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Increasing Spectrum for Broadband: What Are The Options?

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Executive Summary

The growth of wireless broadband is a bright spot in the U.S. economy, but a shortage of flexibly licensed spectrum rights could put a crimp on this expansion. Freeing up spectrum from other uses would allow greater expansion of wireless broadband and would bring substantial gains—likely in the hundreds of billions of dollars—for U.S. consumers, businesses, and the federal treasury.

Despite significant progress toward a more market-based approach to the allocation of spectrum, much of the most valuable spectrum is either unavailable to the private sector or is locked into inefficient uses under FCC license terms. The latter group includes allocations to broadcast TV and mobile satellite services (MSS)—airwaves that are held by private firms but are tied to uses that would likely give way to broadband if service requirements were lifted and licenses were made flexible. An even greater number of bands are unavailable to the market because they are occupied by the federal government.

Failure to allocate sufficient spectrum to a market-based regime entails large costs:

- The development of a vibrant wireless broadband platform capable of competing with wireline platforms will be impeded.
- Broadband prices will be higher and penetration lower; the economic and social benefits of greater broadband penetration will be forgone.
- Prices for wireless services in general will be higher.
- New services will become available later or not at all.
- Hundreds of billions of dollars worth of consumer surplus will be lost.
- Tens of billions of dollars in auction revenues for the federal government will be forgone.

U.S. experience suggests that it takes at least six years, and possibly over a decade, to complete any large-scale reallocation of spectrum. Thus, for policymakers, the "projected" need is actually here today. This paper makes three proposals to increase spectrum available for wireless broadband under a flexibly licensed, market-based regime.

Federal Government Spectrum

Potentially the largest source of additional spectrum is made up of excess capacity within the more than 1500 MHz reserved by the U.S. federal government for agency use. We offer both short-term and long-term recommendations for freeing up spectrum from these bands.

In the short run, we recommend:

- The National Academy of Sciences (NAS) should undertake a study to determine the current opportunity costs of various spectrum bands and identify likely sources of surplus spectrum that could be reallocated to better uses.
- Utilizing the results of the NAS study, a high-level Government Spectrum Reform Task Force, consisting of government officials and private-sector experts, should recommend a

package of spectrum bands that could be vacated by government users and auctioned by the FCC.
- The Office of Management and Budget (OMB) should subsequently become a skeptical auditor of government-held spectrum, its uses, and its opportunity costs.

For the longer run, we propose a market mechanism that is based on the model of the U.S. Government Services Administration (GSA), which the federal government uses for most of its real estate needs:

- We propose the creation of a Government Spectrum Ownership Corporation (GSOC) that would become the owner of all government spectrum and would lease it to government users at market rates. Government agencies should pay rental fees that approximate the opportunity costs of the GSOC's spectrum holdings—much in the same way that agencies pay rent for their use of the GSA's buildings. The GSOC could sell (or rent) surplus spectrum to the private sector, and purchase additional spectrum as needed.

Broadcast TV Spectrum

We advocate transitioning the remaining broadcast television bands from their present allocation. The key to recovering these 294 MHz is to devise a mechanism that produces net benefits for all interested parties: the broadcasters, over-the-air broadcast viewers, consumers of wireless broadband services, and the federal treasury. We recommend:

- Broadcast licensees should be granted flexibility in terms of uses to which their spectrum could be put and their ability to transfer those rights.
- The overlay (i.e., the "white spaces" between channels) rights should be auctioned. The auction winners could then negotiate with the incumbent licensees in order to complete the restructuring. Incumbent broadcast licensees could be permitted to participate in the government auction.
- The interests of over-the-air viewers should be protected by subsidizing the transition of the remaining over-the-air viewers to subscription TV using a portion of the auction revenues.

A similar result could be attained by mandatory clearing of the broadcast spectrum, but the recommended approach gives broadcasters greater flexibility.

Mobile Satellite Service

Finally, we propose transferring the 154 MHz of Mobile Satellite Service (MSS)—"satellite phone"—spectrum to a liberally licensed, market-based regime. These bands cannot currently be utilized efficiently, even with the recent changes that provide MSS licensees some added flexibility. The spectrum should either be auctioned, with adequate compensation for incumbent licensees (and first-refusal rights for their spectrum), or the licenses made more flexible with the incumbents sharing their windfall gain with the taxpayer.

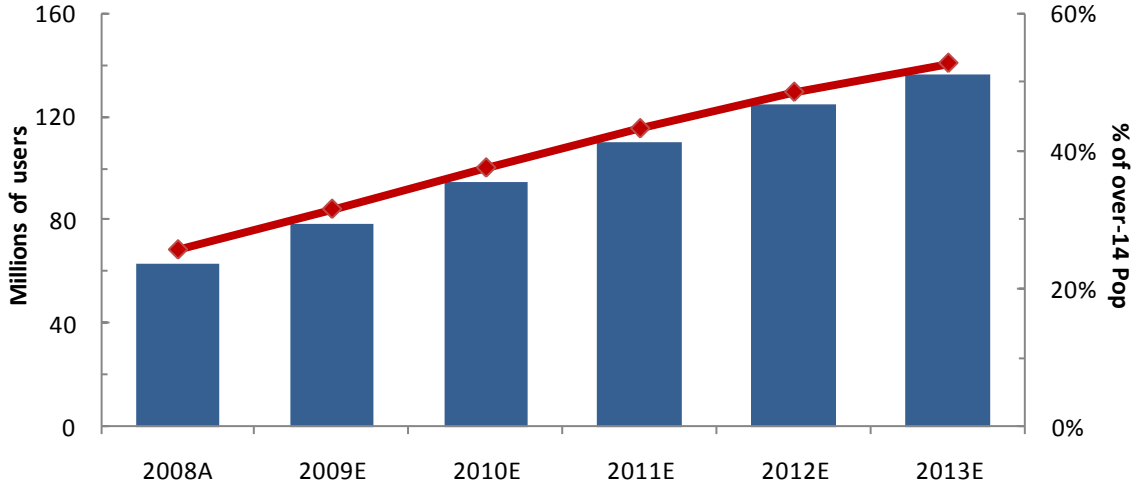
I. Introduction

A. The Mobile Internet Explosion

Mobile wireless is playing an increasingly important role in improving broadband availability and penetration in the United States. According to the Federal Communications Commission (FCC), the number of mobile wireless "advanced service lines," defined as having at least 200 kbps upstream and downstream speeds, passed 20 million in June 2008, up from 1.9 million in 2006.[1] Connections with at least 200 kbps in only one direction totaled almost 60 million in 2008, or 46 percent of high-speed lines across all platforms.[2] The most recent consensus estimates counted 78.7 million wireless broadband users (see Figure 1).[3] That number is expected to grow to over 136 million—more than half of all Americans aged 14 and over—by 2013.[4]

Figure 1

U.S. Wireless Broadband Users (bar) and Penetration (line) Forecast



Source: Atkinson and Schultz (2009), Figure 18.

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[1] FCC, "High Speed Services for Internet Access: Status as of June 30, 2008," available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-292191A1.pdf; Table 2.

[2] *Ibid*, Table 1. The number of mobile wireless subscriptions relative to total high-speed lines across all platforms may overstate the relative number of individual users because mobile subscriptions are generally used by individuals, whereas wireline connections can be used by an entire household or business. Nevertheless, it is clear that this "third pipe" is already significant—especially given that these data are already over a year and a half old.

[3] See Atkinson and Schultz (2009), pp. 59-60. Figure 1 reports 63.1 million wireless broadband users in 2008, which is higher than the FCC's count of 59.7 million. The difference may be explained by the fact that the FCC data are for June, whereas these authors likely report year-end estimates.

[4] This is an average of industry estimates, which appear to be based on the spectrum that is currently available for wireless broadband and in the pipeline. See discussion in Section II.

A large literature documents the broader economic and social benefits of greater broadband penetration.[5] Studies have shown that increased broadband penetration increases economic growth, productivity, and employment. It improves our ability to address national challenges in energy, the environment, health care, and other priority areas. In order for wireless to fulfill its promise in this market, additional spectrum must be made commercially available.

The dramatic growth of mobile Internet access is placing unprecedented pressure on wireless networks. At the end of 2009, so-called smartphones were in the hands of 17 percent of U.S. wireless subscribers, up from seven percent two years earlier.[6] Users of these devices on average consume far more data than do traditional cellular subscribers—30 times the amount, according to a Cisco Systems estimate.[7] Mobile data card users, who access cellular networks on their laptops, and are even more voracious consumers of bandwidth, comprised five percent of subscribers in mid-2008.[8] Over half of their devices had been acquired in the preceding twelve months. Drawing from trends like these, Cisco projects that North American mobile data traffic will rise from 40,808 terabytes (TB) in 2010 to 397,265 TB in 2013—an almost 900 percent increase.[9] These demands on networks are reflected in network operators' sizable bids for licenses in recent years and in statements indicating demand for even more radio spectrum.

Spectrum is a critical input to the "last mile" of any wireless network and is considered the "lifeblood of every mobile operator."[10] Failure to allocate sufficient spectrum to wireless broadband will entail large costs:

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[5] For example: Czernich et al. (2009) find that a 10-percent increase in broadband penetration increases per-capita GDP growth by 0.9-1.5 percentage points. Greenstein and McDevitt (2009) attribute up to $10.6 billion of 2006 GDP to broadband revenue created since 1999, resulting in up to $6.7 billion in additional consumer surplus. Dutz et al. (2009) estimate the net consumer benefits from home broadband at $32 billion per year. All of these authors study fixed line (wired) connections only. Fixed wireless broadband likely conveys similar economic benefits. Mobile broadband is less studied but we expect effects similar to those observed with these technologies. Most analysts see mobile broadband as both a complement to and a substitute for both fixed line broadband and mobile voice service.

[6] Forrester Research blog post at http://blogs.forrester.com/consumer_product_strategy/2010/01/2009-year-of-the-smartphone-kinda.html

[7] Cisco Systems, "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update," January 29, 2009; available at http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf, p. 3 ("Cisco Systems")

[8] Penetration computed from 13 million data card users in Q2 2008 (http://www.marketresearchworld.net/index.php?option=com_content&task=view&id=2238&Itemid=77); out of 262.7 million wireless subscribers in June 2008 (http://files.ctia.org/pdf/CTIA_Survey_Midyear_2009_Graphics.pdf, slide 4).

[9] Cisco Systems, Table 1.

[10] Motorola eZine, October 2008, available at http://www.motorola.com/staticfiles/Business/Solutions/Industry%20Solutions/Service%20Providers/Network%20Operators/LTE/_Document/Static%20Files/LTE%27s%20Spectrum%20of%20Opportunity.pdf?localeId=33

- The development of a vibrant wireless broadband platform capable of competing with wireline platforms will be impeded.
- Broadband prices will be higher and penetration lower; the economic and social benefits of greater broadband penetration will be forgone.
- Prices for wireless services in general will be higher.
- New services will become available later or not at all.
- Hundreds of billions of dollars worth of consumer surplus will be lost.
- Tens of billions of dollars in auction revenues for the federal government will be forgone.

