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SPECTRUM MANAGEMENT

Federal Government's Use of Spectrum and Preliminary Information on Spectrum Sharing

Statement of Mark L. Goldstein, Director
Physical Infrastructure Issues

September 13, 2012

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Highlights

Highlights of GAO-12-1018T, a testimony before the Subcommittee on Communications and Technology, Committee on Energy and Commerce, House of Representatives

Why GAO Did This Study

Demand for spectrum is increasing rapidly with the widespread use of wireless broadband devices and services. However, nearly all usable spectrum has been allocated either by NTIA for federal use or by the Federal Communications Commission (FCC) for commercial and nonfederal use. Federal initiatives are under way to identify federal spectrum that could be repurposed or possibly shared by federal users or wireless broadband providers and other nonfederal users. This statement discusses how NTIA manages spectrum to address governmentwide spectrum needs and the steps NTIA has taken to repurpose spectrum for broadband. As part of an ongoing review, the statement also discusses preliminary information on the factors that prevent spectrum sharing and actions that can encourage sharing and efficient spectrum use. This testimony is based on GAO's prior work on federal spectrum management and ongoing work on spectrum sharing. GAO analyzed NTIA processes, policies and procedures, and interviewed relevant government officials, experts, and industry stakeholders.

What GAO Recommends

In April 2011, GAO recommended that NTIA (1) evaluate its current approach for validating agency-reported data and (2) establish internal controls for its data management systems. NTIA concurred with the recommendations and has proposed approaches to implement new measures to better ensure the accuracy of agency-reported data, and is taking steps to implement internal controls in a cost-efficient manner. GAO provided a draft of this statement to FCC and NTIA.

View GAO-12-1018T. For more information, contact Mark L. Goldstein at (202) 512-2834 or goldsteinm@gao.gov.

What GAO Found

The National Telecommunications and Information Administration (NTIA) is responsible for governmentwide federal spectrum management, but GAO reported in 2011 that NTIA's efforts in this area had been limited. In 2003, the President directed NTIA to develop plans identifying federal and nonfederal spectrum needs, and in 2008, NTIA issued the federal plan. GAO found it did not identify governmentwide spectrum needs and did not contain key elements and conform to best practices for strategic planning. Furthermore, NTIA's primary spectrum management operations do not focus on governmentwide needs. Instead, NTIA depends on agency self-evaluation of spectrum needs and focuses on mitigating interference among spectrum users, with limited emphasis on overall spectrum management. Additionally, NTIA's data management system is antiquated and lacks internal controls to ensure the accuracy of agency-reported data, making it unclear if reliable data inform decisions about federal spectrum use. NTIA is developing a new data management system, but implementation is years away.

Despite these limitations, NTIA has taken steps to identify spectrum that could potentially be made available for broadband use. For example, in 2010 NTIA evaluated various spectrum bands and identified 115 megahertz of spectrum that could be repurposed within the next 5 years. In doing so, NTIA worked with a special steering group consisting of the Assistant Secretaries with spectrum management oversight in agencies that were the major stakeholders in the spectrum bands under consideration. For each of the identified bands, NTIA reviewed the number of federal frequency assignments within the band, the types of federal operations and functions that the assignments support, and the geographic location of federal use.

In addition to efforts to repurpose spectrum, industry stakeholders have also suggested that sharing spectrum between federal and nonfederal users be considered to help make spectrum available for broadband. Our ongoing work has identified several barriers that limit sharing. Primarily, many users may lack incentives to share assigned spectrum. 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. But federal agencies pay only a small fee to NTIA for spectrum assignments, and may, in some contexts, have little incentive to conserve or share it. Federal agencies may also have limited budgets to upgrade to more spectrally-efficient equipment that would better enable sharing. Nonfederal users are also reluctant to share spectrum. For instance, license holders may be reluctant because of concerns that spectrum sharing could encourage competition. A lack of information on federal spectrum use may limit users' ability to easily identify spectrum suitable for sharing.

GAO's ongoing work suggests that some actions might provide greater incentives and opportunities for more efficient spectrum use and sharing. These actions could include assessing spectrum usage fees to provide economic incentive for more efficient use and sharing, expanding the availability of unlicensed spectrum, and increasing the federal focus on research and development of technologies that can enable spectrum sharing and improve spectral efficiency. However, all of these actions also involve challenges and may require further study.

Chairman Walden, Ranking Member Eshoo, and Members of the Subcommittee:

Thank you for the opportunity to testify today on issues related to spectrum management and spectrum sharing practices in the United States. Radio frequency spectrum enables wireless communications services critical to the U.S. economy and a variety of government functions, such as scientific research and national defense. Spectrum capacity is necessary to deliver wireless broadband to consumers and businesses and broadband deployment stimulates economic growth and boosts the nation's capabilities in areas such as education and health care. As the U.S. experiences significant growth in commercial wireless broadband services, the demand for spectrum has increased and additional capacity will be needed. However, nearly all usable spectrum has been allocated either by the National Telecommunications and Information Administration (NTIA) for federal government use or by the Federal Communications Commission (FCC) for commercial and other nonfederal use. Virtually no "green fields" of spectrum are currently available to allocate to new uses or technologies.

