Expected Receipts From Proposed Spectrum Auctions

Coleman Bazelon

The Brattle Group, Inc.

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I. INDUSTRY OVERVIEW

The explosion of wireless broadband services has been a critical factor in economic growth and innovation in the U.S. over the last 10 years and will continue to grow in the coming decade.[1] To meet the growing consumer demand for mobile broadband services, wireless networks must expand capacity in the coming years. The quality and quantity of any additional spectrum made available for commercial use will be key. Wireless networks create capacity by combining spectrum with capital assets. Capacity can be increased by either deploying more spectrum, building a denser deployment of network assets, or a combination of the two.

Over the past decades the wireless industry has grown tremendously. Much of this growth was facilitated by a large increase in the amount of licensed spectrum—approximately 15 fold more than the original analog cellular allocation. In parallel, technical innovations such as successive generations of wireless technology and capital investments to build more sites over the same area have added to capacity by allowing more efficient use of spectrum. The result has been a long history of falling prices and rapidly improving quality of wireless services, along with an explosion of wireless applications. But we are at a critical juncture today, because there is a limit to what can be done with capital and technology alone. As the National Broadband Plan (NBP) emphasizes, 500 MHz of new commercial spectrum allocations are desperately needed in the next 10 years.

Since radio spectrum is a scarce resource, care must be taken to assure it is put to its highest valued uses. Radio spectrum on its own has no inherent value. Rather, the value of spectrum is linked to the value it creates through the services that are enabled by deploying radio spectrum. Over the last decade, increases in demand for wireless broadband services have propelled the demand and value of spectrum that can be used for such services upward.

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[1] For further discussion of the growth and economic benefits of wireless broadband and broadband deployment in the U.S. see, Crandall, Robert W. and Hal J. Singer. "The Economic Impact of Broadband Investment," 2010 (herein "Crandall and Singer (2010)". See, also, Federal Communications Commission. "Connecting America: The National Broadband Plan," 2010 (herein "NBP").

Some spectrum has already been allocated and licensed for mobile broadband uses, including the Cellular, PCS, AWS-1, 2.5 GHz (BRS/EBS), and 700 MHz bands. See Table 2 below. Assignment of this spectrum through FCC auctions has raised substantial revenue for the U.S. government in the past. Much of the remaining spectrum that has not yet been allocated to wireless broadband is currently used by either commercial broadcasters or government users.

As demand for wireless broadband services increases beyond this existing capacity, a number of critical questions arise. First, what other frequencies below about 3 GHz can—and should—be reallocated to meet the increasing demands of wireless broadband? Second, what would be the value of this spectrum if it were reallocated for wireless broadband services? And, finally, how much of this value could the federal government expect to recoup if it were to assign spectrum through auctions?

According to the Principle of Spectrum Reallocation[2], more licensed spectrum should be allocated to support mobile broadband services so long as any given band of spectrum is more valuable supporting mobile broadband services than in its current or other alternative uses. By implication, if spectrum is not being put to its highest valued use, it should be reallocated so that it is. In many cases, this implies that spectrum should be reallocated to wireless broadband spectrum.

The NBP and NTIA have identified over 2,000 MHz of radio spectrum as potential candidates for spectrum reallocation. Based on these targeted bands, the Draft Mobile Broadband Enhancement Act of 2011 identifies 470 MHz of spectrum to be reallocated for commercial wireless broadband uses. This draft legislation would have the FCC assign licenses for this spectrum through a series of 6 auctions, scheduled at 18 month intervals over the next 9 years. See Table 1. The total value of this spectrum is likely to be about $100 billion with a deduction of $6 billion for expected exclusion zones for reallocated federal spectrum and expected clearing costs of about $30 billion, which

[2] For further discussion of the Principle and Spectrum Reallocation, see "Oral Testimony of Coleman Bazelon, The Brattle Group, Inc.," U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Communication and Technology, April 12, 2011. Available at: http://democrats.energycommerce.house.gov/sites/default/files/image_uploads/Testimony_04.12.11_Bazelon.pdf (last visited July 25, 2011). (Herein "Bazelon Testimony (2011)".

implies net revenues of $64 billion. In the past, FCC has been successful in designing auctions which garner close to the full value of the spectrum. For reasons discussed below, it is likely that future well designed FCC spectrum auctions will also generate receipts similar to the full value of spectrum.

A. WIRELESS BROADBAND 10 YEAR PROJECTIONS

The recent explosive growth in demand for capacity on wireless networks is expected to increase dramatically over the next 10 years. The FCC itself projects that by 2014, mobile data traffic will be 35 times 2009 levels, resulting in demand for 1,097 MHz of wireless broadband spectrum.[3] By any objective criteria, the current supply of licensed radio spectrum available for mobile broadband services in the U.S. will not be sufficient to meet demand. The FCC projects that the deficit in wireless broadband spectrum is expected to be 275 MHz by 2014. Several other well-known studies have predicted that wireless data demand will increase at least 26 fold from 2010 to 2015.[4] Further, ITU estimates suggest that growth in demand will continue well beyond 2014. According to their 2006 report, demand is likely to increase by an additional 30% from 2015 to 2020.[5]

This growing demand is expected to generate substantial growth in revenue as well. According to a recent Credit Suisse Report, revenues for wireless services in North America are expected to increase to $216 billion in 2015, up from $178 billion in 2010. These projections are based on revenue growth of 6% in 2011 and 2012, 3% in 2013 and

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[3] According to the FCC projections, there will be 822 MHz in use, with a deficit of an additional -275 MHz needed. See "Mobile Broadband: The Benefits of Additional Spectrum," FCC Staff Technical Working Paper, October 2010, Federal Communications Commission, Washington DC, p. 9. (herein FCC, "Benefits of Broadband," 2010)

[4] See Cisco. "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010–2015," white paper, February 2011, downloaded on March 18, 2011 from: http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html. See also, Rysavy Research. "Spectrum Shortfall Consequences," white paper sponsored by NTIA, April 21, 2010, downloaded on March 18, 2011 from: http://www.rysavy.com/Articles/2010_04_Rysavy_Spectrum_Shortfall_Filing.pdf (herein "Rysavy 2010").

[5] See ITU. "Estimated Spectrum Bandwidth Requirements for the future development of IMT-2000 and IMT-Advanced," Report, 2006, http://www.itu.int/pub/R-REP-M.2078-2006/en, Accessed July 23, 2011.

2014, and 2% in 2015.[6] Although most analyst reports only project revenues until 2015, one projection of Sprint estimates that wireless service revenues will continue to grow at 2% annually through 2020.[7] Such increases in revenue are expected to be driven by increase in demand for wireless services, as revenue per subscriber, or ARPU, for wireless services declines slightly. Based on various industry analyst reports, average monthly revenue per user (ARPU) in 2010 were between $47 and $48, down from between $48 and $49 in 2009.[8]

These revenues support average net margins for wireless services sufficient to acquire spectrum resources for future growth, for both tier 1 nationwide service providers, as well as smaller nationwide and regional providers. According to one analyst report, margins for wireless providers in Q2 2011 range from 18% to nearly 50% of earnings before interest, depreciation and taxes (EBIDTA). For instance, margins for the wireless divisions of AT&T, Verizon and Sprint are 41.4%, 44.5% and 18.7%, respectively. Margins for other service providers offering wireless services are also strong. Cincinnati Bell's margin is 38%, Leap Wireless's margin is 23.4%, MetroPCS is 34.6%, and US Cellular is 20.6%[9] These margins are also consistent with previous years and future projections.[10]

B. MEETING DEMAND FOR WIRELESS BROADBAND SERVICES

While some portion of this increased demand can be met with increased capital expenditures by deploying new technologies and investing in additional network build-out, additional spectrum will also be necessary. Most upcoming planned capital expenditures will involve investment in upgrading existing systems to Long Term Evolution (LTE). These LTE technologies are expected to double capacity over current

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6 See Credit Suisse. "Global Wireless Capex Survey – A multi-year spending cycle," Report, July 2011, slide 10 (Herein "Credit Suisse, July 2011").

7 See J.P. Morgan. "Sprint Nextel," Report, North America Equity Research, July 2011, page 3.

8 *Ibid.* See, also, Roche, Robert T. and Liz Dale. "CTIA'S Wireless Industry Indices, Year-End 2010 Results," *CTIA Public Affairs*, May 2011.

9 See Morgan Stanley. "Telecom Services 2Q Preview: M&A, 4G Roll-outs and Capex in Focus," Industry View, July 19, 2011, exhibit 2, page 4.

10 For instance, Verizon Wireless margins were 46.9% in 2010 and are projected to be 45.8% in 2013. *Op cit.*, p. 40.

3G technologies.[11] As a result, capital expenditure is expected to grow by 10% to $26.7 billion in 2011 and grow to $27.3 billion in 2012 in North America. Capital expenditures in telecom are expected to continue growing by 7%.[12] In addition to LTE build-out, other capital investments in networks—largely the increasingly expensive approach of dividing cells—will further increase the capacity of existing networks. In fact, since all network operators are always adding capacity to their networks (even if they are not adding subscribers)[13] additional spectrum is always of value because it can be deployed as an alternative to cell splitting. Some of the increased demand might also be met by various demand management techniques, such as WiFi offloading, off-peak transmission and on-device storage, and pricing schemes designed to mitigate peak demand.

However, not all demand can, or should, be met by additional capital investment and advances in technology. Even if successfully implemented, these demand and efficiency management techniques are not expected to be able to accommodate all of the growing demand for mobile broadband services.[14] Most increases in capacity cannot be

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[11] Determining the increased capacity of a network is dependent on a number of factors, including the type of hardware and software used with the system and the size of the spectrum band. Rysavy 2010 writes that "deploying a 10 MHz LTE radio channel costs almost the same as deploying a 5 MHz HSPA channel, but the LTE channel has about four times the capacity" (see p. 7). Consensus among experts suggests that the spectral efficiency of LTE is generally twice that of 3G technology (specifically, UMTS/HSPA technology). The spectral efficiency of 5 MHz versus 10 MHz of LTE drops by around 3%, from around 98% to 95% of 20 MHz efficiency. (See Figures 8 and 21 in Rysavy Research, "HSPA to LTE advanced: 3GPP Broadband Evolution to IMT-Advanced (4G)," white paper sponsored by 3G Americas, September 2009, downloaded on March 18, 2011 from: http://www.3gamericas.org/documents/3G_Americas_RysavyResearch_HSPA-LTE_Advanced_Sept2009.pdf).

[12] See Credit Suisse, July 2011, p. 8.

[13] For instance, even as Sprint has experienced flat customer additions and, in some years, declining subscriber counts, Sprints capital expenditure is 9% of revenue for the year, and is expected to remain at least 9% per year through 2020. See Figure 1 in "Sprint Nextel: 2Q11 Preview," *J.P. Morgan Analyst Report*. July 21, 2011.

[14] In his Congressional Testimony, Peter Pitsch stated, "The pace of improvements in radio technology, while impressive, will not keep pace with the increase in mobile data demand. Nor will offloading to WiFi networks, splitting cells and other such techniques solve the problem." See "Testimony of Peter Pitsch Before the Subcommittee on Communications and Technology, United States House of Representatives." April 12, 2011. Available at: http://democrats.energycommerce.house.gov/sites/default/files/image_uploads/Testimony_04.12.11_Pitsch.pdf (last visited on July 23, 2011).
According to one Rysavy Research report, "While carriers will attempt to alleviate congestion in the short term by offloading traffic using femtocells and picocells, mobile innovation will falter without access to the substantial additional spectrum that American consumers and businesses will soon need, and the consequences of inaction for the nation are unacceptable." Rysavy

met with increased technological innovation, but rely on building further infrastructure.[15] Despite all of these other approaches to meeting future demand, additional radio spectrum allocated to mobile broadband will be needed very soon to maintain service quality and meet consumer demand at affordable prices.

Spectrum provides an alternative source of capacity to increasingly expensive capital expenditures. Carriers are already capacity constrained and increased capital expenditures are expected.[16] Building infrastructure affordably is increasingly difficult. Particularly under these circumstances, the FCC estimates the trade-off between capital and spectrum to be significant. They report that an additional 275 MHz by 2014 would save the industry $120 billion in capital expenditures.[17] These cost savings would value spectrum at $436 million per MHz or almost $1.50 per MHz-pop.

Some increase in capacity should be met by radio spectrum reallocated to wireless broadband uses. How much depends on the costs of moving incumbent users off of the frequencies they currently use. In order to reallocate spectrum, FCC and NTIA have been working to identify potential bands with both commercial and other government users for reallocation.