For spectrum to produce the value that it is capable of yielding, much more of it must be made available under a licensed, market-based regime. As a recent paper by a diverse group of scholars concludes: "Although one can identify a number of reasons why a market-based system will not function perfectly…there is no serious contender for a system that can be expected to perform as well or better." (Lenard, White et al., 2006, p. 3). For providers to make the large investments necessary for new wireless broadband services, they will need licenses that give them secure quasi-property rights to the spectrum.[11]

Claims of a shortage of suitable spectrum are supported by a well-known International Telecommunications Union (ITU) study. The ITU estimates that mobile voice and broadband in a high-demand country like the United States could require approximately 840 MHz of bandwidth in 2010, growing to 1.3 GHz in 2015 and 1.7 GHz in 2020.[12] As our discussion in Section II below shows, estimates of what is available or expected under current policies fall far short of those requirements.

Yet another indication of spectrum shortage can be inferred from calculations by WCAI (the trade association of the wireless broadband industry), which show that providers could each require "150 MHz or more of licensed spectrum to adequately meet consumer needs" using 4G (fourth generation) technology.[13] In the top 100 American markets, AT&T and Verizon average

[11] See, e.g., "Comments of MetroPCS Communications Inc," GN Docket No. 09-51, p. 43. ("MetroPCS and others naturally are reluctant to incur the substantial investments in network infrastructure, customer acquisition costs, and constructing the necessary customer service infrastructure in circumstances where they do not have assured exclusive use of an identifiable spectrum resource. A licensee using nonexclusive spectrum has no way of knowing or accurately predicting the level and extent of use by other co-licensees. Thus, it is impossible for a network operator to predict the capacity it will enjoy on its constructed network or the revenues it will earn. Uncertainty of this nature deters investment because it increases risks"); available at http://fjallfoss.fcc.gov/ecfs/document/view?id=7020039899

[12] More specifically, the ITU describes spectrum below 5 GHz allocated for IMT-Advanced (4G, i.e., LTE and WiMax), IMT-2000 (3G), and older systems.

[13] WCAI, "Comments on Commercial Mobile Radio Services Market Competition," WT Docket No. 09-66; available at http://www.wcai.com/images/pdf/2009_fcc06-15.pdf, p. 10-11.

91 MHz each, and Sprint Nextel and T-Mobile each hold 53 and 54 MHz, respectively.[14] Thus, the WCAI analysis indicates that the four major carriers would need an additional 310 MHz to keep up with demands within the lifecycle of 4G.[15] Second-tier cellular carriers have similar requirements.[16]

U.S. experience suggests that it takes at least six years, and possibly over a decade, to complete any large-scale reallocation of spectrum. Thus, for policymakers, the "projected" need is actually here today. The United States is on track to meet less than half of the allocation that will likely be needed over the next five years. Developing a plan to increase the amount of spectrum available for wireless broadband is a high priority of the FCC's Broadband Task Force,[17] which is developing a national broadband plan. Even if the ITU numbers are only roughly correct, the costs of inaction—inferior service and product offerings and higher prices, adding up to perhaps hundreds of billions of dollars of lost consumer welfare—are enormous.

B. The Search for More Spectrum

Despite substantial progress toward a more market-based approach to allocation, much of the most valuable spectrum is either unavailable to the private sector or is locked into inefficient uses under FCC license terms.[18] The latter group includes allocations to broadcast TV and mobile satellite services (MSS): airwaves that are held by private firms but tied to uses that would give way to broadband if service requirements were lifted and licenses were made flexible. An even greater number of bands are unavailable to the market because they are occupied by the federal government.

"Command-and-control" regimes like these—which govern an estimated 75 percent of the radio spectrum—are the only source of more spectrum for wireless broadband. All three of the categories that we consider (federal government, TV, and MSS) occupy capacity that could be

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[14] Morgan Stanley *The Mobile Internet Report Key Themes*, December 15, 2009, slide 541; available at http://www.scribd.com/doc/24128777/The-Mobile-Internet-Report-Key-Themes

[15] This analysis assumes the firms will tend toward license endowments of equal magnitude, which seems appropriate given technological pressures, as well as the continued viability of other relevant spectrum holders, so that much of the deficit cannot be covered by buying licenses from other firms. The 53 MHz reported for Sprint Nextel ignores the company's stake in Clearwire, which holds as much as 150 MHz of microwave spectrum in many markets. See Section II on current allocations.

[16] See, e.g., "Comments of MetroPCS Communications, Inc." on NBP Public Notice #6 (Comment Sought on Spectrum for Broadband), p. 4; available at http://fjallfoss.fcc.gov/ecfs/document/view?id=7020143270

[17] We refer to the "Broadband Task Force" (BTF) in the text; however, their project is formally titled the "Omnibus Broadband Initiative" (OBI). Data from the September presentation is cited as such below.

[18] We document later in this report that some spectrum, although allocated to the market, is underutilized due to band-specific issues.

reallocated to the market. Reallocating broadband from these categories presents substantial practical and political difficulties. This paper suggests ways of dealing with those difficulties.

The federal government has reserved well over 1500 MHz of the most valuable spectrum for government agency use, thus keeping that spectrum off the market. So long as spectrum is a "free" resource to a government agency, in the sense that the agency neither pays to keep its rights nor can (net) gain from selling them, the agency has a clear incentive to hoard under-utilized spectrum, in case that spectrum becomes more useful sometime in the future.

This paper makes two major recommendations for freeing up federal spectrum: an administrative mechanism, and a market-based mechanism. In the short run, administrative mechanisms hold greater promise than do market mechanisms in this context. But a more market-oriented strategy could yield significant benefits over the longer run.

The principal elements of the short-run recommendations for federal spectrum are:

- The National Academy of Sciences (NAS) should undertake a study to determine the current opportunity costs of various spectrum bands and identify likely sources of surplus spectrum that could be reallocated to better uses.
- Utilizing the results of the NAS study, a high-level Government Spectrum Reform Task Force, consisting of government officials and private-sector experts, should recommend a package of spectrum bands that could be vacated by government users and auctioned by the FCC.
- The Office of Management and Budget (OMB) should subsequently become a skeptical auditor of government-held spectrum, its uses, and its opportunity costs.

For the longer run, we propose a market mechanism based on the model of the U.S. Government Services Administration (GSA), which the federal government uses for most of its real estate needs. Specifically, we propose a Government Spectrum Ownership Corporation (GSOC) that would become the owner of all government spectrum and would lease it to government users at market rates. Government agencies should pay rental fees that approximate the opportunity costs of the GSOC's spectrum holdings—much in the same way that agencies pay rent for their use of the GSA's buildings. The GSOC could sell (or rent) surplus spectrum to the private sector, and purchase additional spectrum if necessary.

Although the digital television (DTV) transition freed up valuable spectrum, a much larger remainder—almost 300 MHz—continues to be used for broadcast television. The opportunity cost of using this spectrum for broadcast TV is large. If the TV bands were flexibly licensed, they could move to higher-valued uses such as wireless broadband.

The key to recovering the broadcast TV spectrum is to devise a mechanism that produces net benefits for all interested parties: the broadcasters, over-the-air broadcast viewers, consumers of wireless broadband services, and the federal treasury. We present two options for recovering the broadcast TV spectrum:[19]

- Option 1 involves (a) granting broadcast licensees immediate flexibility in terms of uses to which their spectrum could be put and their ability to transfer those rights, and (b) auctioning overlay (i.e., the "white spaces" between channels) rights. The auction winners could then negotiate with the incumbent licensees in order to complete the restructuring. Incumbent broadcast licensees could be permitted to participate in the government auction.
- Option 2 involves mandatory clearing of the broadcast spectrum, compensating the broadcasters for their licenses (in a way that makes them more than whole), and then repackaging and auctioning the full 294 MHz.

We favor Option 1, because of its more "voluntary" nature. In practice (as we explain the text), the two options would end up not being very different.

Both of the options imply that the FCC's white spaces order, which allocated the TV white spaces to unlicensed uses, should be implicitly or explicitly rescinded, since the TV white spaces would no longer exist.[20] In addition, both would require protecting the interests of over-the-air viewers. We propose that this be done by subsidizing the transition of the remaining over-the-air viewers to subscription TV. This could be done using a portion of the auction revenues and has the advantage of allowing all of the broadcast spectrum to be freed up.

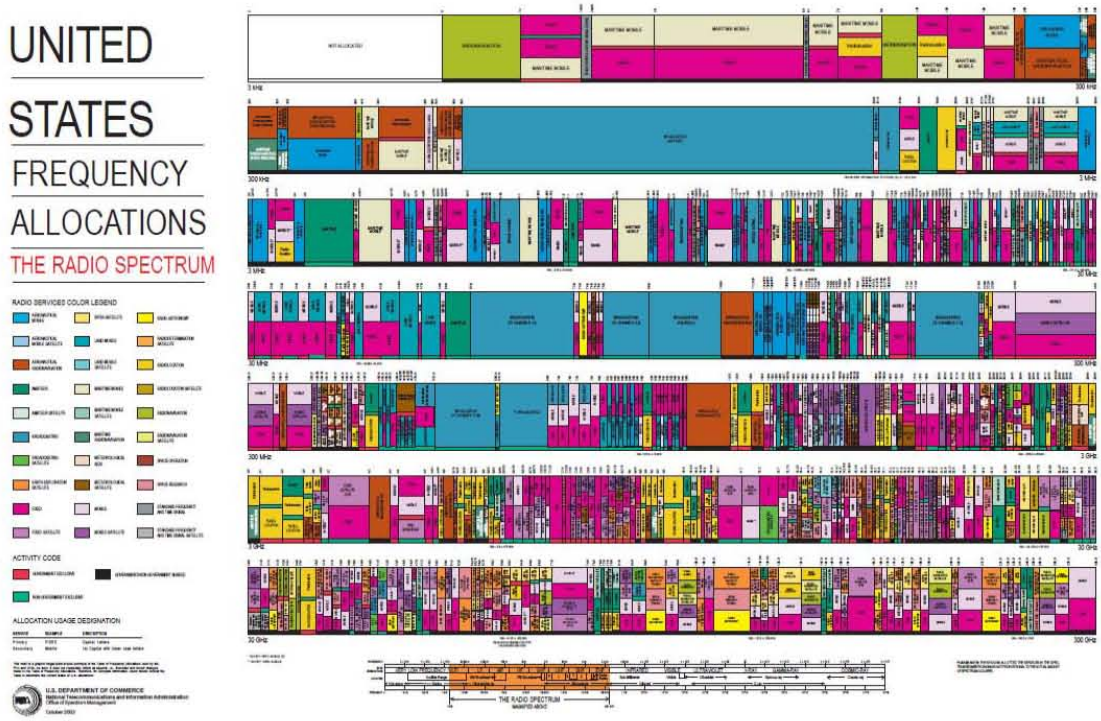
Finally, we propose transferring the MSS spectrum—154 MHz—to a liberally licensed, market-based regime. Even with the recent changes that provide MSS licensees some additional flexibility, this spectrum is not able to be utilized efficiently for wireless broadband purposes. MMS spectrum either should be auctioned, with adequate compensation for incumbent licensees (and first-refusal rights for their spectrum), or the licenses should be made more flexible with the incumbents' sharing their windfall gain with taxpayers.

