Lecture 2: Spectrum Economics

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Spectrum Economics and Market Tools

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Spectrum Economics and Market Tools

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II.1 History of Auctions

Telecommunications Act of 1996

Figure 22. FCC Report to Congress in 1997 on Spectrum Auctions
In the Matter of FCC Report to Congress on Spectrum Auctions, FCC 97-353, WT Docket No. 97-150, Oct. 9, 1997, https://www.fcc.gov/sites/default/files/wireless/auctions/data/papersAndStudies/fc970353.pdf

II.1 History of Auctions

Telecommunications Act of 1996

> *"The new auction paradigm has drawn entry and new financing into telecommunications markets and has spurred the marketing of new technologies and the building of transmission capacity to meet growing demand."*
>
> Source: Thomas J. Duesterberg & Peter K. Pitsch, *Wireless Services, Spectrum Auctions, and Competition in Modern Telecommunications*, Outlook (May 1997), p. 7 (*Duesterberg & Pitsch*).

Figure 23. Quote from FCC Report to Congress on the New Auction Paradigm Thomas J. Duesterberg & Peter K. Pitsch, "Wireless Services, Spectrum Auctions, and Competition in Modern Telecommunications," Outlook (May 1997), at 7, cited by FCC Report, *id*.

II.1 History of Auctions

Telecommunications Act of 1996

Figure 24. William E. Kennard (D), Chairman of the FCC from Nov. 3, 1997 to Jan. 19, 2001

FCC, Commissioners from 1934 to Present, https://www.fcc.gov/commissioners-1934-present; William Powell, Wikipedia, https://en.wikipedia.org/wiki/William_Kennard.

II.1 History of Auctions

Telecommunications Act of 1996

Figure 25. Michael K. Powell (R), Commissioner of the FCC from Nov. 3, 1997 to Mar. 17, 2005, and Chairman of the FCC from Jan. 22, 2001 to Mar. 15, 2005
FCC, Commissioners from 1934 to Present, https://www.fcc.gov/commissioners-1934-present; Michael Powell, Wikipedia, https://en.wikipedia.org/wiki/Michael_Powell_(lobbyist).

II.1 History of Auctions

Auction Results

Auction	Name	Net Winning Bids	Licenses Auctioned	Licenses Won	Rounds	Dates
107	3.7 GHz Service	$81,114,481,921	5,684	5,684	97	12/8/2020 - 2/17/2021
97	AWS-3	$41,329,673,325	1,614	1,611	341	11/13/2014 - 1/29/2015
110	3.45 GHz Service	$22,418,284,236	4,060	4,041	151	10/5/2021 - 1/4/2022
1002	600 MHz Band	$19,318,157,706	2,912	2,776	58	8/16/2016 - 3/30/2017
73	700 MHz Band	$18,957,582,150	1,099	1,090	261	1/24/2008 - 3/18/2008
35	C and F Block PCS	$16,857,046,150	422	422	101	12/12/2000 - 1/26/2001
66	AWS-1	$13,700,267,150	1,122	1,087	161	8/9/2006 - 9/18/2006
5	Broadband PCS C Block	$10,071,708,842	493	493	184	12/18/1995 - 5/6/1996
103	Upper 37, 39, 47 GHz	$7,558,703,201	14,144	14,142	104	12/10/2019 - 3/5/2020
4	Br PCS A and B Block	$7,019,403,797	99	99	112	12/5/1994 - 3/13/1995
105	3.5 GHz Band	$4,543,232,339	22,631	20,625	76	7/23/2020 - 8/25/2020
11	Br PCS D, E, & F Block	$2,517,439,565	1,479	1,472	276	8/26/1996 - 1/14/1997
58	Broadband PCS	$2,043,230,450	242	217	91	1/26/2005 - 2/15/2005
102	Sp Frontiers – 24 GHz	$2,022,676,752	2,909	2,904	91	3/14/2019 - 5/28/2019

Table 1. Completed Spectrum Auctions above $100M Net Winning Bids
Source: FCC, Auctions Summary
FCC, Auctions Summary, https://www.fcc.gov/auctions-summary.