The NBP targets approximately 500 MHz of spectrum that should be reallocated to wireless broadband by 2020. These suggested allocations include 60 MHz in the AWS-2 and AWS-3 allocations, 120 MHz in the broadcast TV bands, and 90 MHz in the MSS bands. Also proposed was the remaining 10 MHz D-Block from the 700 MHz auction and 20 MHz of WCS.[18] In order to facilitate this spectrum reallocation NTIA identified

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Research, "The Spectrum Imperative: Mobile Broadband Spectrum and its Impact for U.S. Consumers and the Economy," An Engineering Analysis. March 16, 2011. Available at: http://www.mobilefuture.org/page/-/rysavy-spectrum-effects-301611.pdf

15 According to one JP Morgan analyst, one problem with the wireless services is "technology gains are likely overstated by at least some magnitude." Further, "research has shown that the number one driver of increased data capacity historically has not been technological innovation, as is commonly thought, but the far more brute force approach of base station additions." See Sullivan, James. "The Economics of Wireless Data-Part One The importance of population density and spectrum," JP Morgan. June 20, 2011.

16 North American Capital Expenditures will grow in 2012 and 2013, and are expected to fall slightly in 2014 and 2015. See Credit Suisse Report, July 2011, slide 9.

17 See Holtz-Eakin, Douglas. "Economic growth out of thin air," *The Hill*. July 26, 2011. Available at http://thehill.com/blogs/congress-blog/technology/172745-economic-growth-ou (last visited July 26, 2011).

18 See NBP Chapter 5.

over 2,000 MHz of spectrum for consideration and evaluation, including the bands identified in the NBP and two bands that might operate as uplink pairs for AWS allocations (*i.e.*, 1675 – 1710 MHz and 1755 – 1850 MHz).[19] Some of these blocks were granted priority consideration by the NTIA in March 2011.[20]

Based on the spectrum under consideration by the NTIA, the Draft Mobile Broadband Enhancement Act of 2011 identifies 470 MHz for reallocation over the next 9 years. Table 1 below summarizes these proposed bands and the proposed timing of auctions. As the table indicates at least some portion of each of these bands were identified either in the NBP, or by NTIA. By releasing this spectrum at predetermined increments the legislation provides certainty to the market by giving ample time to plan for clearing of bands.

Table 1. Proposed Spectrum Auctions

			Other Sources:	
Proposed Auction Date	Spectrum Description [1]	Supply *(MHz)*	NBP (Spectrum identified to be made available in the next 5 years) [2]	NTIA Oct 2010 (Initial band candidates identified) [3]
9/30/2012	AWS: 1755-1780 MHz and 2155-2180 MHz	50	•	•
3/31/2014	Broadcast TV Spectrum	120	•	•
9/30/2015	AWS: 2x40 MHz in 1670-1710 MHz and 2020-2110 MHz	80		•
3/31/2017	2x20 MHz in 1780-1850 MHz and 2180-2200 MHz	40	•	•
9/30/2018	2x40 MHz in 1300-1390 MHz and 2000-2110 MHz	80	•	•
3/31/2020	2x50 MHz in 1780-1850 MHz and 2200-2290 MHz	100		•
	Total	470		

Sources:
[1] Draft Mobile Broadband Enhancement Act of 2011
[2] NBP Ch. 5 "Spectrum": http://download.broadband.gov/plan/national-broadband-plan-chapter-5-spectrum.pdf
[3] NTIA Report Oct 2010 "Plan and Timetable to Make Available 500 MHz of Spectrum for Wireless Broadband" http://www.ntia.doc.gov/reports/2010/TenYearPlan_11152010.pdf

[19] See "First Interim Progress Report on the Ten-Year Plan and Timetable," *NTIA U.S. Department of Commerce*. April 2011, p. 7. Available at: http://www.ntia.doc.gov/reports/2011/First_Interim_Progress_Report_04012011.pdf (last visited July 20, 2011). (Herein. "NTIA, First Interim Progress Report")

[20] Priority consideration blocks under 3 GHz include 1755 – 1850 MHz, 1695 – 1710 MHz, 406.1 – 420 MHz, and 1370 – 1390 MHz. See NTIA, First Interim Progress Report, p. 4.

In the following sections this paper considers the value of this 470 MHz of spectrum and expected receipts associated with the 6 proposed auctions, and then discusses why anticipated auctions would be expected to realize this value.

II. VALUE OF PROPOSED SPECTRUM

A. OVERVIEW OF VALUE OF SPECTRUM

i) Spectrum Value is based on Future Economic Profits[21]

How much does the holder (or potential holder) of an FCC spectrum license value that license? From an economic perspective,[22] the value of a spectrum license is equal to the stream of future economic profits that the license enables the spectrum owner to receive. (Of course, once the spectrum is paid for actual profits may be non-existent.) The "owner" of a band of spectrum could extract economic profits from the use of that spectrum in a couple of ways: either annually through some sort of leasing arrangement[23] or, as when FCC licenses are auctioned, in a lump sum for the current value of holding license rights for some predetermined number of years. The concept of net present value (NPV) is employed to calculate this current value of the potential future stream of economic profits earned from the spectrum over time.

The NPV of a capital investment represents the cash value today of the expected stream of net returns (revenues minus costs) that an investment is expected to yield over its lifetime. The present value of any future payment is equal to the amount you would need to invest today to receive that future return. The NPV discounts the expected stream of future payments for the interest that investment would have otherwise accrued over the investment period if the money had been employed in some other way. For instance, assuming the interest rate is 5%, the present value of $105 next year is $100 today, but

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[21] This discussion draws heavily on Bazelon, Coleman. "The Economic Basis of Spectrum Value: Pairing AWS-3 with the 1755 MHz Band is More Valuable than Pairing it with Frequencies from the 1690 MHz Band," Brattle Group Working Paper. April 11, 2011 (Herein, "Bazelon, "Pairing AWS-3" (2011)"). See that paper for an expanded discussion of spectrum value.

[22] Some spectrum license holders, such as a community owned broadcasters, have interests beyond the economic, This discussion focuses on the economic interests associated with radio spectrum.

[23] For example, spectrum lease agreements typically require payments of between 10% and 20% of gross revenues from using the spectrum. Such payments are a proxy for the economic profits earned from using the band of spectrum.

the present value of receiving $105 in two years, however, is $95 today. The total net present value of any investment is then equal to the sum of present values for each annual net return or cash flow (CF), discounted by the rate of return for that year[24]:

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+R_t)^t}$$

ii) Spectrum Value is Influenced by Differences in Spectrum Quality

Differences in the value of bands of spectrum are driven by differences in the profits earned from using them, which broadly reflects differences in the quality of spectrum. The quality of a band of spectrum is determined by at least three factors: the physical characteristics of the spectrum, including frequency wavelengths and potential pairings; the existence of band compatible technology for both infrastructure and devices; and encumbrances to use, such as incumbent users and service restrictions placed on licenses. Each of these factors of quality impacts the value of a band by affecting the revenues, costs, and uncertainties of using the spectrum. The relative quality of a spectrum band varies by use (*i.e.,* broadcast vs. wireless services), region (*i.e.,* rural vs. urban) and the availability of technology and infrastructure for specific uses of the band.

*Physical characteristics***.** The wavelength of a frequency is a key determinant of its best uses. Frequencies above about 3 GHz are not currently as conducive to mobile communications. Lower frequencies require less energy to transmit signals over a given distance and are more capable of penetrating walls and buildings. Even for frequencies under 3 GHz, higher frequency spectrum within that range requires more cells and higher power levels vis-à-vis lower frequency spectrum for the same level of coverage, resulting in either higher costs for the same level of service, or lower quality service, and diminished revenue. The extent to which higher frequencies are less valuable depends on the intended use. Long signal range is more important during initial build-outs and in rural areas. In areas of high density of users more cells are required, making this issue less relevant.

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[24] See Damodaran, Aswath. *Investment Valuation 2nd Edition*. New York, NY: John Wiley and Sons, 2001.

Spectrum block sizes can also influence value, and that influence likely matters more as technologies progress. Empirical research has demonstrated that auctions raise less revenue if the bandwidth of the licenses sold are too small.[25] Furthermore, newer technologies, such as LTE, perform better with larger bandwidth channels.

Given the current state of technology, pairing spectrum also tends to make the spectrum more valuable. This greater efficiency is seen in relative spectrum prices. For example, in the 700 MHz auction four bands of very similar 700 MHz spectrum were auctioned. The Lower A and B blocks had 12 MHz of paired spectrum with 6 MHz bands each for uplink and downlink (A block: 698-704/728-734 MHz; B block: 704-710/734-740 MHz). The Upper C block totaled 22 MHz of paired spectrum with 11 MHz bands each for uplink and downlink (Upper C block: 746-757/776-787 MHz). Only one unpaired band, the Lower E block which was 6 MHz (E block: 722-728 MHz) was sold at the same time. The average price of the A, B & C blocks was $1.36/MHz-Pop and the average price of the E Block was $0.74/MHz-Pop, a discount of 46% for the unpaired band.[26]

Existence of Applicable Technology. The ecosystem of a band of spectrum—both in technology and in users and services—can greatly affect its value. Any new wireless technology requires network equipment and devices. Spectrum users must find suppliers for both. The compatibility of existing infrastructure, hardware and software with the radio frequencies within a band is a critical determinant of its value because research and development is costly, time consuming and risky.[27] Often a more mature band already has equipment available to use the spectrum, which is considerably less costly to deploy immediately or upgrade. It may also have a more readily accessible user base, potentially increasing expected revenues. A larger amount of bandwidth in a band also tends to create more demand for equipment. Economies of scale and scope decrease the cost and

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[25] See Hazlett, Thomas W. and Roberto E. Munoz. "A Welfare Analysis of Spectrum Allocation Policies," *Rand Journal of Economics*, Volume 40, Number 3, Autumn 2009 (Herein "Hazlett and Munoz (2009)").

[26] Bazelon, Coleman. "Too Many Goals: Problems with the 700 MHz Auction," *Information Economics and Policy*, April 8, 2009. (Herein "Bazelon, "Too Many Goals" (2009)")

[27] For further discussion see, Varrall, Geoff. "RF Cost Economics for Handsets." *RTT* White Paper. May 2007. Found at: http://www.rttonline.com/documents/rfcosteconhsetswp.pdf (last visited July 26, 2011).

burden of fixed research and development costs for individual users of the band because they can take advantage of conventional hardware and software. Internationally harmonized, mature bands tend to have larger user bases, lower costs, and higher certainty of available technology. These factors can easily out-weigh the physical characteristics of the band.

Encumbrances. Restrictions on licensed use, the existence of incumbent users, or interfering neighbors decreases the value of spectrum because it potentially restricts revenues, increases costs and raises uncertainties about profit timing. Many bands have incumbent users that must be migrated to different radio frequencies before the spectrum is fully available. The cost of clearing these incumbent users reduces the value of spectrum if those costs are borne by the new licensees.[28] Exactly when this will occur adds even more uncertainty to a project. Limited use of a band in the interim may be a possibility, but it will likely diminish revenues. Uncertainty in spectrum availability and profit timing can diminish a band's expected value.

Regulatory encumbrances can also diminish value. Such items as open access requirements or overly stringent build-out requirements can diminish the value of spectrum. Though many issues were at play at once in the 700 MHz auction, one band, the Upper 700 MHz C Block, had open access requirements and was won at relatively low prices. Another block in that auction, the D Block, suffered from strict build-out requirements and a mandate for a public-private partnership and did not sell at all.

Licensing restrictions may reduce revenues by limiting the capacity or the types of services for a given spectrum band. This can clearly be seen in the television bands where licensees are restricted to broadcasting and cannot repurpose the spectrum themselves. The spectrum allocated to television broadcasting would be worth about $62 billion if completely unencumbered and reallocated to broadband services, but is only worth about $12 billion when used in broadcasting.[29] This difference of $50 billion

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[28] If these costs are paid out of auction receipts, then from the bidders' perspectives these costs do not affect their valuation of the cleared spectrum.

[29] See Bazelon, Coleman. "The Need for Additional Spectrum for Wireless Broadband: The Economic Benefits and Costs of Reallocations," Sponsored by *Consumer Electronics Association*, 2009. This valuation assumes no restrictions or encumbrances on the reallocated TV frequencies when they are sold.

represents the diminished value of those frequencies as a result of license restrictions, such as not being allowed to lease spectrum for any use except broadcasting.

Having to tolerate interference from—or to prevent interference into—users in neighboring bands also reduces the usefulness of a band and, consequently, its value. Operating in an environment with interference can require higher power levels or other adjustments that decrease the capacity of a band of spectrum. Less capacity, or otherwise doing less with the same inputs, reduces the value of spectrum.