[19] Based on proposals by Hazlett (2009) and Kwerel and Williams (2002).

[20] For the FCC's decision establishing these uses, see "In the Matter of 'Unlicensed Operation in the TV Broadcast Bands' and 'Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band,'" Second Report and Order and Memorandum Opinion and Order, Federal Communications Commission, November 14, 2008, http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-08-260A1.pdf

II. Current Allocations

Figure 2
The U.S. Radio Spectrum (as of 2003)



Source: NTIA

Although the radio spectrum consists of electromagnetic waves ranging from 3 kilohertz (kHz) to 300 gigahertz (GHz) in frequency (see Figure 2), a relatively small subset of this range—namely frequencies below 3 or 4 GHz—has dominated user demand and policy attention. Those waves are commercially and socially valuable because of their propagation characteristics, e.g., their ability to penetrate buildings and other solid objects. Broadcast television, mobile wireless communications, radar, certain scientific research, and other services and tools cannot operate in spectrum that is far from this low-end "sweet spot."

A. How Did We Get Here?

Before considering ways to increase the amount of spectrum devoted to wireless broadband, it is worth considering how (and why) the U.S. economy finds itself with a "shortage" of this valuable resource. This is not a market anomaly or the result of a recent market breakdown. Instead, the current situation is the result of the absence of markets for the allocation and reallocation of spectrum for over 80 years.

Starting in 1912, spectrum allocation has been guided by government mandates—in essence, by "command-and-control" government regulation. That regulation, in turn, arose as a response to the

problem of harmful interference: One person's broadcasts on a specific wavelength at a specific location at a specific time can interfere with another person's broadcast on the same or a nearby wavelength, at the same time, and at the same or a nearby location.

The federal government's response to this problem was to assign specific "parcels" of spectrum at specific locations with specific power characteristics to specific parties for specific purposes.[21] In practice, the recipients of these assignments received a license from the government—almost always at no cost and almost always renewable indefinitely. Although licenses could not be sold directly, the company to which the license had been issued could be bought by another company and the licenses would thereby—with the FCC's permission—be transferred to the purchasing company.

Parcels of spectrum were also allocated to government agencies for national defense, law enforcement, and a variety of other purposes.

As radio technologies improved and engineers were able to utilize broader ranges of the spectrum (e.g., when television broadcasting became feasible), the newly valuable swaths of spectrum continued to be allocated in this manner. When there were competing claimants to a newly opened parcel of spectrum, the FCC would hold comparative hearings (which were quickly dubbed "beauty contests") to determine which party's use of the spectrum would be the most consistent with the "public interest."

This system collapsed of its own weight in the early 1980s, when cell phone technology had improved sufficiently so that the licensing of spectrum for cell phone service rose to the FCC's agenda. The commercial prospects for cell phone use appeared to be so promising that the FCC was swamped with applicants for licenses and realized that the comparative hearings process was infeasible. The FCC appealed to Congress for help, which responded with the authorization for lotteries for these licenses (after a quick initial screening for applicant suitability). The FCC duly conducted lotteries. Huge windfalls accrued to the winners—which became especially apparent when the winners "flipped" their licenses (i.e., sold them to other parties that were in a better position to use the licenses). The windfalls convinced the FCC and the Congress of the superiority of auctions, which had been proposed as early as the 1950s, over lotteries.

The Congress first authorized spectrum auctions in 1993. A major motive was not the allocative efficiencies that would accompany auctions but instead the revenues that would accrue to the federal government from these auctions. Since then, auctions have been a major (though not the

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[21] The U.S. Radio Act of 1912 gave the Department of Commerce authority to issue commercial radio licenses. Since then, spectrum management has transferred between several government departments and independent agencies. Since 1934, the FCC and the Department of Commerce have been the allocating agencies. See Section III below.

only) method for allocating spectrum. From 1994 (the year of the first spectrum auction) through late 2009 there have been 75 auctions that have yielded more than $52.6 billion for the federal government.[22] The spectrum that is auctioned generally carries more flexible usage and transfer rights than does the spectrum that has been allocated through the more traditional licensing system.

Only a small fraction of the usable spectrum in the United States has been made available through the auction system (and only a subset of that total is open to commercial mobile radio services), because large portions have been locked up by administrative legacy. Because of technological change, spectrum demand today is substantially different from the demands that influenced radio spectrum planners over the eight decades of traditional management. Consumer and industry needs will likely change just as drastically in the future. Thus, we cannot presume that new allocations, if restrictive, will be any more successful than those that burden us with the present shortage.

Prudent policymaking requires that spectrum be released from the existing regulatory license regime wherever possible and be flexibly licensed to those who will put it to its most productive use.

B. The Broadband Stock

In order to examine the need for additional spectrum for modern wireless services, we first set forth the amount of useable spectrum input that is already available. This is not a straightforward exercise. We estimate that somewhere between 414.5 and 583 MHz is either currently employed or available for wireless broadband.[23]

The top end of this range is shown in Table 1, which includes all the bands that are licensed to permit broadband.

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[22] This number is adjusted for bidding credits, which inflate the bids of small and very small businesses and entrepreneurs but do not result in actual auction revenue. Including those amounts, winning bids have totaled $78.0 billion.

[23] Note that we are referring to purely terrestrial-based broadband. Satellite providers are also active in the CMRS market and play a role in our discussion of reallocation (see Part III, Section C on Mobile Satellite Service, *infra).*

Table 1 Commercial Mobile Broadband Spectrum Upper Bound Estimate [a]			
Band	**Bandwidth (MHz)**	**Relevant Frequencies**	**Notes [b]**
700 MHz	70	698 - 806 MHz	Lower and Upper 700 MHz Bands, excl. upper D-Block (10 MHz), public safety and 2x2MHz guard bands. Auctioned 9/02, 6/03, 3/08. Part 27.
SMR	14	816 - 824 MHz 861 - 869 MHz	(Enhanced) Specialized Mobile Radio service post-2004 reconfiguration. Excl. channels for public safety, business, and non-cellular SMR. Auctioned 4/96, 12/97, 12/00, 1/02, 2/04. Part 90.
Cellular	50	824 - 849 MHz 869 - 894 MHz	Licensing began in 1982 with 40 MHz; enlarged to 2x25 MHz in 1986. Majority of licenses issued by 1991. Parts 1, 22.
1670-1675 MHz	5	1670-1675 MHz	Single national license held by Crown Castle. Auctioned 4/03. Part 27.
AWS-1	90	1710 - 1755 MHz 2110 - 2155 MHz	Advanced Wireless Services (1). Auctioned 9/06. Part 27.
PCS Broadband	120	1850 - 1910 MHz 1930 - 1990 MHz	Personal Communications Services. Auctioned 3/95, 5/96, 7/96, 1/97, 4/99, 1/01. Part 24.
G Block	10	1910 - 1915 MHz 1990 - 1995 MHz	Granted to Sprint Nextel in exchange for licenses interfering with public safety in SMR. 7/04.
WCS [c]	30	2305 - 2320 MHz 2345 - 2360 MHz	Wireless Communications Services. Auctioned 4/97. Part 27.
BRS & EBS [c]	194	2496 - 2690 MHz	Broadband Radio & Educational Broadband Services. Transitioned from MDS/ITFS 7/04. (MDS auctioned 3/96). Part 27.
Total	583		

Source: FCC (2009), FCC.gov

[a] Pure terrestrial allocations only.

[b] Auction dates are the month that the auction (or re-auction) ended. Part numbers signify service rules as dictated by the relevant portion of the Code of Federal Regulations (Title 47).

[c] Signifies that the allocation overstates bandwidth that is realistically usable for broadband. See Table 2, *infra*

While all of the above spectrum is licensed to permit broadband, the bands listed in Table 2, which comprise a subset of Table 1, have impediments to the deployment of these bands for such purposes.

Table 2
Commercial Mobile Broadband Spectrum
with Impediments to Broadband Deployment [a]

Band	Bandwidth (MHz)	Relevant Frequencies	Notes
WCS	30	2305 - 2320 MHz 2345 - 2360 MHz	Surrounds SDARS (satellite radio) allocation, which in many cases causes interference impeding deployment.
MBS [b]	12	2602 - 2614 MHz	Middle Band Segment (BRS portion only). Rules accommodate video transmissions by high-power incumbents post BRS/EBS transition. Thus low-power cellular operations can be subject to interference.
J & K [b]	8	2568 - 2572 MHz 2614 – 2618 MHz	2x4 MHz guard bands. Operations are secondary to adjacent channel transmission; channels are narrow and channel aggregation required for broadband is unlikely.
Channel 1 [b]	6	2496 - 2502 MHz	Not contiguous with other BRS channels and not itself sufficient for 4G deployment (current WiMax requires 10 MHz). Also interference prone and encumbered by three other co-primary users.
EBS	112.5	2502 - 2568 MHz 2576 - 2606 MHz 2673.5 - 2690 MHz	EBS licenses must be held by non-profit (educational) institutions. A significant portion can be leased to commercial operators but they are required to retain educational character (47 C.F.R. § 27.1214.). Also complicated by site-based nature, which creates white spaces.
Total	168.5	(of the 583 MHz in Table 1)	

Source: FCC (2008), FCC (2009), FCC.gov
[a] Pure terrestrial allocations only.
[b] Indicates that the channel is a subset of Broadband Radio Service (BRS).

The WCS band, while legally available for broadband use since being licensed over a decade ago to companies including Comcast, faces interference from terrestrial repeaters used by satellite radio broadcasters in the neighboring SDARS allocation. A change in license conditions that would permit the WCS licensees to negotiate this issue with the satellite radio licensees might

enable the WCS band to be usefully deployed. In the case of the BRS allocation, the difficulties in certain channels are due to rules that accommodate incumbent operators in the band. Channel width is also an issue in J, K, and Channel 1; narrow licenses that are not contiguous with similar spectrum limit the ability of carriers to best employ new technologies.

The EBS licenses are required to be held by educational institutions, but the bands can be, and are being, leased. Notably, some EBS spectrum has been leased to Clearwire for WiMax deployment. Nevertheless, mandates for (partially) educational use, the inability to transfer the licenses more permanently to broadband providers, and the fragmented control of the EBS bands diminish their value for broadband and inhibit the willingness of some would-be providers to make the large investments that are required for advanced mobile wireless services.