II.1 History of Auctions

Auction Results

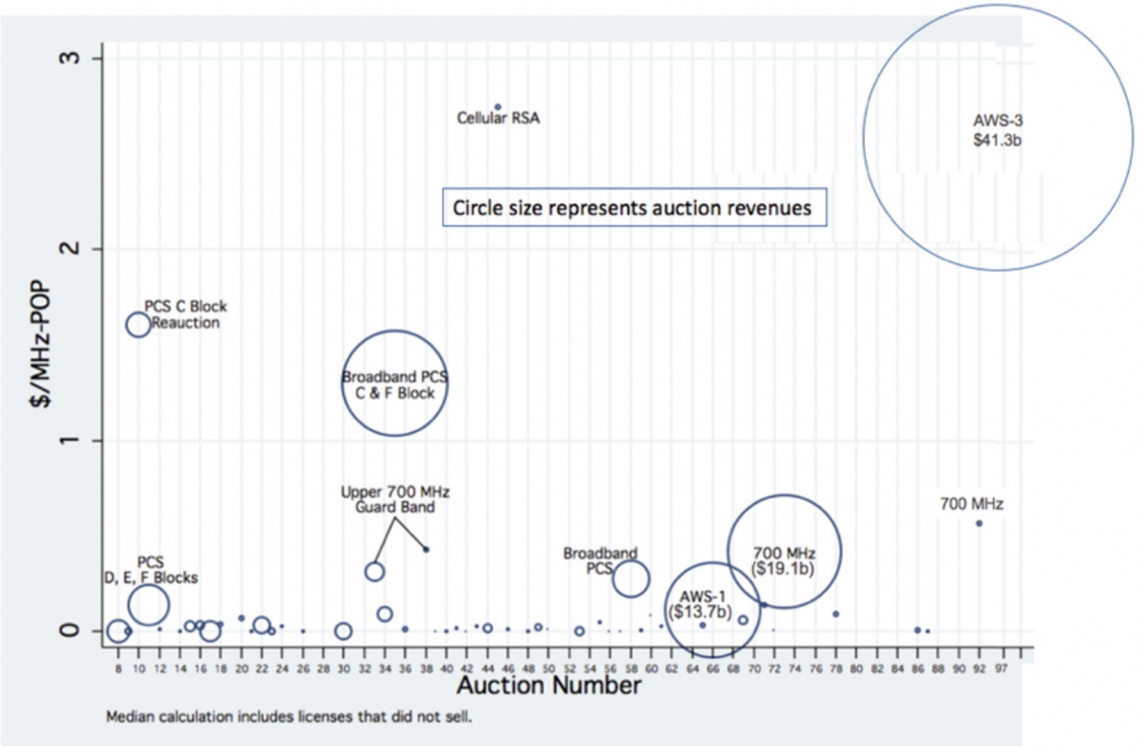


Figure 26. Early Auctions Compared to AWS-3 in Auction 97

Scott Wallsten, "Don't Be Disappointed by the FCC's Incentive Auction," Technology Policy Institute, Jan. 17, 2017, https://techpolicyinstitute.org/publications/miscellaneous/the-fccs-incentive-auction-is-not-a-disappointment/.

II.1 History of Auctions

Auction Process

Box 1: Combinatorial Bidding

Combinatorial bidding, also known as "package bidding," allows bidders to place single bids for groups of licenses. For example, in one type of combinatorial auction, bidder A could place a bid of $100,000 for licenses 1, 2 and 4, while bidder B places a bid of $500,000 for licenses 2, 3 and 5. The computer system then calculates the revenue maximizing solution and awards the high bids for that round to the appropriate package(s).

Combinatorial bidding has advantages over other auction designs when there are strong synergies among items being auctioned and strong and divergent preferences among bidders. In the FCC auctions, strong synergies exist when licenses are worth more to some bidders as a package than individually. Strong and divergent preferences occur, for example, when a large company's business plan is not viable unless it is awarded a nationwide service area, whereas smaller users may desire the same spectrum for local service and need only a smaller service area.

Figure 29. Combinatorial Bidding or "Package Bidding"
1997 FCC Report at 4.

II.1 History of Auctions

Auction Process

Box 5:
Some Procedural & Policy Rules for the Simultaneous Multiple-Round Auction

Upfront Payment: Upfront payments ensure that a bidder is sincere and financially prepared to win a license. It provides a bidder sufficient eligibility to bid upon licenses and entitles the bidder to a certain number of bidding units. These units determine a bidder's eligibility to bid on licenses in the auction, round by round. The upfront payment is not attributed to specific licenses, but instead, defines the maximum number of bidding units on which the bidder is permitted to bid in any single round. At the close of the auction, the Commission applies the upfront payment towards the winning bid amount, or other payments in the event of withdrawal or default. If a bidder does not win any licenses and has no withdrawal payments, then the upfront payment will be refunded.

Figure 31. Rules for Simultaneous Multiple-Round Auctions
1997 FCC Report at 20.