Currently, federal government initiatives are under way to identify spectrum that can be made available to meet the nation's increased demand for commercial wireless broadband services. In particular, the *National Broadband Plan* recommended that 500 megahertz (MHz) of spectrum be made newly available for broadband use within the next 10 years,[1] and in June 2010, the President issued a memorandum directing NTIA to begin identifying federal spectrum that can be made available for wireless broadband.[2] Solutions geared toward greater sharing of spectrum among users—federal and nonfederal—have become attractive because of the potential access to more spectrum and opportunities to use spectrum more efficiently that sharing presents. The President's Council of Advisors on Science and Technology (PCAST) recommended

[1]In 2010, an FCC task force issued the *National Broadband Plan.* Federal Communications Commission*, Connecting America: The National Broadband Plan*, p. 84, Recommendation 5.8, (Mar. 16, 2010)

[2]*See, Unleashing the Wireless Broadband Revolution,* 75 Fed. Reg. 38387 (2010).

that 1,000 MHz of spectrum previously occupied only by federal users be shared with nonfederal users.[3]

Based on our April 2011 report, my testimony today discusses NTIA's spectrum management to address governmentwide spectrum needs and the steps NTIA has taken to repurpose spectrum for broadband.[4] Based on an ongoing review, I will also discuss our preliminary information on the factors that prevent spectrum sharing and actions that might be taken to encourage sharing and efficient spectrum use. We plan to issue a report on these issues in fall 2012. In conducting our work, we reviewed NTIA documents, including its *Manual of Regulations and Procedures for the Federal Radio Frequency Management* (commonly referred to as the Redbook); an assessment of spectrum bands that could possibly be repurposed for wireless broadband (referred to as the Fast Track Evaluation); and other documentation of NTIA's current processes, policies, and procedures. We interviewed officials from NTIA's Office of Spectrum Management about their spectrum management policies and procedures and interviewed stakeholders with knowledge of spectrum issues including industry and academic experts, and representatives of an industry association and telecommunications companies. We selected the experts and industry stakeholders based on prior published literature, stakeholders' recognition and affiliation with the spectrum management industry, and NTIA and other stakeholders' recommendations. We also reviewed federal legislation, regulations, and processes regarding spectrum sharing, including various FCC plans, notices, orders and other publications. We conducted interviews with officials from FCC, NTIA, and various advisory committees, including the Commerce Spectrum Management Advisory Committee (CSMAC).[5] We also interviewed several agencies on the Interdepartment Radio Advisory Committee

[3]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).

[4]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.: April 12, 2011).

[5]CSMAC is a federal advisory committee that provides advice and recommendations to NTIA. It is organized through NTIA's Office of Policy Analysis and Development and consists of approximately 25 spectrum policy experts from the private sector.

(IRAC).[6] Additional information on our scope and methodology is provided in our 2011 report. We conducted our work related to federal management and use of spectrum from May 2010 to April 2011 and our work related to spectrum sharing from September 2011 to September 2012. All of our work was conducted in accordance with generally accepted government auditing standards. We provided a draft of this statement related to spectrum sharing to FCC and NTIA officials to obtain their comments. FCC and NTIA provided technical corrections, which we incorporated where appropriate.