Our estimates fall within the range of other recent estimates (see Table 3).

Table 3
Estimates of Present Broadband Spectrum

Source	Total Bandwidth (MHz)	Label, Components Identified
TPI	414.5 - 583	Commercial Mobile Broadband Spectrum Table 1, Table 2
OBI	534	"Spectrum available for mobile broadband" Cellular, PCS, BRS/EBS, AWS-1, 700 MHz, G Block
CTIA	409.5	"Spectrum assigned for commercial wireless use" Cellular, PCS, SMR, BRS (@55.5), AWS-1, 700 MHz (@80) [a]
Bazelon	544	"Base of liberally licensed radio spectrum" Cellular, PCS, SMR (@20), BRS/EBS (@174), AWS-1, 700 MHz (@80), G Block

Source: CTIA (2009), OBI (2009), Bazelon (2009)
Note: "@" indicates size of band given if different from definition in Table 1.
[a] Appears to follow the FCC's definition of "suitable" spectrum in Sprint Nextel (See FCC [2008], ¶¶ 53-74).

The differences between the various estimates are as follows: Relative to our upper bound estimate, Bazelon drops Wireless Communications Services (30 MHz) and 20 MHz of BRS/EBS

for usability reasons,[24] and largely ignores 1670-1675 MHz. He also attributes an extra 6 MHz to SMR, and adds the 10 MHz D-Block, which we and the Task Force exclude. Like Bazelon, the Broadband Task Force (OBI) leaves out the WCS band along with 1670-1675 MHz. The Task Force also differs in that they fail to count any SMR. CTIA's estimate is close to our lower bound, which excludes the WCS, the EBS, and portions of the BRS bands—airwaves that are assigned but face some impediment.

C. <u>The Broadband Spectrum Pipeline</u>

There is also spectrum that is moving toward the market, but is not yet available. In Table 4 we present 50 MHz of spectrum that is "in the pipeline."

The Broadband Task Force provides an equivalent estimate, and CTIA (p. 17) agrees that 50 MHz is "potentially usable spectrum/in the pipeline."[25] The AWS bands named below are "pipeline" in the strictest sense, in that they are outside the commercial broadband stock but are expected to join that pool of resources soon. The 700 MHz D-Block, on the other hand, is somewhat different. It was offered to providers at auction, but was not sufficiently enticing for purchase due to service requirements.[26] In order to move this spectrum into the market, either the service requirements or the reserve price will likely have to be modified.

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[24] Bazelon (2009, Table 1, note [D]). The "usability reasons" are implicit in the choice of channels but not stated directly. Note that we take Bazelon's estimation of "100 percent probability" to be synonymous with "presently allocated." Also, Bazelon does not ignore WCS entirely, but calls it "expected," with a 33 percent chance of gaining liberal licensing. See footnote 25, *infra*.

[25] Due to the particular goal of his analysis, to evaluate the gains from a reallocation of the television broadcast band, Bazelon takes a different approach to the pipeline. He directly incorporates some elements of underutilization and uncertainty for which we instead provide more details and leave for the reader to judge. Bazelon presents the liberally licensed bands that are in the hands of operators alongside those that "have yet to be licensed or [for which] the final rules of how the bands can be used are uncertain" (p. 7), which comprise a sort of pipeline, in essence. He totals that category to 120 MHz, including WCS, ATC spectrum (tallied at 55 MHz), AWS-3 (at 30 MHz, reflecting the proposed expansion), and the "H Block," a subset of AWS-2. Discounting these nominal amounts by the likelihood of their timely transition to flexible licensing, Bazelon finds an expected 69 MHz, not far from the consensus that we share with OBI and CTIA.

[26] No bidder met the $1.3 billion reserve for the block, which was reserved for a single nationwide license in a public-private partnership. The startup that pushed for those terms, Frontier Wireless, failed to raise the funds required for an Auction 73 bid.

Table 4 Commercial Mobile Broadband Spectrum Pipeline			
Band	**Bandwidth (MHz)**	**Relevant Frequencies**	**Notes**
D-Block	10	758 - 763 MHz 788 - 793 MHz	700 MHz band single nationwide license for public-private partnership. Did not meet reserve bid.
AWS-2	20	1915 - 1920 MHz 1995 - 2000 MHz 2020 - 2025 MHz 2175 - 2180 MHz	Band pairs are known as H Block and J Block (in order). Service rules being considered by Commission (6/08)
AWS-3	20	2155 - 2175 MHz	Rulemaking in process. FNPRM proposed adding 5 MHz at 2175-2180 MHz (6/08)
Total	50		

Source: OBI (2009), FCC (2009), FCC.gov

III. Where to Look for Additional Spectrum

In all, radio frequencies in the U.S. are divided into about 800 bands of varying size, which can be characterized broadly as either under federal control, licensed exclusively (or practically exclusively) to the private sector, or subject to some shared arrangement between those groups.

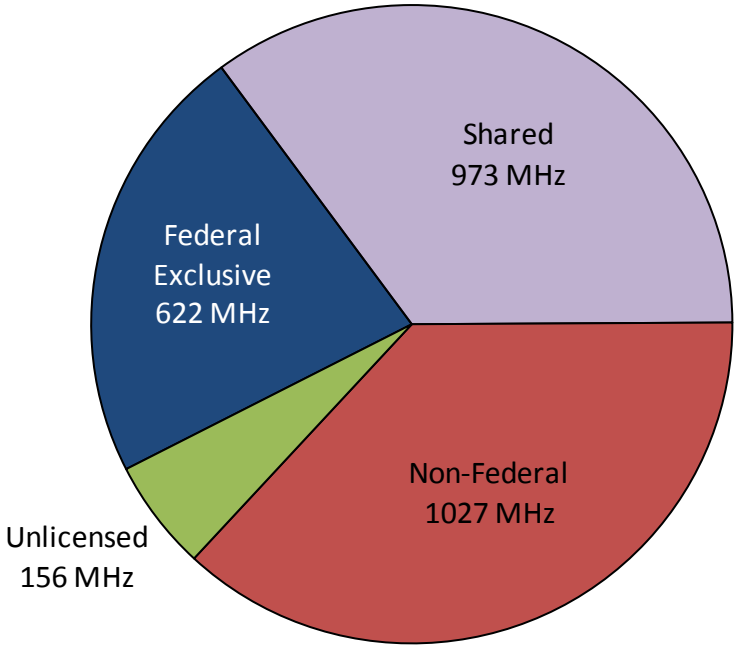
The separation of responsibilities between the two government agencies that oversee spectrum use—the National Telecommunications and Information Administration (NTIA) within the Department of Commerce, and the Federal Communications Commission (FCC)—reflects this divide in spectrum allocation, separating frequencies that are held by the federal government from those assigned to firms, state and local governments, public safety operators, and individuals,[27] which require a license for rightful access. Essentially, the NTIA coordinates U.S. government spectrum use, and the FCC oversees the rest of the bands; in practice, however, the delineation is not so clear-cut (as the official depiction reproduced in Figure 2 above suggests).[28]

[27] We sometimes refer to these parties (any licensed user outside the federal government) interchangeably as "non-government" or "non-federal."

[28] The law does not specify which bands are allocated to federal, non-federal, or shared use; the balance is instead struck through agreements between the two agencies (Cave and Morris 2005, p. 3). NTIA lacks enforcement authority if third parties cause harmful interference in federal bands (Carter and Marcus 2009, p. 6).

Figure 3

Relative Shares, 300 MHz - 3 GHz



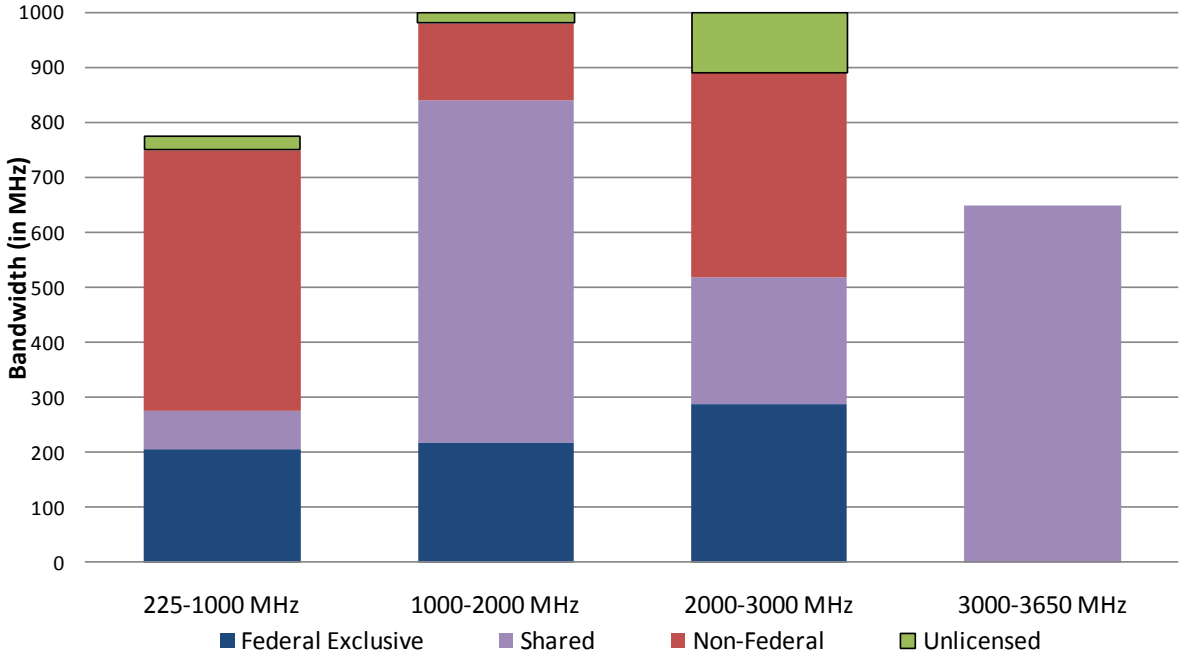
Source: Williams (2002), updated by authors.
Range is imprecise (i.e., chart components do not sum to 2700 MHz)

Figure 3 provides a rough approximation of spectrum shares. "Non-federal" includes television and radio broadcasters (both terrestrial and satellite), the wireless industry, radio dispatchers, and licenses held by other private entities. In the figure we total bands that are allocated to each group without any indication of how much of each band is utilized by, or assigned to, specific users. This deficiency applies especially to shared spectrum, where a band that is weighted very heavily toward federal use would appear no different from one in which private parties are nearly the sole occupants. In addition, the above proportions may also be misleading in that some bands that are mandated for non-government occupancy also support essential federal applications. For example, U.S. agencies may access the "non-government" 450-470 MHz band in order to communicate with civilian radio operators.

