



*Federal-Commercial Spectrum Sharing Workshop:  
Models, Applications, and Impacts of  
Incentives for Sharing*

NITRD Wireless Spectrum R&D Senior Steering Group  
Workshop VII Report

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## Executive Summary

The goal of Workshop VII was to identify opportunities and challenges that need to be addressed in order to incentivize spectrum sharing. Increased bi-directional spectrum sharing between non-Federal<sup>1</sup> (including commercial<sup>2</sup>) and Federal<sup>3</sup> users will expand access to spectrum resources and will enhance the robustness, flexibility, and efficiency for both Federal and non-Federal users. However, incentivizing bi-directional spectrum sharing presents significant challenges that will require innovations in technology, business and administrative practices, and policy. The Wireless Spectrum R&D Senior Steering Group (WSRD SSG) has conducted a series of workshops focused on understanding the fundamental issues involved in Federal and non-Federal spectrum sharing. WSRD VII, the seventh workshop in this series, was held at Stevens Institute of Technology on March 19, 2015, and focused on identifying incentives to encourage and improve bi-directional spectrum sharing.

The one-day workshop provided an opportunity for a diverse group of experts from industry, government, and academia to inform and share ideas about research and practical strategies. It was organized around two sets of breakout sessions: the morning focused on understanding the opportunities and constraints that shape stakeholder incentives; the afternoon was devoted to building on these discussions to identify incentive strategies. Participants were first asked to consider three basic sharing scenarios where the incumbent was either Federal or commercial<sup>4</sup>, and the spectrum was licensed or unlicensed. Once the various frameworks for spectrum sharing were established, the afternoon strategy sessions focused on three different categories of incentives: market; administrative and budgetary; and technical and enforcement.

### *Major themes from the workshop discussions:*

1. Bi-directional spectrum sharing offers both commercial and Federal spectrum users an important opportunity for increasing access to spectrum.

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<sup>1</sup> Non-Federal spectrum use is any use by a commercial, local government, or other entity of non-Federal or Federal/non-Federal shared spectrum authorized by the FCC in accordance with rules and regulations that are located in Title 47 of the Code of Federal Regulations (CFR).

<sup>2</sup> Commercial spectrum use is defined as any use of spectrum authorized by the FCC for the provision of commercial wireless services to customers using either licensed or unlicensed spectrum. Note: This definition is for the purpose of identifying these entities in this report only and is not necessarily applicable to the use of the term commercial spectrum in any other context.

<sup>3</sup> Federal spectrum use is any use of Federal or Federal/non-Federal shared spectrum by an agency or agent of the U.S. federal government in accordance with the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management.

<sup>4</sup> The fact that there are other non-Federal, non-commercial users of spectrum that are candidates for Federal/non-Federal spectrum sharing was acknowledged, however, for the purposes of this workshop, the planning committee chose to focus on scenarios involving commercial and Federal users only.

2. Incentivizing bi-directional spectrum sharing will require innovations in technology, business and administrative practices, and policy.
3. Both commercial and Federal users require spectrum access rights that are predictable and easily adaptable to ever changing needs and operating environments.
4. Spectrum sharing between commercial and Federal users requires mutual understanding, collective learning, and building social capital between disparate stakeholders.
5. Development of a national spectrum strategy would help build trust, provide predictability, and facilitate future investment.
6. Credible enforcement is necessary for any spectrum sharing incentive framework to be sustainable.

Suggestions for potential research and further exploration are organized into three categories and summarized below:

1. **Market based incentives:** Ideas for spectrum valuation studies were suggested to address the discrepancy of spectrum valuation between Federal and commercial users. For example, an assessment of opportunity cost for spectrum uses can be conducted by assigning a value to various spectrum uses and conducting spectrum use audits. The outcome of such assessments can be used to create incentives to spectrum sharing by providing insight on how Federal and commercial spectrum users can increase the value of the spectrum they are using.
2. **Administrative and budgetary incentives:** Administrative constraints limit Federal and commercial users' ability to take advantage of spectrum sharing incentives. Potential research includes examining the use of spectrum bucks<sup>5</sup>, changes to the spectrum relocation fund (SRF), implementing a Federal spectrum clearinghouse, or developing other approaches that may enable Federal Agencies to benefit from spectrum efficiency enhancements.
3. **Technical and policy incentives:** Technical innovation and new policy ideas have the ability to increase opportunities for spectrum sharing. Potential studies could assess new methodologies for conducting costs/benefits analyses to account for various technical and policy changes or requirements when spectrum sharing scenarios are reformulated.

## Background and Workshop Description

The genesis of the WSRD SSG workshop series was the Presidential Memorandum issued on June 14, 2013, entitled *Expanding America's Leadership in Wireless Innovation*<sup>6</sup> which

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<sup>5</sup> "Spectrum bucks" refers to budgetary dollar-equivalents that provide an indirect mechanism for mapping from government budgets to spectrum efficiency decision-making. Introducing an artificial "currency" in this context is intended to provide flexibility to address the challenges of introducing efficient economic behavior incentives in a non-profit decision making environment (WSRD Workshop Report IV, page 16).