Background

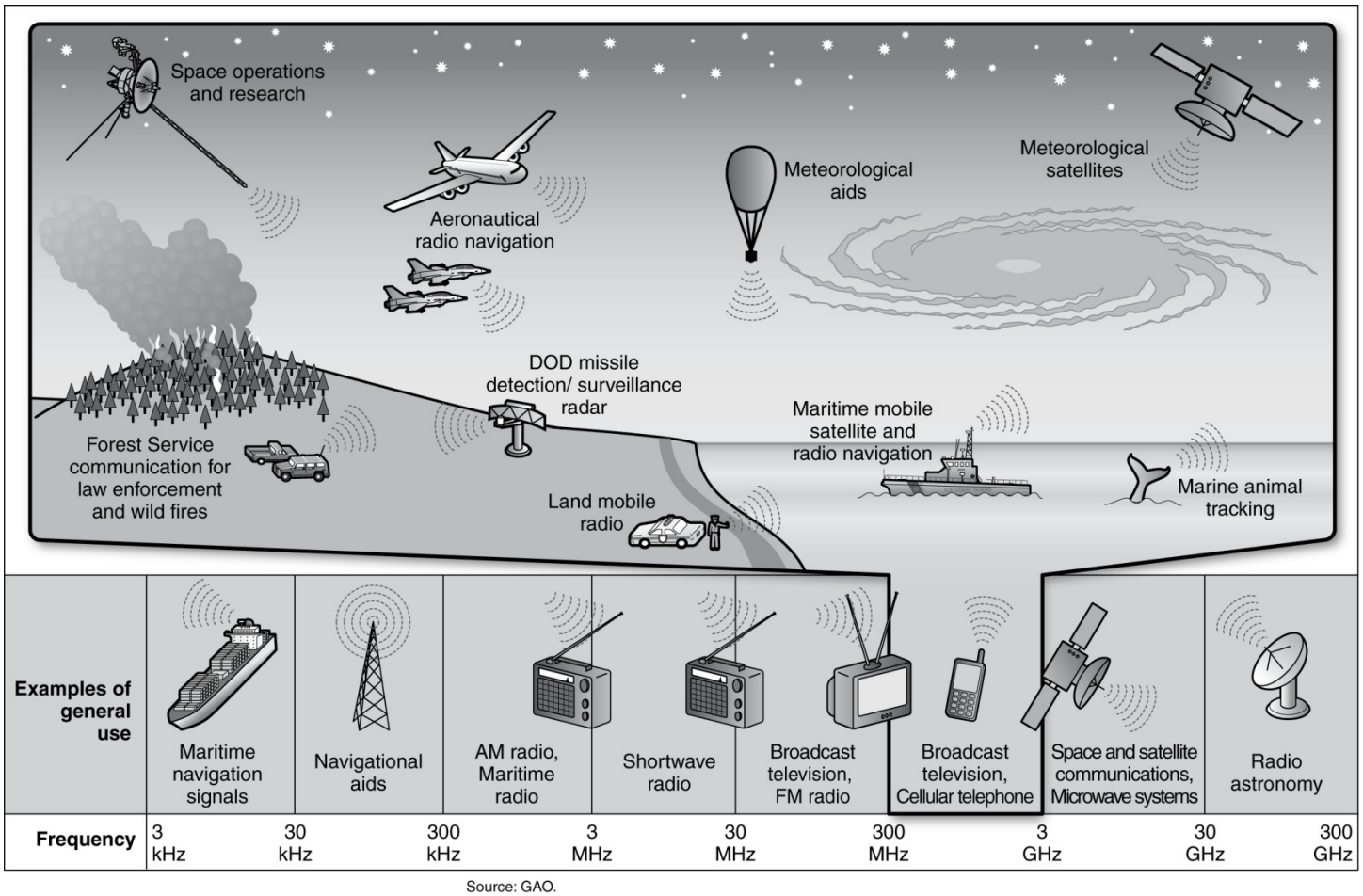
The radio frequency spectrum is the part of the natural spectrum of electromagnetic radiation lying between the frequency limits of 3 kilohertz (kHz) and 300 gigahertz (GHz). Not all spectrum has equal value. The spectrum most highly valued generally consists of frequencies between 225 MHz and 3700 MHz, as these frequencies have properties well suited to many important wireless technologies, such as mobile phones, radio, and television broadcasting. According to NTIA, as of September 2012, federal agencies had exclusive access to about 18 percent of these high-value frequencies, and nonfederal users had exclusive licenses to about 33 percent. The remainder of this spectrum is allocated to shared use. However, in many cases in these shared bands, federal or nonfederal uses may dominate and actual sharing is nominal. NTIA has concluded that overall, approximately 43 percent of these high-value frequencies are predominantly used by federal operations.

Federal agencies use spectrum to help meet a variety of missions, including emergency communications, national defense, land management, and law enforcement. Over 60 federal agencies and departments combined have over 240,000 frequency assignments. Agencies and departments within the Department of Defense have the most assignments, followed by the Federal Aviation Administration, the Department of Justice, the Department of Homeland Security, the Department of the Interior, the Department of Agriculture, U.S. Coast Guard, the Department of Energy, and the Department of Commerce, respectively. These federal agencies and departments hold 94 percent of

[6]IRAC is an interagency advisory committee that was established in 1922 to coordinate federal use of spectrum and provide policy advice on spectrum issues. It is comprised of representatives from 19 federal agencies that use spectrum. Those agencies hold over 90 percent of federally assigned spectrum.

all federally assigned spectrum. 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 (see fig. 1).

Figure 1: Examples of Allocated Spectrum Uses, and Federal Spectrum Use in the High-Value Range