II.1 History of Auctions

Auction Bidding

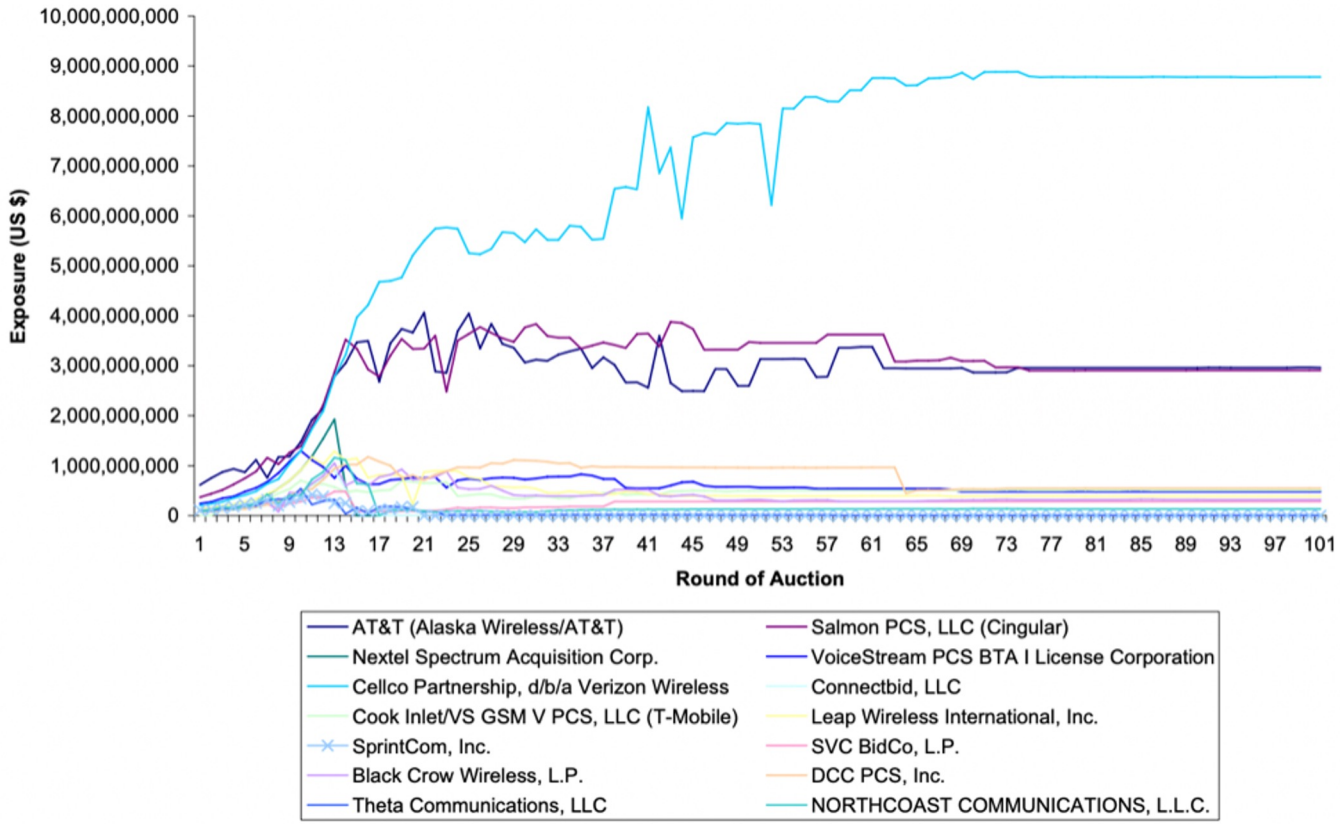


Figure 32. Bidder Exposure in Auction 35 (Bulow, et al., 2009)
Bulow et al., Winning Play, supra note 87, at 34, fig. 5a.

