NEW AMERICA FOUNDATION

Working Paper #25 *June 2009*

The End of Spectrum 'Scarcity':
Building on the TV Bands Database to Access Unused Public Airwaves

*By Michael Calabrese**

I. INTRODUCTION AND SUMMARY

Wireless is the most cost-effective and rapid means to bring broadband access to under-served rural and urban residents. Even after high-capacity Internet access becomes universal, wireless remains as the complementary infrastructure needed to achieve the larger goal of *pervasive connectivity*. Within a few short years, most Americans are likely to spend more hours each week on mobile than on wired Internet connections. Demand for spectrum will outpace availability under current spectrum management policies. Meanwhile, in every community across the country, large swaths of valuable spectrum lie fallow the majority of the time. This underutilized spectrum represents enormous, untapped, public capacity for high-speed and pervasive broadband connectivity. Therefore it is vital to a national broadband plan to consider policies that will encourage more intensive and efficient use of the nation's spectrum resources.

The gross underutilization of the nation's spectrum resource should be an urgent concern for national broadband policy. Spectrum is not only an immensely valuable and publicly-owned resource, but one that is infinitely renewable. It is indisputable that a variety of spectrum management tools (e.g., building on the forthcoming TV Bands Database) and "smart radio" technologies (e.g., geolocation, sensing and dynamic frequency selection) will support dynamic, shared use of a large number of federal and non-federal bands with little risk of interference to incumbents.

This paper recommends that the Obama administration and the FCC make mapping and actively facilitating opportunistic access to unused and underutilized frequency bands a priority as part of any national broadband policy. Unlocking the "vast wasteland" of unused spectrum capacity can be achieved through three overlapping steps:

First, under a White House-led initiative, the NTIA and FCC should conduct an Inventory of the Airwaves that maps how our public spectrum resource is being utilized or underutilized in various bands, by both commercial and government users. Actual spectrum measurement data should be included. The Commission could draw upon funding from the American Recovery and Reinvestment Act to map this vital component of the nation's basic broadband capabilities.

Second, while spectrum mapping will greatly facilitate the identification of bands that can be reallocated for more intensive and efficient use, the process of unlocking unused spectrum capacity should begin immediately on a band-by-band basis. The most promising mechanism is to build on the TV Bands Database that will be certified by the FCC as a means of authorizing unlicensed access to va-

Michael Calabrese is the Director of the New America Foundation's Wireless Future Program. He can be contacted at calabrese@newamerica.net.

cant TV channels ('white space') on a market-by-market basis. There is no reason to limit the functionality of the TV Bands Database to the TV band frequencies. If a potentially useful frequency band is not being used at particular locations (e.g., in New York City but not in West Virginia), or is being used only at certain times, or at certain altitudes or angles of reception, then that currently wasted spectrum capacity could at a minimum be listed in the Database for opportunistic access, subject to whatever power limits or other conditions would be necessary to avoid harmful interference with sensitive incumbent operations.

Third, NTIA and FCC should commence a set of inquiries into the technologies, incentives, institutional arrangements and "rules of the road" that can best facilitate a future of more open, intensive and opportunistic sharing of the nation's spectrum resource. For example, incentives to encourage the sharing of unused capacity by both federal agencies and private sector licensees (such as device certification fees and/or real-time auctions to avoid congestion) should be explicitly studied and debated. In the near term, we believe that Congress and/or the administration need to adopt a policy that federal agency communication systems will be designed to actively facilitate spectrum sharing with the private sector, moving beyond today's passive sharing limited mainly to radar bands. In addition, ultimate authority for federal spectrum policy coordination should be brought back into the White House, so that the nation's overall interests can be better considered and coordinated.

II. SPECTRUM IS ABUNDANT, IF ONLY CITIZENS COULD USE IT

A national goal of not merely affordable broadband access, but of truly pervasive connectivity – with seamless and mobile connectivity anywhere and anytime – will require an enormous increase in available spectrum capacity.[1] As a leading indicator of latent demand for mobile connectivity, the iPhone may be the canary in the spectrum coal mine. According to Nielsen research, the average iPhone user is consuming about 400 megabytes of capacity each month, at least five times the average smartphone user.[2] The launch of higher-capacity 4th Generation (4G) mobile data services next year will accelerate this trend. WiFi and other unlicensed applications are exploding as well – and will continue to rapidly increase as mobile carriers begin to allow WiFi connectivity as an option on devices.

Despite the Commission's acknowledgment that traditional "command and control" spectrum management is outdated and inefficient;[3] the federal government has continued to approach spectrum allocation in a piecemeal fashion that reinforces the conventional wisdom that spectrum is a scare resource that needs to be centrally managed. The reality is that it is only government permission to use spectrum (licenses) that is scarce. Spectrum capacity itself is abundant. Indeed, while actual spectrum measurement studies are difficult to find, those in the public domain have demonstrated that even in the so-called "beachfront" frequencies below 3 GHz, the vast majority of frequency bands are not being used in most locations and at most times.

The gross underutilization of the nation's spectrum resource should be an urgent concern for national broadband policy. Spectrum is not only an immensely valuable and publicly-owned resource, but one that is infinitely renewable: every millisecond that a frequency band is not used for communication, that capacity is wasted forever. In that respect, when former FCC Chairman Newt Minow famously called television a "vast wasteland," he could have been describing more literally the nation's spectrum resource under the prevailing exclusive zoning (licensing) system.

In spectrum measurement studies for the New America Foundation (2003), and in a larger study funded by the National Science Foundation (2004), Mark McHenry, a former manager of DARPA's NeXt Generation spectrum program, found that even in Manhattan and in Washington D.C. near the White House, less than 20 percent of the frequency bands below 3 GHz were in use over the course of a business day.[4] McHenry's NSF study demonstrated in a mix of urban, suburban and exurban areas that the vast majority of the most valuable spectrum bands are vacant or unused for the majority of the time.[5] The highest occupancy rate on the prime beachfront spectrum below 3 GHz was just 13 percent in New York City, while the average across locations studied was just 6 percent. Across the country, this underutilized spectrum represents an enormous untapped capacity for broadband; particularly in rural areas where average usage of "beachfront" spectrum is in the low single digits.[6]

Nowhere is spectrum underutilization more evident than in many of the bands reserved for use by the federal government itself.[7] It is estimated that the federal government exclusively controls over 13 percent of all allocated spectrum bands and has primary access to shared bands comprising 56 percent of all other bands,.[8] Although federal data on which agencies control what spectrum is out of date and/or not available to the public, one NTIA chart estimates that 81.8 percent of the spectrum between 3MHz and 30MHz is allocated to the federal government.[9] Research by the New America Foundation estimated that federal government exclusive and shared bands account for 64 percent of all allocations below 3.1 GHz, which roughly aligns with the detailed spreadsheet inventory unofficially maintained by former FCC economist John Williams.[10]

Table 1. U.S. Spectrum Allocation Categories, 300-3000 MHz

Category	Fraction
Federal Government	22.4%
Non-Federal Government	34.7%
Shared: Fed Gov & Non-Fed Gov	34.7%
In transition from Federal to Non-Federal	2.5%
Unlicensed and Managed by FCC	5.6%

Source: John R. Williams, FCC, 2002

Federal government documents obtained under the Freedom of Information Act by the New America Foundation in 2004 and 2005 revealed a list of government agency frequency assignments that, with greater transparency and scrutiny, could prove to be reserving bands that could be opened for at least shared commercial use. One of the biggest blocks is found between 225 and 400 MHz, which "is devoted to military aircraft, tactical and training communications, satellite links for ground, air, surface and subsurface users, rocket test and telemetry, position location networks and presidential communications."[11] While the military maintains that the 225 – 400 MHz band is among the most critical spectrum bands for tactical air and training missions both at home and overseas, the McHenry measurements indicate that at least in the urban and suburban areas where most Americans live and communicate, the military is utilizing very little, if any of that capacity on most days and in most places. (McHenry's measurements showed activity on a maximum 3 percent of those 175 MHz in the six locations measured). Federal spectrum bands between 902 and 1850 MHz (particularly 1755 to 1850 MHz) and smaller bands at 108 – 174 and 400 – 450 MHz, appear similarly unused in most ar-

eas at most times, particularly in the more densely populated areas of the country with insufficient capacity for future demand for wireless broadband data services.