One of the advantages of the Draft Mobile Broadband Enhancement Act of 2011 is that it addresses many of the issues that drive spectrum value. Large block sizes, restrictions on regulatory or other encumbrances and a degree of certainty created by a measured release of spectrum to prospective bidders at auction.

iii) Current Wireless Broadband Spectrum Value

As explained below, the price of unencumbered spectrum available for wireless broadband services is currently close to an average price of $1.03 per MHz-pop.[30] Since, as discussed above, the quality and value of spectrum does vary across bands, this price is based on the value of spectrum equivalent in capacity and quality to the existing AWS-1 spectrum. On this AWS-1 value-weighted basis, the supply of spectrum available for wireless broadband uses is currently around 850 MHz of AWS-1 equivalent spectrum. See Table 2.

[30] The unit price of spectrum is typically expressed in terms of value in dollars per MHz-pops, where MHz-pops is the product of total MHz of a band and population covered by the region of a license.

Table 2. Potential Spectrum Available for Wireless Broadband Services

	Band Name	Location	MHz [1] *(MHz)*	Assigned [2] *(%)*	Potential Spectrum Supply [3] *(MHz)*	Value Weight [4] *(Index)*	AWS-1 Equivalent Value Weighted Potential Spectrum Supply [5] *(MHz)*
[A]	PCS	1.9 GHz	130	100%	130	3	390
[B]	Cellular	800 MHz	50	100%	50	3	150
[C]	SMR	800 MHz / 900 MHz	14	100%	14	1	14
[D]	BRS/EBS	2.5 GHz	174	100%	174	0.5	87
[E]	AWS-1	1.7 GHz / 2.1 GHz	90	100%	90	1	90
[F]	700 MHz	700 MHz	80	88%	70	1.3	92
[G]	ATC Spectrum	1.5 GHz / 2 GHz	88	50%	44	0.5	22
	Total		626		572		845

Notes:
[3]: [1] * [2]
[A] [4] - [G] [4]: TBG calculation
[5]: [3] * [4]
Sources:
[A] [1]: Congressional Budget Office, Where Do We Go From Here? The FCC Auctions and the Future of Radio Spectrum Management, (Apr. 1997)
Improving Public Safety Communications in the 800 MHz Band, Report and Order, Fifth Report and Order, Fourth Memorandum Opinion and Order, and Order, 19 FCC Rcd 14969 (2004)
[B] [1]: FCC Wireless Telecommunications Bureau, Cellular Services, available at http://wireless.fcc.gov/services/cellular/
[C] [1]: FCC Wireless Telecommunications Bureau, 900 MHz SMR, available at http://wireless.fcc.gov/smrs/900.html
[D] [1]: FCC Wireless Telecommunications Bureau, BRS & EBS Radio Services, available at http://wireless.fcc.gov/services/brsebs/
[E] [1]: Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 MHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, Including Third Generation Wireless Systems, Second Report and Order, 17 FCC Rcd 23193 (2002)
[F] [1]: Revised 700 MHz Band Plan for Commercial Services (2007) includes D block and is available at http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=33
[F] [1]: FCC Wireless Telecommunications Bureau, 700 MHz Guard Bands, available at http://wireless.fcc.gov/services/index.htm?job=service_home&id=700_guard
Supply is equal to the band plan's total allocation, including D Block, less 700 MHz guard bands
[G] [1]: The bandwidth includes the licensed MSS spectrum holdings of MSV (28 MHz), TerreStar (13.3 MHz), and ICO Satellite Services (13.3 MHz). See, W.P. Zarakas and K. Wallman, "The Brattle Group Report," October 5, 2005, contained in Motient Corp. June 2, 2006 SEC Form DFAN14A (filed June 2, 2006), via Edgar, accessed October 2009.

I use the AWS-1 average nationwide price as a baseline price for wireless broadband services. The AWS-1 auction in September 2006 is generally accepted as having been a competitive auction, which realized the true value of AWS spectrum licenses.[31] Also, the AWS-1 price is a particularly good benchmark for the purposes of this analysis, because many of the spectrum allocations proposed are essentially extensions of this AWS-1 allocation. The SpecEx Spectrum Index is a useful tool to calculate the change in spectrum value over time. According to the SpecEx Spectrum Index, since September 18, 2006 the value of spectrum has increased 90% (based on an

[31] Bulow, Jeremy, Jonathan Levine and Paul Milgram. "Winning Play in Spectrum Auctions." NBER Working Paper No. 14765, March 2009.

end date of July 24, 2011).[32] Updating the average price of AWS-1 spectrum by this percentage provides a current price of $1.03/MHz-pop.[33]

As with all economic goods, the price and value of spectrum is expected to fall as additional supply is introduced. The price of spectrum can be represented as the balance between supply and demand. The increase in supply shifts the supply curve of spectrum rightward. Absent any unexpected changes in demand, the rightward shift in the supply curve means that the point of equilibrium between supply and demand will be lower down the demand curve (to the right of the initial point representing a larger quantity of spectrum at a lower price.) How far the point of equilibrium shifts depends on how much the supply of spectrum increases and the elasticity of the demand curve for spectrum.

Wireless broadband spectrum is generally thought to have a price elasticity of around -1.2,[34] which implies that a 1% increase in the base supply of spectrum should result in a 1.2% decrease in its price. In what follows, I assume constant price elasticity for spectrum, which is consistent with the previous experiences. Even as additional spectrum has been introduced, the elasticity has remained close to -1.2.[35]

B. VALUE OF PROPOSED BANDS AT AUCTION

The proposed release of 470 MHz of spectrum at 18 month intervals is summarized in Table 1. In order to evaluate the merits of this reallocation, we must determine both what the value of these new wireless broadband spectrum allocations will be, and how

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[32] SpecEx Spectrum Index from Spectrum Bridge® values of 156 on September 18, 2006 and 297 on July 25, 2011 retrieved July 2011 from http://spectrumbridge.com/specex/index.aspx (last visited July 25, 2011).

[33] This change in spectrum value for SpecEx also reflects changes in the supply of spectrum between 2006 and today. There is no need to separately account for changes in supply between 2006 and today. For further discussion on the accuracy and validity of using the SpecEx Spectrum Index as a tool for updating spectrum values, see footnote 23 in Bazelon, "Pairing AWS-3" (2011).

[34] See discussion in Bazelon, Coleman, "Analysis of an Accelerated Digital Television Transition," May 31, 2005, citing Ingraham, Allen T. and Gregory Sidak, "Do States Tax Wireless Services Inefficiently? Evidence on the Price Elasticity of Demand," 24 *Virginia Tax Review,* 2004 (Herein "Ingraham and Sidak (2004)"). More recent research also suggests that a price elasticity for wireless telephony between -1.12 and -1.29 is appropriate see Hazlett and Munoz (2009). This elasticity is also consistent with recent broadband price elasticity estimates between -1 and -1.5. See Crandall and Singer (2010).

[35] Ingraham and Sidak (2004) initially estimated an elasticity of between -1.12 and -1.29 in 2004. Even after the AWS Auction 66 and 700 MHz auction 73, Hazlett and Munoz (2009) confirms that the elasticity is likely to be similar.

the value of existing spectrum will change as a result. As discussed above, the law of supply and demand dictates that allocating additional spectrum to wireless broadband will, all else equal, decrease the price of wireless broadband spectrum.

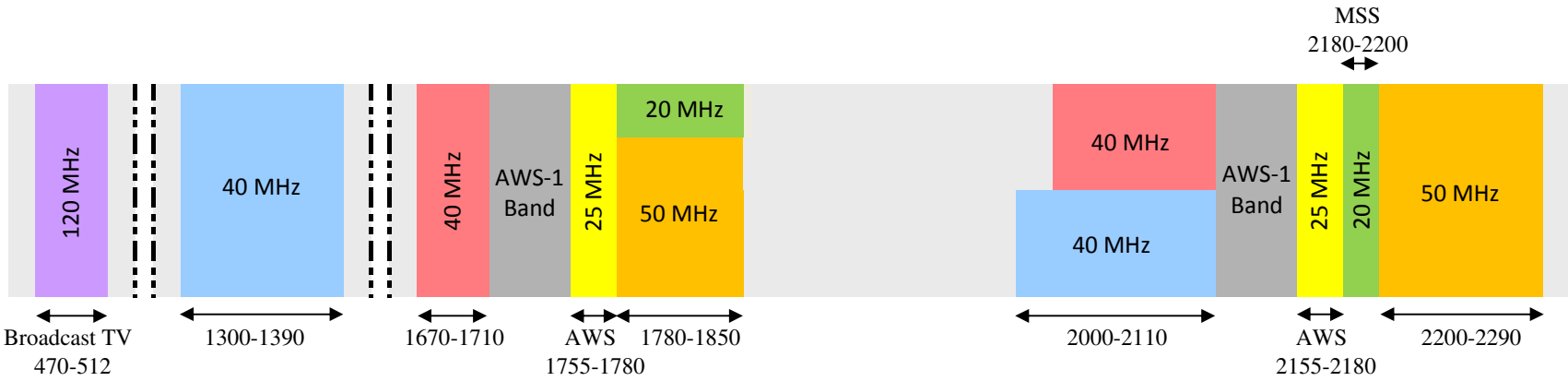
Net revenue from each auction is equal to the value of spectrum licenses sold, less the costs of clearing incumbent users from the band. As discussed above, the value of licenses sold are a function of equilibrium supply and demand of spectrum generally, and characteristics of the specific band. In order to estimate the price of any spectrum allocation based on the baseline AWS-1 price, adjustments must be applied to account for any changes in spectrum value based on spectrum capacity, quality, time and total supply.

Differences in capacity and quality are evaluated on a band-by-band basis. To account for these band-specific differences, I apply value weights. Since the nationwide average price of spectrum is based on the updated AWS-1 price, any spectrum with value equal in quality to the AWS-1 band has a weight of 1. Spectrum that is not allocated in internationally harmonized, nationwide, symmetrically paired, contiguous blocks that are sufficiently sized to support mobile broadband applications is likely to get an AWS-1 equivalent value weight of less than 1. That is, because these factors diminish the value of spectrum license, such spectrum is not likely to receive a price equal to the AWS spectrum that does meet these criteria. Bands with no encumbrances and more mature ecosystems than AWS-1 spectrum receive a value weight greater than 1. Since the difference in quality effectively adjusts the capacity available on this spectrum, the value weight is applied to the quantity of spectrum available.

As discussed above, the base price decreases with each auction as additional supply is introduced. Once the proposed legislation is passed, bidders will be able to anticipate future auctions and the reallocation of additional spectrum. This knowledge should be taken into consideration in any decision about bidding prices and quantities. Exactly how the future spectrum will be incorporated into current expectations is complicated and rests on many specifics of how bidders would form expectations. Rather than attempt to solve that problem, I will use a much simpler formulation of expectations that, though only an approximation, incorporates future spectrum auctions into current pricing decisions in a reasonable—and tractable—manner. When planning for meeting spectrum

needs, firms must take the certainty of the timing of future allocations into account. For sure, having opportunities in future auctions is relevant to deciding how much to pay for spectrum now. Nevertheless, the further in the future those auctions are, the less salience they will have in evaluating the value of spectrum available now. Even if it is anticipated, future spectrum introduced beyond a year or two is not likely to be heavily factored into a firms' evaluation of their current spectrum needs and willingness to pay a certain price. Thus, for purposes of evaluating the price effects of future auctions on the eve of an auction, the relevant supply includes the existing spectrum assignments, the additional spectrum being assigned in the upcoming auction, and any spectrum that will be auctioned in the next auction 18 months hence. This anticipated change in supply determines the change in baseline price.

Figure 1. Band Plan for Proposed Auctions



Auction 1 50 MHz of 1755-1780 MHz paired with 2155-2180 MHz
Auction 2 120MHz of broadcast TV spectrum
Auction 3 80 MHz auction (1670-1710 MHz paired with contiguous 40 MHz block in 2020-2110 MHz band)
Auction 4 40 MHz auction (contiguous 20 MHz block in 1780-1850 MHz band paired with 2180-2200 MHz)
Auction 5 80 MHz auction (contiguous 40 MHz block in 1300-1390 MHz band paired with contiguous 40 MHz block in 2000-2110 MHz band)
Auction 6 100 MHz auction (contiguous 50 MHz block in 1780-1850 MHz band paired with contiguous 50 MHz block in 2200-2290 MHz band)

Spectrum not auctioned
AWS-1 Band

i) Auction 1

The first proposed auction would release 50 MHz of spectrum, allocated in two 25 MHz contiguous, symmetrically paired bands. The proposed bands would be 1755 – 1780 MHz band for uplink, paired with the 2155 – 2180 MHz block for downlink. As Figure 1 illustrates, this pairing would essentially extend the AWS-1 band above the current allocation. With similar duplex spacing and international harmonization, the quality of this spectrum would be very similar to the AWS-1. Combined, these factors suggest the value of this spectrum should be equal to the AWS-1 current allocations, and implies a value weight equal to 1.

