Before the
U.S. DEPARTMENT OF COMMERCE
National Telecommunications Information Administration

In the Matter of	)	
	)	
United States Spectrum	)	Docket No. 040127027-4027-01
Management Policy	)	
For the 21st Century	)	

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

The National Academy of Sciences, through the National Research Council's Committee on Radio Frequencies (hereinafter, CORF[1]), hereby submits its comments in response to the National Telecommunications and Information Administration (NTIA) Notice of Inquiry (NOI) in Docket No. 040127027-4027-01 announcing that the NTIA seeks comments on a range of issues relevant to spectrum policy reform. Herein, CORF shows support in the record for the propositions that (1) passive scientific use of the spectrum has substantial value that cannot be easily measured in economic terms, so that application of market-oriented allocation and assignment policies to such use is inappropriate, and (2) passive scientific use of the spectrum, which CORF emphasizes is *not non-use*, is uniquely vulnerable to interference, and protection of such services cannot be based on simple economic factors. In these Comments, CORF is responding to selected questions that it believes are pertinent to the passive services.

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

CORF has a substantial interest in this proceeding, as it represents the interests of the scientific users of the radio spectrum, including users of the Radio Astronomy Service (RAS) and the Earth Exploration Satellite Service (EESS) bands. Both RAS and EESS observers perform extremely important yet vulnerable research. As has long been recognized, radio astronomy is a vitally important tool used by scientists to study our universe. The EESS is a critical and unique resource for monitoring the global atmospheric and surface state. The data obtained from EESS missions provide scientists with indications of the physical health of the planet, a topic of increasing concern to society.

The emissions that radio astronomers measure are extremely weak--a typical radio telescope receives only about one-trillionth of a watt from even the strongest cosmic source. Because radio astronomy receivers are designed to pick up such remarkably weak signals, such facilities are therefore particularly vulnerable to interference from spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and from those that produce harmonic emissions that fall into the RAS bands. Similarly, the emissions received by passive EESS radiometers in Earth orbit are also extremely weak by comparison with both the noise background and the emissions from other services.

In addition to the gains in scientific knowledge that result from radio astronomy and Earth sensing, CORF notes that such research enables technological developments that are of direct and tangible benefit to the public. Continued development of new critical technologies from passive scientific observation of the spectrum depends on scientists having continued access to interference-free spectrum. More directly, the underlying science undertaken by the observers cannot be performed without access to interference-free spectrum. Loss of such access constitutes a loss for the scientific and cultural heritage of all people, as well as for the practical civil and military applications from the information learned and the technologies developed.

In regard to the NOI's examination of the objective of modernizing spectrum management, CORF notes that RAS and EESS practitioners are actively developing techniques to improve excision of interference in time, frequency, and angle domains--efforts requiring more detailed monitoring and identification of sources of interference made possible by the relentless advance of modern electronics. Many such improvements are being incorporated in new and upgraded RAS facilities and new EESS missions.

The RAS community is in the process of significantly modernizing its facilities and improving its techniques. A new telescope facility, the National Radio Astronomy Observatory Green Bank Telescope in West Virginia, has recently been built, and an old facility, the National Ionosphere Center Arecibo telescope in Puerto Rico, has been upgraded. The Very Large Array in New Mexico is now being upgraded, and an extension that includes new array sites is planned. The California Array for Millimeter Astronomy is scheduled for completion in 2005, and the Allen Telescope Array in 2006. The Low Frequency Array and the Frequency Agile Solar Radiotelescope are being designed, and the Square Kilometer Array is being planned for the next decade.

Similarly, several EESS missions are under development to address important science and operational needs. Of note for spectrum management are two of NASA's Earth System Science Pathfinder (ESSP) missions--HYDROS and Aquarius--as well as the European Space Agency's Soil Moisture Ocean Salinity (SMOS) mission. These missions support two important objectives in Earth science: (1) measurement of soil moisture to more fully understand changes in water cycling and (2) measurement of sea surface salinity to understand the variability of ocean circulation on interannual, decadal, and longer time scales. These science objectives are achieved through global measurements of Earth's microwave brightness from space, which rely heavily on the availability of uncontaminated radio frequency spectrum near 1.4 GHz for passive observations on a global basis over land and oceans. Also of note are the Conical

Scanning Microwave Imager and Sounder (CMIS) and the Advanced Technology Microwave Sounder (ATMS) that will orbit aboard the National Polar-orbiting Operational Environmental Satellite System (NPOESS); CMIS is funded by the Integrated Program Office, which is staffed by personnel from the Department of Defense and the Department of Commerce/NOAA, and the ATMS is under development by NASA for NPOESS.

