Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Services	)	GN Docket No. 14-177
	)	
Establishing a More Flexible Framework to Facilitate Satellite Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands	)	IB Docket No. 15-256
	)	
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band	)	RM-11664
	)	
Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 To Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services	)	WT Docket No. 10-112
	)	IB Docket No. 97-95
Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations	)	

**COMMENTS OF THE
NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES**

The National Academy of Sciences, through its Committee on Radio Frequencies (hereinafter, CORF)[1], hereby submits its comments in response to the Commission's July 14, 2016, *Further Notice of Proposed Rulemaking* (FNPRM) in the above-captioned

[1] See the Appendix for the membership of the Committee on Radio Frequencies.

dockets. In the Report and Order (R&O) in this proceeding, the Commission took a number of steps to protect important passive scientific observations of the spectrum. Such protections serve the public interest, and CORF appreciates the Commission's recognition of the importance of such observations in the R&O, and in the FNPRM. In these comments, CORF responds to questions regarding additional important protections for passive scientific use of the spectrum.

I. Introduction: The Role of Radio Astronomy and Earth Remote Sensing, and the Unique Vulnerability of Passive Services to Interference.

CORF has a substantial interest in this proceeding, as it represents the interests of the passive scientific users of the radio spectrum, including users of the Radio Astronomy Service (RAS) and Earth Exploration-Satellite Service (EESS) bands. These users perform extremely important, yet vulnerable, research. Furthermore, extensive experience in operating instruments above 24 GHz makes this community well suited to comment on technical matters in this frequency range.

As the Commission has also long recognized, radio astronomy is a vitally important tool used by scientists to study our universe. It was through the use of radio astronomy that scientists discovered the first planets outside the solar system, circling a distant pulsar. The discovery of pulsars by radio astronomers has led to the recognition of a widespread galactic population of rapidly spinning neutron stars with gravitational fields at their surface up to 100 billion times stronger than on Earth's surface. Subsequent radio observations of pulsars have revolutionized understanding of the physics of neutron stars and resulted in the first experimental evidence for gravitational radiation. With the first and subsequent detections of gravity waves now having been made by the Laser Interferometer Gravitational-Wave Observatory, radio astronomy observations will provide one of the best means for localizing the sources of the gravity waves. Radio astronomy has also enabled the discovery of organic matter and prebiotic molecules outside our solar system, leading to new insights into the potential existence of life elsewhere in our galaxy. Radio spectroscopy and broadband continuum observations have identified and characterized the birth sites of stars in the Milky Way, the processes by which stars slowly die, and the complex distribution and evolution of galaxies in the universe. The enormous energies contained in the enigmatic quasars and radio galaxies discovered by radio astronomers have led to the recognition that most galaxies, including our own Milky Way, contain supermassive black holes at their centers, a phenomenon that appears to be crucial to the creation and evolution of galaxies. Synchronized observations using widely spaced radio telescopes around the world give extraordinarily high angular resolution, far superior to that which can be obtained using the largest optical telescopes on the ground or in space.

The critical science undertaken by RAS observers, however, cannot be performed without access to interference-free bands. Notably, the emissions that radio astronomers receive are extremely weak—a radio telescope receives less than 1 percent of one-billionth of one-billionth of a watt (10^{-20} W) from a typical cosmic object. Because radio astronomy receivers are designed to pick up such remarkably weak signals, radio observatories are particularly vulnerable to interference from in-band emissions, spurious and out-of-band (OOB) emissions from licensed and unlicensed users of neighboring bands, and emissions that produce harmonic signals in the RAS bands—even if those artificial emissions are weak and distant.

