COMMUNICATIONS AND SOCIETY PROGRAM

Making Waves

Alternative Paths to Flexible Use Spectrum

Dorothy Robyn, Rapporteur

THE ASPEN INSTITUTE

Making Waves

Alternative Paths to Flexible Use Spectrum

Dorothy Robyn
Rapporteur

THE ASPEN INSTITUTE

Communications and Society Program
Charles M. Firestone
Executive Director
Washington, D.C.
2015

To purchase additional copies of this report, please contact:

The Aspen Institute
Publications Office
P.O. Box 222
2014 Carmichael Road
Queenstown, Maryland 21658
Phone: (410) 820-5326
Fax: (410) 827-9174
E-mail: publications@aspeninstitute.org

For all other inquiries, please contact:

The Aspen Institute
Communications and Society Program
One Dupont Circle, NW
Suite 700
Washington, DC 20036
Phone: (202) 736-5818
Fax: (202) 467-0790

Charles M. Firestone
Executive Director

Patricia K. Kelly
Assistant Director

The Aspen Institute
One Dupont Circle, NW
Suite 700
Washington, DC 20036

Published in the United States of America in 2015
by The Aspen Institute

Printed in the United States of America

ISBN: 0-89843-625-7

15/014

2036CSP/15-BK

Contents

This report is written from the perspective of an informed observer at the Aspen Institute Roundtable on Spectrum Policy. Unless attributed to a particular person, none of the comments or ideas contained in this report should be taken as embodying the views or carrying the endorsement of any specific participant at the Roundtable.

Foreword

Current spectrum policies allocate and assign much of the usable spectrum for specific uses, such as broadcast, cellular telephony or aeronautics. Increasingly the FCC has moved to market-oriented approaches to allocations, allowing licensees more flexible use of the spectrum where it can. With the progress of these alternative approaches, many believe that the U.S. should make the more drastic move to a regime that has all spectrum, other than some carved out for specific public benefit, to be considered general use spectrum eligible for the highest and best use available.

The 2014 Aspen Institute Roundtable on Spectrum Policy (AIRS), "Moving Towards General Purpose Spectrum," met on October 22-24, 2014 to consider the value of such a goal, its limitations and the uses that warrant exclusion.

The 26 leading communications policy experts who met at the Aspen Wye River Conference Centers in Queenstown, Maryland examined the feasibility of a general spectrum national plan based around four general questions:

- Is such a regime a realistic and worthwhile goal, and what would it potentially look like?
- What are the limits of general purpose spectrum?
- What regulatory and technical elements are needed to enable general purpose spectrum?
- What are some approaches for overcoming inevitable political and institutional impediments?

As the following report details, the discussions were spirited, informed and often contentious. Throughout the report the Roundtable rapporteur, Dorothy Robyn, tackles the task of describing what general purpose spectrum actually is; discusses the practical, political and institutional limits and ways to overcome them; and details the necessary technical advances and regulatory actions to make general purpose spectrum a reality. The report concludes with a number of proposals for facilitating the creation of a general purpose spectrum regime, and for

overcoming the barriers and opponents that will undeniably stand in its way. While these proposals generally reflect the sense of the meeting, no votes were taken. Accordingly, participation in the dialogue should not be construed as agreement with any particular statement in the report by the participant or his or her employer.

Acknowledgments

I would like to acknowledge and thank the entities represented in this conference who have also contributed to the Communications and Society Program. They are AT&T, Cisco Systems, Comcast Corporation, Google, Intel Corporation, Microsoft, New Street Research, Qualcomm, Time Warner Cable, T-Mobile USA, Inc. and Verizon Wireless.

I also want to acknowledge and thank Dorothy Robyn, our rapporteur, for her extensive and informative account of the conference discussions; and our participants for their contributions to these complicated topics. Finally, I want to thank Ian Smalley, Senior Project Manager, for producing the conference and this report, along with the Communications and Society Program Assistant Director Patricia Kelly, who oversaw its editing and publication.

Charles M. Firestone
Executive Director
Communications and Society Program
The Aspen Institute
Washington, D.C.
June 2015

Making Waves
Alternative Paths to Flexible Use Spectrum

Dorothy Robyn

Making Waves
Alternative Paths to Flexible Use Spectrum

Dorothy Robyn

I. Introduction

The Federal Communications Commission's (FCC) recent auction of 65 megahertz of spectrum for mobile broadband (Auction 97) generated a record-setting $41 billion. This amount is twice the unit price paid for comparable spectrum in the FCC's 2008 auction (Auction 73) and five times that paid in 2006 (Auction 66).[1] This trend is the clearest indication yet, that the supply of spectrum access is not keeping pace with the tsunami of demand for wireless devices such as smartphones and tablets, and the spectrum-based applications they support.

Although spectrum, like other economic resources, is inherently scarce in some sense, economists have long argued that government policy, not physics, is the major cause of the immediate shortage of radio frequencies. The federal government's traditional, command-and-control approach to spectrum regulation successfully limits interference but at the expense of efficient spectrum utilization and technological innovation. In recent decades the FCC has embraced more flexible approaches to managing certain bands, and with dramatic results. Nevertheless, most prime spectrum is still subject to legacy regulation.

…economists have long argued that government policy, not physics, is the major cause of the immediate shortage of radio frequencies.

With the success of these alternative approaches, support for reform of spectrum management has grown. The various reform proposals are alike in calling for more flexible use of the spectrum. However, they reflect competing, if not conflicting, visions of what spectrum flex-

ibility would mean, and they all face major political and institutional impediments.

In October 2014, the Aspen Institute Communications and Society Program convened its annual Roundtable on Spectrum Policy to explore the potential for "general purpose spectrum," which Roundtable organizers described as a regime in which all non-federal spectrum, other than some carved out for specific socially beneficial services, would be eligible for the widest possible range of uses. (The organizers excluded federal spectrum only because it had been the focus of past conferences.) At a two-day offsite convening at the Aspen Wye River Conference Centers in Queenstown, Maryland, a group of two dozen invited experts—from government, industry, academia and non-profit organizations—discussed the scope and feasibility of such a concept.

The Roundtable was loosely organized around four broad questions:

- What would a general purpose spectrum regime look like, and is it a worthwhile goal?
- What are the limits of general purpose spectrum; in particular, what (if any) socially beneficial services will still require a set-aside of dedicated, single-use spectrum?
- From an engineering perspective, what is needed to enable a general purpose spectrum regime, including technical breakthroughs and government regulatory actions?
- What are some concrete strategies for overcoming the (non-technical) impediments to a general purpose spectrum regime?

This report represents a thematic rather than a chronological account of the discussion that took place. Section II provides a brief history of FCC regulation of spectrum use, Sections III through V summarize the discussion relevant to each of the four questions. Section VI offers a brief synopsis of post-Roundtable developments pertinent to the topic.

II. Background: FCC Regulation of Spectrum—A Brief History

The federal government imposed command-and-control regulation of spectrum 90 years ago in response to conditions of overcrowding and interference in the AM radio broadcasting bands. Established by

the Radio Act of 1927, the basic administrative model—block allocation and licensing based on "public interest" criteria—carried over into the Communications Act of 1934, and it is still in use today. Under this approach, the FCC allocates an individual band to one or more narrowly defined uses ("services") and permits little significant modification of the designated use. In addition, it specifies the power limits, build-out requirements and other rules to which the service(s) allocated to such a band must adhere, based on the technology and business models that existed at the time of the allocation. Finally, prior to the mid-1990s, the FCC assigned licenses for individual bands using a non-market mechanism—historically, it employed a slow and costly comparative hearing process.

Alternatives to Command and Control

Although most prime spectrum is still subject to command and control regulation, in recent decades the FCC has embraced two alternative models: a market approach that treats exclusively licensed spectrum like private property and a spectrum "commons" approach that eschews licensing altogether.[2] These alternative models are not mutually exclusive, and both have yielded dramatic gains for consumers. Nevertheless, proponents of the two models have engaged in a long-running intellectual battle over their relative benefits.[3] Recently, this lively and important debate has expanded to include a third approach, dubbed "spectrum sharing."

Exclusive (Flexible) Use. The licensed alternative to command-and-control regulation preserves the benefits of exclusivity while taking advantage of flexible, transferable spectrum use rights. Economists have long favored a market approach to the allocation of resources, generally, and spectrum, in particular.[4] As early as 1959, Nobel Prize-winning economist Ronald Coase wrote that spectrum was a fixed factor of production, like land or labor, and should be treated in the same way, with its use determined by the forces of the market rather than the decisions of government. In an analysis of FCC regulation that led directly to the seminal essay he published the following year, Coase concluded that the assignment of well-defined property rights in spectrum use that such an allocation would entail, would be sufficient to prevent inefficient broadcast interference.[5]

Economists argue that a market-based approach to spectrum regulation has two advantages over command-and-control regulation (and over unlicensed allocation, discussed below). The first is efficiency in use. Economists believe that the profit motive will deliver spectrum, like any other valuable resource, to those who can put it to the uses most desired by the public. Over time, the inexorable pressure to make efficient use of a scarce resource such as spectrum leads to increased investment and innovation, which produces dynamic efficiency.[6]

Although the FCC traditionally allowed some role for the market in spectrum management (e.g., radio licenses have long been bought and sold), that role expanded markedly in 1993, when Congress authorized the use of auctions to award spectrum licenses for non-broadcast services. The FCC has auctioned 385 megahertz of "new" spectrum for mobile voice and data services (known collectively as Commercial Mobile Radio Services, or CMRS) since then, and it has taken additional steps to promote a secondary market in spectrum rights. Even more important, the FCC has granted increasingly flexible spectrum usage rights to CMRS operators, allowing them to choose which services to offer and the technology with which to deploy them.