II. Response to Specific Questions

CORF responds below to specific questions raised by the NTIA:

4. The table of allocations divides the spectrum into various categories: government exclusive, non-government exclusive, and shared. Are the current exclusive allocations justified?

The Radio Astronomy Service and the Earth Exploration Satellite Service make passive (receive-only) use of the radio spectrum for much of their scientific research. The signals they detect are extremely faint, less than a trillionth of a watt in the case of the RAS, and thus are very vulnerable to man-made interference. The exclusive government allocations for the RAS and the EESS serve the essential purpose of protecting these bands from man-made interference and are thus fully justified. Passive use is *not non-use*, even though no signals would be detected in these bands by ordinary receivers. It is essential that these bands remain protected for our own use and that of future generations in as pristine and natural a state as possible.

8. Should the U.S. spectrum management system include long-range planning activities by NTIA, the FCC, and other Federal agencies?

Structures for spectrum management planning for the sciences are already in place, and it is extremely important to maintain them and to improve them where necessary. Because the spectrum needs and regulatory procedures are complex, communication of future directions both within federally supported scientific services and between the scientific services and federal spectrum management agencies is essential.

CORF has an important role in U.S. spectrum management and policy development for the scientific services. Representing the interests of U.S. scientists who use radio frequencies for research--for example, radio astronomers and remote sensing researchers--CORF files comments under the aegis of the National Academy of Sciences in public proceedings of the Federal Communications Commission (FCC) that involve radio-frequency requirements and interference protection. CORF also acts as a channel for representing the interests of U.S. scientists in the work of the Inter-Union Commission on Frequency Allocations for Radio Astronomy and Space Science (IUCAF) of the International Council of Scientific Unions and in working groups of the Radiocommunication Sector of the International Telecommunication Union (ITU).

CORF meets regularly to discuss the needs of the RAS and the EESS. The open portion of its annual meeting is regularly attended by representatives of many agencies involved with spectrum use and management. The National Science Foundation spectrum management activity in the Astronomy Program of the Mathematics and Physical Sciences Division is of particular importance to the RAS. RAS and EESS practitioners involved with Working Party 7C and 7D of the ITU also play a key role in protecting spectrum uses. International standards are essential. The RAS operates interferometer facilities that span the globe, and the EESS makes observations that survey the global climate.

9. NTIA seeks comment on whether the current long-range spectrum-planning mechanisms in place at the NTIA, the FCC, and the ITU provide appropriate assurances to consumers, service providers, and government institutions that sufficient spectrum will be available to satisfy projected requirements.

The electromagnetic spectrum is an extraordinarily valuable, shared resource. The remarkable degree of participation and eventual agreement as to how it is used, based ultimately on individual countries adhering to ITU regulations and recommendations, is a measure of those countries' enlightened self-interest. CORF strongly supports the current practices of spectrum management and coordination by the ITU.

10. Efficiency has been defined in a number of ways, e.g., technical efficiency (bandwidth, frequency reuse, geographical coverage, etc.), economic efficiency (revenue, profit, added value, etc.), and functional efficiency (reliability, quality, ease of use, etc). Depending on the balance of these types of efficiency metrics, there could be different benefits to users, taxpayers, various stakeholders, the economy, and society. NTIA seeks comment on the definitions of these terms and how they may be used in developing spectrum policy.

11. Considering these economic, technical, and functional metrics, how should the term "spectrum efficiency" be defined to provide useful tools in managing the spectrum resource? What metrics can be used to apply the definition?