Table 2. Examples of Spectrum Allocated for Primary Use by Federal Agencies

108 – 121 MHz (Aeronautical Mobile and Radionavigation)
138 – 144 MHz (Fixed and Mobile)
225 – 399 MHz (Fixed and Mobile Air Navigation & Telemetry)
902 – 928 MHz (Radiolocation)
960 – 1215 MHz (Aeronautical Radionavigation)
1350 – 1390 MHz (Fixed, Mobile and Radiolocation)
1400 – 1427 MHz (Radio Astronomy)
1435 – 1525 MHz (Mobile Aeronautical telemetry)
1525 – 1559 MHz (Mobile-Satellite)
1559 – 1660 MHz (Mobile-Satellite, Radio Astronomy, and Radionavigation)
1675 – 1700 MHz (Meteorological Aids and Satellite)
1755 – 1850 MHz (Fixed, Mobile and Space Operation)
2200 – 2290 MHz (Space Operation, Satellite, Fixed and Mobile)
2700 – 2900 MHz (Aeronautical Radionavigation and Meteorological Aids)

Source: Manual of Regulation and Procedures for Federal Radio Frequency Management, NTIA January 2008

It is important to be clear that just because a frequency band is not fully or frequently utilized in a particular geographic area – which is what the McHenry/NSF spectrum measurements indicate – does not mean it is not serving its assigned purpose. Many military bands in particular are assigned for mission-critical training and emergency purposes that are episodic or geographically limited in nature. While in most cases "clearing" a band of its current licensee and reassigning it exclusively to private sector licensees could not be justified, there is nevertheless tremendous communications capacity that could be productively used at no cost or harm to the incumbent – just as the military today shares several radar bands with unlicensed users of low-power unlicensed devices.[12]

At the same time, even a band that would register as "occupied" over the course of a day or week may still have tremendous unused spectrum capacity. A band of frequencies can be 'white' (underutilized) and potentially shared on a number of different dimensions. Retired NTIA engineer Robert Matheson described seven dimensions that define the potential capacity of a given band of spectrum – and the potential for dynamic, or flexible, spectrum usage rights – as illustrated in Table 3 below:

Table 3. Electrospace Model: Dimensions of Spectrum Sharing[13]

Quantity	*Units*	*No. of Dimensions*
Frequency	kHz, MHz or GHz	1
Time	seconds, hours, months	1
Spatial Location	latitude, longitude, altitude	3
Angle of Arrival	azimuth, elevation angle	2

While this model describes what may be considered the theoretical potential for squeezing the maximum communications capacity out of a band of spectrum, it also highlights the inefficiency of today's two-dimensional spectrum "zoning" policies. Even without relying on the relatively expensive technologies required to share underutilized bands along many simultaneous directions, it is clear that with today's technology, a competent "inventory" of the airwaves would reveal sufficient data to allow policymakers to facilitate more efficient use of currently wasted spectrum capacity.

III. THREE STEPS TO ENDING SPECTRUM SCARCITY

Spectrum is infinitely renewable: every millisecond that a frequency band is not used for communication, that capacity is wasted forever. Yet antiquated spectrum policies continue to leave considerable amounts of spectrum unused or underutilized, while more efficient spectrum technology remains limited to just a few sporadic bands. In order to reverse this, the U.S. must begin a concerted effort to assess what spectrum resources are being used, how they are being used, and where there are opportunities to leverage opportunistic access to limit spectrum scarcity. As part of that effort, here are three important steps the U.S. government should pursue:

1. A comprehensive, transparent inventory of unused spectrum capacity,
2. Expand the TV bands 'white space' database to include additional bands, and,
3. Fresh inquiries into incentives, DSA technologies and institutional arrangements.

A. A Comprehensive, Transparent Inventory of Unused Spectrum Capacity

The best first step toward making substantially more spectrum capacity available for wireless broadband services and innovation is to determine and disclose how, where and when this publicly-owned resource is currently being used – or not used – by current public agency and private sector licensees. As New America recommended to the Obama transition team – and in comments filed in the FCC's Rural Broadband inquiry in February and in the more recent inquiry regarding a national broadband plan – the White House should lead a joint NTIA/FCC effort to undertake a comprehensive ***Inventory of the Airwaves*** that maps and makes publicly available how our public spectrum resource is being utilized or underutilized in at least the most valuable bands below 6 GHz.[14] The Commission and the public need to have a more complete, comprehensive inventory of what frequencies are *actually* in use, for what purpose, with what technology, at what locations, frequencies and times. Both government and private sector assignments and uses should be included in the map. Actual spectrum use measurements in a large and regionally diverse sampling of markets should be part of the Commission's broadband mapping exercise. As Dale Hatfield, former NTIA director and chairman of the Commerce Spectrum Management Advisory Committee, has observed, "the government cannot efficiently manage a resource it doesn't measure."

Spectrum mapping would help facilitate expanded access to broadband providers in at least three ways:

- First, more complete and transparent frequency-by-location data online will improve the functioning of secondary markets for spectrum license transfers and leasing.
- Second, it will provide information on what will be required to clear some heavily underutilized bands, so that they can be reassigned for commercial use.

- Third, it will reveal the far greater number of frequency bands that could be made available for opportunistic access in discrete geographic areas, at certain times of day or year, or at certain altitudes or directions of arrival (azimuth, elevation).

Rural areas would be the most likely and immediate beneficiaries of a mapping of the U.S. spectrum capabilities. Wireless remains the most cost-effective and rapid means by which to bring broadband access to rural residents. It will quickly become clear that particular frequency bands are either completely unused or grossly underutilized in many rural markets. A web-map of spectrum utilization on a localized basis (such as by Rural Service Area and Metropolitan Statistical Area) would provide the Commission or Congress with the information it needs to reallocate or at least to open frequencies for non-interfering use by rural broadband providers, as well as for wireless innovation more broadly.

It is critically important that spectrum mapping be adopted as a presidential initiative coordinated from the White House, most likely under the guidance of the President's Chief Technology Officer and in cooperation with the National Economic Council. In addition to signaling the importance of pervasive connectivity to the economy and American competitiveness, White House leadership is necessary to secure the full cooperation of departments and agencies across the government. While the NTIA and FCC are the essential co-partners in this effort – and show promising signs of being able to work in tandem under their respective new leaderships – it will be critical for the entire executive branch to respond to this initiative as a presidential broadband imperative.