In 2013 alone, U.S. wireless carriers spent $33 billion to build out and upgrade their networks….

This model of exhaustive assignment of exclusive, flexible rights has worked extremely well for CMRS carriers, who want predictably high quality-of-service and 24/7 availability over large geographic (including national) coverage areas. In 2013 alone, U.S. wireless carriers spent $33 billion to build out and upgrade their networks, a pattern of capital investment that has allowed them to seamlessly deploy successive generations of wireless technology.[7] The fourth generation (4G) technology, LTE (for Long Term Evolution), is designed to transfer large amounts of data (e.g., video streaming) at high speeds and to operate in high-interference environments. These investments have generated enormous benefits for consumers: As one indication, in 2013, U.S.

wireless carriers generated $189 billion in revenue.[8] The steep prices paid in the FCC's recent auction are another indication of the value of exclusive, flexible-use rights to spectrum.

Unlicensed Use. At the same time that market-based reforms of spectrum regulation were gaining wider acceptance, some legal scholars and a group of technology firms were urging the FCC to eschew licensing altogether and treat the spectrum, or large blocks of it, as a common resource. As early as 1938, the Commission adopted rules (Part 15) allowing for the operation of non-licensed, low-power devices that did not cause harmful interference to licensed services. For many years, most Part 15 devices were designed to operate below 30 MHz, but over time, the FCC amended and expanded the rules to permit such devices to operate at higher power in certain higher frequencies. In the 1980s, the FCC permitted the use of spread spectrum radio systems on an unlicensed basis at a significantly higher power level in three bands (902–928, 2400–2483.5 and 5725–5850 MHz).[9] Over time, the rules governing unlicensed bands have been relaxed to permit the use of any digital modulation, not just spread spectrum, and in response to a growing chorus of supporters, the FCC has set aside significant additional spectrum for unlicensed use, including 425 megahertz in the 5 GHz band.[10]

Proponents argue that the unlicensed model—by eliminating the cost of spectrum acquisition and infrastructure investment—enables device manufacturers and service providers to develop markets in sophisticated equipment and network services built on them to deliver reliable connectivity.[11] In response to challenges that the absence of licensing will result in a "tragedy of the commons," proponents maintain that the imposition of exclusive-use rights to prevent interference is neither necessary nor desirable. Exclusivity is not necessary, they argue, because the amount of spectrum that many new uses require is minimal, and newer receivers can adapt to the presence of interference at levels that would have caused traditional technologies to fail. Moreover, it is in the interests of equipment manufacturers to invest in designs that perform robustly in the presence of interference as a way to expand their volume of business. Nor is exclusivity desirable, according to this view, because the transaction costs of arranging to get the necessary spectrum rights for this newer technology would exceed the benefits.

The unlicensed model has enabled a game-changing set of spectrum uses that is both different from and complementary to CMRS. The "killer app" is Wi-Fi hot spots—small, isolated base stations that allow wireless devices in a home or office to connect to the Internet through a wireless or wireline connection. Wi-Fi's ability to operate independent of a larger wireless infrastructure, together with the availability of significant amounts of unlicensed spectrum, make possible low-cost devices that operate at extremely high data rates.

In addition to enabling Internet access in homes and businesses, unlicensed spectrum is key to the emerging markets in machine-to-machine (M2M) connectivity (also called the "Internet of Things"), including radio frequency devices for inventory management, automated meter readers and other "smart grid" applications, and wireless health care. Significantly, mobile broadband itself has become reliant on unlicensed spectrum, as CMRS carriers use Wi-Fi to offload an increasing amount of Internet-related data traffic from their congested (licensed) networks.

In addition to enabling Internet access in homes and businesses, unlicensed spectrum is key to the emerging markets in machine-to-machine (M2M) connectivity (also called the "Internet of Things")….

The barrier separating unlicensed Wi-Fi and licensed CMRS will become even less distinct once cellular operators implement their plans to extend LTE technology to unlicensed spectrum. Although this technology, dubbed LTE-U, could in principle be deployed in any unlicensed band, the CMRS operators are focusing initially on the 5 GHz band, in part because of the large amount of unlicensed spectrum (500 megahertz) that is available there on a global basis. LTE-U, also known as Licensed Assisted Access (LAA), will allow a CMRS operator to integrate the licensed and unlicensed elements of its network into a unified LTE network. Among other benefits, that will reduce the complexity of the hand off between Wi-Fi and CMRS. In addition, because

LTE networks are managed, they use spectrum more efficiently than Wi-Fi networks, especially when demand is high.[12] Although efficiency is not the only relevant goal for such networks—competitive access and resilience are also important—LTE's ability to carry more data traffic in a fixed amount of spectrum will complement the ubiquity and other strengths of Wi-Fi in the unlicensed bands.

The barrier separating unlicensed Wi-Fi and licensed CMRS will become even less distinct once cellular operators implement their plans to extend LTE technology to unlicensed spectrum.

Despite this potentially powerful complementarity, the implementation of LTE-U/LAA raises important implementation issues that the LTE and Wi-Fi standards organizations are working together to resolve. A key issue is the nature and transparency of the algorithm used to allocate spectrum on a dynamic basis between LTE devices and Wi-Fi devices. Although it will take time to resolve these issues, LTE-U/LAA is almost certain to be deployed in the next few years.

Shared Use. Recently, the debate over spectrum management has expanded to include a third alternative to command and control—referred to as spectrum sharing, shared use or protected shared access. Spectrum sharing is nothing new. In exclusively licensed spectrum, a CMRS operator manages the sharing on behalf of its customers ("cooperative" sharing), and in unlicensed bands, opportunistic users engage in unmanaged ("non-cooperative") sharing among themselves and between themselves and primary users. By contrast, protected shared access involves sharing among operators of multiple radio networks (not just CMRS), each with licensed, interference-protected access rights. Some versions of the model include opportunistic sharing as well.

This emerging model is a response to the fact that much prime spectrum is encumbered but underutilized. In particular, many prime bands are assigned to government users or other incumbents that cannot be relocated in the short-term or that have a long-term need for the spectrum but use it on an intermittent or piecemeal basis, e.g.,

only during certain time periods and/or in specific geographic areas. Largely due to advances in technology, it may be possible for regulators to allow a limited number of licensees to operate, on an interference-protected basis, in a frequency band that is already assigned to one or more incumbent users. Secondary licensees could be required to pay for (shared) access, which would create an incentive for incumbents to free up or share underutilized spectrum.

Proponents of this model have focused initially on higher frequencies (the 2.3 GHz band in Europe and the 3.5 GHz band in the United States), which lend themselves to the deployment of small cells. Cellular operators use small cells in part to augment capacity in places where the demand for network connectivity is highly concentrated (e.g., sports stadiums and transit stations).[13] Because of their limited geographic coverage and low-power transmissions, small cells are less likely to interfere with incumbent systems, thus reducing the size of the "exclusion zones" needed to protect such systems.

The protected shared access model is a global development. In 2012, the European Commission asked the relevant organizations in Europe to develop standards to enable the Licensed Shared Access (LSA) model, also known as Authorized Shared Access (ASA).[14] LSA/ASA is a two-tier system for sharing licensed spectrum between incumbents and secondary users in the 2.3 GHz band, which is widely used outside Europe for mobile broad-band but is encumbered inside Europe. That same year, in the United States, the President's Council of Advisors on Science and Technology (PCAST) proposed something similar to LSA/ASA but with a third tier for opportunistic access. The PCAST proposal focused on the 3.5 GHz band, which is allocated to high-power military radars and non-federal Fixed Satellite Service (FSS) earth stations. More broadly, PCAST called for the creation of 1,000-megahertz-wide "spectrum superhighways" in which dynamic spectrum sharing would replace the single-use allocation as the normal mode of operations.

PCAST also called for the regulation of receivers. Although interference is a reciprocal harm—it results from the performance of the receiver no less than that of the transmitter—regulators have traditionally viewed transmitters as the source of interference and receivers as innocent "victims." In some cases, this limits the potential for adjacent bands to support valuable new services. PCAST argued that having

clearly defined "receiver interference limits" would help achieve more efficient trade-offs between the rights of transmitters and receivers, with the goal of maximizing concurrent operations as opposed to minimizing harmful interference.

Shortly after the PCAST report was issued, the FCC proposed to create a Citizens Broadband Radio Service (CBRS) in the 3.5 GHz band along the lines of the PCAST proposal.[15] Following a two-year proceeding, the FCC recently adopted rules that allow for commercial operation in 150 megahertz at 3550–3700 MHz using a three-tier sharing system.[16] Two CBRS tiers of users—Priority Access (PA) and General Authorized Access (GAA)—will share the band with a third tier of protected incumbents (military radar and FSS users). The Report and Order sets aside 100 megahertz of the band (3550–3650 MHz) for PA use. Would-be PA users will be able to bid via auction for short-term, geographically targeted licenses that afford interference protection from GAA users. (The rules facilitate PA deployment of small-cell technologies, for which the 3.5 GHz band is well-suited.) An 80-megahertz block of channels will be reserved for opportunistic use by any FCC-certified GAA device. GAA users will also be able to operate on any unused channel allocated to PA use.