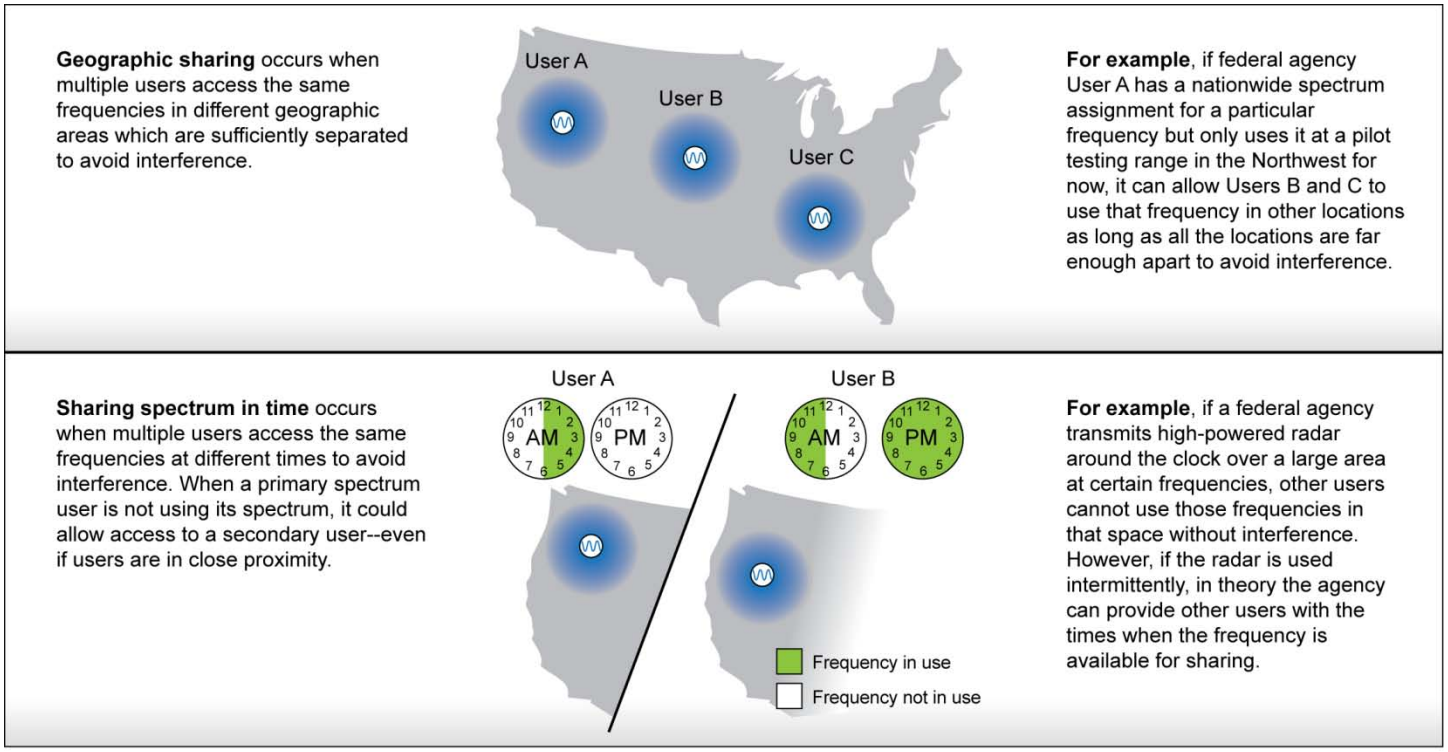
Source: GAO.

In the United States, responsibility for spectrum management is divided between NTIA and FCC. NTIA and FCC jointly determine the amount of spectrum allocated for federal, nonfederal, and shared use. After this allocation occurs, in order to use spectrum, nonfederal users must follow

rules and obtain authorizations from FCC to use specific spectrum frequencies, and federal users must follow rules and obtain frequency assignments from NTIA. In order for nonfederal users to share federal spectrum, NTIA and FCC are jointly involved in the process. The nonfederal party petitions FCC, and FCC in turn coordinates rulemakings and licenses with NTIA through IRAC. NTIA manages sharing between federal users on a day-to-day basis. If federal users are requesting frequency assignments in exclusive nonfederal or shared bands, that request is coordinated through IRAC with FCC. If sharing is solely between nonfederal users in exclusive nonfederal bands, sharing is generally governed by FCC rules and does not go through NTIA, unless there could be out-of-band interference. In addition to its spectrum allocation and authorization duties, NTIA serves as the President's principal advisor on telecommunications and information policy and manages federally assigned spectrum, including preparing for, participating in, and implementing the results of international radio conferences, as well as conducting extensive research and technical studies through its research and engineering laboratory, the Institute for Telecommunication Sciences. NTIA has authority to issue rules and regulations as may be necessary to ensure the effective, efficient, and equitable use of spectrum both nationally and internationally. It also has authority to develop long-range spectrum plans to meet future spectrum requirements for the federal government.

Spectrum sharing can be defined as the cooperative use of common spectrum. 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.

Spectrum sharing also occurs with unlicensed use of spectrum, since it is accessible to anyone using wireless equipment certified by FCC for those frequencies. Equipment such as wireless microphones, baby monitors, and garage door openers typically share spectrum with other services on a non-interference basis using low power levels to avoid interference with higher priority uses. In contrast with most licensed spectrum use, unlicensed spectrum users have no regulatory protection against interference from other licensed or unlicensed users in the band. However, unlicensed use is regulated to ensure that unlicensed devices do not cause undue interference to operations with a higher priority. For example, in the 5 GHz band, wireless fidelity (Wi-Fi) devices share a band with military radar subject to the condition that the Wi-Fi devices are capable of spectrum sensing and dynamic frequency selection; if radar is detected, the unlicensed user must immediately vacate the channel.

