NEW AMERICA
FOUNDATION

September 30, 2008

Marlene H. Dortch, Secretary
Federal Communications Commission
Office of the Secretary
445 12th Street, SW Washington, DC 20554

VIA ELECTRONIC FILING

Re: ET Docket No. 04-186 Economic Analysis of Auctioning the DTV White Space

Dear Ms. Dortch:

The New America Foundation submits the following report: "No Windfall in the White Space, The Economics of Auctioning the DTV White Space" responding to arguments from interest groups advocating for an auction of the TV white spaces. Although, these groups have claimed an auction will provide a windfall in revenue to the federal budget, the paper explains that such a proposal would result not only in a failed auction and negligible revenue, but the continued waste of invaluable TV band spectrum.

Although unlicensed access would facilitate innovation and allow every home, business, rural, college and community wireless network to deploy broadband at lower cost, TV band incumbents have pointed to a Brattle Group study, commissioned by QUALCOMM, claiming a white space auction could raise $9.9 billion or more based on prices paid at this year's 700 MHz auction. New America's paper shows why these estimates are wildly inflated.

Rather than a windfall, a one-time auction of licenses useful for commercial services would provide *negligible* revenue to the Treasury, ***while simultaneously ensuring that most of this unused "beachfront" spectrum will remain unused***, stifling innovation that could generate far more long-term economic growth and benefits.

- ***Severely limit the availability of spectrum:*** Given the need for expanded interference protections for higher-power licensed use, the nation's most populous metropolitan areas would have little or no useable white space available for an auction.

- ***Increased interference protections:*** In order to make an auction of TV white space even conceivably appealing to commercial carriers, the Brattle study makes the reasonable assumption that licensees will operate downlinks at considerably higher power, certainly over 400 mW and most likely up to 4 watts, although this critical variable is not specified. As a result, what the Brattle study calls its most realistic scenarios exclude access to the adjacent channel on each side of a "DTV facility." As the Brattle II study states: *a licensing regime with "[a]djacent channel protection reduces the total amount of white space available by about half."* In addition, at a transmit power level that requires full adjacent channel blocking, co-channel protection would also be necessary.

- ***VHF channel protections:*** Assuming, as Brattle does, that adjacent channels cannot be used for licensed services, the vast majority of available spectrum in crowded urban markets such

as Boston-Providence is located in the VHF band on channels 2-13 (78 MHz). Counting all of these channels as available and highly-valuable for high-power mobile services lacks credibility. First, the FCC has proposed excluding channels 2-6 from any white space allocation, due to demonstrated "pick-up" interference with cable TV set-top boxes; and the cable industry has submitted studies claiming to show that this type of interference is particularly problematic on all the VHF channels (2-13) even for low-power unlicensed uses. Second, given the propagation characteristics of this band, the spectrum is ill suited for mobile voice and data services.

- ***No available spectrum in major metro areas:*** The result of these probable protections is that high-auction-value metro area markets are likely to have no channel availability at all. For example the Brattle study finds that the Dallas/Fort Worth MTA would have 12 MHz (equivalent of two TV channels) of "bandwidth" available for auction. However, adjacent and co-channel protection leaves not a single channel available for use at a transmit power that is conceivably useful for a licensed service (viz., over one watt). This unavailability of even one consistent vacant TV channel for the higher-power licensed use that the Brattle's auction estimates contemplate appears to be generally the case for the nation's 20 most populous metropolitan areas.

Having over-estimated the amount of white space that could be used by a commercial licensee, the Brattle study proceeds to grossly overestimate potential auction revenues by assuming that this incredibly encumbered spectrum is as valuable to wireless carriers as the nationally-cleared 700 MHz band TV spectrum that was auctioned earlier this year.

- ***'Swiss Cheese' spectrum is costly to aggregate and use:*** This "Swiss cheese" makeup of the TV White Spaces makes it extremely difficult to define license rights for higher-power operation. Unlike low-power unlicensed devices, which are designed to transmit hundreds of yards (certainly less than a kilometer), the cost of both base station infrastructure and consumer hardware would escalate enormously if a licensed operator and its customers needed the ability to access many different, widely separated frequencies depending on location. This does not fit the technological or business model of any recent major bidder in the auctions Brattle uses as comparables (except perhaps QUALCOMM, since they are broadcasting and not providing interactive service).

- ***Frequencies not consistently available within metro markets:*** The Brattle studies report the "minimum" amount of "bandwidth" that would be available for auction across an entire metropolitan trading area (e.g., 6 MHz in Miami-Ft. Lauderdale EA, 12 MHz in Boston-Providence). However, the "bandwidth" they report available for auction is an "average amount of white space (averaged across census block groups)." This means that when Brattle reports 24 MHz can be licensed and auctioned in a market, this doesn't correspond to four channel frequencies consistently available across the entire metropolitan trading area (MTA). Because Brattle aggregated the available white space based on the number of census blocks that are outside a station's FCC-designated coverage area (the "B contour"), what they measure as 24 MHz of bandwidth may not be fully useable to an auction winner with a business model based on devices that hop among 6 or 8 or more different frequencies depending on where in the EA they are communicating. No existing company uses this technology or business model for a commercial service.

- ***White Space spectrum is unpaired:*** When advocates of auctioning the white space point at this year's 700 MHz auction, which generated over $19 billion in revenue, or the 2006 AWS-1 auctions, which raised nearly $14 billion, what's not mentioned is that more than 90 percent of the bands auctioned will not only be cleared nationally for very high-power

transmission, but they were auctioned in pairs configured to fit the two-way technology and business models of incumbent cellular phone and data carriers. Unpaired spectrum fits the business model of only a few potential bidders, notably QUALCOMM, since its MediaFLO mobile video service is "downlink only." It is difficult to say who would make a multi-billion dollar bid for unpaired and fragmented frequency bands that can only be used at power levels that are a fraction of what the 700 MHz E Block licenses permit (which Brattle uses as a comparable).

- ***Avoiding interference with wireless microphones:*** The Brattle analysis assumes that the existing 500,000 licensed and (mostly) unlicensed wireless microphone systems operating throughout the TV white spaces will not need the sort of detect-and-avoid protection from interference that the FCC is currently considering in the context of unlicensed use of these same channels. Brattle acknowledges the problem, but minimizes the potential cost and uncertainty it creates for any potential licensed service. It's important to note that more than 95 percent of wireless microphones are not licensed – and therefore neither the FCC nor a new licensee would have any way to identify them or stop them from transmitting. In a gross understatement, Brattle shrugs off the problem (and the political power of professional sports, Broadway and the nation's churches) by concluding that "reasonable coordination policies, together with the appropriate technologies, could protect wireless microphones, **albeit at some cost to the capacity and/or efficiency of the licensed system**."

In sum, beneath all the elaborate analysis in the Brattle studies are two inescapable facts: First, the auction of exclusive licenses that allow a transmit power useful to even QUALCOMM's mobile video broadcast service would leave the vast majority of the white space fallow. This outcome is highly wasteful of spectrum compared to a combination of unlicensed access at very low-power (for mobile and indoor routing devices) and at higher power (for fixed broadband services in rural areas). Second, the Brattle Group's auction estimates are wildly inflated not only because they use flawed auction comparables, but more fundamentally because there is nary a deep-pocketed bidder in sight for fragmented, encumbered, unpaired and still relatively low-power license rights that cannot be used to reach customers in most of the nation's most populous metro markets. An auction might give QUALCOMM a bit more bargain-basement spectrum, but it will not yield a fragment of the economic and social benefits that would aggregate from the incredible variety of broadband, sensing and other innovative applications envisioned by supporters of a low-power unlicensed allocation.

Respectfully Submitted,

/s/
Michael Calabrese
Director, Wireless Future Program

NEW AMERICA FOUNDATION
WIRELESS FUTURE PROGRAM

WORKING PAPER

Working Paper #22 *September 2008*

There is No Windfall in the White Space
THE ECONOMICS OF AUCTIONING DTV WHITE SPACE SPECTRUM

By Michael Calabrese and Dr. Gregory Rose*

Summary

As Alexander Pope opined, hope springs eternal: And exploiting this natural optimism are interest groups holding out the hope of a budgetary windfall for a cash-strapped Congress if only more spectrum can be auctioned at ever-higher prices. Now it is the turn of the digital television (DTV) "white space" to spur this forlorn hope. And this hope is as precisely forlorn as the economic analysis presented below concludes. A one-time auction of the guard band and other vacant channels in each local television market – so-called "spectrum white space" – would provide minimal revenue to the Treasury, while simultaneously ensuring that most of this unused "beachfront" spectrum will remain fallow, stifling the broadband services and innovation that could generate far more long-term economic activity. Unlike the recent 700 MHz auction, or the 2006 AWS-1 auction, TV white space spectrum is so fragmented and encumbered that an auction is likely to produce outcomes not unlike the recent failure of the 700 MHz "D Block" auction. Alternatively, opening unlicensed access to the DTV white space for use by all American homes and businesses would do far more to promote opportunities for broadband deployment, innovation and efficient utilization of this spectrum.

Incumbent TV band licensees lobbying against the FCC's proposed reallocation of the TV white space for WiFi-type unlicensed use all rely on a study, funded by QUALCOMM (itself a holder of TV spectrum licenses), that concludes an auction could generate as much as $9.9 billion, or even as much as $24 billion if TV viewers are not protected from interference from new licensed services.[1] This cornerstone study for the case in support of auctioning exclusive licenses to use TV band white space was authored by the Brattle Group, an economic consultancy. This paper demonstrates that the Brattle study's auction revenue estimates are wildly inflated thanks to the multiplier effect of a series of flawed and unreasonable assumptions. Because this particular spectrum fits the business model of very few companies other than QUALCOMM, the auction is likely to raise a negligible amount of revenue – certainly just a fraction of what Brattle estimates by comparing it to the auction of frequency bands that can be aggregated for contiguous high-power use across entire regions and even nationally. Perhaps more significantly, this paper reveals that under Brattle's own assumptions, the auction they recommend would necessarily leave the vast majority of TV white space spectrum fallow, provide little or no availability of vacant TV channels in the nation's largest metro markets, preclude low-power use of the band by individual homes and business, and even preclude continued use of the band by hundreds of thousands of churches, theaters, sporting arenas, concert halls and other venues currently using the white spaces to operate wireless microphone systems.

Michael Calabrese is the Director of the Wireless Future Program at the New America Foundation. Dr. Gregory Rose is a game theorist and econometrician who consults on telecommunications economics and auction theory for public interest organizations. Analysis of TV markets and white space availability was provided by Derek Turner, Research Director for Free Press.

Among the flawed assumptions and negative policy implications of the Brattle group study are the following:

Wasted White Space: 'Not Much Left to Auction'

Like today's WiFi technology, mobile devices and local area networks (LANs) accessing the TV white space on an *unlicensed* basis would operate at very low transmit power (under 100 milliwatts), allowing the use of vacant channels adjacent to DTV stations. In order to make an auction of TV white space even conceivably appealing to commercial carriers, the Brattle study makes the reasonable assumption that licensees will operate downlinks at considerably higher power, certainly over 400 mW and most likely up to 4 watts, the still relatively low transmit power associated with the draft IEEE 802.22 standard for fixed point-to-point transmission on white space frequencies, although this critical variable is not specified. As a result, what the Brattle study calls its most realistic scenarios exclude access to the adjacent channel on each side of a "DTV facility."[2] As the Brattle II study states: **a licensing regime with "[a]djacent channel protection reduces the total amount of white space available by about half."[3]**

While the need for adjacent channel protection would leave half of the nation's vacant DTV channels unused *on average*, in many of the largest urban market areas – which have fewer vacant channels to begin with – the need for complete adjacent channel protection results in ***little or no consistently useable white space at all***. Under Brattle II's most realistic scenario (Scenario Q, which adds interference protection for public safety and medical telemetry), portions of the New York and Los Angeles/San Diego metro markets would have not even one frequency channel available metro-wide for a licensed service; central and southern Florida would have the equivalent of one channel of bandwidth (6 MHz); the San Francisco Bay Area, Boston-Providence, Dallas/Fort Worth and Richmond-Norfolk would have two (12 MHz).[4] This is just a fraction of the number of channels and bandwidth that would be available for mobile devices and certain fixed uses (such as home and business routers) under the very low-power limits the FCC is considering for unlicensed use. For example, Boston would have 16 TV channels available for very low-power unlicensed use and Dallas/Fort Worth, 13 channels. Moreover, as explained further below, it appears that not even the "minimum" of 6 or 12 MHz of "bandwidth" available across these high-population metro markets for licensed use represents the consistent availability of any particular channel frequency – but rather the aggregation of frequency bits and pieces.