Subject to the same caveats, Figure 4 presents a more disaggregated picture of these key frequencies, with additional bands included at the extremes.

Figure 4

Shares by Frequency Range, 225 MHz - 3.65 GHz



Source: Williams (2002) updated by authors, NTIA (2003), DOC (2008)

(Note that this chart does not reflect unlicensed use of television white spaces.)

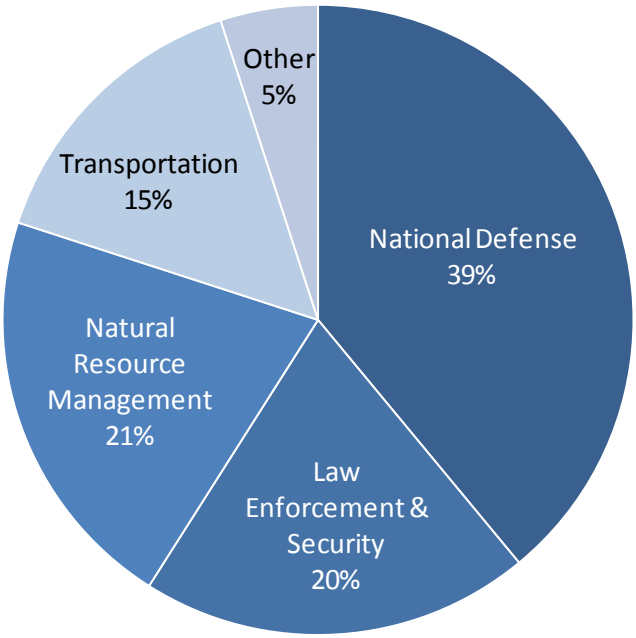
Federal-exclusive and shared federal/non-federal bands are by definition within the command-and-control regime. Conversely, liberally-licensed spectrum necessarily falls under the "non-federal" group in the depictions above. The non-federal group also includes private spectrum that is narrowly restricted in use by the command-and-control regime. We propose to free-up two of the most significant allocations of this category—television broadcast and mobile satellite—in sections B and C below.

A. <u>Federal Government Spectrum</u>

Figure 4 shows that the majority of the airwaves that are adequate for wireless broadband are not available exclusively to the private sector, let alone with flexible rules. To determine what portions of this government spectrum may be attractive for reallocation, we now examine the bands in greater detail. Rather than offer a precise roadmap for spectrum reallocation, our aim for this section is to present some background on the magnitude and purpose of much of this largest class of spectrum that lies outside of market-determined outcomes.

Figure 5

Federal Government Spectrum Assignments, 3 MHz - 3 GHz



Source: DOC (2004)

Figure 5 categorizes by function the federal government's use of both shared and exclusive bands based on nearly 237,000 frequency assignments near the radio low-end. These assignments account for 92 percent of the government's assignments across the entire radio spectrum. The metric used—assignments—is not perfect, because assignments are not necessarily equivalent; i.e., one may cover more frequencies, greater land area, and more devices than another. These assignments also ignore the value of government agencies' investments in equipment. It should be noted that these data extend to frequencies that are lower than those included in the other figures and tables.

As the labels in Figure 5 indicate, federal government users hold spectrum for purposes that are instrumental in supporting the well-being and security of millions of Americans each day. But while the government's ends are often critically important, they may not be met efficiently. In light of opportunity costs, the spectrum that has been set aside for the monitoring of natural resources, for example, is inappropriate in areas where such resources are few and consumers are many—such as major metropolitan areas. Policymakers should scrutinize current usage and develop innovative workarounds to move spectrum into configurations that are productive and flexible.

The federal-exclusive bands that are surveyed below sum to almost 730 MHz. These allocations, which our earlier data showed to be the smallest of the groups in aggregate (excluding unlicensed), are individually relatively large.[29] The average contiguous portion surveyed in Table 5 spans almost 74 MHz, and is still close to 60 MHz after omitting the very large swath of spectrum at 2700 MHz. Broad slices of spectrum are ideal for next-generation cellular networks, because of the volume of the information that they can transmit and the efficiency gains that large licenses allow.

Table 5
Federal Exclusive Allocations

Frequency Range	Bandwidth (MHz)	Selected Uses
162 - 173 MHz	11	"Backbone" of federal land mobile communications.[a] Contains the most frequency assignments of any band allocated to federal government.
225 - 328.6 MHz	103.6	FAA, DOD (and NATO), Coast Guard fixed and mobile communications.
335.4 - 399.9 MHz	64.5	DOD radio communications, mobile satellite service.
410 - 450 MHz	40	Radiolocation (radar), fixed and mobile communication links.
1215 - 1240 MHz	25	GPS; radar for national defense and transport.
1240 - 1300 MHz	60	Radar for national defense and commercial transport.
1350 - 1390 MHz	40	Radar for national defense and commercial transport.
1755 - 1850 MHz	95	Extensive use by DOD for advanced mobile wireless (e.g. video control links); Army Corps of Engineers fixed monitoring of waterways.
2200 - 2290 MHz	90	NOAA satellite telemetry; Meteorological Aids Service
2700 - 2900 MHz	200	FAA airport surveillance radar; DOD airfield surveillance; DOT weather radar

Source: Williams (2002), NTIA (2003), DOC (2008)

[a] Much of this band has actually been made available to industry (though not for commercial wireless service) under Part 22 Paging and Part 90 Land Mobile licenses. It is included because of its importance in federal holdings. In reference to allocations, "mobile" is a general term and is not synonymous with "cellular." Technically, it "includes stations used for communications purposes while in motion on various platforms such as handheld, automobile, ships and aircraft." See DOC (2008) p. B-4.

[29] We have consolidated small contiguous bands that are allocated to relevant user groups in each table (in this case, federal-exclusive, in Table 6, shared bands); thus this is sometimes not precisely "band level," but is close enough for our purposes.

Without a detailed analysis of these frequencies, there is no way of knowing which might be cost-effectively transitioned into broadband-friendly licensing. A number of bands will almost certainly not be candidates for reallocation: the 25 MHz span that is close to 1.2 GHz that houses the GPS L2 signal, and the frequencies that are harmonized with NATO for international communication and radiolocation, for example. Others may have greater potential. CTIA has identified the low end of the 1.75 GHz tract—namely, the 25 MHz span that is at 1755-80 MHz—as the most promising for timely addition to the spectrum pipeline. CTIA notes that the relocation of government microwave links that this would require is familiar to the market because of similar experience in the adjacent AWS spectrum and even earlier experience in the release of the PCS band.[30] The proposed strategy of claiming part of the government's spectrum in a "neighborhood" where it is relatively abundant may be a cost-effective course for making bands available for commerce without substantially impinging on federal users.

Table 6 shows federal deployment in over 1500 MHz of prime shared allocations. These contiguous regions are more numerous than are the government-exclusive group, but these regions are also more fragmented. The allocations vary between small and massive. With regard to the upper frequencies in this range—i.e., those above 2900 MHz—it appears that policymakers have avoided granting rights only to federal or other interests, opting instead for an extensive shared swath. There is otherwise little or no organization to the system, other than that the government has retained swaths around the frequency needs of radio technologies that it wished to employ.

Shared spectrum on the whole may be more viable for reallocation and private-sector licensing than are the exclusive federal bands. Because the government has already conceded rights in these bands to other parties, they may be utilized less comprehensively (on a MHz-pop basis) by agencies. The wide allocations to this user group are also potentially attractive in their potential as a "landing pad" for relocated users. While the commercial wireless industry may not be interested in bands above 3 GHz, this region can serve as the resting place for previous users of lower frequencies for whom somewhat higher frequency assignments will suffice.

Counting both exclusive and shared allocations, the federal government occupies about 1500 MHz of the most valuable spectrum—bands below 2900 MHz (see Tables 5 and 6). The opportunity cost for this spectrum is high and it should be examined carefully for reallocation.

[30] CTIA (2009, pp. 20-22).

Table 6
Shared Government/Non-Government Allocations

Frequency Range	Bandwidth (MHz)	Selected Uses
216 - 220 MHz	4	Maritime mobile service (AMTS), radiolocation.
328.6 - 335.4 MHz	6.8	Aircraft navigation (Instrument Landing System)
399.9 - 410 MHz	11.1	Non-military federal communications (similar to exclusive 162-173 MHz); fixed links; DOD weather research for air traffic control support.
608 - 614 MHz	6	Radio astronomy, medical telemetry, medical radio communications
932 - 935 MHz	3	Federal agency fixed data and control links.
941 - 944 MHz	3	Federal agency fixed data and control links.
960 - 1215 MHz	255	Critical, extensive, internationally standard aircraft navigation and identification (especially at 1030, 1090, and 978 MHz).
1300 - 1350 MHz	50	Air traffic control radar, long range surveillance radar
1395 - 1400 MHz	5	Medical telemetry [a]
1400 - 1427 MHz	27	Earth Exploration-Satellite, Radio Astronomy, Space Research
1432 - 1710 MHz	278	Aeronautical mobile satellite service; GPS signals; NOAA meteorological operations
2025 - 2110 MHz	85	Earth Exploration-Satellite telemetry, tracking and command; meteorological satellite uplink
2290 - 2300 MHz	10	Earth Exploration-Satellite telemetry, tracking and command; DOD aircraft and missile-flight testing telemetry communication
2360 - 2385 MHz	25	Aeronautical telemetry and telecommand, mobile/land mobile
2900 - 3100 MHz	200	Transportable military radar; Coast Guard land-based maritime radio navigation radar; meteorological radar
3100 - 3300 MHz	200	Navy shipborne radar
3300 - 3500 MHz	200	Navy shipborne radar
3500 - 3600 MHz	100	Airport surveillance radar and surface detection equipment, US Fish and Wildlife Service telemetry
3600 - 3650 MHz	50	Aeronautical radio navigation

Source: Williams (2002), NTIA (2003), DOC (2008)

[a] Dept. of Veterans Affairs has not yet used this band since suitable equipment has not been made available to the agency.

Freeing up Federal Spectrum

There appears to be a widespread consensus that spectrum in government hands is likely not being used efficiently and that some—perhaps a significant amount—could be reallocated to more efficient private uses.[31] However, efforts to determine the extent of this "surplus" and then to devise a method of freeing it from government hands confront a dilemma: the absence of a market mechanism, or even a budgetary mechanism, that can help.

First, government agencies do not operate in a market context, and profit maximization is not their goal. Consequently, the "opportunity cost" paradigm that naturally applies in a market-oriented context is often neglected within government agencies.

Second, unlike most of the inputs that are used by a government agency—e.g., personnel, materials, vehicles and equipment, rental real estate—which are subject to annual budgetary allocations, the spectrum that is under a government agency's control was received from the Department of Commerce and now is effectively "owned" by the government agency. From the agency's perspective (i.e., the perspective of the agency's senior management), the spectrum is a free resource, for which it pays no rent or upkeep costs. The perceived opportunity costs of spectrum are small at best, since there is no market for this spectrum.

