Before the
UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL TELECOMMUNICATIONS & INFORMATION ADMINISTRATION
Washington, DC

In the Matter of	)	
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Spectrum Monitoring Pilot Program	)	Docket No. 130809703-3703-01
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Notice of Inquiry	)	
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COMMENTS BY ICF INTERNATIONAL

ICF International applauds NTIA for its efforts to evaluate spectrum sharing approaches to support the continued growth in demand for spectrum for commercial wireless services, unlicensed devices, and government operations. NTIA's initiative for a pilot program to monitor spectrum usage in ten metropolitan cities to identify relocation or spectrum sharing opportunities will enable greater utilization and efficiency for spectrum sharing across a variety of different networks in the same geographic area. By using advanced data gathering and analysis techniques which focus on the nature and extent of actual spectrum usage, NTIA can develop guidelines, assess technologies, and define opportunities to increase spectrum utilization while protecting key government operations.

1. ICF International Background

Since 1969, ICF International (ICF) has been serving government at all levels, major corporations, and multilateral institutions. With more than 4,500 employees worldwide, we bring deep domain expertise, problem-solving capabilities, and a results-driven approach to deliver strategic value across the lifecycle of client programs. ICF has been involved with America's broadband issues for the last eight years. ICF's Broadband practice helps communities, governments, non-profits, and businesses leverage broadband infrastructure to meet community goals, including public safety, while improving the quality of life for residents. ICF staff members have completed broadband feasibility studies and broadband network designs for fiber to the premise (FTTP), cable, wireless, LTE, WiMAX, satellite, and combined solutions for communities throughout the U.S. In addition, expertise in Universal Service Fund (USF) programs and ongoing support to the United States Department of Agriculture (USDA) Rural Utilities Service (RUS) American Recovery and Reinvestment Act (ARRA) Broadband Initiatives Program (BIP) provide clients with in depth broadband planning and analysis.

In addition to our planning and analysis consulting services, ICF's Broadband practice has developed and refined a spectrum monitoring system that identifies and characterizes wireless signals over large geographic areas or various observation periods of time. Our automation algorithms are used in characterizing spectrum usage, locating transmission sources, and identifying interference.

2. Summary of ICF International Comments on Spectrum Monitoring Pilot Program

The Notice of Inquiry requests information on the proposed pilot program measurement system features. ICF recommends NTIA consider several features be incorporated into the Spectrum Monitoring Pilot Program. First, we recommend that the monitoring system incorporate a combination of stationary and non-stationary signal capture devices. This will enable NTIA to gather data from a broader geographic perspective on what signals are present in which parts of the spectrum. Second, we recommend that the non-stationary collection devices not be limited to a particular collection method (e.g. ground vehicle, airborne, etc.). Third, we recommend NTIA consider gathering full-bandwidth spectrum recordings. By recording the spectrum of selected bands, much more information is available compared to a parametric monitoring station. Spectrum recording also has the advantage of preserving the recorded signals in full fidelity that allow deeper signals analysis, and in many cases, full signal decoding. Fourth, the spectrum recording technique should be combined with automated spectrum data processing. This processing capability should not only determine spectrum occupancy, but also extract and identify signal types, determine the location of the transmission, and the party that is transmitting without requiring *a priori* knowledge of the signal format.

3. ICF International Comments on Specific Questions in the Spectrum Monitoring NOI

1. How should a measurement system be designed to measure a variety of emissions, including weak or intermittent signals, airborne platforms, and radar systems, while keeping incremental costs in check?

ICF recommends that NTIA design a system that does not solely rely on parametric measurements but includes the gathering of recorded spectrum data to enable robust post-processing and analysis beyond the initial data acquisition.

Spectrum recording together with an automated, post-processing software that captures, identifies, and extracts any type of signal that is present in the spectrum will enhance the value of the pilot program. Recording of spectrum, rather than sampling the signal strength, preserves the signal characteristics for simple yet precise analysis and signal characterization. This is particularly useful when there are emissions to be measured which have widely varying signal strengths and other signal characteristics for which the measurement device has no *a priori* knowledge. Multiple signal extraction algorithms can be run against the recordings to find short-duration pulsed signals such as radar pulses. This recording technique is also well suited to capture and catalog intermittently transmitted signals.