The Commission has also long recognized that satellite-based Earth remote sensing, including sensing by users of the EESS bands, is a critical and uniquely valuable resource for monitoring aspects of the global atmosphere, land, and oceans. For certain applications, satellite-based microwave remote sensing represents the only practical method of obtaining atmospheric and surface data for the entire planet. EESS data have contributed substantially to the study of meteorology, atmospheric chemistry, climatology, and oceanography. Currently, instruments operating in the EESS bands provide regular and reliable quantitative atmospheric, oceanic, and land measurements to support a broad variety of scientific, commercial, and government (civil and military) data users. U.S. EESS satellites represent billions of dollars in investment and provide data for major governmental users, including the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation, the National Aeronautics and Space Administration (NASA), the Department of Defense (DoD, especially the U.S. Navy), the Department of Agriculture, the U.S. Geological Survey, the Agency for International Development, the Federal Emergency Management Agency, and the U.S. Forest Service. These agencies use EESS data on issues impacting hundreds of billions of dollars in the U.S. economy. Moreover, EESS data is critical to weather forecasting, and public safety benefits from accurate weather forecasts.

As a general technical note applicable to all proposed new frequency allocations, care must be taken in assessment of the impact on incumbent EESS bands. While RAS bands can be protected regionally by limiting emissions from terrestrial services within a certain radius of a facility, this is not the case with EESS observations, which are typically satellite-based and global in extent.

In sum, the important science performed by radio astronomers and Earth remote sensing scientists cannot be performed without access to interference-free bands. Loss of such access constitutes a loss for the scientific and cultural heritage of all people, as well as a loss of the practical applications enabled by this access, which can include both human and property losses arising from impaired weather forecasting and climate monitoring. CORF generally supports the sharing of frequency allocations, where practical, but protection of passive scientific observations, as discussed herein, must be addressed.

II. Protection of Passive Scientific Use of Specific Frequency Bands.

The FNPRM's inquiries regarding certain specific bands are discussed below.

A. <u>24 GHz Band</u>

The FNPRM proposes to add a mobile allocation to the 24.25-24.45 and 24.75-25.25 GHz segments of the 24 GHz band and a fixed allocation to 24.75-25.05 GHz, and to authorize both mobile and fixed operations in those segments under the new Upper Microwave Flexible Use Service (UMFUS) rules. Internationally, EESS has a secondary (active) allocation at 24.05-24.5 GHz, and a co-primary allocation (space-to-Earth) at 25.5-27 GHz. There is also an RAS/EESS passive primary allocation at 23.6-24.0 GHz, and Footnote US246 prohibits transmissions in that band. The band 23.6-24.0 GHz is also protected internationally by Footnote RR 5.340 (all emissions in the band are prohibited) and is close to the lower edge of the frequencies under consideration. The protected band is intended to cover a water vapor absorption line that is unique because it is not opaque at sea level. This band is extremely important for forecasting the weather and is used operationally by many nations. Accordingly, CORF urges the Commission not to expand its proposal below 24.25 GHz; but if it does so, any consideration of use of frequencies below 24.25 GHz should include measures to protect the neighboring 23.6-24.0 GHz EESS band consistent with the requirements of Recommendation ITU-R SA.1029-2.

B. 32 GHz Band

In the FNPRM, the Commission proposes to add primary fixed and mobile service allocations at 31.8-33.4 GHz. The 31.8-32.3 GHz portion of the band is currently allocated to the Space Research Service (SRS; space-to-Earth), although use of that band for the SRS is limited to Goldstone, California. There are also EESS and RAS primary allocations at 31.3-31.8 GHz. Footnote US246 prohibits transmission at 31.3-31.8 GHz. The band is also protected internationally by Footnote RR 5.340 (all emissions in the band are prohibited). In the original NPRM in this proceeding, the Commission noted the “difficult challenges” in allocating 31.8-33.0 GHz for mobile uses, specifically including the need to protect the RAS at 31.3-31.8 GHz.

In paragraphs 394-397, the FNPRM restates the information that CORF previously filed regarding passive use of 31.3-31.8 GHz and the need to protect such observations. The FNPRM seeks comments on how active operations could protect RAS and EESS generally, and specifically regarding the use of guard bands.