NTIA's Processes for Managing Federal Spectrum Lack Governmentwide Focus and Accountability

NTIA's Spectrum Management Efforts

As the federal agency authorized to develop national spectrum policy, NTIA has been directed to conduct several projects focused on reforming governmentwide federal spectrum management and promoting efficiency among federal users of spectrum; however, we reported in 2011 that its efforts in this area had resulted in limited progress toward improved spectrum management. NTIA has authority to, among other things, establish policies concerning assigning spectrum to federal agencies, coordinate spectrum use across federal agencies, and promote efficient use of spectrum by federal agencies in a manner which encourages the most beneficial public use. As such, NTIA has a role in ensuring that federally allocated spectrum is used efficiently. According to NTIA's Redbook and agency officials, efficient use includes ensuring that federal agencies' decisions to use spectrum to support government missions have been adequately justified and that all viable tradeoffs and options have been explored before making the decision to use spectrum-dependent technology, and ensuring that these tradeoffs are continuously reviewed to determine if the need for spectrum has changed over time. NTIA's primary guidance to federal agencies is technical guidance provided through NTIA's Redbook concerning how to manage assigned spectrum.

In 2003, the Bush Administration directed NTIA to develop strategic plans, and in March 2008, NTIA issued its report on federal spectrum use entitled the *Federal Strategic Spectrum Plan*.[7] While the intent of the *Federal Strategic Spectrum Plan* was to identify the current and projected spectrum requirements and long-range planning processes for the federal government, we reported in 2011 that the final plan is limited in these

[7]Department of Commerce, National Telecommunications and Information Administration, *Spectrum Policy for the 21st Century – The President's Spectrum Policy Initiative: The Federal Strategic Spectrum Plan* (March 2008).

areas. For example, the plan does not identify or include quantitative governmentwide data on federal spectrum needs. Instead, NTIA's plan primarily consists of a compilation of the plans submitted by 15 of the more than 60 agencies that use federal spectrum. Additionally, due to the fact that they contained limited information regarding future requirements and technology needs, NTIA concluded that its "long-range assumptions are necessarily also limited." Furthermore, NTIA's plan did not contain key elements and best practices of strategic planning.

NTIA Focuses on Interference Mitigation Rather than on Best Use of Spectrum across Government

NTIA's primary spectrum management operations include authorizing federal frequency assignments and certifying spectrum-dependent equipment for federal users; however, these processes are primarily focused on interference mitigation as determined by IRAC and do not focus on ensuring the best use of spectrum across the federal government. In 2011, we found that the process as established by federal regulations for review and approval of frequency assignment and system certification was technical in nature, focusing on ensuring that the new frequency or system that an agency wants to use would not interfere with another agency's operations. According to NTIA officials, this focus on day-to-day spectrum activities, such as interference mitigation, is due to the agency's limited resources. This focus, while important, makes limited consideration about the overall best use of federally allocated spectrum. Therefore, NTIA's current processes provide limited assurance that federal spectrum use is evaluated from a governmentwide perspective to ensure that decisions will meet the current and future needs of the agencies, as well as the federal government as a whole.

NTIA's Current Data Management System Is of Limited Usefulness

NTIA's data management system is antiquated and lacks transparency and internal controls. In 2011, we reported that NTIA collects all federal spectrum data in the Government Master File (GMF), which according to NTIA officials is an outdated legacy system that was developed primarily to store descriptive data. These data are not detailed enough to support the current analytical needs of NTIA or other federal users, as the system was not designed to conduct such analyses. NTIA does not generate any data, but maintains agency-reported spectrum data in the GMF, which are collected during the frequency assignment and review processes.

NTIA's processes for collecting and verifying GMF data lack key internal controls, including those focused on data accuracy, integrity, and completeness. Control activities such as data verification and reconciliation are essential for ensuring accountability for government

resources and achieving effective and efficient program results. In 2011, we reported that NTIA's data collection processes lack accuracy controls and do not provide assurance that data are being accurately reported by agencies. Rather, NTIA expects federal agencies to supply accurate and up-to-date data submissions, but it does not provide agencies with specific requirements on how to justify that the agencies' spectrum assignments will fulfill their mission needs.

NTIA is developing a new data management system—the Federal Spectrum Management System (FSMS)—to replace the GMF. According to NTIA officials, the new system will modernize and improve spectrum management processes by applying modern information technology to provide more rapid access to spectrum and make the spectrum management process more effective and efficient. NTIA projects that FSMS will improve existing GMF data quality, but not until 2018. According to NTIA's FSMS transition plan, at that time data accuracy will improve by over 50 percent. However, in the meantime it is unclear whether important decisions regarding current and future spectrum needs are based on reliable data.

NTIA Has Taken Steps to Identify Spectrum for Future Wireless Broadband Use

NTIA Efforts to Identify Spectrum for Broadband

In response to the government initiatives to make a total of 500 MHz of spectrum available for wireless broadband, in 2010 NTIA (1) identified 115 MHz of federally allocated spectrum to be made available for wireless broadband use within the next 5 years, referred to as the Fast Track Evaluation, and (2) developed an initial plan and timetable for repurposing additional spectrum for broadband, referred to as the 10-Year Plan.