For profiling signals over a large geographic area that have a high degree of temporal correlation, a stable, proven airborne spectrum recording platform operating at low altitude (1000-3000 ft.) provides a means to cost effectively gather data. A large geographic area can be covered in a short period of time for a very low cost. This is an excellent alternative to a mobile "drive testing" platform which can be time consuming and limited to capturing signals near roads. Furthermore, spectrum recordings from an airborne platform are not hindered or obscured by signal attenuation or reflections from objects near ground level such as buildings, hills, and trees. Airborne testing can

provide more geographic area data for less cost than the cost of drive testing and is unhindered by the availability of roads and highways.

2. What types of measurement/ monitoring techniques should be used for the different types of radio services?

ICF recommends that NTIA use a spectrum recording technique to capture all signals, regardless of the radio service. The capture bandwidth should be at least 100MHz, sample rates of 150Msps or greater, with a spurious free dynamic range (SFDR) of 75 dB or better. The system should be capable of measuring all frequencies between 1 MHz and 6 GHz. This is further described in the above Narrative Comments and response to Question 1.

3. What frequency bands should initially be measured during the pilot phase of the program?

ICF recommends that several frequency bands be measured initially during the pilot phase of the program. First, we recommend examining spectrum that has already had re-purposing/sharing activities. Second, we recommend examining bands that could be re-purposed or shared:

- A spectrum recording survey of TV white space deployments should be made in order to validate the contents of the databases. If the "spectrum management via databases" concept is to be deployed, it would be necessary to validate the contents of the existing databases, providing answers such as the extent to which the TV white space is being used and what types of signals are employed to provide services. Using an airborne spectrum recording platform can provide data for a large area, which will benefit the pilot program, since many of these spectrum services are targeted for areas outside of city centers. Also, data could be collected for multiple neighboring markets during a single airborne campaign.

- Other bands that should be examined include some those identified in the NTIA Fast Track Evaluation of October 2010[1]:
  - 1695-1710 MHz
  - 1755-1850 MHz (key focus on 1755-1780 MHz band which is targeted for one of the first auctions, better harmonization with 3GPP band class 10)
  - 3550 – 3650 MHz

In order to determine how wireless broadband systems could share with incumbent radio systems, it would be instructive to record spectrum in occupied commercial bands such as AWS-1, 700 MHz, and Broadband PCS.

4. How should measurement and monitoring parameters (*e.g.,* resolution and video bandwidths, sampling rate, dwell time, detector selection, antennas, pre-selector filtering, dynamic range) be specified?

ICF recommends using spectrum recording in the Spectrum Monitoring Pilot Program, in addition parametric monitoring stations. Using recording, concepts such as resolution bandwidth do not need to be determined in advance. Full-bandwidth recordings can be processed time and again using different filter coefficients. Also, capture bandwidths over 100 MHz can be used, with high sampling rates that preserve the signals in full fidelity. Within the capture bandwidth, the dwell time is effectively infinite, since a recording is being made, rather than measurements of signal parameters. Switched filter banks and electrically tunable filters can be used to manage band pre-selection dynamically and can improve performance significantly.

[1] http://www.ntia.doc.gov/files/ntia/publications/fasttrackevaluation_11152010.pdf

5. Which geographic locations within major metropolitan areas or other communities throughout the country would provide the greatest value for the pilot?

ICF recommends that NTIA consider the following types of geographic areas monitored in the pilot program:

- Areas with known incumbent radio activity in band(s) under study
- International Border regions
- Areas around military bases where incumbent radio systems are known to be in use
- Exclusion-type zones and surrounding areas identified/proposed in FCC Notice of Proposed Rulemakings (NPRMs), such as 3.5 GHz band, and in committees such as NTIA Commerce Spectrum Management Advisory Committee (CSMAC)
- Transportation corridors
- Major cities, together with their suburbs and exurbs
- Key areas where people gather such as shopping areas, business parks, and airports.

