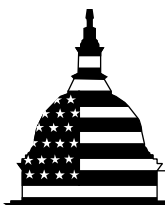


November 2012

SPECTRUM MANAGEMENT

Incentives, Opportunities, and Testing Needed to Enhance Spectrum Sharing



G A O

Accountability * Integrity * Reliability

Highlights of [GAO-13-7](#), a report to congressional committees.

Why GAO Did This Study

The increasing popularity of wireless devices that use spectrum, combined with federal spectrum needs for national defense and other public safety activities, have created concerns that a “spectrum crunch” is looming. However, there is also evidence that at any given time or place, spectrum lies fallow or is only intermittently used. In an effort to use spectrum as efficiently as possible, advisory groups and others have proposed solutions to share spectrum.

This requested report examines (1) what factors prevent users from sharing spectrum more frequently and (2) what actions the Federal Communications Commission (FCC), the National Communications Information Administration (NTIA), and others can take to encourage more sharing and efficient spectrum use. GAO reviewed plans and documents from FCC and NTIA regarding their management of nonfederal and federal spectrum-sharing activities, respectively. GAO also interviewed federal and commercial spectrum users, industry and academic experts, and other stakeholders.

What GAO Recommends

FCC and NTIA should jointly (1) report to Congress on the potential merits and effects of a spectrum fee, (2) determine how to best promote spectrum research and development, and (3) evaluate what regulatory changes might improve the spectrum sharing process. The agencies generally agreed with GAO’s findings but identified ongoing efforts that address the recommendations. GAO has modified the recommendations as described further in the report.

View [GAO-13-7](#). For more information, contact Mark Goldstein at (202) 512-2834 or goldsteinm@gao.gov.

November 2012

SPECTRUM MANAGEMENT

Incentives, Opportunities, and Testing Needed to Enhance Spectrum Sharing

What GAO Found

Some spectrum users may lack incentive to share spectrum or otherwise use it efficiently, and federal agencies and private users currently cannot easily identify spectrum available for sharing. Typically, paying the market price for a good or service helps to inform users of the value of the good and provides an incentive for efficient use. Federal agencies, however, pay only a small fee to the NTIA for spectrum assignments and therefore have little incentive to share spectrum. Federal agencies also face concerns that sharing could risk the success of security or safety missions, or could be costly in terms of upgrades to more spectrally efficient equipment. Nonfederal users, such as private companies, are also reluctant to share spectrum. For instance, license holders may be reluctant to encourage additional competition, and companies may be hesitant to enter into sharing agreements that require potentially lengthy and unpredictable regulatory processes. Sharing can be costly for them, too. For example, nonfederal users may be required to cover all interference mitigation costs to use a federal spectrum band, which might include multiple federal users. Sharing can also be hindered because information on federal spectrum use is lacking and information regarding some federal spectrum use may never be publicly available, a situation that makes it difficult for users to identify potential spectrum for sharing.

Federal advisors, agency officials, and experts have identified several options that could provide greater incentives and opportunities for more efficient spectrum use and sharing by federal and nonfederal users. These options include, among other things: considering spectrum usage fees to provide economic incentive for more efficient use and sharing; identifying more spectrum that could be made available for unlicensed use, since unlicensed use is inherently shared; encouraging research and development of technologies that can better enable sharing; and improving and expediting regulatory processes related to sharing. However, these options involve implementation challenges. For example, setting spectrum usage fees for federal users may not result in creating the proper incentives, because agency budgets might simply be increased to accommodate their current use. While new technologies that overcome some of the inherent challenges with sharing spectrum are being developed, proving those technologies under real-world conditions can be difficult, and few incentives exist at the federal level to encourage such technology development. Finally, FCC and NTIA have taken some actions to potentially reduce the amount of time and even the need for potential rulemakings sometimes associated with spectrum sharing, but stakeholders and experts suggested that more could be done to expedite the approval process, such as automating some steps and developing better capabilities to track the status of spectrum-sharing applications. However, any changes to federal regulatory processes related to spectrum management and sharing would need to be carefully studied with respect to potential benefits and costs.

Contents

Letter		1
	Scope and Methodology	3
	Background	4
	Some Users Lack Incentives and Face Barriers to Sharing Spectrum	11
	Incentives and Opportunities to Share Spectrum Could Be Expanded	17
	Conclusions	28
	Recommendations for Executive Action	28
	Agency Comments and Our Evaluation	29
Appendix I	Federal Agencies, Nonfederal Spectrum Users and Experts Interviewed Regarding Spectrum Sharing	32
Appendix II	Comments From the Department of Commerce	34
Appendix III	Comments From the Federal Communications Commission	37
Appendix IV	GAO Contact and Staff Acknowledgements	39
Table		
	Table 1: Subject Matter Experts Interviewed	33
Figures		
	Figure 1: Percentage of Federal Agency Frequency Assignments, 2012	6
	Figure 2: Illustration and Examples of Spectrum Sharing	7

Abbreviations

4G	fourth generation
AIP	Administered Incentive Pricing
CSMAC	Commerce Spectrum Management Advisory Committee
DARPA	Defense Advanced Research Projects Agency
FCC	Federal Communications Commission
FSMS	Federal Spectrum Management System
GHz	gigahertz
IRAC	Interdepartment Radio Advisory Committee
LTE	Long Term Evolution
MHz	megahertz
NTIA	National Telecommunications and Information Administration
OMB	Office of Management and Budget
PCAST	President's Council of Advisors on Science and Technology
Wi-Fi	wireless fidelity

This is a work of the U.S. government and is not subject to copyright protection in the United States. The published product may be reproduced and distributed in its entirety without further permission from GAO. However, because this work may contain copyrighted images or other material, permission from the copyright holder may be necessary if you wish to reproduce this material separately.



United States Government Accountability Office
Washington, DC 20548

November 14, 2012

The Honorable Fred Upton
Chairman
The Honorable Henry A. Waxman
Ranking Member
Committee on Energy and Commerce
House of Representatives

The Honorable John D. Rockefeller IV
Chairman
The Honorable Kay Bailey Hutchison
Ranking Member
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Greg Walden
Chairman
The Honorable Anna G. Eshoo
Ranking Member
Subcommittee on Communications and Technology
Committee on Energy and Commerce
House of Representatives

The propagation and popularity of smart phones, tablets, and other wireless devices has created an explosion in the demand for and use of more radio frequency spectrum to support services and data transmissions on these devices, particularly in dense, urban areas. Federal users—mostly government agencies—also require spectrum for national defense, homeland security, and other vital mission activities. To date, however, nearly all usable radio spectrum has been allocated either by the National Telecommunications and Information Administration (NTIA) within the Department of Commerce for federal government use or by the Federal Communications Commission (FCC) for commercial and other nonfederal use. Therefore, virtually no “green fields” of spectrum are currently available to allocate to new uses or technologies. Going forward, this scarcity could have implications for our economy, our competitiveness in global markets, and the ability of government at all levels to meet its key missions.

This situation notwithstanding, there is substantial evidence that at any given point in time at any given place, there is fallow or intermittently used

spectrum—certainly in sparsely populated rural areas, and even in heavily trafficked urban areas.¹ Some experts suggest that the scarcity of spectrum in the United States is to some extent a result of the manner in which this resource has been allocated, managed, and used, rather than because of a physical scarcity of the resource. In an effort to address increasing demands for spectrum access, the current and past Administrations, Congress, FCC, and others have proposed a variety of policy, economic, and technological solutions to address the availability and efficient use of spectrum. For example, in 2010, the administration set a goal for 500 megahertz (MHz) of federal and nonfederal spectrum currently being unused or under-used to be repurposed for mobile broadband use. However, we have previously reported that repurposing spectrum has been and can be a contentious and highly protracted process, typically taking years.² As a result, solutions geared toward greater sharing of spectrum among users—federal and nonfederal—have become more attractive because of the potential access to more spectrum and opportunities to use spectrum more efficiently that sharing presents. For instance, the President’s Council of Advisors on Science and Technology (PCAST) recently recommended that 1,000 MHz of spectrum previously occupied only by federal users be shared with nonfederal users.³

In light of these issues, and in response to your request, we examined (1) what factors currently prevent users from sharing spectrum more frequently and (2) what actions FCC, NTIA and others can take to encourage more sharing and more efficient spectrum use.

¹See Commerce Spectrum Management Advisory Committee, Incentives Subcommittee Final Report (Washington, D.C.: January 11, 2011); President’s Council of Advisors on Science and Technology, *Report to the President: Realizing the Full Potential of Government-held Spectrum to Spur Economic Growth*, (Washington, D.C.: July 2012); and Department of Commerce, *Spectrum Management for the 21st Century*, (Washington, D.C.: 2008).

²GAO, *Commercial Spectrum: Plans and Actions to Meet Future Needs, Including Continued Use of Auctions*, [GAO-12-118](#) (Washington, D.C.: November 2011).

³*Report to the President: Realizing the Full Potential of Government-held Spectrum to Spur Economic Growth*.

Scope and Methodology

We reviewed federal legislation, regulations, and processes regarding spectrum management and spectrum sharing, including NTIA's Manual of Regulations and Procedures for the Federal Radio Frequency Management; as well as various FCC plans, notices, orders and other publications related to spectrum management and sharing. We conducted multiple interviews with FCC, NTIA, and various advisory committees, such as the Commerce Spectrum Management Advisory Committee (CSMAC). We selected 7 of the 19 Interdepartment Radio Advisory Committee⁴ (IRAC) agencies—the Departments of Commerce, Defense, Homeland Security, Interior, Justice, Transportation, and Treasury—based on which agencies were most likely to have experience with spectrum sharing. We interviewed the spectrum managers for these departments to better understand their experiences with sharing, including successes and challenges, and analyzed the extent to which spectrum sharing was a part of their spectrum management plans.

We also interviewed a variety of stakeholders and experts outside the federal government with knowledge and experience related to spectrum sharing issues. These stakeholders and experts fell into four groups:

- Nonfederal spectrum users: We interviewed officials from seven commercial entities such as Verizon, Sprint, and other wireless and communications companies. We also interviewed local government officials regarding their spectrum sharing experiences. We selected these nonfederal users based on their experiences with sharing spectrum, or based on their vested interest in spectrum policy.
- Companies that create spectrum-sharing solutions: We interviewed two companies that create spectrum sharing technologies. We selected these companies based on recommendations from spectrum experts and federal agency officials about which companies were most active with spectrum sharing technology development.
- Industry and academic experts: We interviewed 16 industry and academic experts. We selected these experts based on their published and recognized research credentials for their work on

⁴IRAC's main function is to assist NTIA in assigning frequencies and in developing policies, procedures, and technical criteria on management and use of spectrum. The Department of Defense has multiple participants on the IRAC from the Army, Navy and Air Force. The other member agencies include the Departments of Agriculture, Energy, State and Veterans Affairs; Broadcasting Board of Governors; United States Coast Guard; National Aeronautics and Space Administration; National Science Foundation and United States Postal Service.

spectrum management, spectrum sharing and the economic impacts of spectrum related policies, and on other stakeholders' and experts' recommendations.