In addition to clearly defined rights, the linchpin of the protected shared-access model is an advanced, highly automated frequency coordinator known as a Spectrum Access System, or SAS. As with LSA/ASA, the CBRS will employ one or more SASs to manage spectrum use in real time using a combination of geolocation and database technologies. This approach builds on one developed for the unlicensed devices that can operate in vacant TV channels (TV white space devices). A communications law blog describes in simple terms how this process would work:

> Every device will have to check in with the SAS, report its own location, request permission to transmit and wait to be assigned a specific frequency. The SAS's job will be to keep everybody off the incumbent spectrum in the exclusion zones, prioritize PA users and assign GAA slots to others.[17]

Although most stakeholders have applauded the FCC's two-year effort to open the 3.5 GHz band to sharing, some have raised concerns about the complexity of the CBRS plan or questioned whether the tech-

nology needed for dynamic sharing is sufficiently mature. (The blog quoted above compared the FCC to an acrobat who is trying to juggle while crossing a tightrope on a unicycle.) Some cellular operators and vendors initially expressed a desire to see the FCC exclude (or delay) the GAA tier, although opposition to a three-tier approach declined over time, and some stakeholders fought for rules that would accommodate the deployment of LTE-U/LAA technology in the third tier. Whatever the concerns with the CBRS, no one disputes that protected shared access (with or without a GAA tier) represents an important new tool for spectrum management—one that can complement exclusive licensing and unlicensed access.

III. What Is General Purpose Spectrum and Is It a Good Idea?

What would a general purpose spectrum regime look like if it existed, and is it a worth-while goal to pursue? Many of the participant comments focused initially on the existing impediments to efficient spectrum usage and technology innovation, i.e., the problems to which general purpose spectrum is seen as the solution. In describing the ideal of a general purpose spectrum regime, participants emphasized flexible use and decentralized control, and they envisioned a "polyglot" that could accommodate the three competing models for spectrum management (exclusive, unlicensed and shared use). Roundtable participants were unanimous in embracing a general-purpose spectrum regime as a long-term, "aspirational" goal, although they emphasized the importance of continued incremental gains, and individual participants viewed their preferred spectrum management model as providing the best transition path.

Existing Impediments to Efficient Spectrum Usage and Technology Innovation

There are a number of ways in which the existing spectrum management regime impedes efficient spectrum usage and technology innovation. A significant one is the FCC's longstanding practice of designating bands for dedicated, narrowly defined uses, together with the Commission's failure to revisit its historical allocations. As Intel's Peter

Pitsch put it, "If we've learned anything about spectrum policy over the last 30 years, it's that…old technologies and uses get locked in, and the…process slows innovation to the detriment of society."

Single-Use Allocation. Preston Marshall from Google identified three dedicated, single-use allocations that account for more than one gigahertz of spectrum, some of it quite valuable: Broadcast Auxiliary Service (BAS), Cable Antenna Relay Service (CARS) and the C-Band spectrum used for FSS. The FCC authorized these allocations at a time when wireless spectrum represented the only option for delivery of (principally) video programming. Although this content is now distributed largely through fiber optic networks and the Internet (and some of it could be delivered using commercial wireless services), the FCC still protects the allocations.

"If we've learned anything about spectrum policy over the last 30 years, it's that…old technologies and uses get locked in, and the…process slows innovation to the detriment of society." – ***Peter Pitsch***

Although not everyone agreed with all three examples, no one disputed the broader critique. The FCC's practice of single-use allocation masks the opportunity cost of the designated usage. The incumbent operator faces an easy choice: "Do I use the spectrum for this narrow purpose, or do I give my license back to the FCC?" However, the choice is flawed from a societal perspective because it creates a classic externality by ignoring the value of alternative uses of the spectrum.

The practice of dedicated, single-use allocation is made worse by the FCC's failure to revisit its historical allocations. Incumbents who are protected by these allocations have a litany of politically persuasive arguments for preserving the status quo, including the investments they have made (sunk costs), the high cost to transition to another band or a different service delivery mode, and the threat that the alternative arrangement allegedly would pose to public safety or some other public good. The result is a fossilized system in which old, inferior technologies tend to crowd out new, superior ones.

The FCC's practice of single-use allocation masks the opportunity cost of the designated usage.

Fossilization generates waste, as evidenced by the large amount of unused or underused capacity, and waste creates scarcity. Scarcity is a triple threat. It impedes innovation because entrepreneurs cannot get access to the spectrum they need at an affordable price. This lack of access limits competition, including competition from fundamentally different business models. And scarcity begets scarcity, as incumbents hoard spectrum that they do not really need in the short-term for fear of losing their longer-term rights to use it.

Fragmentation of Usage Rights. A second impediment to efficient and innovative spectrum usage that the group identified is the fragmentation of usage rights. For land mobile radio and other services, the FCC has sliced up small blocks of spectrum into scores of channels and then assigned the rights to use each channel to one or more licenses in each of hundreds of geographic markets. This process creates hundreds of borders along which licensees must coordinate spectrum usage and raises the transaction costs to aggregate their interests—through private negotiation with one another or with an outside entrepreneur.

The dispute between Nextel Communications and public safety radio users over interference in the 800 MHz band illustrates the problem. In 1991, FCC lawyer-turned-entrepreneur Morgan O'Brien succeeded in getting the FCC to relax its little-used dispatch (Specialized Mobile Radio, or SMR) licenses to allow for the provision of mobile phone services to the public. As millions of mobile handsets began to operate in frequencies that had been used largely to dispatch taxis and delivery trucks, they created interference in the adjacent SMR bands, many of which were used by public safety agencies such as police and fire departments. Although the FCC eventually embraced a spectrum swap proposed by Nextel, the process took a decade to complete in large part because of the FCC's highly fragmented SMR band plan.[18]

The LightSquared-GPS (global positioning satellite) conflict is another example of the high cost of fragmented spectrum rights. LightSquared planned to use L-Band (satellite) frequencies to provide

a nationwide 4G terrestrial wireless network that could compete with carriers such as Verizon and AT&T. After the company had invested a reported $4 billion (out of a planned $14 billion), the FCC suspended its authorization for the network because of concerns that GPS receivers would suffer diminished performance due to emissions from LightSquared signals *in the LightSquared L-Band spectrum*. Because the L-Band spectrum had historically been lightly used, some legacy GPS equipment effectively treated the GPS Band and the adjacent L Band as a single band. Thus, LightSquared's plan to make intensive use of its L-Band spectrum would have adversely affected some GPS devices. The social benefits of an additional nationwide wireless network (LightSquared) arguably outweighed the cost to GPS users, some of whom LightSquared offered to compensate. However, because the GPS interests were so diffuse, it was impossible to reach an accommodation, and LightSquared went bankrupt.[19]

Interference Standards. Another interpretation of the LightSquared-GPS conflict places the blame principally on the FCC's approach to interference harm, which represents a third major impediment to efficient use of the spectrum. As discussed earlier, although interference is a reciprocal harm, the FCC has traditionally viewed transmitters as the sole source of interference. No less important, the FCC has never set clear expectations, or requirements, for receivers. From this perspective, the LightSquared-GPS conflict was a result of the FCC's failure to clearly define the border between the L-Band and the GPS Band or to require better performance from GPS receivers.[20]

These two perspectives on the LightSquared-GPS conflict reflect somewhat different views of the root cause of interference problems. For those who subscribe to the second interpretation, the fundamental problem is that spectrum usage rights are poorly *defined* from an engineering standpoint. For those who subscribe to the first interpretation, the problem is that spectrum usage rights are poorly *assigned* from a legal and economic standpoint. The two perspectives are not mutually exclusive (in fact, they can be seen as linked, in that the technical definition of rights can shape the options for the legal/economic assignment of rights). That said, as discussed in Section VI, they imply different fixes to the FCC's rights-creation process.

Negotiation and Adjudication Procedures. Despite their differences, proponents of both perspectives agreed that spectrum users should have wide latitude to negotiate with their neighbors over usage and interference, as well as avenues to adjudicate differences that cannot be resolved through negotiation. In fact, if the processes for negotiation and adjudication were sufficiently expedient and fair, they could obviate the need to better define and assign spectrum rights.[21] However, the FCC limits both of these activities, which Roundtable participants identified as a major impediment to efficient use of the spectrum.

The best evidence for the value of private negotiations is the CMRS bands, where operators are exempt from many (although not all) of the FCC limits. Roundtable participant and Verizon official Charla Rath described the continuous process of "Coasian bargaining" in which the CMRS operators engage:

> You [can] negotiate rights at the borders—that you can use your neighbor's spectrum, [that] they can use yours.... If you talk to our engineers, they're doing [this] constantly.... We rarely go to the FCC [for] help.... It's just part of a normal negotiation we do.

Although the FCC requires the CMRS operators to keep a record of the negotiated agreements, the Commission does not need to approve them. By contrast, in the bands subject to legacy command-and-control regulation, spectrum "neighbors" generally are not allowed to negotiate their rights (if they have any incentive to do so). As a result, they must rely on regulators to resolve any conflicts.