1. Earth Remote Sensing

Some type of protection in this band is critical,[2] because the incumbent users of these bands designed and developed EESS missions without the expectation of unlicensed communications in such close spectral proximity. Indeed, most incumbent passive users at 31.5 and 37 GHz operate in a direct detection (homodyne) mode. Band definition is achieved with passive filters, limited by the properties of the materials. This leads to a bandwidth and associated OOB rejection which is proportional to frequency, with current state-of-the-art capability of approximately 1% minimum fractional bandwidth. For example, a 60-MHz-wide guard band (−3 dB to −40 dB) is required by the Advanced Technology Microwave Sounder 31.4 GHz channel. Furthermore, for the same reasons, it is unlikely that unlicensed devices, with limited size and cost, will be able to adequately filter their OOB emissions to meet the stringent requirements of these passive bands.[3] Future EESS missions may be able to develop better rejection through different receiver architectures, but that will take time, and in the meantime, the current suite of satellites provide vital weather data.

2. Radio Astronomy

RAS observations at 31 GHz currently are made at the following U.S. observatories: Green Bank, West Virginia[4] (GBT), and the Very Large Array (VLA) at Socorro, New Mexico. This is an important band for continuum measurements because

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[2] As CORF previously noted in its Comments in this proceeding, while RAS bands can be protected regionally by limiting emissions within a certain radius of a facility, this is not the case with EESS observations, which are typically satellite based and global in extent. Other than use of guard bands and out-of-band emission limits, the only technique available to protect these observations is time sharing of the band— as determined by ephemerides and instrument optical characteristics—to accommodate frequent satellite passes overhead.

[3] OOB rejection levels need to be >36 dB and >66 dB rejection for a single 1 W isotropic transmitter and 1,000 such transmitters, respectively.

[4] Green Bank is in West Virginia and not Virginia as mentioned in the FCC's FNPRM.

it lies near the minimum in atmospheric absorption in this part of the spectrum. Combined with measurements in other bands at approximately octave intervals, such measurements provide information on the broad spectrum of astronomical radio sources, such as supernovae, pulsars, radio galaxies, and quasars.[5] The detrimental interference level for this band is -228 dBW/m^2/Hz, averaged across the full 500 MHz width of the band (ITU-R RA.769, Table 1), and as such, careful filtering will be required for protection of RAS from mobile transmitters. With proper coordination, fixed-service operations at 32 GHz could probably protect RAS adequately. The minimum distance for coordination between prospective transmitting stations and RAS sites will need to be calculated for each individual case, based on factors such as altitude and surrounding terrain.

C. 42 GHz Band

In the NPRM in this proceeding, the Commission declined to propose service rules for the 42.0-42.5 GHz band, due in part to concerns that operators would be unable to adequately protect radio astronomy observations in the adjacent 42.5-43.5 GHz band. CORF appreciates the Commission's recognition of the need to protect RAS in that band.[6] Nevertheless, the FNPRM now seeks comments on a proposal to authorize fixed and mobile service operations at 42.0-42.5 GHz.

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5 *See, Handbook on Radio Astronomy* (ITU Radiocommunication Bureau, 2013) at page 35, Table 3.1, noting that the 31.3-31.8 GHz band is one of the preferred RAS bands for continuum observations.

6 Spectral lines at 42.519, 42.821, 43.122, and 43.424 GHz (for observations of silicon monoxide) are among those of greatest importance to radio astronomy. *See, Handbook on Radio Astronomy*, *Id.*, at page 37, Table 3.2. The 42.5-43.5 GHz band is also one of the preferred RAS bands for continuum observations. *Id. at* page 35, Table 3.1.

RAS observations at 42 GHz currently are made at the following U.S. observatories: the 10 sites included in the Very Long Baseline Array (VLBA);[7] at Westford, Massachusetts (the Haystack Observatory); and at the VLA and the GBT. The detrimental levels for continuum and spectral line radio astronomy observations for single dishes are −227 dBW/m^2/Hz and −210 dBW/m^2/Hz, respectively, for the average across the full 1 GHz band and the peak level in any single 500 kHz channel (ITU-R RA.769, Tables 1 and 2, respectively). For observations using the entire VLBA, the corresponding limit is −175 dBW/m^2/Hz.