It is also important that any federal spectrum mapping include actual and ongoing spectrum use measurements at a large and diverse sample of rural, urban and suburban locations around the nation. The NTIA did actual spectrum measurement studies in a number of locations in the mid-1990s, but virtually none in recent years. Indeed, one of the recommendations of the Presidential Task Force on spectrum policy in 2004 called for "spot compliance checks" and "signal measurement surveys" to check the accuracy of NTIA's records and provide the information needed to "evaluate the utility of underutilized spectrum."[15]

> To ensure that the current uses of radiocommunication systems are as efficient as possible . . . NTIA should evaluate all spectrum use by the federal government over a five-year period to determine spectrum efficiency and effectiveness. **The review should include spot compliance checks and signal measurement surveys to verify the accuracy of the records of the Government Master File (GMF), identify congestion and instances of duplicative operations that could be combined, and evaluate the utility of underutilized spectrum.** NTIA should use the results of these reviews in the development of new and improved spectrum management policies, and the Federal Strategic Spectrum Plan.[16]

Fortunately, Congress has already authorized and appropriated adequate resources to begin this mapping immediately. The American Recovery and Reinvestment Act authorizes funds for developing and maintaining "a comprehensive nationwide inventory map of *existing broadband service capability*" [italics added].[17] Just as fiber is the essential conduit for advanced wired connectivity, spectrum is the publicly owned conduit for wireless broadband. Spectrum is "wireless fiber" – the fundamental pipeline for wireless broadband service capability and we believe it would be in the public interest to have a clear and transparent mapping of those capabilities between 30 MHz and at least 6 GHz.

Another very positive development is bipartisan Congressional interest in mapping spectrum. On March 19, Senators John Kerry (D-MA) and Olympia Snowe (R-ME) introduced the Radio Spectrum Inventory Act, which directs NTIA and the FCC "to report on the use of all spectrum bands between 300 Megahertz and 3.5 Gigahertz, including information on the licenses or government user operating in each band, the total spectrum allocation of each licensee or government user, the number and types of radiators that have been deployed in each band, and contour maps illustrating signal coverage and strength."[18] Although the proposed bill would not map all of the most relevant and valuable spectrum bands that should be considered for opportunistic access, and appears to give federal agencies too much discretion to avoid disclosure of spectrum use at all related to national security, nonetheless the legislation is demonstrating increasing bipartisan support for a transparent accounting of spectrum underutilization.

B. Expand the TV Bands 'White Space' Database to Include Additional Bands

Although spectrum mapping would greatly facilitate the identification of bands that can be reallocated for more intensive and efficient use, the process of unlocking unused spectrum capacity should begin immediately on a band-by-band basis. It is indisputable that a variety of "smart radio" technologies (e.g., geolocation, sensing and dynamic frequency selection) and spectrum management tools (e.g., the forthcoming TV Bands Database) will support dynamic, shared use of a large number of federal and non-federal bands with little risk of interference to incumbents. This section highlights what is perhaps the most promising mechanism to facilitate the aggregation and accessibility of scores of underutilized bands on a market-by-market basis.

Access to today's most grossly underutilized spectrum could be facilitated on a band-by-band basis, in at least one of three general ways, each of which has a recent precedent:

- ***Reallocation: Clearing a Band and Relocating Incumbents***

If a band is sparsely populated by users that can be relocated at a reasonable cost to another workable band, then the FCC can clear and reallocate an entire band to new licensees or uses. The last two large-scale spectrum auctions were a result of band clearing: At 700 MHz, where TV channels 52-to-69 were cleared of local broadcast stations as part of the DTV transition; and the so-called AWS spectrum, where 45 MHz was cleared by relocating federal users to new spectrum.[19] However, the options for entirely clearing large bands of spectrum are extremely limited – and typically take five-to-ten years to complete.

- ***Overlay: Filling in Unoccupied 'White Space' Frequencies***

A second means to open underutilized capacity is to reallocate access to a band that is unoccupied in a particular geographic area. A prime example is the vacant frequencies between occupied (licensed) TV channels that came to be known as TV band "white space." These guard band and otherwise unassigned channels were reallocated by the FCC last November for shared, unlicensed use by relatively low-power fixed and mobile devices. The Educational Broadband Service at 2.5 GHz is another example of a band with substantial amounts of unassigned license areas sprinkled around the country, albeit primarily in rural areas. However, like band clearing, future opportunities to free up large, contiguous blocks of valuable spectrum for licensing seem very limited.

- ***Underlay: Sharing Underutilized Frequencies with a Primary User***

By far the largest amount of underutilized spectrum capacity available would involve sharing the same frequency band with incumbent services. This typically has occurred where the secondary user adopts technology that can "work around" the primary licensee without causing interference. For example, in 2004 the Department of Defense agreed to permit the sharing of the 5.25 – 5.35 and 5.47 – 5.725 GHz radar bands by unlicensed WiFi systems with the capability to scan, detect and rapidly hop off frequencies if a radar transmission is detected.[20] The incumbent licensee is typically passive, although in most cases bands could be shared more intensively if the incumbent took steps to actively facilitate band-sharing.[21]

Whatever approach is adopted, a band-by-band approach is necessary since issues concerning the incumbent users and avoiding interference with neighboring bands will be different. In some bands, Congress or the Commission may determine that it is feasible to relocate incumbent users to accommodate the reassignment of frequencies on an exclusively-licensed basis, as occurred with the 90 MHz of federal and broadcast auxiliary spectrum cleared under the Commercial Spectrum Enhancement Act of 2004, noted just above. In a far larger number of bands, where it is not practical to relocate current band users, or where that would likely take many years, spectrum capacity can be made available more rapidly by opening the bands to "opportunistic access" on a secondary basis that requires the user to avoid causing harmful interference with the incumbent use.

Building on the TV White Space Database

The most promising mechanism for making substantial new allocations of spectrum available for wireless broadband deployments and other innovation is to leverage the TV Bands Database, which the Commission's Office of Engineering and Technology will certify as means of identifying and accessing available "white space" channels not in use in discrete geographic locations across the nation's 210 local TV markets. Under the Report & Order adopted unanimously by the Commission last November,[22] both fixed and mobile broadband devices will be allowed to operate on an unlicensed basis on unused DTV channels ("white space") provided the devices have GPS and the capability to periodically check an online database of available TV channel frequencies in that discrete geographic location. TV band white space devices (WSDs) will be required to query a national database to determine available channels at their current location before transmit capabilities are engaged.

There appears to be no reason to limit the functionality of the TV Bands Database to the TV band frequencies – and no reason not to add more fallow bandwidth to the "common pool" that is parceled out via the TV white space geolocate and look-up system. If a potentially useful frequency band is not being used at particular locations (e.g., in New York City but not in West Virginia), or is being used only at certain times or at certain altitudes or angles of reception, then that currently wasted spectrum capacity could at a minimum be listed in the Database for opportunistic access, subject to whatever power limits or other conditions would be necessary to avoid harmful interference with sensitive incumbent operations.