The adjusted price for this auction, however, must incorporate both this 50 MHz, as well as the additional spectrum expected from reallocating of the TV broadcast spectrum in the second auction. For reasons discussed below, the TV broadcast spectrum has a value weight of 1.3—implying the AWS-1 value-weighted additional supply from this auction is 156 MHz of AWS-1 equivalent MHz. Taking the relevant, value-weighted total increase in quantity to be 206 MHz (50 MHz plus 156 MHz), the average price at auction is expected to be $0.86 per MHz-pop, or $12 billion in gross revenue.

ii) Auction 2

Eighteen months after the auction of 50 MHz of AWS spectrum, the second proposed auction is 120 MHz of spectrum reallocated from the broadcast TV band. The broadcast TV spectrum is adjacent to the 700 MHz block, in the 470 – 698 MHz band. Current proposals for reallocation expect to clear 120 MHz from the top of the band for wireless broadband. Once cleared, the 120 MHz of spectrum should have similar propagation characteristics and value as the 700 MHz wireless broadband spectrum. Based on results from the FCC Auction 73, there is a 30% price premium on 700 MHz spectrum, as compared with AWS spectrum.[36] This additional value is due in large part to the significant amount of contiguous spectrum with propagation characteristics ideal

[36] In March 2008, the average nationwide price for the 700 MHz A, B, and C blocks was $1.36. At the time of Auction 73, the SpecEx Index value was 300, implying an adjusted AWS-1 price of $1.04. This suggests the price for 700 MHz spectrum was $0.32 higher than AWS-1, a premium of about 30%. See SpecEx Spectrum Index® at http://www.spectrumbridge.com/products-services/spectrum-analysis/index.aspx (last visited July 24, 2011).

for mobile broadband. Due to this price difference, the TV broadcast spectrum has a value weight of 1.3.

Provided that the broadcast TV spectrum is auctioned second, and that there is an additional AWS-1 value-weighted 72 MHz of AWS-1 equivalent spectrum to be auctioned 18 month later (see Auction 3, below), the price of this broadcast TV spectrum is expected to be $0.81 per MHz-pop. While the market will have already anticipated this addition of value-weighted 156 MHz from this auction of TV broadcast spectrum, bidders will now add the additional value-weighted 72 MHz of AWS-1 equivalent spectrum from the upcoming auction to their expectation. Provided that 120 MHz are cleared through incentive auctions, there will be no need for shared regions or exclusion zones. The gross revenue from this auction is expected to be $36 billion.

iii) Auction 3

The third proposed auction of 80 MHz is expected to be a licensed, contiguous 40 MHz block of 1670 – 1710 MHz, paired with a symmetric, contiguous 40 MHz block in the 2020 – 2110 MHz band. Similar to Auction 1, this pairing has the potential to also be adjacent to the bottom of AWS-1 for both uplink and downlink and would benefit from the AWS-1 ecosystem by maintaining the same duplex spacing as the AWS-1 band. See Figure 1. Nevertheless, the value might still be slightly lower than the original AWS-1. First, there is some chance that the spectrum will not be perfectly aligned with the existing AWS-1.[37] Second, this pairing is not internationally harmonized. Based on these factors, this band has a value weight of 0.9, implying the band is equivalent to 72 MHz of AWS-1 spectrum.

With an additional value-weighted 36 MHz expected to be auctioned in 18 months, the price of this spectrum in this band is $0.79 per MHz-pop. Based on NTIA reports, however, it is possible that, at least on an interim basis, regions of the uplink in 1670 –

[37] In a previous paper this year I showed how pairing the 1695 – 1710 MHz band with the 2155 – 2175 MHz band spectrum would result in a value discount of 39%. There are several reasons why such a discount would not apply here. First, one major reason for the additional cost was the cost of developing unharmonized equipment with a non-standard, wide duplex pairing. For the lower downlink at 2020 – 2110 MHz, however, this would not apply. Second, the uplink was expected to be an asymmetric 15 MHz pairing, leaving 5 MHz effectively unpaired. In this case, we are considering a symmetric pair. See Bazelon, "AWS-1 Pairing" (2011).

1710 MHz may need to be excluded in order to accommodate weather satellites that currently operate in the band and cannot be moved in the foreseeable future.[38] I previously calculated that these exclusions would discount the value of the spectrum by 17%.[39] This further discount for regional exclusions would imply a discounted nationwide price of $0.66 per MHz-pop, or total gross revenue of $14 billion.

iv) Auction 4

The fourth auction would reallocate two contiguous 20 MHz blocks, including the 1780 – 1850 MHz uplink band and the 20 MHz band at 2180 – 2200 MHz. One potential scenario is for this auction to reallocate the 1780 – 1800 MHz band. If so, Auction 4 would extend the AWS an additional 20 MHz beyond what was previously added in Auction 1. See Figure 1. The 2180 – 2200 MHz band, however, does include some MSS satellites that must be accommodated. In order to get a contiguous, nationwide 20 MHz block without exclusion zones, the duplex spacing of this pair may not be precisely aligned with the spectrum from Auction 1. Contiguous spectrum is preferred so relocation of some satellite links maybe necessary over time. Further, the allocation is not yet internationally harmonized for wireless broadband spectrum. For these reason, I assign this spectrum a value weight of 0.9. Including the value weight, this auction will assign licenses for 36 MHz of AWS-1 equivalent spectrum.

Factoring an additional 40 MHz of AWS-1 value-weighted spectrum to be auctioned in the upcoming fifth auction, the price of spectrum in the fourth auction is $0.77 per MHz-pop. Since it should be feasible to carve out 20 MHz of contiguous nationwide spectrum from the 1780 – 1850 MHz band, there will be no need account for exclusion zones. The total expected gross revenue is then $7.9 billion.

v) Auction 5

The proposed fifth auction will assign a 40 MHz block of contiguous spectrum in 1300 – 1390 MHz with a contiguous 40 MHz block in the 2000 – 2110 MHz for a total of

[38] NTIA U.S. Department of Commerce. "An Assessment of the Near Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, and 4200-4220 MHz, 4380-4400 MHz Bands," October 2010.

[39] Bazelon, "AWS-1 Pairing" (2011).

80 MHz. This lower 1.3 GHz spectrum is currently used for aeronautical radio navigation services for the FAA. 1370 – 1390 MHz spectrum is currently used for satellite services and relay of nuclear burst information.[40] Based on expected availability, therefore, the reallocated block is most likely the 1300 - 1350 MHz band. With respect to the quality of spectrum, this pairing is a non-standard duplex. Earlier this year, I estimated that the costs and uncertainties with a similarly wide, non-standard pairing of 1690 – 1710 MHz with 2020 – 2110 MHz would result in nearly a 40% loss in spectrum value. Such a wide duplex spacing is likely to have a similar effect here. Further, this 1.3 GHz downlink is not, as of now, internationally harmonized for commercial wireless broadband. Based on these factors, I assign a value weight of 0.5. Accordingly, on a AWS-1 value-weighted basis, Auction 5 introduces an additional 40 MHz of AWS-1 equivalent spectrum in total.

At the time of this auction, the market will anticipate the final reallocation of 90 MHz of AWS-1 equivalent spectrum, or total of 444 MHz of value-weighted additional supply of AWS-1 equivalent spectrum (470 MHz of non-weighted spectrum). As in the final auction the price at this penultimate auction will be $0.72 and the total gross value will be $8.3 billion.

vi) Auction 6

The final auction is intended to reallocate two contiguous 50 MHz blocks in the 1780 – 1850 MHz and 2200 – 2290 MHz bands. Similar to the third and fourth auction, this spectrum will be close to an extension of the AWS-1, but may not be a precise match. See Figure 1. Similar to these earlier two auctions, I assign a value weight of 0.9. The most likely uplink pairing will be at the top of this 1780 – 1850 MHz band. Currently this is used by the Department of Defense and NASA, among other possible Federal users. On an AWS-1 value-weighted basis, Auction 6 reallocates 90 MHz of AWS-1 equivalent spectrum.

As in the previous Auction 5, the price of spectrum is $0.72 per MHz-pops. At the time of this last auction, there is no new supply anticipated, and no further adjustment to

[40] NTIA U.S. Department of Commerce. "Federal Spectrum Use Summary: 30 MHz – 3000 GHz," June 21, 2010.

the price level. Even with a 10 year horizon to anticipate and plan for this transition, spectrum reallocation will likely involve some exclusion zones. Supposing that these exclusion zones are similar to those suggested by NTIA for 1670 – 1710 MHz, there is likely to be a 17% discount to the value of spectrum. After, this discount for excluded spectrum, the average price at auction is expected to be $0.60 per MHz-pop, or $15 billion in net revenue.

C. COST OF CLEARING

The cost or ability to clear any band of incumbent users depends on the types of users currently utilizing the spectrum and their ability to operate on alternative spectrum. Below I consider the costs of clearing the downlink and uplink bands separately. Based on the experience of the AWS-1 auction, the costs of clearing the uplink 1710 – 1755 MHz block ultimately totaled close to $1 billion—substantially less than originally anticipated.[41] This cost went to clearing 12 federal agencies from the 1710 MHz band. Depending on the service, users were compensated with replacement equipment (receivers and transmitters) to switch current operations to different frequencies or to switch to alternative services that did not require new spectrum assignments.

Aside from the broadcast TV and aviation spectrum, the users and uplink bands around 1.7 GHz being considered for reallocation have similar qualities and uses to the former incumbents of AWS-1.[42] Similar to the AWS-1 clearing, expenses will likely include replacing radios and transmitters so users can switch to using alternative spectrum. Relative to the value of spectrum for commercial wireless broadband, the costs to clear federal spectrum are expected to be relatively low because only the functionality needs to be replaced—and it is possible to replace a lot of radios for $1 billion. In addition, the 10 year horizon for reallocating all 470 MHz allows agencies to plan ahead and implement long-run strategies to transition out of the spectrum band.

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41 See "Commercial Spectrum Enhancement Act. Report to Congress on Agency Plans for Spectrum Relocation Funds," *Office of Management and Budget*. February 16, 2007.

42 While the 1.3 GHz spectrum is primarily used by the FAA for a slightly different purpose, the costs of relocating will be similar. Given over seven years to plan, this system can either be moved to alternative spectrum, or the FAA may choose to utilize a different technology. For instance, the cost of clearing may be used to assist the transfer the FAA to the GPS system.

Even if some incumbent users require additional time to transfer services, there is spectrum available for the next 10 years to utilize while making transitions.[43]

For AWS-1 it cost close to $1 billion to clear the uplink 1710 – 1755 MHz block. This suggests that, on average, the estimated cost of clearing AWS-1 uplink was around $22 million per MHz. The AWS-1 was the first band and likely the least costly spectrum to clear from the region of federal users around 1.7 GHz. Given the number of fixed-point users in the 1755 – 1780 MHz band and the speed at which it will have to be cleared, I assume the first auction will be twice as costly as the AWS-1 on a per MHz basis. This implies a cost per MHz of $44 million, or a total cost to clear all 25 MHz around $1.1 billion. Similarly, I estimate that clearing the 1670 – 1710 MHz band for Auction 3 will be $44 million per MHz or $1.8 billion. As the series of auctions progress, however, the spectrum becomes increasingly difficult to clear. I estimate that clearing a 20 MHz block from 1780 – 1850 MHz for Auction 4 will likely be three times as costly as AWS-1. At $66 million per MHz, Auction 4 will cost $1.3 billion. Finally, clearing 50 MHz in the 1780 – 1850 MHz band for Auction 6 is also likely to the most costly—maybe four times the cost of AWS-1, or $4.4 billion in total.

Based on my previous projections, I expect that the cost of clearing the entire TV broadcast spectrum through incentive auctions will be about $15 billion.[44] This cost will cover the expected payout for an incentive auction to buy back licenses from broadcasters willing to forgo their UHF license entirely, and repack the remaining broadcasters currently above channel 30. Finally, for Auction 5, I assume the cost of clearing 40 MHz of downlink spectrum in the 1300 – 1390 MHz band is approximately $2 billion.

After the 2155 – 2180 MHz band (Auction 1), which is already cleared, I estimate the cost of clearing the downlink pairings around 2 GHz will be $1 billion per auction. This is likely to be a conservative assumption. Auction 3 (contiguous 40 MHz at 2020 - 2110 MHz) and Auction 5 (contiguous 40 MHz at 2000 - 2110 MHz) will have to either

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[43] Despite this extended horizon, however, the one service that will likely be difficult to move will be satellites. Given the expected lifetime of a satellite, it is likely that regional sharing agreements will have to be established to allow these users continued operations in their existing band. As discussed below, I treat regional sharing agreements as discounts to the total value of spectrum.