- International spectrum management officials: We interviewed spectrum management officials from Canada, the United Kingdom, and Australia to compare other countries' spectrum management and spectrum-sharing practices to that of the United States. We chose these three countries based on their level of experience dealing with spectrum-sharing issues. We also interviewed officials from the International Telecommunication Union to understand its role in advising international spectrum management and spectrum sharing policies.⁵

We also completed a literature search and reviewed recent reports and articles related to spectrum sharing, including academic and government reports as well as speeches and articles by the groups of officials and experts we interviewed as described above.

A complete list of the departments and agencies, experts and companies that we interviewed can be found in appendix I. The information and perspectives that we obtained from the interviews may not be generalized to all experts and industry stakeholders that have an interest in spectrum policy. Rather, comments and views were reviewed in context with current literature on spectrum management issues.

We conducted this performance audit from September 2011 to October 2012 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

In the United States, responsibility for managing spectrum—including allocating, assigning, regulating, and facilitating the sharing of spectrum—

⁵The International Telecommunication Union allocates global radio spectrum and develops technical standards for information and communication technologies and their networks, among other things. It was founded in 1865 and became a specialized agency of the United Nations in 1947. Its membership comprises 193 countries and over 700 private-sector entities.

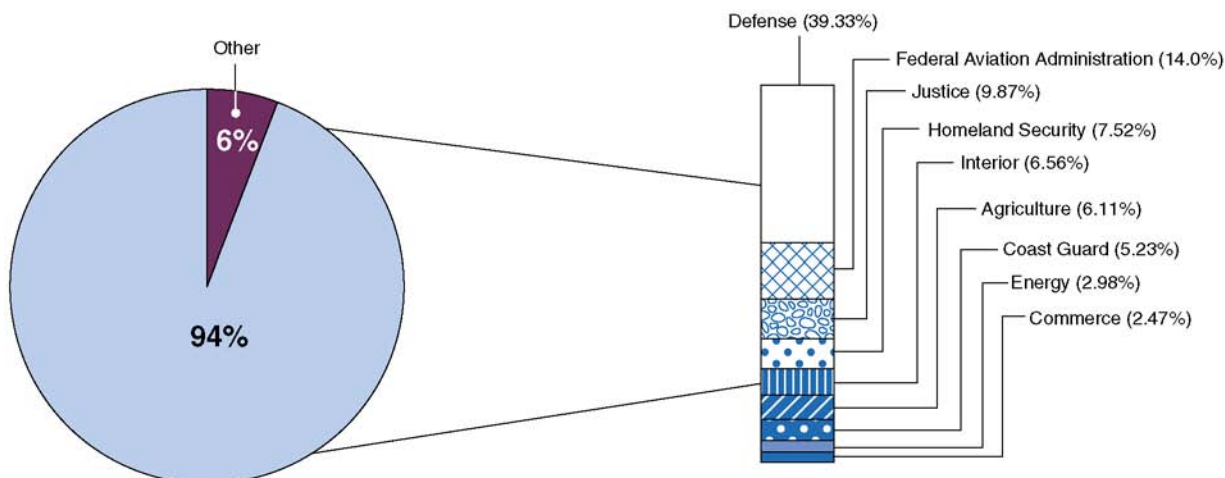
is divided between two agencies, NTIA and FCC. NTIA and FCC jointly determine the amount of spectrum allocated for federal and nonfederal use, including both exclusive and shared use. After this allocation occurs, in order to use spectrum, nonfederal users, such as wireless companies and local governments, must follow rules and be authorized by FCC to use specific frequencies.⁶ When spectrum is repurposed, FCC may also be authorized to hold an auction to distribute licenses through a bidding process. Federal users, like the military, must follow rules, and obtain frequency assignments from NTIA.⁷ Both NTIA and FCC have authority to issue rules and regulations on use of spectrum as necessary to ensure effective, efficient, and equitable domestic spectrum use.

Federal agencies use spectrum to help meet a variety of missions, including emergency communications, national defense, land management, and law enforcement. More than 60 federal agencies and departments combined have over 240,000 frequency assignments. As of September 2012, 9 departments and agencies had the vast majority of the assignments: the Department of Defense, the Federal Aviation Administration, the Department of Justice, the Department of Homeland Security, the Department of the Interior, the Department of Agriculture, the United States Coast Guard, the Department of Energy, and the Department of Commerce, respectively, hold 94 percent of all federally assigned spectrum. (See fig. 1.) Nonfederal entities (which include commercial companies and state and local governments) also use spectrum to provide a variety of services. For example, state and local police departments, fire departments, and other emergency services agencies use spectrum to transmit and receive critical voice and data communications, while commercial entities use spectrum to provide wireless services, including mobile voice and data, paging, broadcast radio and television, and satellite services.

⁶Act of June 19, 1934, ch. 652, 48 Stat. 1064, as amended by the Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, Title VI, §§ 6401, 6402, 126 Stat. 156, 223-225 (Feb. 22, 2012) (Communications Act), codified as title 47, United States Code Annotated §§ 307-3011 (Westlaw 2012).

⁷Telecommunications Authorization Act of 1992, Pub. L. No. 102-538, Title I, 106 Stat. 3533 (Oct. 27, 1992), as amended, codified at 47 U.S.C. ch. 8 (NTIA Authorization Act).

Figure 1: Percentage of Federal Agency Frequency Assignments, 2012



Source: GAO analysis of NTIA data.

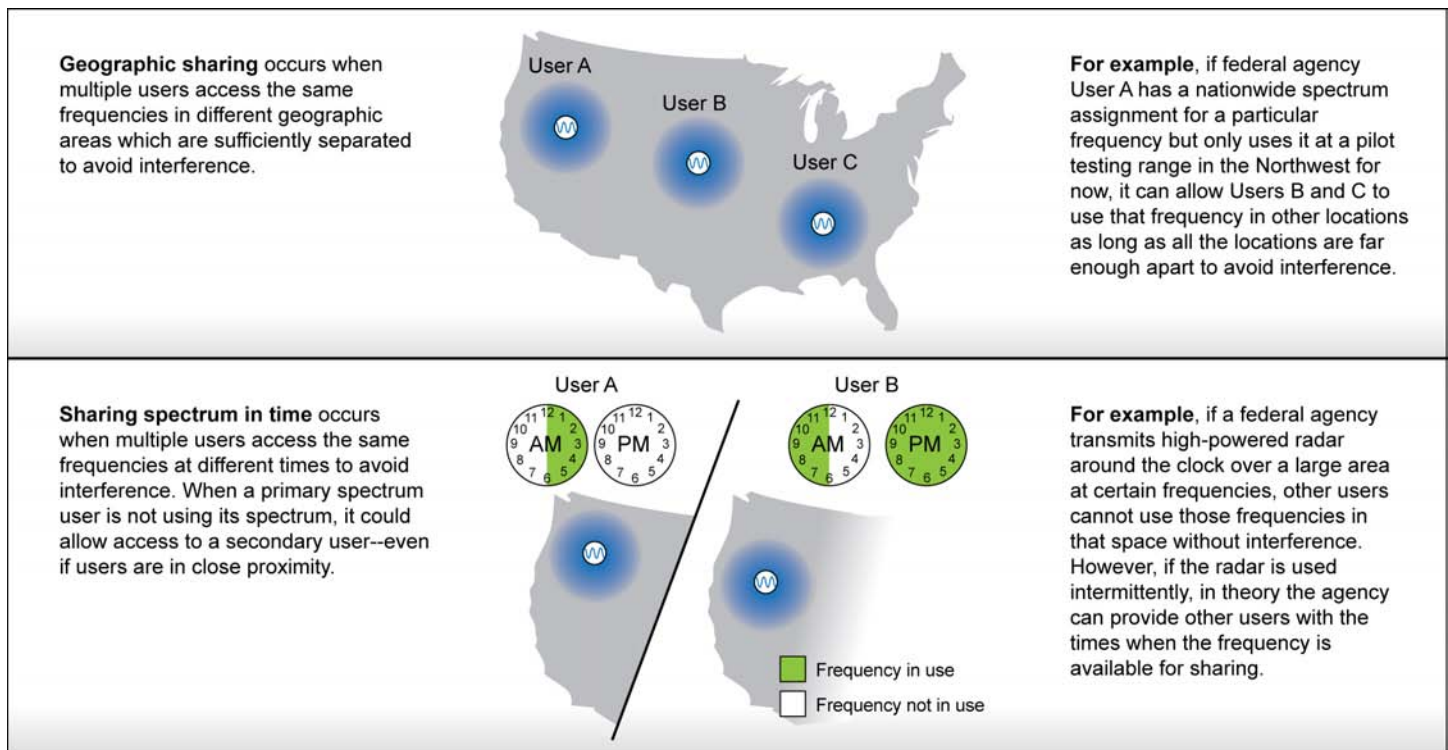
Not all spectrum has equal value. The spectrum most highly valued generally consists of frequencies between 225 and 3700 MHz, as these frequencies have properties well suited to many important wireless technologies, such as mobile devices, and radio and television broadcasting. According to NTIA's Office of Spectrum Management, federal agencies have exclusive use of about 18 percent of this highly valued spectrum, while nonfederal users have exclusive licenses to approximately 33 percent.⁸ The remainder of this spectrum is allocated to shared use. The types of and degree of sharing between governmental and nongovernmental users varies across the bands included within this shared spectrum. In addition, increasing demands on spectrum mean that federal and nonfederal users increasingly occupy adjacent bands, which in practice necessitates intensive coordination on technical rules. Estimates of the extent of predominant federal use within the spectrum allocated for shared use vary depending on the particular evaluation model and analyses employed. Depending on the estimate used, the total

⁸For many mobile radio systems, this is the portion of the spectrum where scarcity concerns are the greatest. However, for some industry representatives, the range of high-value spectrum is larger, located anywhere between 100 MHz to 6 GHz. As spectrum-dependent technologies improve over time, the definition of high-value spectrum can change.

percentage of the most highly valued spectrum exclusively or predominantly used by the federal government ranges from approximately 39 percent to 57 percent.