<sup>6</sup> "Expanding America's Leadership in Wireless Innovation: Presidential Memorandum", *White House*. <https://www.whitehouse.gov/the-press-office/2013/06/14/presidential-memorandum-expanding-americas-leadership-wireless-innovatio>. [www.whitehouse.gov](http://www.whitehouse.gov).

proposed making more wireless spectrum available for commercial use by encouraging shared access by non-Federal and Federal users. One of the directives was to explore and recommend approaches based on the market or other influences that would incentivize Federal and non-Federal users to cooperate in sharing spectrum. The President's Council of Advisors on Science and Technology (PCAST, 2012),<sup>7</sup> the Institute of Defense Analysis (IDA, 2013)<sup>8</sup> and other groups, have proposed or outlined a variety of budgetary and administrative incentives for Federal agencies. Proposals have included introduction of a spectrum currency, and setting aside some portion of spectrum auction revenues to establish a spectrum efficiency or relocation fund. Internationally, the United Kingdom has explored charging spectrum usage fees to government agencies<sup>9</sup> and recently released a new framework for spectrum sharing for which it is soliciting public views (i.e. a clear policy signal focused on sharing)<sup>10</sup>.

As with earlier workshops, WSRD VII brought together key individuals from industry, academia, and the public sector with WSRD SSG members to develop strategies and identify research topics that will help promote progress toward increased spectrum sharing (see Appendix C for a list of participants). The workshop was organized around two breakout sessions, with introductory talks and panel discussions to help frame the day's discussion. The goal of Workshop VII was to identify opportunities and challenges that need to be addressed in order to incentivize spectrum sharing.

## Framing the Incentives Challenge

In order to generate useful and practical ideas for incentivizing spectrum sharing, the Workshop dedicated the morning to hearing spectrum and policy experts discuss where we are, what has been tried, and what they believe are the necessary steps needed to move forward. The detailed commentary is contained in Appendix B, and has been summarized around four themes described below.

### Incentives are Necessary, But Challenging

Stakeholders do not want to share spectrum unless it protects meeting the current and future mission requirements for Federal stakeholders or increases the revenue for commercial entities.

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<sup>7</sup> “Realizing the Full Potential of Government-held Spectrum to Spur Economic Growth: PCAST Report”, *White House*. [http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast\\_spectrum\\_report\\_final\\_july\\_20\\_2012.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf). [www.whitehouse.gov](http://www.whitehouse.gov).

<sup>8</sup> “A Review of Approaches to Sharing or Relinquishing Agency-Assigned Spectrum; IDA Paper P-5102”, *IDA Science and Technology Institute*. <https://www.ida.org/upload/stpi/pdfs/p5102final.pdf>. [www.ida.org](http://www.ida.org)

<sup>9</sup> Forge, Simon; Horvitz, Robert; Blackman, Colin, “Report to the European Commission, Perspectives on the value of shared spectrum access,” *European Commission*. [http://ec.europa.eu/digital-agenda/sites/digital-agenda/files/scf\\_study\\_shared\\_spectrum\\_access\\_20120210.pdf](http://ec.europa.eu/digital-agenda/sites/digital-agenda/files/scf_study_shared_spectrum_access_20120210.pdf). <http://ec.europa.eu/>.

<sup>10</sup> “A Framework for Spectrum Sharing”, *Ofcom*. <http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing-framework/summary/spectrum-sharing-framework.pdf>. <http://www.ofcom.org.uk/>.

When considering incentives to increase spectrum sharing, the panel agreed that both positive and punitive strategies need to be considered along with appropriate enforcement action. For example, new, more spectrally efficient technologies could lower costs; use of Spectrum Relocation Funds (SRF) could improve access to spectrum for Federal users while minimizing spectrum acquisition costs to commercial users; spectrum scarcity leading to declining Quality of Service (QoS) could degrade access, and spectrum fees could raise costs. Incentives can be provided in many forms: market; administrative and budgetary; and technical.<sup>11</sup> These along with enforcement strategies will be explored more fully later in this report.

One of the major challenges in designing incentives is bridging the disparate motivations of the parties involved. The commercial sector, with its need to generate profits, and the Federal sector, with its need to fulfil Agencies' missions, have different needs and therefore different motivations to share spectrum. Finding mutually acceptable incentives can be challenging. The market economics that drive the commercial sector are very different from the administrative and legal constraints that the Federal sector confronts. For example, there are legal and budget constraints that limit the ability of Federal Agencies to negotiate contracts or payments from commercial entities even when both parties agree on a spectrum sharing framework. Likewise, the need for future system and capacity growth and an increasingly competitive marketplace may limit the motivation of commercial entities to share with Federal users. QoS requirements differ as well. For example, a certain level of sharing may be possible under normal operating conditions, but in an emergency situation bands may need to be cleared for heavy and immediate use by particular users. This situation is not unique to commercial-Federal sharing but also exists with commercial to commercial and Federal to Federal sharing.

Spectrum sharing also demands a level of trust. A major concern is that the implementation of spectrum sharing policies requires an increased need for disparate users to exchange information about operational and system configuration data. This could compromise the security of intellectual property and proprietary information or expose strategic decisions and classified information. Building trust will involve the development of realistic testing environments, tracking of experiments, and transparency of results. A body of respected research and case studies will help prove the viability of innovative spectrum sharing technologies or techniques and alleviate the concerns.

### **Bi-directional Sharing is the Path Forward**

The need for flexible spectrum access is increasing rapidly in both the non-Federal and Federal sectors and is no longer the subject of debate. Although the drive to find underutilized spectrum for new dedicated assignments will continue, such efforts are no longer sufficient to meet the growing spectrum demands. The user community must shift its focus and promote sharing as a legitimate and affordable way to increase spectrum access.