CORF shares the doubt expressed by the Commission in the NPRM that mobile services in the 42 GHz band could adequately protect RAS observations, other than with OOB emission limits based on ITU-R RA.769. On the other hand, with proper coordination, fixed-service operations at 42.0-42.5 GHz could probably protect RAS adequately. The minimum distance between prospective fixed stations and RAS sites will need to be calculated for each individual case, based on factors such as altitude and surrounding terrain. Note that for high-altitude RAS sites, the required distance might result in Earth's curvature providing the main screening. For the Kitt Peak, Arizona, station of the VLBA, for example, using D(km) = 4.12*sqrt(H)(km), the result is a horizon distance, and thus the minimum distance for a fixed station itself at ground level would be about 160 kilometers.

D. <u>47 GHz Band</u>

The FNPRM proposes to authorize fixed and mobile operations at 47.2-50.2 GHz. There is a primary allocation for EESS at 50.2-50.4 GHz, with additional

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7 For a listing of those sites, *see e.g.*, Footnote US131.

protection (transmissions prohibited) for that allocation from Footnote US246 and internationally protected under Footnote RR 5.340. The 48.94-49.04 GHz band is also used by radio astronomy for spectral line observations, and under Footnote US342 all practicable steps must be taken to protect radio astronomy in that band from interference.[8] The FNPRM recognizes the importance of protecting these passive uses and seeks information on how to best facilitate that protection.

1. Radio Astronomy

RAS observations at 49 GHz currently are made at the following U.S. observatories: the VLA, GBT, and Haystack. Power flux density limits on the co-extant and neighboring services are set by international Footnote 5.555B: −151.8 dB(W/m^2) in any 500 kHz band at the site of a radio astronomy station by any geostationary space station in the fixed satellite service (space-to-Earth) operating in the bands 48.2-48.54 GHz and 49.44-50.2 GHz. Any further consideration of spectrum allocations in neighboring bands should include the same restriction on emissions.

2. Earth Remote Sensing

The FNPRM recognizes the need to protect vital EESS observations at 50.2-50.4 GHz, noting that "at WRC-12, the WRC recognized 'that long-term protection of the EESS in the [, *inter alia*, 50.2-50.4 GHz band] is vital to weather prediction and disaster management.'"[9] Given the critical importance of this band, CORF recommends that Footnote US157 be adopted to establish emission limits (unwanted emissions power in the adjacent 50.2-50.4 band shall not exceed −33 dBW/100 MHz, measured at the input

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[8] Radio astronomy observations in this band are also protected by Footnote RR 5.149 and Footnote RR 5.340 (no emissions are permitted from airborne stations in this frequency range).
[9] FNPRM at para. 416, citing 47 CFR § 2.106 n.5.338 and WRC-12 Resolution 750.

of the transmit antenna).

E. 50 GHz Band

The FNPRM proposes to authorize fixed and mobile operations at 50.4-52.6 GHz. There is a primary allocation for EESS at 50.2-50.4 GHz, with additional protection (transmissions prohibited) for that allocation from Footnote US246 and internationally protected under Footnote RR 5.340. It should be noted that when combined with the FNPRM's proposal to authorize services at 47.2-50.2 GHz, the EESS allocation would be completely surrounded by active transmissions. For these reasons and as noted above, CORF recommends that Footnote US157 be adopted to establish emission limits (unwanted emissions power in the adjacent 50.2-50.4 band shall not exceed −33 dBW/100 MHz, measured at the input of the transmit antenna).