Spectrum sharing can be defined as the cooperative use of common spectrum that allows disparate missions to be achieved. In this way, multiple users agree to access the same spectrum at different times or locations, as well as negotiate other technical parameters, to avoid adversely interfering with one another. For sharing to occur, users and regulators must negotiate and resolve where (geographic sharing), when (sharing in time), and how (technical parameters) spectrum will be used. (See fig. 2.)

Figure 2: Illustration and Examples of Spectrum Sharing



Sources: GAO and Map Resources.

Both FCC and NTIA manage the process that leads to spectrum sharing between federal and nonfederal users. The steps involved in the process include the following:

-
- Prior to authorizing a nonfederal user to share spectrum with federal users, FCC will coordinate with NTIA on the allocation and service rulemakings required that define the technical and operating conditions for shared access to spectrum.⁹ NTIA will provide draft findings to IRAC, which provides advice to NTIA regarding federal spectrum. FCC participates in IRAC as a liaison. IRAC determines which agencies would be affected by the nonfederal use of spectrum and acts as the forum where those agencies consider how they may accommodate the nonfederal user. According to NTIA, any nonfederal user may approach NTIA and IRAC to discuss a proposal to use federal or shared bands to determine any obstacles and best ways forward. In some cases, FCC encourages nonfederal applicants to work directly with concerned agencies to try to reach agreement on an arrangement that could then be adapted to FCC rules or licenses. Similarly, if federal users request frequency assignments in nonfederal or shared bands, these requests must be coordinated with FCC through IRAC. According to NTIA, thus far, all requests by federal entities to change an allocation have gone through NTIA to FCC and have required an FCC rulemaking.
 - To have access to federal spectrum, the nonfederal entity must also obtain an FCC license. FCC will coordinate the allocation change or license application, including technical and operational conditions, for sharing federal spectrum through the Frequency Assignment Subcommittee of IRAC.
 - Next, before any spectrum sharing takes place in federal or shared spectrum, NTIA must vet the coordinating parties' requests, assign frequencies, and ensure that the systems the parties will be using—such as the land mobile radios used by state and local emergency responders that share spectrum with federal users—are compatible.

When spectrum sharing occurs solely among federal users within federal exclusive bands, IRAC's Frequency Assignment Subcommittee, using NTIA's database of federal frequency assignments, reviews the spectrum

⁹Under a Memorandum of Understanding between FCC and NTIA, all proposed actions that could potentially cause interference to government operations are coordinated with NTIA. In cases where a rulemaking is necessary to provide parties with access to federal spectrum, the rulemaking is coordinated with NTIA. For instance, FCC followed this process when a medical devices company sought to share spectrum used by the Department of Defense and other federal agencies. The proposed devices required wider bandwidths of spectrum to operate than similar medical devices that previously operated in medical network spectrum bands. To accommodate this and other similar uses, an FCC rulemaking was required to expand the amount of spectrum set aside for medical implant devices.

requests and identifies any potential interference concerns prior to commencing the shared use. Federal sharing occurs routinely. For example, the Departments of Defense, and Transportation, and Department of Commerce's National Oceanic and Atmospheric Administration share spectrum for directing aircraft and monitoring weather conditions. The Department of Defense also frequently shares spectrum among its own various programs, internal services and agencies.

When sharing occurs solely among nonfederal users, FCC seeks to allow flexibility for license holders to coordinate and negotiate spectrum-sharing agreements among themselves. FCC provides flexibility in a couple of ways. One way is through the expanded issuance of flexible use licenses. As opposed to traditional licenses, where usage is limited to the specific terms of the license (e.g., TV broadcast stations in specific markets), flexible use licenses allow for a wider array of uses without having to seek additional FCC authorization. Licensing expands the pool of potential entities that would be able to innovate and share the spectrum beyond those that would use the spectrum in a similar manner. However, with both traditional and flexible use licenses, if a proposed shared use is not consistent with the terms of a license, an FCC rulemaking would be required to allow that use. Another way FCC provides flexibility is with respect to its secondary market policies and rules that permit licensees to share their spectrum resource through spectrum lease arrangements.¹⁰ While FCC tracks these secondary market transactions, users negotiate their own terms, making it difficult to gauge the extent to which sharing occurs among these users, if at all.

Spectrum sharing also occurs through unlicensed access by anyone using wireless equipment certified by FCC for those frequencies. Equipment such as wireless microphones, baby monitors, and garage door openers share spectrum with other services on a non-interference basis typically within a limited geographic range and at low power levels to avoid interference with higher priority uses. In contrast with most licensed spectrum use, unlicensed users have no regulatory protection

¹⁰*In the Matter of Promoting Efficient Use of Spectrum through Elimination of Barriers to the Development of Secondary Markets*, 18 FCC Rcd. 20604 (2003) (*First Report and Order*); 18 FCC Rcd. 24817 (2003) (*Erratum*); 19 FCC Rcd. 17503 (2004) (*Second Report and Order*), , 22 FCC Rcd. 7209 (April 11, 2007) (*Third Report and Order*); *see also* 47 C.F.R. Pt. 1, Subpt. X.

against interference from other licensed or unlicensed users in the band. Unlicensed use is regulated to ensure that devices do not cause interference to other operations in the spectrum. For example, wireless fidelity (Wi-Fi)¹¹ devices share some band segments in the 5 gigahertz (GHz) range with military radar subject to the condition that the Wi-Fi devices are capable of spectrum sensing via dynamic frequency selection; if the Wi-Fi device detects a radar signal, the device must immediately vacate the channel the radar signal is on.

Many technological developments have also increased spectrum efficiency and further enabled sharing. For example, dynamic spectrum access technologies under development could allow equipment to sense and select among available frequencies in an area, efficiently using whatever frequencies might be available. This allows users to share frequencies in the same location in very small increments of time.¹² Software-defined radios also use spectrum more efficiently by accessing different frequencies in one location. In addition, these radios use more efficient batteries that allow them to perform more sophisticated tasks while using less spectrum than traditional radios. As another example, small cell technology allows users to share the same frequencies in close proximity to each other. Further, emerging fourth generation (4G) Long Term Evolution (LTE) technologies, as used by some smart phones to access the Internet, promise improvement in data transfer speeds.¹³ Research continues on these and other fronts to enable more efficient use of spectrum, including sharing.

¹¹Wi-Fi is a technology that is often used in conjunction with a customer's Internet service to connect devices, such as computers and smart phones, located within the customer's home or business to the Internet.

¹²Dynamic spectrum access technologies are currently able to sense for available frequencies before transmission (listen before talk), but not sense during transmission. (listen while talk) Sensing before transmission involves sensing available frequencies, then jumping and transmitting, which causes lag time. The technology to enable sensing during transmission, which would allow a user to seamlessly continue communication while moving geographically through spectrum bands is still under development.

¹³The international definition of 4G technology is transmitting data at 100 Megabits per second, but current 4G LTE technologies deliver top speeds of only 15 Megabits per second.

Some Users Lack Incentives and Face Barriers to Sharing Spectrum

Some Users Lack Economic Incentives to Share Spectrum

While federal spectrum users often share spectrum among themselves, they may have little economic incentive to otherwise use spectrum efficiently, including sharing it with nonfederal users. From an economic perspective, when a consumer pays the market price for a good or service and thus cannot get more of it without this expense, the consumer has an incentive to get the most value and efficiency out of the good as possible. If no price is attached to a good—which is essentially the case with federal agencies’ use of spectrum¹⁴—the normal market incentive to use the good efficiently may be muted. In the case of federal spectrum users, obtaining new spectrum assignments may be difficult, so an agency may have an incentive to conserve and use the spectrum it currently has assigned to it or currently shares efficiently, but the extent of that incentive is likely weaker than if the agency had to pay market price for all of its spectrum needs. Consequently, federal spectrum users do not fully face a market incentive to conserve on their use of spectrum or use it in an efficient manner. The full market value of the spectrum assigned to federal agencies has not been assessed, but, according to one industry observer, would most likely be valued in the tens of billions of dollars. Similarly, many nonfederal users, such as television broadcasters and public safety entities, did not pay for spectrum when it was assigned to them and do not pay the full market price for their continuing use of spectrum, so, like federal agencies, they may not fully have market-based incentives to use spectrum efficiently.¹⁵

In contrast, licensed, commercial users that purchase spectrum at auction generally have market incentives to use their spectrum holdings efficiently, but these users also have incentives that work against their

¹⁴Agencies pay only a small, annual fee for their spectrum which is not comparable to its full market value. According to NTIA, federal agencies pay \$122 for each frequency assignment, totaling about \$30 million paid by 47 agencies to NTIA for fiscal year 2012.

¹⁵It is the case, however, that when ownership of these companies changes hands, purchasers do pay for the value of all the assets of the company—including the value of the spectrum license.

sharing spectrum. FCC officials and industry stakeholders and experts told us that these users may prefer not to share their unused spectrum because they are concerned about the potential for interference to degrade service quality to their customers. Also, they may not want to give potential competitors access to spectrum. Industry stakeholders and experts also said that companies seeking spectrum may prefer obtaining exclusive spectrum licenses over sharing spectrum that is licensed to another company or federal user, given uncertainties about regulatory approvals, interference, and enforcement if interference occurs.

Several Barriers Can Deter Users from Sharing Spectrum

Federal agencies will not risk mission failure, particularly when there are security and public safety implications. According to the agency officials we contacted, federal agencies will typically not agree to share spectrum if it puts achievement of their mission at risk. The officials stressed that when missions have security and safety implications, sharing spectrum may pose unacceptable risks. For example, the military tests aircraft and trains pilots using test ranges that can stretch hundreds of miles, maintaining constant wireless contact. While there may be times and locations where the frequencies are not in use because aircraft are not in the area, communication frequencies in the test ranges cannot be shared, according to officials in the Department of Defense, because even accidental interference in communications with an aircraft could result in catastrophic mission failure. Further, sharing information about such flights could expose pilots and aircraft, or the military's larger mission, to increased risk. Federal law enforcement agencies are also concerned about how sharing spectrum could put missions at risk. For example, officials at the Departments of Treasury and Justice explained that interference with communications among agents could put the agents in danger and cause them to miss mission critical information. According to officials from the Department of Justice, the department tested sharing spectrum with a major commercial carrier in a metropolitan area in 2008 and concluded that the department and the carrier could not co-exist on the same spectrum. NTIA also reported that although sharing should be accommodated when appropriate, it is necessary to establish clear regulatory mechanisms for sharing to ensure that federal users are not required to assume responsibility for mitigating interference.¹⁶

¹⁶United States Department of Commerce, *Relocation of Federal Radio Systems from the 1710- 1755 MHz Spectrum Band: Fourth Annual Progress Report* (March 2011).