[44] See "Bazelon Testimony (2011)

relocate or be carved out around the Broadcast Auxiliary Services (BAS) around 2020 - 2110 MHz, as well as remote point-to-point (truck to station) TV and cable relay, and NASA satellite earth to space uplink operations in the 2025 - 2110 MHz band. There may also be some little-used MSS satellites in the 2180 - 2200 MHz band relocated for the fourth auction. As mentioned previously, the final reallocation in Auction 6 will likely have to accommodate federal satellite systems with regional sharing arrangements. Recent Congressional testimony by NTIA suggests that markets in Florida would likely be excluded.

D. NET VALUE OF ALL AUCTIONS

Based on my evaluation as described above, the six auctions as proposed will introduce 470 MHz (444 MHz of AWS-1 equivalent spectrum) and generate approximately $94 billion in gross receipts and $64 billion in net revenues over the next 10 years. Table 3 summarizes the timing of each auction, expected revenue and costs of clearing. As this table illustrates, the net return of each auction varies between $5 billion and $21 billion, suggesting that the Principle of Spectrum Reallocation is satisfied for each individual auction, as well as overall.

Table 3. Expected Auction Receipts

	Proposed Auction Date	Spectrum Description*	Supply *MHz* [1]	*Quality Adjustment* Weights [2]	Quality Adj. Supply *MHz* [3]	*Auction Receipts* Cumulative Supply *MHz* [4]	Price *$/MHz-Pop* [5]	Revenues *$ Bn* [6]	Exclusion Zone Penalty [7]	Revenues Net of Penalty [8]	Clearing Costs *$ Bn* [9]	Net Revenues *$ Bn* [10]
[A]	9/30/2012	AWS: 1755-1780 MHz and 2155-2180 MHz	50	1.00	50	206	$0.86	$12.2		$12.2	$1.1	$11.1
[B]	3/31/2014	Broadcast TV Spectrum	120	1.30	156	278	$0.81	$36.1		$36.1	$15.0	$21.1
[C]	9/30/2015	AWS: 2x40 MHz in 1670-1710 MHz and 2020-2110 MHz	80	0.90	72	314	$0.79	$16.2	$2.8	$13.5	$2.8	$10.7
[D]	3/31/2017	2x20 MHz in 1780-1850 MHz and 2180-2200 MHz	40	0.90	36	354	$0.77	$7.9		$7.9	$2.3	$5.6
[E]	9/30/2018	2x40 MHz in 1300-1390 MHz and 2000-2110 MHz	80	0.50	40	444	$0.72	$8.3		$8.3	$3.0	$5.3
[F]	3/31/2020	2x50 MHz in 1780-1850 MHz and 2200-2290 MHz	100	0.90	90	444	$0.72	$18.6	$3.1	$15.4	$5.4	$10.0
			470		444			$99.4	$5.9	$93.4	$29.6	$63.8

Source and Notes:
[A] [1] - [F] [1]: Draft Mobile Broadband Enhancement Act of 2011.
[2]: TBG Assumption.
[3]: [1] * [2].
[4]: Cumulative sum of [3].
[5]: Based on a constant elasticity of demand of -1.2, initial price of $1.03/MHz-pop and an initial base of AWS-1 value-weighted spectrum of 845 MHz.
[6]: [3] * [5] * population for FCC Auction 66 (285,620,445 pops).
[7]: Exlusion zone penalty of 17% applied. See, Bazelon, "Pairing AWS-3" (2011).
[8]: [6] - [7].
[9]: See report text.
[10]: [8] - [9].

III. REALIZING SPECTRUM VALUE

The previous sections demonstrated that the wireless industry is expected to remain robust and will support significant value in proposed auctions of spectrum licenses. Some concern exists, however, that the wireless industry will not have the financial capacity to absorb the significant amounts of additional spectrum that would come to the market under the draft Mobile Broadband Enhancement Act of 2011.

In this section, I examine the industry's ability to robustly participate in the proposed auctions in 4 steps. First, I briefly review the source of spectrum value and note that if an auction did not realize the value of the underlying spectrum, money would be left on the table—an unlikely event in our modern economy. Second, I review the markets for spectrum licenses to put the proposed auctions in the context of the larger market in which they exist. Third, I review some aspects of bidders' incentives that would suggest an auction would realize full value. Finally, I review potential bidders and their financial resources and evaluate them in the context of the proposed auctions. Overall, I conclude that despite the significant amount of spectrum proposed to be put on the market, the wireless industry should have no problem financially absorbing the increased supply and the proposed auctions would be expected to be competitive and realize full value of that spectrum.

A. INDUSTRY ECONOMICS SUPPORT THE VALUE OF MORE SPECTRUM

As discussed in Section I above, wireless industry revenues were $178 billion in 2010 and expected to exceed $216 billion within 5 years and continue to grow thereafter. Currently, industry margins range from 18% to 50% of revenues.[45] Conservatively assuming industry margins of 25%, annual industry revenues of $200 billion growing at 2% per year, and an industry discount rate of 10% implies an NPV of industry profits equal to $688 billion.[46] If the spectrum sold in the proposed auctions represents about 34% of the post auction spectrum supply, then in a very rough sense future profits of several hundred billions of dollars should be available to pay for this spectrum. That is,

[45] As represented by EBITDA margins.

[46] Equal to $200 billion * 25% * 12.625, where 12.625 = (1+10%) / (10% - 2%).

the proposed auction receipts of $94 billion are well within the reasonable range considering the expected margins of the wireless industry.

Given the amount of future profits expected to be available in the wireless industry and the need to acquire spectrum to support future services, it seems very likely that several entities would be willing to purchase a right to a portion of that stream of profits in the form of FCC spectrum licenses. To be sure, markets are often imperfect in allocating resources, but an absence of willing buyers for spectrum licenses sufficient to prevent license auctions from realizing full value would represent a very significant market failure. In particular, it would represent a failure of capital markets—the most fluid markets in our economy—to adequately allocate capital to seize on profitable opportunities. It would truly be an example of the proverbial $20 bill left on the ground.

B. THE TOTAL MARKET FOR SPECTRUM SALES

To evaluate the ability of potential purchasers of spectrum licenses to buy auctioned spectrum, it is useful to look at the overall market for spectrum purchases. Purchased spectrum includes licenses won at FCC auctions, but also includes licenses purchased in the secondary market. Together, they represent the amount of money spent by firms on spectrum licenses.

The earlier discussion of the sources of spectrum value (future economic profits) was not dependent on the spectrum coming from an FCC auction versus coming from a secondary market transaction. Both auctions and the secondary market represent significant purchases of spectrum. See Table 4. That table shows the value of secondary market transactions for just one band of spectrum, PCS, and revenues from auctions. What is notable is the high level of annual turnover of spectrum licenses. The total churn of spectrum would be larger if other bands, including Cellular, SMR, and AWS were included. The total amount spent by private entities on spectrum licenses was more than $306 billion from 2000 through 2008. Spending about one-third of that amount over the next nine years does not seem exceptional.

Table 4. Secondary Market Transactions

			2000	2001	2002	2003	2004	2005	2006	2007	2008
	PCS Spectrum Traded										
[A]	PCS	Billions MHz-Pop	13.436	9.175	5.390	12.613	14.575	7.659	8.918	9.143	12.581
[B]		$/MHz-Pop	$3.33	$2.43	$1.53	$1.36	$1.57	$1.62	$2.34	$5.14	$4.64
[C]		$ Billions	$44.74	$22.26	$8.23	$17.14	$22.94	$12.41	$20.91	$46.99	$58.39
	Recent Auctions of PCS, AWS, and 700 MHz Spectrum										
[D]		Billions MHz-Pop	1.515	4.541	4.546	2.144		2.149	25.706	0.069	17.916
[E]		$ Billions	$0.52	$16.89	$0.09	$0.06		$2.04	$13.70	$0.01	$18.98
[F]	SubTotal of PCS and Auctions	$ Billions	$45.26	$39.15	$8.32	$17.20	$22.94	$14.45	$34.61	$47.01	$77.37

Sources and Notes:
[A], [D]: John W. Mayo and Scott Wallsten, 'Enabling efficient wireless communications: The role of secondary spectrum markets,' Information Economics and Policy 22 (2010): 61-72.
[B]: 2005 Nextel FCC spectrum swap of $1.62/MHz-Pop adjusted using annual average of TTH index before 2005 and annual average of SpecEx index after 2005.
[C]: [A] * [B].
[E]: Total of net bids for each band referenced in [D] from http://wireless.fcc.gov/auctions/default.htm?job=auctions_home.
[F]: [C] + [E].

C. BIDDERS' INCENTIVES TO BID

There are two aspects of bidders' incentives when bidding in an FCC spectrum auction that support the idea that full value would be realized. The first is an aspect of spectrum design that means total demand does not need to be much more than total supply to realize value in an auction. The second is an incentive created by the proposed 9-year timeframe in which to conduct the auctions for bidders to bid even in the absence of excess demand.

i) The McCaw Effect

The proposition that there does not need to be much excess demand in an auction to drive up auction bids was illustrated by Craig McCaw in the original Broadband PCS auction (Auction #4). As Peter Cramton noted, [47]

> McCaw apparently recognized that in some markets there might not be enough deep-pocketed bidders for prices to reach full value. By putting down just $33 million in earnest money, McCaw gained eligibility to bid

[47] Peter Cramton, "The FCC Spectrum Auction: An Early Assessment," Journal of Economics and Management Strategy, 6:3, 431-495, 1997, p. 17.

> in many large markets. At almost no cost (the lost interest on the $33 million upfront payment), McCaw was buying the option to step in and snatch licenses that were underpriced because of a lack of competition. He was an opportunistic bidder, who in the end did not find any opportunities.

Cramton estimates that in the markets where McCaw bid, and bidding for that market ended when he dropped out, the difference between the price McCaw set and the price that would have been set by the next highest bidder totaled $825 million. That is, a bidder with a $33 million deposit placed bids that increased final license prices by 25 times that amount.

ii) Bidders' Incentives to Bid

Although bidders may not have an incentive to bid against each other in an auction without excess demand, incentives change when there is a predictable series of auctions conducted over time. In this case, since access to all the frequencies will not happen immediately, the time dimension becomes important to bidder incentives. To the extent carriers, or potential carriers, need spectrum now, they will have an incentive to bid in earlier auctions to gain access to frequencies sooner.

This incentive for bidders to bid against each other even when there is no total excess demand for licenses is very similar to the Interlicense Competition idea I proposed with Michael Rothkopf.[48] In that analysis, the issue of selling expanded rights to spectrum that only incumbent licensees would value was addressed by not selling all rights at one time. Here, the series of 6 auctions over 9 years creates the same type of incentive structure as proposed in the Interlicense Competition paper. The time dimension creates additional incentives for bidders to bid.

D. POTENTIAL BIDDERS

Previous FCC spectrum auctions have attracted hundreds of bidders. See Appendix Tables A-1 and A-2. Although many of those bidders expressed only limited demand in the auctions, cumulatively they represented significant demand. Furthermore, as

[48] Michael H. Rothkopf and Coleman Bazelon, "Combinatorial Interlicense Competition: Spectrum Deregulation Without Confiscation or Giveaways," in OBTAINING THE BEST FROM REGULATION AND COMPETITION, Michael A. Crew and Menahem Spiegel, eds. Kluwer Academic Publishers, 2005), pp. 135-159.

discussed above in reference to Craig McCaw's experience in the Broadband PCS auction, a bidder with only limited interest can have a significant impact on final prices. It seems highly likely that many auction participants that ultimately did not purchase licenses—like Craig McCaw who ultimately did not purchase any licenses—would have remained active in an auction and found bargains, if had they existed. There is no reason to believe that similar numbers of bidders would not show up to future FCC auctions.

As in previous auctions, we expect primarily 4 types of bidders—all with financing and motive to bid competitively—to participate in any auction for radio spectrum allocated to wireless broadband. Tier 1 firms are nationwide wireless broadband service providers, including Verizon, AT&T, Sprint, and, possibly, T-Mobile. As demand for their wireless services grows, these firms have an increasing need for additional spectrum. Without the ability to acquire more spectrum, these nationwide providers will be forced to invest even more heavily in capital expenditures and even then would unlikely be able to meet future expected demand. As Table 5 illustrates, these firms have substantial value and the financial resources to participate in an auction. It is also worth noting that previous auctions have not been dependent on the presence of all nationwide providers in order to be competitive. For instance, both Sprint and T-Mobile choose not to enter the 700 MHz auction.