In addition to the need to continue using thousands of adjacent channels as guard bands, the degree of underutilization of white space under Brattle's license-and-auction scheme is actually far more extensive than they concede, for the following reasons:

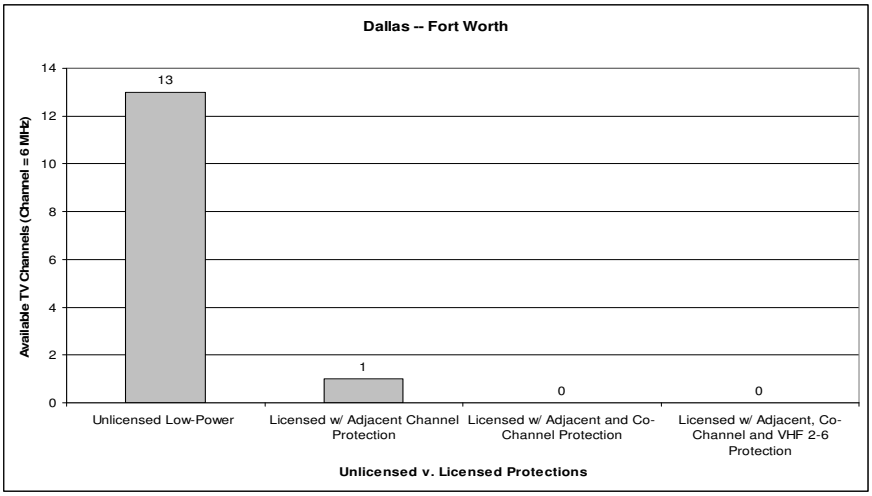
- ***Co-Channel Protection***: At a transmit power level that requires full adjacent channel blocking, co-channel protection would also be necessary. That is, although very low-power WiFi devices in one media market (e.g., Chicago) should be able to use a frequency band (channel) used for DTV in a neighboring but distant market (e.g., Milwaukee), a high-power service probably cannot. At a minimum, it could use that frequency channel (and the two adjacent channels) only in a portion of the local market, which is highly problematic for a commercial business model. Ignoring this limitation allows Brattle to assume there will be more spectrum auctioned in potentially lucrative urban markets. The Brattle study vaguely claims that license winners can "engineer" around the problem[5] and could be permitted by the FCC to engage in "interference negotiations ('Coasian bargaining') with broadcasters."[6] However, as the Public Interest Spectrum Coalition has pointed out, although some DTV station owners may have an incentive to negotiate payments in exchange for giving up a portion of their local viewing audience (or exposing them to a high risk of interference), it's exceedingly unlikely that the FCC has either the statutory authority or

inclination to use this proceeding to allow broadcasters – who received their spectrum free in return for the obligation to offer a free local television service – to accept payments to selectively disenfranchise local viewers.[7]

- ***VHF Channels 2 to 13:*** Brattle ignores the critical differences between VHF and UHF channels with respect to both interference constraints and value. Assuming, as Brattle does, that adjacent channels cannot be used for licensed services, the vast majority of available spectrum in crowded urban markets such as Boston-Providence is located in the VHF band on channels 2-13 (78 MHz). Counting all of these channels as available and highly-valuable for high-power mobile services lacks credibility. First, the FCC has proposed excluding channels 2-6 from any white space allocation, due to demonstrated "pick-up" interference with cable TV set-top boxes; and the cable industry has submitted studies claiming to show that this type of interference is particularly problematic on all the VHF channels (2-13) even for low-power unlicensed uses. Second, given the propagation characteristics of this band, the spectrum is ill suited for mobile voice and data services. The high-tech companies that support reallocating TV white spaces for broadband are not even seeking use of channels 2-13, conceding they are highly problematic for mobile services because of heightened interference risk and especially because the large antenna size needed at those frequencies would be too cumbersome for mobile devices. In fact, one of the key reasons so many VHF channels will be empty after the DTV transition, is that many VHF stations are migrating their digital assignments to higher channel placements in the UHF band.

Of course, it's not difficult to see why Brattle ignores co-channel protection and includes channels 2-6 in its auction plan: if it protected these channels, even more of the high-auction-value metro markets would have no channel availability at all. For example the Brattle study finds that the Dallas/Fort Worth MTA would have 12 MHz (equivalent of two TV channels) of "bandwidth" available for auction. However, as the chart below indicates, adjacent and co-channel protection leaves not a single channel available for use at a transmit power that is conceivably useful for a licensed service (viz., over one watt).[8] This unavailability of even one consistent vacant TV channel for the higher-power licensed use that the Brattle's auction estimates contemplate appears to be generally the case for the nation's 20 most populous metropolitan areas. (See charts in section II.A.1 below.)

Figure 1.
Available Post-DTV Channels for Dallas/Fort Worth[9]



Wildly Unrealistic Auction Comparables

Having over-estimated the amount of white space that could be used by a commercial licensee, the Brattle study proceeds to grossly overestimate potential auction revenues by assuming that this incredibly encumbered spectrum is as valuable to wireless carriers as the nationally-cleared 700 MHz band TV spectrum that was auctioned earlier this year. This paper explains a number of reasons why the auction comparables relied on by Brattle lead to gross overestimates and why the government could expect only a tiny fraction of the revenue Brattle projects by auctioning "Swiss cheese" spectrum in the DTV band that doesn't fit the business model of the companies that are at all likely to bid billions of dollars for additional spectrum, including:

- ***'Swiss Cheese' Spectrum is Costly to Aggregate and Use:*** Broadcast stations occupy a different pattern of channels in each of the nation's 210 local television markets. Unlike the auctions Brattle uses as comparables – in which the frequencies are cleared nationally and can be aggregated to fit a variety of business models (metro market, regional, national) – a TV channel may be unassigned in Baltimore, but occupied in nearby Washington, D.C. This "Swiss cheese" problem is greatly exacerbated when it comes to defining license rights for higher-power operation. Unlike low-power unlicensed devices, which are designed to transmit hundreds of yards (certainly less than a kilometer), the cost of both base station infrastructure and consumer hardware would escalate enormously if a licensed operator and its customers needed the ability to access many different, widely separated frequencies depending on location. This does not fit the technological or business model of any recent major bidder in the auctions Brattle uses as comparables (except perhaps QUALCOMM, since they are broadcasting and not providing interactive service).

- ***Frequencies Not Consistently Available Within Metro Markets:*** The inter-market aggregation problem is compounded by intra-market fragmentation when it comes to operating above a very low power level, as most big-dollar bidders would require. The Brattle studies report the "minimum" amount of "bandwidth" that would be available for auction across an entire metropolitan trading area (e.g., 6 MHz in Miami-Ft. Lauderdale EA, 12 MHz in Boston-Providence). Areas within an EA could have more bandwidth available. However, the "bandwidth" they report available for auction is an "average amount of white space (averaged across census block groups)." This means that when Brattle reports 24 MHz can be licensed and auctioned in a market, this doesn't correspond to four channel frequencies consistently available across the entire metropolitan trading area (MTA). Because Brattle aggregated the available white space based on the number of census blocks that are outside a station's FCC-designated coverage area (the "B contour"), what they measure as 24 MHz of bandwidth may not be fully useable to an auction winner with a business model based on devices that hop among 6 or 8 or more different frequencies depending on where in the EA they are communicating. No existing company uses this technology or business model for a commercial service.

- ***White Space Spectrum is Unpaired:*** When advocates of auctioning the white space point at this year's 700 MHz auction, which generated over $19 billion in revenue, or the 2006 AWS-1 auctions, which raised nearly $14 billion, what's not mentioned is that more than 90 percent of the bands auctioned will not only be cleared nationally for very high-power transmission, but they were auctioned in pairs configured to fit the two-way technology and business models of incumbent cellular phone and data carriers. Unpaired spectrum fits the business model of only a few potential bidders,

notably QUALCOMM, since its MediaFLO mobile video service is "downlink only."[10] Again, it's difficult to say who would make a multi-billion dollar bid for unpaired and fragmented frequency bands that can only be used at power levels that are a fraction of what the 700 MHz E Block licenses permit (which Brattle uses as a comparable). Intel, which drove the development of WiMax – the leading technology for broadband over unpaired spectrum – has long supported unlicensed allocation of the TV white space since it concluded that the fragmented nature of the band, power, and severe interference constraints was incompatible with a metro-wide WiMax service (with transmit power up to 2000 watts). Notice as well that Sprint and Clearwire, the leading WiMax operators, have not offered to bid for licenses to operate WiMax in the TV band. Sprint's own proposal rejects the idea of an auction and calls for the FCC to give it and other carriers no-cost licenses to use white space channels in rural areas not for WiMAX, but for point-to-point backhaul links at high power.[11]

- ***Avoiding Interference with Wireless Microphones:*** The Brattle analysis assumes that the existing 500,000 licensed and (mostly) unlicensed wireless microphone systems operating throughout the TV white spaces will not need the sort of detect-and-avoid protection from interference that the FCC is currently considering in the context of unlicensed use of these same channels. Brattle acknowledges the problem, but minimizes the potential cost and uncertainty it creates for any potential licensed service. It's important to note that more than 95 percent of wireless microphones are not licensed – and therefore neither the FCC nor a new licensee would have any way to identify them or stop them from transmitting. In a gross understatement, Brattle shrugs off the problem (and the political power of professional sports, Broadway and the nation's churches) by concluding that "reasonable coordination policies, together with the appropriate technologies, could protect wireless microphones, **albeit at some cost to the capacity and/or efficiency of the licensed system**."[12]

In sum, beneath all the elaborate analysis in the Brattle studies are two inescapable facts: First, the auction of exclusive licenses that allow a transmit power useful to even QUALCOMM's mobile video broadcast service would leave the vast majority of the white space fallow. This outcome is highly wasteful of spectrum compared to a combination of unlicensed access at very low-power (for mobile and indoor routing devices) and at higher power (for fixed broadband services in rural areas). Second, the Brattle Group's auction estimates are wildly inflated not only because they use flawed auction comparables, but more fundamentally because there is nary a deep-pocketed bidder in sight for fragmented, encumbered, unpaired and still relatively low-power license rights that cannot be used to reach customers in most of the nation's most populous metro markets. An auction might give QUALCOMM a bit more bargain-basement spectrum, but it will not yield a fragment of the economic and social benefits that would aggregate from the incredible variety of broadband, sensing and other innovative applications envisioned by supporters of a low-power unlicensed allocation.

I. Background

What is DTV white space? It is essentially the vacant (unassigned) channels in each of the nation's 210 local TV markets. After the transition from analog to digital television concludes in February, the majority of channels in every market will not be used for broadcasting. This abundance of unused frequency bands results from several factors. Because analog TV technology was susceptible to interference from signals on adjacent channels, the FCC created a band plan that reserved at least one vacant channel on each side of every licensed TV channel ("adjacent channel guard bands") and did not permit operation on the same channel used in a neighboring market ("co-channel guard bands"). Currently nearly every full power station

transmits an analog signal on one 6 MHz channel and a digital signal (in some cases multiple DTV signals) on a second 6 MHz channel. As analog signs off forever, the number of vacant channels will roughly double. Moreover, since digital TV receivers are less susceptible to inference, it becomes more feasible for other devices to operate at very low power on the adjacent channels without causing harmful interference.

"White space" also arises from the fact that the same number of 6 MHz-wide channels (67) were allocated nationwide for TV (402 MHz in total) even though substantially fewer stations are licensed in rural and small town markets than in large metropolitan markets. Finally, some white space is a result of the fact that many licensees operate at low power and serve only part of their market area, while other white space arises from the uneven propagation rates of signals over real terrain. While digital TV receivers are less susceptible to interference than analog TV receivers, they are still vulnerable to transmissions that are close in frequency and above a relatively low power threshold. This issue highlights a key set of constraints on utilization of white space spectrum that make it different from most of the spectrum which the FCC has auctioned hitherto.

Pierre de Vries has summarized the history of how the unlicensed utilization of this white space spectrum has been handled by the FCC, which highlights the importance of these technical constraints:

> In its 2004 Notice of Proposed Rulemaking, which remains pending, the Commission proposed the authorization of unlicensed access to vacant TV channels (below Channel 52) for certified low-power devices of two types:
>
> • "Personal/portable" unlicensed devices – such as Wi-Fi cards in laptop computers, or wireless in-home LANs, which operate at very low power – with a maximum power out of 100 milliwatt (mW), and a permanently attached integral antenna with a maximum permissible gain of 6 dBi.
>
> • "Fixed/access" unlicensed devices that are generally operated from a fixed location and may be used to provide a commercial service such as wireless broadband Internet access. These devices can operate with a transmitter output power of up to one watt (the current Part 15 power limit for devices operating in the unlicensed 2.4 GHz and 900 MHz bands) and employ higher gain directional antennas, with requirements for transmitter output reductions for antennas with gains above 6 dBi.
>
> These are very low power levels, even in the "higher power" fixed/access mode. The maximum permissible omni-directional power for unlicensed use in the 2.4 GHz band is one watt; unlicensed emissions in the TV bands are likely to be no higher than this for fixed/access operation, and one-tenth of this power in the case of personal/portable uses.[13]

In 2006 the FCC issued a *First Report and Order and Further Notice of Proposed Rulemaking* (2006 FNPRM) "to develop additional information concerning the rules that will be necessary to enable low power devices to operate in the TV bands without causing harmful interference to other authorized operations in those bands."[14]

The FCC's willingness to entertain the DTV white space as unlicensed spectrum has resulted in the predictable rush of spectrum incumbents to oppose any change to the typical regime of auctioning licensed spectrum. As the Public Interest Spectrum Coalition explained in comments to the Commission,

> Some of the [incumbents'] comments are transparent efforts to leverage the proceeding to grab additional spectrum rights; others are blatant attempts to stifle competition to their licensed offerings; while still others are desperate bids to protect an inefficient and eroding status quo despite the enormous social and economic opportunity costs of continuing to warehouse TV band spectrum rather than redeploy it to facilitate wireless broadband and other innovation.[15]

Not surprisingly, virtually all the TV band spectrum incumbents -- most prominently the National Association of Broadcasters, QUALCOMM, wireless microphone manufacturers, and cell phone carriers – have been prominent in these efforts to stifle competition, warehouse spectrum, and finagle additional spectrum rights for themselves in the DTV white space.

II. White Space is More Valuable for Unlicensed than Licensed Use

The nature of DTV white space puts intrinsic limitations on its auction value as exclusively licensed spectrum – or even for unlicensed use above a very low level of transmit power. Any reasonable evaluation of the white space spectrum suggests strongly that unlicensed use of the spectrum is likely to accrue both greater revenue to the government and significantly higher economic benefit.

A. Use of TV White Space Spectrum is Inherently Constrained and Encumbered

A great deal of the problem of licensing DTV white space arises from two of its characteristics. First, the licensed TV broadcasters occupy different channel patterns in different geographic localities; leading to what Pierre de Vries has termed the "licensed Swiss cheese" dilemma: "Licensed incumbents occupy a different pattern of channels in each of the 210 television markets. A channel that is available in Baltimore, for example, may not be useable in nearby Washington, D.C." [16] Moreover, both within and between local TV markets the viewability of broadcast signals vary tremendously based on terrain, the DTV licensee's transmit power, antenna height and other factors.

Second, utilization of the spectrum requires serious technical constraints to avoid interference with incumbent uses including broadcast television and wireless microphones. To avoid interference with incumbents, it is necessary that devices operating in the DTV band operate at very low levels of power, under 100 milliwatts, and employ cognitive radio sensing to detect incumbent signals and/or GPS-equipped devices to avoid transmissions on frequencies occupied by incumbent license holders. The alternative, which the Brattle study assumes in all but one of its scenarios, is to operate at higher power (e.g., the 4 watts proposed by IEEE's 802.22 standard), but to leave the adjacent channels (and possibly the co-channel) unutilized as guard bands.

The consequence of non-contiguous spectrum and severe interference constraints is that the high-power cellular network infrastructure and inexpensive consumer handsets that define the business model of the incumbent cellular carriers (viz., Verizon, AT&T, and Sprint) would not be workable on TV white space. Both incumbent and new entrant service providers (which, after all, have been by far the highest bidders in recent auctions), would need to build out an entirely new and costly network infrastructure premised on densely located, multi-channel access points and cognitive radio handsets in order to offer two-way consumer broadband service with even regional coverage.[17] Indeed, as the failure of the 700 MHz D-Block demonstrated earlier this year, there is little demand for spectrum if build-out costs are high and especially when capital markets are constrained. Paying for towers, base stations, backhaul, and service centers is by far the larger cost. Some other low value-added services (particularly point-to-point backhaul or one-way broadcast-type services) could work in less densely populated markets, as FiberTower and QUALCOMM have proposed, but this outcome would leave the majority of white space

fallow and deprive the majority of American consumers living in major metro markets any benefit from low-power devices, services and future innovation.