The FCC's Office of Engineering and Technology proposed the feasibility of a geolocational database back in the original 2004 Notice of Proposed Rulemaking as one means of allowing unlicensed but non-interfering access to unassigned TV channel frequencies. After extended testing, that option was adopted unanimously by the Commission (although without excluding the possibility of certify-

ing systems relying exclusively on spectrum sensing and DFS, and not on geolocational database lookup, in the future). Under the Order, the TV Bands Database is likely to rely on a Repository Service (a data repository that contains information on all the Protected Entities – i.e., licensed users – as well as on the registered devices and systems seeking access to the band) and on one or more Query Services (which will refer to a daily or even real-time copy of the Database to give operators of devices and systems a list of channels available for use at their actual GPS coordinates).[23]

Although location and time are not the only dimensions along which underutilized frequency bands can be shared dynamically by "smart" radio technologies and protocols,[24] adding other bands to the TVWS Database could ultimately increase available spectrum capacity by hundreds of megahertz or more, particularly in rural areas where measured spectrum usage below 3 GHz is in the low single digits today.

The Commission's access rules for TV white space anticipates the use of frequency-hopping, multi-band radios, which is increasingly common and affordable in commercial mobile systems. Device makers and service providers would simply choose the combination of frequencies most appropriate to their needs. Devices (whether fixed access points or mobile handsets) would scan and select the clearest frequency from among those their equipment is tuned to utilize.

Both federal and non-federal bands should be added to the Database, with access to each band subject to conditions that are tailored to avoid harmful interference to existing, licensed use. For example, the ability to opportunistically share military radar bands is technically very different than sharing a band used primarily for fixed services, such as satellite or point-to-point microwave links, or a trunked land mobile radio system. One feature that facilitates the Pentagon's willingness to allow dynamic sharing of radar frequencies in the 5 GHz band, is that unlike television reception, for example, radar poses no "hidden node" challenge to spectrum sensing and Dynamic Frequency Selection technologies because the transmitter and receiver are co-located. In a fixed service band, by contrast, sensing may be less reliable than simply calculating the availability of frequencies in discrete locations based on the listing of protected transmit sites.

Kevin Werbach, a professor at the Wharton School and a former FCC technologist, suggests that "properly designed, this system [the TV Bands Database] could be the basis for a distributed dynamic routing database, analogous to the DNS (Domain Name System) on the wired Internet."[25] He also correctly observes that:

> To achieve such a result, however, the database must not be limited to White Space devices alone. The FCC and industry must also take care to avoid the mistakes and failings of the current DNS infrastructure. These include the imposition of artificial scarcities, the creation of a private monopolist, and the bureaucratization of technical management functions.

Bands reserved for federal agency use seem particularly well-suited for opportunistic access for a variety of reasons. Among these are that federal bands are at least nominally controlled by NTIA and, unlike a private sector licensee, the Department of Commerce and other federal users can be expected to balance their own needs with the public interest in expanding available wireless broadband capacity. The military in particular has both very wide bands of spectrum that are unused in most locations on most days – and the ability of enforce priority-in-use over opportunistic private sector users during

the occasional emergency that justifies reserving those bands. Indeed, the Department of Defense (DoD) has done exactly that in the past – opening up extensive military radar bands for passive sharing with low-power unlicensed users equipped with 'smart radio' technology that is able to sense if radar is operating and vacate the channel in under one second.[26]

By tailoring and listing the means by which a user can gain opportunistic access to unused capacity on a particular band, almost any underutilized band could be opened for some degree of access. Even if the location of radar sites cannot be listed in a Database (to facilitate access by geolocational lookup), sensing alone can facilitate opportunistic access, particularly if federal agencies adopt a more pro-active posture toward facilitating shared use (viz., by "turning on the headlights" so that other users can more easily detect and avoid causing interference to them).[27] It's quite likely, in fact, that various combinations of sensing and geolocation will prove to be the most efficient and protective way to open many bands for shared use. Federal systems and practices could be designed to affirmatively facilitate spectrum sharing to a far greater degree, an issue discussed further in section C below.

Unique Advantages of a Dynamic Spectrum Access Database

Building on the TV Bands Database (TVBD) has a number of other distinct advantages, particularly if it is utilized for opportunistic access. One great advantage of the geolocate database approach is that the "assignment" of bands for opportunistic access need not be permanent, or even long-term. A band can be added, or withdrawn, or limited to a particular geographic area or time of day, at any time. Opportunistic access virtually presumes that devices will increasingly be multi-band and capable of frequency hopping. Unlike licensed bands, where it is expensive and time-consuming to upgrade or clear off existing users, no legacy devices need to be tied to a particular frequency. Bands can be opened or closed for sharing – nationally, regionally, or locally – and even on short notice, without "stranding" any users or equipment. This is an unheralded advantage of the Commission's TV white space Order as well. Under the TV white space rules, the Commission reserves the option to license additional TV stations, thereby "delisting" a vacant channel from the Database in that particular local market area.

The policy flexibility to list and delist bands would free up capacity, at least for periods of time, that are wasted simply because there is no alternative to the virtually all-or-nothing ethos of long-term exclusive licensing. For example, for years the Commission has struggled with the issue of how best to reallocate the very sparsely-used AWS-3 band at 2155 – 2175 MHz. With a geolocate database in place, any fallow band could be listed for immediate access – and then delisted (or restricted in additional ways) once a new licensee has been selected and builds out. In fact, a further advantage is that even after new licenses are granted, the band could continue to remain in use in many parts of the country where the licensee is not built out – and may not be for years under the terms of the license build-out requirements.

Opportunistic access using a geolocate database could address more generally the vexing problem of valuable licenses that are not built out, particularly in rural areas, even after many years. For example, there are PCS and AWS frequency blocs that are not being used and may never be built out for economic reasons in rural and small town areas. These unused frequencies could be made available to local broadband providers, such as local WISPs and community networks, on an opportunistic basis. Under this scenario, the Commission would not even need to go as far as a "use it or lose it rule"

if it allowed opportunistic access until a licensee gave notice of the date when it would build out and begin operating in a specific area. In addition to expanding available spectrum capacity, this would have the additional benefit of making licensee build-out and spectrum usage more transparent. This would be a boon for rural broadband deployment in particular, since those are the areas with the most valuable spectrum lying fallow.

Another distinct advantage of a geolocate database is that variable rules can be associated with different bands. There is no need for one-size-fits-all access to opportunistically available spectrum. Each listed frequency band can carry its own "rules of the road" with respect to maximum signal power, leakage into adjoining bands, or even the times of day or angle of transmission that are allowed. This would permit the Commission, where appropriate, to factor in conditions that protect incumbent services, not only on the same frequency, but on adjacent frequencies. The TV Bands Database will necessarily have a simple version of this capability. For example, fixed access points operating at up to 4 Watts EIRP will be given permission to access an entirely different and more limited set of channels in each market than very low-power mobile devices. Mobile TVWS devices can receive authorization from the Database to access channels immediately adjacent to licensed TV stations, whereas higher-power fixed devices cannot, the mobile devices will be blocked from channels below 21, whereas fixed devices can request permission to operate on those channels.

C. Fresh Inquiries into Incentives, DSA Technologies and Institutional Arrangements

However well we map spectrum usage and incrementally expand on the TV Bands Database, there will be no "radio revolution" without a wholesale rethinking of how the nation should best organize access to the public airwaves in the emerging era of pervasive and high-capacity wireless connectivity. NTIA and FCC should therefore commence a complementary set of inquiries into the incentives, technologies and institutional arrangements that can best facilitate a future of more open, intensive and opportunistic sharing of the nation's spectrum resource.