Participants were especially critical of the FCC's reliance on rulemaking, a process designed to make policy, to resolve disputes that should be subjected to fact-based adjudication. One concern is efficiency. Compared to adjudication, rulemaking is slow and inefficient, and companies sometimes go bankrupt while waiting for the FCC to resolve what amounts to a make-or-break issue for them. A related concern is discretion. As an adjudicator, the FCC is limited to the facts of the case at hand and subject to a "substantial evidence" standard of review on appeal. By contrast, in a rulemaking proceeding, the record can be broad and conflicting, there are no sworn affidavits or opportunities for cross-examination, and appeals are guided by the more discretionary "arbitrary and capricious" standard of review.

Clemson University Professor Thomas Hazlett used the term "vertical integration of government" to refer to the FCC's tendency to use a policy process (rulemaking) to resolve issues that should be decided based on objective criteria (e.g., technical performance standards). As Hazlett put it, we do not want a public interest fight over "whether or not the Forest Service is going to use a fiber optic line versus a wireless connection. We really want that to be an efficiency decision."

Transferability. A final problem that the group flagged is the inability of certain classes of spectrum users to transfer their spectrum usage rights. Nextel's challenge was made harder by the fact that spectrum allocated for public safety cannot be traded and can only be used for public safety communications. As a result, O'Brien was unable to buy out public safety licensees individually as he had done with the similarly fragmented private SMR licensees (O'Brien acquired some 40,000 SMR licenses).

…even if a federal agency had the legal authority to sell or lease its spectrum, under current law, it could not directly benefit financially from doing so by retaining or spending the proceeds.

Federal agencies face similarly flawed incentives. The National Telecommunications and Information Administration (NTIA) in the Department of Commerce assigns spectrum to federal agencies, and those assignments (they are not licenses) are not transferable. Moreover, under the Miscellaneous Receipts Act, any money received for the United States must be deposited in the U.S. Treasury. A closely related constraint is the Antideficiency Act, which prohibits an agency from spending money that has not been appropriated by Congress. Thus, even if a federal agency had the legal authority to sell or lease its spectrum, under current law, it could not directly benefit financially from doing so by retaining or spending the proceeds.

Some believe that the NTIA's use of assignments to convey spectrum rights creates an even more basic problem. FCC licenses and NTIA assignments represent two different "languages," and those entities that

are eligible to hold a license typically are not eligible to hold an assignment and vice versa. As a result, even mundane transactions between the two groups, such as when a commercial operator leases some spectrum to a federal agency, become complicated because the two parties must use an intermediary to "translate" for them.

General Purpose Spectrum Described

When participants described what a general purpose spectrum regime should look like, their watchwords were "flexibility" and "decentralized control." At a "content" level, spectrum users/operators should have maximum flexibility to determine what service to provide and with which technology to provide it—that is, the regime should be "service and technology neutral." At a procedural level, operators should be able to change the way they use the spectrum, including leasing or transferring their usage rights, without going to the FCC for approval.

Participants emphasized the importance of procedural flexibility, in particular. As Coleman Bazelon from The Brattle Group cautioned, "general purpose spectrum" sounds like an FCC allocation, and we know from experience that the allocation process tends to limit rather than expand opportunities. Underscoring that point, the FCC's John Leibovitz noted that it is impossible to write allocation and service rules that are flexible enough to completely anticipate the future: "You don't really bump into limitations until something new [that you hadn't thought of] comes along."

Carnegie Mellon professor Jon Peha questioned whether flexibility was the right goal, as opposed to "using the spectrum efficiently" or "providing the right [spectrum-based] products and services." However, others argued that flexibility offers the best tool for determining the cost/benefit tradeoff of alternative spectrum-use choices. Returning to the theme of opportunity costs, Peter Pitsch observed that the more flexibility the operator has, the better its opportunity-cost calculation from a societal standpoint. At the point where an operator has complete flexibility, it faces something approaching the true social costs and benefits associated with the use of its spectrum.

Participants discussed other desirable features of a general purpose spectrum regime. One participant proposed a policy of automatic

approval of any non-interfering spectrum usages, based on the logic that led the FCC to look at using the noise temperature concept to permit unlicensed devices to underlay the signals of existing (licensed) services. Several participants endorsed having an output-oriented interference parameter that would recognize the reciprocal role of receivers in causing interference. (Sections V and VI discuss this concept further.)

…like a "polyglot" that can converse in multiple languages, a general purpose spectrum regime should accommodate the three basic models of spectrum management: licensed, shared and unlicensed use.

Finally, the group concluded that the concept of general purpose spectrum was itself flexible: like a "polyglot" that can converse in multiple languages, a general purpose spectrum regime should accommodate the three basic models of spectrum management: licensed, shared and unlicensed use. Under the first model, spectrum would be licensed for flexible use, as it is now, but the use in any given band or geographic location would be determined solely by the market. Under the second model, a more agile newcomer could share a given band with a less agile incumbent. (Although PCAST proposed sharing largely as a way to exploit underutilized federal spectrum, participants felt the model would work just as well in underutilized commercial spectrum.) Under the third model, based on the traditional concept of unlicensed access, users could operate any qualified device subject to limits on power.

The Transition to a General Purpose Spectrum Regime

Although Roundtable participants were unanimous in embracing a general purpose spectrum regime as an aspirational goal, they were emphatic about the need to continue making incremental gains. Not surprisingly, individual participants tended to view their preferred spectrum management model as providing the best transition path.

The advocates of *shared use* argued forcefully for that approach as an ideal transition path. First, from a strategic perspective, it is designed to

accommodate hard-to-move incumbents. Thus, it offers an alternative to the "brute-force tool" of complete reallocation ("forced relocation"), which can require enormous time and expense to accomplish. Second, from a substantive perspective, permitting agile newcomers to operate in an encumbered band will help to establish the opportunity cost of protecting the legacy use, i.e., the subsidy going to that use. Once that subsidy cost is known, regulators can compare it to the cost of providing the same service using a different technology (e.g., distributing video programming via fiber optic cable instead of spectrum-enabled satellites or fixed microwave links). Over time, as the FCC and NTIA assign more flexible usage rights to the incumbent users, the incumbents will have an incentive to make spectrum available for other, more valuable uses.

Spectrum sharing advocates underscored the ability of their approach to be highly targeted and incremental, which can facilitate the transition process. To return to an earlier example, the allocation for FSS downlink (space-to-earth) signals covers 500 megahertz of contiguous spectrum in a highly desirable part of the C-Band (3700–4200 MHz). Every ground station set up to receive those C-band signals excludes usage by others, and a ground station located in the middle of a large city excludes more usage (that is, its opportunity cost is higher) than one located in a rural area. If the FSS spectrum were opened up to sharing, an agile newcomer could negotiate with the incumbent FSS operator to reach a mutually advantageous deal. For example, the newcomer might pay the FSS operator to use fewer ground stations or to rely disproportionately on the ground stations whose opportunity costs are lower.

Advocates for (flexible) *licensed use* made some of the same arguments for their model as a superior transition path to a general purpose spectrum regime. The CMRS bands have most of the features needed for flexible use of spectrum. (Although many of these features, or authorities, were part of the original allocation, the FCC approved others later as part of what has been a gradual process of liberalization.) Thus, these bands offer a proven approach that can be extended to other bands, as the FCC did when it relaxed the restrictions on the 800 MHz SMR bands. Precisely because it permits so much flexibility, the flexible licensed use approach would do a better job of clarifying the opportunity costs, according to its supporters.

The licensed use model can also accommodate hard-to-move incumbents, in the view of these supporters. One tool is the spectrum overlay. The FCC's auction of Personal Communications Service (PCS) spectrum in the 1990s illustrates one type of overlay. Rather than clear the PCS bands in advance, the FCC issued licenses with overlay rights: Licensees could use the PCS bands as long as they did not degrade the transmissions of existing users during a multi-year transition period. Many licensees paid incumbents to vacate the frequencies early, thus expediting the process by which bandwidth was freed up for wireless voice and data communications.[22] Under an alternative approach to overlays, incumbents are not required to vacate the spectrum.

A second tool for accommodating hard-to-move incumbents is the incentive auction, such as the one the FCC is planning to hold in 2016 to repurpose broadcast spectrum for mobile broadband use. Under the FCC's proposed plan, broadcasters will be able to relinquish some or all of their spectrum usage rights in exchange for incentive payments.

A third tool is the assignment of additional rights to incumbents. For example, the FCC has granted certain Mobile Satellite Service (MSS) operators the right to use their spectrum for terrestrial mobile broadband while preserving sufficient MSS capability to serve key national needs. (The FCC also allowed the MSS operators to transfer their MSS/terrestrial spectrum usage rights in the secondary market.) Although the FCC considered using an auction process to assign those new rights, in part because there were so few licensees remaining, it opted to grant the rights to incumbents at no cost.

In contrast to supporters of exclusive use and shared use, proponents of *unlicensed use* did not advocate for their model as *the* preferred transition path to a general purpose spectrum regime. In fact, proponents of unlicensed use generally expressed support for the shared use model, at least insofar as it accommodates opportunistic users. However, they argued for giving unlicensed and opportunistic devices maximum access to unused capacity in shared use bands as well as bands that have yet to transition to a flexible regime.