There also are profound definitional problems which could lead to years of new proceedings before exclusive license rights to the "white space" could be auctioned. For instance, the incumbent license rights of DTV stations are not based on well-defined geographic boundaries; they are based on the statistical probability of a viewer located on the outskirts of a local media market (DMA) being able to view a television signal at least 50 percent of the time (since, in addition to terrain and antenna height, weather conditions and even time of the day alter the propagation of television signals). Moreover, the strategic complexity of an auction in which major carriers attempt to aggregate frequencies with similar propagation characteristics into economically viable regional coverage areas from spectrum with as much bandwidth and geographic variability as DTV "white space" introduces higher elements of business risk compared with any previous major FCC auction. This will almost certainly depress prices further and result in large numbers of licenses failing to clear, as well as reducing the number of bidders willing to accept the elevated risk associated with the spectrum.

This is further complicated by uncertainties brought on by the possibility of the FCC changing channel frequency assignments for DTV stations, or even licensing new stations in the future. Auctioned frequencies could become unavailable years later depending on the future needs of current and even future DTV licensees. As the FCC stated in the 2006 FNPRM:

> As an initial matter, we note that the frequencies and amount of unused television spectrum in the TV band will vary from location to location and, depending on the approach we ultimately adopt, could change over time as additional television stations are licensed or change frequency. For example, the assignment of low power television stations is not scheduled to be complete by the end of the DTV transition in February 2009. Also, under existing rules, currently authorized DTV stations would be permitted to seek to change frequencies after that date, which could complicate licensing of the white spaces spectrum, particularly if the Commission were to license the spectrum pursuant to auction. For example, if licensed wireless operations are required to protect other types of licensees in the TV bands, then wireless licensees in the TV bands could potentially lose their ability to operate on some, or even all, of their authorized frequencies when new operations with higher allocation status are authorized to operate in the same area. We also observe that, if protection of incumbents is required, devices operating in the TV bands would need to operate at lower power levels than are typical of many licensed services.[18]

The uncertainties created by the Commission's policy that new entrants will be secondary to the superior claims of DTV incumbents is another potent deterrent to bidder entry and will reduce the value of the spectrum at auction, as well as increase the likelihood of substantial delays in the deployment of services. Broadcasters are currently seeking to expand their interference protection rights in several pending proceedings and are also expected to seek a new round of "minor modifications" after the final DTV allotment table is finalized.[19] Bidders are unlikely to risk investing huge sums in not only purchasing spectrum rights but capital investments if there remains the possibility that they could lose access to the spectrum or their services held up a result of incumbents continued utilization.

Another reality of the TV band ecosystem is the unlicensed operation of hundreds of thousands of wireless microphone devices. Considering the political influence of professional sports, Broadway theaters, the nation's churches and countless other entertainment venues – all of which are already active in this proceeding – the need to avoid interference with (and from) wireless

microphones is a potentially expensive problem that introduces further uncertainty for potential bidders. Although the roughly 500,000 wireless microphones operating today on vacant TV channels technically require a license, FCC records show that only 958 licenses have been issued under Part 74 of the Commission's rules. Yet on nearly every UHF channel (channels 14-69) there are potentially tens of thousands of systems operating at churches, sporting events, concerts, and other venues, on an unlicensed basis.[20] Even if they were all licensed, their locations would not be known because they tend to move around. The pending IEEE proposal (802.22) to allow higher power operation in the white space, would rely upon the use of geolocation (GPS capability and an active database of DTV transmission sites) to avoid interfering with incumbent users, including both broadcasters and *licensed* users of wireless microphones. Even if an accurate database of *all* wireless microphone users could be compiled (licensed and unlicensed), avoiding interference with hundreds of thousands of these devices would be highly spectrum inefficient, potentially ceding vast amounts of spectrum above channel 14 in nearly every city and town in the country.

In response, advocates of licensing the white space have offered to reserve one or more channels in the white spaces for wireless microphones.[21] But they fail to explain how in practice this transition would take place considering it would require hundreds of thousands of currently unregistered users to voluntarily migrate. Would the FCC force all of the nation's churches, theaters, schools, etc. to immediately purchase new equipment and pay for spectrum access elsewhere? At a minimum, it seems likely that whether white space access is licensed or unlicensed, the new entrants will need to use cognitive radios capable of sensing a beacon that wireless microphone users would turn on during their events, putting the frequency temporarily off limits. This is yet another encumbrance that increases business uncertainty and reduces potential auction revenues compared to previous FCC auctions.

B. The Economic Benefits of Unlicensed Access are Likely to Be Greater than Projected Auction Revenue

There is substantial evidence that unlicensed utilization of spectrum spurs both technological innovation and increased productive use of spectrum which, in turn, imply greater cumulative revenues to federal, state, and local governments from sales and income taxation over the next ten years than are likely from a one-time auction of licensed spectrum in the heavily-encumbered TV white spaces.

The experience of the 2.4 GHz ISM band suggests significant technological innovation benefits from unlicensed allocation of spectrum. Both the widespread adoption and utility of low-power WiFi technologies continue to mushroom. The maximum data-throughput for Wi-Fi technology has increased tenfold in less than a decade.[22] The 2.4 GHz band – once derided as the unlicensed "junk band" – is the range of frequencies now used on an unlicensed basis by at least 500 million consumer devices, ranging from home and business WiFi networks, to cordless phones, baby monitors and microwave ovens. As New America, et al. reported in comments filed in 2007 with respect to the evolving IEEE standards that make WiFi and its offspring interoperable and relatively inexpensive to mass produce:

> This has all happened very quickly: the first 802.11 standards underlying Wi-Fi were only ratified in 1999/2000. The worldwide market for wireless local area networks had grown to $2.5 billion by 2005. By 2009, only a decade after its inception, overall Wi-Fi market revenues are forecast to reach $4.8 billion. Unlicensed allocations encourage new players to enter the market, leading to innovation and competition…. New applications continue to emerge. Commercial networks of wireless hotspots emerged in 2003 (Boingo, Wayport, iPass, T-Mobile, and others), metro mesh networks started to appear in large

> numbers in 2005, and Internet voice services over wireless networks are now being created, particularly in enterprises.
>
> There has also been dramatic business model innovation, from rural entrepreneurs offering broadband Internet access to their communities for the first time, to hotspot access packages from mobile-telephone companies. Few would argue that Wi-Fi networking and all the social and economic benefits outlined for the six industry sectors above would have materialized had licenses to operate in this band been auctioned off.[23]

The relative rates of innovation between unlicensed and licensed spectrum are also evident: For example, there have been more than twenty-five times more equipment authorizations in the unlicensed 2.4 GHz spectrum than in licensed mobile telephony spectrum.[24] Among the uses to which new technology in unlicensed spectrum has been put include wireless technology to facilitate rural broadband access, home networking, enterprise networking, education, and community wireless networking.[25]

A simple example suggests the kind of revenue benefits which unlicensed use of DTV white space allows. Under the most conservative assumptions, unlicensed use of the DTV white space would increase broadband subscribership by 15 percent over ten years, particularly in rural and inner city areas which are currently under-serviced and which would benefit from mesh network technology facilitated by unlicensed spectrum. Revenue to the U.S. Treasury from corporate income taxation of service providers arising from this 15 percent subscriber increase over that ten-year period has been project at slightly over $4.5 billion.[26] This ongoing flow of tax revenue – from subscription-based broadband alone – is close to the one-time revenue projected by some of the most optimistic advocates of auctioning the white space as licensed spectrum and considerably more than a realistic assessment of likely auction revenue.

This estimate does not begin to take into account the revenue and other economic benefits of future technological innovation in an unlicensed environment. Nor does this estimate include what is likely to be the largest initial source of consumer welfare from more and better unlicensed spectrum access: A new generation of home and business wireless network using off-the-shelf routers and other devices that do not depend on purchasing a subscription for wireless bandwidth from some licensed intermediary. Currently, on the crowded and propagation-constrained 2.4 GHz unlicensed band, tens of millions of American homes, businesses and public spaces are able to accommodate multiple PCs simultaneously sharing a single wired Internet connection because a standardized (and inexpensive) WiFi router and and modem chip or card retransmits that connectivity over *unlicensed* airwaves at low power. This saves consumers and business owners additional hundreds of millions of dollars in Internet connectivity costs – and allows consumers to spend much more time online at the same cost, which boosts both business and personal productivity. With access to the additional capacity and superior propagation characteristics of the vacant TV channels, high-tech companies including Dell, Hewlett-Packard and Philips Electronics envision homes and offices that rapidly become fully networked and "unwired," further increasing home and office productivity, while also stimulating a huge volume of next generation computers, home entertainment systems, appliances and other innovations that incorporate wireless networking and Internet connectivity.

C. Unlicensed White Space Spectrum is "Regulatory Insurance."

As both MIT's William Lehr[27] and Pierre de Vries[28] have explained in earlier New America Foundation Working Papers, unlicensed white space spectrum is also "regulatory insurance" in two senses: it offers consumers a hedge against both non-scarcity of spectrum and government

"greed" (federal spectrum hoarding and the myopic reach for one-time spectrum revenue). The unfortunate reality is that government tends to create an artificial scarcity in spectrum by dribbling out exclusive licenses and extracting scarcity rents through auctions.[29] To the extent that licensed spectrum will remain the dominant form of spectrum for the foreseeable future it is useful for the FCC to allocate spectrum to accommodate a variety of both exclusively licensed and unlicensed business models. As NAF, et al. has previously argued:

> There is no agreed way to decide the degree of scarcity for all spectrum, even at a single moment in time, let alone in a dynamic situation where technology and usage feed off each other. Hence, one cannot make an a priori determination of which scenario is the most suitable. As long as both regulatory models exist, each provides a market test, and a check on potential inefficiencies, for the other.
>
> Whether government decides to license or allow open, shared access to a band, it partly determines the business models, uses and competitive entrants. Hence, the AWS auctions have been—necessarily—a recipe for predominantly large, incumbent and well-capitalized companies to invest in a business model for broadband based on centralized infrastructure. In contrast, the unlicensed bands—particularly 2.4 GHz—facilitate competitive entry by a far larger number of smaller entrepreneurs with business models premised on decentralized capital spending, most of it by consumers who buy and connect their own interoperable consumer devices to the edge of the network.[30]

Unlicensed allocations, therefore, serve as a hedge to both government greed and rent-seeking behaviors by large carriers. This latter point is often overlooked. If technological innovation reduces spectrum scarcity to the point that license holders, particularly large carriers, are able to extract rents from consumers only because of the structure of an exclusive licensing system which presupposes greater scarcity of spectrum than actually obtains. The availability of unlicensed spectrum provides a significant regulatory safeguard which makes the extraction of such rents by license holders less possible.

II. Auctioning the White Space Will Not Realize the Predicted Revenue

It is important to review the technical reasons for which DTV white space is substantially different from the spectrum which has been subject to recent multi-billion-dollar FCC auctions. First, the TV white spaces present severe frequency aggregation problems that have not been an issue in prior high-value spectrum auctions. The white spaces are "Swiss cheese spectrum," since frequency bands will be narrow (maximum 6 MHz), non-contiguous between local TV market areas and, particularly above an extremely low transmit power, not available at all in many of the largest metro markets or in all locations within a metro market (depending on DTV operations in neighboring markets).

Second, there are significant power constraints on utilization of this spectrum. A maximum transmit power of 100 mW – comparable to a home WiFi router – would be needed to allow the use of channels immediately adjacent to DTV transmissions (channels which represents roughly half the vacant TV channels and the vast majority of channel availability in and near the nation's largest metro markets).[31] To put this in perspective, 100 mW is one-tenth the power level allowed by the FCC under its Part 15 device certification rules for what are considered low-power unlicensed devices (e.g., WiFi and cordless phones). It is also one ten-thousandth (0.0001) the power level permitted for licensed operators who purchased the 700 MHz E Block licenses that the Brattle II study uses as a direct market comparable for TV white space (more on this in II.B below). This limit would be a substantial restriction on power relative to the almost any existing licensed spectrum business model and to the overwhelming majority of spectrum previously

auctioned by the FCC. At such low power, a cellular service would need thousands of additional tower sitings (or localized access points) to bring its signal close enough to customers to cover an entire region, let alone nationwide. This power limitation alone dramatically reduces both the availability and the potential auction value of the DTV white space.

Additionally, interference avoidance requires either (1) the development and deployment of expensive cognitive ("smart radio") devices – which represent a front-end cost to potential bidders which must be calculated in setting the upper range of acceptable bidding price in addition to the usual costs of deployment present for bidders in previous auctions, or (2) limitation to fixed-location services, eliminating what has become the most lucrative use of licensed spectrum, mobile services. Both work to constrain the willingness of potential bidders to bid up this spectrum. Such constraints were not present for prior FCC auctions that raised multi-billions of dollars: e.g., the Personal Communications Services (PCS), Advanced Wireless Services-1 (AWS-1), and 700 MHz Band auctions this year. To the extent that estimates of DTV white space auction revenue do not take these constraints into account, they seriously over-estimate the potential revenue. And, as we'll see below, the Brattle Group justifies multi-billion dollar revenue estimates by effectively "wishing away" many of these constraints on geographic aggregation, power levels, and interference protection for broadcast and microphone incumbents, constraints that cumulatively make the white space a very poor fit with the business model of the licensed-based wireless industry.

Finally, the utterly unrealistic nature of the Brattle Group's auction revenue comparability assumptions is reinforced by the wireless industry itself. In the past two major auctions for nationally-cleared and high-power spectrum, the overwhelming share of the nearly $34 billion in winning bids were made by incumbent cellular carriers. In this year's 700 MHz auction, for example, $16 billion of the $19.6 billion in winning bids came from AT&T and Verizon. Yet not a single carrier has proposed auctioning the TV white space for integration with their current cellular system. To the contrary, Sprint and T-Mobile support FiberTower's proposal to award licenses in the white space exclusively for use as wireless backhaul for their networks, primarily in rural areas. Indeed, Sprint even opposes auctioning the white spaces for this limited purpose, advocating instead that the Commission give carriers access to exclusive license rights for this use on a first-come, first-serve and no-cost basis. Clearly, no wireless carrier has signaled a willingness to spend *billions* on such non-contiguous and heavily-encumbered spectrum.