The trajectory of growing requirements, technological development, and market trends are consistent with the need for increased bi-directional spectrum sharing. However, because few

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<sup>11</sup> For example, incentives could exist as a monetary exchange for access to spectrum. In addition, use of database sharing techniques could offer an incentive by providing incumbents better ability to manage their own spectrum use. Spectrum sharing could also enable an incumbent to take advantage of newly offered services to its own benefit. Finally, an incentive to spectrum sharing could be that it is required by law.

sharing scenarios are exactly the same, diverse and increasingly flexible methods of sharing need to be available to take advantage of different use patterns. These patterns are dictated by frequency, bandwidth, time, and location as well as the function of the system (e.g., communications links, radar, etc.). In addition, sharing can be facilitated by various access technologies and protocols such as Spectrum Access System (SAS) databases, sensing, cognitive and software defined radios, 4G LTE Cellular and more. For successful sharing to occur, incentives must be designed so that both the incumbent and the entrant have access to additional resources as needed. An incumbent is concerned about losing access to resources (and losing its ability to expand its system) when a new entrant shares the band. The new entrant needs access to additional resources, but needs to do so in a way that doesn't constrain the incumbent. This is the scenario whether it involves non-Federal into Federal, or Federal into non-Federal sharing. The spectrum user community must strive to eliminate the false dichotomy of separate spectrum resources and demonstrate how sharing can enhance robustness, mission effectiveness, and lower costs through economies of scale and increased interoperability and agility.

This will require a national strategy and leadership and cooperation from all stakeholders. The Presidential Memoranda<sup>12</sup> is a beginning, but more work is needed at multiple levels to engage relevant Federal Agencies and non-Federal entities to resolve the details. Increased research into spectrum sharing technologies and strategies must be encouraged. Such activities can show ways to break through the significant legal, administrative, budgetary, and legislative impediments to spectrum sharing that currently exist. Some progress has been made. Groups such as PCAST (President's Counsel of Advisors on Science and Technology) have encouraged increased spectrum sharing and the Model City initiative<sup>13</sup> can provide a testbed to develop and assess new technologies and sharing techniques under real world conditions. In addition, the Department of Defense has developed a Spectrum Strategy<sup>14</sup> and the FCC and NTIA have already taken action in several bands that will lead to more spectrum sharing.<sup>15</sup>

### **Predictability and Flexibility are Critical**

Participants from both the non-Federal and Federal sectors emphasized the need for predictability and flexibility if spectrum sharing is to be successful. Commercial users require flexibility in order to adapt to changing market conditions such as competition, supply and demand, and availability of new technologies. Federal users need this same flexibility to adjust for changing mission requirements and regulatory environments. Sharing should not require being locked-in to legacy technology or protocols. Predictability involves better modeling and sharing of information. Similar to building trust (mentioned above), predictability is a challenge for all stakeholders due to continually changing requirements and regulatory environments.

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<sup>12</sup> "Expanding America's Leadership in Wireless Innovation: Presidential Memorandum," *White House*. <https://www.whitehouse.gov/the-press-office/2013/06/14/presidential-memorandum-expanding-americas-leadership-wireless-innovatio> . [www.whitehouse.com](http://www.whitehouse.com).

<sup>13</sup> "Bringing Spectrum Sharing to a 'Model City'," *National Telecommunications and Information Administration (NTIA)*. <http://www.ntia.doc.gov/blog/2015/bringing-spectrum-sharing-model-city>. [www.ntia.doc.gov](http://www.ntia.doc.gov) .

<sup>14</sup> "A Call to Action: Electromagnetic Spectrum Strategy, 2013," *Department of Defense (DoD)*. <http://archive.defense.gov/news/dodspectrumstrategy.pdf>. <http://Archive.defense.gov> .

<sup>15</sup> For example: Incentive Auctions, AWS-3, 3.5GHz, 5GHz, above 20GHz, etc.



## Credible Enforcement is Necessary

An inevitable consequence of successful spectrum sharing will be an increase in usage and therefore an increased potential for interference and disputes. Ex ante and ex post enforcement mechanisms will need to be credible, cost-effective, and compatible with incentives. Parties will need to understand and trust that the process will be as understandable, transparent, consistent, fair, and expedient as possible. Any enforcement action will also need to be cost-effective in that it must require minimal overhead, be timely, and minimize the impact on society. Compliance must be viewed as rational and consistent with incentives both to minimize the likelihood that enforcement action is needed (ex ante) and to insure that there is an efficient response when problems arise (ex post). An effective enforcement strategy requires a combination of technology, regulatory, legal, and economic factors working together.

## Spectrum Sharing within Specific Scenarios

Moving from the general discussion to the more specific, the workshop participants were divided into three groups to consider the challenge and opportunities of incentives for spectrum sharing within specific scenarios. With the goal of understanding the perspectives of licensed commercial, unlicensed commercial and Federal users on incentives, each group was asked to consider one of the following scenarios:

- Scenario #1 Licensed Commercial (entrant) into Federal (incumbent) spectrum
- Scenario #2 Unlicensed Commercial (entrant) into Federal (incumbent) spectrum
- Scenario #3 Federal (entrant) into Commercial (licensed or unlicensed) spectrum

The purpose of this exercise was to examine the needs of each user within the three scenarios and understand what incentives would motivate them to remove barriers and increase their willingness to participate in a spectrum sharing regime.