In a different vein, John Leibovitz urged the participants to think about the transition to general purpose spectrum—and the goal of flexibility, in particular—more incrementally, with an eye to actions that would not require reallocation by the FCC or NTIA. For example,

he asked them to consider whether there were categories of like services (e.g., airborne systems) that could be combined into one "uber-service." If that were done, the relevant bands would still be constrained by service-level stovepipes, but the stovepipes would be larger and thus more flexible. He suggested that this approach might have applicability in federal as well as non-federal bands. As another example, he suggested that they consider how to make "flexible (licensed) use" even more flexible.

IV. What Are the Limits of General Purpose Spectrum?

As its second task, the Roundtable was asked to consider the practical limits of general purpose spectrum. Specifically, what, if any, socially beneficial services will not be provided by the market and thus will require a traditional allocation of (no-cost) single-use spectrum? The group concluded that, while the market will provide many of the services that the FCC traditionally ensured through command-and-control regulation of spectrum, some socially beneficial services will still require government support. That said, participants disagreed strongly about whether that support should ever take the form of a traditional spectrum allocation. The group also looked at technical issues related to command-and-control regulation and concluded that, from an engineering standpoint, the FCC would no longer need to have single-use allocations because shared-use bands could accommodate any and all spectrum-dependent applications.

Economic Analysis

There was broad agreement that, under a general purpose spectrum regime, the market will provide many of the kinds of services that the FCC traditionally ensured through command-and-control allocations of dedicated, single-use spectrum. In addition to the examples discussed earlier (BAS, CARS and FSS), participants pointed to "spectrum for schools and libraries" as an example of a single-use allocation for which the original "use case" has disappeared. In 1963, the FCC provided access to certain fixed microwave bands to eligible entities that offered Instructional Television Fixed Service (ITFS), now known as the Educational Broadcast Service (EBS). That allocation allowed educational institutions, including schools and libraries, to deliver live and

pre-recorded instructional video to multiple sites and campuses. The technology has changed substantially over time, and most educational video is now transmitted over the Internet. Although the EBS allocation remains, licensees lease much of the spectrum in the secondary market to wireless broadband providers such as Sprint.

Participants also pointed to a recent case in which a group of railroads obtained spectrum to deploy positive train control (PTC), a communications-based technology for collision avoidance, through secondary market transactions. In 2008, following a series of accidents, Congress passed the Rail Safety Improvement Act, which mandates that all passenger railroads and certain freight railroads install PTC by December 31, 2015. Two of the largest U.S. freight railroads had formed a company (PTC-220 LLC) in 2007 to acquire and manage the spectrum needed to deploy PTC. Through a series of transactions in the secondary market, PTC-220, which is now owned by the seven largest U.S. freight railroads, acquired the rights to enough spectrum in the 220 MHz band to cover those carriers' needs, and it leases some of it to smaller freight and public commuter railroads that are implementing a compatible PTC system.[23]

Although Roundtable participants cited the PTC case as evidence that, in the future, spectrum for safety-related communications will not necessarily have to come from no-cost FCC allocations, the case also illustrates why the FCC will continue to face pressure to make such allocations. Commuter railroads in the Northeast and parts of Amtrak's intercity passenger operation are implementing a PTC system that is not compatible with that of the freight railroads. Thus, these entities cannot leverage the PTC-220 spectrum holdings and must acquire spectrum rights on their own. Moreover, as publicly funded entities, they are subject to acquisition rules that hinder their ability to collaborate in the purchase of such rights as the freight railroads did.[24] Faced with funding and other constraints, the commuter and intercity passenger railroads are pressing Congress to direct the FCC to provide a no-cost allocation of spectrum for PTC implementation.[25]

Despite the trend toward market provision of spectrum rights, Roundtable participants felt that there would be a limited number of socially beneficial spectrum uses for which the market on its own might not provide. These include public safety communications, vehicle-to-vehicle communications to ensure safety, and certain niche services

such as radio astronomy and wireless medical telemetry. (Certain of the federal government's spectrum needs provide other examples, but Roundtable participants focused exclusively on non-federal spectrum.)

Although participants agreed that the government would need to do something to provide for these socially beneficial spectrum uses, they disagreed sharply about what that "something" should be. Most participants felt that, so as not to distort spectrum usage decisions, the government should subsidize the desired social good (e.g., public safety) directly and let the relevant group acquire either spectrum or spectrum-based services in the market. However, a few participants argued that, under limited circumstances, the government should provide the subsidy in the form of dedicated spectrum.

The debate among Roundtable participants focused largely on public safety communications. The FCC allocates spectrum for state and local public safety and emergency radio services. As discussed earlier, public safety agencies such as police and fire departments are assigned licenses to use narrow slices of this dedicated land mobile spectrum. With some limited exceptions, public safety agencies cannot sell or lease the rights that these licenses confer.

Most participants believe this approach is doubly flawed. First, reserving spectrum exclusively for public safety is problematic because it is such a small market segment that equipment manufacturers lack the scale and competitive pressure to provide innovative technology. Moreover, this approach turns first responders into uncompetitive network providers. One participant, Thomas Hazlett, has written about the powerful local public safety radio chiefs who become vested in vintage technologies and oppose digitization as a threat to their authority.[26] Second, the form of the spectrum subsidy to public safety compounds the problem. Because the public safety agencies are unable to sell or lease spectrum that they do not need, they have little motivation to use it efficiently—for example, by investing in newer, more spectrum-efficient communications equipment. Not surprisingly, many public safety agencies use older, bandwidth-hogging equipment, despite overcrowding on the public safety bands. Citing both of these problems, economists have argued that it would be preferable to give public safety agencies cash, with which they could purchase the specialized spectrum services they need on the market—just as they buy police cars from commercial automakers.

…reserving spectrum exclusively for public safety…turns first responders into uncompetitive network providers.

The counterargument that a few participants made is that the FCC's reservation of dedicated public safety bands has created a critical mass in terms of market demand for the specialized equipment that public safety agencies need. Motorola and a few other equipment manufacturers have responded to that demand, and it has proven to be a profitable niche market. Absent the dedicated bands, however, public safety agencies would not have been able to compete for spectrum against more popular uses, and their demand would have gone unmet. More broadly, according to this view, absent a "special purpose band," the market will ignore or forego the profit to be made from certain socially beneficial services because there is even more profit to be made from other services that can be served with general purpose spectrum.

Although they could not resolve their differences regarding public safety, participants were struck by the extent of their agreement that, in the future, dedicated, single-use allocations will be unnecessary in many other areas. Two of the participants staged a symbolic "group hug" to mark their consensus that libraries no longer need their own spectrum. (One of the two would argue that they never did!) Moreover, there was a shared recognition that the provision of a dedicated allocation can be a disservice. As Jon Peha said, "We would like [for] our schools and libraries to have great broadband access, but if you create a band just for schools and libraries, their spectrum would be free but their equipment could be a hundred times as expensive. So you may in some cases make matters worse."

Technical Analysis

The FCC's decision to allocate spectrum to a particular use has traditionally reflected technical as well as economic considerations. The approach has been to "put like services with like services" so as to reduce the risk of harmful interference. Historically, the use of dedi-

cated bands has also facilitated interoperability by allowing equipment owned by different entities to communicate.

At the Roundtable, a subset of technical experts looked at whether, in the future, the technical rationale for having bands of spectrum dedicated to particular uses will still apply. Stated differently, what (if any) kinds of applications will likely still require single-purpose spectrum on technical grounds? The group concluded that, purely from an engineering standpoint, no applications will require single-purpose spectrum in the future.

The technical experts' logic was straightforward. In engineering terms, one spectrum use differs from another only in terms of its "operating rights," referring to the amount of energy a device can transmit and the amount of protection from interference that a receiving system is entitled to have. However, under the conditions associated with spectrum sharing, a single band of spectrum will be able to accommodate multiple sets of operating rights. Thus, purely from an engineering standpoint, shared spectrum will be able accommodate any spectrum use, thus obviating the need for dedicated bands of spectrum.

That said, there may be circumstances where having dedicated bands of spectrum may be preferable because it allows for greater technical efficiency. The technical experts acknowledged that possibility but did not look at its implications.

Political Reality

In discussing the limits of general purpose spectrum, Roundtable participants focused heavily on economic and technical considerations. However, they acknowledged that political reality often trumps those considerations. A key reason is that a cash subsidy, the economist's ideal, is simply not an option in many cases. Consider Congress' action requiring deployment of PTC technology, a multi-billion dollar endeavor (spectrum is only one cost component) that many stakeholders in the rail industry view as an unfunded mandate because Congress provided no appropriations for it.

Even if they have the choice, most user groups would prefer to receive a subsidy in the form of spectrum than the equivalent amount of cash. A key reason is that a spectrum allocation is less transparent

than a budget appropriation (cash). Lack of transparency makes a spectrum allocation less of a target for subsidy opponents. Moreover, unlike budget decisions, which get revisited annually, FCC allocations tend to endure.

V. Technical Elements of a General Purpose Spectrum Regime

A general purpose spectrum regime that accommodates all three models of spectrum management will require sophisticated technology and an enlightened regulatory underpinning. Thus, the Roundtable devoted considerable attention to the technical elements of such a regime. The discussion focused largely on what is needed to implement the spectrum-sharing model, because it is the newest and most technically demanding of the three models.