Fast Track Evaluation. NTIA and the Policy and Plans Steering Group (PPSG)[8] identified and recommended portions of two frequency bands,

[8]The PPSG consists of the Assistant Secretaries, or equivalent, with spectrum management oversight in agencies that are major stakeholders in the spectrum issues under consideration.

totaling 115 MHz of spectrum within the ranges of 1695–1710 MHz and 3550–3650 MHz to be made available for wireless broadband use.[9] For each of these bands, NTIA reviewed the number of federal frequency assignments within the band, the types of federal operations and functions that the assignments support, and the geographic location of federal use. Since clearing these bands of federal users and relocating incumbent federal users to new bands was not an option in the given time frame, the bands that NTIA recommended be made available will be opened to geographic sharing by incumbent federal users and commercial broadband.

10-Year Plan. By a presidential memorandum, NTIA was directed to collaborate with FCC to make available 500 MHz of spectrum over the next 10 years, suitable for both mobile and fixed wireless broadband use, and complete by October 1, 2010, a specific plan and timetable for identifying and making available the 500 MHz for broadband use.[10] NTIA publicly released this report in November 2010.[11] In total, NTIA and the National Broadband Plan identified 2,264 MHz of spectrum to analyze for possible repurposing, of which 639 MHz is exclusively used by the federal government and will be analyzed by NTIA. Additionally, NTIA will collaborate with FCC to analyze 835 MHz of spectrum that is currently located in bands that are shared by federal and nonfederal users. Furthermore, NTIA has stated that it plans to seek advice and assistance from CSMAC, its federal advisory committee comprised of industry representatives and experts, as it conducts analyses under the 10-Year Plan.

In January 2011, NTIA announced that it had selected the 1755–1850 MHz band as the first priority for detailed evaluation under the 10-Year Plan. According to NTIA, this band was given top priority for evaluation by NTIA and the federal agencies, based on a variety of factors, including industry interest and the band's potential for commercial use within 10 years. This is not the first time NTIA has studied this band. This band was

[9]In November 2010, NTIA publicly released its results. In its final report, NTIA summarized its analysis of four frequency bands: 1675–1710 MHz, 1755–1780 MHz, 3500–3650 MHz, and 4200–4400 MHz.

[10] *Unleashing the Wireless Broadband Revolution,* 75 Fed. Reg. 38387.

[11]NTIA, *10 Year Plan and Timetable to Make Available 500 MHz of Spectrum for Wireless Broadband* (2010).

previously evaluated for reallocation, and in 2001, we reported that at the time adequate information was not currently available to fully identify and address the uncertainties and risks of reallocation.[12]

Industry Concerns with the Usefulness of the Identified Spectrum

Industry stakeholders, including wireless service providers, representatives of an industry association, and a think tank representative we contacted in 2011 expressed concerns over the usefulness of the spectrum identified by NTIA in the Fast Track Evaluation, since most of the spectrum identified (100 of the 115 MHz) is outside the range considered to have the best propagation characteristics for mobile broadband. Overall, there has been limited interest in the bands above 3 GHz for mobile broadband use because, according to industry stakeholders, there has been minimal development of mobile broadband in bands above 3 GHz and no foreseeable advances in this area at this time.

According to industry representatives, the 1755–1780 MHz band that NTIA considered as part of the Fast Track Evaluation has the best characteristics for mobile broadband use, and it is internationally harmonized for this use. NTIA did not select this band to be made available in the 5-year time frame due to the large number of federal users currently operating there. However, NTIA identified it as the first band to be analyzed under the 10-Year Plan to determine if it can be made available for commercial broadband use. An industry stakeholder has stated that the 1695–1710 MHz band identified by NTIA in the Fast Track Evaluation is the second-best alternative for wireless broadband if the 1755–1780 MHz band were not made available; however, the 1695–1710 MHz band is not currently used internationally for wireless broadband, which may reduce device manufacturers' incentive for developing technology that can be used in these frequencies.

[12]GAO, *Defense Spectrum Management: More Analysis Needed to Support Spectrum Use Decisions for the 1755-1850 MHz Band*, GAO-01-795 (Washington, D.C.: Aug. 21, 2001).

Some Users Lack Incentives and Face Several Barriers to Sharing Spectrum, and Cannot Easily Identify Available Spectrum to Share

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 spectrum[13]—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 had to pay a market price for the all of their spectrum needs. As such, 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 expert, 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.

While licensed, commercial users who purchased spectrum at auction generally have market incentives to use their spectrum holdings

[13]Agencies 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.

efficiently, these users also have incentives that work against sharing spectrum, except in those instances where the incumbent licensee is unlikely to build out its network or offer services to a particular area, such as in certain remote, sparsely populated areas. 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 prefer to not 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

There are several barriers that can deter sharing. One such barrier is that 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 achieving their missions at risk. The officials stressed that when missions have security and safety implications, sharing may pose unacceptable risks. For example, the military tests aircraft and trains pilots over test ranges that can stretch hundreds of miles, maintaining constant wireless contact. The ranges, according to officials, cannot share the communication frequencies because even accidental interference in communications with an aircraft could result in catastrophic mission failure. Further, sharing information about such flights could expose particular pilots and aircraft, or the military's larger mission, to increased risk.