### Scenario #1: Licensed Commercial Sharing with Federal Incumbent

Commercial users have heterogeneous requirements for spectrum, but in most cases, they are well-defined with respect to usage-cycles and latency requirements. On the Federal side, there are often multiple government agencies with various requirements that share spectrum in the same band; on the commercial side, there may also be multiple operators in the same band with diverse interests and commercial arrangements.

Licensed commercial operators are also constrained and influenced by national policy and market influences. For example, the outcome of the upcoming broadcast incentive auction, as well as other sharing and reallocation initiatives now under consideration, will influence operators' level of interest and strategic positioning for any proposed commercial-Federal sharing program.

## Scenario #2: Unlicensed Commercial Sharing with Federal Incumbent

Unlicensed users are a mix of private end-users and commercial wireless enterprises with a wide range of business models. This group includes equipment vendors, application and content providers, as well as wireless service providers. Existing wireless instrumentation as well as impending internet-of-things (IoT) activities in the utility and industrial sector has the potential for millions of deployed devices by large and small supplier and end user companies. Growth in this sector can become hampered because they are all operating in the ISM<sup>16</sup> bands. Although unlicensed users do not pay directly for spectrum resources, they do incur capital costs in infrastructure and operations when operating on an unlicensed basis. On a spectrum value basis, reports place the value of spectrum in industrial use as 5-10 times higher than the returns from the broadcast or mobile communications sectors.

An additional nuanced spectrum sharing situation arises when multiple private sector end-users wish to share the same spectrum with Federal incumbents. An example would be utility companies deploying mobile broadband devices, sensors, and systems in a frequency band with a Federal incumbent. The need for access to and integration of a Spectrum Access System (SAS) combined with spectrum sensing, sharing and potentially financial transaction communications (“renting the spectrum”) in lightweight<sup>17</sup> and inexpensive devices across many users may open an area for significant research and development.

Sharing between Federal and unlicensed users is impeded by lack of trust and lack of incentives. Unlicensed entrants need to build trust by developing and validating credible techniques to avoid interfering with incumbents. Improved enforcement techniques are also needed to ensure that the interference avoidance techniques are working properly. In this scenario, economic incentives are difficult to craft as there is no mechanism for unlicensed commercial users to transfer funds to Federal users. This is in contrast to scenario #1 in which auction proceeds can be used to relocate incumbent Federal users and act as an incentive for Federal users to share spectrum. One idea mentioned at the workshop was to impose a device tax on radios operating in the unlicensed bands with the resulting revenues being transferred to the Federal users. This and other models need to be explored to overcome this disincentive for sharing between Federal and unlicensed users.

## Scenario #3: Federal Users Sharing with Commercial Incumbent

Federal users are non-profit, mission-driven, budget funded organizations whose spectrum needs, similar to commercial operators, are growing. Traditionally, while commercial business models focus primarily on revenue generation and as a consequence often try to maximize their spectrum utilization; Federal models focus first on mission requirements and assured communications with less emphasis on the efficient use of the spectrum. Yet spectrum sharing with the commercial sector is an important part of the Federal spectrum plan moving forward. For example, the Department of Defense (DoD) believes that increased sharing in non-Federal spectrum can enhance robustness and enable operational flexibility of Federal systems. However, quality of

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<sup>16</sup> Industrial, scientific, and medical (ISM) bands are radio bands reserved internationally for the use of radio frequency for industrial, scientific, and medical purposes other than telecommunications.

<sup>17</sup> “lightweight” in the sense of code and computational complexity

service (QoS) is a challenge for Federal systems co-existing with commercial operators. As an example, disaster responses during events such as Hurricane Sandy or a major medical outbreak would benefit from additional capacity on-demand for first responders, however, this is often when commercial customer usage also peaks. Tradeoffs and judgements must be made to avoid a conflict in priorities. As a possible way forward, studies to develop a unified commercial-provider service model consistent with Federal infrastructure and assured connectivity were mentioned, as well as interest in developing technologies that allow Federal users to overlay commercial use without causing interference (secondary user mode). Other possibilities include research into sharing core networks in addition to sharing spectrum, and the identification of policy and regulatory mechanisms to enable Federal users to more easily share commercial spectrum.

## Incentive Mechanisms for Spectrum Sharing

The goal of the afternoon session was to explore ideas for how the sharing scenarios might be modified to best enhance spectrum sharing incentives. Each of the sessions considered different categories of incentive mechanisms based on: the market; administrative and budgetary mechanisms; and technology and policy issues. The Workshop produced a variety of ideas that involved multiple categories. These would need further study before making specific recommendations. For example, topics such as a Federal spectrum-usage audit, or crowd-sensing of spectrum usage to assist enforcement, are relevant to more than one topic area. Therefore effective incentive models may require the co-evolution of all three categories as well as the ability to adapt to changing business, technical, and policy environments over time.

### General Themes

Transitioning from a legacy system to a new one may have many benefits, but is often costly and involves risk. Trust between stakeholders is essential and requires mutual understanding, collective learning, and building social capital. There are technical, regulatory, operational, legal, and economic issues to be addressed and they should be explored and tested on a large enough scale to build trust, but a small enough scale to limit risk.