Minimum Requirements

Participants wrestled first with the question of just how flexible the regulatory rules could be under a general purpose spectrum regime. Stated differently, what are the minimum requirements that regulators would need to impose? The group concluded that, strictly from an engineering perspective, a general purpose spectrum regime would need to impose just two requirements: "operating rights" and "admission control." The group's analysis of these requirements drew heavily on the work of the FCC's Technological Advisory Council (TAC). The TAC is a formal advisory committee established under the Federal Advisory Committee Act, and several of the Roundtable participants are active members of the TAC.

Operating Rights. Operating rights consist of transmit rights and interference protection rights. Transmit rights, or "transmission permissions," refer to the amount of electromagnetic energy a spectrum-using device is allowed to deliver. This could be a measure of the energy a device transmits (transmit power) or, alternatively, the energy that gets received by other devices in the field (field strength).

As the technical experts in the group envisioned them, transmission permissions will have several novel features. First, the defining parameters will be expressed as probabilities rather than absolute values. For

example, the license might require that the power density not exceed a specified level more than five percent of the time at more than 95 percent of locations for a given time window and test area. Second, a transmission permission will not entail an obligation to prevent "harmful interference" to other concurrent operations, as is the case with traditional FCC licenses. Rather, if resulting energy levels meet the (probabilistic) requirements specified in the license, the licensee will not be liable for harm to other operators.[27]

Interference rights, or "interference protections," answer the question of how much protection from interference a receiving system is entitled to. Specifically, interference protections (also known as reception limits, interference limits and harm claim thresholds) will quantify the level of interference from a third party that any particular receiver will be expected to tolerate before the radio system can have a claim of harmful interference. As with transmission permissions, the relevant parameters of interference protections will be defined probabilistically (e.g., a rule might say that a specified field strength or power flux density is not to be exceeded more than a set percentage of times and at more than a set percentage of locations within a particular service area).

…it is more efficient to specify a performance requirement and leave it up to device manufacturers to figure out the best way to achieve it.

Two basic points about interference protections are worth noting. First, as discussed in Section III, a reception-oriented interference requirement represents a new element of spectrum management—one designed to avoid cases such as Nextel-public safety and LightSquared-GPS, in which the performance of receivers limits the potential for adjacent bands to support valuable new services. Having clearly defined interference-protection rights should help to achieve more efficient trade-offs between the rights of transmitters and receivers, with the goal of maximizing concurrent operations as opposed to minimizing harmful interference. Moreover, operators should be able to negotiate

these arrangements privately and routinely, with much less need for regulatory intervention.

Second, interference protections represent a performance (or output) measure, as distinct from receiver standards, which are a design (or input) measure. Although mandated design standards would recognize the importance of receivers in managing interference, they could have unintended consequences, e.g., such standards often become tied to a specific technology, which impedes innovation. Thus, spectrum experts have come to believe that, in addressing the need for a receiver-oriented interference requirement, it is more efficient to specify a performance requirement and leave it up to device manufacturers to figure out the best way to achieve it.

Admission Control. The second technical requirement for a general purpose spectrum regime, admission control, refers to the process or mechanism for deciding who can get access (admission) to a spectrum band at any given time. Access can include not just permission to transmit but also permission to operate a receive-only radio station, such as a satellite receive station or a radio telescope.

Admission control can be accomplished in a number of ways, beginning with the use of licensing. Another approach is ex ante device certification; for example, in unlicensed bands, any device can operate as long as it is compliant with the FCC's Part 15 rules. A third approach to admission control is an SAS, which uses some combination of geolocation/database and spectrum sensing techniques to limit the access of devices to shared or unlicensed spectrum. Yet a fourth approach is ex post removal of a non-compliant device. (Ex post admission control is part of an enforcement regime, which is discussed more below.)

No Usage Requirement. Participants stressed that a general purpose spectrum regime could function with no requirements other than operating rights and admission control. Specifically, there is no need to limit a particular band to a specific use, such as public safety radio services or satellite communication of broadcast signals. This flexibility is possible because, as noted earlier, spectrum uses differ only in their operating rights, and under the conditions associated with spectrum sharing, a single band of spectrum will be able to accommodate multiple sets of operating rights.

Role of the SAS and the Emergence of Assured Coexistence Engines (ACE)

Participants emphasized the critical role that the SAS will play in a general purpose spectrum regime—at least in shared-use bands. In addition to their admission-control role, such systems can facilitate interference resolution and system management, thus allowing for more effective utilization of shared-use spectrum (as measured in terms of efficiency, resilience or other criteria). By contrast to shared-use bands, exclusive-use bands will have less need for an SAS because the spectrum operator already performs the same function. In traditional unlicensed bands, the strict limits on power will obviate much of the need for access control and system management, although an SAS can nevertheless add value by providing a tool with which the rights of unlicensed devices can be modified.

Participants noted that there are several emerging technologies for SAS management. One is the approach used in the TV white space, which combines geolocation and database techniques. With this approach, the system stores information on spectrum utilization by incumbents and other authorized users in a central database. New users are required to communicate with the database and to dynamically select channels, times and/or locations that will avoid interference. An alternative approach is spectrum sensing, which requires new users to monitor the actual usage of spectrum by incumbents and other authorized users, and restricts them from selecting channels, times and/or locations that would cause interference.

A major fault line in the debate over spectrum sharing has to do with the appropriate number of tiers. A number of industry stakeholders, including members of the Wi-Fi community, prefer the three-tier approach proposed by PCAST (and recently approved by the FCC in its 3.5 GHz proceeding). As noted earlier, some wireless carriers and vendors initially expressed a preference for a two-tier approach to sharing, such as ASA/LSA, although that may be changing, and some stakeholders are now discussing the use of LTE-U/LAA in the third (GAA) tier of a three-tier system.

Significantly, Roundtable participants concluded that an individual band of spectrum could accommodate both a two-tier approach (LSA/ASA) and a three-tier approach (PCAST/CBRS) to shared access.

Other approaches, such as the one used for unlicensed access to TV white space, could also be accommodated. The group coined the term "Assured Coexistence Engines," or ACE, to describe this vision. The implication of ACE is that operators and regulators do not need to choose one approach to protected shared access over another—they can have multiple approaches in a single band (although, as discussed below, regulators will need to provide for interoperability).

The implication of "Assured Coexistence Engines" (ACE) is that operators and regulators do not need to choose one approach to protected shared access over another—they can have multiple approaches in a single band….

The group discussed at length how the SAS admission control function should handle excess demand. Specifically, if a shared-use band is nearing the ceiling on aggregate interference, as defined by the interference protection standard, how will the SAS decide which GAA devices to admit and which ones to turn away? Some participants pointed out that, while this is not an issue in unlicensed bands because there is no guarantee of quality of service, with the approach envisioned in the PCAST report, in which PA users have protected access, there will need to be an "etiquette" or "protocol" for limiting GAA devices. Peter Pitsch said he saw the issue of who determines that protocol as a red flag: "To the extent you are creating a legal advantage and [there is] more than one person who wants it, then you're going to have policy questions that arise inevitably out of that."

Pierre de Vries from the University of Colorado's Silicon Flatirons Center defined that as a "fairness issue" and said there was a variety of algorithms for making spectrum access decisions on the grounds of "fairness." He pointed out that, traditionally, the spectrum community has not wanted to see the FCC select the fairness algorithm because (as with design standards) it inevitably becomes technology-specific, which stifles innovation. Consistent with that view, a number of participants felt that the technical community could develop an access protocol,

much as it develops equipment standards. One participant pointed to the 3650–3700 MHz band, which the FCC set aside for contention-based use by unlicensed devices; the technical community came up with a contention-based protocol that users have followed in that band.

However, other participants stressed that this was something the FCC needed to bless, if not design. This is particularly the case because there will be multiple SASs operating in a single band, and they will need to be synchronized. As Jon Peha put it, "You can't have rough consensus" on something this challenging and important. "You really need to codify it…as a form of etiquette, and etiquettes are something that the FCC at least has to bless."

Technical Advances that Would Facilitate a General Purpose Spectrum Regime

Participants also considered what technological changes are needed to enable a general purpose spectrum regime, which in this context referred to wide-scale spectrum sharing. The group concluded that existing technology is capable of supporting this goal at the pilot stage. (As one participant put it, "the technology is ready to go from lab to street.") Thus, technology should not be a reason to delay. At the same time, there is a "chicken-and-egg problem": technology companies need rules in order to build a fully functional system, but the FCC needs evidence that the technology will work (and that there will be a demand for it) before it can write the rules.

There are four concrete areas where additional technical advances are needed to take wide-scale spectrum sharing beyond the pilot stage:

- *Wide-band sensors:* Spectrum sharing requires sensors that can scan a large spectral bandwidth—several hundred megahertz or even several gigahertz—to detect unused spectrum. Current technology does not allow sensors to sample the spectrum at a rate high enough to provide the needed resolution. To get the desired resolution, the technology needs to incorporate advanced signal sensing and sampling techniques.

- *Self-Organizing Networks (SON):* Wireless networks consist of thousands of base stations, each with hundreds of settings. Self-organizing networks are an automation tool, designed to allow

a network operator to organize, manage and "heal" its network more efficiently—for example, by managing neighbor cell relations (known as Automatic Neighbor Relations, or ANR). The massive deployment of small cells that is likely to occur in shared-use bands will require much more sophisticated ANR functionality.