According to FCC officials, concerns about risk of mission failure can drive conservative technical standards for federal agencies' missions that can make sharing spectrum impractical. In general, the technical analyses and resulting standards federal agencies develop are based on worst-case scenarios and not on assessments of the most likely scenario or a range of scenarios. Moreover, in contrast to FCC's open rulemaking process, there is little opportunity for public input to the federal agencies' standards-setting process. Stakeholders may meet or have discussions with NTIA and the relevant federal agencies, but this occurs without any formal public process. Nor do stakeholders have any effective means to appeal other than by asking FCC to reject NTIA's analysis or standards.

Spectrum sharing can be costly. FCC and NTIA officials, as well as other agency officials and an industry stakeholder, told us that sharing federal spectrum can be costly for both the nonfederal and federal users seeking to share for the following reasons:

- Users may find that mitigation of potential interference can be costly in terms of equipment design and operation. For example, according to officials from one agency, sharing spectrum outside a law enforcement environment would require cognitive radios, which could be costly.¹⁷
- Users applying to share federal frequencies may find that those frequencies are being used by more than one federal agency or program. As a result of needing to mitigate interference for multiple users, costs to share spectrum in that band could increase.
- Federal users often use and rely on proven older technology that was designed to use spectrum to meet a specific mission and may be less efficient than more modern systems. Limited budgets may also prevent users from being able to invest in newer technology that can facilitate easier sharing. For example, officials at one agency said they maintain and use systems until the end of the system's life cycle to assure continuity of operations and security.

Spectrum-sharing approval and enforcement processes can be lengthy and unpredictable. FCC and NTIA processes can cause two main problems when nonfederal users seek to share federal spectrum, according to stakeholders:

¹⁷ In any moment in time, cognitive radios have the ability to determine and use spectrum that is unused and available.

-
- The spectrum-sharing approval process between FCC and NTIA can be lengthy and unpredictable, and the risk associated with it can be costly for new entrants. FCC officials told us that its internal processes can potentially last years if a rulemaking is required to allow shared use of spectrum.¹⁸ In addition to that time, NTIA officials said that IRAC's investigation of potential harmful interference could also take months. In one example, federal users currently share the spectrum band of 413-457 MHz with a nonprofit medical devices provider. The spectrum is used for transmissions related to implant products for veterans. It took FCC, NTIA and the spectrum users approximately 2 years (from 2009 to 2011) to facilitate this arrangement because an FCC rulemaking was required and all parties agreed to a lengthy evaluation of potential interference.¹⁹ The nonprofit in this case was funded by an endowment and was not dependent on income from the device to sustain itself during this process, but such delays, and the potential for a denial because of findings of harmful interference risks, could discourage for-profit companies from developing and investing in business plans that rely on sharing federal spectrum. However, officials at one agency commented that they have seen the timing of NTIA approval of federal participation drastically reduced over the past several years, from many months to less than a month as a result of additional coordination and negotiation of sharing done prior to the submission of frequency requests.
 - Stakeholders we interviewed told us that when federal and nonfederal users share spectrum, both parties worry that harmful interference may affect their missions or operations if the other party overreaches or does not follow the agreement. They also fear that any enforcement actions taken by FCC will happen too slowly to protect their interests and that enforcement outcomes may be unfavorable. According to officials at one agency, there are not many examples of large scale sharing of federal and nonfederal systems and limited

¹⁸The time it takes to complete rules varies because of the unique nature of each rulemaking. Certain factors, such as the technical complexity of the issue being addressed and the priority of the rulemaking in comparison to other issues, can also affect rulemaking time frames. FCC's rulemaking process includes multiple steps as outlined by law with opportunities for the public to participate. FCC is generally not required to complete rules within limited time frames.

¹⁹According to Department of Defense officials, both the federal stakeholders, including the Department of Defense, and the medical device provider were involved in the interference analysis.

governance and enforcement mechanisms exist to support such efforts.

Similar problems can arise when nonfederal users share spectrum with each other. Distrust of each other and of FCC's decision-making and enforcement processes could discourage sharing. For example, if a proposed shared use does not fall within the terms of the incumbent's license, FCC may need to engage in rulemaking proceedings, which can be long and unpredictable and can make spectrum-sharing arrangements unattractive to companies that otherwise might consider sharing.

Users May Be Unable to Easily Identify Spectrum Available for Sharing

Besides lacking incentives and overcoming other barriers, users may also have difficulty identifying spectrum available for sharing because data on available spectrum is incomplete or inaccurate, and information on some federal spectrum usage is not publicly available. According to NTIA officials, coordinating spectrum sharing requires accurate data on users, frequencies, locations, times, power levels, and equipment, among other things. We recently reported that both FCC's and NTIA's spectrum databases may contain incomplete and inaccurate data.²⁰ We reported that a substantial number of surveyed users of FCC's largest and most accessed license database, the Universal Licensing System, said that inaccurate and missing data hindered their use of the system to a great or moderate extent.²¹ NTIA collects basic, descriptive information on federal spectrum use, such as agency name, frequency, and location, in its Government Master File, and relies on agencies to evaluate and report their own current and future spectrum needs, even though agencies have not always provided accurate information on their spectrum use, which could be useful in coordinating sharing arrangements.²² Further, federal agency spectrum managers told us that agencies have not been asked to

²⁰In November 2011, we reported on FCC's Universal Licensing System, Consolidated Database System, International Bureau Filing System, and Experimental Licensing System. See GAO, *Commercial Spectrum: Plans and Actions to Meet Future Needs, Including Continued Use of Auctions*, [GAO-12-118](#) (Washington, D.C.: Nov. 23, 2011). In April 2011, we reported on NTIA's Government Master File database. See GAO, *Spectrum Management: NTIA Planning and Processes Need Strengthening to Promote the Efficient Use of Spectrum by Federal Agencies*, [GAO-11-352](#) (Washington, D.C.: Apr. 12, 2011).

²¹[GAO-12-118](#).

²²[GAO-11-352](#).

regularly update their spectrum plans, in which they were required to include an accounting of spectrum use. Federal agencies were directed to submit spectrum plans to NTIA and provide updates every 2 years.²³ Since 2008, NTIA has ceased requesting those updates and has put its strategic planning initiatives on hold because of limited resources.

NTIA is developing a new data system that officials believe will provide more robust data that will enable more accurate analysis of spectrum usage and potential interference. The new system may in turn identify more sharing opportunities. NTIA officials plan for the new Federal Spectrum Management System (FSMS) to house more detailed data about agencies' spectrum usage than the current Government Master File, including times of use, power levels, and equipment, among other information not currently collected. FSMS is scheduled to be operational in fiscal year 2014. However, the data will only be available to IRAC members and will not be publicly available.

Legislation has been introduced to try to address the lack of publicly available data on spectrum usage broadly.²⁴ The legislation would require in part that FCC, in consultation with NTIA and the White House Office of Science and Technology, prepare a report for Congress that includes an inventory of each radio spectrum band they manage. The inventory is also to include data on the number of transmitters and receiver terminals in use, if available. Other technical parameters that allow for more specific evaluation of how spectrum can be shared will also be inventoried, including coverage area, receiver performance, location of transmitters, percentage and time of use, and a list and described use of unlicensed devices authorized to operate in the band. However, experts and federal officials we contacted told us that there may be some limitations to creating such an inventory. For instance, measuring spectrum usage can be difficult because it can only be accomplished on a small scale and technologies to measure or map widespread spectrum usage are not yet available.²⁵ Additionally, FCC and NTIA officials told us that information on some federal spectrum bands may never be made

²³See, *President's Memorandum on Improving Spectrum Management for the 21st Century*, 49 Weekly Comp. Pres. Doc. 2875 (Nov. 29, 2004).

²⁴S. 455, § 3, 112th Cong. (2011).

²⁵The Department of Defense's Defense Advanced Research Projects Agency is working on frequency mapping, as discussed later in this report.

publicly available because of the sensitive or classified nature of some federal spectrum use.

Incentives and Opportunities to Share Spectrum Could Be Expanded

Federal advisors and experts we spoke with identified several options that could provide incentives and opportunities for more efficient spectrum use and sharing, by federal and nonfederal users, which include, among others: (1) assessing spectrum fees; (2) expanding the availability of unlicensed spectrum; (3) identifying federal spectrum that can be shared and promoting sharing; (4) requiring agencies to give more consideration to sharing and efficiency; (5) improving and expediting the spectrum-sharing process; and (6) increasing the federal focus on research, development and testing of technologies that can enable sharing, and improve spectral efficiency. We have previously reported that to improve spectrum efficiency among federal agencies, Congress may wish to consider evaluating what mechanisms could be adopted to provide better incentives and opportunities for agencies to move toward more efficient use of spectrum, which could free up some spectrum allocated for federal use to be made available for sharing or other purposes.²⁶

Assessing Spectrum Fees

Several advisory groups and industry experts, including those we interviewed, have recommended that fees be assessed based on spectrum usage. As previously mentioned, with the exception of fees for frequency assignments, federal users incur no costs for using spectrum and have few requirements for efficient use. As a result, federal users may have little incentive to share spectrum assigned to them with nonfederal users or identify opportunities to use it more efficiently—except to the extent that sharing or more efficient use helps them achieve their mission requirements. In 2011, the CSMAC Incentives Subcommittee recommended that NTIA and FCC study the implementation of spectrum fees and solicit input from both federal and nonfederal users that might be subject to fees.²⁷ The National Broadband Plan has also recommended that Congress consider granting FCC and NTIA authority to impose fees on unauctioned spectrum license holders—

²⁶GAO, *2012 Annual Report: Opportunities to Reduce Duplication, Overlap and Fragmentation, Achieve Savings, and Enhance Revenue*, [GAO-12-342SP](#) (Washington, D.C.: Feb. 28, 2012).