In addition to the large, nationwide providers, there are also a variety of regional and multi-regional wireless service providers who hold current spectrum licenses and offer wireless broadband services throughout the U.S. Many of these players are well known, and financially situated to participate. For instance, Table 5 lists some of the more well known Tier 2 firms, including Clearwire, MetroPCS, Leap/Cricket, U.S. Cellular, and LightSquared. Other regional providers also include Cox, Appalachian, TelePak, nTELOs, Bluegrass, Cincinnati Wireless, Cellular South, Atlantic Tele-Network.[49] Many of these other players have expressed significant demand in prior auctions, including approximately $9 billion of unmet demonstrated willingness to bid in

[49] See, also, discussion of entry by new suppliers including Clearwire, Leap Wireless (Cricket), MetroPCS, LightSquared, and super regional carriers including U.S. Cellular, Cellular South, and Atlantic Tele-Network. Faulhaber, Gerald R.; Robert W. Hahn and Hal J. Singer. "Assessing Competition in U.S. Wireless Markets: Review of the FCC's Competition Reports." Working Paper. Available at: http://ssrn.com/abstract-1880964 (last visited July 26, 2011).

the 700 MHz auction.[50] As is illustrated in Appendix Tables A-1 and A-2, many of these regional providers have participated in auctions before. Many of these firms appear to be in a strong position to invest in additional spectrum.[51]

Table 5. Examples of Potential Bidders

Firm	Enterprise Value [1] *($ Billions)*	Not Publicly Traded
Tier 1		
AT&T	$243.19	
Verizon	$150.41	
Sprint	$29.98	
Tier 2		
MetroPCS	$8.82	Appalachian Wireless
U.S. Cellular	$4.33	Bluegrass
Clearwire	$3.63	Cox
Leap/Cricket	$3.61	LightSquared
Cincinnati Wireless	$3.28	Telapex
nTELOs	$1.57	
Atlantic Tele-Network	$0.84	
Related Industry		
Microsoft	$196.60	
Google	$167.65	
Intel	$112.97	
Comcast	$107.27	
Qualcomm	$84.22	
Time Warner	$52.83	
DirectTV	$50.02	
News Corporation	$44.37	
EchoStar	$2.43	

Source:
[1]: http://finance.yahoo.com, accessed on July 27, 2011.

[50] See Bazelon, "Too Many Goals" (2009), p. 126.

[51] Reviewing summary analyst reports of the telecom services industry provides a better picture of the financial position of these tier-2 providers. For instance, Morgan Stanley tracks at least 22 individual service providers—only three of which would be considered Tier 1 telecom service providers (Verizon, AT&T and Sprint). See Exhibit 2 in "Telecom Services 2Q Preview: M&A, 4G Roll-outs and Capex in Focus," *Morgan Stanley*, July 19, 2011. There is substantial cash available for auctions in the next few years. Combined, the telecom sector cash balances are currently greater than $26 billion.

Also noted in Table 5, in addition to service providers there are related industry players who have participated spectrum auctions in the past. For instance, Google and Qualcomm have both participated in spectrum auctions before. Microsoft has also expressed interest in wireless broadband spectrum and related technologies. Finally, as Table 6 outlines, a number of investment firms have also expressed interest in the telecommunications sector.

Table 6. Examples of Investment Groups Interested in Telecommunications

	Firm	Assets Under Management	Size
[1]	Abry Partners	Completed $27 billion since 1989; $3.5 billion in active funds	Over 450 investments; investments range from $25 million to $150 million
[2]	Bain Capital	$65 billion under management	375 employees, with more than 250 investments
[3]	Battery Ventures	Raised $4 billion since 1983; currently investing in a $750 million fund	Investments range from a few hundred thousand dollars to $100 million
[4]	Blackstone	$150 billion under management	1,470 employees in 22 offices
[5]	Carlyle Group	$107.6 billion under management	More than 450 employees in 19 countries; 84 funds
[6]	Catalyst Investors	Unknown	Size of investments range from $5 - $40 million; raised $230 million for Xplornet, a Canadian Telecom founded in 2006
[7]	Columbia Capital	$2.5 billion under management	Funded over 130 companies since 1989
[8]	Court Square	$6 billion under management	Invested over $4.5 billion in more than 150 transactions, which have returned $14 billion to date
[9]	General Atlantic	$17 billion under management	Over 75 investment professionals in over 10 countries; invest in 8-12 companies per year
[10]	GI Partners	$6 billion under management	37 investment professionals; focused on investments in US and Western Europe; typically invests $50 million to $250 million
[11]	KKR	$61 billion under management	More than 45 professionals in 14 offices world-wide
[12]	Madison Dearborn Partners	Raised over $18 billion since its formation in 1992	Investments range from $100 million to $600 million of equity capital in each transaction
[13]	M/C Partners	Invested $1.5 billion over the course of two decades	Investments range from $5 million to $50 million; currently investing in a $550 million equity fund raised in 2006
[14]	Oak Hill Capital Partners	$8 billion under management	Oak Hill Capital Partners is one of numerous Oak Hill partnerships which total $25 billion
[15]	Pamlico Capital	$2 billion under management; currently investing in a $1.1 billion fund	Investments range from $15 million to $100 million per transaction
[16]	Providence Partners	$23 billion under management	6 global offices; seeks investments between $150 and $800 million
[17]	Seaport Capital	Have invested over $400 million; raised over $2.5 billion (no time line given)	Seeks market capitalizations between $10 million and $100 million and junior capital needs of $5 million and $20 million
[18]	Silver Lake	$14 billion under management	90 investment professionals in 6 offices world-wide
[19]	TA Associates	$16 billion capital base; raised more than $15 billion since 1995	60 investment professionals in 5 offices world-wide; able to invest up to $500 million in a single transaction
[20]	TPG	$48 billion under management	14 offices world-wide; typically holds investments for an average of

Sources and Notes:

[1] http://www.abry.com/Home/AboutUs/OurFunds.aspx
[2] http://www.baincapital.com/AboutBainCapital/Default.aspx
[3] http://www.battery.com/about/index.html
[4] http://www.blackstone.com/cps/rde/xchg/bxcom/hs/firm.htm
[5] http://www.carlyle.com/Company/item1676.html
[6] http://www.catalystinvestors.com/news_detail/216/
[7] http://www.colcap.com/about/
[8] http://www.courtsquare.com/#/about_us/
[9] http://www.generalatlantic.com/en/strategy/overview
[10] http://www.gipartners.com/overview.aspx
[11] http://www.kkr.com/company/company_overview.cfm
[12] http://mdcp.com/overview.asp
[13] http://www.mcpartners.com/
[14] http://www.oakhillcapital.com/index.html
[15] http://www.pamlicocapital.com/AboutUs/InvestmentCriteria.aspx
[16] http://www.provequity.com/about_us/index.asp?Section=1,0,0
[17] http://www.seaportcapital.com/home/index.php
[18] http://www.silverlake.com/content.php?page=about
[19] http://www.ta.com/about/about.asp
[20] http://www.tpg.com/index.html

IV. CONCLUSION

As the National Broadband Plan (NBP) emphasizes, 500 MHz of new commercial spectrum allocations are desperately needed in the next 10 years to avoid what FCC Chairman Genachowski has referred to as a spectrum crisis. The FCC projects that by

2014, mobile data traffic will be 35 times 2009 levels, resulting in demand for 1,097 MHz of wireless broadband spectrum. To meet the growing consumer demand for mobile broadband services, wireless networks must expand capacity in the coming years. The quality and quantity of any additional spectrum made available for commercial use will be key.

The Draft Mobile Broadband Enhancement Act of 2011 identifies 470 MHz of spectrum in large, contiguous blocks to be reallocated for commercial wireless broadband through a series of six auctions scheduled at 18-month intervals over 9 years. This legislation addresses many issues that influence spectrum value, resolving them in favor of higher valuations. The total value of this spectrum is likely to be about $100 billion minus an estimate $6 billion for exclusion zones protecting critical government systems in federal spectrum reallocated for commercial use with expected clearing costs of about $30 billion, which implies net revenues of $64 billion. By providing a reasonable time schedule and identifying contiguous blocks of at least 20 MHz, this bill allows the FCC to design competitive auctions that will realize the full value of this spectrum in auction receipts. Based on the past decade of tremendous growth in the wireless industry, the strong financial position of both national and regional wireless service providers, and experiences of previous FCC auctions, these 6 proposed auctions promise to be highly competitive.

APPENDIX A-1
AUCTION 66: BIDDERS AND PWB WINNERS

	Bidder [A]	Upfront Payment [B]	Initial Eligiblity [C]	Licenses Won [D]	Total PWB [E]
	PWB Winners				
[1]	T-Mobile License LLC	$583,518,750	583,518,750	120	$4,182,312,000
[2]	Cellco Partnership d/b/a Verizon Wireless	$383,343,000	255,562,000	13	$2,808,599,000
[3]	SpectrumCo LLC	$637,709,000	637,709,000	137	$2,377,609,000
[4]	MetroPCS AWS, LLC	$200,000,000	200,000,000	8	$1,391,410,000
[5]	Cingular AWS, LLC	$500,000,000	333,333,334	48	$1,334,610,000
[6]	Cricket Licensee (Reauction), Inc.	$255,000,000	255,000,000	99	$710,214,000
[7]	Denali Spectrum License, LLC	$50,000,000	50,000,000	1	$365,445,000
[8]	Barat Wireless, L.P.	$80,000,000	80,000,000	17	$169,520,000
[9]	AWS Wireless Inc.	$142,830,000	142,830,000	154	$115,503,000
[10]	Atlantic Wireless, L.P.	$52,000,000	52,000,000	15	$100,392,000
[11]	American Cellular Corporation	$17,000,000	17,000,000	85	$65,880,000
[12]	Cincinnati Bell Wireless LLC	$7,000,000	7,000,000	9	$37,071,000
[13]	Cellular South Licenses, Inc.	$7,000,000	7,000,000	12	$33,025,000
[14]	Cable One, Inc.	$3,531,000	3,531,000	30	$22,148,000
[15]	Cavalier Wireless, LLC	$18,800,000	18,800,000	30	$19,943,000
[16]	Daredevil Communications LLC	$8,888,000	8,888,000	14	$13,441,000
[17]	Iowa Telecommunications Services, Inc.	$3,102,000	3,102,000	15	$11,473,000
[18]	Centennial Michiana License Company LLC	$5,000,000	5,000,000	2	$9,134,000
[19]	Red Rock Spectrum Holdings, LLC	$6,000,000	6,000,000	42	$7,466,000
[20]	Public Service Wireless Services, Inc.	$4,501,000	4,501,000	7	$5,480,000
[21]	Central Texas Telephone Investments, LP	$2,567,000	2,567,000	5	$4,940,000
[22]	Hill Country Telephone Cooperative, Inc.	$254,000	254,000	2	$4,700,000
[23]	Carolina West Wireless, Inc.	$6,000,000	6,000,000	9	$4,621,000
[24]	Palmetto Rural Telephone Cooperative, Inc.	$1,242,000	1,242,000	2	$4,483,000
[25]	Plateau Telecommunications, Inc.	$3,000,000	3,000,000	4	$4,200,000
[26]	LL License Holdings II, LLC	$2,500,000	2,500,000	8	$3,435,000
[27]	Triad AWS, Inc.	$40,000,000	40,000,000	5	$3,193,000
[28]	KTC AWS Limited Partnership	$700,000	678,000	11	$3,108,000
[29]	Vermont Telephone Company, Inc.	$563,000	563,000	3	$2,911,000
[30]	CROSS TELEPHONE COMPANY	$1,049,000	1,049,000	3	$2,450,000
[31]	Manti Telephone Company	$563,000	563,000	5	$2,421,000
[32]	Chequamegon Communications Cooperative, Inc.	$1,281,700	1,281,700	3	$2,419,000
[33]	Mediapolis Telephone Company	$250,000	250,000	2	$2,392,000
[34]	MTPCS License Co., LLC	$2,000,000	2,000,000	4	$2,348,000
[35]	NTELOS Inc.	$2,660,000	2,660,000	7	$2,295,000
[36]	MTA Communications, Inc.	$1,220,000	1,220,000	3	$2,251,000
[37]	Command Connect, LLC	$3,300,000	3,300,000	5	$2,210,000
[38]	FMTC Wireless, Inc.	$325,000	325,000	2	$2,197,000
[39]	Spotlight Media Corp	$1,149,000	1,149,000	2	$2,192,000
[40]	NSIGHTTEL WIRELESS, LLC	$1,800,000	1,800,000	5	$2,099,000
[41]	Smithville Spectrum, LLC	$425,000	416,000	2	$2,011,000
[42]	Union Telephone Company	$800,000	800,000	8	$1,948,200
[43]	Blackfoot Telephone Cooperative, Inc.	$782,100	782,100	4	$1,798,000
[44]	Hemingford Cooperative Telephone Company	$750,000	750,000	11	$1,660,000
[45]	West Carolina Piedmont Bidding Consortium	$380,400	380,400	3	$1,642,000