Further, even if there were an active spectrum market (and hence readily apparent opportunity costs), and even if a government agency were interested in increasing the resources that are at its disposal, the agency could nevertheless be largely indifferent to those opportunity costs for the following reason: If an agency were to sell its spectrum, the agency's net gain might be far smaller than the selling price—or even zero. That result could occur due to budget reallocations that would net out the agency's gain. From an agency's perspective, a better strategy might well be to make some use of the spectrum under its control (even if that use is of low value, as judged by opportunity costs), or even to let the resource lie idle and wait for some future use, since doing so is costless.

As an analogy, one might think of real estate that, at some time in the past, had somehow come under a government agency's ownership and control. If that real estate has little or no upkeep costs, then from the agency's perspective it is a free resource. The opportunity costs of the real estate may be of little interest to the agency, for the budgetary recoupment reasons mentioned above. The agency may put the real estate to low-value uses, or even keep it idle. When challenged by higher

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[31] This is implied by the broadly popular Radio Spectrum Inventory Act, which is premised on the ability to "promote the efficient use" of spectrum. Bykowsky and Marcus (2002) note that some believe that the public sector employs too much spectrum to meet its ends; e.g., in 1996 former senator Larry Pressler recommended that the federal government reallocate 25% of its holdings below 5 GHz (see https://www.policyarchive.org/bitstream/handle/10207/8335/bg-1085.pdf, p. 8). In addition, Cave and Morris (2005), and Carter and Marcus (2009) illustrate why the nature of government users leads to the expectation that they will not use spectrum efficiently.

governmental authority, an agency's narrow interests will be best served by claiming that the real estate is vital to the agency's current and future functions.

There are limits, of course, to the real estate analogy. As compared with spectrum, the opportunity costs of an agency's real estate holdings are likely to be much clearer. Physical inspection of the property to determine whether the agency is making reasonable use of it (in light of its opportunity costs) is surely easier as well.

Accordingly, the task of determining the extent of surplus spectrum in government hands and "liberating" it for reallocation to wireless broadband use will be even more difficult than if the resource being considered were real estate. Further, implicit in this discussion is the inability to bring the power of the profit motive as a force for assisting in the reallocation.

As a consequence, we are pessimistic that market or quasi-market mechanisms can be used effectively—at least in the short run—to identify and free up government spectrum. The experiences of other countries support this pessimism. Although many governments give some lip service to improving their allocation of spectrum, only the United Kingdom appears actually to have instituted a system of "administered incentive pricing" (AIP), which has provided direct pricing incentives for some government agencies to use spectrum more efficiently. But the United Kingdom began developing its AIP policies over a decade ago, and AIP appears to have induced only marginal results during that time.[32]

This general skepticism of the ability of market-based efforts to identify and free up existing spectrum that is in government hands does not extend to the use of market-based methods when agencies seek additional spectrum. In such instances, agencies should be required to pay the opportunity costs for their spectrum use. Consistent with this approach, agencies should also be encouraged to purchase communications services rather than the spectrum itself, since such purchases would likely mean greater economizing on the use of the spectrum.

Short-Run Recommendations

We believe that administrative mechanisms hold the greatest promise, at least for the short run. Specifically, we recommend the following:

1. The Congress should commission a report by the National Academy of Sciences (NAS) on the current allocation of spectrum generally and of government-held spectrum more specifically and on likely sources of surplus (idle or underused or low-value-use) spectrum

[32] See, for example, Cave and Morris (2005); HM Treasury (2005); Ofcom (2006, 2007); Cave et al. (2007); UK Spectrum Strategy Committee (2009); and Carter and Marcus (2009).

that could be reallocated to better uses.[33] The NAS should include in this report—as fundamental to its efforts to determine likely sources of surplus spectrum—estimates of the current opportunity costs of the various spectrum bands.[34]

2. The Administration should form a Government Spectrum Reform Task Force consisting of government officials (including the Director of the Office of Management and Budget [OMB], the Secretary of Commerce, and the Chairman of the FCC) and private-sector experts that would, using the NAS study as a basis, recommend a package of spectrum bands that could be vacated by government users and auctioned by the FCC. In developing its recommendations, the Task Force would incorporate the costs of relocating government users in order to free up spectrum.
3. Subsequent to the release of the Task Force recommendations, NTIA should prepare an annual report that updates the data on the government's spectrum inventory, the opportunity costs of the various bands, and the likely sources of surplus spectrum. The updates of surplus positions especially would take into account changes in usage and technology.
4. OMB, as part of its annual budget process, should require any U.S. government agency that has a spectrum allocation to provide an annual accounting of that agency's use of that spectrum. OMB should have a heightened awareness of spectrum as a scarce resource (the NAS/NTIA estimations of opportunity costs would help in this awareness) and should routinely search for under-utilized spectrum that could be auctioned by the FCC.[35] In essence, OMB should become a skeptical auditor of government-held spectrum, its use, and its opportunity costs.
5. OMB should encourage (and provide the funding for) agencies to create employee incentive plans that would provide rewards (including cash awards) to agency employees for devising ways for their agency to economize on its use of spectrum. The spirit of these awards would be consistent with other government awards that encourage employees to take special efforts to utilize resources efficiently and to provide outstanding performance.

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[33] Alternatively, NTIA and the FCC could be directed to prepare a report on current allocations, as called for in the Radio Spectrum Inventory Act, introduced in 2009 by Senators John Kerry, Olympia Snowe, Bill Nelson, and Roger Wicker. This legislation would relieve the NAS of the need to compile the inventory. Nevertheless, a NAS report that then focuses on opportunity costs and the identification of underused spectrum would still have high value.

[34] There have been past efforts–some within the current decade–to develop inventories of government-held spectrum. See, for example, U.S. Department of Commerce (2008). But, without a focus on opportunity costs and on finding underused spectrum for reallocation, these efforts provide little guidance for potential gains from reallocations.

[35] OMB should also be encouraging agencies to share the use of under-utilized spectrum, again encouraging greater efficiency.

Long-Run Recommendation: A Government Spectrum Ownership Corporation

Pricing mechanisms for allocating existing government-held spectrum are likely to be ineffective for the short run, but the federal government should pursue AIP mechanisms over the longer run.

One simple model for exploration in this direction is based on the market-oriented rental rates that agencies are charged when they lease space in buildings that are owned (or leased) by the U.S. Government Services Administration (GSA). The GSA's Federal Buildings Fund (FBF) provides recognition of the opportunity costs of those buildings.[36] The government agencies make rental payments to GSA, which can use the money to acquire additional property if necessary. These rental payments provide an incentive for government agencies to economize on space.

Suppose, then, that all U.S. government-used spectrum were "owned" by a central government agency (the "Government Spectrum Ownership Corporation," or GSOC) and leased to government users. In this case, the idea that the spectrum-using agencies should pay rental fees to GSOC—and that those rental fees should represent something approximating the opportunity costs of the GSOC's spectrum holdings—would not be much different from the practice that government agencies pay rent for their use of the GSA's buildings.

Accordingly, we recommend that the federal government create a GSOC. The GSOC would take possession of all government-held spectrum, with the existing user agencies granted annual leases (that are perpetually renewable at the option of the agency) at annual rental rates that are determined by the GSOC, based on its estimates of the relevant opportunity costs. The GSOC would forward its net proceeds to the Treasury. In the first year OMB would add to each using agency's budget a sum that is just equal to the rental payment, so the first year's financial transactions would be a "wash" for all agencies (and for the Treasury).

In subsequent years the agencies' budgets would start from the base that included the initial allocations and rental charges; but the GSOC would change the rental rates in light of updated information about opportunity costs. The agencies and OMB would then negotiate (as they do now) over resource usage and budget allocations; but, although the agency's budget would take into account its spectrum rental costs, there need not (and should not) be a one-to-one adjustment in an agency's budget allocation in relation to any changes in its spectrum rental costs. Instead, the agency's budget allocation should reflect its overall resource needs in light of its overall mission and operations. Thus, this "normal" budgetary negotiation process would recognize the opportunity costs of spectrum in the same ways that the opportunity costs of an agency's use of other resources are recognized.

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[36] As another analogy, government agencies pay postal rates to the U.S. Postal Service (USPS) when the agencies make hard-copy mailings through the USPS.

The goal would be that such a system would (like the GSA framework) provide sensible incentives for agencies to economize on spectrum use. The GSOC might then have a surplus of spectrum that it could sell or lease to the private sector (or turn over to the FCC for auctions). The GSOC could also accumulate a fund (again, similar to GSA) that could be used to purchase additional spectrum if needed for leasing to government agencies.

B. Broadcast TV Spectrum

When the transition to digital television was completed in June 2009, broadcasters had vacated channels 52 to 69, freeing up 108 MHz of valuable spectrum. The final 52 MHz of this spectrum was sold through the FCC's 700 MHz auction in March 2008, generating almost $20 billion in federal revenues.[37] This leaves 294 MHz of prime spectrum still allocated to broadcast TV (see Table 7). There is widespread agreement that this remaining spectrum is misallocated.[38] If the broadcasters operated under flexible licenses, the spectrum would move to more valuable uses, such as wireless broadband.

Table 7
Broadcast Television

	Frequency Ranges	Channels	Bandwidth (MHz)
Below 300 MHz (VHF)	54 - 72 MHz	2 – 4	72
	76 - 88 MHz	5 – 6	
	174 - 216 MHz	7 – 13	
Above 300 MHz (UHF)	470 - 512 MHz	14 – 20	222
	512 - 608 MHz	21 – 36	
	614 - 698 MHz	38 – 51	
		Total	294

Source: NTIA (2003)

[37] To arrive at the 52 MHz sold successfully, subtract the following from 108 MHz: 24 MHz reserved for public safety uses, 18 MHz auctioned previously, and 4 MHz of guard bands, plus the 10 MHz D block, for which the reserve price was not met.

[38] For example: "the spectrum dedicated to UHF TV broadcasting has less value as a medium for transmitting TV signals than it does for an array of other uses" (Weiser, 2008, p. 20); " the current use of these TV broadcast bands involves a rather large opportunity cost, relative to its alternative use in cellular" (Faulhaber, 2006, p. 262).

As is often noted, the breadth (especially in UHF) and propagative properties of this spectrum make it very attractive for broadband networks, much like the former television bands that were reallocated with the DTV transition.

Today television broadcasting occupies only slightly less bandwidth than the entire allocation for commercial wireless services under 2 GHz. In terms of the most desirable spectrum—say, bands below 1.5 GHz—broadcast TV amounts to double the combined spectral assets of wireless service providers. Liberalizing the TV bands in their entirety would increase the spectrum available for broadband by over 46 percent,[39] pushing the United States above the ITU-recommended endowment of 840 MHz in 2010.

