research Initiative
- FY20 - $12M SWIFT

- See Solicitation NSF 20-537

Crosscutting

Spectrum and Wireless Innovation enabled by Future Technologies (SWIFT) C

Effective Spectrum Utilization and/or Coexistence - Although the growing demands on the wireless spectrum are mainly driven by commercial active uses (e.g., mobile broadband wireless), critical passive uses (e.g., radio astronomy, atmospheric and geospace sciences, and climatological observations) as well as critical active uses (e.g., weather radar and GPS) also need consideration as systems that will share the same or adjacent spectrum bands are deployed. Current means of spectrum sharing are limited to sensing and database management around mostly active users; exploring new spectrum utilization and sharing paradigms for bidirectional sharing with passive uses such as radio-astronomy have largely remained unexplored. Proposals that intend to use specific frequency bands should demonstrate awareness of incumbent passive and active uses and address coexistence issues with these uses. Specifically:

- Proposers should articulate how their proposed efforts will ensure that the scarce EM spectrum will be effectively utilized while other uses are being protected through RFI excision, avoidance, and other methods. An alternative approach could be to develop new methods and techniques that allow co-channel or adjacent channel use of spectrum bands currently exclusively reserved for passive use such that passive uses can continue to operate satisfactorily. Such methods should account for the fact that the interference thresholds for passive users are orders of magnitude lower than those of active users of spectrum.
- Examples of specific bands of interest include passive bands recognized for protection in the International Telecommunication Union (ITU) Radio Regulations (RR) such as 1400 – 1427 MHz, 1610.6 – 1613.8 MHz, 2690 – 2700 MHz, 10.68 – 10.7 GHz, 15.35 – 15.4 GHz, 18.6 – 18.8 GHz, 23.6 – 24 GHz, 42.5 – 43.5 GHz, 50.2 – 50.4 GHz, and other bands noted as allocated to passive services or explicitly noted in RR No. 5.340 and 5.149 [3].
- Research may also include exploring new frequency allocations, sharing and compatibility studies, measurement or characterization of the radio noise floor, or other applications within the EM spectrum. Research may facilitate dynamic sharing with active and passive users, including topics such as device control, hardware infrastructure and software systems for real-time waveform detection and spectrum sensing, leading to the establishment of a testbed in synergy with a future National Radio Dynamic Zone (NRDZ) [4].

Education and Workforce Development

Education and Workforce Development

- Encouraging the development of a skilled and diverse workforce through education and training programs
- In response to noted shortage in skilled spectrum workforce, building on NSF's experience with workforce pipelines (e.g. REU programs)
- The SII-Center solicitation highlights the importance of education, broadening participation and workforce development

NSF Spectrum Overview

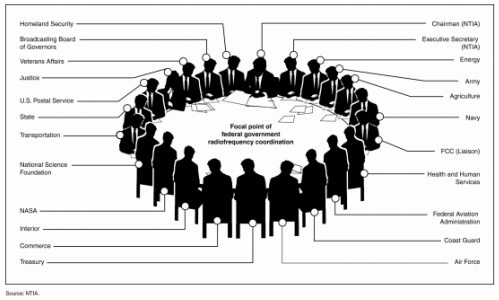
NSF Goals

- **Keep protected scientific <u>allocations</u> 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 <u>increase</u> 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)*

- **<u>Coordination</u> – internal at NSF and external stakeholders**
  - *Spectrum sharing*
  - *Costs must be considered; resources are investment in the future*

NSF ESM Unit Activities



- 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)

ITU

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

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 Federal Agencies, including NASA, NOAA and DOE

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

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

NSF funds a wide variety of programs whose research mission

- *requires usage of the radio spectrum*
- *supports use radio spectrum wireless research & development*

Participating Directorates include

- Biological Sciences
- Computer and Information Science and Engineering
- Education and Human Resources
- Engineering
- Geosciences
- Mathematical and Physical Sciences
- Social, Behavioral and Economic Sciences