According to FCC officials, concerns about risk can drive conservative technical standards that can make sharing impractical. In general, the technical analyses and resulting standards 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 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.

Another barrier is that spectrum sharing can be costly. Stakeholders told us that sharing federal spectrum can be costly for both the nonfederal and federal users seeking to share for the following reasons:

- Mitigation of potential interference can be costly in terms of equipment design and operation.
- 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 inference 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 typically is not conducive to operating as efficiently or flexibly as the state-of-the-art technologies might now allow. Limited budgets may prevent them from being able to invest in newer technology which can facilitate easier sharing.

Additionally, we found that 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, or when nonfederal users share with one another, according to stakeholders:

- 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 requiring a rulemaking to accommodate shared use of spectrum.[14] In addition to that time, NTIA officials said that IRAC's evaluation of potential harmful interference could take months. In one example, the Department of Defense, along with other federal agencies and nonfederal entities, currently shares a spectrum band between 413-457 MHz with a nonprofit medical devices provider for use in implant products for veterans. It took approximately 2 years

[14]The time it takes to complete rules may vary 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, and FCC is generally not required by statute to complete rules within limited time frames.

(from 2009 to 2011) for FCC and NTIA to facilitate this arrangement, as FCC required a rulemaking and NTIA required a lengthy evaluation of potential interference. This nonprofit is 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, could discourage for-profit companies from developing and investing in business plans that rely on sharing federal spectrum.

- Stakeholders we interviewed told us that when federal or nonfederal users share spectrum, both parties have concern that harmful interference may affect their missions or operations if the other party overreaches or does not follow the agreement. They also fear that the enforcement actions that are taken by FCC will happen too slowly to protect their interests or that enforcement outcomes can be unpredictable.

Users May Be Unable to Easily Identify Spectrum Suitable for Sharing

Besides lacking incentives and overcoming other barriers, users may also have difficulty identifying spectrum suitable 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.[15] Further, federal agency spectrum managers told us that agencies have not been asked to regularly update their strategic spectrum plans, in which they were required to include an accounting of spectrum use.[16]

As mentioned, 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, which may in turn identify

[15]In 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.: November 23, 2011). In April 2011, we reported on NTIA's Government Master File database. See GAO-11-352.

[16]The Bush Administration directed federal agencies to submit spectrum plans to NTIA and provide updates every 2 years. Since 2008, NTIA has ceased requesting those updates, and has put its strategic planning initiatives on hold due to limited resources.

more sharing opportunities. In addition, recently proposed legislation would require in part that FCC, in consultation with NTIA and the White House Office of Science and Technology Policy, prepare a report for Congress that includes an inventory of each radio spectrum band they manage.[17] The inventory is also to include data on the number of transmitters and receiver terminals in use, if available, as well as other technical parameters—coverage area, receiver performance, location of transmitters, percentage and time of use, a list of unlicensed devices authorized to operate in the band and description of use—that allow for more specific evaluation of how spectrum can be shared. 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.[18] Additionally, FCC and NTIA officials told us that information on some federal spectrum bands may never be made publicly available because of the sensitive and classified nature of some federal spectrum use.

Incentives and Opportunities to Share Could Be Expanded

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 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.[19] Federal advisors and experts we talked to identified several options that could provide incentives and opportunities for more efficient spectrum use and spectrum sharing by federal and nonfederal users, which include, among others: (1) assessing spectrum usage fees; (2) expanding the availability of spectrum for unlicensed uses; and (3) increasing the federal focus on research and development of technologies that can enable spectrum sharing and improve spectral efficiency.

[17]S, 455, § 3, 112th Cong. (2011).

[18]The Department of Defense's Defense Advanced Research Projects Agency is working on frequency mapping.

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

Assessing spectrum usage fees. Several advisory groups and spectrum industry experts, including those we interviewed, have recommended that spectrum fees be assessed based on spectrum usage. As previously mentioned, with the exception of administrative fees for frequency assignments, federal users incur no costs for using spectrum. As such, federal users may have little incentive to share spectrum assigned to them with nonfederal users or identify opportunities to use spectrum 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 to drive greater efficiency and solicit input from both federal and nonfederal users who might be subject to fees.[20] The *National Broadband Plan* has also recommended that Congress consider granting FCC and NTIA authority to impose spectrum fees on unauctioned spectrum license holders—such as TV broadcasters and public safety entities—as well as government users. Fees may help to free spectrum for new uses, since licensees who use spectrum inefficiently may reduce their holdings or pursue sharing opportunities once they bear the opportunity cost of letting it remain fallow or underused. Further, FCC officials told us that they have proposed spectrum usage fees at various times, including in FCC's most recent congressional budget submission, and requested the legislative authorities to implement such a program.[21]

While noting the benefits, the CSMAC Incentives Subcommittee report mentions 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 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 also avoid disrupting public

[20]CSMAC Incentives Subcommittee Final Report (Washington, D.C.: January 11, 2011).