A critical principle in CORF's views on the ongoing spectrum policy review is that "passive use" does not mean "non-use." Based on this principle CORF addresses technical efficiency further in response to queries 12 and 24 below. There is only one universe for the RAS to study, and interference-free use of the electromagnetic spectrum is the central means of observation. What would be the cost of interference impeding a scientist from observing phenomena so deep in space and time that the principles resulting in the creation of the universe are finally explained? CORF does not know how to measure the economic loss in such a case, but the cultural and scientific loss would certainly be immense.

Remote sensing by the EESS of the land, oceans, and atmosphere requires the measurement of natural emissions uncorrupted by man-made communication signals. This cost-effective data collection is used for programs involved in research and operational meteorology, climatology, and the study of the environment by both civilian and military users. The data are essential in national and international environmental policy development.

In summary, only with protection from such interference can scientists use the spectrum allocated to them efficiently. The necessary levels of interference protection for the RAS and the EESS are discussed below. CORF urges the NTIA and the FCC to be cautious in balancing short-term economic gains against long-term shifts in policy.

A detrimental interference level for RAS observations was established decades ago within the ITU-R RA.769. This level is 10^{-24} W m^{-2} Hz^{-1} (10 GHz), which translates to 6 x 10^{-5} K for isotropic reception. This ultra-low level reflects the extreme sensitivity of the large radio telescopes that employ the most sensitive receivers ever constructed and use long integration times.

Radio astronomy is conducted at relatively few sites around the nation, and it is at these sites where interference levels are critical. Radio quiet and coordination zones around the often remote sites are essential. Along with this geographic protection, the concept of "good neighbors" in frequency allocations (e.g., separating passive bands from those services most likely to cause harmful interference and where sharing of bands is required, compatible services such as sharing with medical imaging) aids the RAS uses of the spectrum most efficiently for basic research.

In the EESS standard, ITU-R SA.1029, the harmful interference level is approximately 10^{-3} K. While the level is higher than that for the RAS, the region of use is global--urban, rural, and over the sea.

12. What incentives or changes in policy should be imposed on the Federal and private sector spectrum users or potential users to use the spectrum more effectively and efficiently?

24. Discussions on efficient use of the spectrum may focus on receiver performance standards. Most spectrum uses involve at least one electromagnetic emission and at least one receiver/detector to recover the information contained in the emission. In activities such as radio astronomy and a variety of "electromagnetic" sensing activities (such as those of the National Aeronautics and Space Administration and Department of Commerce), only the receivers can be controlled because the emissions come from nature or space. In most other spectrum uses, the opportunity exists for controlling, through design, the operational performance of both the receiver and the emitter. NTIA seeks comments on how receiver performance standards can be employed to increase spectrum efficiency and minimize harmful interference.

The question of what constitutes efficient use of the radio spectrum arises several times in the NOI, in particular in questions 6, 10, 11, 12, and 24. In general, efficient use involves transmission of important information using a minimum spectral bandwidth, since the *active* use of the same spectrum by other services within the same geographic region is thereby limited or denied. In the case of *passive* services, efficient use of the allocated bands requires simply that these bands be free from wanted and/or unwanted transmissions of other services down to a level that allows the passive services to operate at the limits of sensitivity set only by the intrinsic noise levels of their instruments. In most cases it is *unwanted* (out-of-band and spurious) emissions falling within RAS and EESS bands that result in interference to passive services. Thus CORF emphasizes that in judging the spectral efficiency of an active service, it is essential to take account of how well the service avoids causing any deterioration of the spectrum outside its allocated band, in addition to how well it makes use of its allocated spectrum.   Improvements in receivers (question 24) cannot in most cases protect against interference that falls within bands used by passive services, but recent developments, for example, in the use of digital filters, are being used to maximize the efficiency with which radio astronomy receivers reject signals in adjacent bands.