1. Incentives: A Potential 'Comedy of the Commons'

While a straightforward use of the TV Bands Database to list and green-light access to additional bands at discrete locations and times would by itself boost spectrum access and efficiency, the Database could also evolve to enable compensation for costs incurred by incumbents and to ensure that there is no "tragedy of the commons" on a particular band. For example, the Database could give permission to access certain bands only in exchange for micro-payments to certain licensees that need to be compensated for offering opportunistic access (e.g., as an incentive or compensation for a licensee's investment in more interference-resistant receivers, or for other affirmative measures to facilitate shared access).[28] Payments would be tantamount to user fees and could be collected upfront (as FCC device certification fees) or on an ongoing, real-time basis. Eli Noam first suggested micropayments as a safeguard against potential congestion on the most desirable bands (or in the highest demand markets, such as New York or L.A).[29]

More recently, Google Telecomm Policy Counsel Rick Whitt suggested that web-based technologies could now support a real-time auction of frequency slots on an automated and fairly low-cost basis, just as Google conducts real-time auctions matching advertisers to search terms:

> For every query using Google's search engine, the company separately performs its own real-time auction to determine the market price of a particular advertisement linked to a particular

> search term. In the same way, an auction could be performed for a radio transmission in a pertinent place and time to determine the economic value the market would support for that transmission.[30]

It's important to note in this regard that while micro-payments could be useful as a prophylactic against congestion, there is no reason the Commission should assume either that congestion is inevitable, or that all legacy licensees need to be 'bribed' to permit public use of otherwise wasted capacity. While spectrum capacity could certainly become constrained in absolute terms in our wireless future, we are nowhere near that point. With a majority of the spectrum below 3.1 GHz available even in New York City at any particular time, the only near-term risk of congestion would be if the Commission did not move quickly or aggressively enough to stock the Database with underutilized frequencies.

Nor should spectrum incumbents expect to be 'bribed' for squatting on fallow spectrum. Licensing under the Communications Act is explicitly temporary and does not contemplate exhaustive rights to the spectrum capacity on a band, but rather the right to use the designated frequency to the extent needed to provide a communications service that serves the public interest. Unused spectrum capacity on any band, in any location, remains public property. Therefore, even without waiting for license renewal, the Commission can at any time permit use of the otherwise wasted spectrum capacity on a non-interfering basis. Indeed, as Eli Noam wrote over a decade ago, the government has an obligation not to create any unnecessary barriers to citizen communication, particularly over conduits (the airwaves) that are intrinsically a public forum:

> [S]pectrum access is traffic control, not real estate development. It's about flows, not stocks. . . .
>
> The emergence of technologies that make it possible for multiple users of spectrum to cohabit and move around frequencies has profound effects. It is not just that it is arguably a more efficient system . . . But, more importantly, it is *constitutionally* the stronger system. . . . Electronic speech is protected by the First Amendment's Free Speech Clause. Therefore the state may abridge it only in pursuance of a "compelling state interest" and through the "least restrictive means" that "must be carefully tailored to achieve such interest."[31]

At the same time, to the extent that either federal agency or private sector incumbents truly need compensation or incentive to facilitate shared access, a permission Database mechanism provides one means by which to collect "user fees." Another means would be to impose a one-time equipment certification fee on devices tuned to operate in bands governed by the Database, since the FCC must certify devices in any case.[32]

Opportunistic Access is a Win-Win for the Military

Beyond compensation for costs and/or serving the public interest, an expansion of the Database and more broadly of regulated, opportunistic access technologies would ultimately be in the best interest of the Military. Preston Marshall, who until recently directed DARPA's successful NeXt Generation (XG) dynamic spectrum program, argues that the Pentagon is moving toward dynamic spectrum technologies for its own purposes, and that there is "a natural mutual interest between advocates of DSA and the military; dynamic access to spectrum on a world-wide basis."[33] He writes:

> If the dialog for DSA was less about "taking spectrum from DoD" (in the United States), and more about "increasing flexibility of world-wide spectrum access," advocates could form a common interest with the military that could accelerate DSA throughout the world.[34]

There are two reasons why the military in particular should welcome a shift toward dynamic, shared access to underutilized bands. One is that federal users, particularly DoD, occasionally need access to *more* spectrum capacity – or at different frequencies – than they currently reserve. This need for access to greater capacity at a particular location or time will increase as the military's electronic war-fighting capabilities proliferate. Opportunistic access can work both ways: DoD can use the TV Bands Database, sensing and other methods to both contribute unused spectrum capacity to the social "pool" – and, in return, gain its own opportunistic access to non-federal bands as needed. Indeed, the ability to dynamically utilize available frequencies to establish secure, ad hoc mesh networks in the field, globally, is what DARPA's XG program was all about.[35]

More importantly, as exclusively-licensed spectrum access becomes more valuable and scarce in the rest of the world – and more rapidly in potential operational zones such as Southeast Asia, the Middle East, and central and eastern Europe – the U.S. military is likely to begin to lose the privileged access it has had to the same specific frequencies it reserves here in the U.S. Harmonizing a regime of *opportunistic access* to the bands it will need most in the future, with priority-in-use access – both domestically and overseas – may be the most pragmatic way to ensure adequate spectrum access in a diplomatically-sustainable arrangement. In addition, to the extent that DARPA's XG technology suggests that it will be increasingly necessary outside the U.S. to dynamically detect and use unused bands (in order to avoid disrupting civilian communications), it would seem to make sense to move steadily toward shared, opportunistic access to spectrum domestically as well.

2. Technologies: Implications of Dynamic Spectrum Access

What are often cumulatively called Dynamic Spectrum Access (DSA) technologies – including both cognitive radio and software defined radio technologies – hold profound implications for organizing and advancing wireless communication that are still largely unexamined by policymakers. As my New America colleagues write in their paper focused on the potential for opportunistic access to federal spectrum bands:

> Computers and other digital technologies have enabled an entirely new communications medium—distributed, portable, "device as infrastructure" networks. Within these networks, end-user devices are "smart," capable of adapting to changing environments and maximizing efficient use of available spectrum to deliver mobile, affordable broadband connectivity.[36]

In his new paper on "A Potential Alliance for World-Wide Dynamic Spectrum Access," Preston Marshall emphasizes that DSA technologies hold enormous potential "to benefit both licensed and unlicensed users," even if a service has more than sufficient spectrum. Through sensing, information sharing and better coordinating users within a band in real time, DSA:

- provides for increased density, better system management, and inherent in-channel and co-site interference resolution; and,

- enables opportunistic access to the spectrum for uncoordinated sharing of spectrum on a non-interference basis.[37]

Although the FCC's Spectrum Policy Task Force greatly advanced the consensus concerning options for moving beyond analog-era command-and-control spectrum policy, wireless technologies and consumer demand are moving so fast that another inquiry into DSA, broadly defined, is needed. Among other things, a couple of the inquiries it spawned (concerning cognitive radio technology and the concept of "interference temperature") would perhaps acquire more relevance today as pieces of a broader inquiry. While it's not my purpose here to sketch the entire scope of such an inquiry, a few focus points seem particularly important.