A. The Brattle Group Estimates: Comparing Spectrum Apples to Oranges

The principal basis for predictions of a significant revenue windfall from auctioning the DTV white space is a study by the Brattle Group, commissioned by Qualcomm and submitted to the FCC in the white space proceeding.[32] The initial Brattle study (Brattle I) was submitted in January 2007, based on one set of spectrum availability and auction market comparables, and then updated in a June 2008 submission (Brattle II), which offered somewhat more conservative estimates of bandwidth available for auction at higher-power and employed this year's 700 MHz E Block auction as the market comparable for revenue estimation.[33]

Brattle I developed five scenarios estimating potential DTV white space on an MTA and national basis[34] and presented a market comparables argument for the valuation of that white space on which their revenue estimations are based.[35] Specifically, they argue that the closest comparable to the majority of DTV white space is the BRS/EBS band at 2.5 GHz,[36] which they value at $0.15 MHz-pop, based on secondary market transactions of 2.5 GHz BRS/EBS licenses and comparison to secondary market valuations of PCS and AWS licenses. Additionally, Brattle I estimate the value of a hypothesized 24 MHz nationwide license of white space as $0.50 MHz-pop, based on the mean value of spectrum allocated in the AWS-1 auction ($0.54 MHz-pop). On this basis they present revenue estimates under one of their scenarios for auctioning a 24 MHz national

"overlay" license, involving all DTV and Class A stations and TV translators that would require protecting the existing license rights of all DTV incumbents by not operating on the station's frequency or on the first adjacent channel on either side. As they state, winning bidders "would have the right to use any spectrum not encumbered" by existing or future TV stations. Brattle I concluded by projecting total white space auction revenue in a range from $3.7 billion to $6.0 billion. Revenue estimates based on these scenarios are discussed below.

1. Higher Transmit Power: Where Did All the White Space Go?

One of several factors explaining the Brattle study's high estimate is their assumption that even in the most populous metro markets, where spectrum is most valuable but DTV incumbents are most numerous, that co-channel protection will not be needed, thereby providing less interference protection and freeing up more spectrum than is assumed by other parties. As noted above, this fails to take into account the technical and geographic characteristics of DTV band spectrum, including the likely need for substantial co-channel protection at the higher transmit power they contemplate (but don't specify precisely), as well as political odds against the FCC or Congress approving nationwide licenses or giving local DTV stations the discretion to negotiate payments in return for accepting interference with the reception of portions of their local viewing audience.[37]

Brattle I rejects the two principal prior studies estimating DTV white space availability. The methodologically sophisticated effort of the Association of Maximum Service Television, Inc., (MSTV) to estimate available DTV white space[38] was rejected on the grounds that it assumes an excessive interference protection rule,[39] despite the fact that the MSTV study used a rule consistent with the FCC's current interference policy. However, the principal objection appears to be that the MSTV study found too little DTV white space, particularly in the high-price big city markets. The New America Foundation/Free Press study was rejected on various methodological grounds for both under-counting and over-counting such white space,[40] although this seems to be primarily because the NAF/FP estimates were based on counting all channels available for very low-power, unlicensed use – and therefore did not block off adjacent channels.

Using their own estimation method,[41] Jackson and Robyn arrive at estimates of potential DTV white space that differ from the MSTV study primarily in finding more white space in potentially lucrative urban markets. It is possible to criticize Jackson and Robyn on technical grounds for potentially overestimating the amount of available white space, but there is no reason not to accept their white space estimates for purposes of argument. What is objectionable is their selection of a scenario which appears to maximize estimation of white space in a way which is calculated simply to maximize estimation of auction revenue. The Brattle studies do this by assuming that unlike unlicensed devices (or at least unlike higher-power unlicensed devices, such as the fixed 802.22 access points contemplated for rural areas), licensed devices will be able to operate at the border of a DTV station's protected coverage area (the B contour) and on the same frequency with no "buffer" (i.e., no co-channel protection) to protect DTV viewers who live near the edge of the station's coverage zone (and who therefore receive relatively weak and hence more vulnerable DTV signals).

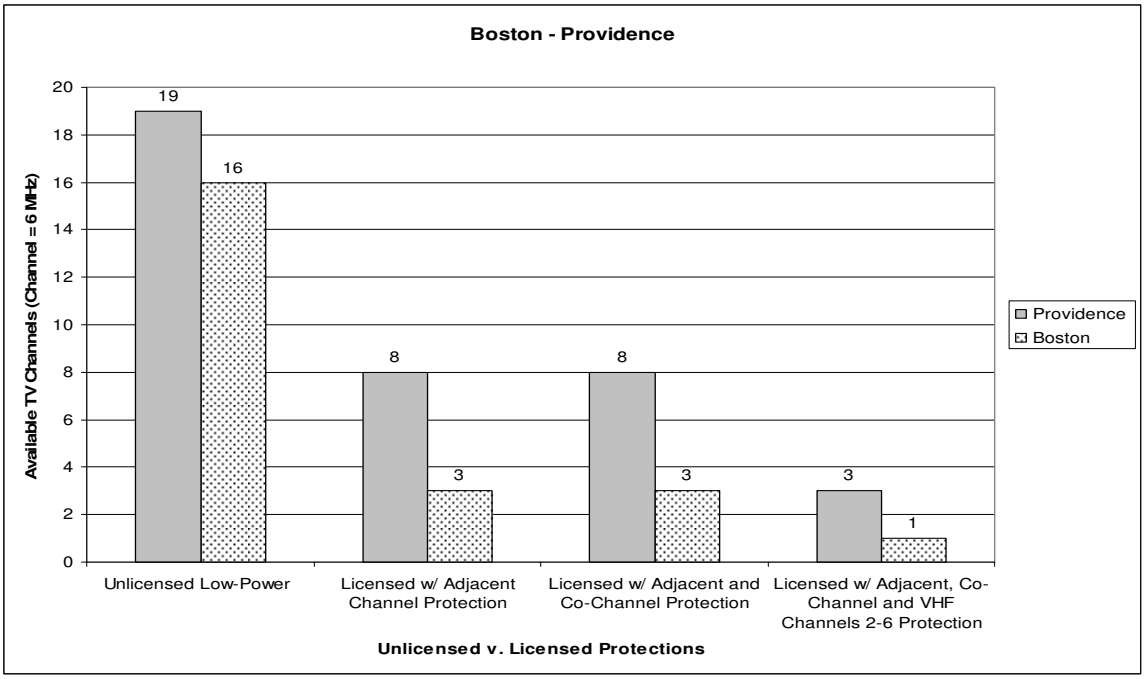
Indeed, Brattle I concedes that if their hypothesized licensed users were subject to the same interference protection standard that the FCC is likely to impose on high-power *unlicensed* users, **this "additional buffer protection [under the unlicensed scenario] reduces the availability of white space . . . by one-quarter to one-half, depending on how it is measured."**[42] Note that this reduction would be on top of the approximately 50 percent overall reduction in available white space bandwidth due to the exclusion of the channels adjacent to each licensed DTV facility, which is assumed under all but one of the Brattle scenarios since they assume that the auctioned license rights will allow a transmit power substantially above the 100 mW level

proposed for unlicensed access personal/portable devices.

As noted in the Summary section above, Brattle's failure to account for co-channel protection and for the likely exclusion of VHF channels 2-to-6, as the FCC has proposed, allows it to show that at least one, two or three channels are available in the nation's most populous metropolitan markets. However, as the chart for Dallas showed (above), and the charts for Boston-Providence, Detroit and New York City show below, taking account of the co-channel and VHF channel 2-6 interference protection that would be necessary at transmit power levels conceivably useful to a commercial service (viz., above 1 watt EIRP) would leave potential licensees with not a single channel in nearly all of the nation's largest metropolitan areas.

For example, in the Dallas-Fort Worth-Arlington metropolitan statistical area, protecting channels immediately adjacent to the channels occupied by DTV facilities leaves only channel 29 available. However, that channel is overlapped substantially by the B contour of two other channels in neighboring markets. Thus, even if we assume that all the VHF channels could be licensed in metro Dallas; there is still not a single channel available for auction. Similarly, the Brattle study finds that the Boston-Providence metropolitan trading area (MTA), which includes the region around those cities, would have a minimum total of 12 MHz of "bandwidth" available for auction. However, as the chart below shows, protecting adjacent DTV channels leaves only channels 5, 6 and 7 available in the Boston metro. Not only are these low VHF channels of limited use for mobile services (which is what brings high prices in an auction), but since the FCC has already proposed excluding channels 2-to-6, the maximum number of useable channels available for auction in Boston is one. Providence has three, but since those are not available in most of the Boston market, there is not a single consistent channel available for licensed use across even the Boston-Providence MTA (let alone all of New England). A similar situation holds for Detroit (one channel available) and the New York City area (no channels), as the charts on the following pages indicate.

Figure 2.
Available Post-DTV Channels for Boston/Providence[43]



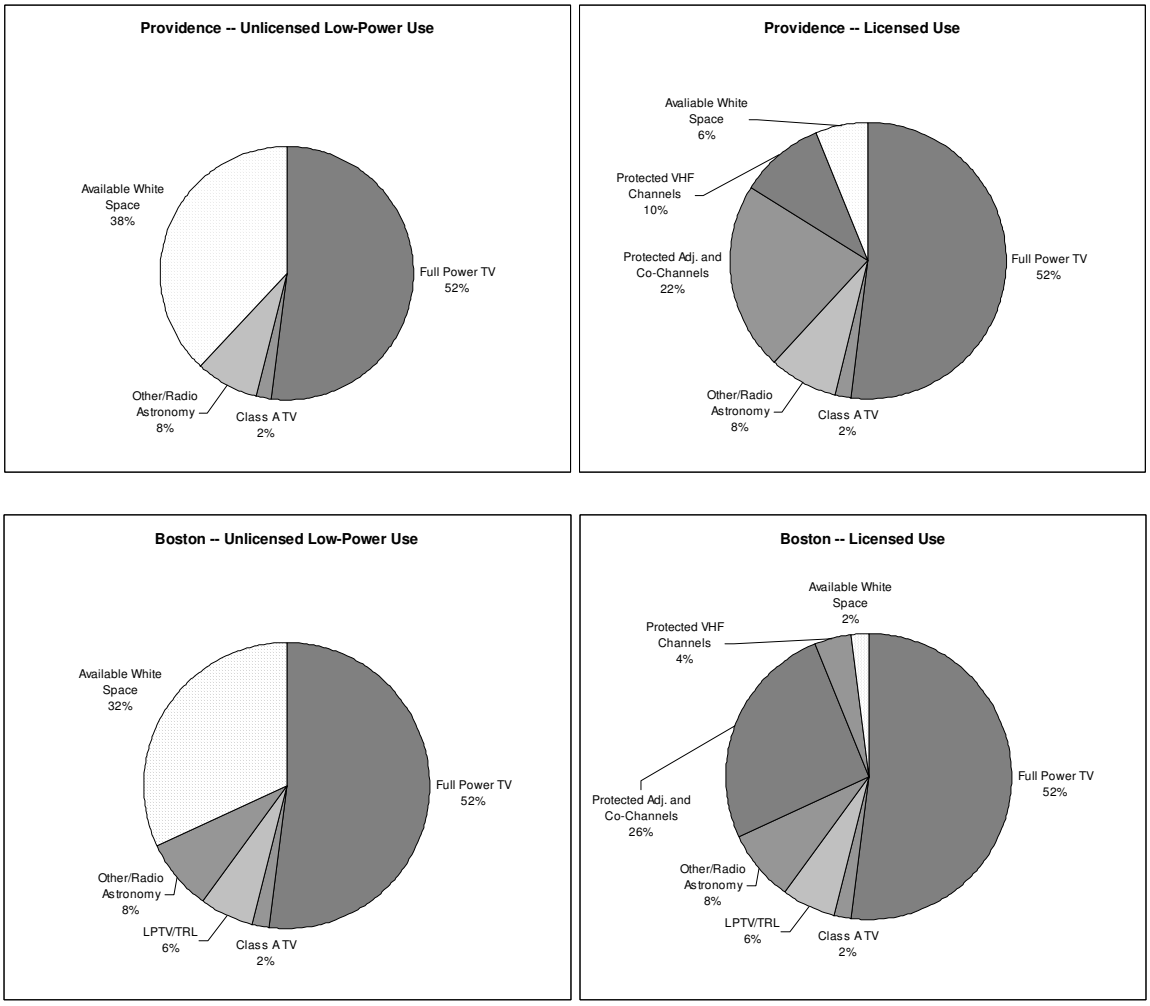
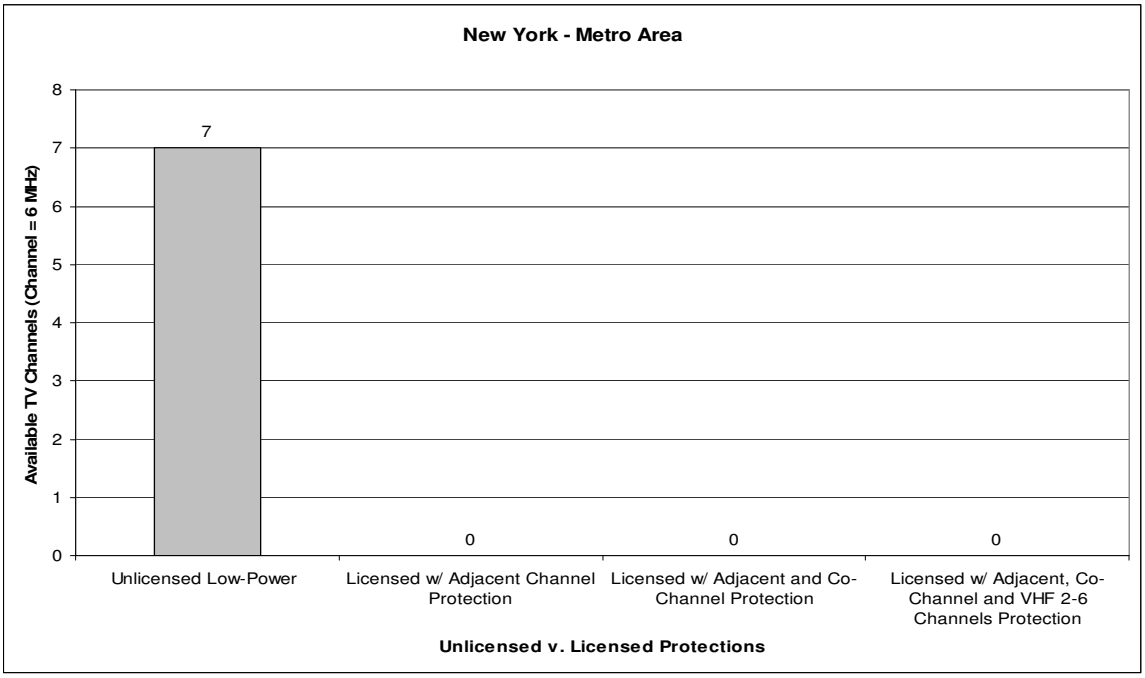