Forecasting the future of spectrum use is also a persistent challenge but can be mitigated in part by thoughtful administrative and budgetary reforms based on a national spectrum strategy. Such a strategy should be based on case studies and the lessons learned from both successes and failures<sup>18</sup>, and it should consider advanced capabilities testing and what technologies are on the horizon. Updated definitions of property rights and spectrum access rights may be required to allow for flexible assignments and to maximize the social value of spectrum over time. Recognition that protection from harmful interference is scenario dependent, and can be accomplished in many different ways, will require that technology, operations, administrative and enforcement processes will need to be increasingly dynamic as well.

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<sup>18</sup> For example, a study could be conducted comparing attempts to revise spectrum rules and/or reallocate spectrum such as TVWS v. incentive auctions v. 3.5GHz v. AT&T/Qualcomm transfer of MediaFlo spectrum, etc.

## Market Based Incentives

Two key aspects of potential incentive approaches based on the market include, (a) markets where spectrum resources may be accessed or traded; and (b) price signals of the opportunity costs of resource use (spectrum value, costs of sharing, etc.). Ideas about how to structure spectrum markets, implement pricing mechanisms, or inferring spectrum values and opportunity costs were all relevant topics for this discussion.

Economic incentives can come in many forms but for markets to work, participants need to know the price, to understand the goods to be exchanged, and the process to complete the exchange. For the spectrum market this leads to three basic questions: how to estimate the spectrum opportunity cost (i.e. price); how to define the good that is to be exchanged (i.e. property rights); and how to structure the exchange (i.e. the spectrum market). Establishing a price for spectrum requires the study of spectrum valuation which is inherently uncertain and unstable. Complicating this is the fact that social and private values are not aligned and high prices paid by the licensed commercial sector for spectrum make it prohibitive for many new and innovative entrants to compete. These high prices also complicate the idea of establishing “prices” for Federal users. When commercial carriers pay for spectrum at auction, they fully expect to recoup their costs by raising consumer prices. However, any “price” levied on Federal spectrum users cannot be recouped directly from the American public who does not pay for services such as Air Traffic Control, weather forecasts, etc.

The debate over licensed v. Federal v. unlicensed spectrum “value” demonstrates no single best way. Econometric, engineering cost modeling, general equilibrium, and other measures need consideration if spectrum values are to be incorporated into both public and private budget planning. For example, one way of performing an incentive valuation would entail assigning a value to spectrum usage and then conducting spectrum audits to establish the needs and the basis for cost assessment. This could allow the Congressional Budget Office (CBO) to score spectrum repurposing in a way that promotes sharing<sup>19</sup>. What is certain is that market mechanisms cannot be the only factor for determining the value of spectrum because evaluating agency mission and associated spectrum needs is challenging.

Understanding property rights and methods of exchange were discussed including whether the definition of spectrum property rights needs to be changed and if property rights should even be exchanged as a way to incentivize sharing. Does anyone own the spectrum? This requires a legal research project to define “ownership”. The legal and technical implications of shared infrastructure, including public/private partnerships, need to be explored including pre-emption for public safety. There were several other suggestions including forming a working group to study what works well in other administrations such as: flexible transaction models, spectrum exchanges, real-time band managers, barter/swaps allowing Federal and commercial users to negotiate directly, and tradable licenses.

There is also the tension between unlicensed and licensed spectrum usage to be considered. For example, deployments of unlicensed devices under FCC Part 15 are not tracked, creating a challenge of assessing aggregate interference levels into licensed spectrum. Additionally,

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<sup>19</sup> Note: this would require administrative and transition costs to implement and will result in uncertain gains.

impediments to transitioning to new unlicensed technologies are suggested for further study. A major concern is the need to study and develop regulations that will ensure continued opportunities for entrepreneurs and innovators by continuing to provide opportunities for unlicensed devices.

### **Administrative and Budgetary Incentives**

Unlike commercial users that are generally profit motivated, Federal users are subject to budgetary and administrative constraints that limit their ability to respond to market based incentives. Federal Agencies already realize a benefit from using their spectrum more efficiently as part of current incentives to share spectrum<sup>20</sup>. Additional incentive ideas such as spectrum bucks, extending the use of the Spectrum Relocation Fund (SRF), and a Federal spectrum clearinghouse were mentioned as possible solutions; however, applicability and practicality of each idea requires further evaluation.

A full range of administrative reforms were discussed from decentralization of spectrum decisions to give individual Agencies direct authority to repurpose or share spectrum, to letting individual Agencies enjoy the benefits of their spectrum sharing efforts, to the establishment of a single point of government contact for coordinating spectrum.<sup>21</sup> Other proposals included the use of trusted third-party intermediaries (i.e. multi-stakeholder groups) to broker deals; and using a system similar to the DoD's base-realignment/closure process to reclaim spectrum resources.

### **Technical and Policy Incentives**

The Workshop participants discussed how technical innovation can enable sharing and concluded that technology and policy mechanisms incentivize sharing when they improve the costs/benefits ratio in any given sharing scenario. Studies could consider innovative technology and policy mechanisms in combination to reformulate and model given scenarios. This “tweaking” of scenarios using different technologies and policies would create a landscape of options that may help determine the optimal combination of factors.

The following are examples of spectrum sharing activities that might benefit from this type of research:

- Modeling and empirical analysis of spectrum usage to forecast future demand and/or test whether technology capabilities will work in sharing scenarios as promised, prior to full deployment
- Modeling and testing of interference in sharing scenarios
- Performance bounds to enable flexible Service Level Agreements (SLAs) for sharing

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<sup>20</sup> Federal agencies already share spectrum extensively and must use spectrum efficiently in order to effectively meet mission requirements. In addition, current statutory baseline provisions protect Federal agency missions when reallocation decisions are made (including for full cost reimbursement, comparable replacement spectrum, and adequate timelines) which provide incentives for agencies to further share spectrum, including with commercial users (e.g., 2025-2110 MHz).