6. How should individual measurement units be deployed in each community?

ICF recommends a combination of fixed monitoring locations and wide geographic area low-altitude airborne spectrum monitoring collections. The fixed locations should be in geographic areas of where there is known spectral activity in the band under study. Since expanding a fixed ground system over a large area would increase deployment and operations costs exponentially, the program should be supplemented with wide area spectrum measurement and characterization studies. Employing a mobile platform to obtain wide area measurements can be used to identify specific locations that would benefit from further study with fixed monitoring spectrum equipment.

7. How could the long- or short-term placement of multiple fixed units within the same general geographic area improve the accuracy and reliability of the data collected in each community and at what incremental cost?

ICF recognizes the benefit of collecting spectrum data from multiple geographic locations. It is possible to capture signals present at one location, but not present at others. Measurements from multiple locations also facilitate the geolocation of the transmitter. Long term placement will provide NTIA with time-based data but the incremental cost is high for additional terrestrial fixed units and expands nonlinearly with larger study areas, especially if terrain and ground clutter are nontrivial. Each location requires its own measurement unit, and carries with it the burden of maintenance, repair, signal collection, and adds significantly to data processing system complexity.

An alternative to multiple terrestrial fixed units with similar benefits is collection from an airborne collection platform. This method collects spectrum information from multiple locations within a very short span of time, giving the benefits of measuring across a large geographic area, hidden node identification, and ability to geolocate transmitters. An airborne platform implicitly has the advantage of being self-synchronized and has a view of all signals from the air, without obstruction by buildings, hills, or trees. Given the amount of area that can be measured by such a system, the overall cost of deployment of an airborne platform can be significantly lower than even a few dozen fixed units.

8. How could mobile or portable units be utilized to supplement data collected at fixed sites within a community and at what incremental cost?

While ICF recommends a mobile platform, and based on its practical experience in this area, ground-based mobile systems are of very limited practical value for this program's objectives, and likely not cost effective. This is evidenced by recognizing that although vehicular measurement collection is used by existing wireless operators today, it is not used to assess general signal conditions over large bandwidths or random non-cellular telecommunications protocols. Please also see answer to question 7.

9. How long should measurement data be collected to provide statistically relevant results, particularly for intermittent operations, at each geographic location?

The spectrum utilization landscape will profile differently based on region, time of day, season, population density and demographic, and will present challenges for a single definition. In dense urban areas with stable populations and an even mix of commercial and residential areas, spectrum utilization will vary based on time of day, day of the week and seasonality, but the network loads should remain fairly predictable. The frequency of monitoring intervals could be weekly, bi-weekly or monthly. As areas become increasingly rural, band utilization may well be far more dynamic and spectrally sparse. As the monitoring program matures, resources can be tuned to better meet the local conditions.

10. How should the measurement system design take into account variations in population densities, buildings, terrain and other factors within or surrounding selected measurement locations (*i.e.,* in urban, Suburban, and rural parts of a metropolitan area)?

Population densities will effect overall spectrum utilization, whereas dynamics such as diurnal and seasonal fluctuations will affect channel utilization efficiency at any point in time. For many applications, bandwidth demand will follow population movements as much as generalized

population densities. Fixed-location systems may well track local utilization and efficiency but will need to be quite expansive in areas where the populace is highly mobile or is seasonally driven. As areas become increasingly rural, fixed location monitoring costs can multiply significantly and become cost-prohibitive to study. Road systems are often ill-suited to efficiently monitor large suburban or rural areas. Airborne platforms operating from reasonably low altitude can monitor conditions in areas as small as a few square miles or as large as several hundred. In terms of covering large rural areas, or those that require monitoring that are not accessible by roads, such as border areas, an airborne platform offers a cost effective method to obtain relevant spectral data without being cost-prohibitive.

11. What steps can be taken to eliminate or minimize the possibility of ''hidden nodes'' when conducting measurements?

Aerially based spectrum recording measurements provide an unobstructed view of all transmitting devices across a wide geographic area. The aerial measurements would be able to measure and locate signals that would be obstructed while propagating toward a fixed ground-based measurement location. When using aerial based data collection, the power profile is not corrupted by refraction or diffraction which occurs for ground based measurement due to ground clutter. While it is sometimes assumed that transmissions would not be detectable from such a position, the unobstructed propagation distance of 1000-3000 feet is quite reasonable even for relatively low power transmissions.