F. 57-71 GHz

In its Comments and Reply Comments earlier in this proceeding, CORF discussed in detail its concerns regarding the Commission's proposal to unify rules in the 64-71 GHz band with those for operations at 57-64 GHz, and the negative impact that aeronautical transmissions would have on EESS observations at 57-59.3 GHz, which are vitally important for weather forecasting. CORF strongly urged the Commission to use great caution before authorizing aeronautical transmissions at 57-59.3 GHz and recommended the following instead: (1) further study of real-world transmission scenarios in aircraft prior to authorizing unlicensed airborne use of this band, (2) making any service at 57-59.3 GHz licensed and requiring aircraft operator licensees to retain responsibility for ensuring that radio frequency (RF) leakage levels are below required threshold levels (for the aggregate transmissions from the aircraft) if aeronautical operations are permitted, or (3) in the absence of better data, prohibiting airborne use of WiGig Channel 1 (57.24-59.4 GHz).

In light of CORF's detailed and documented discussion, as well as disagreement between other parties interested in the band, the R&O prohibited unlicensed operations at 60 GHz on aircraft. Specifically, the R&O extended the restriction on on-board aircraft operation in Section 15.255(a)(1) to cover the entire 57-71 GHz band.[10] In addition, the R&O states that the FCC expects manufacturers/host integrators of WiGig transmitters that are incorporated into mobile devices such as laptops to provide instructions to end users regarding the prohibition of operating such transmitters on-board aircraft.[11] Consequently, end users will be made aware of this rule, to perhaps avoid or reduce device-to-device transmissions on aircraft. These Commission actions furthered the public interest by protecting data collection critical to weather forecasting, and thus to public safety and to the U.S. economy.

The FNPRM now seeks further technical analyses and sharing studies regarding the impact of 60 GHz unlicensed aeronautical operations on EESS and RAS observations. CORF commends the Commission for seeking *specific* studies regarding various types of on-board aircraft provision of service (direct transmission to computers versus bouncing the signal inside the aircraft), variations of aircraft fuselages, and signal leakage through unshielded windows. Studies should also account for variations due to aircraft roll. As the R&O noted (at para. 331), any studies should be based on transmissions specifically at 59-60 GHz, as opposed to references to ITU (International Telecommunication Union) documents based on much lower frequencies. Lastly,

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[10] R&O at para. 333.

[11] *Id.*

special consideration should be given to peer-peer communications, which would be uncontrolled upon the authorization of airborne unlicensed use.

Until such studies are completed and conclusively predict minimal impact (<0.01% loss of data) to the protected band, airborne use of the 57-59.3 GHz band should remain prohibited.

The FNPRM's reference to use of the 57-71 GHz band for airborne wireless avionics intra-communication (WAIC) raises substantial new concerns. Such systems may be located outside the aircraft and radiate isotropically. While studies might show at least some level of shielding by aircraft fuselages for transmissions inside the aircraft, to the extent that use of this band for WAIC involves transmitters and receivers outside the fuselage, then interference to EESS observations in the upper atmosphere (as well as to RAS) is virtually guaranteed. CORF strongly urges the Commission to prohibit WAIC operations in this band in order to protect vital weather forecasting data collection.

The FNPRM asks (at para. 516) whether prohibition on airborne operations at 57.24-59.4 GHz would ameliorate the need to protect harmonic emissions into protected RAS bands. The RAS has co-primary allocations at the first and second harmonics at 128-142 GHz and at 192-213 GHz. While that proposal would likely eliminate emissions of harmonics of 57.24-59.4 GHz, it would not ameliorate the need to address harmonics of the remaining 59.4-71 GHz.

In regards to observations at 59.4-71 GHz, while some U.S. RAS facilities observe in this frequency range (GBT from 67-115.3 GHz), due to atmospheric transmission properties in these frequencies, the primary concerns are OOB emissions into harmonic frequencies. The first harmonic covers several RAS bands (130-134 GHz and 136-148.5 GHz), which are used for observations of complex organic molecules, such as formaldehyde. Footnote US342 prohibits transmissions in 130-134 GHz. The second harmonic covers several regions that have good atmospheric transmission properties, and thus are of great use to radio astronomers, including 200-209 GHz, which is also subject to protection under US246 and internationally protected under Footnote RR 5.340.[12] This band is used to search for redshifted carbon monoxide in distant galaxies. Again, any aeronautical use of these bands must require strict OOB emission limits at the harmonics and should be considered in the aggregate within the airplane (and also aggregate planes within the beam and sidelobes of the telescope).