The reason that the broadcast spectrum should be considered to be misallocated in its current use is straightforward: The value that consumers place on broadband and the content and applications that it allows is greater than the value that broadcasters can earn through advertising plus the net value of over-the-air broadcasting to those households that choose over-the-air rather than a cable or satellite alternative. This is partly because comparatively few people still watch over-the-air TV. According to the latest FCC report, almost 87 percent of the 110 million TV-viewing households subscribe to cable, satellite, or other multichannel video programming distributors (MVPDs), leaving about 14 million households that use over-the-air broadcasting.[40] More recent data indicate that only about 10 million households—less than 10 percent of all U.S. households—use over-the-air broadcasts exclusively.[41]

Recent estimates indicate that the social costs of retaining the current allocation of the TV spectrum—the costs of inaction—could be in excess of $1 trillion. For example, Hazlett (2009) estimates that the 294 MHz TV band would be worth $120 billion to new service providers (at 2008 auction prices) and at least ten times more to consumers, if it were available for new services. Bazelon (2009) estimates that the broadcasters' spectrum, if it were available for wireless broadband, would command $62 billion at auction; total benefits, including consumer surplus, would be between $500 billion and $1.2 trillion.

Bazelon estimates that the market value of the broadcast spectrum in its current use, in contrast, is only about $12 billion. The fact that spectrum used for new services has a market value that is five to ten times higher than spectrum used for TV broadcasting is evidence of a serious misallocation of this resource.

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[39] This is made conservative by using the totals of Table 1 and Table 4 (50 MHz pipeline). The percentage increase is greater if we ignore the troublesome bands in the base (Table 2).

[40] See annual report at http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-07-206A1.pdf. This report, released in 2009, is based on 2006 data.

[41] Bazelon (2009, p. 15).

Moreover, because there is so much unrealized value in the existing spectrum allocation, it should be possible to reallocate spectrum in a way that assures that each of the affected groups is better off. Affected groups include, in addition to consumers of wireless broadband services, broadcasters, over-the-air viewers, and taxpayers. Each would stand to gain from a program that moved broadcast licenses to a more flexible, market-driven regime.

Over-the-Air Viewers

There are two principal alternatives to meet the needs of over-the-air viewers. Licensees could be required to continue broadcasting at a less spectrum-intensive level. Given current technologies, a single standard-definition video stream can be broadcast with a fraction of a 6 MHz channel, freeing up most of the spectrum for other uses. Alternatively, the federal government could establish a program to transition over-the-air viewers to subscription TV. In this case practically all of the broadcast spectrum can be freed up.[42]

Subscription TV—cable, satellite, or video wireline that is provided by telephone carriers—is available virtually everywhere. Hazlett (2009) estimates that households can be connected to a subscription TV service for $300 each, for a total cost of $3 billion for the 10 million remaining over-the-air households. Bazelon (2009) estimates that the costs of connection plus providing a lifetime subscription would be $930, for a total cost of $9.3 billion for 10 million households.

A program to transition over-the-air viewers to subscription services should rely on procurement auctions (which are sometimes described as "reverse auctions"), in which multichannel video programming distributors (MVPDs) would enter bids (the price that they would need to be paid) for providing basic MVPD service to a designated block of transitioning viewers.[43] We would expect that MVPDs would be eager to participate in such a program, because it offers them the opportunity to gain additional customers who could at some point transition to become regular paying customers or upgrade from the basic package. Thus, the MVPDs would bid the price down to their marginal costs of providing the service, so the government's costs might be even lower than estimated.

The other alternative is to retain a portion of the broadcast band to provide continuing service for over-the-air viewers. Bazelon examines the alternative of keeping VHF channels (2-13) for over-the-air broadcasting and reallocating the UHF channels (14-36 and 38-51), freeing up 216

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[42] As others, including most notably Hazlett (2009), have also proposed.

[43] There would need to be some mechanism to assure that the transitioning program did not encourage subscription viewers to cancel their subscription service to becoming over-the-air-viewers in order to qualify for the subsidy. A requirement could be put in place that viewers could not qualify for the program unless they lacked subscription service for at least six months prior to receiving the subsidy. MVPDs should be able to enforce such a requirement.

MHz of spectrum. He estimates that this would lower the value of broadcasters' licenses by about half, to $6.2 billion. It would also lower the market value of the freed-up spectrum to just under $48 billion—about 20 percent less than the estimated value of the entire broadcast spectrum. The decrease in associated consumer surplus would be proportional.

Having just gone through the DTV transition, Congress may be reluctant to mandate another switchover that might be disruptive to their constituents.[44] Nevertheless, the additional value associated with the 78 MHz of extra spectrum (in Bazelon's example) is substantial. Over-the-air TV exists today only because of inflexibilities in the spectrum licensing regime. Given the opportunity cost of spectrum, broadcast television would not be economically viable without artificial constraints.

Transition Options

Developing a specific program also raises the question of how to divide the financial gains from flexibly licensing the broadcast spectrum. Many, if not most, broadcast licenses have probably been purchased in secondary markets, even though initial licenses were directly granted. However, the value of these licenses will increase if they are allowed to be used for more valuable purposes, such as wireless broadband. To what degree should current licensees benefit? To what degree should the federal treasury (and thus taxpayers) benefit?

The gains need to be divided so that both the broadcasters and the government have a strong incentive to undertake what is obviously a difficult, but socially beneficial, process. If Bazelon's estimates are used, the market value of the flexibly licensed spectrum would be a little more than $60 billion, as compared to about $12.5 billion in its current broadcasting use. Thus, there is a surplus of about $50 billion, which should be sufficient to make the effort worthwhile for both the broadcasters and the federal treasury. If Hazlett's estimates are used, the surplus is even larger.

There are basically two options that can be employed along with a reverse auction to transition over-the-air viewers to subscription TV. The first involves giving the broadcasters flexible licenses to the spectrum that they now have under specific broadcast licenses, combined with a government auction of the white spaces. The second involves the government's clearing the spectrum and then auctioning it. More specifically:

[44] In principle, the costs of the DTV transition are sunk and therefore should not affect future decisions.

Option 1: Voluntary Clearing of Broadcast Spectrum

1. The FCC would define basic subscription TV service, hold a procurement auction with providers, and award contracts to those who would provide the service at the lowest cost. Over-the-air viewers would receive vouchers and would have a fixed period of time—say, six months—to exercise them.
2. Incumbent licensees would gain immediate flexibility in terms of the uses to which they could put their property (so long as any change did not generate interference with another spectrum owner's existing property rights), as well as gain the immediate ability to transfer, add, and/or subdivide holdings.
3. Meanwhile, the FCC would divide the broadcast band into large parcels (Hazlett [2009] has suggested seven of 42 MHz each) and auction the overlay rights—i.e., the rights to the white spaces. The auction winners would then be able to negotiate with the incumbent licensees.
4. Incumbent licensees could be permitted to participate in the auction (as proposed by Kwerel and Williams, 2002). Some incumbents might decide that they would be better off participating in an auction, given the uncertain outcome of post-auction bargaining. Others might decide they could profit by "holding out" until after the auction.

Under this option, spectrum restructuring would take place through the auction as well as through post-auction negotiations and marketplace transactions between the incumbent licensees and the owners of the overlay rights. Indeed, the parties may form consortia prior to the bidding for the overlay licenses.

The question of how to divide the gains is essentially a political one. The government would directly gain the revenues from the auction and be responsible for funding the transition voucher program. White space auction revenues, which have been conservatively estimated to be between $9.4 billion and $24.4 billion, would be more than sufficient to fund the transition program (Jackson, Robyn, and Bazelon, 2008, p. 2).

The value of incumbents' licenses would increase substantially. The question is whether the government should share in a portion of that gain in economic value beyond the concomitant increased tax revenues.

A disadvantage of this approach is that there could be significant transactions costs associated with the spectrum restructuring process. The costs to wireless broadband providers of assembling the large parcels that they need could be substantial. However, the government auction would divide the overlay licenses into large parcels, which should mitigate this problem.

In addition, the fact that most remaining over-the-air viewers would be transitioning to a subscription service would greatly diminish the value of licenses for over-the-air broadcasting.

This, in turn, would diminish broadcasters' post-auction bargaining power, and would likely give them an incentive to participate in an auction, which would lower transactions costs.

Option 2: Mandatory Clearing of Broadcast Spectrum

1. The FCC would hold a procurement auction as above.
2. Once the transition to subscription TV had taken place, the government could repackage and auction the full 294 MHz.
3. Broadcasters would be compensated in a way that would make them more than whole. One way to do this would be to give the incumbents transferable auction vouchers based on the value of their spectrum at auction and tradable for cash.[45] The broadcasters would thereby receive a share of the increased value of the spectrum, while the federal government would receive the remainder.

Either option would achieve the goal of freeing up the broadcast spectrum. In the end, the two might not be very different; with over-the-air viewers transitioning to subscription TV, broadcasters would likely be inclined to participate in the auction under Option 1. We tend to favor Option 1 because of its voluntary nature—it gives broadcasters more flexibility to participate in the auction, negotiate after the auction, or retain their spectrum.

White Spaces

Either option would require the FCC to change course from its decision to allocate television white spaces to unlicensed uses, which the Commission adopted on November 4, 2008.[46] There would be no white spaces with either Option 1 or Option 2 and thus no room for any white-space device (WSD) to operate.

At this stage, the reversal of the FCC's white spaces decision would not leave significant investment stranded or disenfranchise an established user base. As of year-end 2009, only one white space deployment has been attempted, using experimental fixed equipment, as rules for device certification are still undetermined. One party that is involved with the project anticipates that rules will be finalized in 2010, and that mass-market equipment will be available for sale a year to 18 months after that.[47] Others are more uncertain of WSD potential.[48]

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[45] See Kwerel and Williams (2002).

[46] The allowance is, of course, subject to a number of sophisticated stipulations regarding non-interference; see *supra*, footnote 20.

[47] IT Business Edge interview with Rick Rotondo of Spectrum Bridge, available at http://www.itbusinessedge.com/cm/community/features/interviews/blog/white-space-channels-move-closer-to-reality/?cs=38237&page=2

Rescinding the white spaces decision would not preclude allocating some of the broadcast spectrum to unlicensed uses.[49] A proposal to do this, however, should be subject to a careful benefit-cost analysis. Moreover, the government should be required to purchase in the open market any spectrum that it chooses to allocate to such uses, much as it might purchase land to convert into a public park.[50] Required purchase would force the government to face the opportunity cost of spectrum allocated to unlicensed uses, leading to a better evaluation of the tradeoff between setting aside spectrum for such uses and letting market participants compete to acquire spectrum property rights.

Must Carry

Currently, broadcasters enjoy "must carry" rights, under which cable systems can be required to carry a local broadcaster's programming. These rights would be lost if a broadcaster ceased to broadcast. It is unclear, however, how valuable these rights are to broadcasters, many of whom choose to negotiate terms of carriage with cable companies (Bazelon 2009). As part of any spectrum deal, the broadcasters' must carry rights could be grandfathered.