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

safety, national defense, and other essential government services that protect human life, safety, and property.[22]

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 incentive to use their assignments more efficiently or share spectrum. In the PCAST proposal, agencies would also be rewarded for making spectrum available to others for sharing, by being reimbursed for their investments in improving spectrum sharing from a proposed Spectrum Efficiency Fund.[23]

Expanding the availability of spectrum for unlicensed use. Unlicensed spectrum use is inherently shared spectrum access, and according to spectrum experts we interviewed and other stakeholders, unlicensed use of spectrum is a valuable complement to licensed spectrum 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.[24] Increasing the amount of spectrum for unlicensed use may allow more users to share without going through lengthy negotiations and interference mitigations, and also allow for more experimentation and innovation.

[22] *The National Broadband Plan*, p. 83, Recommendation 5.6, (Mar. 16, 2010).

[23] The 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.

[24] The Industrial (900-928 MHz), Scientific (2.4 – 2.485 GHz) and Medical (5.7 – 5.825 GHz) are examples of the unlicensed spectrum bands. Wi-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.

More recently, FCC has provided unlicensed access to additional spectrum, known as TV "white spaces," to help address spectrum demands.[25] The white spaces refer to the buffer zones that FCC assigned the television broadcasters to mitigate unwanted inference between adjacent stations. With the more efficient TV transmission capabilities that resulted from the digital television transition, 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 which responds with a list of the frequencies that are available for use at the device's location.[26] As an example, one local official explained that his city uses TV white space spectrum to provide a network of public Wi-Fi access and public safety surveillance functions.

Increasing the federal focus on research and development of technologies. 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 between frequencies to seamlessly continue communication as the user moves geographically and through the spectrum. According to experts and researchers we contacted, progress has been made but there is no indication of how long it will be before this technology is fully deployable. 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 harmful interference, and agreements and rulemakings that are currently needed may be streamlined or unnecessary to enable sharing.

Although industry participants indicated that extensive testing under realistic conditions is critical to conducting basic research on spectrum

[25]*In the Matter of Unlicensed Operation in the TV Broadcast Bands*, 27 FCC Rcd. 3,692 (April 5, 2012).

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

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 also said six companies responded to NTIA's invitation to participate in the previously mentioned dynamic spectrum access testing project. However, only two working devices were received for the testing, and a third device received 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.

Recent federal advisory committee recommendations 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 Fund[27] release funds for this purpose and (2) the current Spectrum Relocation Fund be redefined as the Spectrum Efficiency Fund. As discussed, this adjustment would allow for federal agencies to be reimbursed for general investments in improving spectrum sharing. 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.[28]

[27]The 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.

[28]CSMAC Incentives Subcommittee Final Report.

Conclusions and Recommendations

Radio frequency spectrum is a scarce national resource that enables wireless communications services vital to the U.S. economy and to a variety of government functions, yet NTIA has not developed a strategic, governmentwide vision for managing federal use of this valuable resource. NTIA's spectrum management authority is broad in scope, but NTIA's focus is on the narrow technical aspects of spectrum management, such as ensuring new frequency assignments will not cause interference to spectrum-dependent devices already in use, rather than on whether new assignments should be approved based on a comprehensive evaluation of federal spectrum use from a governmentwide perspective. Lacking an overall strategic vision, NTIA cannot ensure that spectrum is being used efficiently by federal agencies. Furthermore, agencies are not required to submit justifications for their spectrum use and NTIA does not have a mechanism in place to validate and verify the accuracy of spectrum-related data submitted by the federal agencies. This has led to decreased accountability and transparency in how federal spectrum is being used and whether the spectrum-dependent systems the agencies have in place are necessary. Without meaningful data validation requirements, NTIA has limited assurance that the agency-reported data it collects are accurate and complete.

In our April 2011 report, we recommended that NTIA (1) develop an updated plan that includes key elements of a strategic plan, as well as information on how spectrum is being used across the federal government, opportunities to increase efficient use of federally allocated spectrum and infrastructure, an assessment of future spectrum needs, and plans to incorporate these needs in the frequency assignment, equipment certification, and review processes; (2) examine the assignment review processes and consider best practices to determine if the current approach for collecting and validating data from federal agencies can be streamlined or improved; and (3) establish internal controls for management oversight of the accuracy and completeness of currently reported agency data.[29] With respect to our first recommendation, NTIA has not developed an updated strategic plan and previously noted that the Presidential Memorandum of June 28, 2010, and the Wireless Innovation Initiative provide significant strategic direction for NTIA and the other federal agencies. In September 2012, NTIA officials told us that NTIA intends to update its strategic plan by October

[29]GAO-11-352

2013. NTIA concurred with our other two recommendations and is taking action to address them. For example, NTIA has proposed approaches to implement new measures to better ensure the accuracy of agency-reported data, and is taking steps to implement internal controls for its data management system in a cost efficient manner.

With respect to spectrum sharing, there are currently insufficient incentives to encourage more sharing, and even if incentives were created, several barriers to sharing will continue. Options to address these issues in turn create new challenges, and may require further study.

Chairman Walden, Ranking Member Eshoo, and Members of the Subcommittee, this concludes my prepared statement. I will be happy to respond to any questions you may have at this time.

GAO Contact and Staff Acknowledgments

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