Aerial based measurements provide multiple power measurement of transmitting source to determine relative power over a wide area to locate hidden node by using signal strength, time difference of arrival, and angle of arrival.

12. What kind of spectrum utilization and occupancy information (*e.g.,* precise received field strength levels, time-of day occupancy percentages, times that signals are measured above specified thresholds) would be most useful to spectrum stakeholders?

Classifying signals by protocol type, spectrum utilization, operator, power given in terms relevant to the protocol, point of transmission, and sector information would prove useful for bands whose signals can be so classified, such as those used for cellular communications. Other bands, such as ISM, may benefit from different metrics. Our experience has shown that given the wide dispersion of sources in these bands and privacy concerns, it may be better to register overall signal power in dBm/Hz per channel. Utilization in these bands is anticipated to be fairly constant given the nature of these systems, allowing for regular measurements done over large areas relatively infrequently, perhaps every few months.

13. What detection thresholds should be used to measure and characterize the usage patterns of incumbent systems?

ICF recommends that a spectrum recording technique be used in the Spectrum Monitoring Pilot Program. Rather than simply setting detection thresholds, the signatures of the incumbent signals can be identified, characterized, and then measured. The ability to identify the incumbent signal type should play into the answer of whether or not the signal is indicated as present. This can be done via the spectrum recording technique and would eliminate the need to arbitrarily choose a resolution bandwidth and other measurement parameters.

14. What data and information would be useful in evaluating potential sharing compatibility with wireless broadband devices?

Recording exact spectrum scenarios and signals as they exist in their "native environment" is useful to determine the conditions under which incumbent and new entrant signals can coexist. This includes determining signal characteristics such as modulation format, rise/fall times, etc.

The recorded signals that must coexist can be played back simultaneously with the ability to vary amplitude and other transmission parameters. The amount of degradation to each signal can be examined by using metrics such as error vector magnitude (EVM), modulation error ratio (MER), carrier to noise and interference ratio (CINR), etc. This information can be used to determine the conditions under which the signals can properly coexist.

15. How can the gathered data and analysis better inform spectrum policy decisions, enhance research and development of advanced wireless technologies and services?

In addition to measuring general spectrum occupancy conditions, ICF recommends that NTIA consider characterizing signal protocols, coupled with an understanding of the geographic distribution of the transmitters versus population and terrain. Some spectrum may be fully occupied but chronically congested owing to the use of older technologies or minimalist deployment scenarios. Without a detailed understanding of the underlying facts, solutions such as setting requirements for equipment upgrades to make more efficient use of existing spectrum may well be missed. Without such knowledge, bandwidth may get reclaimed from other legitimate users unnecessarily, or opportunities to use spectrum for innovative technologies may be severely limited or completely restricted.

As discussed in question 15, the data and analysis gathered from the Spectrum Monitoring Pilot Project could be used to see exactly how incumbent and wireless broadband signals could coexist.

16. What data formats and evaluation tools should be employed?

NTIA should consider using industry standard database formats such as geospatially aware SQL in the pilot program. Database formats should prioritize conserving storage space rather than focusing on a human-readable format such as text.

17. How can the large amounts of measurement data be effectively managed, stored, and distributed?

ICF recommends NTIA utilize several specific strategies for data management and distribution. Large spectrum recording files can be pre-processed packaged for general viewing and qualitative analyses. For example, full animations of 100 MHz of recorded spectrum can be played in as little as several hundred kilobits per second (kbps) with the same screen resolution and scale accuracy as any modern signal analyzer. Post-processing of recorded files can fit easily into relational databases, both with and without spatial engines. These allow for easy and straightforward management. Files depicting geographic shapes, animations showing spectrogram data, power spectrum data, and channel broadcast information can be easily stored, replicated and transmitted via the internet. Using these techniques, it is possible to allow certain users to re-process the recorded data to see different filtering and frequency spans in specific time intervals. For those with a demonstrated need, raw IQ files could be made available, wherein users could fully characterize individual transmission down to the symbol level.

Respectfully Submitted,

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