II.1 History of Auctions

Auction Bidding

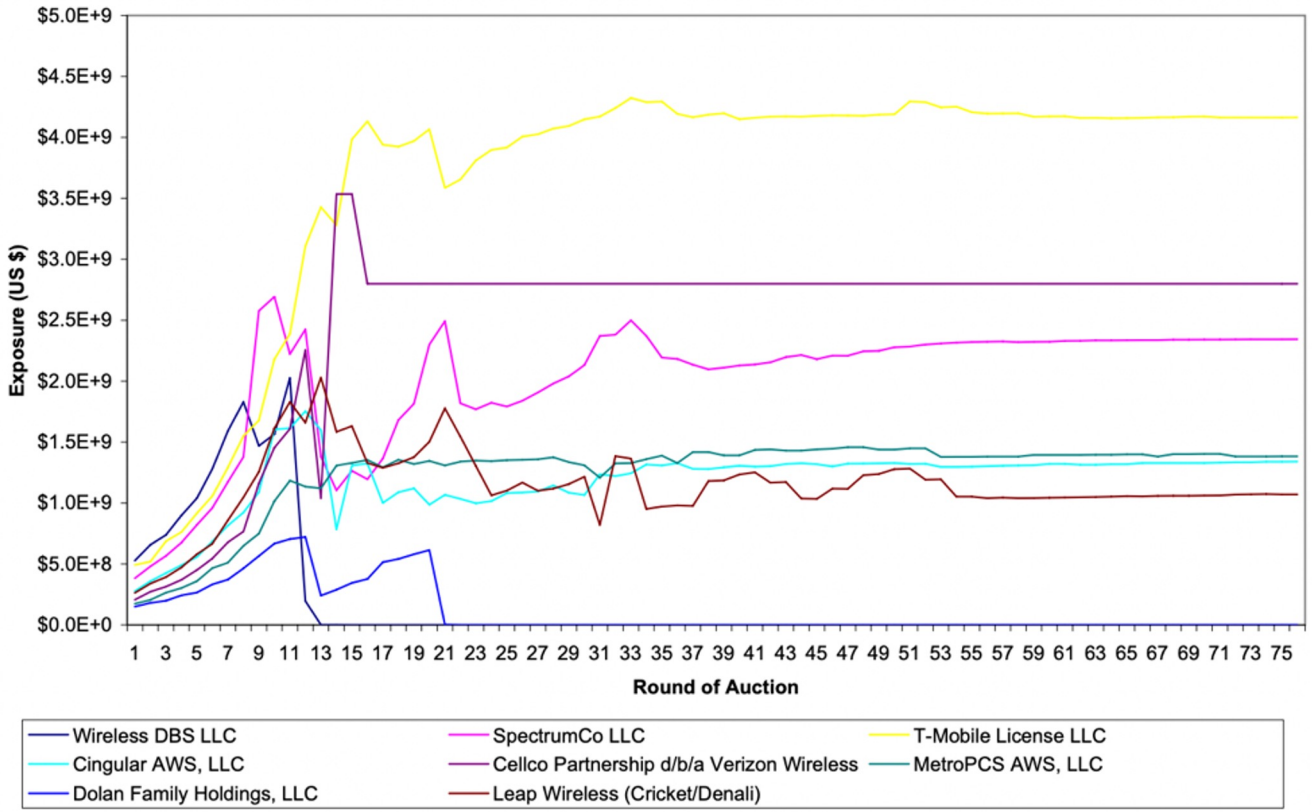
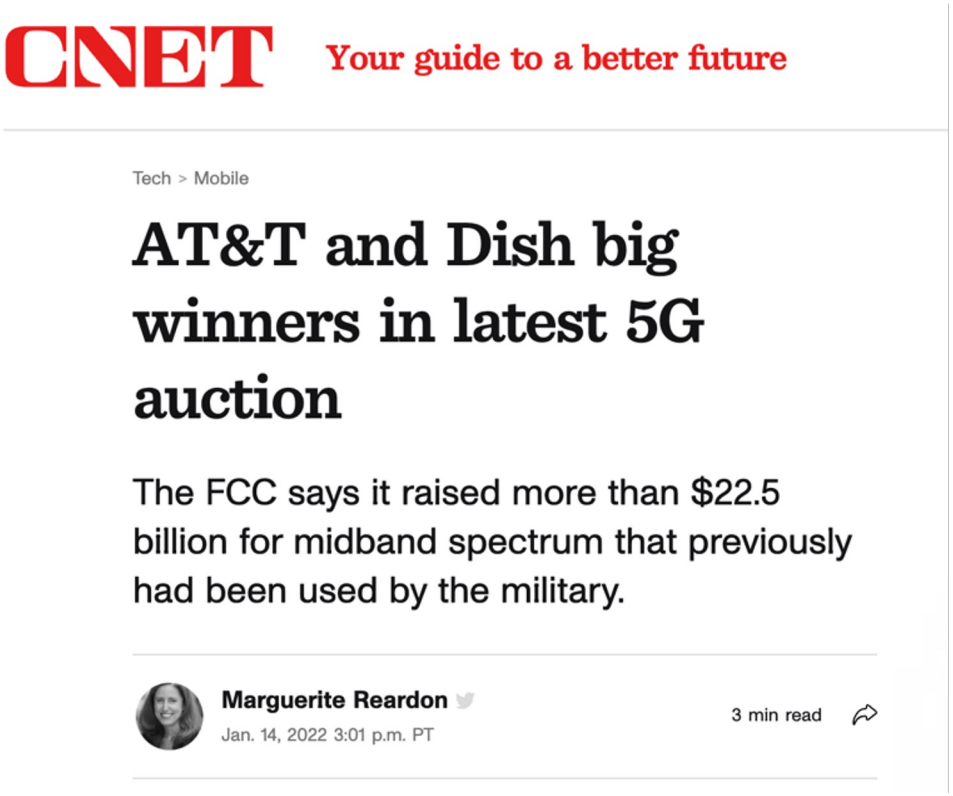


Figure 33. Bidder Exposure in Auction 66 (Bulow et al., 2009)
Bulow et al., Winning Play, supra note 87, at 34, fig. 5b.