Figure 3.
Available Post-DTV Channels for New York - Metro Area[44]



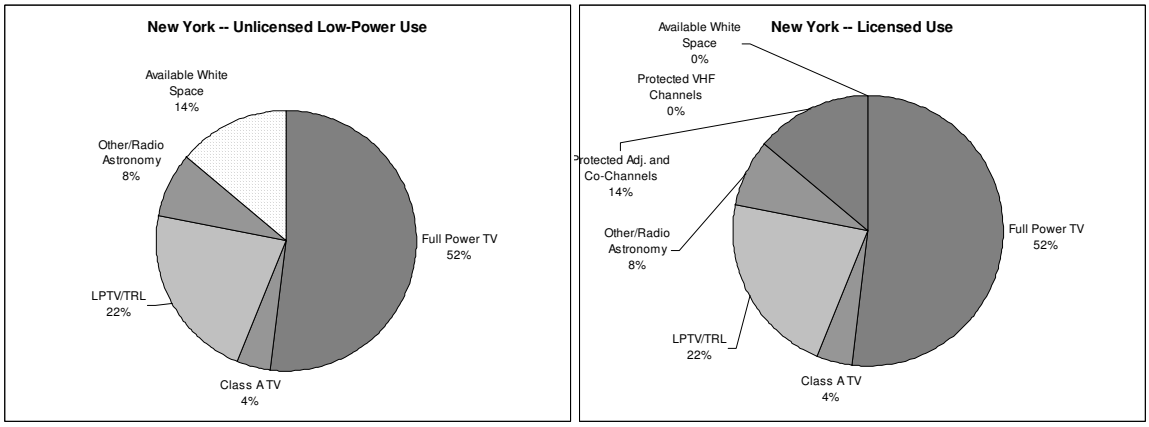
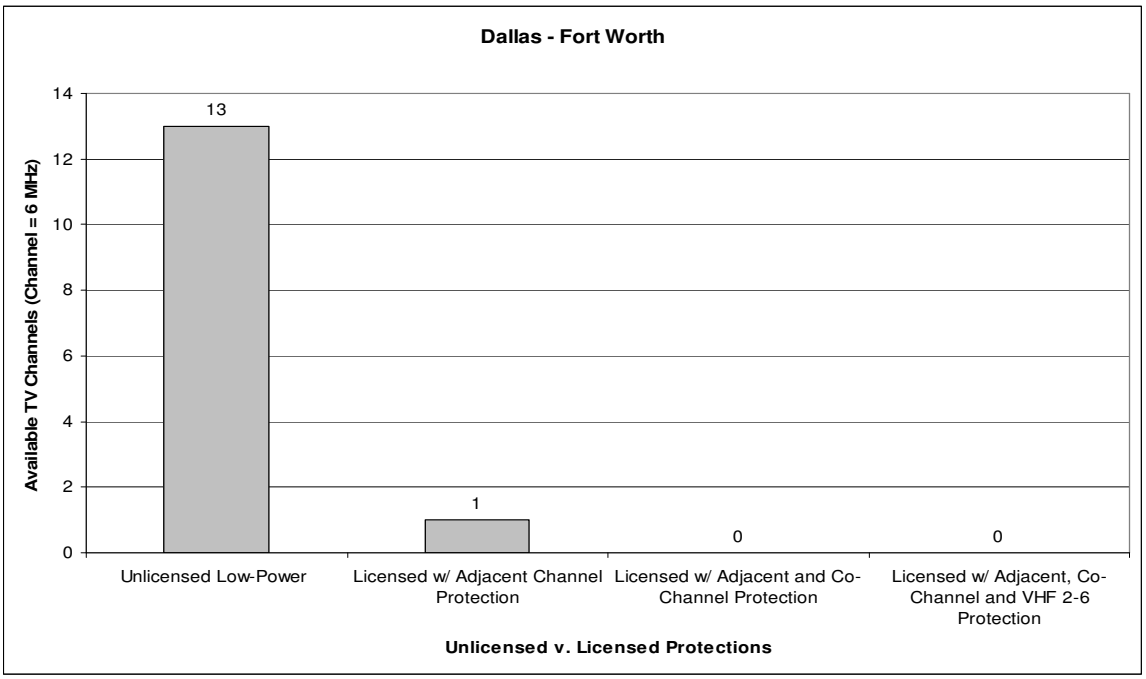


Figure 3.
Available Post-DTV Channels for Dallas/Fort Worth - Metro Area[45]



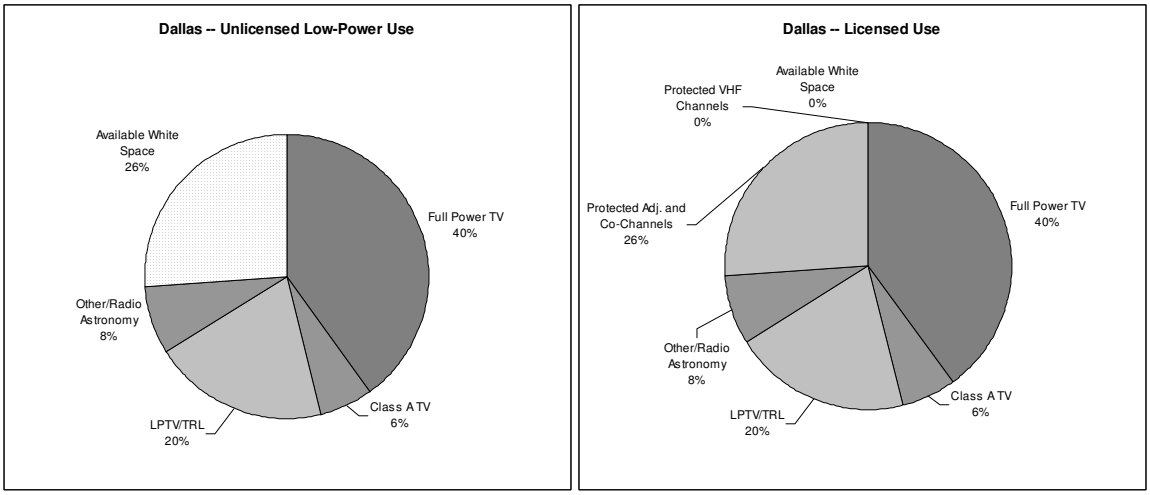
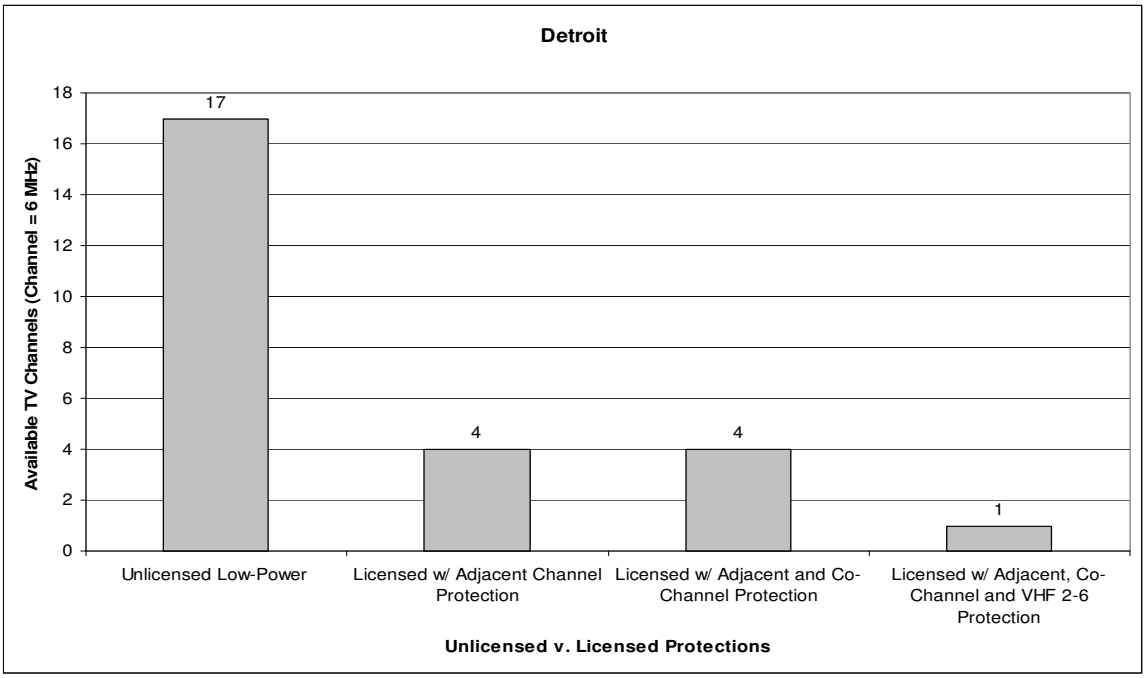
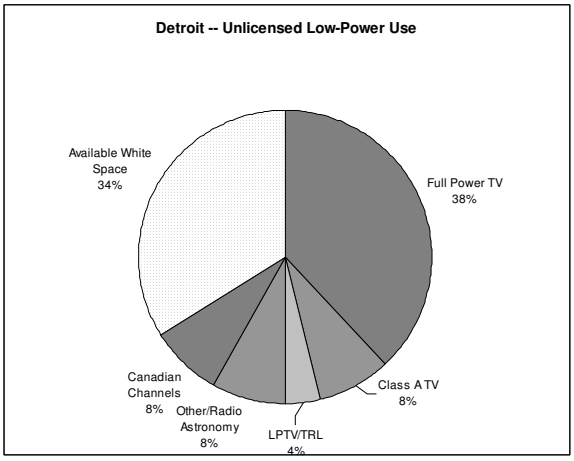
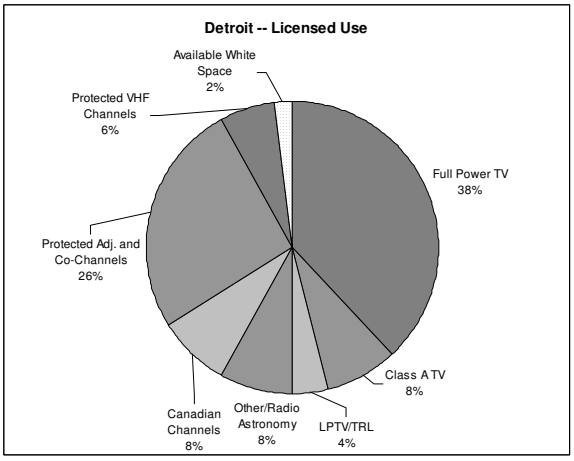


Figure 4.
Available Post-DTV Channels for Detroit - Metro Area[46]







2. Brattle I's Estimates are Based on Fatally Flawed Analysis of Market Comparability

Even assuming Brattle's estimate of the minimum average amount of white space "bandwidth" available for auction in each regional metro market is not inflated, their revenue estimates are wildly exaggerated since they are based on auctions for contiguous, high power and relatively unencumbered spectrum which – unlike the TV white space – were allocated to fit the business model of the incumbent wireless carriers. The market comparables analysis put forward by Brattle is also questionable because, although they reference the fourteen previous FCC auctions of more analogous white space spectrum,[47] they take none of the data from those auctions into consideration.

Appendix 1 shows relevant data from the previous white space auctions and from the PCS and AWS-1 auctions cited by Brattle I as comparable. Several things are immediately apparent from examination of this data. First, valuation of spectrum in the previous white space auctions varies

radically, depending on the use of that spectrum specified for the auctioned licenses, the bandwidth plan, and the regional allocation of licenses. Additionally, spectrum value does not reliably correlate with population characteristics of a license area. In a handful of auctions, spectrum value is highly positively correlated to population of license, but weakly negatively correlated in the majority of auctions. Furthermore, the auctions themselves exhibited considerable variation in strategic dynamics (measured by the variation in mean rates of convergence to PWB) and willingness of bidders to bid (evidenced by the large number of licenses not PWB in some auctions because the FCC reserve price was never met), both of which had substantial impact on clearing prices.

In light of the existence of empirical evidence of market valuation of white space in previous auctions, the selection of the value of 2.5 GHz Broadband Radio Service/Educational Broadband Service (BRS/EBS) spectrum as the basis for valuing DTV white space seems completely arbitrary and highly questionable given Brattle I's repeated citing of uncertainty as to the FCC's ultimate determinations of spectrum use, bandwidth plan, and interference protection. We cannot say with certainty that the mean revenue raised in the 14 previous white space auctions are precisely comparable or predictive, but it is safe to conclude that the secondary market transactions for 2.5 GHz spectrum are not. The FCC re-banded the prior ITFS/MMDS bands specifically with licensed, high-power WiMax services in mind. It is most definitely not the very lower-power, "Swiss cheese" spectrum that characterizes the need to protect television on the DTV white space. Indeed, the WiMAX Coalition insisted that they required exclusive use, at high power and over larger geographic areas, in order to ensure metro-wide coverage, economies of scale, and the quality of service needed for commercial broadband subscription services.

Brattle I simply ignores the lack of comparability between the two bands. In fact, one essential difference between the IEEE standards that govern WiMax (designed for licensed use) and WiFi (designed for unlicensed) is transmit power and coverage area. WiMax uses a cellular architecture transmitting at high power to blanket relatively large geographic areas from a single tower (2000 watts of allowable power downlink, 2 watts up from mobile devices). At 2000 watts, WiMAX licenses permit transmissions at 500 times the power level of the proposed 4 watt limit for 802.22 fixed base stations on white space – enough power to penetrate buildings and allow WiMAX to be marketed as a substitute for DSL and other wired broadband services. High transmit power also reduces capital investment costs. The WiFi standard, by contrast, is designed to operate on unlicensed bands and wide channels (20 MHz), at a fraction of the power, allowing only local area networks (LANs), such as around a home or at most a few square blocks. WiFi access points can be meshed together to cover larger areas – but this is a more intensive and different infrastructure than the licensed, cellular business model. Moreover, in order to achieve greater spectrum efficiency by making use of vacant DTV channels immediately adjacent to occupied/licensed channels, mobile white space devices are expected to be limited to transmit power levels just a fraction of what's allowed for WiFi under Part 15 rules.