<sup>21</sup> This refers to the division of spectrum coordination responsibilities between the FCC (non-Federal, including commercial) and the NTIA (Federal).

- Modeling and empirical analysis of unauthorized usage (e.g. enforcement challenges) and impact

Some of the options suggested included testing of different technologies of radio systems, infrastructure (e.g. SAS, sensors), standards, interfaces, performance metrics, architectures, ex ante/ex post enforcement mechanisms, and adjudication processes.

This type of modeling could also be used for evaluating technology insertion. For example, the growth of the Internet of Things (IoT) and advances in smarter radio systems (antennas, cognitive radios, etc.) are making sharing more feasible. Research questions include: What are the practical limits of these advances? How soon and how fast should these technologies be introduced into any given environment?

Evaluating the efficacy and impact of SAS database and sensing infrastructures would be another example. Does the system need improved security/reliability? How dynamic (granular) is control in time, space, band, or usage? Sensing for real-time management is computationally complex and information demanding. This type of modeling could help determine the most important and sensitive items to catalog, reference, and manage.

Perhaps one of the most common complaints regarding interference regulation is that protections are based on worst-case scenarios. If multiple and varied scenarios were tested and compared perhaps more realistic estimates of what is practical can be established. Other topics that were mentioned included: distributed and crowdsourced sensing, SAS design and how to interoperate or upgrade, technical performance standards, interoperability requirements, understanding how macro-cells off-load to micro-cells, and exploring opportunities and limits for real-time spectrum management.

## Summary

Providing incentives that are tailored for both the rapidly expanding requirements of Federal Agencies and the demands of commercial providers will accelerate the acceptance and use of spectrum sharing. Incentives for sharing must enhance the cost/benefit ratio, build trust among disparate stakeholders, be founded in flexible and innovative policy, provide predictability, and be sustainable. Bi-directional spectrum sharing is the path forward, and a national spectrum strategy would be needed to help devise incentives for sharing that can help alleviate spectrum scarcity.

Based on information gathered at the Workshop, the WSRD SSG provides the following suggestions for potential research and further exploration:<sup>22</sup>

1. Research pricing models that support certainty and stability of spectrum valuation under different sharing scenarios.

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<sup>22</sup> These suggestions were developed based on the topic areas discussed and information gathered at the Workshop. They are not intended to be a comprehensive list and may not include recommendations that are generated by individual agencies outside of this context.

2. Consider econometric, engineering cost modeling, general equilibrium, and other measures to allow spectrum values to be incorporated into both public and private budget planning.
3. Explore advanced modeling techniques to improve forecasting of spectrum requirements for both incumbents and entrants.
4. Investigate incentive models for unlicensed users that include mechanisms for transferring funds or trading resources with Federal users.
5. Consider commercial-provider service models that are consistent with Federal wireless infrastructure requirements and provide assured connectivity.
6. Research technology that allows Federal users secondary spectrum access by overlaying licensed commercial users without causing interference.
7. Experiment with the sharing of both commercial core networks and spectrum with Federal users.
8. Research on identification of policy and regulatory mechanisms to enable bi-directional spectrum sharing.
9. Research both how to assign value for usage of spectrum and how to audit that usage.
10. Study the legal and technical implications of shared infrastructure, including public/private partnerships and pre-emption for public safety.
11. Consider a national spectrum strategy for flexible and increased spectrum access/sharing that could include the establishment of a credible band manager for certain bands or types of usage.
12. Clearly define spectrum property rights and determine whether they could be exchanged as a means to incentivize sharing.
13. Study the effectiveness of various spectrum sharing incentives that have been implemented in other administrations.
14. Study and model regulations that will ensure continued opportunities for entrepreneurs and innovators.
15. Reformulate and model given spectrum sharing scenarios using various combinations of innovative technology and policy mechanisms.
16. Evaluate potential efficacy and impact of the SAS database and sensing infrastructures.
17. Model sensing for real-time management to help determine the most important and sensitive items to catalog, reference and manage.
18. Test and compare multiple and varied interference scenarios to determine the feasibility of establishing refined estimates of what is practical rather than just using the “worst case” scenario, noting that there might not be a one size fits all solution.



## Appendix A: Workshop Agenda

### *Federal - Commercial Spectrum Sharing Workshop: Models, Application, and Impacts of Incentives for Sharing*

Stevens Institute of Technology  
Wesley J. Howe Center, Bissinger Room  
Hoboken, NJ  
March 19, 2015