- *Software to manage the co-existence of old and new devices:* Wide-scale spectrum sharing will require the software to ensure that older, less spectrum-efficient devices do not crowd out newer, more spectrum-efficient ones. One approach is to "reflash" older devices so that they have more advanced capabilities. Another is to "brick up" such devices, in effect, rendering them unusable.

- *Filters, power amplifiers and antennas to allow for dynamic spectrum access:* The "front end" environment for a mobile device is increasingly complex and can include 10–20 components, such as a filter, power amplifiers, antenna tuners and switches. With more sophisticated front-end technologies, devices will be able to tolerate higher levels of interference and take better advantage of shared access bands.

Participants observed that the correlation between the price of a good and the scale of production poses its own chicken-and-egg problem. To elaborate, to get this technology into the market, it needs to be very low cost. That is relatively easy for a manufacturer, once it is producing at high volume. The challenge is to develop ways to "flatten this curve so that the technology is cheap even at small scale."

Government Responsibilities

Participants looked next at what the federal government needs to do to enable a general purpose spectrum regime. The group identified three key steps that it wants to see regulators take in the near future. By "regulators," the group had in mind NTIA as well as the FCC.

First, the government needs to define the two sets of requirements discussed above: operating rights (transmit rights and interference-protection rights) and admission control. Regulators should give pri-

ority to interference-protections rights, because they represent a new element of spectrum management and thus are an area in which regulators have less experience. The FCC's 3.5 GHz proceeding specifies the amount of interference protection to which Tier 2 licensees (PA users) are entitled. Separately, the FCC needs to specify protection limits for Tier 1 licensees, such as C-band earth stations. Ideally, NTIA will set similar limits for federal spectrum users.

Second, the FCC needs to set the requirements necessary to allow SASs to operate and interoperate. As noted above, there is no need to select one over another, because the systems can co-exist. However, the government needs to set performance specifications for these systems as well as requirements for synchronization and interoperability.

Third, the government needs to facilitate "markets in interference protection," referring to the ability of spectrum users to modify their transmit rights and interference protection rights through bilateral negotiations. The key action required is the definition of these rights (step one above) and a specification of the mechanism for their enforcement.

Enforcement

Finally, participants addressed the question of how a general purpose spectrum regime would identify and punish bad behavior. Using automobile transportation as an analogy, the group identified four stages to the enforcement process:

1. Observation (watching drivers, measuring their speed to see if they're driving recklessly);

2. Allegation (e.g., a police officer writes a ticket);

3. Adjudication (the individual who got the ticket disputes the allegation, so the two sides must go to court); and

4. Remediation (depending on the outcome of the court proceeding, the government takes some action, such as imposing a fine, putting points on the driver's license or taking the license away altogether).

To promote efficient and innovative use of spectrum technologies, the goal is to jump directly from the observation of a problem to reme-

diation wherever possible. That is, although mechanisms for allegation and adjudication would exist as a backstop, it is preferable to invoke them infrequently. For example, when an electronic sign on the road shows a car's current driving speed (and the speed limit), most drivers slow down to conform to the speed limit.

To promote efficient and innovative use of spectrum technologies, the goal is to jump directly from the observation of a problem to remediation wherever possible.

Participants also considered the role of technology in the enforcement process and concluded that technology can facilitate enforcement at every stage. Observation will benefit from the use of tools like crowdsourcing (using the vast number of deployed devices to track problems) as well as the SASs themselves, which are a form of "big data." Those same tools will be critically important at the allegation stage, where it will be necessary to have an "audit trail" and, in effect, "prove that your radar gun was accurately calibrated." Stage three, adjudication, requires judgment, which is an inherently human function; nevertheless, technology can streamline the process (and obviate it in some cases). Finally, at the remediation stage, as an alternative to taking punitive action, an SAS can redirect an interference-causing user to a non-interfering spectrum position. Moreover, by tracking the trends in ad hoc interference resolution, technology can help to flag emerging remediation problems.

VI. Strategies for Overcoming Impediments to General Purpose Spectrum

As their last assignment, participants were asked to propose strategies for overcoming the (non-technical) impediments to a general purpose spectrum regime. The strategies they proposed fell into two categories. The first was aimed at overcoming resistance from—or incentivizing desired actions on the part of—incumbents in legacy, single-use bands.

The group focused largely on federal incumbents. The second category of strategies was aimed at overcoming one or more of the impediments to more efficient spectrum usage that the group had identified earlier.

Overcoming Resistance from Incumbents

The discussion of strategies to overcome resistance from incumbents dealt largely with federal spectrum. This marked a shift from the earlier discussion at the Roundtable, which by design had focused on non-federal spectrum. This shift in focus reflected participants' views that the time is right for additional legislation to encourage federal agencies to dispose of or share underutilized federal spectrum. The group proposed three complementary strategies aimed at federal spectrum as well as a fourth that could apply to all spectrum: create transferable federal spectrum rights; address Congressional scoring of spectrum; exchange of federal spectrum rights for improved equipment; the "Shockwave" approach.

Strategy 1: Create Transferable Federal Spectrum Rights

Proposal: NTIA should convert federal agencies' spectrum assignments into flexible licenses. Congress should authorize the largest spectrum-using federal agencies (or the FCC or NTIA, on their behalf) to sell or lease some or all of the rights provided under their licenses and to retain a significant share (say, 40 percent) of any proceeds. Agencies should also be given the authority to retain the proceeds from arrangements (already legal) that involve the sharing of federal spectrum with non-federal entities.

Rationale: Federal agencies use a significant amount of spectrum to meet their mission needs for wireless services, and they face relatively weak incentives to use it efficiently. NTIA assigns spectrum to federal agencies (there are no "licenses"), and the assignments are not transferable. Moreover, even if a federal agency had the legal authority to sell or lease its spectrum, under current law, it could not retain the proceeds (Miscellaneous Receipts Act) or spend them (Antideficiency Act). Giving federal agencies negotiable rights to their spec-

> trum and the ability to retain a meaningful share of the proceeds would strengthen the incentives for efficient use directly. It would also contribute to that goal indirectly by creating a common "language" with which spectrum rights holders in federal and non-federal spectrum could converse.

The Spectrum Relocation Fund (SRF), which reimburses federal agencies for the costs they incur in clearing spectrum to be auctioned, reduces a major disincentive to federal spectrum clearing. Although the SRF is a key element of federal spectrum management, it stops short of creating a positive incentive for federal agencies to free up or share underutilized spectrum. This proposal is designed to provide that positive incentive. There are two sets of concerns with the proposal—one having to do with its desirability, the other with its efficacy. However, neither is a sufficient reason not to pursue the proposal.

With respect to the *desirability* of transferable federal spectrum rights, two somewhat conflicting concerns have been raised. The first is that such a policy could have the perverse effect of encouraging hoarding. According to this argument, if agencies had transferable rights, they might hang on to spectrum that they otherwise would clear in order to get a better price for the asset as it appreciates, generally, or as it becomes more critical to a particular buyer (i.e., hold-out strategy). Although it is important to consider the potential for unintended consequences, the reality is that agencies already hoard spectrum, and there is no penalty for doing so. If agencies were allowed to transfer or share spectrum and retain a meaningful share of the proceeds, hoarding would at least carry a penalty in the form of foregone proceeds.

A second argument (which runs counter to the first) is that budget-strapped agencies would be overly eager to trade spectrum for revenue and that multiple transactions by agencies acting individually would result in the sell-off of a vital federal asset. One Roundtable participant argued forcefully that this concern rose to the level of a constitutional issue—namely, the principle of the unified executive, which says that individual agencies do not have authority over federal assets that the executive branch happens to control. Other Roundtable participants acknowledged the need for safeguards but argued that putting such controls in place was not a difficult challenge. In fact, precedents for such controls already exist, including limits on federal disposal of real property.

With respect to the *efficacy* of transferable federal spectrum rights, skeptics have raised two concerns. One is that it would be difficult to sell or lease federal spectrum to a non-federal entity because most federal spectrum is shared by multiple agencies, and thus any individual deal would entail large transaction costs (including the cost of overcoming the kind of hold-out issues mentioned above). Although this is a valid concern, it should not be a basis for inaction. Some bands may lend themselves to transactions more than others. And even if the sale or lease of spectrum is impractical in a given federal band, spectrum sharing may be feasible. (Although federal agencies can share spectrum with non-federal entities now, the ability to be compensated for it should make sharing more attractive.)

A second efficacy argument—and the one that has gotten the most traction in the spectrum community—is that the ability to retain the proceeds will not motivate federal agencies to transfer their spectrum because of the nature of the budget process. According to this argument, if an agency were to take in, say, $50 million for the lease or sale of some of its spectrum rights, congressional appropriators would simply take $50 million out of the agency's budget the following year. In anticipation of this zero-sum dynamic, agencies would forego the opportunity to trade spectrum for money.

However, there is a revisionist view that the ability to retain a meaningful share of the proceeds might in fact motivate federal spectrum users. Support for this view comes in part from a recent Brookings Institution paper by this rapporteur, which draws lessons for spectrum policy from the management of federal real property (buildings and land).[28] Lesson one of the paper is that "the ability to retain the proceeds from the disposal of real property (buildings, structures and land) is a key motivator for federal agencies."