One line of inquiry, in coordination with NTIA, should investigate and recommend ways in which federal and non-federal spectrum incumbents can take affirmative steps to enable more intensive access and band-sharing by other users. Although the DoD, for example, has begun sharing military radar bands with low-power unlicensed operations, government users are entirely passive and take no affirmative steps to facilitate private sector use of lightly-used bands. Michael Marcus, a career-long chief spectrum engineer at the FCC, suggests that it's time to require that new and upgraded federal systems be designed and procured with the broader public interest in spectrum access in mind.[38] As Marcus observes:

> What both generations of federal band sharing have most in common is that government users are entirely passive; they do nothing to facilitate private sector use of these lightly-used bands. Shared use is permitted, but only to a very limited degree that places the entire burden on private industry to 'work around' federal systems to avoid interference. . . . However, a third generation of sharing could be based on new technologies for federal government radio systems that are designed with sharing in mind and that can actually *facilitate* sharing.[39]

In addition to examining the technical issues related to opportunistic access to a diverse range of federal and non-federal bands, the wider implications of DSA technologies for spectrum licensing itself should be reexamined. For example, in a world of widespread DSA technology, it may be possible to transition to a definition of "licensing" that is far more functional (viz., the guaranteed transport of bits), cooperative, and spectrum efficient than it is territorial (viz., the exclusive control of frequencies). A hybrid model that prioritized licensed bit flows while leaving any unused capacity available for opportunistic, unlicensed access could prove far more flexible and efficient in a world of affordable DSA technology than today's ossified, analog-era system of exclusive licensing. Likewise, one or more new bands opened for unlicensed access could facilitate more intensive and higher-quality broadband networking with distinctive Part 15 rules based on 'cooperative' rather than 'contention-based' sharing protocols.

Looking out longer-term, an inquiry into the feasibility and implications of widespread dynamic spectrum access should also explicitly consider whether much larger and contiguous portions of the spectrum can be opened to spread spectrum technologies that can operate without causing harmful interference to incumbent services. The history of the Commission's disjointed inquiries into spread spectrum technologies and unlicensed allocations highlight, as Mike Marcus has written, that "a key factor was leadership at the FCC that had the confidence to look at technical issues on both their own

merits and public interest considerations; not necessarily picking the most common viewpoint of powerful industry players."[40]

While it's not widely known or remembered today, the Commission's May 1985 Report & Order authorizing unlicensed, low-power use of spread spectrum technologies on the Industrial, Scientific and Medical (ISM) bands at 900, 2400 and 5700 MHz – paving the way for the then-unimagined innovation we know today as WiFi – was at the time a victory for incumbent special interests determined to stymie the much more open and efficient spectrum policy recommended by the FCC's in-house engineering staff.[41] The R&O adopted as a compromise in 1985 had begun as an objective and technically robust Notice of Inquiry on spread spectrum technology in 1981.[42]

Although every major equipment manufacturer opposed the commercial use of spread spectrum, the Commission issued a Notice of Proposed Rulemaking in 1984 that proposed low-power underlays (then called overlays) "on an unlicensed basis on *all* bands above 70 MHz, except on 28 specific bands to which NTIA refused to agree during interagency coordination."[43] NTIA and IRAC even agreed that federal systems could tolerate spread spectrum (except on the excluded bands) at powers up to 7 Watts, which is considerably above the current 1 Watt limit later adopted under Part 15 of the Commission's rules.[44] In the end, however, the broad unlicensed spread spectrum access recommended by the Commission's engineering staff fell victim to a concerted lobbying campaign by industry interests. Yet, despite this setback, the R&O had approved the use of spread spectrum on an unlicensed basis under Part 15 on the ISM bands, which within a decade led to many innovations, including the wireless low-power LAN standard known today as WiFi.

It took another 17 years before the feasibility of a more widespread authorization of spread spectrum was taken up by the FCC's Spectrum Policy Task Force under Chairman Michael Powell.[45] The Task Force report recommended an inquiry into the concept of underlays that would be subject to a variable "interference temperature" calibrated to avoid harmful interference with incumbent operations. The Commission adopted a Notice of Inquiry on the topic shortly thereafter, but it was later terminated after incumbent industry licensees once again reacted with what Marcus and others remember as the classic "NIMBY" ("not in my backyard"). Hopefully, spurred by the imperatives of a national broadband policy and plan that must necessarily prioritize wireless capacity and innovation, the FCC's new chairman and majority will revisit these technical issues in a neutral fashion from the perspective of greatly expanding spectrum access.

3. Institutional Arrangements: Beyond Stovepiping

As suggested above with respect to undertaking a comprehensive and fully transparent Inventory of the Airwaves, Congress and the President should agree to bring the ultimate authority for federal spectrum policy coordination back into the White House, so that the nation's overall interests can be better considered and coordinated.[46] The fragmented and self-interested nature of federal spectrum management inhibits the sort of rapid policy innovation that is the key to our wireless future. Federal agencies hold the rights to the majority of the spectrum frequency bands best suited for mobile Internet services and applications. These rights are spread across dozens of agencies and coordinated by an office within NTIA (the Office of Spectrum Management) that is notoriously conflicted by its primary role as protector of federal agency prerogatives, with a culture shaped by dependence on spectrum management fees budgeted by these agencies.[47] The FCC, meanwhile, is an independent regulatory agency that can neither command, nor be commanded by, the NTIA or other executive

branch departments. Congress, which has generally played a constructive role in pressuring the FCC and executive branch to undertake at least some innovation (e.g., opening TV white space and the military radar bands at 5 GHz for unlicensed sharing) is nevertheless utterly lacking in technical expertise.

Another set of institutional arrangements that inhibit the innovative potential of the airwaves are many of the practices and expectations that have built up around exclusive licensing – beginning with the concept of one-off auctions, but including as well the nature of renewal expectations, build-out obligations, interference protection, and receiver regulation (or lack thereof). It is both impractical to tackle these large and sensitive issues at once – and beyond the scope of this paper to delve into alternatives. Nonetheless, as the Commission addresses the potential of technologies including DSA, real-time geo-permission databases and sensing to end spectrum scarcity and drive wireless innovation, it will be important to account for the implications of these vestiges of the fading analog era of command-and-control spectrum management.

IV. CONCLUSIONS

Spectrum is an infinitely renewable resource, yet studies show that only a fraction of even prime frequencies below 3 GHz are in use, even in the largest cities, at any particular place or time. Federal agencies sit on hundreds of MHz that are unused in most areas; and many private licensees are warehousing spectrum, particularly in rural areas. The most promising mechanism to tap into this available spectrum capacity and maximize spectrum efficiency is to build on the TV Bands Database that will be certified by the FCC as a means of authorizing unlicensed access to vacant TV channels ('white space'). Underutilized bands not in use in discrete geographic areas, or at particular times, altitudes or angles of reception, can be listed as available for opportunistic sharing (or delisted if the licensee builds out in a manner that makes shared access infeasible due to interference) – providing the necessary capacity to fuel pervasive wireless connectivity.

A vital first step towards creating a roadmap for unlocking the 'vast wasteland' of unused spectrum, is a White House-led initiative, managed by the FCC and NTIA, to conduct an Inventory of the Airwaves that maps how our public spectrum resource is being utilized (or underutilized) in various bands, by both commercial and government users, including actual spectrum measurement data. The Commission and NTIA could begin this immediately by drawing upon funds appropriated under the American Recovery and Reinvestment Act to map the nation's basic broadband capabilities, of which spectrum and wireless broadband deployments are core components. Based on the inventory of actual spectrum usage, the FCC should encourage and ideally lead a joint initiative with NTIA to build on the TV Bands Database and identify the most underutilized bands, as well as the technologies, rules, and incentives that will permit firms, government agencies and citizens alike to gain shared access to available spectrum capacity and facilitate a new era of technological innovation and connectivity.