APPENDIX A-1
AUCTION 66: BIDDERS AND PWB WINNERS

	Bidder [A]	Upfront Payment [B]	Initial Eligiblity [C]	Licenses Won [D]	Total PWB [E]
[46]	Wittenberg Telephone Company	$855,000	855,000	3	$1,519,000
[47]	Fidelity Communications Company	$900,000	900,000	7	$1,501,000
[48]	Atlantic Seawinds Communications, LLC	$233,000	233,000	1	$1,477,000
[49]	CTC Telcom, Inc.	$220,000	220,000	1	$1,407,000
[50]	FTC Management Group, Inc.	$243,000	243,000	2	$1,380,000
[51]	NEIT Wireless, LLC	$475,000	475,000	3	$1,315,000
[52]	Sandhill Communications, LLC	$133,000	133,000	1	$1,179,000
[53]	Chester Telephone Company	$103,000	103,000	1	$1,100,000
[54]	3 Rivers Telephone Cooperative, Inc.	$821,000	821,000	4	$1,066,000
[55]	AGRI-VALLEY COMMUNICATIONS, INC.	$2,037,000	2,037,000	5	$1,045,000
[56]	Horry Telephone Cooperative, Inc.	$1,012,800	1,012,800	1	$925,000
[57]	Space Data Spectrum Holdings, LLC	$520,000	520,000	3	$777,000
[58]	SKT, Inc.	$814,000	814,000	1	$774,000
[59]	18th Street Spectrum, LLC	$750,000	750,000	4	$751,000
[60]	Blue Valley Tele-Communications, Inc.	$109,000	109,000	2	$711,000
[61]	Southeastern Indiana Rural Telephone Coop., Inc.	$242,400	242,400	1	$658,000
[62]	Hancock Rural Telephone Corporation	$400,000	384,000	1	$629,000
[63]	Pine Cellular Phones, Inc.	$226,000	226,000	2	$601,000
[64]	Telephone Electronics Coporation	$1,338,000	1,338,000	3	$559,000
[65]	Bend Cable Communications, LLC	$176,000	176,000	2	$528,000
[66]	LCDW Wireless Limited Partnership	$150,000	144,000	1	$514,000
[67]	Midwest AWS Limited Partnership	$128,000	128,000	1	$489,000
[68]	Lynch AWS Corporation	$1,500,000	1,500,000	1	$485,000
[69]	CenturyTel Broadband Wireless LLC	$59,098,000	59,098,000	6	$468,000
[70]	Alenco Communications, Inc.	$325,000	325,000	1	$437,000
[71]	Stayton Cooperative Telephone Company	$658,000	658,000	1	$391,000
[72]	James Valley	$75,000	75,000	1	$373,000
[73]	Paul Bunyan Rural Telephone Cooperative	$620,000	620,000	3	$329,000
[74]	Ligtel Communications, Inc.	$300,000	296,000	2	$319,000
[75]	Mutual Telephone Company	$370,000	364,000	1	$312,000
[76]	BEK COMMUNICATIONS COOPERATIVE	$196,000	196,000	2	$312,000
[77]	Comporium Wireless, LLC	$673,000	673,000	1	$295,000
[78]	ETCOM, LLC	$81,000	81,000	1	$283,000
[79]	La Ward Cellular Telephone Company, Inc.	$84,000	84,000	1	$273,000
[80]	Chariton Valley Communication Corporation, Inc.	$131,000	131,000	2	$268,000
[81]	Big River Telephone Company, LLC	$250,000	250,000	2	$243,000
[82]	BPS Telephone Company	$192,000	192,000	1	$228,000
[83]	CCTN BIDDING CONSORTIUM	$140,100	140,100	6	$228,000
[84]	Mt. Vernon. Net, Inc.	$291,000	291,000	1	$227,000
[85]	C&W Enterprises INC.	$141,000	141,000	1	$226,000
[86]	Dakota Wireless Group, LLC	$100,000	100,000	2	$222,000
[87]	Green Hills Area Cellular Telephone, Inc.	$43,000	43,000	1	$213,000
[88]	Innovative Communication Corporation	$97,500	65,000	2	$184,000
[89]	North Dakota Network Company	$581,000	581,000	3	$177,000
[90]	City of Ketchikan dba Ketchikan Public Utilities	$44,000	44,000	1	$157,000

APPENDIX A-1
AUCTION 66: BIDDERS AND PWB WINNERS

	Bidder [A]	Upfront Payment [B]	Initial Eligiblity [C]	Licenses Won [D]	Total PWB [E]
[91]	Big Bend Telecom, LTD	$34,000	34,000	2	$129,000
[92]	Volcano Internet Provider	$89,000	89,000	1	$105,000
[93]	Grand River Communications, Inc.	$103,000	103,000	1	$103,000
[94]	Reservation Telephone Cooperative, Inc.	$37,000	37,000	1	$92,000
[95]	Farmers Telecommunications Cooperative, Inc.	$85,000	85,000	1	$85,000
[96]	Route 66 Wireless, LLC	$500,000	500,000	1	$72,000
[97]	Three River Telco	$88,000	88,000	1	$72,000
[98]	The S&T Telephone Cooperative Association, Inc.	$28,000	28,000	2	$72,000
[99]	PetroCom License Corporation	$60,000	60,000	2	$70,000
[100]	Churchill County Telephone d/b/a CC Communications	$60,000	60,000	2	$60,000
[101]	AST Telecom, LLC	$34,000	34,000	1	$34,000
[102]	Northeast Missouri Rural Telephone Company	$55,000	55,000	1	$28,000
[103]	Northwest Missouri Cellular Limited Partnership	$128,000	128,000	1	$26,000
[104]	WUE INC	$8,000	8,000	1	$8,000
	Sub-Total	*$3,119,969,750*	*2,825,426,584*	*1,087*	*$13,879,110,200*

APPENDIX A-1
AUCTION 66: BIDDERS AND PWB WINNERS

	Bidder [A]	Upfront Payment [B]	Initial Eligiblity [C]	Licenses Won [D]	Total PWB [E]
	Bidders that did not Win a License				
[105]	Wireless DBS LLC	$972,546,000	648,364,000	0	$0
[106]	Dolan Family Holdings, LLC	$149,983,000	149,983,000	0	$0
[107]	Antares Holdings, LLC	$21,000,000	21,000,000	0	$0
[108]	Shenandoah Mobile Company	$4,749,000	4,749,000	0	$0
[109]	PCS Partners, L.P.	$3,000,000	3,000,000	0	$0
[110]	Hawaiian Telcom Communications, Inc.	$2,155,000	2,155,000	0	$0
[111]	Iowa Intelegra Consortium, LLC	$2,000,000	2,000,000	0	$0
[112]	Bluestreak Wireless LLC	$1,000,000	1,000,000	0	$0
[113]	Leaco Rural Telephone Cooperative Inc	$712,500	475,000	0	$0
[114]	St. Cloud Wireless Holdings, LLC	$630,000	630,000	0	$0
[115]	WEST CENTRAL COMMUNICATIONS, LLC	$536,000	536,000	0	$0
[116]	Cal-Ore Telephone Co.	$500,000	500,000	0	$0
[117]	Central Utah Telephone Company	$500,000	500,000	0	$0
[118]	Western New Mexico Telephone Company, Inc.	$500,000	500,000	0	$0
[119]	Craw-Kan Telephone Cooperative, Inc.	$434,000	434,000	0	$0
[120]	Granite State Long Distance, Inc.	$381,000	381,000	0	$0
[121]	Allcom Communications, Inc.	$368,000	368,000	0	$0
[122]	The Chillicothe Telephone Company	$359,000	359,000	0	$0
[123]	South Slope Cooperative Telephone Company, Inc.	$350,000	303,000	0	$0
[124]	West Central Telephone Association	$310,000	294,000	0	$0
[125]	ACS Wireless License Sub, Inc.	$304,000	304,000	0	$0
[126]	Northeast Nebraska Telephone Company	$302,000	302,000	0	$0
[127]	Kingdom Telephone Company	$300,000	300,000	0	$0
[128]	Carolina Personal Communications, Inc.	$286,000	286,000	0	$0
[129]	Advanced Communications Technology, Inc.	$264,000	264,000	0	$0
[130]	Tri-Valley Communications, LLC	$249,000	249,000	0	$0
[131]	XIT Leasing, Inc.	$210,000	210,000	0	$0
[132]	Northern Iowa Communications Partners, LLC	$200,000	200,000	0	$0
[133]	Rodriguez, Marcos	$195,000	195,000	0	$0
[134]	Heart of Iowa Communications Cooperative	$175,000	163,000	0	$0
[135]	Shoreline Investments LLC	$173,000	173,000	0	$0
[136]	MAC Wireless, LLC	$160,000	154,000	0	$0
[137]	Van Buren Wireless, Inc.	$160,000	147,000	0	$0
[138]	Partnership Wireless LLC	$158,000	158,000	0	$0
[139]	WWW BROADBAND, LLC	$157,000	157,000	0	$0
[140]	Ellijay Telephone Company	$154,000	154,000	0	$0
[141]	Jefferson Telephone Company	$150,000	150,000	0	$0
[142]	Wheat State Telephone, Inc.	$141,000	141,000	0	$0
[143]	Graceba Total Communications, Inc.	$138,000	138,000	0	$0
[144]	Arapahoe Telephone Company d/b/a ATC Communication	$136,000	136,000	0	$0
[145]	Perry-Spencer Rural Telephone Coop., Inc. dba PSC	$136,000	136,000	0	$0
[146]	The Pioneer Telephone Association, Inc.	$134,000	134,000	0	$0
[147]	UNITED WIRELESS COMMUNICATIONS INC.	$130,000	130,000	0	$0
[148]	SALINA SPAVINAW TELEPHONE COMPANY, INC.	$125,000	125,000	0	$0

APPENDIX A-1
AUCTION 66: BIDDERS AND PWB WINNERS

	Bidder	Upfront Payment	Initial Eligiblity	Licenses Won	Total PWB
	[A]	[B]	[C]	[D]	[E]
[149]	Ropir Communications, Inc.	$118,000	118,000	0	$0
[150]	Coleman County Telecommunications, LTD	$116,000	116,000	0	$0
[151]	The Tri-County Telephone Association, Inc.	$116,000	116,000	0	$0
[152]	South #5 RSA Limited Partnership d/b/a Brazos Cell	$103,000	103,000	0	$0
[153]	Diller Telephone Company	$101,000	101,000	0	$0
[154]	Aztech Communications, Inc.	$93,000	93,000	0	$0
[155]	Clay County Rural Telephone Cooperative, Inc.	$80,000	76,000	0	$0
[156]	Rainbow Telecommunications Association, Inc.	$70,000	70,000	0	$0
[157]	McDonald County Telephone Company	$67,000	67,000	0	$0
[158]	Plains Cooperative Telephone Association, Inc.	$64,000	64,000	0	$0
[159]	Roberts County Telephone Cooperative Association	$61,500	41,000	0	$0
[160]	MUENSTER TELEPHONE CORPORATION OF TEXAS	$55,000	55,000	0	$0
[161]	Farmers Mutual Telephone Company	$43,000	43,000	0	$0
[162]	UNITED TELEPHONE MUTUAL AID CORPORATION	$35,000	35,000	0	$0
[163]	Breda Telephone Corp.	$33,000	33,000	0	$0
[164]	Panora Telecommunications, Inc.	$33,000	33,000	0	$0
[165]	XIT Telecommunication & Technology, Ltd.	$33,000	33,000	0	$0
[166]	Clinker LLC	$20,000	20,000	0	$0
[167]	Beehive Telephone Company, Inc.	$17,000	17,000	0	$0
[168]	Panhandle Telecommunication Systems, Inc.	$17,000	17,000	0	$0
	Sub-Total	*$1,167,826,000*	*843,288,000*	*0*	*$0*

Source and Notes:
[A] - [E]: http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=66