²⁷CSMAC Incentives Subcommittee Final Report.

such as TV broadcasters and public safety entities—as well as government users.²⁸ Fees could help to free spectrum for new uses, since licensees that use spectrum inefficiently may reduce their holdings or pursue sharing opportunities once they bear the opportunity cost of letting their spectrum remain fallow or underused. FCC officials told us that they have proposed spectrum usage fees at various times including in FCC's most recent congressional budget submission and have requested, but have yet to receive, legislative authority to implement such a program.²⁹

While noting the benefits of spectrum fees, the CSMAC Incentives Subcommittee report also notes specific concerns about the impact of spectrum fees on government users. For instance, some CSMAC members expressed concern that fees do not fit into the federal annual appropriations process and that new appropriations to cover fees are neither realistic nor warranted in the current budget environment. Other members suggested that fees will have no effect because agencies will be assured additional funds for their spectrum needs. Similarly, the National Broadband Plan notes that a different approach to setting fees may be appropriate for different spectrum users, and that a fee system must avoid disrupting public safety, national defense, and other essential government services that protect human life, safety, and property.³⁰

To address some of the concerns regarding agency budgets, the recent PCAST report recommended the use of a “spectrum currency” process to promote spectrum efficiency. Rather than using funds to pay for spectrum, federal agencies would each be given an allocation of synthetic currency that they could use to “buy” their spectrum usage rights. Usage fees would be set based on valuations of comparable private sector uses for which the market has already set a price. Agencies would then have an incentive to use their assignments more efficiently or share spectrum. In the PCAST proposal, agencies would also not bear the costs of making spectrum available to others for sharing, because they could be

²⁸ In 2010, an FCC task force issued the *National Broadband Plan*. Federal Communications Commission, *Connecting America: The National Broadband Plan*, p. 83, Recommendation 5.6, (Mar. 16, 2010).

²⁹ Federal Communications Commission, *Fiscal Year 2013 Budget Estimates Submitted to Congress*, p15 (Washington, D.C.: February 2012).

³⁰ *The National Broadband Plan*, p83, Recommendation 5.6 (Mar. 16, 2010).

reimbursed for their investments that made sharing possible from a proposed Spectrum Efficiency Fund.³¹

Internationally, some regulatory agencies have moved forward with charging market based rates for spectrum. Officials in two of the countries we spoke with said that the regulatory agency in their country collects user fees for government-agency spectrum use that reflect the opportunity cost of spectrum and serve as a means to encourage greater efficiency. For instance, the Australian Communications and Media Authority assesses two types of license fees for devices: (1) administrative charges to recover the direct costs of spectrum management and (2) annual license taxes to recover the indirect government costs of spectrum management. Officials suggested that license fees provide incentives for efficient use. Similarly, the Office of Communications in the United Kingdom uses a concept known as Administered Incentive Pricing (AIP) to set charges for spectrum holdings to reflect the value of the spectrum and to promote efficient use. Officials in these countries told us that the fee structure also encourages agencies to seek more opportunities to share spectrum. For example, in response to the United Kingdom's AIP system, one ministry conducted a study of which spectrum bands could be shared or, if not in full use, released for use by others. The ministry identified at least five bands to share and released additional bands because the cost associated with retaining those rights was not economically feasible for intermittent use. As a result, the ministry relinquished its rights to those underused bands.

Expanding Unlicensed Use

According to stakeholders, unlicensed use is a valuable complement to licensed use and more spectrum could be made available for unlicensed use. Spectrum for unlicensed use can be used efficiently and for high value applications, like Wi-Fi, for example.³² While FCC has generally

³¹The PCAST recommended that the existing Spectrum Relocation Fund be redefined as a revolving Spectrum Efficiency Fund that reimburses federal agencies for investments in spectrum sharing and efficiency.

³²Wi-Fi networks can permit multiple computing devices in each discrete location to share a single wired connection to the Internet, thus efficiently sharing spectrum. Wi-Fi technologies are also being used to relieve network congestion. One report suggests that major wireless carriers, even with their large portfolios of exclusive-use, licensed spectrum, often rely on Wi-Fi infrastructure to offload traffic from their networks in congested areas, as much as 21 percent by some accounts.

relied on auctions to license spectrum, which over the years have generated billions in dollars of revenue for the United States Treasury, FCC is attempting to make more unlicensed spectrum available in the hope of fueling innovation and economic growth. Increasing the amount of spectrum available for unlicensed use allows more users to share spectrum without going through lengthy negotiations and interference mitigations, and also promotes more experimentation and innovation. To access exclusively licensed spectrum, users must enter into sharing agreements with the license holder and negotiate access each time they wish to use that spectrum. By contrast, when spectrum is available for unlicensed purposes, such negotiation is generally not needed and, according to some experts, may lead to more widespread experimentation and the development of innovative technologies.

More recently, FCC has provided unlicensed access to additional spectrum, known as TV “white spaces,” to help address spectrum demands.³³ The white spaces refer to the buffer zones that FCC provided between the television broadcasters to mitigate unwanted interference between adjacent stations. In the TV white space rules, the buffer zones are no longer needed, and FCC approved the previously unused spectrum for unlicensed use. To identify available white space spectrum, devices must access a database that responds with a list of the frequencies that are available for use at the device’s location.³⁴ As an example, one local official explained that the City of Wilmington, North Carolina, uses TV white space spectrum to provide a network of public Wi-Fi access and public-safety surveillance functions. However, some experts have noted that the use of white space for rural areas holds more promise than large, dense urban areas because the sheer number of TV stations and higher usage in those areas makes use of the white spaces more challenging.

³³In the Matter of Unlicensed Operation in the TV Broadcast Bands, 27 FCC 3,692 (Apr. 5, 2012).

³⁴To date, FCC has designated two administrators to locate available white space spectrum for users of unlicensed devices, Spectrum Bridge and Telcordia Technologies. Devices must operate only on those channels designated by the administrator.

Identifying Federal Spectrum That Can Be Shared and Promoting Sharing

FCC and NTIA have noted the importance of sharing federal spectrum as a means to address spectrum demand. FCC's Chairman recently said that it has become increasingly harder to find free and clear blocks of spectrum.³⁵ The Chairman further said that it would be counterproductive to be limited to the choices of reallocation or nothing and that it may be the case that in some bands, sharing could allow access to spectrum that might otherwise take years and be costly to make available to other users. As we previously mentioned, in 2010, the President directed federal agencies to clear 500 MHz of spectrum for nonfederal uses by 2020.³⁶ In response to this directive, NTIA identified bands to evaluate for repurposing. For example, an interagency group was formed to determine the viability of accommodating commercial wireless broadband in the 1755-1850 MHz band.³⁷ However, the evaluation found that clearing this 95 MHz band may take 10 years, cost \$18 billion, and cause significant disruption. Furthermore, some federal systems could remain in the band indefinitely. To support NTIA's effort regarding this band, FCC recently granted special temporary authority for T-Mobile to conduct tests to explore sharing between commercial wireless services and federal systems operating in the 1755-1780 MHz band.³⁸ NTIA has also noted that the federal government must ensure effective spectrum use and push for sharing and other innovative uses wherever possible.³⁹ Further, it is critical that agencies participate in identifying strategies for more efficient use of spectrum, including sharing it, while maintaining essential federal missions. For example, NTIA asked CSMAC to advise on what kinds of sharing are workable in the long term. Consequently, CSMAC is reviewing options to analyze the impact federal systems remaining in the band might have on future commercial uses, and the sharing conditions that might be required to protect incumbent systems.

³⁵FCC Chairman Julius Genachowski, *Prepared Remarks to International CTIA Wireless* (May 8, 2012).

³⁶*Unleashing the Wireless Broadband Revolution*, 75 Fed. Reg. 38,387 (June 28, 2010).

³⁷U.S. Department of Commerce, *An Assessment of the Viability of Accommodating Wireless Broadband in the 1755-1850 MHz Band* (March 2012).

³⁸Special license granted to T-Mobile License LLC effective August 13, 2012.

³⁹United States Department of Commerce, *Plan and Timetable to Make available 500 Megahertz of Spectrum available for Wireless Broadband* (October 2010).

Recent PCAST recommendations could also create opportunities for nonfederal users to share 1,000 MHz of spectrum previously occupied only by federal users. Out of concern that additional clearing of federal users from spectrum is not sustainable, PCAST recently recommended that the President issue a new policy memorandum calling for the federal government to immediately identify 1,000 MHz of federal spectrum for sharing with nonfederal users.⁴⁰ To facilitate sharing this spectrum, PCAST also recommended that FCC and NTIA implement a federal spectrum access system that includes data on when and where federal users could allow access to fallow spectrum. Such a system could help streamline the regulatory processes involved in sharing that we discussed earlier. However, PCAST acknowledged that implementing the structure they recommended will not be easy and could take a long time. Moreover, some experts and industry stakeholders suggest that sharing 1,000 MHz of federal spectrum may be no easier or less costly than previous efforts to vacate half that amount, given the barriers to sharing that exist.

Requiring Agencies to Give More Consideration to Spectrum Sharing and Efficiency

In 2011, the Office of Management and Budget (OMB) updated its guidance to federal agencies on preparing the fiscal year 2013 budget by asking agencies to consider the economic value of spectrum when developing their economic justifications for procuring new equipment.⁴¹ The guidance noted that spectrum should generally not be considered a free resource, but rather should be considered to have value. Therefore, budget requests for systems that require spectrum should include the evaluation of alternative systems or methods that reduce spectrum needs, such as spectrum sharing. In January 2011, CSMAC reported that the focus of this process had been on capital planning. The Committee stated that it believed it would be more useful to focus on ensuring that agencies give more consideration to trade-offs in spectrum use in their management processes. They also said that doing so will likely yield greater improvements in overall spectrum management and use. Toward that end, with respect to the budget for major spectrum-dependent communications systems, the Committee rewrote the circular, recommending that agencies specify in their spectrum proposals (a)

⁴⁰*Report to the President; Realizing the Full Potential of Government-held Spectrum to Spur Economic Growth.*

⁴¹Office of Management and Budget, *Preparation, Submission, and Execution of the Budget, Circular No. A-11* (Washington, D.C.: August 2011).

whether the system will share with other existing systems, (b) the extent to which replacement systems will be more spectrally efficient compared to the prior system, and (c) that there was consideration of non-spectrum dependent or commercial alternatives. The Middle Class Tax Relief and Job Creation Act required that OMB implement these recommendations.⁴² We have also reported that federal agencies generally invest in more spectrally efficient technologies when mission needs demand it, not according to any underlying, systematic consideration of spectrum efficiency.⁴³ As a result, we recommended that FCC and NTIA jointly develop accepted models and methodologies to assess the impact of new technologies on overall spectrum use and that NTIA determine how to provide incentives to agencies to use spectrum more efficiently.⁴⁴

Improving and Expediting the Spectrum-Sharing Process

FCC and NTIA have taken some actions to potentially reduce the amount of time and even the need for some potential rulemakings associated with spectrum sharing, but stakeholders and experts we interviewed suggested that more could be done to expedite the process. NTIA also encourages communication between federal and nonfederal users regarding sharing plans to deal with potential interference and other technical issues early in the process. These communications are important to provide certainty to nonfederal users about the availability of shared spectrum while also ensuring that critical federal operations are protected.