Arecibo Observatory, Puerto Rico

Green Bank Observatory
National Radio Quiet Zone

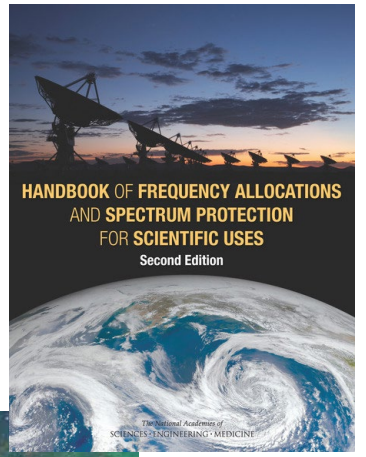
Advisory Process to NSF

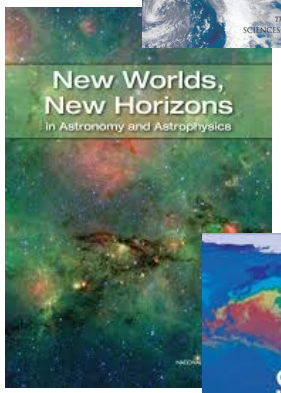
Advisory to our Key Goals

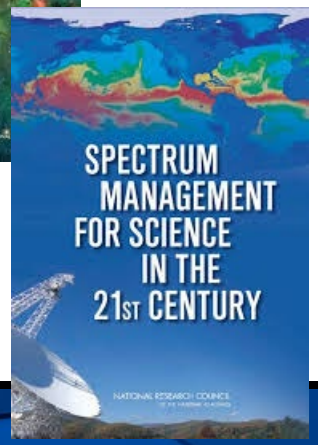
I. NASEM – CORF, BPA

II. NSF: AAAC, MPSAC

III. Community input, e.g., Astronomy & Astrophysics Decadal







Views of the U.S. National Academies of Sciences, Engineering, and Medicine on Agenda Items of Interest to the Science Services at the World Radiocommunication Conference 2019

- Report to articulate the views of the U.S. science community on specific WRC-19 Agenda Items related to the Radio Astronomy Services and the Earth Exploration-Satellite Services

- Recommendations given on 11 agenda items for WRC-19, and one for WRC-23
    - Power Limits for Earth Stations
    - Earth Stations in Motion (ESIM)
    - Non-GSO FSS Satellite Systems at 37 – 50 GHz
    - Spectrum Needs for non-GSO Satellites
    - Global Maritime Distress Safety Systems
    - Autonomous Maritime Radio Devices
    - Maritime Mobile-Satellite Allocations
    - Future Development of International Mobile Telecommunications
    - High-Altitude Platform Systems (HAPS)
    - 275 – 450 GHz
    - Wireless Access between 5150 and 5925 MHz
    - Radar Sounders at 45 MHz

Domestic Issues

Issues from the FCC and NTIA

- Spectrum repurposing analyses
- Unlicensed devices
- Spectrum Horizons and Spectrum Frontiers
- Satellites
- UWB Devices
- Examining issues from new proposed applications
- ***Whatever tomorrow may bring…***

International Work

Radiocommunication Study Groups

- www.itu.int/en/ITU-R/study-groups

- SG 1: Spectrum Management**
- SG 3: Radiowave Propagation
- SG 4: Satellite Services**
- SG 5: Terrestrial Services**
- SG 6: Broadcasting Services
- SG 7: Science Services**
  - Working Party 7A – Time signals and frequency standards
  - Working Party 7B – Space Radiocommunication applications
  - Working Party 7C – Remote sensing systems
  - Working Party 7D – Radio astronomy

Bi-annual meetings in Geneva for all Study Groups and Working Parties, monthly national preparatory meetings leading up to International meetings

WRC-23 and WRC-27

- We are halfway through!
- WRC-23
  - 19 Items on the regular agenda
  - 4 Items in the Director's Report
  - One standing agenda item for satellite coordination issues
  - 13 issues of particular interest
- WRC-27
  - 13 issues pushed back to this WRC
  - 9 issues of particular interest

WRC-23 issues

- 1.1: Protection of Aeronautical and Maritime Mobile Stations in 4800-4990 MHz
- 1.2: Mid-band IMT-studies in bands between 3.3 and 10.5 GHz
- 1.4: HAPS/IMT in existing IMT bands below 2.7 GHz
- 1.5: Region 1 spectrum use review in 470-960 MHz
- 1.10: New aeronautical mobile allocations in 15.4-15.7 GHz and 22-22.21 GHz
- 1.11: GMDSS
- 1.12: Spaceborne radar sounders for EESS (active) around 45 MHz

WRC-23 issues

- 1.13: SRS upgrade in 14.8-15.35 GHz
- 1.14: Review of EESS (passive) allocations from 231.5-252 GHz
- 1.16: ESIMS in 17.7-18.6 GHz, 18.8-19.3 GHz, 19.7-20.2 GHz, 27.5-29.1 GHz, and 29.5-30.0 GHz
- 1.17: Inter-satellite links in 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8-20.2 GHz, and 27.5-30.0 GHz
- 1.19: FSS allocation in 17.3-17.7 GHz in Region 2
- 9.1(a): Space Weather
- 9.1 (c): IMT in bands allocated to the fixed service
- 9.1 (d): Protection of EESS (passive) in 36-37 GHz from NGSO sats

WRC-27 Issues

- Many may not ever make it to the agenda, BUT
- We're watching for anything to come up, and participating!
- Most future agenda items identified at this point were pushed there at WRC-19 to resolve disagreements

WRC-27 Issues

- 2.1: Additional RLS allocations/identifications in 231.5-1000 GHz
- 2.2: ESIMS in Q/V-bands
- 2.3: 43.5-45.5 GHz FSS
- 2.4: Satellite services in 71-76 and 81-86 GHz
- 2.5: Passive protection in 71-76 and 81-86 GHz
- 2.6: Space Weather
- 2.7: NGSO feeder links in 71-76 and 81-86 GHz
- 2.8: ISL MSS links
- 2.11: EESS allocation in 22.55-23.15 GHz