II.1 History of Auctions

Recent Auctions



CNET Your guide to a better future

Tech > Mobile

AT&T and Dish big winners in latest 5G auction

The FCC says it raised more than $22.5 billion for midband spectrum that previously had been used by the military.

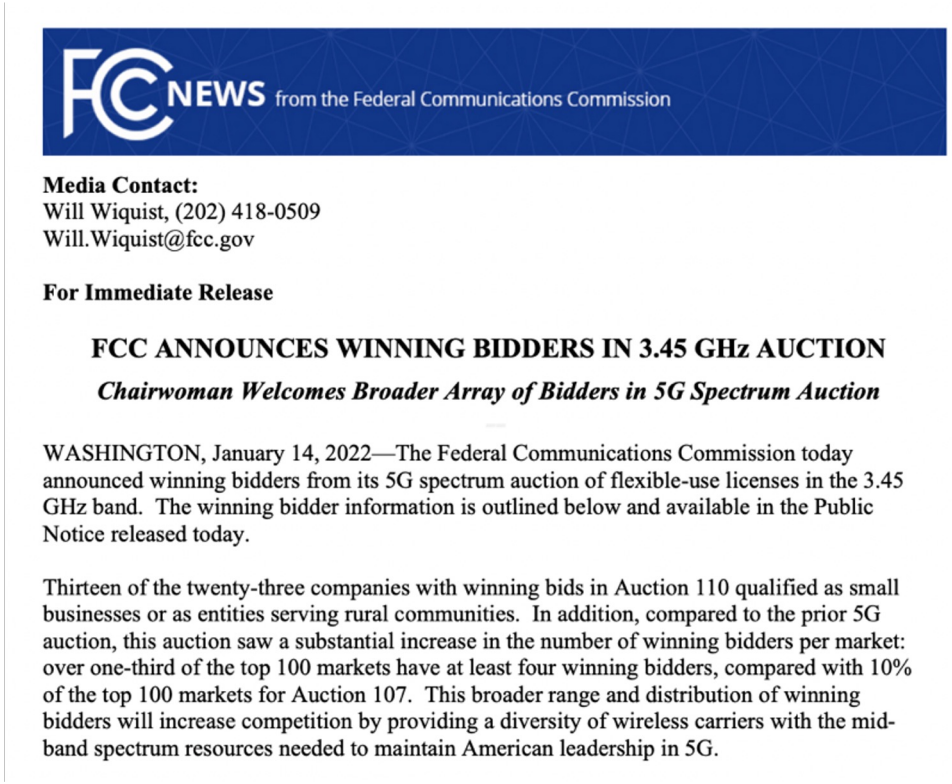
Marguerite Reardon
Jan. 14, 2022 3:01 p.m. PT

3 min read

Figure 34. Headline on Auction 110 Winners Marguerite Reardon, "AT&T and Dish Big Winners in Latest 5G Auction," CNET, Jan. 14, 2022, https://www.cnet.com/tech/mobile/at-t-and-dish-big-winners-in-latest-5g-auction/.

II.1 History of Auctions

Recent Auctions



FCC NEWS from the Federal Communications Commission

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Will.Wiquist@fcc.gov

For Immediate Release

FCC ANNOUNCES WINNING BIDDERS IN 3.45 GHz AUCTION

Chairwoman Welcomes Broader Array of Bidders in 5G Spectrum Auction

WASHINGTON, January 14, 2022—The Federal Communications Commission today announced winning bidders from its 5G spectrum auction of flexible-use licenses in the 3.45 GHz band. The winning bidder information is outlined below and available in the Public Notice released today.

Thirteen of the twenty-three companies with winning bids in Auction 110 qualified as small businesses or as entities serving rural communities. In addition, compared to the prior 5G auction, this auction saw a substantial increase in the number of winning bidders per market: over one-third of the top 100 markets have at least four winning bidders, compared with 10% of the top 100 markets for Auction 107. This broader range and distribution of winning bidders will increase competition by providing a diversity of wireless carriers with the mid-band spectrum resources needed to maintain American leadership in 5G.