U.S. based RAS facilities observing at the second harmonic include the Mt. Graham site of the Arizona Radio Observatories.

G. 70/80 GHz Bands

In its initial comments in this proceeding, CORF discussed the need to protect RAS observations at 76.0-77.5 GHz and 78.0-94 GHz and EESS observations at 86-92 GHz. Both services have primary allocations in those respective bands. Paragraph 430 of the FNPRM recognized these concerns. The FNPRM seeks comments on additional services that could be authorized at 71-76 GHz and 81-86 GHz and methods for regulating those services.

CORF takes no position on the three-tiered Spectrum Access System (SAS) spectrum-sharing framework proposed for these bands in the FNRPM. While such a framework does not appear to be designed to include protection of passive services,

[12] The 250-252 GHz band is also protected under US246 and internationally protected under Footnote RR 5.340.

there are regulatory requirements that might provide the required protection, under some circumstances. For example, fixed microwave links in 70/80 GHz bands already coordinate with certain radio astronomy observatories, and CORF understands that such coordination has been successful. Any newly authorized fixed use should be subject to the same coordination.[13] For any newly authorized mobile licensed uses, the FNPRM's reference to exclusion and protection zones (FNPRM at page 155) provides a basis for protection of RAS,[14] and CORF directs commenters and the Commission to the data in pages 16-20 of CORF's initial Comments for use in the creation of such zones.[15] For unlicensed devices operating at 71-76 GHz, OOB emission limits will be required, and Section 15.255(c) restricts spurious emissions to a power density limit of 90 pW/cm^2 at a distance of 3 meters for frequencies between 40 and 200 GHz. CORF recommends that unlicensed mobile devices not be permitted at 81-86 GHz.

In regards to EESS observations at 86-92 GHz, Footnote US246 and international Footnote RR 5.340 prohibit transmissions in that band. Accordingly, protection of the EESS in these bands will require effective OOB emission limits. Calculations indicate that Section 15.255(c) restrictions on spurious emission will not

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[13] Footnote US161 provides that in the bands 81-86 GHz, 92-94 GHz, and 94.1-95 GHz, and within the coordination distances indicated therein, assignments to "allocated services" shall be coordinated with the radio astronomy observatories listed therein. The "allocated services" are Fixed, Mobile and Fixed Satellite Service.

[14] Footnote US342 provides that for 76-86 GHz, "all practicable steps shall be taken to protect the radio astronomy service from harmful interference."

[15] In its initial Comments, CORF noted that the primary U.S. sites where RAS observations are made in this band are located at Mt. Graham, as well as Kitt Peak, Arizona, and Mauna Kea, Hawaii, and the eight other sites in the Very Long Baseline Array. CORF hereby alerts the Commission that RAS observations in this band also occur at the GBT. In addition to the protections discussed herein and in the FNPRM, the GBT is also protected by the Quiet Zone provisions of Section 1.924 of the Commission's rules, as applied to permanent fixed stations.

provide sufficient protection (ITU-R SA.1029-2) in this band for multiple transmitters in the antenna beam of an EESS sensor.

H. Bands Above 95 GHz

As noted in the FNPRM, many of the existing frequency allocations above 95 GHz are for passive services—the RAS and EESS. RR 5.340 explicitly prohibits any transmissions in numerous bands above 95 GHz—specifically, 100-102 GHz, 109.5-111.80 GHz, 114.25-116 GHz, 148.5-151.5 GHz, 164-167 GHz, 182-185 GHz, 190-191.8 GHz, 200-209 GHz, 226-231.5 GHz, and 250-252 GHz. Frequencies between 275 and 1000 GHz have not been formally allocated to specific services, although some bands have been identified for passive service applications, as noted in International Footnote RR 5.565. CORF generally supports the shared use of frequency bands where the avoidance of interference from such sharing is practicable. While the transmission characteristics of the millimeter-wave bands support some productive uses by active services with the ability to protect passive users from harmful interference, attention will need to be paid to such protection. CORF appreciates the detailed nature of the questions asked in paragraph 445 of the FNPRM, and in response, CORF provides the following information.