Stakeholders suggested that NTIA and FCC could do more to streamline or automate their processes, and that more complete databases of spectrum use, as discussed earlier, could help potential sharing entities identify opportunities. Some experts argued for FCC to shift from a “command and control” approach for spectrum management to a regulatory approach that was more flexible and adaptable to new technologies. Others argue that the process is further slowed down and

⁴²47 U.S.C. § 1456.

⁴³GAO, *Spectrum Management: Better Knowledge Needed to Take Advantage of Technologies That May Improve Spectrum Efficiency*, [GAO-04-666](#) (Washington, D.C.: May 2004).

⁴⁴In response to the recommendation, FCC and NTIA jointly prepared the Federal Strategic Spectrum Plan which established a test bed and models to measure the impact of new technologies on spectrum use.

complicated because two regulatory agencies are involved as opposed to a single agency, as is the case in other countries, and other industries.

CSMAC also reported that FCC and NTIA could do more to streamline the sharing approval process. For example, a common frustration is that a nonfederal entity seeking to share federal spectrum is unable to precisely follow the status of its spectrum sharing application once it is filed with the FCC. Further, it is not transparent in the experimental licensing process on the FCC website when FCC transmits applications to NTIA, when NTIA responds to FCC, and whether that response contains questions to which the applicant must respond to progress the application. On the NTIA side, IRAC's Frequency Assignment Subcommittee established a review period of approximately nine days to respond with concurrence or concerns regarding an application. NTIA's website provides some information regarding the status of an application in the IRAC process; however, the information is very generic and the nonfederal applicant has no means to obtain information as to why its request was tabled or to engage directly with the concerned parties. For applicants to more proactively engage FCC regarding concerns or other actions, CSMAC recommended that there be a public tracking capability that allows an FCC applicant to readily identify when FCC sent the application to NTIA, when NTIA responded, and whether NTIA had specific questions regarding the merits or technical components of the application. Regardless, any such changes to how spectrum is currently managed and regulated would need to be carefully studied with respect to potential benefits and costs.

Increasing the Federal Focus on Research, Development and Testing

Several technological advances promise to make sharing easier, but are still at early stages of development and testing. For example, various spectrum users and experts we contacted mentioned the potential of dynamic spectrum access technology. If made fully operational, dynamic spectrum access technology will be able to sense available frequencies in an area and jump among frequencies to seamlessly continue communication as the user moves geographically through spectrum bands. According to experts and researchers we spoke with, progress has been made but there is no indication of how long it will be before this technology is fully deployable. Similarly, current fourth generation (4G) Long Term Evolution (LTE) technologies promise the ability to facilitate channel sharing as well as much faster data transfer rates over time, which could also potentially free frequencies more quickly for use by others. However, experts we talked to could not predict how long it will be before data networks reach international 4G transmission standards and

thus, maximize spectral efficiency. Such new technologies can obviate or lessen the need for extensive regulatory procedures to enable sharing and can open up new market opportunities for wireless service providers. If a secondary user or sharing entity employs these technologies, the incumbent user or primary user would theoretically not experience interference, and agreements and rulemakings that are currently needed may not be necessary to enable sharing.

Although industry participants indicated that extensive testing under realistic conditions is critical to conducting basic research on spectrum efficient technologies, we found that only a few companies are involved in such research and may experience challenges in the testing process. Companies tend to focus technology development on current business objectives as opposed to conducting basic research that may not show an immediate business return. For example, NTIA officials told us that one company that indicated it would participate in NTIA's dynamic spectrum access-testing project removed its technologist from the testing effort to a project more closely related to its internal business objectives. Furthermore, some products are too early in the development stage to even be fully tested. For example, NTIA officials said six companies responded to NTIA's invitation to participate in the previously mentioned dynamic spectrum access-testing project. However, three handsets were received for the testing, and one of those did not work as intended. Other companies that responded told NTIA that they only had a concept and were not ready to test an actual prototype.

We have previously reported that the federal government has a key role in performing or otherwise encouraging research that the private industry would not do on its own.⁴⁵ With respect to research and development on spectrum sharing and spectrum efficiency, we found that FCC and NTIA are involved in creating test beds and other opportunities for research and development.⁴⁶ For example, when FCC proposed a rulemaking to improve its experimental license program in November 2010, it invited comments on a number of ideas including the need to identify locations for test beds, where new technologies could be tested before being

⁴⁵GAO, *Research and Development: Lessons learned from Previous Research Could Benefit FreedomCAR Initiative*, [GAO-02-810T](#) (Washington, D.C.: June 2002).

⁴⁶A spectrum test bed consists of specific segments of spectrum set aside to test technologies, services or related techniques.

introduced to the market and frequency bands where FCC might provide increased flexibility to conduct experiments. Further, FCC is seeking to establish provisions that encourage the exploration of new technologies, including technologies that would facilitate spectrum sharing. To expand testing opportunities, PCAST recommended that real-world test services be provided to test federal and public-safety frequency bands. Similarly, the Wireless Spectrum Research and Development's Senior Steering Group is conducting workshops regarding the development of a national wireless test environment.⁴⁷ However, spectrum users told us that even though they understand the benefits of testing and development, they are reluctant to allow testing in their spectrum because of the potential for harmful interference. As previously mentioned, NTIA also has a pilot test bed program to evaluate dynamic spectrum access and technology for spectrum sharing in land mobile radio bands, but the program is in the early stages and requires additional access to spectrum for testing to be fully implemented.⁴⁸

The Department of Defense—the federal agency with the largest number of spectrum assignments—is also involved in researching and developing new spectrum technologies, although they are still in the early stages. The Department's Defense Advanced Research Projects Agency (DARPA) has several such efforts under way. For example, unlike existing databases that only provide limited, descriptive frequency assignment information, DARPA's Advanced Radio Frequency Mapping program seeks to provide real-time awareness of spectrum use across frequency, geography, and time. With this information, spectrum managers and automatic spectrum allocation and management systems could operate more efficiently through improved interference mitigation. However, agency officials told us that this technology is at the basic research level and years away from market readiness. Also, in the beginning phases, the Communications Under Extreme Radio Frequency Spectrum Conditions program plans to address spectrum use and interference mitigation in a congested communications environment. According to DARPA officials, the program will work to develop

⁴⁷Formed as result of the President's 2010 memorandum, *Unleashing the Wireless Broadband Revolution*, the Wireless Spectrum Research and Development's Senior Steering Group coordinates spectrum-related research and development activities across the federal government, and helps identify gaps in the government's research and development portfolio with respect to spectrally efficient technologies.

⁴⁸Frequencies in the 410-420 MHz land-mobile-radio band will be used in this test bed.

interference mitigation technologies (especially for jamming),⁴⁹ interference tolerance, and higher spectrum utilization.

Recent federal advisory committee recommendations and international examples also emphasize the importance of funding and providing incentives for research and development endeavors. For example, to promote research in efficient technologies, PCAST recommended that (1) the Research and Development Wireless Innovation Fund⁵⁰ release funds for this purpose and (2) the current Spectrum Relocation Fund be redefined as the Spectrum Efficiency Fund.⁵¹ This adjustment would allow federal agencies to be reimbursed for general investments in improving spectrum sharing. PCAST also recently suggested that a partnership between the federal government and the private sector is the best mechanism to ensure optimal use of federal spectrum and related spectrum research and testing.⁵² Similarly, CSMAC recommended the creation of a Spectrum Innovation Fund. Unlike the Spectrum Relocation Fund, which is strictly limited to the actual costs incurred in relocating federal systems from auctioned spectrum bands, the Spectrum Innovation Fund could also be used for spectrum sharing and other opportunities to enhance spectrum efficiency.⁵³ To deal with similar problems, the Canadian government instituted tax credits for research and development efforts by Canadian wireless companies, and required wireless companies to commit 2 percent of all revenues toward research and development activities related to spectrum.

⁴⁹FCC defines jamming as illegal radio frequency transmissions that are designed to block, jam, or otherwise interfere with authorized radio communications.

⁵⁰The Wireless Innovation Fund is a part of the 2012 Payroll tax agreement for spectrum research and development. It will initially be a \$100 million fund at the National Institute of Standards and Technology. The fund will receive an additional \$200 million after approved auction income has been secured.

⁵¹The Spectrum Relocation Fund exists for the purpose of reimbursing agencies for the actual costs incurred in relocating or sharing federal spectrum. NTIA Authorization Act, § 118, 47 U.S.C. § 928.

⁵²*Report to the President; Realizing the Full Potential of Government-held Spectrum to Spur Economic Growth.*

⁵³CSMAC Incentives Subcommittee Final Report.

Conclusions

As the demand for and use of spectrum continues to increase, federal and nonfederal users will need to be more cognizant of how efficiently spectrum is used. Sharing spectrum is one way to use spectrum more efficiently and make more spectrum available. While a number of barriers exist to sharing spectrum—such as incompatible uses, potentially prohibitive costs, and cumbersome regulatory processes—it is clear that first and foremost, users currently lack incentives to share the spectrum that is assigned or licensed to them. To address the incentive problem, spectrum experts, federal advisory groups, and others have made recommendations but have also identified implementation problems associated with different options. First, we agree with experts that spectrum usage fees should be given further consideration. We previously reported that incentive-based fees are designed to promote the efficient use of spectrum by compelling users to recognize the value to society of the spectrum that they use. Yet, designing a fee system is fraught with numerous obstacles and challenges, such as how such fees should be incorporated into agency budgets and the appropriations process in order to create the right incentives. A full evaluation of the potential benefits and impacts of implementing a fee structure would be a potential step in identifying the most prudent and effective approach. Second, because new technologies that could better facilitate sharing are in some cases years from market readiness, spectrum users could be encouraged to dedicate more resources to research and development. Additionally, users need spectrum access for testing new technologies. If there are continued limitations to accessing spectrum for testing, it may be impossible to validate technologies under realistic conditions, further delaying the availability of these technologies to users and the opening of new market opportunities and economic growth. Third, users have expressed concern about the timeliness of FCC and NTIA spectrum-sharing processes. If these processes continue to be lengthy and unpredictable, federal and nonfederal users may continue to be reluctant to share spectrum. As the debate about these options continues, it is clear that more information is needed to further the understanding and discussion about which incentives and opportunities will be the most feasible and effective toward promoting sharing as a viable solution to address increasing spectrum demand.