Our priorities

- WRC-23 issues most important to RAS
- ITU-R 7D: IMT-RAS compatibility 42 GHz; IMT-EESS compatibility 24 GHz; Distributed Arrays; Low Frequency; others!
- ITU-R 7C; Space Weather and Geophysics
- Any other ITU-R venue where issues impacting Radio Astronomy are raised
- CITEL Sciences Working Group; scientific workshops
- Collaboration with other federal agencies, industry and academia
- Unlicensed Devices
- Frequency Assignments and NRQZ Coordination
- NRQZ/NRDZ – airborne protections
- Encouraging technical studies, innovation and solutions to the spectrum challenges

NSF Spectrum Goals:

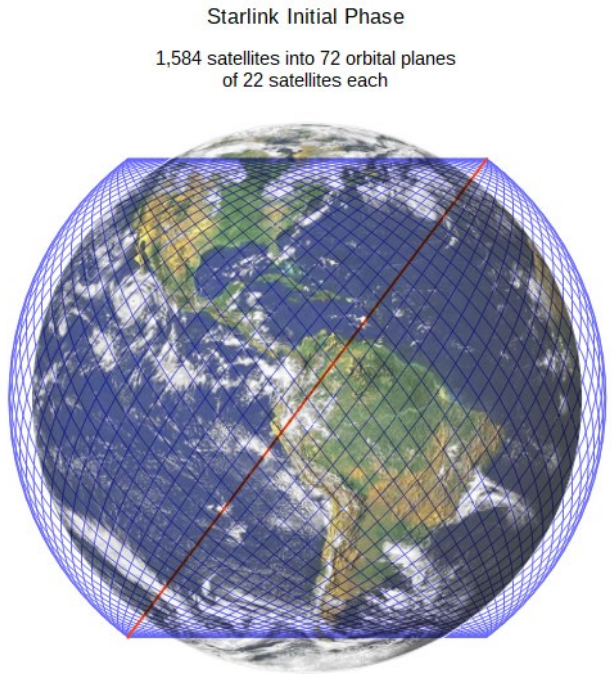
Innovate and *Secure*

Thank you!

Back-up slides

Changes in Satellite Constellations

- Numbers of satellites is increasing;
  -factor of 10 over the next 20 years
- Type of orbit is changing;
  -GSO -> NGSO constellations in LEO; 500 – 1200 km
  -Closer, brighter
- Radio frequencies utilized is increasing;
  -problem for radio astronomy
- Spacecraft design is changing;
  -smaller, phased arrays (trade-offs abound)



Images: Wikipedia SpaceX entry

WRC-19 Outcomes: IMT (Mobile Broadband)

- Identification in 24.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 GHz, 66-71 GHz (regions 1 & 3, plus Brazil)
  - In-band and adjacent to radio astronomy frequencies
  - WRC Resolution calling for development of Recommendations and Reports providing guidance to protect Radio Astronomy
  - EESS (passive) protections in 23.6-24 GHz from IMT (modifications to Resolution 750 (Rev WRC-19)):
    - −33 dB(W/200 MHz), IMT base stations; −39 dB(W/200 MHz) after 1 September 2027
    - −29 dB(W/200 MHz), IMT mobile stations; −35 dB(W/200 MHz) after 1 September 2027
- No changes in 48.2-50.2 GHz and 50.4-52.6 GHz.
- Modifications to numerous country footnotes adding IMT identification

WRC-19 Outcomes: High-Altitude Platforms (HAPS) and 275-450 GHz Terrestrial

- HAPS
  - Added to existing HAPS identifications
  - Identification in 21.4-22 GHz, 24.25-25.24 GHz, 31-31.3 GHz, 38-39.5 GHz
  - Significant protections for radio astronomy and EESS (passive) (more strict than Recommendation ITU-R RA.739-2)
- 275-450 GHz Terrestrial
  - 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz identified for land-mobile and fixed service applications
  - Protecting radio astronomy assets were indicated as necessary

WRC-19 Outcomes: Iridium

- 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
- Political support provided by CEPT, RCC
- End result:
  - GMDSS operation allowed in frequency band 1621.35-1626 GHz, on primary basis
  - 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 (band removed from Resolution 739 (Rev WRC-19)

WRC-19 Outcomes: Short-Duration Satellites

- 137.025-138 MHz, space operation (s-E), NGSO
  - PFD limited to −140 dB(W/(m2 · 4 kHz))
  - Non-interference basis
- 148-149.9 MHz, mobile satellite (E-s), NGSO
  - PFD at border of certain countries limited to −149 dB(W/(m2 · 4 kHz))
  - Non-interference basis