ENDNOTES

[1] A 2006 report by the International Telecommunications Union projected that by the year 2020, the traffic demand from a widespread deployment and take-up of 4G wireless Internet/data services could require additional spectrum capacity ranging from 500 MHz (in areas of low market demand) to 1 GHz (in areas of high market demand). This would represent traffic growth and spectrum increases of two to three times current levels for Europe compared with today. ITU-R

Report M.2078 (Doc. 8/148), "Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced" (2006). The report's estimates are included in ITU Radiocommunication Sector, "Conference Preparatory Material: Report on technical, operational and regulatory/procedural matters to be considered by the 2007 World Radiocommunication Conference" (Geneva, 2007), available at http://www.itu.int/md/R07-CPM-R-0001/en. *See also* Motorola, "Spectrum Analysis for Future LTE Deployments," White Paper (2007), which concludes: "It is clear that existing bands will not be enough for IMT services approximately after the year 2015 and additional bands are needed. In order to deliver a true broadband experience, large blocks of spectrum will need to be identified and allocated."

[2] Leslie Cauley, "iPhone Gulps AT&T Network Capacity," *USA Today*, June 17, 2009.

[3] *See* "Principles for Reallocation of Spectrum to Encourage the Development of Telecommunications Technologies for the New Millennium," *Policy Statement,* 14 FCC Rcd 19868 (1999).

[4] Mark McHenry, "Dupont Circle Spectrum Utilization During Peak Hours, A Collaborative Effort of The New America Foundation and The Shared Spectrum Company," New America Foundation Issue Brief (2003), available at http://www.newamerica.net/files/archive/Doc_File_183_1.pdf. Mark McHenry, "NSF Spectrum Occupancy Measurements: Project Summary," Shared Spectrum Company (August 2005)), available at http://www.sharedspectrum.com/measurements/. McHenry's 2005 study collected frequency use data in six locations along the East coast in 2004 and documented an average total spectrum use of less than 10%. Specific findings over a day-long period included: 3.4% in Great Falls, Virginia; 6.9% in Vienna, Virginia (location 1); 11.4% in Arlington, Virginia; 13.1% in New York City; 1.0% in Green Back, West Virginia; and 11.7% in Vienna, Virginia (location 2). The New York City measurements were taken during a national party convention (when a far higher-than-average use of law enforcement and federal agency spectrum would be expected), yet the vast majority of the public airwaves still remains unused

[5] *See "*Spectrum Occupancy Measurements," Shared Spectrum Company, available at. http://www.sharedspectrum.com/measurements/.

[6] *See* Tugba Erpek, Mark Lofquist, and Ken Patton, "Spectrum Occupancy Measurements Loring Commerce Centre Limestone, Maine September 18-20, 2007" Shared Spectrum Company (2006), available http://www.sharedspectrum.com/measurements/download/Loring_Spectrum_Occupancy_Measurements_v2_3.pdf.

[7] For an in-depth discussion of the utilization of federal spectrum and policy recommendations for reallocation of this underutilized spectrum, *see* Victor Pickard and Sascha D. Meinrath, "Revitalizing the Public Airwaves: Opportunistic Reuse of Government Spectrum," Wireless Future Working Paper, New America Foundation (June 2009), also forthcoming in *International Journal of Communications* (2009).

[8] Jonathan E. Nuechterlein & Philip J. Weiser, *Digital Crossroads: American Telecommunications Policy in the Internet Age,* MIT Press: Cambridge, MA (2005).

[9] For an overview, see the new CED chart: www.cedmagazine.com/WorkArea/downloadasset.aspx?id=157960.

[10] New America Foundation, "The Citizen's Guide to the Airwaves: A Graphic Depiction of the Uses – and Misuses – of the Radio Frequency Spectrum" (Washington, DC 2003); John R. Williams, "U.S. Spectrum Allocations: 300 – 3000 MHz," FCC/OPP (March 6, 2002). Since Williams's tabulation, both the non-federal and unlicensed share of spectrum below 3000 MHz have increased somewhat, primarily due to reallocations of 45 MHz of federal spectrum through the 2006 AWS auctions and the FCC's reallocation of vacant TV channel spectrum below 700 MHz for unlicensed access.

[11] Bennett Z. Kobb,*Wireless Spectrum Finder: Telecommunications, Government, and Scientific Radio Frequency Allocations in the U.S. 30 MHz-300 GHz*, New York: McCraw-Hill, 2001.

[12] *See* Michael J. Marcus, "New Approaches to Private Sector Sharing of Federal Governmment Spectrum," Wireless Future Program Issue Brief #26, New America Foundation (June 2009).

[13] Robert J. Matheson, "Flexible Spectrum Use Rights," *Journal of Communications and Networks*, 8 (June 2006), 144, available at http://www.its.bldrdoc.gov/pub/ntia-rpt/05-418/05-418_matheson.pdf.
See also Robert J. Matheson, "The Electrospace Model as a Tool for Spectrum Management," NTIA Institute for Telecommunications Sciences, presented at ISART 2003. Matheson adapted his Electrospace Model from the work a quarter-century earlier of W. R. Hinchman. *See* W.R. Hinchman, "Use and Management of Electrospace: A New Concept of the Radio Resource," in *Proc. IEEE ICC'69*, 1969.

[14] *See* "Ex Parte Comments of New America Foundation," GN Docket No. 09-29, Federal Communications Commission, March 25, 2009, http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520203629, *see also* "Comments of the New America Foundation, Public Knowledge and Media Access Project, GN. Docket No. 09-51, Federal Communication Commission, June 8, 2009, http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520220266 .

[15] The Task Force was part of the Spectrum Policy Initiative initiated by President Bush in 2003 and led by NTIA. U.S. Department of Commerce, *Spectrum Policy for the 21st Century–The President's Spectrum Policy Initiative: Report 1,*

Recommendations of the Federal Government Spectrum Task Force (June 2004), at http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report1_06242004.htm; *see also* http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report2_06242004.htm.

[16] *Ibid. See also* National Telecommunications and Information Administration (May 29, 2003). "Presidential Memorandum on Spectrum Policy for the 21st Century," available at http://www.ntia.doc.gov/ntiahome/frnotices/2004/PresMemoonSpectrumPolicy.htm.

[17] *See* Sec. 6001, American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, 123 Stat. 115 (2009).

[18] Background and links to the bill are available at http://www.opencongress.org/bill/111-s649/show.

[19] Congress facilitated the relocation by earmarking a share of the 2006 auction revenues into a Spectrum Relocation Fund that reimbursed agencies for the cost of purchasing new systems and moving to different frequencies. Commercial Spectrum Enhancement Act (CSEA), Title II of P.L. 108-494, was signed into law in December 2004. On September 18, 2006, the FCC concluded an auction of licenses for Advanced Wireless Services (AWS), on radio spectrum in the 1710 megahertz (MHz) to 1755 MHz band that had been assigned primarily to federal agencies, which was paired with the 2110 MHz to 2155 MHz band (Broadcast Auxiliary Services) in the auction. *See also"*Commercial Spectrum Enhancement Act: Report to Congress on Agency Plans for Spectrum Relocation Funds," Office of Management and Budget (Feb. 16, 2007), available at http://www.ntia.doc.gov/reports/2007/OMBSpectrumRelocationCongressionalNotification_final.pdf.