Recommendations for Executive Action

To better identify the most feasible incentives to promote spectrum efficiency and sharing, we recommend that the NTIA Administrator and the FCC Chairman jointly take the following three actions:

-
- Report their agencies' views and conclusions regarding spectrum usage fees to the relevant congressional committees, specifically with respect to the merits, potential effects, and implementation challenges of such a fee structure, and what authority, if any, Congress would need to grant for such a structure to be implemented.
 - Based on the findings of current research and development efforts under way, determine how the federal government can best promote federal and nonfederal investment in the research and development of spectrally efficient technologies, and whether additional spectrum is needed for testing new spectrum efficient technologies.
 - Evaluate regulatory changes, if any, that can help improve and expedite the spectrum sharing process.

Agency Comments and Our Evaluation

We provided a draft of this report to the Department of Commerce and FCC for review and comment. In response to our draft report, Commerce and FCC provided written comments, which are reprinted in appendix II and III, respectively. The agencies also provided technical corrections to the draft report, which we incorporated as appropriate. In summary, Commerce concurred with our findings, but believes that activities completed or under way by NTIA and FCC satisfy the recommendations contained in our draft report. In its written comments, FCC noted that the agency was pursuing the goals outlined in the National Broadband Plan, and highlighted several actions it is taking to promote more shared access to spectrum.

In our draft report, we included four recommendations. The first recommendation was that NTIA and FCC jointly examine the merits and challenges associated with implementing spectrum usage fees. Commerce noted that the issue was examined by the CSMAC in 2010 and 2011 and that consensus could not be reached regarding the imposition of such fees. Moreover, the agency states that further study is unlikely to resolve the issues. We agree that implementation of spectrum usage fees or a similar structure that can provide users with greater incentive to efficiently use or share spectrum raises several difficult questions, such as authority to implement a new fee structure and ensuring that federal operations are not disrupted. We also agree that further study may not resolve these issues. Nevertheless, our findings suggest that additional incentives are still needed for users to seek out more efficient ways of using spectrum, such as sharing, and that Congress could benefit from more information to fully understand the implications of a fee structure. Therefore, we altered our recommendation to state that NTIA and FCC, rather than initiate additional study on the issue, should provide Congress with the agencies' views and conclusions

regarding the merits, potential effects, and implementation challenges of such a fee structure, and authorities that Congress would need to grant that such a structure be implemented. We believe such actions would help provide members of Congress with information they could use to evaluate any proposed fee structure or other proposed incentive schemes.

Our second recommendation was that FCC and NTIA jointly study whether spectrum should be repurposed and made available for unlicensed use. However, in written comments the agencies identified NTIA's and FCC's recent efforts to identify spectrum for repurposing, which have focused on allowing unlicensed users to share the spectrum. Consequently, we removed that recommendation from our final report.

Our draft report also recommended that the agencies jointly study (1) actions that could help spur research and development and (2) regulatory changes that might improve the spectrum-sharing process. Commerce stated that NTIA and FCC already have efforts under way in these areas that fulfill the goals of these recommendations and that additional study is unnecessary. We acknowledge throughout the report that NTIA and FCC have activities under way in these areas, some of which were initiated during the course of our review. The intent of our recommendations was not to displace these activities with additional study, but rather to support these actions, and to encourage the agencies to take further steps to enable real world testing of spectrum-sharing technologies and to streamline and improve the regulatory processes that enable spectrum sharing. We revised our draft recommendations to clarify that we are encouraging NTIA and FCC to take further actions in these areas, as opposed to further study, and we will continue to monitor the agencies' efforts in these areas.

In addition to Commerce and FCC, we also provided the Departments of Defense, Homeland Security, Interior, Justice, Transportation, and Treasury the opportunity to comment on segments of the report that pertain to the data and information they provided. Except for the Department of Transportation, which did not provide any comment, the agencies verified the key facts we obtained from them and provided technical corrections to the draft report, which we incorporated as appropriate.

We are sending copies of this report to the Secretary of Commerce, the Chairman of the Federal Communications Commission, and appropriate

congressional committees. In addition, the report will be available at no charge on GAO's website at <http://www.gao.gov>. If you or members of your staff have any questions about this report, please contact me at (202) 512-2834 or goldsteinm@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Major contributors to this report are listed in appendix IV.

A handwritten signature in black ink, appearing to read 'M. Goldstein', with a long horizontal flourish extending to the right.

Mark L. Goldstein
Director, Physical Infrastructure

Appendix I: Federal Agencies, Nonfederal Spectrum Users and Experts Interviewed Regarding Spectrum Sharing

Selected Interdepartmental Radio Advisory Committee Member Agencies

- Department of Commerce
 - National Oceanic and Aviation Administration
 - National Telecommunications and Information Administration
- Department of Defense
 - Army
 - Air Force
 - Defense Advanced Research Projects Agency
 - Defense Information Systems Agency
 - Navy
- Department of Homeland Security
 - Wireless Service Spectrum Management Office
 - Customs and Border Patrol
- Department of the Interior
- Department of Justice
- Department of Transportation
- Department of the Treasury
 - Treasury Inspector General for Tax Administration
- Federal Communications Commission

Nonfederal Spectrum Users

- City of Wilmington, North Carolina
- Google
- Metro PCS
- Microsoft
- Shared Spectrum (a spectrum sharing solutions company)
- Spectrum Bridge (a spectrum user, and also a spectrum sharing solutions company)
- Sprint
- T-Mobile
- United States Cellular
- Verizon

**Appendix I: Federal Agencies, Nonfederal
Spectrum Users and Experts Interviewed
Regarding Spectrum Sharing**

Table 1: Subject Matter Experts Interviewed

Name	Institution^a
Phillippe Aubineau	International Telecommunications Union
Coleman D. Bazelon	The Brattle Group
Michael Christensen	Industry Canada
Andrew W. Clegg	National Science Foundation
Larry Downes	Spectrum consultant and author
Pierre de Vries	University of Colorado
Gary M. Epstein	Aspen Institute, International Digital Economy Accords
Tomas E. Gergely	National Science Foundation
Thomas W. Hazlett	George Mason University School of Law
Stephen Jones	Office of Communications, U.K.
William Lehr	Massachusetts Institute of Technology
Nevio Marinelli	Australian Communications and Media Authority
Preston F. Marshall	University of Southern California
Geoff McMillen	Australian Communications and Media Authority
Linda K. Moore	Congressional Research Service
Jon M. Peha	Carnegie Mellon University
Jerry Pi	Samsung
Ravi Prakash	University of Texas, Dallas Texas
Francois Rancy	International Telecommunications Union
Richard Reaser	CSMAC Raytheon
Greg Rosston	Stanford Institute for Economic Policy Research
Jennifer A. Warren	Lockheed Martin
Chris Woolford	Office of Communications, U.K.

Source: GAO.

^aWe interviewed experts as individuals, not as representatives of any institution. We provide information on institutions to help readers identify experts.

Appendix II: Comments from the Department of Commerce



UNITED STATES DEPARTMENT OF COMMERCE
The Secretary of Commerce
Washington, D.C. 20230

October 25, 2012

The Honorable Gene L. Dodaro
Comptroller General
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Comptroller General Dodaro:

Thank you for the opportunity to review and comment on the U.S. Government Accountability Office's (GAO) draft report entitled *Spectrum Management: Incentives, Opportunities, and Testing Needed to Enhance Spectrum Sharing* (GAO-13-7) (Report). We appreciate the work that the GAO has done to illuminate the challenges confronting both federal and non-federal spectrum managers when wireless communications users may need to share spectrum with each other. The Report touches the core issues affecting spectrum sharing and reflects the focus of some of our past and current study efforts. While we concur with the Report's findings, we only concur with the recommendations in part because we are currently addressing these issues via existing workstreams that cover areas of concern to GAO. These activities will more than adequately satisfy the GAO recommendations and advance our goal of making more spectrum available for wireless broadband.

The Report examines factors that can deter spectrum sharing and suggests actions the Federal Communications Commission (FCC), the National Telecommunications and Information Administration (NTIA), and others can take to encourage more sharing and more efficient spectrum use. The Report ultimately recommends a joint NTIA/FCC study on: (1) the potential merits and effects of imposing a spectrum fee structure; (2) whether additional spectrum should be repurposed for unlicensed use; (3) actions that can help spur research and development; and (4) regulatory changes that might improve the spectrum sharing process.

Regarding spectrum fees, the Report recognizes that NTIA previously has sought expert advice from the Commerce Spectrum Management Advisory Committee (CSMAC). CSMAC studied the issue in 2010-11, but could not reach consensus to recommend imposing value-based fees on federal agencies. Some CSMAC members raised concerns because the Committee's study had not addressed how to avoid disrupting government services. They stressed that proposals for fees still needed to deal with major questions regarding the appropriations processes or the means for government agencies to participate in a competitive market. Furthermore, members argued that the nature of government use, the international aspects of some federal operations, the lack of agency ownership of spectrum, and ongoing sharing of spectrum between agencies further complicated application of value-based fee concepts. We do not find that further study will readily resolve these issues, at least without significant effort, and given these inherent challenges, we think our resources are better spent focusing on identifying spectrum for repurposing.

The Honorable Gene L. Dodaro
Page 2

Additionally, in August 2012, the Office of Management and Budget (OMB) updated Circular A-11 pursuant to the Middle Class Tax Relief and Job Creation Act of 2012 to reflect spectrum valuation language recommended by the CSMAC. The update provides new guidance that directs agencies to consider the value of spectrum-dependent assets that will enable federal spectrum efficiency solutions with the highest net benefits to emerge during system development. In time, we expect to realize the benefits of this new value-based approach.

NTIA's current spectrum fee system, which allows us to recover our costs of administering the federal spectrum management process, was legislatively determined by Congress. New legislation would, therefore, be necessary to establish additional fees or to change the nature or purpose of the existing fee structure. We defer to the FCC on the merits and effects of additional spectrum fees for non-federal users. Therefore, at this time, we see no real purpose to undertaking yet another study of value-based spectrum fees.