Figure 35. Winning Bidders in 3.45 GHz Auction 110
FCC, "FCC Announces Winning Bidders in 3.45 GHz Auction,"
https://www.fcc.gov/document/fcc-announces-winning-bidders-345-ghz-auction.

II.1 History of Auctions

Recent Auctions

The five bidders with the largest total gross winning bid amounts from both the clock and assignments phases were as follows:

Bidder	Total Gross Winning Bids
AT&T Auction Holdings, LLC	$9,079,177,491
Weminuche L.L.C.	$7,327,989,290
T-Mobile License LLC	$2,898,418,995
Three Forty-Five Spectrum, LLC	$1,379,489,483
United States Cellular Corp.	$579,646,526

The five bidders winning the largest number of licenses were as follows:

Bidder	Number of Licenses Won
AT&T Auction Holdings, LLC	1,624
Weminuche L.L.C.	1,232
United States Cellular Corp.	380
Cherry Wireless, LLC	319
T-Mobile License LLC	199

Figure 36. Winning Bidders in 3.45 GHz Auction 110
FCC, "FCC Announces Winning Bidders in 3.45 GHz Auction,"
https://www.fcc.gov/document/fcc-announces-winning-bidders-345-ghz-auction.

II.2 Spectrum Valuation Methods

Indefinitely Lived Intangible Assets

1. Market approach, or "M&A" approach
2. Income approach, or "Greenfield" approach

II.2 Spectrum Valuation Methods

Spectrum Holdings of Publicly Traded Companies

U.S. Wireless Licenses

The fair value of U.S. wireless licenses is assessed using a discounted cash flow model (the Greenfield Approach) and a qualitative collaborative market approach based on auction prices, depending upon auction activity. The Greenfield Approach assumes a company initially owns only the wireless licenses and makes investments required to build an operation comparable to current use. These licenses are tested annually for impairment on an aggregated basis, consistent with their use on a national scope for the United States. For impairment testing, we assume subscriber and revenue growth will trend up to projected levels, with a long-term growth rate reflecting expected long-term inflation trends. We assume churn rates will initially exceed our current experience but decline to rates that are in line with industry-leading churn. We used a discount rate of 9.25%, based on the optimal long-term capital structure of a market participant and its associated cost of debt and equity for the licenses, to calculate the present value of the projected cash flows. If either the projected rate of long-term growth of cash flows or revenues declined by 0.5%, or if the discount rate increased by 0.5%, the fair values of these wireless licenses would still be higher than the book value of the licenses. The fair value of these wireless licenses exceeded their book values by more than 10%.

Figure 37. Description of Impairment Testing of AT&T Wireless Licenses
AT&T 2021 Annual Report, at 27.

II.2 Spectrum Valuation Methods

Spectrum Holdings of Publicly Traded Companies

Consolidated Balance Sheets
Dollars in millions except per share amounts

	December 31,	
	2021	2020
Assets		
Current Assets		
Cash and cash equivalents	**$ 21,169**	$ 9,740
Accounts receivable – net of related allowance for credit loss of $771 and $1,221	**17,571**	20,215
Inventories	**3,464**	3,695
Prepaid and other current assets	**17,793**	18,358
Total current assets	**59,997**	52,008
Noncurrent Inventories and Theatrical Film and Television Production Costs	**18,983**	14,752
Property, Plant and Equipment – Net	**125,904**	127,315
Goodwill	**133,223**	135,259
Licenses – Net	**113,830**	93,840
Trademarks and Trade Names – Net	**21,938**	23,297
Distribution Networks – Net	**11,942**	13,793
Other Intangible Assets – Net	**11,783**	15,386
Investments in and Advances to Equity Affiliates	**7,274**	1,780
Operating Lease Right-Of-Use Assets	**24,180**	24,714
Other Assets	**22,568**	23,617
Total Assets	**$ 551,622**	$ 525,761

Figure 38. Balance Sheet of AT&T Showing "Licenses – Net" in Spectrum Assets
AT&T 2021 Annual Report, at 48.