[20] *See* Michael J. Marcus, "New Approaches to Private Sector Sharing of Federal Government Spectrum," Issue Brief #26, New America Foundation (June 2009).

[21] *Ibid.*

[22] Federal Communications Commission, Unlicensed Operation in the TV Broadcast Bands, *Second Report and Order and Memorandum Opinion and Order*, ET Docket No. 04-186, ET Docket No. 02-380, FCC 08-2360 (released November 14, 2008).

[23] *See Ex Parte* Filing of the White Spaces Database Group, in ET Docket No. 04-186, April 10, 2009, which outlines a potential architecture for the Database as proposed by a broad-based industry and consumer consortium that includes Comsearch, Dell, Fox, Google, Microsoft, Motorola, MSTV, NetLogix, Neustar and the Public Interest Spectrum Coalition.

[24] *See, e.g.,* Robert J. Matheson, "Flexible Spectrum Use Rights," 8 Journal of Communications and Networks 144, June 2006, *available at http://www.its.bldrdoc.gov/pub/ntia-rpt/05-418/05-418_matheson.pdf.*

[25] Kevin Werbach, "A Domain Name System (DNS) in the Air," blogpost at CircleID.com, May 21, 2009, http://www.circleid.com/posts/20090521_addressing_system_for_next_wireless_internet/. Professor Werbach is currently writing a more indepth paper on this topic for publication by the New America Foundation (forthcoming) and presentation at the Telecommunications Policy Research Council this fall.

[26] For a brief history of how DoD shares radar bands with the private sector, and a proposal describing how federal agencies can take affirmative steps to facilitate expanded and more efficient band sharing, see Michael J. Marcus, "New Approaches to Private Sector Sharing of Federal Governmment Spectrum," Wireless Future Program Issue Brief #25, New America Foundation (June 2009), at 4-6.

[27] *See* Michael J. Marcus, "New Approaches to Private Sector Sharing of Federal Government Spectrum," Issue Brief #26, New America Foundation (June 2009).

[28] It's important to note in this regard that licensing under the Communications Act does not contemplate exhaustive rights to the spectrum capacity on a band, but rather the right to use the designated frequency to the extent needed to provide a communications service that serves the public interest. Unused spectrum capacity on any band, in any location, remains public property. Therefore, even without waiting for license renewal, the Commission can at any time permit use of the otherwise wasted spectrum capacity on a non-interfering basis.

[29] Eli Noam, "Yesterday's Heresy, Today's Orthodoxy, Tomorrow's Anachronism: Taking the Next Step to Open Spectrum Access," *Journal of Law & Economics*,, Vol. 41(2), at 765-90 (1998), available at http://www.citi.columbia.edu/elinoam/articles/SPECTRM1.htm. *See also* Eli Noam, "Taking the Next Step Beyond Spectrum Auctions: Open Spectrum Access," *IEEE Communications,* Vol. 33(12), December 1995.

[30] Richard S. Whitt, Google *Ex Parte* filing with FCC in WC Docket 06-150, concerning Service Rules for the 700 MHz Spectrum Auction (May 21, 2007), Appendix A, at 6.

[31] Noam, "Yesterday's Heresy, Today's Orthodoxy, Tomorrow's Anachronism: Taking the Next Step to Open Spectrum Access," *Journal of Law & Economics*,, Vol. 41(2), at 765-90 (1998), available at http://www.citi.columbia.edu/elinoam/articles/SPECTRM1.htm.

[32] *Ibid.*

[33] Preston Marshall, "A Potential Alliance for World-Wide Dynamic Spectrum Access," Wireless Future Program Issue Brief #25, New America Foundation (June 2009), at 5-6.
[34] *Ibid.*
[35] *See, e.g.,* Shared Spectrum. Press Release for Successful Demo of Next Generation Wireless (2006), http://www.sharedspectrum.com/inc/content/press/XG_Demo_News_Release_060918.pdf.
[36] Sascha Meinrath & Victor Pickard, "Revitalizing the Public Airwaves: Opportunistic Unlicensed Reuse of Government Spectrum," Wireless Future Working Paper, New America Foundation (June 2009).
[37] Preston Marshall, "A Potential Alliance for World-Wide Dynamic Spectrum Access," Wireless Future Program Issue Brief #25, New America Foundation (June 2009), at 1.
[38] *See* Michael J. Marcus, "New Approaches to Private Sector Sharing of Federal Government Spectrum," Issue Brief #26, New America Foundation (June 2009).
[39] *Id. at* 4-5.
[40] Michael J. Marcus, "Wi-Fi and Bluetooth: The Path from Carter and Reagan-Era Faith in Deregulation to Widespread Products Impacting Our World," a paper presented at the George mason University School of Law conference on The Genesis of Unlicensed Wireless Policy (April 4, 2008), at 25.
[41] FCC, First Report and Order, Docket 81-413, 101 F.C.C.2d 419 (May 9, 1985), available at http://www.marcus-spectrum.com/documents/81413RO.txt. The history related here draws primarily from a firsthand recollection presented by Michael J. Marcus, former FCC/OET chief spectrum engineer and the spread spectrum project leader at that time. *See* Marcus, "Wi-Fi and Bluetooth: The Path from Carter and Reagan-Era Faith in Deregulation to Widespread Products Impacting Our World," *supra note 39.*
[42] FCC, Notice of Inquiry, Docket No. 81-413, 87 F.C.C.2d 876 (June 30, 1981), available at http://www.marcus-spectrum.com/documents/SpreadSpectrumNOI.pdf.
[43] *Id.* at 14. *See* FCC, Further Notice of Inquiry and Notice of Proposed Rulemaking, Docket 81-413, 98 F.C.C.2d 380, available at http://www.marcusspectrum.com/documents/SpreadSpectrumFNOINPRM.pdf, at 16-18.
[44] Marcus, "Wi-Fi and Bluetooth," *supra,* at 16.
[45] Federal Communications Commission, *Spectrum Policy Task Force Report*, ET Docket No. 02-135 (November, 2002), available at www.fcc.gov/sptf/reports.html.
[46] According to Marcus: "Throughout most of the history of radio regulation in the United States the President's Section 305 authority was implemented by a White House entity. However, President Nixon began and President Carter completed the migration of this function to the Commerce Department – ironically, just before spectrum policy became of critical importance due to our emerging information technology economy." Marcus, "New Approaches to Private Sector Sharing of Federal Government Spectrum,"*supra*, at 2.
[47] The NTIA assigns spectrum primarily on the basis of an exclusive use licenses, for a particular purpose and generally for a five-year term. NTIA technically controls all federal frequency assignments under policies developed in cooperation with the Interdepartmental Radio Advisory Committee (IRAC), which NTIA now chairs. The IRAC's membership includes representatives from 20 federal agencies that rely on spectrum in carrying out their various responsibilities. For an overview of IRAC, see General Accounting Office, "IRAC Representatives Effectively Coordinate Federal Spectrum but Lack Seniority to Advise on Contentious Policy Issues," GAO-0401028, September, 2004.