A more reasonable approach would have been either (1) to note the extreme variation in spectrum valuation in these auctions and attempt to make a more detailed assessment of the comparability of this spectrum and behavior of actors in these previous auctions to the hypothesized DTV white space spectrum and auction, or (2) to take a weighted mean of the dollar per MHz-pop of those auctions involving unpaired spectrum and use that as the estimator of the dollar per MHz-pop value of the hypothesized DTV white space. Revenue estimates using the latter technique will be discussed below.

It is also patent from review of Appendix 1 that any argument that the PCS and AWS-1 are genuine market comparables to a hypothesized DTV white space auction must explain and overcome the profound differences in auction dynamics and outcomes between those auctions and the previous white space auctions, a task which the authors of Brattle I eschew, as well as the

clear differences in quantity, quality, and technical/geographic constraints on DTV white space that were not present in the PCS and AWS-1 auctions. The dollar per MHz-pop value of the 700 MHz auction spectrum is also provided in Appendix 1, to further demonstrate that the PCS and AWS-1 auction prices are more similar to 700 MHz spectrum than to the "Swiss-cheese" spectrum associated with the DTV white space, making even more patent the inappropriateness of the assumed market comparability by Brattle I.

Brattle I also grossly overestimate the mean dollar per MHz-pop prices fetched by licenses in the AWS-1 auction, which they use to arrive at the high end of their estimation range ($6 billion). The usual figure cited for the AWS-1 price per MHz-pop is $0.54. However, this figure is arrived at by averaging over all blocks of spectrum at auction and it ignores a serious skew in the data. Nearly $11.5 billion of the $13.9 billion in revenue raised by the AWS-1 auction, i.e., 82.84% of revenue, was raised by fifty licenses, 4.46% of the licenses at auction.[48] There were significantly more EA and CMA licenses at auction in AWS-1 than REAGs, despite the fact that it is from the REAGs and a handful of EAs and CMAs that the overwhelming majority of revenue was raised. A more representative measure of the performance of the average license is arrived at by weighting for number of licenses in category of spectrum. To do otherwise is to assume that all licenses cleared on average at a very high price. Calculating from the FCC raw data for the auction, the means for the five categories of spectrum are:

Table 1
Mean per License $/MHz/Pop Calculation for AWS-1 Auction

License Category	% of Licenses PWB	Mean per License $/MHZ/Pop
CMA 20 MHz	65.56	0.1624
BEA 10 MHz	15.93	0.2407
BEA 20 MHz	15.84	0.2187
REAG 10 MHz	1.84	0.4183
REAG 20 MHz	0.83	0.5276
AWS-1Mean Weighted by % of Licenses in Type	-	0.1916

Source: FCC

It is the case that by weighting the averages for each license category by the percent of total licenses PWB in each category, one arrives at a dollar per MHZ-pop mean which more closely reflects overall performance at auction. This is particularly important because the smaller CMA and EA licenses were hugely more numerous and tended to draw significantly lower prices. Given the fact that the technical and geographic constraints of DTV white space are well-known, and that they rule out the feasibility of large regional aggregation licenses – such as the AWS-1

auction REAGs – the Brattle I study's failure to weigh the AWS-1 mean dollar per MHz-pop by percentage of licenses in spectrum category amounts to intentional over-estimation of per license value.

3. Brattle I Assumes Away Severe Inference Constraints Proposed by the FCC to Protect DTV Viewers and Secondary White Space Users

Brattle I's use of 2.5 GHz and AWS-1 licenses as market comparables for estimating the auction proceeds for DTV white space involves fundamentally assuming away interference constraints which the FCC has proposed to protect DTV viewers and were simply not present in the 2.5 GHz BRS/EBS and AWS-1 spectrum. The constraints call their revenue estimates profoundly into question, because MHz for MHz, these interference constraints substantially reduce the value of DTV white space spectrum at auction.

For example, the AWS-1 auction in 2006 offered carriers the opportunity to bid on paired bands of spectrum that was tailor-made to fit the existing technology and business models of the deep-pocketed incumbents (with an uplink and a downlink, separated by frequency to avoid self-interference). In fact, the banding plan for AWS-1 was not only paired with at least 10 MHz wide channels, but the downlink band was located where it could operate at extremely high power compared to the uplink band (which in some cases bordered broadcast auxiliary spectrum used for sensitive TV news feeds). The power constraints imposed by the FCC on the 1710-1755 MHz bands was a maximum of one watt and on the 2110-2155 MHz bands either a maximum of 200 watts in a county with a population density of 100 or fewer persons per square mile, or 100 watts elsewhere. In contrast, the FCC's anticipated permissible power limit for personal/portable (mobile) DTV white space devices is 100 mW or .01 watts. And even assuming (as Brattle generally does) that the license rights for TV white space will allow higher transmit power, it will likely be no more than 1 to 4 watts and come at the price of limiting the use of the spectrum to fixed-location services, whereas AWS-1 supports truly mobile 3G and 4G broadband. The difference is staggering, but Brattle I take no account of it. The AWS-1 spectrum also can be aggregated seamlessly across regions or nationwide; and there are no constraints related to utilizing cognitive radio devices or GPS-equipped devices on the AWS-1 spectrum, nor was it limited to fixed-location services in the absence of such devices. And although some AWS-1 license holders face delays while federal incumbents use the auction proceeds (escrowed on their behalf in a spectrum relocation trust) to migrate to other bands, they are not required indefinitely to avoid interference with such unlicensed users as wireless microphone systems, as is virtually certain for the DTV white space. All these constraints figure prominently in the FCC's anti-interference regimen for the DTV white space. Brattle I can use AWS-1 pricing as a market comparable for DTV white space only by ignoring the patent difference in restrictions on the two types of spectrum.

The situation is the same for the 2.5 GHz BRS/EBS spectrum. The power of BRS and EBS base stations is limited to 2000 watts, while that of BRS and EBS mobile stations is limited to 2 watts. There are no constraints to utilize cognitive radio devices or GPS-equipped devices on the BRS/EBS spectrum, nor is it limited to fixed-location services in the absence of such devices. And yet again, no requirement was imposed upon license holders to avoid interference with such unlicensed users as wireless microphone systems.

Finally, Brattle I authors Jackson and Robyn also make a critical and utterly unrealistic assumption about the bargaining posture of a licensed regime for DTV white space which has direct implication for spectrum valuation. Jackson and Robyn contend that a licensed approach would:

> …produce more efficient use of the white space, even in the short-run: most important, the parties—the potential interference-generating licensee and the potentially interfered-with

> broadcaster—would have an incentive to negotiate deviations from FCC interference standards, resulting in greater capacity.[49]

In Brattle I Jackson and Robyn cite only a single historical example of such negotiation from FCC interference standards, a 1986 FCC study of frequency coordination in the common-carrier point-to-point microwave service,[50] and vaguely suggest that a similar regime might be tried in the aftermath the 700 MHz, auction. In general, Brattle I provide no empirical evidence to back up this assertion.

More critically, although white space licensees may indeed have an "incentive" to negotiate payments to local DTV stations for what Jackson and Robyn call "deviations from FCC interference standards, resulting in greater capacity," in practice this presumes a change in the statute (which requires broadcasters to provide their local market area at least one free programming channel) and/or regulations designed explicitly to allow broadcasters (who received their licenses free of charge) to cut off a portion of their viewing audience from free over-the-air service. NAF, et al.'s Technical Reply Comments are directly to the point:

> Negotiate what, exactly? The only "negotiation" that would increase the useable spectrum for a licensed service, as compared to a low-power unlicensed regime, would come at the expense of localism by disenfranchising some portion of a local station's viewing audience! Is the Commission really prepared to use this proceeding to facilitate a recommendation that TV licensees, who are bound by statute to provide at least a primary stream of free over-the-air programming, should be encouraged to negotiate away the interference protection of all or some substantial portion of their viewing audience? Even if the Commission determined it had the authority to indirectly subvert the Communications Act to pursue this pragmatic tradeoff, the entire premise of the Qualcomm/Brattle proposal for "negotiations" to relax interference protections for local TV viewers is irrelevant since that issue has not been noticed in this proceeding. It is an argument premised on a red herring that has no legally or politically viable basis.
>
> Furthermore, a casual reading of the comments filed by the broadcasting interests in this proceeding show how unlikely this assumption is vis-à-vis the incumbent licensees. There has never been the slightest indication that local broadcasters are willing to negotiate away their "birthright" (and, possibly, their must-carry rights) for incremental income rather than directly serving the public with their signals.[51]

This assumption runs contrary to the consistent position of broadcasters for decades and assumes legal powers and political will which the FCC simply does not have. The only reason for this assumption is to avoid taking into account the value reduction which DTV white space spectrum will encounter at auction as a result of FCC interference standards by assuming that they will magically go away through some hypothesized private negotiations.

B. Brattle II: Compounding Erroneous Assumptions

In June 2008 the Brattle Group, again on behalf of QUALCOMM, issued a revision of the January 2007 paper in the form of new comments by Jackson, Robyn, and Coleman Bazelon (Brattle II). While the approach taken by the revised paper is econometrically much more sophisticated than the that of the original paper – revising down the estimate of available white space, estimating revenue by extrapolation from dollar per MHz-pop, using Auction 73 (700 MHz Band) E Block data at the Economic Area (EA) level, and calculating an elasticity adjustment to correct for price effects of the increase in the amount of licensed spectrum on the estimated white space prices – it reinstates many of the original paper's erroneous assumptions and compounds them by selecting an extremely unlikely market comparable, E Block of Auction 73, for the key estimates. Furthermore, it seems patently designed to advocate an auction design

favored by the research's funder, QUALCOMM, by predicating the estimates on EA-level auction of 6 unpaired MHz spectrum in accordance with the business plan underlying QUALCOMM's bidding strategy in Auction 73.

1. Brattle II Still Overestimates Available White Space

While Jackson and Robyn presented five scenarios under different interference protection conditions,[52] Brattle II adds a Scenario Q to take account of an emerging consensus that the FCC will not allow higher-power access (and possibly not even very low-power unlicensed access) to channels 36 and 38 (since channels 37 is reserved for sensitive medical telemetry devices) and to the 13 metro markets where public safety has licenses to channels between 14 and 20 for land mobile radios.[53] Table 2 shows the various scenarios and the estimates of available white space in MHz-pops:

Table 2. White Spaces Estimates in Jackson and Robyn and Jackson, Robyn, and Bazelon

	Included Facilities	Co-Channel protection	Adjacent Channel Protection	Channels	Jackson and Robyn, MHz-Pops (in billions)	Jackson, Robyn, and Bazelon, MHz-Pops (in billions)
Scenario X	All US, Canadian, and Mexican regular and Class A stations and land systems in the UHF TV spectrum	FCC Radius	None	2 to 51	53.678	50.847
Scenario Y	All US, Canadian, and Mexican regular and Class A stations and land systems in the UHF TV spectrum	FCC Radius	FCC Radius	2 to 51	28.266	25.685
Scenario Z	All US, Canadian, and Mexican regular and Class A stations and land systems in the UHF TV spectrum, and all TV translators	FCC Radius	FCC Radius	2 to 51	27.156	24.604
Scenario UL-1	All US, Canadian, and Mexican regular and Class A stations and land systems in the UHF TV spectrum	FCC Radius plus 46, 30, and 17 miles for low VHF, high VHF, and UHF	FCC Radius plus 5 miles	2 to 51	21.028	-
Scenario UL-2	All US, Canadian, and Mexican regular and Class A stations and land systems in the UHF TV spectrum. Channels 2-4 and 14-20 excluded.	FCC Radius plus 46, 30, and 17 miles for low VHF, high VHF, and UHF	FCC Radius plus 5 miles	2 to 51	15.160	-
Scenario Q	All US, Canadian, and Mexican regular and Class A stations and land systems in the UHF TV spectrum, and all TV translators. Channels 14-20, 36, and 38 excluded.	FCC Radius	FCC Radius	2 to 51	-	19.839

Despite reducing the estimates of available white space in the more realistic Scenarios Y and Z by 9.13 percent and 9.40 percent, respectively, Brattle II strangely fails to exclude channels 2, 3 and 4 from Scenario Q, as Jackson and Robyn had in Brattle I's Scenario UL-1, despite the fact that the FCC stated in the NPRM that channels 2-to-6 (amounting to 30 MHz at 55-72 and 77-88 MHz) will likely be excluded from any white space allocation due to potential interference with cable set-top boxes, DVD/DVRs, and other video peripheral devices. Brattle II provides no rationale for including channels 2-to-6, despite the FCC's clear indication they will be.

Exclusion of channels 2-to-6 reduces the average available white space by 9.8 percent. And even this exclusion would overestimate the availability of VHF white space. None of the companies advocating unlicensed use of the DTV white space advocate including VHF channels 7-to-13 in the white space precisely because they regard these channels as too fraught with interference problems and useless for mobile devices because antenna size would need to be too large at such low frequencies. This eliminates another 36 MHz in many markets. Exclusion of channels 2-13 would reduce the average available white space by a total 23.53%. More critically, since incumbent television stations have been relocating to higher-frequency UHF channels – because of the inferior propagation characteristics of the lower VHF band for digital signals – in the major metro markets nearly all of the vacant channels left after excluding first adjacent channels (as Brattle assumes is necessary to operate at higher power) are on the problematic VHF band.