II.2 Spectrum Valuation Methods

Spectrum Holdings of Publicly Traded Companies

Our other intangible assets at December 31 are summarized as follows:

Other Intangible Assets	Weighted-Average Life	2021 Gross Carrying Amount	2021 Accumulated Amortization	2021 Currency Translation Adjustment	2020 Gross Carrying Amount	2020 Accumulated Amortization	2020 Currency Translation Adjustment
Amortized intangible assets:							
Wireless licenses	21.6 years	**$ 3,083**	**$ 307**	**$ (440)**	$ 2,979	$ 271	$ (421)
Orbital slots	N/A	**—**	**—**	**—**	5,825	—	—
Trademarks and trade names	38.3 years	**18,781**	**2,077**	**(7)**	20,016	1,518	(442)
Distribution network	10.0 years	**18,399**	**6,457**	**—**	18,414	4,621	—
Released television and film content	17.8 years	**10,939**	**6,978**	**—**	10,940	6,240	—
Customer lists and relationships	11.2 years	**637**	**483**	**(98)**	4,100	1,645	(460)
Other	22.3 years	**10,987**	**3,221**	**—**	11,311	2,615	(5)
Total	24.6 years	**$ 62,826**	**$ 19,523**	**$ (545)**	$ 73,585	$ 16,910	$ (1,328)
Indefinite-lived intangible assets not subject to amortization:							
Wireless licenses		**$ 111,494**			$ 85,728		
Trade names		**5,241**			5,241		
Total		**$ 116,735**			$ 90,969		

Figure 39. AT&T's Wireless Licenses Amortized and Not Subject to Amortization
AT&T 2021 Annual Report, at 70.

II.2 Spectrum Valuation Methods

Price per Mhz-Pop

Auction	Year	Name	Gross Bids	Start MHz	End MHz	Bandwidth
97	2015	AWS-3	$44,899,451,600	1695 MHz	2180 MHz	65 MHz
73	2008	700 MHz Band	$19,120,378,000	698 MHz	806 MHz	62 MHz
35	2001	PCS (A, B, C, D, E, & F Block)	$17,597,015,000	15 MHz	10 MHz	70 MHz
66	2006	AWS-1	$13,879,110,200	1710 MHz	2155 MHz	90 MHz
5	1996	PCS (A, B, C, D, E, & F Block)	$13,428,945,122	1895 MHz	1990 MHz	30 MHz
4	1995	PCS (A, B, C, D, E, & F Block)	$7,019,403,797	1850 MHz	1965 MHz	30 MHz
11	1997	PCS (A, B, C, D, E, & F Block)	$2,715,885,604	1865 MHz	1975 MHz	30 MHz
58	2005	PCS (A, B, C, D, E, & F Block)	$2,253,802,000	1850 MHz	1975 MHz	30 MHz
96	2014	H Block	$1,564,000,000	1915 MHz	2000 MHz	10 MHz
10	1996	PCS (A, B, C, D, E, & F Block)	$904,607,467	1895 MHz	1990 MHz	30 MHz
17	1998	LMDS	$834,177,095	27,500 MHz	31,300 MHz	1300 MHz
1	1994	Narrowband PCS	$650,306,674	901 MHz	941 MHz	0.7875 MHz
33	2000	Upper 700 MHz & Guard Bands	$545,885,000	746 MHz	794 MHz	6 MHz
22	1999	PCS (A, B, C, D, E, & F Block)	$532,970,215	1895 MHz	1975 MHz	55 MHz
3	1994	Narrowband PCS	$488,772,800	901 MHz	941 MHz	450 kHz
30	2000	39 GHz	$467,214,200	38.6 GHz	40.0 GHz	1400 MHz
34	2000	SMR 800 MHz	$337,494,900	806.0125 MHz	854.7375 MHz	10 MHz
2	1994	218-219 MHz (Formerly IVDS)	$248,743,000	218 MHz	219 MHz	1 MHz
6	1996	MDS	$239,729,992	2150 MHz	2680 MHz	78 MHz

Table 2. Bandwidths Auctioned (pre-2015)

Source: FCC, Available Band Plans, https://www.fcc.gov/economics-analytics/auctions-division/auctions/band-plans.