1. Radio Astronomy

Important scientific research occurs in RAS observations above 95 GHz. For example, some of the spectral lines of greatest interest to astronomy, including transitions for carbon monosulfide, carbon monoxide, methanol, and other complex organic compounds, are located within this frequency range. *See*, *Handbook on Radio Astronomy*, (ITU Radiocommunication Bureau, 2013) at Table 3.2. These molecular transitions provide measurements of the physical conditions (temperature, density, and distribution) of the medium between stars and the potential sites for future star formation within our galaxy and others. In addition, Table 3.1 of the *ITU Handbook* lists 76-116, 123-158.5, and 164-167 GHz as among the frequency bands preferred for continuum observations.

The radio telescope observatories in the United States that currently observe between 95 and 163 GHz are located on Kitt Peak (Arizona Radio Observatory, ARO) and Mt. Graham in Arizona (ARO Sub-millimeter telescope, SMT); in Westford, Massachusetts (the Haystack Observatory); and in Green Bank, West Virginia (GBT).[16] Specifically, RAS observations between 95 and 163 GHz are currently[17] made as follows: 85-116 GHz: ARO, GBT, Haystack; 125-163 GHz: SMT.[18]

The mountain observatory sites in Arizona (and Hawaii) have been chosen for particularly low atmospheric attenuation at millimeter waves—they are high, extremely dry sites. In assessing interference potential and setting any exclusion zones around

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[16] Although not within the jurisdiction of the FCC, the United States has nevertheless invested significant assets in the billion-dollar ALMA observatory in northern Chile, as well as in the Large Millimeter-wave Telescope (LMT) in Puebla, Mexico. As multi-national corporations develop new technologies, pressure will increase to deploy products as widely as possible, including in countries in which the United States has made considerable investments in scientific facilities. Thus, allocation of millimeter-wave frequency bands for use in the United Statees would drive sales and operation of such devices in other countries, such as Chile and Mexico, and potentially disrupt the considerable U.S. scientific investment there. CORF therefore urges that, in allocating frequency bands to different services, the impact on significant U.S. installations outside the United States also be considered.

[17] Other existing and future U.S. observatories may make regular observations above 95 GHz in the future. For example, CORF understands that the Owens Valley Radio Observatory (OVRO) in California has plans to observe at 85-116 GHz. The Commission should address procedures for protection of future new radio astronomy sites where observations above 95 GHz may occur, as well as for observations on additional millimeter-wave bands at existing sites.

[18] The SMT also observes at frequencies higher than 163 GHz, between 211 and 720 GHz. In addition, the James Clerk Maxwell Telescope (JCMT) in Mauna Kea, Hawaii, observes at various frequencies between 211 and 720 GHz.

these observatories, the low atmospheric attenuation at the specific locations must be taken into account. High-frequency observations at Haystack and the GBT do not benefit from the higher atmospheric transparency, but depend on favorable weather conditions, so that radio frequency interference during those limited (and unpredictable) observing windows is particularly damaging.

2. Earth Remote Sensing

EESS observations at frequencies above 95 GHz are used extensively for atmospheric profiling, precipitation mapping, and analysis of atmospheric chemistry. For example, measurements of atmospheric temperature are obtained using passive radiometric observations on or near the 118.75 GHz O_2 line (by the Microwave Limb Sounder), and measurements of atmospheric moisture are obtained using passive radiometric observations on or near the 183.31 GHz H_2O line (by the Advanced Microwave Sounding Unit-B, Advanced Technology Microwave Sounder, Global Precipitation Measurement Microwave Imager, and Microwave Humidity Sounder). In addition to these profiling bands, critically important observations are also obtained in the troughs of the absorption lines to assess continuum absorption and detect and characterize cirrus clouds for more effective numerical weather prediction. Some currently operational systems observe near 150 GHz (the Advanced Microwave Sounding Unit-B),[19] 157 GHz (the Microwave Humidity Sounder),[20] and 166 GHz (the Advanced Technology Microwave Sounder and GPM Microwave Imager),[21] and future systems now funded for development will observe near 196 and 206 GHz (MicroMAS