2. Brattle II Base Their Estimates on an Inappropriate Market Comparable.

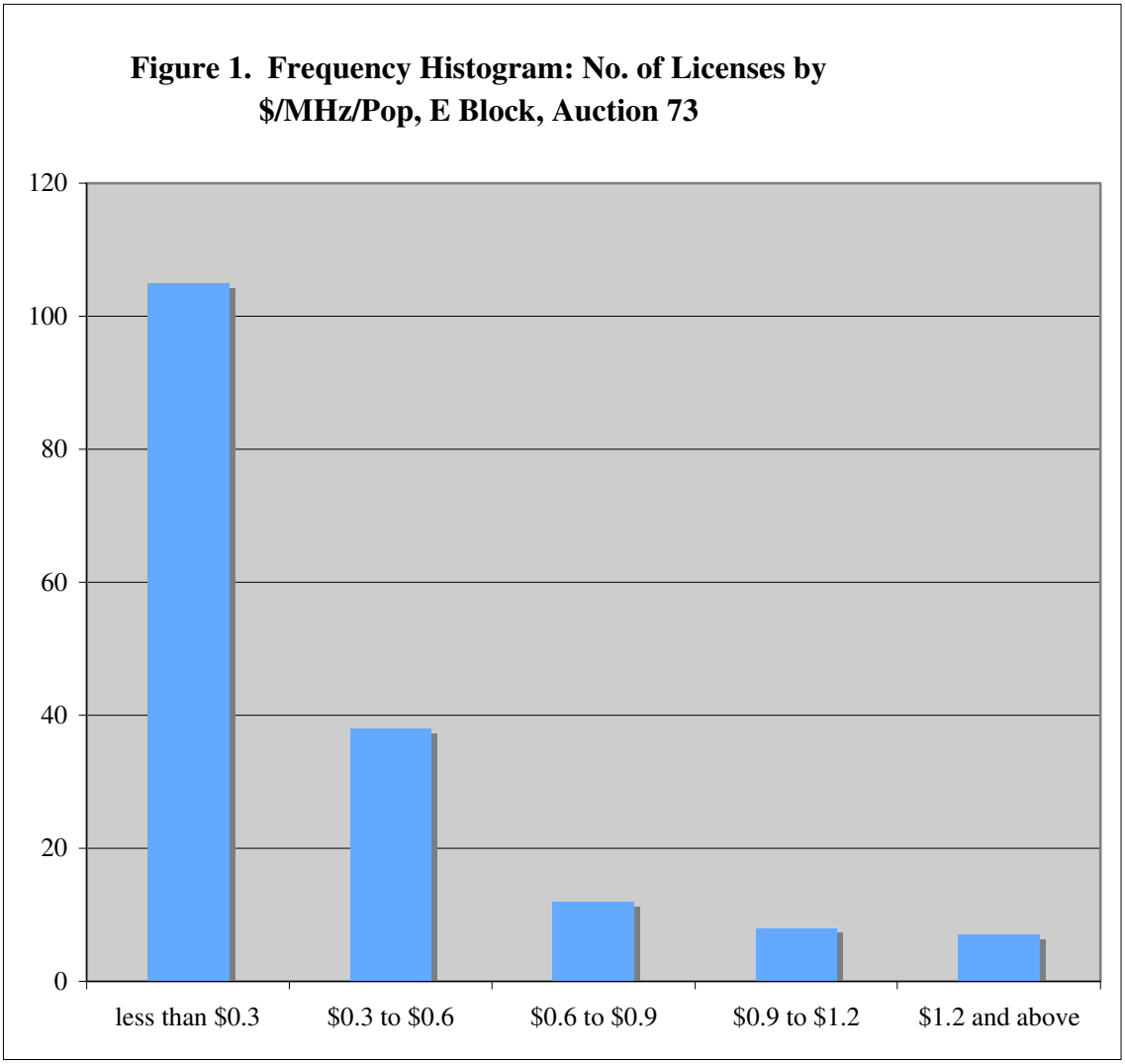
While the E Block frequencies in this year's Auction 73 (700 MHz Band) consisted of 6 MHz of unpaired spectrum, in virtually every other respect E Block is an inappropriate market comparable for DTV white space. An examination of the most salient technical differences between E Block and white space spectrum, as well as consideration of the bidding dynamics in E Block of Auction 73, show this to be an inescapable conclusion.

> Even with a substantial unpairing discount, E Block sold at a 47.83% mean premium over the 10 MHz paired spectrum also auctioned at the EA level in C Block of Auction 66 (AWS-1). This results from the considerably better propagation characteristics of 700 MHz Band spectrum, capable of penetrating structures and other ground clutter at long distances. Furthermore, the 700 MHz Band spectrum is contiguous, which DTV white space is not. The discontinuous, "swiss cheese" character of white space frequency availability requires that uses analogous to the uses of the 700 MHz Band will be limited to relatively small geographic coverage areas and use more cognitive (and more expensive) radio devices which must be rigged for compatibility across noncontiguous spectrum, This characteristic of DTV white spectrum implies a significant price discount against 700 MHz Band spectrum because economies of scale and integration afforded by contiguous spectrum do not obtain. Like the AWS-1 and BRS/EBS licenses discussed above, the power levels at which 700 MHz Band licensees are permitted to operate is magnitudes greater (1000 watts for fixed base stations, 3 watts for personal/portable handsets) than those at which users of DTV white space are anticipated to operate due to interference constraints:[54]

DTV white space users will be limited to a power level of 100 mW (.01 watts). That is 100,000 to 300,000 times less powerful than the authorized power levels of 700 MHz Band licensees. This implies that the prices fetched by DTV white space at auction will be hugely discounted in comparison to the prices fetched by E Block licenses in Auction 73.

The price structure of E Block exhibited the significant skew of price by population density characteristic of virtually all FCC spectrum auctions: competition is much more intense and prices are, thus, considerably higher for the small number of licenses with the highest population

density. Figure 1 shows the effects of this skew:



This skew is likewise demonstrable by the difference between the mean dollar per MHz-pop for E Block taken as a whole ($0.74) and the mean per license dollar per MHz-pop ($0.34). Brattle II's use of summed EA prices from E Block as a market comparable for DTV white space controls for this, but the approach of the earlier Jackson and Robyn study (Brattle I) does not.

This price skew in E Block was accompanied by the way a single bidder, Frontier Wireless (the company name under which EchoStar, the satellite TV broadcaster, competed for spectrum in AUCTION 73) accumulated the overwhelming majority of licenses to auction. Frontier Wireless received 95.5 percent of E Block licenses, QUALCOMM received 2.5 percent, and other bidders 1.70 percent. This is to be expected, given the way that the Wireless DBS consortium, of which EchoStar was a major partner, was entirely excluded from obtaining spectrum in AWS-1.[55] Frontier Wireless' bidding strategy was dictated by the realization that failure to prevail in Auction 73 would force EchoStar to seek partners with appropriate spectrum on unfavorable terms if it was to provide the broadband service necessary to compete with cable operators able to offer broadband, video, and phone services. This increased the premium at which E Block cleared over EA-level spectrum in AWS-1. In key higher population density EA markets competition between Frontier Wireless and QUALCOMM pushed dollar per MHz-pop to nearly

three times the per license mean. None of these dynamics are likely to obtain in any hypothesized DTV white spaces auction, and this fact renders E Block of Auction 73 strikingly inappropriate as a market comparable for such an auction.

III. Conclusion

QUALCOMM and its Brattle Group studies dangle a pot of fool's gold in front of revenue-hungy legislators, hoping they will pressure the FCC to reverse course and spend the next two or three years designing an auction destined to fail. The Brattle studies grossly overestimate the potential revenue that could be raised from a one-time auction of DTV white space. The Brattle studies make auction estimates based on prices for 700 MHz, AWS-1 and WiMax spectrum licenses that are not severely encumbered as white space auction rights would be in terms of aggregation, power levels, interference protections and the ability to serve the most lucrative major metro market areas.

More disturbingly, in order to make the white space auction attractive to potential bidders (and useful to QUALCOMM itself), the licensing rights proposed by Brattle Group would leave the vast majority of the TV white space fallow. Tremendous capacity in the very best "beachfront" bands of spectrum would be wasted needlessly and indefinitely under the QUALCOMM scheme. Brattle concedes that the adjacent channel guard bands required for auctionable spectrum would by itself leave half the white space unused, on average, and block off nearly all of the more limited number of vacant channels in the nation's largest metro markets. Moreover, by greatly under-estimating the additional amounts of white space that would not be useable by a more-than-very-low-power service – due to the need for co-channel protection, the unavailability of channels 2-to-6, and the challenges to making more than limited use of channels 7-to-13 – the study obscures the fact that there may be no useable white space at all to auction in the major coastal metro market areas.

Appendix

Appendix 1
Comparison of Previous White Space, PCS, AWS, and 700 MHz Auctions

									$/Mhz/Pop		Rate of Convergence to PWB (Rnds)	
Auction No.	**Spectrum/Service Type**	**Net Revenue ($ millions)**	**MHz**	**License Plan**	**No. of Licenses**	**No. of Licenses PWB**	**No. of Bidders**	**No. of Rounds**	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**
6	Multipoint/ Multichannel Distribution Services	216.24	6	493 BTAs; 1 license each	493	193	155	181	0.24	0.27	95.95	37.05
7	900 MHz Specialized Mobile Radio Service	204.27	0.25	51 MTAs; 20 licenses each	1020	1020	123	168	0.93	1.53	77.19	42.92
16	800 MHz Specialized Mobile Radio Service	96.23	1 (A) 3 (B) 6 (C)	175 Eas; 3 licenses each	525	525	62	235	0.07	0.14	86,83	61.63
26	929 and 931 MHz Paging Service	4.12	0.02	51 MEAs; 12 929 MHz and 37 931 MHz licenses in each MEA	2499	985	81	28	0	0	1.14	3.01
34	800 MHz SMR General Category Service	319.45	1.25 (GC) 1 (A) 3 (B) 6 (C)	1,050 licenses for 800 MHz General Category; 6 contiguous 25 channel blocks i8n 175 Eas; 3 licenses for selected Eas; 800 MHz Upper Band: 1 20 channel block (A), 1 60 channel block (B), and 1 120 channel block ©	1053	1030	26	76	0.19	0.28	29.66	14.71
36	800 MHz SMR Lower 80 Channels Service	28.98	0.025	16 non-contiguous 5 channel blocks in 17y5 Eas	2800	2800	28	151	0.01	0.04	28.77	44.45
40	Paging	12.9	2.12	14,000 lower bands paging licenses in 175 Eas; 1,514 upper bands paging licenses in 51 MEAs	15514	5323	193	140	0.000045	0.000087	14.33	23.51
42	Multiple Address Systems Spectrum	1.2	0.25 (AA-BB) .1 (BC)	5,104 licenses in 176 Eas	5104	878	13	36	0.06	0.08	4.08	6.43
53	Multichannel Video Distribution & Data Service	118.72	500	214 DMAs; 1 license each	214	192	14	49	0.14	0.17	17.45	11.1
55	900 Specialized Mobile Radio Service	4.86	0.25	55 licenses in 31 MTAs	55	55	17	76	0.02	0.02	23.91	21.96
57	Automated Maritime Telecommunications System	1.06	1	20 AMTS Areas; 1 license each	20	10	4	3	0.0034	0.0006	1.1	0.32
59	Multiple Address Systems Spectrum	3.87	0.03	4,226 MAS licenses in 176 Eas	4226	2223	32	126	0.25	1.64	23.28	32.52
61	Automated Maritime Telecommunications System	7.09	1	10 AMTS Areas; 1 license each	10	10	7	116	0.04	0.03	89.5	19.92
63	Multichannel Video Distribution & Data Service	0.13	500	22 DV-MVD Areas; 1 license each	22	22	3	3	0.1	0.09	1.91	0.29
5	Broadband PCS C Block	10,071.71	30	493 BTAs; 1 license each	493	493	255	184	0.78	0.52	89.29	15.52

11	Broadband PCS D, E, & F Block	2,517.44	10	493 BTAs; 3 blocks each	1472	1472	153	276	0.27	0.46	117	67.68
66	Advanced Wirelrss Services	13,700.27	20 (A,B) 10 (C,D, E) 20 (F)	734 CMS, 1 license each (A); 176 EAs, 1 license each (B,C); 12 REAGs, 1 license each (D,E,F)	1122	1087	168	161	0.19	0.21	58.86	29.79
73	700 MHz Band	10,053.35 *	12 (A,B) 22 (©) 10 (D) 6 (E)	176 EA licenses (A); 734 CMA Licenses (B); 12 REAG licenses (©); 176 EA licenses (E); 1 nationwide license (D)	1099	1090	214	261	0.89	1.11	58.71	49.36

Source: FCC

Endnotes

[1] Comments of Charles L. Jackson, Dorothy Robyn and Coleman Bazelon in WT Docket 06-150 and PS docket 06-229, June 20, 2008 (hereinafter "Brattle II"). This submission updated an earlier study by Jackson and Robyn, submitted in ET Docket 04-186, January 31, 2007 (hereinafter Brattle I), which had projected potential auction revenue in the range of $3.7 to $6 billion, depending on the degree of DTV interference protection. Both submissions acknowledge QUALCOMM for underwriting the studies.
[2] *Brattle I*, at 14 and n. 23: "For those scenarios . . . that provided adjacent channel protection ... we treated each DTV facility as if it operated at three TV channels – its own channel and the channels directly below and above."
[3] *Brattle II*, at 5.
[4] *Brattle II*, Appendix B, Figure B-8, "Scenario Q – Minimum Bandwidth of White Space by MTA."
[5] *Brattle I*, Appendix, at p. 39; *Brattle I* at 41.
[6] *Brattle II*, at 2;
[7] New America Foundation, et al., Technical Reply Comments in ET Docket 04-186, March 2, 2007, at 12.
[8] The FCC's Part 15 power limits for WiFi on unlicensed band is 1 watt; and the IEEE's 802.22 Working Group's proposed limit for fixed location base stations on white space is up to 4 watts. By contrast, QUALCOMM's mediaFlo service, operating on TV band channel 55, transmits at up to 50 kilowatts (50,000 watts), which allows coverage areas as large as 30-40 square kilometers. Murali R. Chari, Fuyun Ling, Ashok Mantravadi, Raghuraman Krishnamoorthi, Rajiv Vijayan,
G. Kent Walker, and Rob Chandhok, "FLO Physical Layer: An Overview, IEEE Transactions On Broadcasting, Vol. 53, No. 1 (March 2007), available at
http://www.qualcomm.com/common/documents/articles/FLO_physical_layer_IEEE.pdf.
[9] A complete channel listing of all Full-Power, Class-A, Low-Power, Satellite, and translator stations was compiled for the Dallas/Fort Worth (DMA), and all surrounding DMAs using BIA Media Access Pro. Stations whose Grade-B signal contour lies within the Dallas/Fort Worth area (defined by Collin, Dallas, Denton, Ellis, Hunt, Johnson, Kaufman, Parker, Rockwall, and Tarrant counties) were determined using BIA Media Access Pro. An additional 18 MHz (3 channels) were set aside for public safety, and other potential licensees.
[10] *See Brattle II*, at 6, n. 13. Above and beyond the utterly unrealistic revenue forecasts, *Brattle II* proposes an auction that allocates white space spectrum in Economic Area (EA) units of 6 unpaired MHz, replicating the E Block of Auction 73 in which QUALCOMM was trounced by Frontier Wireless, thus conveniently giving QUALCOMM another chance at realizing its business plan. Interestingly, a few pages later Brattle concedes that the transaction costs of negotiating interference agreements with hundreds of individual broadcast licensees could best be remedied by auctioning nationwide licenses. *Compare Brattle I*, at 46-48 and at 51-53.
[11] *Ex parte* filing of FiberTower Corporation, *Optimizing the TV Bands White Spaces*, at ET Docket Nos. 04-186 and 02-380, October 2, 2007.
[12] *Brattle I*, at 55.
[13] Pierre de Vries, "Populating the Vacant Channels: The Case for Allocating Unused Spectrum in the Digital TV Bands to Unlicensed Use for Broadband and Wireless Innovation," New America Foundation, Working Paper #14, August 2006, at 4-5, available at:
http://www.newamerica.net/publications/policy/populating_the_vacant_channels.
[14] First Report and Order and Further Notice of Proposed Rulemaking in ET Docket No. 04-186, 2006 *FNPRM* at ¶23.
[15] Economic/Legal Reply Comments of New America Foundation, et al., at ET Docket Nos. 04-186 and 02-380, March 2, 2007, 3.
[16] De Vries, *op. cit.*, 15.
[17] Brattle I argue at one point that these limitations could be mitigated by auctioning either a single or a few nationwide licenses, which would better allow a company to piece together a set of channels in every market, and by allowing local DTV stations to negotiate payments in exchange for relaxing FCC-imposed interference protections. Putting aside the odds against the FCC or Congress agreeing to allow DTV licensees to cut off portions of their local viewing audience in exchange for payments, which is discussed below, a nationwide license seems almost as unlikely. In every recent auction the FCC has yielded to intense political pressure to auction frequency assignments by local market area in order to meet the needs of rural and regional carriers, as well as to limit market concentration. For example, in this year's 700 MHz auction (Auction 73), Chairman Martin proposed allocating the 700 MHz band in the form of