APPENDIX A-2
AUCTION 73: BIDDERS AND PWB WINNERS

	Bidder [A]	Total PWB [B]
	PWB Winners	
[1]	Cellco Partnership d/b/a Verizon Wireless	$9,363,160,000
[2]	AT&T Mobility Spectrum, LLC	$6,636,658,000
[3]	QUALCOMM Incorporated	$1,030,184,000
[4]	Frontier Wireless LLC	$711,871,000
[5]	King Street Wireless, L.P.	$400,638,000
[6]	MetroPCS 700 MHz, LLC	$313,267,000
[7]	Cox Wireless, Inc.	$304,633,000
[8]	Cellular South Licenses, Inc.	$191,533,000
[9]	CenturyTel Broadband Wireless LLC	$148,964,000
[10]	Vulcan Spectrum LLC	$112,793,000
[11]	Continuum 700 LLC	$88,179,000
[12]	Cavalier Wireless, LLC	$61,803,000
[13]	Puerto Rico Telephone Company, Inc.	$31,402,000
[14]	Triad 700, LLC	$22,694,000
[15]	MCBRIDE SPECTRUM PARTNERS, LLC	$8,490,000
[16]	Horry Telephone Cooperative, Inc.	$8,469,000
[17]	Wireless Communications Venture	$8,055,000
[18]	Redwood Wireless Corp.	$7,845,000
[19]	Miller, David	$7,812,000
[20]	Bend Cable Communications, LLC	$6,745,000
[21]	Central Texas Telephone Investments, LP	$6,347,000
[22]	I-700, LLC	$5,960,000
[23]	Iowa Telecommunications Services, Inc.	$5,894,000
[24]	Whidbey Telephone Company	$5,496,000
[25]	Union Telephone Company	$4,385,000
[26]	Manti Telephone Company	$4,099,000
[27]	KTC AWS Limited Partnership	$3,864,000
[28]	Bresnan Communications, Inc.	$3,859,000
[29]	LL License Holdings, LLC	$3,812,000
[30]	PVT Networks, Inc.	$3,605,000
[31]	NSIGHTTEL WIRELESS, LLC	$3,359,000
[32]	Bluegrass Wireless LLC	$3,272,000
[33]	Blue Valley Tele-Communications, Inc.	$3,079,000
[34]	SAL Spectrum, LLC	$2,941,000
[35]	Cincinnati Bell Wireless LLC	$2,829,000
[36]	PCS Partners, L.P.	$2,821,000
[37]	Agri-Valley Communications, Inc.	$2,508,000
[38]	Comporium Wireless, LLC	$2,350,000
[39]	Chariton Valley Communication Corporation, Inc.	$2,335,000
[40]	Sky Com 700 MHZ, LLC	$2,227,000
[41]	Club 42 CM Limited Partnership	$2,227,000
[42]	Cross Telephone Company, LLC	$2,051,000
[43]	N.E. Colorado Wireless Technologies, Inc.	$2,022,000
[44]	Star Telephone Membership Corporation	$1,968,000
[45]	VentureTel 700, Inc.	$1,940,000

APPENDIX A-2
AUCTION 73: BIDDERS AND PWB WINNERS

	Bidder [A]	Total PWB [B]
[46]	Worldcall Inc.	$1,918,000
[47]	Cable Montana LLC	$1,770,000
[48]	Iowa Intelegra Consortium, LLC	$1,696,000
[49]	CHEVRON USA INC.	$1,663,000
[50]	Pine Cellular Phones, Inc.	$1,646,000
[51]	Vermont Telephone Company, Inc.	$1,597,000
[52]	Sandhill Communications, LLC	$1,590,000
[53]	Glenwood Telephone Membership, Corporation	$1,527,000
[54]	Midwest AWS Limited Partnership	$1,519,000
[55]	The World Company	$1,495,000
[56]	Kurian, Thomas K	$1,479,000
[57]	MTN3B Consortium	$1,409,000
[58]	PTI Pacifica, Inc.	$1,293,000
[59]	Broadband Wireless Unlimited, LLC	$1,239,000
[60]	Ligtel Communications, Inc.	$1,219,000
[61]	Buggs Island Telephone Cooperative	$1,132,000
[62]	Small Ventures USA, L.P.	$1,055,000
[63]	Public Service Wireless Services, Inc.	$1,039,000
[64]	The Chillicothe Telephone Company	$1,038,000
[65]	Choice Phone LLC	$1,003,000
[66]	Bascom Long Distance, Inc.	$925,000
[67]	AWS Spectrum, LLC	$887,000
[68]	Toba Inlet PCS, LLC	$871,000
[69]	Columbia Cellular, Inc.	$793,000
[70]	Gold Radio Group, LLC	$710,000
[71]	Great American Broadband, Inc.	$699,000
[72]	AlasConnect, Inc.	$560,000
[73]	Dragon Arch, Inc.	$538,000
[74]	Panhandle Telecommunication Systems, Inc.	$435,000
[75]	Data-Max Wireless LLC	$434,000
[76]	BPS Telephone Company	$421,000
[77]	Piedmont Rural Telephone Cooperative, Inc.	$418,000
[78]	West Carolina Communications, LLC	$406,000
[79]	East Kentucky Network, LLC	$406,000
[80]	Miles Communications Corp	$392,000
[81]	USA Choice Internet Services Company LLC	$387,000
[82]	BEK Communications Cooperative	$383,000
[83]	Buffalo-Lake Erie Wireless Systems Co., L.L.C.	$375,000
[84]	PBP Bidco LLC	$326,000
[85]	James Valley Cooperative Telephone Company	$306,000
[86]	Hemingford Cooperative Telephone Company	$282,000
[87]	Red River Rural Telephone Association, Inc.	$267,000
[88]	Chester Telephone Company	$254,000
[89]	Pioneer Telephone Cooperative, Inc.	$252,000
[90]	MTA Communications, Inc.	$239,000

APPENDIX A-2
AUCTION 73: BIDDERS AND PWB WINNERS

	Bidder	Total PWB
	[A]	[B]
[91]	Spectrum Acquisitions, Inc.	$238,000
[92]	Churchill County Telephone d/b/a CC Communications	$210,000
[93]	maxima international llc	$208,000
[94]	The S&T Telephone Cooperative Association, Inc.	$192,000
[95]	WUE, Inc.	$189,000
[96]	Paul Bunyan Rural Telephone Cooperative, Inc.	$175,000
[97]	GreenFly LLC	$159,000
[98]	C&W Enterprises, Inc.	$129,000
[99]	Rural Telephone Service Company, Inc.	$107,000
[100]	Reiter, Scott D	$55,000
[101]	AST Telecom, LLC	$20,000
	Sub-Total	$19,592,420,000

APPENDIX A-2
AUCTION 73: BIDDERS AND PWB WINNERS

	Bidder	Total PWB
	[A]	[B]
	Bidders that did not Win a License	
[102]	ACS Wireless License Sub, Inc.	$0
[103]	Adams Telcom, Inc.	$0
[104]	Advance/Newhouse Partnership	$0
[105]	Alltel Corporation	$0
[106]	Aristotle Inc.	$0
[107]	Bay Electronics, Inc.	$0
[108]	Bayou Internet, Inc.	$0
[109]	Blanca Telephone Company	$0
[110]	Blaze Broadband LLC	$0
[111]	BlueBird Telecommunications Ltd.	$0
[112]	Bluewater Wireless, L.P.	$0
[113]	Budget Phone	$0
[114]	Cascade Access, L.L.C.	$0
[115]	Central Wisconsin Communications, Inc.	$0
[116]	Chequamegon Communications Cooperative, Inc.	$0
[117]	Citizens Mutual Telephone Cooperative	$0
[118]	COLI INc	$0
[119]	Command Connect, LLC	$0
[120]	Computer Techniques, Inc.	$0
[121]	ComSouth Tellular, Inc.	$0
[122]	Copper Valley Wireless, Inc.	$0
[123]	Corn Belt Telephone Company, Inc.	$0
[124]	Cricket Licensee 2007, LLC	$0
[125]	CRT Holdings, Inc.	$0
[126]	CSC Spectrum Holdings LLC	$0
[127]	CSConnect Inc.	$0
[128]	CTC Telcom, Inc.	$0
[129]	Cumby Telephone Cooperative, Inc.	$0
[130]	Danville Mutual Telephone Company	$0
[131]	Day Management Corporation	$0
[132]	Delmarva Broadband LLC	$0
[133]	East Ascension Telephone Company, LLC	$0
[134]	Eastern Colorado Wireless II, LLC	$0
[135]	Ellijay Telephone Company	$0
[136]	Farmers Telecommunications Cooperative, Inc.	$0
[137]	Farmers Telephone Company, Inc.	$0
[138]	Fidelity Communications Company	$0
[139]	First Mile Holdings, Inc.	$0
[140]	FMTC Wireless, Inc.	$0
[141]	Forum Communications Company	$0
[142]	FTC Management Group, Inc.	$0
[143]	FWC Communications, Inc.	$0
[144]	Glass, Laurence B	$0
[145]	Golden Belt Telephone Association, Inc.	$0
[146]	Google Airwaves Inc.	$0
[147]	Grand River Communication, Inc.	$0

APPENDIX A-2
AUCTION 73: BIDDERS AND PWB WINNERS

	Bidder [A]	Total PWB [B]
[148]	Granite State Long Distance, Inc.	$0
[149]	Green Hills Area Cellular Telephone, Inc.	$0
[150]	Guam Cellular & Paging	$0
[151]	H & B Communications, Inc.	$0
[152]	Huxley Communications Corp.	$0
[153]	IdeaOne Telecom Group, LLC	$0
[154]	Independents Fiber Network, LLC	$0
[155]	Inland Cellular Telephone Company	$0
[156]	Kaplan Telephone Company, Inc.	$0
[157]	Kinex Networking Solutions, Inc.	$0
[158]	Kingdom Telephone Company	$0
[159]	Lackawaxen Long Distance Company, Inc.	$0
[160]	LCDW Wireless Limited Partnership	$0
[161]	Lexcom, Inc.	$0
[162]	Lynch Wireless Broadband Company, LLC	$0
[163]	MAC Wireless, LLC	$0
[164]	McDonald County Telephone Company	$0
[165]	Mediapolis Telephone Company	$0
[166]	MH Telecom, LLC	$0
[167]	Mid-Missouri Telephone Company	$0
[168]	Missouri Valley Wireless, LLC	$0
[169]	Muenster Telephone Corporation of Texas	$0
[170]	Mulberry Cooperative Telephone Company, Inc	$0
[171]	Muskrat Wireless, LP	$0
[172]	NatTel, LLC	$0
[173]	Neptuno Media	$0
[174]	New Ulm Telecom, Inc.	$0
[175]	North Dakota Network Company	$0
[176]	Northeast Missouri Rural Telephone Company	$0
[177]	Northeast Nebraska Telephone Company	$0
[178]	Northern Iowa Communications Partners, LLC	$0
[179]	Northern New Mexico Telecom, Inc.	$0
[180]	Northwest Missouri Cellular Limited Partnership	$0
[181]	Nunn Communications, LLC	$0
[182]	Palmetto Rural Telephone Cooperative, Inc.	$0
[183]	Poka Lambro Telecommunications, LTD	$0
[184]	Polar Communications Mutual Aid Corporation	$0
[185]	Pulse Mobile LLC	$0
[186]	Rainbow Telecommunications Association, Inc.	$0
[187]	Robinson, Jack E	$0
[188]	RONAN TELEPHONE COMPANY	$0
[189]	SeaBytes, L.L.C.	$0
[190]	Sierra Cellular, Inc.	$0
[191]	Siskiyou Telephone Company	$0
[192]	Slopeside Internet	$0
[193]	Socket Telecom LLC	$0
[194]	Surry Telecommunications, Inc.	$0
[195]	TCT West, Inc.	$0
[196]	The Pioneer Telephone Association, Inc.	$0

APPENDIX A-2
AUCTION 73: BIDDERS AND PWB WINNERS

	Bidder [A]	Total PWB [B]
[197]	The Ponderosa Telephone Co.	$0
[198]	The Tri-County Telephone Association, Inc.	$0
[199]	Three River Telco	$0
[200]	Towerstream Corporation	$0
[201]	Tri-Valley Communications, LLC	$0
[202]	United Wireless Communications Inc.	$0
[203]	USA Broadband LLC	$0
[204]	Valley Telephone Cooperative, Inc.	$0
[205]	Van Buren Wireless, Inc.	$0
[206]	Vavasi NexGen Inc.	$0
[207]	Washington County Rural Telephone Cooperative, Inc	$0
[208]	West Wisconsin Telcom Cooperative, Inc.	$0
[209]	Western Iowa Telephone Association	$0
[210]	world network international services Inc.	$0
[211]	WWW Broadband, LLC	$0
[212]	Xanadoo 700 MHz DE, LLC	$0
[213]	Xpressweb Internet Services, Inc.	$0

Source and Notes:
[A] & [B]: http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=73