#### AGENDA

08:00 AM	Continental Breakfast
08:30 AM	<b>Opening Remarks:</b> <i>Rangam Subramanian, NTIA</i>
08:45 AM	<b>Keynote(s):</b> <i>Janice Obuchowski, Freedom Technologies, and Scott Blake Harris, HWG LLP</i>
09:30 AM	<b>Panel: Insights and Imperatives for Spectrum Sharing Incentives</b> <i>Moderator: Peter Tenhula, NTIA</i> <i>Panelists: Stuart Timerman, DoD, John Leibovitz, FCC, Simon Forge, SCF Associates, Mark Gibson, Comsearch, Aalok Mehta (OMB)</i>
10:30 AM	Break
10:45 AM	Guidance for Breakouts
11:00 AM	<b>AM Breakout: Motives and Opportunities for Spectrum Sharing</b> Scenario I - Incumbent: Federal / Entrant: Licensed Commercial <i>Moderator: Vanu Bose, Vanu Inc.</i> Scenario II - Incumbent: Federal / Entrant: Unlicensed Commercial <i>Moderator: Ira Keltz, FCC</i> Scenario III - Incumbent: Commercial (licensed &/or unlicensed)/Entrant: Federal <i>Moderators: Carolyn Kahn, MITRE, and Joe Heaps, DOJ-NIJ</i>
12:30 PM	Lunch
01:30 PM	<b>Panel: AM Breakout Report</b> <i>Moderator: Carl Kutsche, INL</i> <i>Panelists: Vanu Bose, Ira Keltz, Carolyn Kahn and Joe Heaps</i>
02:00 PM	<b>PM Breakout: Impacts and Models</b> Session I - Market Based Incentives <i>Moderator: Bill Lehr, MIT</i> Session II - Administrative Incentives <i>Moderator: Jim Craig, Alpha Six supporting DOJ</i> Session III - Technical Incentives <i>Moderator: Martin Weiss, University of Pittsburgh</i>
03:30 PM	Break
04:00 PM	<b>Panel: PM Breakout Report</b> <i>Moderator: Carl Kutsche</i> <i>Panelists: Bill Lehr, Jim Craig, and Martin Weiss</i>
04:30 PM	<b>Research Recommendations</b> <i>Moderators: Carl Kutsche and Bill Lehr</i>
05:00 PM	<b>Concluding Remarks:</b> <i>Thyaga Nandagopal, NSF</i>



## Appendix B: Notes on Opening Remarks and Panel Sessions

The day began with opening remarks from Rangam Subramanian (NTIA) and keynote talks from Janice Obuchowski (Freedom Technologies) and Scott Blake Harris (Harris, Wiltshire & Grannis LLP). Those talks were followed by a panel discussion with speakers representing a variety of stakeholder perspectives on spectrum sharing.

Dr. Subramanian highlighted some of the big challenges confronting stakeholders as options for sharing are expanded. For sharing to be successful it has to enable co-existence of diverse radio systems that provide appropriate interference protection for all users. Security is important for all users, but especially for Federal users with public interest and national security concerns to protect. To engender support for sharing, all parties have to enjoy the benefits to participating.

Mr. Harris and Ms. Obuchowski both emphasized the necessity of continued progress in promoting bi-directional spectrum sharing. The debate has moved beyond discussions of whether such sharing is desirable to discussions surrounding the best ways to implement such spectrum sharing. Both sides recognize that expanding non-Federal-Federal sharing is critical to address spectrum scarcity needs for all users. Furthermore, both Federal and non-Federal stakeholders recognize the need for greater understanding of their spectrum usage models to take advantage of such sharing opportunities to enhance the capabilities, robustness, and efficiency of their wireless networks and operations.

Mr. Harris noted that while the key stakeholders may recognize that sharing offers the only path forward, they are understandably resistant. In a world of increasingly scarce spectrum, folks resist relinquishing status quo rights without adequate assurances that their interests will be protected in a shared spectrum future. We need to move beyond the false dichotomy of thinking about Federal versus non-Federal spectrum, and think in terms of spectrum resources for all users. Mr. Harris also specifically discussed some proposed ideas on moving spectrum sharing forward to include using spectrum fees, strengthening budgetary audits by OMB of spectrum use by agencies, and a process modeled on the military base re-alignment and closure process for re-allocating Federal spectrum resources. The challenge is to make practical progress moving beyond arguing about the desirability of sharing to actual implementation of sharing frameworks. It is time to start down the path that folks may wish to avoid, and focus on how best to accommodate the sharing that needs to occur.

Ms. Obuchowski agreed with Mr. Harris that we are on the cusp of a transformational moment in spectrum management and that increased non-Federal-Federal sharing is necessary. Ms. Obuchowski stressed the importance that sharing opportunities be bi-directional. The debate needs to shift from a zero-sum game that positions the move to sharing as a one-way transference of value from incumbents (Federal users) to entrants (non-Federal users) to a positive-sum game that benefit both. “Old” ways of thinking about increased access based on fear – fees or clearing and relocation – must give way to a new sharing landscape based on opportunity. Both non-Federal and Federal users should see benefits in expanded opportunities for sharing. For this to be the case, policy and administrative process reforms are necessary. The idea that non-Federal and Federal spectrum sharing is desirable is hardly a new idea. The NTIA issued a report in 1991 that pointed to this as a desired goal and part of the future spectrum roadmap. While progress has been made, much more needs to be done. To make progress, it is important to align operational

and financial incentives for all parties. Federal users need the administrative flexibility and budgetary resources to enable them to participate in sharing.

After these opening remarks, a panel of experts representing different perspectives on the issue helped set the stage for the later breakout sessions. Peter Tenhula (NTIA) moderated the panel, which included Stuart Timerman (DoD), John Leibovitz (FCC), Simon Forge (SCF Associates), Mark Gibson (Comsearch), and Aalok Mehta (OMB). The panelists agreed with the opening speakers on the necessity of sharing, the need that incentives be bi-directional, and the challenges of implementing successful strategies for better incentivizing sharing.