II.2 Spectrum Valuation Methods

Valuation Estimates: Federal Inventory

Bill	Title	Congress	Introduced	Co-Sponsors
S.4117	Spectrum Innovation Act of 2022[122]	117th Congress (2021-2022)	April 28, 2022	Sen. Ben Lujan, Sen. John Thune, Sen. Marsha Blackburn
S.553	Government Spectrum Valuation Act[123]	117th Congress (2021-2022)	March 3, 2021	Sen. Mike Lee
S.3717, S.1605, P.L. 117-81	Spectrum IT Modernization Act of 2020,[124] included in National Defense Authorization Act for Fiscal Year 2022[125]	116th Congress (2019-2020)	May 13, 2020	Sen. Roger Wicker, Sen. Maria Cantwell, Sen. James Inhofe, Sen. Jack Reed
S.1626	Government Spectrum Valuation Act[126]	116th Congress (2019-2020)	May 22, 2019	Sen. Mike Lee, Sen. Ted Cruz
P.L. 1625	Mobile Now Act,[127] included in the Consolidated Appropriations Act of 2018	115th Congress (2017-2018)	Jan. 3, 2017	Sen. John Thune, Sen. Bill Nelson
S.2211	Spectrum Relocation Fund Act of 2015[128]	114th Congress (2015-2016)	Oct. 27, 2015	Sen. Jerry Moran, Sen. Tom Udall
P.L. 114-74	Spectrum Pipeline Act of 2015, included in the Bipartisan Budget Act of 2015[129]	114th Congress (2015-2016)	March 4, 2015	Rep. Patrick Meehan, Rep. Peter Roskam, Rep. Tom Reed
S.3433	Radio Spectrum Inventory Act of 2012[130]	112th Congress (2011-2012)	July 25, 2012	Sen. Olympia Snowe, Sen. Mark Warner
P.L. 112-96	Middle Class Tax Relief and Job Creation Act of 2012[131]	112th Congress (2011-2012)	Dec. 9, 2011	Rep. Dave Camp, Rep. Spencer Bachus, Rep.

Table 3. Proposed Legislation Related to Federal Spectrum

II.3 Spectrum Valuation Factors

Factors

1. Frequency
2. Paired vs. Unpaired
3. Encumbered vs. Unencumbered
4. International Harmonization
5. Licensed vs. Unlicensed
6. Non-Market Values

II.3 Spectrum Valuation Factors

Factors

What drives the value of a spectrum license, as observed in auction transactions and secondary market sales? Is it the size of the band, the use of the band, the market location, the band plan, or the frequency of the band? Economists have studied data from transactions in the United States and globally. Some of the hypotheses lack counterfactual data, but policymakers generally agree on certain observations from the market.

Frequency

Mobile devices that generate the most economic value and commercial revenue are deployed on certain frequencies that have favorable propagation characteristics. The particular frequency of a spectrum license thus drives the value of the spectrum because of the valuable uses that are deployed on those airwaves.

Paired vs. Unpaired

Aside from the frequency of the band, the structure of the band plan also can facilitate certain technologies and uses. Mobile devices with two-way communications have been designed to transmit signals on paired bands "by diminishing interference from incompatible adjacent operations."

In the AWS-3 auction, the FCC asked the public for comment on how to design the band plan for 1675 MHz-1710 MHz band with a focus on the 15 or 20 MHz in the upper portion of the band, from 1690 MHz-1710 MHz and 1695 MHz-1710 MHz.

II.3 Spectrum Valuation Factors

Factors

Encumbered vs. Unencumbered

Uncertainty in whether to expect interference or not through encumbrances can lower the desirability of spectrum licenses for commercial operations.

International Harmonization

Spectrum bands are more valuable if global standards are aligned with certain technologies on those bands. Hardware devices are manufactured at scale to serve a larger user base with network effects.

Licensed vs. Unlicensed

Exclusive use or unlicensed shared use are two types of spectrum license rules. The FCC decides whether to deem a particular band eligible for licensed or unlicensed use. What was written in 2009 is still true today, "[a]t present, no existing market mechanism allows for the trading of radio spectrum between licensed and unlicensed uses. Whenever spectrum is made available for reallocation, the FCC faces a dilemma in determining which access regime to use." There are tradeoffs, however, in using a particular band for licensed or unlicensed use.

II.3 Spectrum Valuation Factors

Factors

Licensed vs. Unlicensed

Regulators are currently "attempting to guess how much bandwidth should be allocated to various types of licensed and unlicensed services – and imposing different rules within and across these allocations," but some scholars have been calling for a more systematic, market-based way of deciding these allocation tradeoffs.

It's undisputed that unlicensed spectrum, particularly the bands under Part 15 rules, generates enormous economic value through Wi-Fi technologies. However, the lesson from Wi-Fi often does not translate to other unlicensed bands. Moreover, the relevant comparison for policymakers is how much more or less value could be achieved from market-driven demand for flexible exclusive use licenses, which, used by nationwide networks, generates consumer and producer surplus in the trillions of dollars.

Non-Market Values

National security and other values influence the way that spectrum allocations are weighted against each other. The Department of Defense has the most influence in radio spectrum policy due to its large wireless operations and national security mandate. These non-market values predominate in politics and may be at odds with economic efficiency in some cases. The DoD Electromagnetic Spectrum Superiority Strategy is one of several defense initiatives that contribute to a national spectrum strategy that affects other federal agencies.

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Spectrum Economics and Market Tools

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    2. Local Governance

VI. Conclusion

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