[19] *See, e.g.*, https://nwpsaf.eu/deliverables/aapp/amsu_b.html and http://mirs.nesdis.noaa.gov/amsub.php.
[20] *See, e.g.*, http://mirs.nesdis.noaa.gov/mhs.php.
[21] *See, e.g.*, http://www.jpss.noaa.gov/atms.html.

and TROPICS)[22] to derive information on precipitation intensity and structure and water vapor continuum absorption for weather prediction and climate change research. Additionally, measurements obtained at frequencies near 118, 183, 190, and 205 GHz are used to measure O_3, SO_2, and HNO_3 for studies of atmospheric chemistry with a variety of applications spanning many facets of atmospheric and climate study.

I. Federal Sharing Issues—37 GHz Band (37-38.6 GHz)

CORF notes that in addition to an existing allocation for Space Research at 37-38 GHz, there are EESS allocations in the bands from 35.5-37.0 GHz.[23] In the original NPRM in this proceeding, the Commission asked whether specific means of protecting those EESS observations was necessary, and if so, whether a 100 MHz guard band would be sufficient. CORF responded that protection is necessary, with at least a 100 MHz guard band. Unfortunately, the R&O (at paras. 156-157) declined to create that guard band, asserting that it did not want to take spectrum away from active use, and that the UMFUS OOB emission limit will provide sufficient protection.

In the FNPRM, the Commission seeks comment on the sharing arrangement between federal and nonfederal stakeholders in the 37 GHz band. In that context, CORF notes that the users of the passive band are in fact federal stakeholders. The FNPRM's proposed banding/sharing scheme with 100 MHz bands provides the opportunity to meet both the needs of the federal and nonfederal users, passive and active. The coordination mechanism proposed is primarily geographic in nature. If the Commission includes a temporal component to this coordination, all concerns related to

22 *See, e.g.*, https://tropics.ll.mit.edu/CMS/tropics/The-MicroMAS-2-Cubesat.
23 There is also an RAS allocation at 36.43-36.50 GHz that is subject to protection under Footnote US342.

OOB emissions into EESS bands might be alleviated. If, within the lowest 100 MHz band, the Commission implements a database system that includes the ephemerides of the federal EESS satellite assets, transmissions can be ceased for the roughly 2 minutes per pass that the asset is overhead. This provides both the spectral access desired by the nonfederal users as well as the protection needed by the federal incumbents. If, as the R&O contends, there is sufficient protection provided by existing OOB limits, then this constraint can be removed at a later date with a simple database modification.

III. Conclusion.

In the R&O in this proceeding, the Commission took a number of steps to protect important passive scientific observation of the spectrum. Such protections serve the public interest, and CORF appreciates the Commission's recognition of the importance of such observations in the FNPRM. CORF generally supports the sharing of frequency allocations, where practical, but protection of passive scientific observations, as discussed herein, must be addressed.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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DATE

Appendix

Membership of the Committee on Radio Frequencies

Members

Jasmeet Judge, University of Florida, *Chair*
Liese van Zee, Indiana University, *Vice Chair*
William Blackwell, MIT Lincoln Laboratory
Todd Gaier, Jet Propulsion Laboratory
David Le Vine, NASA Goddard Space Flight Center
Amy Lovell, Agnes Scott College
Paul Siqueira, University of Massachusetts, Amherst

Consultants

Michael Davis, SETI Institute (retired)
Darrel Emerson, National Radio Astronomy Observatory (retired)
Paul Feldman, Fletcher, Heald, and Hildreth