The speakers noted many of the challenges and opportunities that were discussed more fully during the course of the day. These included the need for further research and funding to enable stakeholders (especially Federal spectrum users and regulators) to implement and participate sustainably in sharing frameworks. Additionally, while wireless experts in government, industry, and academia agree that increased sharing between Federal and non-Federal uses offers an important path forward, there are many who do not understand the issues and need to be educated regarding the need for sharing. Creative strategies are needed to enable progress toward sharing. Lessons can be learned from past successes and failures. For example, the Dynamic Frequency Selection (DFS) framework that was put in place in the 5GHz band is a notable success story. Stuart Timerman (DoD) emphasized that a strong economy contributes to national security and a strong commercial wireless sector is part of that. Spectrum auctions have made everyone recognize that spectrum is a valuable and scarce resource and all wireless users need to plan for a future of increased demand.

John Leibovitz (FCC) highlighted the multiple initiatives under way to expand commercial access to spectrum, including the planned broadcast incentive and recently completed AWS-3 auctions, 3.5GHz and 5 GHz proceedings, and exploration of management frameworks for spectrum above 20 GHz. He noted that markets are messy and getting the incentives right is only part of the challenge. There are lots of details that will need to be worked out.

Simon Forge (SCF Associates) offered a European perspective, which focused on the UK experience since the UK has been a leader in initiating spectrum management reform. Mr. Forge noted that the UK benefited from having a single spectrum regulator, Ofcom, responsible for both Federal and non-Federal spectrum management. This contrasts with the bifurcated situation in the U.S. where the NTIA is responsible for managing Federal usage and the FCC is responsible for non-Federal usage.

Mark Gibson (Comsearch) pointed to the good work done by the Commerce Spectrum Management Advisory Committee (CSMAC) in this area in addressing many of the important details regarding spectrum sharing between commercial and Federal users. A sustainable sharing framework is a three-legged stool that has to appropriately address technical considerations, regulatory issues, and user incentives to work effectively. Issues like ensuring that radio equipment be appropriately certified and installed are important details to be considered.

Aalok Mehta (OMB) mentioned the multiple ways in which OMB is engaged in this effort. A key area of focus is the SRF and strategies for how this might be modified to make it more flexible and effective for promoting sharing. OMB is looking into how the SRF might be used to support pilot testing and research. They are also looking at different strategies for monetizing Federal spectrum resources either through the budget process or via other mechanisms.

After their opening remarks, the panelists engaged in lively discussion with each other and with the assembled expert participants over past experiences and ideas for the future that may enhance progress toward spectrum sharing. The discussion addressed such topics as the potential role of the DoD-sponsored National Spectrum Consortium (NSC) initiative as a nexus for active collaboration among commercial and Federal spectrum users to the enforcement role of the FCC. There was general agreement that progress would benefit if prospective commercial and Federal sharers had more scope and flexibility to negotiate, but existing administrative rules stood in the way. There are legal, process, and budget impediments that constrain commercial and Federal entities from exploiting sharing arrangements that both sides recognize would be advantageous.

## Appendix C: Participant List

Rob Alderfer (CableLabs)  
Wayne Bale (Rivada)  
Byron Barker (NTIA)  
Randall Berry (Northwestern University)  
Vanu Bose (Vanu Inc.)  
Dean Brenner (Qualcomm)  
Michael Calabrese (New America Foundation)  
Mouli Chandramouli (Stevens Institute)  
Mike Chartier (Intel)  
Andrew Clegg (WinnForum/Google)  
Jim Craig (Alpha Six supporting DOJ)  
Sandra Cruz-Pol (NSF/EARS)  
Paul de Sa (U.S. Telecom)  
Thomas Dombrowsky (Wiley Rein)  
Simon Forge (SCF Associates)  
Peter Fuhr (DOE/ORNL)  
Mark Gibson (Comsearch)  
John Graybeal (Cisco)  
Varun Gupta (Columbia U.)  
Tao Han (NJIT)  
Scott Blake Harris (HWG Law)  
Tom Hazlett (George Mason)  
Joe Heaps (DOJ/INL)  
Michael Honig (Northwestern)  
Daryl Hunter (ViaSat)  
John Hunter (T-Mobile)  
Carolyn Kahn (MITRE)  
William Keane (Duane Morris)  
Ira Keltz (FCC)  
Carl Kutsche (INL)  
George Kyriakou (NYU)  
William Lehr (MIT)  
John Leibovitz (FCC)  
Eman Mahmoodi (Stevens Institute)  
Giulia McHenry (Brattle Group)  
Aalok Mehta (OMB)  
Paul Milgrom (Stanford)  
Steve Molina (DoD/DISA)  
Thyaga Nandagopal (NSF)  
Karl Nebbia (Wiley Rein)  
Janice Obuchowski (Freedom Technologies)  
Jerry Park (Virginia Tech)  
Jon Peha (CMU)  
Veena Rawat (GSMA)  
Jeff Reed (VT)  
Dorothy Robyn (National Economic Council (NEC))  
Kevin Rump (DoD CIO)  
Vidya Sagar (Stevens Institute)  
Shweta Sagari (Rutgers WinLab)  
Anand Santhanakrishnan (NYU)  
Kurt Schaubach (Federated Wireless)  
Brian Shepherd (Colorado Governor's Office of Information Technology)  
Rick Soto (CrownCastle)  
Rangam Subramanian (NTIA)  
Peter Tenhula (NTIA)  
Stuart Timerman (DoD)  
Jennifer Warren (Lockheed Martin)  
Martin Weiss (U. Pittsburgh)