Measurement of unwanted emissions within a passive band, at the threshold levels of power spectral density that result in detrimental loss in sensitivity of the passive services, is necessarily difficult. The threshold levels are those that result in responses at some fraction (typically 1/10) of the rms noise (power) fluctuations at the output of a radio astronomy receiver after averaging of the detected output voltage for a time interval of typically 2000 s. In radio astronomy, the threshold levels are specified with respect to reception of the interference through antenna sidelobes of gain 0 dBi. To obtain a reliable measurement of interference at the threshold level, it is necessary to use a high-gain antenna pointed toward the source of interference, or else to make measurements at a closer distance to the transmitter than would actually occur in operation. In the case of satellites in orbit, measurements can be made only at a distance, and the motion of many satellites across the sky is faster than can be followed by the large antennas typically used in radio astronomy. Thus CORF believes that an important step toward improving efficient use of the spectrum would be to require that satellites be tested for unwanted emissions before being launched. Similarly, unlicensed devices should be tested in the laboratory for unwanted emissions before such devices are released for use in the field.

An alternate approach to improving efficient use of the spectrum that is currently in development is the use of spread spectrum transmission, a technique that does not minimize the bandwidth per transmission, but rather potentially allows multiple uses of the same swath of spectrum through coding/decoding. While the transmitted signals may approach random noise and hence behave like small increases to the natural background noise, at the levels measured by the RAS such signals will remain interference owing to their unsteadiness during long integration times as a result of both the transmissions themselves and the reception gain in the direction of the transmissions. Time domain sharing is another approach to efficient spectrum use (reuse). Both the RAS and the EESS have some experience with time domain sharing--they regularly make use of unallocated spectrum by employing excision techniques at unscheduled opportunities (EESS and RAS) and via informal arrangements with geographic neighbors (RAS). Formal efforts for strictly defined time-sharing have been plagued with practical difficulties.

17. Should NTIA establish a pilot secondary lease program whereby the Federal government can lease temporary and/or preemptable access to Federal government spectrum to non-government users?

Although CORF takes no position on secondary lease programs for portions of the spectrum not used for scientific research, it does have great concern about secondary leasing of spectrum primarily allocated for passive scientific use. Their unique sensitivity makes receivers used for radio astronomy and Earth science extremely vulnerable to interference if the "secondary" user continues transmission when it is prohibited. While the leasing of scientific spectrum for unlicensed mass-market services would present the greatest danger, CORF also knows of no precedent at this time for the successful secondary leasing of spectrum primarily allocated for passive scientific observation.

33. What policy reforms are needed to satisfy spectrum access, interoperability, and interference protection requirements?

To enhance the ability of scientific observers to fully use the spectrum that has been primarily allocated for passive research, both spectrum allocations and service rules must recognize the vulnerability of passive scientific observation to out-of-band and spurious emissions from neighboring services. As noted above, given the unique sensitivity of the receivers used for RAS and EESS observations, such instruments are extremely vulnerable to harmful interference. Thus, in allocating spectrum for new services, care must be taken to avoid, wherever possible, placing services that have the greatest likelihood of causing harmful interference next to passive science bands. Examples of such unwise allocations would be the allocation of satellite downlinks in frequencies adjacent to bands allocated for radio astronomy, and allocation of satellite uplinks in frequencies adjacent to bands allocated for the EESS. Similarly, in drafting service rules for services such as satellite uplinks and downlinks, or unlicensed terrestrial devices, the FCC and the NTIA should be mindful of international standards for measuring harmful interference to passive scientific users, such as ITU-R RA.769 for the RAS, and ITU-R SA.1029 for the EESS.

III. Concluding Remarks

In summary, CORF emphasizes that scientific uses of the spectrum--for exploration of the universe by the RAS and for understanding and predicting Earth's climate by the EESS--are mainly passive uses. In protected as well as shared bands scientific use requires access to natural emissions in the electromagnetic spectrum in a pristine state that is not corrupted by man-made communication signals. CORF emphasizes that *passive use does not mean non-use*. At the time of a measurement, there are simple metrics for conditions that enable these scientific uses: the temperature levels implicit in ITU-R RA.769 for the RAS and ITU-R SA.1029 for the EESS. These uses are geographically limited in the case of the RAS and are global for the EESS. Protection of scientific access to pristine spectrum is critical--in protected frequency bands and in protected locations (radio quiet and coordination zones) scientists seek measurements of the natural state of the electromagnetic spectrum, now and for generations to come.

Respectfully submitted,

_____/S/______________
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[1] A roster of the committee is attached.