multiple nationwide licenses, which led the rest of the Commission, reflecting pressure from rural interests on Capitol Hill, to reject the proposal out of hand, preferring an auction mix heavy with 734 smaller Cellular Marketing Area (CMA) and 176 Economic Area (EA) licenses, twelve Regional Economic Area Grouping (REAG) licenses, and a single nationwide commercial/public safety joint venture license which seems unlikely to meet its reserve price at auction. This lack of nationwide overlay licenses would serve to depress the value of the spectrum as it would conflict with the dominant business models of telecommunications carriers that do not integrate well with the aggregation of widely disparate channels over considerable geographic variability.

[18] *2006 FNPRM* at ¶28.

[19] See Comments of NAF, et al., at ET Docket Nos. 04-186 and 02-380, January 31, 2007, 47.

[20] In July 2008 the Public Interest Spectrum Coalition filed a complaint and petition with the FCC addressing this problem, particularly as it relates to continued wireless microphone use of TV channel 52-69 (700 MHz) spectrum that has been auctioned or assigned exclusively for public safety use after the conclusion of the DTV transition next February. See [cite]

[21] *Ex parte* filing of FiberTower Corporation, *Optimizing the TV Bands White Spaces*, at ET Docket Nos. 04-186 and 02-380, October 2, 2007, 19.

[22] From a maximum of 11 mbps for 802.11b, to 54 mbps for 802.11g and 802.11a, to 100 mbps and higher with the newly deployed 802.11n WiFi standard. Currently the IEEE's Very High Throughput Study Group is finalizing plans to launch a standards group to pursue WiFi products with a throughput approaching 1 gigabyte per second. John Cox, "IEEE readies launch of gigabit Wi-Fi project," *NetworkWorld*, September 11, 2008, available at http://www.networkworld.com/news/2008/091108-ieee.html.

[23] Comments of NAF, et al., in ET Docket Nos. 04-186 and 02-380, January 31, 2007, 37-38.

[24] *Ibid.*, at18.

[25] *Id.* at 20 -30.

[26] Gregory F. Rose, "Downstream Revenue Consequences of Broadband Deployment in Unlicensed DTV White Space: A Ten-Year Estimate," Econometric Research and Analysis, working paper, November 2007.

[27] William Lehr, "The Economic Case for Dedicated Unlicensed Spectrum Below 3GHz," New America Foundation Working Paper, July 2004, available at: http://www.newamerica.net/publications/policy/the_economic_case_for_dedicated_unlicensed_spectrum_below_3ghz.

[28] Pierre de Vries, *op. cit*.

[29] *Ibid.*, 9-18, provides several examples.

[30] Comments of NAF, et al., in ET Docket Nos. 04-186 and 02-380, January 31, 2007, at 39-40.

[31] This low-power limit on the utility of first adjacent DTV channels was independently confirmed by testing at the University of Kansas spectrum labs and submitted to the FCC; see New America Foundation, Final Results of University of Kansas TV White Space Interference Study, at ET Docket Nos. 04-186 and 02-380, January 31, 2007 (including D. De Pardo, et al., "Quantifying the Impact of Unlicensed Devices on Digital TV Receivers," University of Kansas, Technical Report ITTC-FY2007-44910-01, January 31, 2007). The NAB and their technical affiliate, the Association for Maximum Service Television (MSTV) has steadfastly argued that even 100 mW of transmit power would cause intolerable interference to DTV viewing not only on the first adjacent channel, but even on the second and possibly third adjacent channels depending on the circumstances.

[32] *Battle I*.

[33] See fn 1 above for full citations of *Brattle I* and *Brattle II*.

[34] *Brattle I*, 12-21.

[35] *Ibid.*, 55-58.

[36] BRS/EBS refers to the rebanded Broadband Radio and Educational Broadband Services band at 2.5 GHz. This band is most notably used by Sprint and Clearwire for the deployment of wide-area (high-power) WiMax broadband networks covering entire metro markets, initially Washington, DC and Baltimore (later this year). This WiMax spectrum comparable represents the low range of the Brattle estimate, with the high end based on the 2006 AWS-1 auction for lower-frequency spectrum configured in pairs to match the business model of cellular carriers.

[37] It is also useful in this context to review the Economic/Legal Reply Comments of New America Foundation, et al., ET Docket Nos. 04-186 and 02-380, March 2, 2007, and the Technical Reply Comments of New America Foundation, et al., ET Docket Nos., 04-186 and 02-380, March 2, 2007.

[38] Exhibit A in "Joint Comments of the Association for Maximum Service Television, Inc., and the

National Association of Broadcasters," ET Docket Nos. 04-186 and 02-380, November 30, 2004. The study is incorrectly cited by Jackson/Robyn.

[39] *Brattle I*, 12.

[40] *Id.*

[41] The method is summarized in "Appendix A: Calculation of White Space in the TV Core Following the DTV Transition" in *Brattle I.*

[42] *Brattle I*, 15.

[43] A complete channel listing of all Full-Power, Class-A, Low-Power, Satellite, and translator stations was compiled for the Boston and Providence areas and all surrounding DMAs using BIA Media Access Pro. Stations whose Grade-B signal contour lies within the Boston or Providence area were determined using BIA Media Access Pro. An additional 18 MHz (3 channels) were set aside for public safety, and other potential licensees.

[44] A complete channel listing of all Full-Power, Class-A, Low-Power, Satellite, and translator stations was compiled for the New York Metro area and all surrounding DMAs using BIA Media Access Pro. Stations whose Grade-B signal contour lies within the New York Metro area were determined using BIA Media Access Pro. An additional 18 MHz (3 channels) were set aside for public safety, and other potential licensees.

[45] See endnote 9 for methodology.

[46] A complete channel listing of all Full-Power, Class-A, Low-Power, Satellite, and translator stations was compiled for the Detroit Designated Market Area (DMA), and all surrounding DMAs using BIA Media Access Pro. Stations whose Grade-B signal contour lies within the Detroit metro area (defined as the tri-counties of Macomb, Oakland and Wayne) were determined using BIA Media Access Pro. An additional 18 MHz (3 channels) were set aside for public safety, and other potential licensees. Canadian channels were confirmed using the FCC CDBS database, and digital channel elections were confirmed with data filed with the FCC's International Bureau. In addition to the four Canadian channels listed in the above table, there are five other Canadian channels with Grade-B contours viewable in the eastern portion of the Detroit metro area. One of these channels (CBLN-TV-2) has a DTV channel (46) that is occupied by a Toledo station and accounted for in our analysis. The other four Canadian stations all have DTV channel elections that are above channel 51, and thus will not impact this analysis. However, if those channels move below 51 as part of Canada's DTV transition, this could reduce available white space under a low-power, unlicensed allocation to as few as 13 channels.

[47] *Brattle I*, 45.

[48] The top fifty revenue producing-licenses were:

• 18 REAGs (of 36 REAG licenses at auction, 50%)-- AW-REA001-D (Northeast), AW-REA001-E (Northeast), AW-REA001-F (Northeast), AW-REA002-D (Southeast), AW-REA002-E (Southeast), AW-REA002-F (Southeast), AW-REA003-D (Great Lakes), AW-REA003-E (Great Lakes), AW-REA003-F (Great Lakes), AW-REA004-D (Mississippi Valley), AW-REA004-E (Mississippi Valley), AW-REA004-F (Mississippi Valley), AW-REA005-D (Central), AW-REA005-E (Central), AW-REA005-F (Central), AW-REA006-D (West), AW-REA006-E (West), and AW-REA006-F (West)

• 10 CMAs (of 734 CMA licenses at auction, 1.36%) -- AW-CMA001-A (New York-Newark, NY-NJ), AW-CMA002-A (Los Angeles-Anaheim, CA), AW-CMA003-A (Chicago, IL), AW-CMA004-A (Philadelphia, PA), AW-CMA005-A (Detroit-Ann Arbor, MI), AW-CMA006-A (Boston-Brockton-Lowell, MA-NH), AW-CMA008-A (Washington, DC-MD-VA), AW-CMA009-A (Dallas-Fort Worth, TX), AW-CMA012-A (Miami-Fort Lauderdale, FL), and AW-CMA014-A (Baltimore, MD)

• and 22 EAs (of EA 528 licenses, 4.17%) -- AW-BEA003-B (Boston-Worcester MA-NH-RI-VT), AW-BEA010-B (NYC-Long Is. NY-NJ-CT-PA-MA-VT), AW-BEA010-C (NYC-Long Is. NY-NJ-CT-PA-MA-VT), AW-BEA012-B (Phil.-Atl. City PA-NJ-DE-MD), AW-BEA012-C (Phil.-Atl. City PA-NJ-DE-MD), AW-BEA013-B (Wash.-Balt. DC-MD-VA-WV-PA), AW-BEA013-C (Wash.-Balt. DC-MD-VA-WV-PA), AW-BEA031-B (Miami-Fort Lauderdale FL), AW-BEA040-B (Atlanta GA-AL-NC), AW-BEA057-B (Detroit-Ann Arbor-Flint MI), AW-BEA057-C (Detroit-Ann Arbor-Flint MI), AW-BEA064-B (Chicago-Gary-Kenosha IL-IN-WI), AW-BEA064-C (Chicago-Gary-Kenosha IL-IN-WI), AW-BEA096-B (St. Louis MO-IL), AW-BEA107-B (Minneapolis-St. Paul MN-WI-IA), AW-BEA127-B (Dallas-Fort Worth TX-AR-OK), AW-BEA127-C (Dallas-Fort Worth TX-AR-OK), AW-BEA131-B (Houston-Galveston-Brazoria TX), AW-BEA160-B (LA-Riverside-Orange Cnty CA-AZ), AW-BEA160-C (LA-Riverside-Orange Cnty CA-AZ), AW-BEA163-B (San Fran.-Oakland-San Jose CA), and AW-BEA170-B (Seattle-Tacoma-Bremerton WA).

[49] *Brattle I*, 41.

[50] John R. Williams, "Private Frequency Coordination in the Common-Carrier Point-to-Point Microwave Service," FCC OPP Working Paper Series, Number 21 (September 1986).
[51] Technical Comments of New America Foundation in ET Docket Nos. 4-186 and 2-380, March 2, 2007, 12.
[52] *Brattle I*, 14.
[53] *Brattle II*, 3-4.
[54] CFR 47 § 90.542(a). The following power limits apply to the 763-768/793-798 MHz band:

(1) Fixed and base stations transmitting a signal in the 763-768 MHz band with an emission bandwidth of 1 MHz or less must not exceed an ERP of 1000 watts and an antenna height of 305 m HAAT, except that antenna heights greater than 305 m HAAT are permitted if power levels are reduced below 1000 watts ERP in accordance with Table 1 of this section.

(2) Fixed and base stations located in a county with population density of 100 or fewer persons per square mile, based upon the most recently available population statistics from the Bureau of the Census, and transmitting a signal in the 763-768 MHz band with an emission bandwidth of 1 MHz or less must not exceed an ERP of 2000 watts and an antenna height of 305 m HAAT, except that antenna heights greater than 305 m HAAT are permitted if power levels are reduced below 2000 watts ERP in accordance with Table 2 of this section.

(3) Fixed and base stations transmitting a signal in the 763-768 MHz band with an emission bandwidth greater than 1 MHz must not exceed an ERP of 1000 watts/MHz and an antenna height of 305 m HAAT, except that antenna heights greater than 305 m HAAT are permitted if power levels are reduced below 1000 watts/MHz ERP accordance with Table 3 of this section.

(4) Fixed and base stations located in a county with population density of 100 or fewer persons per square mile, based upon the most recently available population statistics from the Bureau of the Census, and transmitting a signal in the 763-768 MHz band with an emission bandwidth greater than 1 MHz must not exceed an ERP of 2000 watts/MHz and an antenna height of 305 m HAAT, except that antenna heights greater than 305 m HAAT are permitted if power levels are reduced below 2000 watts/MHz ERP in accordance with Table 4 of this section.

(5) Licensees of fixed or base stations transmitting a signal in the 763-768 MHz band at an ERP greater than 1000 watts must comply with the provisions set forth in paragraph (b).

(6) Control stations and mobile stations transmitting in the 763-768 MHz band and the 793-798 MHz band are limited to 30 watts ERP.

(7) Portable stations (hand-held devices) transmitting in the 763-768 MHz band and the 793-798 MHz band are limited to 3 watts ERP.

[55] Gregory Rose, "How Incumbents Manipulate FCC Auction Rules to Block Broadband Competition," Working Paper # 18, New America Foundation, 16-18.