The recommendation that the study include the potential for repurposing additional spectrum for shared or unlicensed use is also unnecessary because such work is already underway. In 2010, President Obama directed the Department of Commerce, working through NTIA, and the FCC to identify 500 megahertz of spectrum that could be reallocated for wireless broadband services, including via sharing or unlicensed use. NTIA, the FCC, and the federal agencies are aggressively pursuing that goal. Much of the spectrum that NTIA has put forward thus far will involve some level of sharing. For example, NTIA is currently studying the 5350-5470 MHz and 5850-5925 MHz bands to allow unlicensed uses to share this spectrum with federal agency operations. Given the extensive work that is already occurring, an additional study is superfluous at this time.

The Report also recommends that the study include ways to spur additional investment in research and development (R&D) of spectrally-efficient technologies. Both agencies are already actively pursuing ways to increase spectrum technology R&D. For example, the Wireless Spectrum R&D (WSRD) Senior Steering Group (SSG), a federal government group with industry participation, is currently coordinating spectrum-related research and development activities across the federal government. The WSRD SSG is part of the Networking and Information Technology Research and Development (NITRD) program administered by the National Science and Technology Council, and provides recommendations for federal R&D investment, including opportunities for technology transfer to the private sector. NTIA is very active as a co-chair of the WSRD, enhancing R&D efforts by acting as an information resource connecting programs together as they develop new technologies. The FCC is also a member of the WSRD.

NTIA and the FCC are also actively facilitating R&D via experimental licensing. Experimental licenses permit private entities to access federal and shared federal/non-federal spectrum for experimentation and testing, enabling development of new technologies, equipment, and radio services. Over 8,800 FCC experimental licensees have access to exclusive federal or shared federal/non-federal spectrum. The FCC also has an open proceeding promoting

The Honorable Gene L. Dodaro
Page 3

innovation and efficiency in spectrum use in the Experimental Radio Service rules.¹ The FCC will coordinate this item with NTIA and expects to take action next year.

Important collaborative work on sharing R&D is currently underway. Most significantly, T-Mobile USA, on behalf of the wireless industry, recently received experimental authorization to engage in a pilot program to test sharing approaches and determine the feasibility of sharing the 1755-1850 MHz band with select Department of Defense systems. Additionally, in May, Verizon committed \$5 million to further testing of spectrum sharing approaches. We strongly support these types of collaborative efforts between federal agencies, the wireless industry, and other wireless technology innovators. Accordingly, we believe that current work should proceed as expeditiously as possible and that lessons learned from these efforts could inform a future study, if needed.

Finally, the Report recommends that the joint study examine regulatory changes to improve spectrum sharing. NTIA usually authorizes non-federal access to shared spectrum within nine working days. For requests for a Special Temporary Authority, NTIA typically responds in a matter of hours. In 2005, NTIA and the FCC improved and significantly expedited spectrum sharing in the 70, 80, and 90 GHz bands through online spectrum coordination. NTIA intends to work with the FCC on potentially expanding automated coordination to other frequency bands. NTIA will also address improved spectrum coordination techniques and greater cooperation between industry and government in its upcoming Strategic Plan for Federal Spectrum Management, which will also include lessons learned from the agency-industry collaborative study of sharing in the 1695-1710 MHz and 1755-1850 MHz bands. These activities should result in identifying regulatory changes to expedite spectrum sharing, thereby fulfilling the goals of the GAO recommendation.

The Department of Commerce is committed to achieving the President's goal of bringing broadband wireless services to the Nation, and moving it forward technologically to expand the economy and create jobs. While we do not believe new studies are needed in addition to all the work currently underway at this time, we support the overall concept and intent of the Report. As an alternative to conducting the new studies recommended in the Report, we would be pleased to update GAO periodically on the progress of existing work in the areas covered in the Report. Thank you again for the opportunity to review and comment on the draft report.

Sincerely,


Rebecca M. Blank
Acting Secretary of Commerce

¹ See FCC Notice of Proposed Rulemaking, *In the Matter of Promoting Expanded Opportunities for Radio Experimentation and Market Trials under Part 5 of the Commission's Rules and Streamlining Other Related Rules* 2006 Biennial Review of Telecommunications Regulations – Part 2 Administered by the Office Of Engineering and Technology (OET), 25 FCC Rcd 16544 (2010).

Appendix III: Comments from the Federal Communications Commission



Federal Communications Commission
Washington, D.C. 20554

November 1, 2012

Mr. Gene L. Dodaro
Comptroller General
Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Dodaro:

Thank you for the opportunity to review and comment on the Government Accountability Office's (GAO) draft report, entitled Spectrum Management: Incentives, Opportunities, and Testing Needed to Enhance Spectrum Sharing. We recognize the many benefits that shared access to spectrum has to offer.

The National Broadband Plan issued in March 2010 recommended that the FCC make 500 megahertz of spectrum available for licensed and unlicensed broadband use within the next 10 years, including 300 megahertz between 225 MHz and 3.7 GHz for mobile use in the next 5 years. The FCC has collaborated with NTIA to make available a total of 500 megahertz of Federal and non-Federal spectrum, suitable for both mobile and fixed wireless broadband use by 2020. The Commission is on track to exceed the first benchmark of freeing up 300 megahertz of spectrum for mobile broadband, and is aggressively pursuing the 10-year goal as well. To do this, we generally have focused on four complementary approaches: auctioning additional spectrum, removing regulatory barriers to flexible spectrum use, clearing new bands for flexible broadband use, and promoting dynamic spectrum sharing.

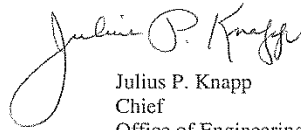
In order to promote the flexible use of spectrum for advanced mobile networks, the Commission is taking numerous concrete steps. Notably, we are implementing Incentive Auction authority granted by Congress in February 2012 to free up spectrum in the TV bands for mobile broadband, an idea first identified in the National Broadband Plan. We recently finalized the Wireless Communication Service (WCS) spectrum rules to provide for LTE operation in the 2.3 GHz band. By the end of this year, we intend to issue rules to allow Advanced Wireless Services (AWS) in the 2000-2020 MHz and 2180-2200 MHz Mobile Satellite Service (MSS) bands. And we are planning for spectrum auctions required by the third anniversary of the Middle Class Tax Relief and Job Creation Act of 2012.

As indicated, the Commission's spectrum agenda also includes promoting more shared access to spectrum. Specifically, the Commission intends to initiate a rulemaking to repurpose the 3550-3650 MHz band of spectrum for small cell technology. We are currently working to issue a notice of proposed rulemaking by the end of the year that would broadly reflect recommendations made in a recent report by the President's Council of Advisors on Science and Technology (PCAST) to enable sharing through use of a database model similar to the one

developed by the FCC for white spaces in the TV bands. We are also extensively involved in several working groups of the Commerce Spectrum Management Advisory Committee (CSMAC) that are evaluating possible shared commercial access to spectrum in the 1695-1710 MHz and 1755-1850 MHz bands. Furthermore, we will be evaluating expanded unlicensed use of the 5 GHz band, and will continue to follow technological developments that will facilitate dynamic spectrum access to shared spectrum on a licensed or unlicensed basis.

We are committed to achieving the National Broadband Plan's goal of making newly available 500 megahertz of spectrum for broadband by 2020, and making available 300 megahertz available by 2015 for mobile broadband, either through exclusive flexible use or shared spectrum access models. To achieve these goals, the FCC will continue to work closely with NTIA and other Federal stakeholders. We would be happy to provide an update to GAO on our activities to promote shared Federal/non-Federal access to spectrum as we advance our commercial wireless broadband goals.

Sincerely,



Julius P. Knapp
Chief
Office of Engineering and Technology
Federal Communications Commission



Ruth Milkman
Chief
Wireless Telecommunications Bureau
Federal Communications Commission

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

Mark L. Goldstein, (202) 512-2834 or goldsteinm@gao.gov

Staff Acknowledgments

In addition to the contact person named above, Andrew Von Ah (Assistant Director), Eli Albagli, Amy Abramowitz, Michael Clements, Andy Clinton, David Goldstein, Brian Hartman, Bert Japikse, Elke Kolodinski, Jean McSween, Erica Miles, Sally Moino, Joshua Ormond, Amy Rosewarne, Hai Tran, and Jarrod West made key contributions to this report.

GAO's Mission

The Government Accountability Office, the audit, evaluation, and investigative arm of Congress, exists to support Congress in meeting its constitutional responsibilities and to help improve the performance and accountability of the federal government for the American people. GAO examines the use of public funds; evaluates federal programs and policies; and provides analyses, recommendations, and other assistance to help Congress make informed oversight, policy, and funding decisions. GAO's commitment to good government is reflected in its core values of accountability, integrity, and reliability.

Obtaining Copies of GAO Reports and Testimony

The fastest and easiest way to obtain copies of GAO documents at no cost is through GAO's website (<http://www.gao.gov>). Each weekday afternoon, GAO posts on its website newly released reports, testimony, and correspondence. To have GAO e-mail you a list of newly posted products, go to <http://www.gao.gov> and select "E-mail Updates."

Order by Phone

The price of each GAO publication reflects GAO's actual cost of production and distribution and depends on the number of pages in the publication and whether the publication is printed in color or black and white. Pricing and ordering information is posted on GAO's website, <http://www.gao.gov/ordering.htm>.

Place orders by calling (202) 512-6000, toll free (866) 801-7077, or TDD (202) 512-2537.

Orders may be paid for using American Express, Discover Card, MasterCard, Visa, check, or money order. Call for additional information.

Connect with GAO

Connect with GAO on [Facebook](#), [Flickr](#), [Twitter](#), and [YouTube](#). Subscribe to our [RSS Feeds](#) or [E-mail Updates](#). Listen to our [Podcasts](#). Visit GAO on the web at www.gao.gov.

To Report Fraud, Waste, and Abuse in Federal Programs

Contact:

Website: <http://www.gao.gov/fraudnet/fraudnet.htm>

E-mail: fraudnet@gao.gov

Automated answering system: (800) 424-5454 or (202) 512-7470

Congressional Relations

Katherine Siggerud, Managing Director, siggerudk@gao.gov, (202) 512-4400, U.S. Government Accountability Office, 441 G Street NW, Room 7125, Washington, DC 20548

Public Affairs

Chuck Young, Managing Director, youngc1@gao.gov, (202) 512-4800 U.S. Government Accountability Office, 441 G Street NW, Room 7149 Washington, DC 20548



Please Print on Recycled Paper.