C. Mobile Satellite Service

The MSS, or Mobile Satellite Service, allocation is set aside for communication between orbiters and mobile devices— i.e., for "satellite phone" networks. MSS operators are considered commercial mobile radio services (CMRS) providers by the FCC. In principle they have rights to sell broadband Internet access and other modern services. In practice, however, MSS has been very different from the traditional cellular experience. Even the world's most advanced system can provide customers with data downloads of only up to 64 kbps[51]—far less than the throughput achieved with state-of-the-art technology in nearby terrestrial bands. Satellite phones are more expensive and more complicated to use than are standard mobile phones. Although there is a demand for satellite phones for use in isolated areas where there is no standard cellular service, the devices have been adopted by a much smaller subscriber base—just over 1 million at year-

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[48] See news articles at http://www.informationweek.com/news/mobility/business/showArticle.jhtml?articleID=222000087, http://urgentcomm.com/policy_and_law/commentary/white-space-devices-questions-1022/index.html,

[49] See Lenard, White et al. (2006).

[50] If the government participated in an auction, procedures would need to be developed to assure that the government did not have any "insider" advantage.

[51] Utilizing the Terrestar-1 orbiter, launched in July 2009 by TerreStar. See http://www.dailywireless.org/2009/07/10/terrestar-successfully-launched/

end 2007.[52] Reflecting the difficulties of this business model, license holders in the band have had high rates of bankruptcy since the allocation was instated in the early 1990s.

Table 8
Mobile Satellite Services (MSS) Spectrum [a]
Possible Ancillary Terrestrial Component (ATC)

Band	Bandwidth (MHz)	Relevant Frequencies	Notes
L-Band	68	1525 - 1559 MHz 1626.5 - 1660.5 MHz	First with extensive commercial MSS. L-Band refers to 1-2 GHz generally. Inmarsat, SkyTerra (formerly MSV)
Big LEO	45.7	1610 - 1626.5 MHz 2483.5 - 2496 MHz	Big Low Earth Orbit. Allocated in 1993 for two-way voice and data. Globalstar, Iridum.
2 GHz (S-Band)	40	2000 - 2020 MHz 2180 – 2200 MHz	Allocated in 1997 for data, voice, and messaging. S-Band refers to 2-4 GHz generally. Terrestar, ICO
Total	153.7	per FCC (2009) [b]	

Source: FCC (2009), FCC.gov

[a] Does not include "Little LEO," a 4 MHz MSS allocation for narrowband services.

[b] FCC (2009) also counts a Big LEO downlink at 1613.8-1626.5, which falls entirely within the range tabled above. FCC.gov (http://fcc.gov/ib/sd/ssr/atc.html) lists frequencies that would attribute 33 MHz to Big LEO (which rectifies the above), but differs regarding L-Band (here 66 MHz), and 2 GHz (here 70 MHz: 1990-2025 and 2165-2200). The alternate total is thus 169 MHz.

The MSS industry is in the midst of an adjustment, however, following a rule change in 2003. The FCC now allows licensees of L-Band, Big LEO, and 2 GHz MSS allocations to introduce an "Ancillary Terrestrial Component" (ATC) to their satellite networks, provided that their activities meet FCC approval on several criteria.[53] Implementing ATC within a satellite system allows for superior coverage of hard-to-reach areas (e.g., dense urban zones) and greater service variety. In the words of MSS carriers, ATC would allow them to "dramatically

[52] See FCC (2009, Table 18).

[53] See *Satellite Flexibility Order* as referenced in note 743, FCC (2009). In short, licensees must maintain satellite-based service meeting coverage requirements, and restrict ATC (terrestrial) transmission to within their authorized footprint.

enhance…service offerings and expand their customer base."[54] Prior to receiving approval, one provider estimated that it could support 490 ATC calls in the bandwidth that it devotes to a single MSS call.[55] In effect, the deployment of terrestrial components is likely to reduce the differences between mobile voice/broadband as provided in MSS spectrum when compared with that of mainstream cellular networks.[56]

The FCC has granted ATC authority to several operators for a notable slice of spectrum, starting with MSV (now SkyTerra) in 2004. In October 2008, Globalstar (and affiliates) received FCC approval to make terrestrial transmissions in 19.275 MHz of the company's license.[57] The company will use this authority to lease spectrum to Open Range Communications, a rural wireless Internet service provider (WISP), for WiMax to be available to over six million Americans within five years.[58] ICO Global Communications was given ATC authority for 20 MHz of spectrum,[59] and has been in talks with Clearwire.[60] In January 2010 the FCC also approved Terrestar's 20 MHz for ancillary terrestrial use.[61]

The ATC order represents a compromise. It gives licensees greater flexibility to offer a combined satellite-cellular service, in order to give them a better chance of developing viable business models. However, flexibility is limited by the requirement that the terrestrial service be offered in combination with a satellite service. Thus, the ability to compete with cellular carriers is artificially constrained, presumably because the MSS licensees received their spectrum for free, while most of the cellular licensees paid for their spectrum at auction.

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[54] Mobile Satellite Service Provider Comments (ICO, MSV, Inmarsat, Globalstar, Terrestar), filed Mar. 2008. See FCC (2008), note 747.

[55] FCC, *Global Star, LCC Order and Authorization* (January 2006), ¶13; available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-06-121A1.pdf

[56] For regulatory purposes, satellite has not been considered a substitute for terrestrial service, due to its higher price and difficulty of use. When appropriate, MSS licensees are, however, considered CMRS providers. See FCC (2008, ¶¶ 246-247).

[57] Up from an initial authorization of 11 MHz in 2006. See Globalstar Inc. press release, May 2008; available at http://www.globalstar.com/en/news/pressreleases/press_display.php?pressId=484

[58]Globalstar press release, January 2009; available at http://www.globalstar.com/en/news/pressreleases/press_display.php?pressId=522

[59] ICO Global Communications press release, January 2009; available at http://files.shareholder.com/downloads/ICOG/820299933x0x264460/5fe38b31-6a93-4f47-83c0-38f64e2a7a8f/ICOG_News_2009_1_15_General.pdf

[60] ICO press release, (undated); available at http://investor.ico.com/releasedetail.cfm?ReleaseID=263326

[61] Press release reproduced at http://finance.yahoo.com/news/FCC-Grants-TerreStar-ATC-prnews-4257589070.html?x=0&.v=1

The MSS allocation is somewhat analogous to that of the television broadcast spectrum. It should, however, be simpler to solve because there are no over-the-air viewers to take care of. There will presumably be some stranded assets, which the broadcasters also have.

The simplest solution would be simply to make the licenses flexible, which would allow the spectrum to move (in due time) to its highest-valued use—likely to be mostly terrestrial wireless broadband, but only the market will can determine that. From an economics perspective, this is all that is required for efficiency.

There may be equity considerations, however, vis-à-vis incumbent wireless providers who paid large sums for their spectrum (the bands in Table 1 and perhaps soon, Table 4). One solution would be to allow the MSS licensees to participate in an auction (perhaps one of the auctions for federal or broadcast spectrum) under an arrangement that permits them to either sell the spectrum and share the gains with the government, or repurchase the spectrum under a flexible license with a formula that gives them some preferential treatment.

IV. Conclusion

The expansion of wireless broadband is a bright spot in the U.S. economy, but a shortage of liberally licensed spectrum rights could put a crimp in this expansion. Freeing up spectrum from other uses would allow greater expansion of wireless broadband and would bring substantial gains—likely in the hundreds of billions of dollars—for U.S. consumers, businesses, and the federal treasury. Because the legacy "command and control" regime for licensing spectrum does not allow market-based transactions to realize this reallocation and its concomitant gains, administrative and political actions are necessary.

In this report we have identified three major potential sources of spectrum that could be freed up for reallocation, along with the administrative and political steps that would be necessary. One route focuses on the freeing up of under-used government-held spectrum; the second route involves the transfer of spectrum that is currently used for television broadcasting; the third route involves liberalizing the MSS spectrum.

For freeing up under-used government spectrum, we have both short-run and long-run recommendations:

- For the short-run, we recommend that a National Academy of Sciences study compile an inventory of government-held spectrum and its uses, identify the opportunity costs of that spectrum, and make recommendations for the reallocation of under-used spectrum. That report would be followed by a high-level Government Spectrum Reform Task Force that would recommend a specific package of spectrum bands to be vacated by government and auctioned by the FCC. In subsequent years, NTIA should compile annual reports on

government uses of spectrum, the opportunity costs, and candidate bands for reallocation, and OMB should become a skeptical auditor of agencies' spectrum holdings and uses.

- For the long-run, we propose that a Government Spectrum Ownership Corporation (GSOC) should take ownership of all government-held spectrum and lease it to government users, at rates that would reflect the opportunity costs of the resources. This structure would mirror the current practice of the federal government's use of the General Services Administration (GSA) with respect to real estate and would introduce a much greater markets-orientation for government-held spectrum.

Our recommendation for the transfer of TV broadcasting spectrum starts with the recognition that the current market value of that spectrum is far below its market value for wireless broadband use, primarily because only a small fraction of American households still use over-the-air transmission for their TV reception. If these households could be subsidized to transition to subscription services, the 294 MHz of spectrum that is currently used for broadcasting would be available for reallocation. In either of the transition options that we offer, government revenues from auctioning freed-up spectrum plus taxes on the gain in spectrum value would be more than sufficient to cover the costs of the subsidies:

- Under Option 1, the current broadcast licensees would gain immediate flexibility in terms of the uses to which the spectrum could be put and their ability to transfer those rights, while the government would auction the overlay (white spaces) rights. Incumbent licensees could be permitted to participate in the government auction. A crucial issue would be whether (and to what extent) the federal treasury should share in the "windfall" that the broadcasters would receive.
- Under Option 2, the federal government would auction the entire 294 MHz of the broadcast spectrum and compensate the broadcasters at rates that would make them more than whole. Again, a crucial issue is the compensation (and thus the size of the broadcasters' windfall). An upper limit would be the market value of the spectrum at auction.

For reasons discussed in this paper, the two transition options would probably end up being quite similar. We favor Option 1, which gives broadcasters greater flexibility.

The MSS spectrum represents the third major opportunity for liberalizing licenses to permit the redeployment of the spectrum to higher-valued wireless broadband uses. The solution here is similar to the solution for broadband, but should be easier to implement because there is no problem analogous to that of over-the-air viewers who have to be taken care of. There are, however, equity considerations similar to those that characterize the broadcast spectrum. Nevertheless, it should be possible to liberalize the MSS licenses in a way that benefits all concerned.

The economic gains for the U.S. economy from expanding wireless broadband by freeing up under-used government spectrum and reallocating broadcast and MSS spectrum would be very large. This is truly a “win-win” opportunity that should be seized.

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