In 1987, when the Office of the Secretary of Defense (OSD) wanted to motivate the Services to undertake another round of base closures, it held out the prospect that they could retain the proceeds from the sale of excessed property. At the time, General Services Administration (GSA) was responsible for all federal property disposal, and the proceeds went into a land conservation fund. At the urging of the Department of Defense (DoD)—and despite opposition from GSA—Congress delegated GSA's disposal authority to DoD for base closure

property and created a Base Realignment and Closure (BRAC) Fund into which the proceeds would go, to be used for real property upkeep. The ability to retain proceeds from the sale of property was key to getting Service participation in the early BRAC rounds, and it continues to be a strong motivator.

Another, non-BRAC example from the Brookings paper underscores the lesson (federal agencies are motivated by the prospect of generating revenue) while cautioning that the details matter:

> …DoD's experience with Enhanced Use Leases (EULs) [shows] that agencies are sensitive to which organization within the agency gets to keep the revenue. An EUL is a long-term lease of underutilized property for which the developer pays the agency rent in the form of cash or in-kind services. Initially, DoD's statutory EUL authority specified that "the Department" could keep 100 percent of the revenue. An EUL requires a significant commitment of time and effort by the staff of an individual military installation, and the installations at first showed little interest in using the new authority. However, after the statute was changed to allow 50 percent of the revenue to stay with the installation, "the projects flowed," in the words of one observer.[29]

In evaluating the relevance of these examples for federal spectrum, it is useful to ask why the prospect of a "take-back" by appropriators does not seem to deter federal property managers from pursuing BRAC and EUL transactions. One reason may be that the dollars involved are not large enough to get the attention of appropriators. Although the Navy received $850 million for the sale of property at two Marine Corps bases in California that were closed as part of the BRAC process, most BRAC property sales and leases yield far less, and the buyer (often the neighboring community) in many cases pays DoD for the property in installments. In the case of EULs, rent payments often take the form of in-kind services rather than cash, which are even less visible to appropriators. Finally, the Services use the money from the sale/lease of BRAC property exclusively to pay for BRAC-related expenses (e.g., environmental cleanup, property maintenance and relocation)—expenses that generally amount to small change in the context of DoD's large military construction budget—and they can do so without prior authorization.

A second reason the skeptics' budget argument may not explain the behavior of federal property managers is timing. Even if, over the long term, appropriators reduce an agency's budget to offset the proceeds generated from property sales/leases, such an outcome is not apparent in the near term. Thus, to a budget-strapped federal agency, the proceeds from property transactions represent incremental funding.

In short, at least when it comes to federal real property, the budget process is "stickier" than the skeptics' argument acknowledges. The transactions are too small to attract much notice from appropriators, at least in the short run. At the same time, they are large enough to make it worth the effort of cash-strapped agencies to pursue. Importantly, land and buildings require upkeep, which can make disposal of excess property attractive even if the proceeds are small.

…letting federal agencies transfer or share their spectrum rights and retain a meaningful share of the proceeds is an idea worth pursuing.

The differences between real property and spectrum may or may not be that significant in this context. In sharp contrast to real property, there is no direct cost for hoarding spectrum. (Although spectrum-intensive equipment, such as antiquated radars, is typically very expensive to maintain, a federal agency can tackle that expense without ridding itself of the spectrum itself.) Moreover, the budget process may be less "sticky" insofar as the proceeds from spectrum transactions are larger. That said, the goal of this proposal is to enable a large spectrum-using federal agency to enter into transactions routinely (for example, one can imagine DoD leasing 10 megahertz of spectrum to, say, T-Mobile with the proviso that T-Mobile has to quit using it within 100 miles of a certain point within two minutes of being notified to do so). As with BRAC and EUL transactions, such routine spectrum transactions could provide much-needed cash to a federal agency without causing appropriators to react.

In sum, letting federal agencies transfer or share their spectrum rights and retain a meaningful share of the proceeds is an idea worth

pursuing. The policy arguments against it are not showstoppers. Granted, the concerns about whether it will be effective may have some merit; however, those concerns should lead policymakers to lower their expectations for this approach, not to forego it altogether.

Strategy 2: Address Congressional Scoring of Spectrum

> *Proposal:* Address the risk that the Congressional Budget Office (CBO) would "score" the legislation needed to carry out the first proposal unfavorably, thereby making the legislation prohibitively expensive. Do this by (a) limiting the scope of the legislation to selected bands, (b) attempting to demonstrate how this proposal would change the assumptions in CBO's budget baseline and, if necessary, (c) identifying a source of offsetting revenues (a "pay-for").
>
> *Rationale:* CBO calculates the impact on the budget of any proposed legislation (referred to as "scoring"), and a negative score—meaning that by CBO's calculations, the legislation will impose a net loss on the federal budget—can doom a bill. Taken alone, legislation to let federal agencies keep a share of the proceeds from spectrum transactions should get a positive score because such legislation might generate additional revenue (proceeds from transactions that would not otherwise occur), and any costs (the proceeds that the federal agencies could keep) are conditional on those revenues coming in. However, CBO's annual budget baseline anticipates, or assumes, the sale of some amount of federal spectrum. Stated differently, CBO has already incorporated some of the benefits of federal spectrum sales into its budget, and it has not incorporated any costs. Thus, depending on the specifics of the legislative proposal and CBO's baseline assumptions on federal spectrum sales, CBO could score the proposal as having costs in excess of revenue.

CBO scoring of legislation authorizing the sale of spectrum, particularly federal spectrum, has long been a bone of contention. In the 1990s, when Congress began to propose legislation to allow the FCC to auction federal spectrum, CBO gave the bills a neutral score, because

the federal government's rules did not allow the revenues from federal asset sales to be counted in the budget. This caused a major riff because Congress saw spectrum auctions as a way to reduce the budget deficit. Eventually, the House and Senate Budget Committees overrode CBO.

As a more recent example, in 2013, Representatives Brett Guthrie (R-KY) and Doris Matsui (D-CA) introduced legislation to encourage federal agencies to vacate or share underutilized spectrum. Among other things, the bill authorized federal agencies to keep one percent of the revenue from the auction for commercial use of spectrum that had been assigned to them. Concerns about CBO scoring were reportedly one reason that the legislators limited the federal agency share to one percent.

Roundtable participants discussed three tactical steps to address the risk of a negative budget score. The first is to limit the legislation to selected bands. The Guthrie-Matsui bill covered all federal spectrum. A more targeted approach would pose less budget risk. Step two is to persuade CBO that the proposed policy would fundamentally alter the assumptions in its baseline. To the extent that CBO believes the legislation is likely to change the behavior of federal agencies and induce more spectrum to be sold than would otherwise be the case, it will reflect that in its score. CBO's spectrum scorekeepers routinely meet with subject matter experts before they score a piece of legislation. Although they tend to take a fiscally conservative stance, they are willing to debate their analysis. New evidence, such as the results from federal real property management, might help change their minds. The steep prices paid for spectrum in the recent FCC auction may also affect CBO's analysis. Step three is to identify a source of revenue to offset some or all of any positive score that CBO assigns to such legislation. Having a "pay-for" will be key to getting broad support for the legislation in Congress.

Strategy 3: Exchange of Federal Spectrum Rights for Improved Equipment

> *Proposal:* Identify opportunities for federal agencies to exchange spectrum usage rights for spectrum-conserving upgrades to radar and other radio equipment. If necessary, get Congress to authorize one or more agencies to carry out such exchanges.

Rationale: A small number of federal agencies have the authority to exchange an underutilized property (e.g., a building or a piece of land) for something else—either property or construction services—of equivalent value. (An EUL is a type of exchange, because the lessee can pay rent in the form of in-kind services rather than cash.) Among other advantages, a property exchange allows an agency to bypass certain steps in the budget process. If federal agencies had the necessary authority, they could receive upgrades to outdated radio systems in exchange for some of the spectrum that the upgrade would free up.

Exchanges, a form of barter, have long been common in the real estate sector, because they provide tax advantages and reduce transaction costs. Public agencies use exchanges to avoid risks associated with the budget or property disposal process.

To illustrate, consider the Department of Transportation's (DOT) National Transportation Systems Center (Volpe Center), which occupies a large, antiquated building and 14 acres in Kendall Square in Cambridge, Massachusetts. Kendall Square, adjacent to the Massachusetts Institute of Technology, is some of the most valuable real estate in the country. GSA is exploring ways to use its exchange authority to convey significant portions of the valuable federal land to a developer or other buyer in exchange for construction services to transform the Volpe Center into a state-of-the-art facility.[30] The alternative to an exchange would be a much more cumbersome and risky process requiring GSA to sell the excess land, bank the revenue, and then get an appropriation from Congress to renovate the Volpe Center. And with no guarantee that the revenue from the land sale would go to pay for the renovation, it is unlikely that DOT would agree to give up the land in the first place.

The concept of exchange is applicable to federal spectrum management. Federal agencies have radio systems that are the equivalent of the Volpe Center: they are antiquated, and they consume a large amount of valuable spectrum "real estate." As with the Volpe Center, upgrading of equipment could be financed by the sale or lease of some of that valuable spectrum property—specifically, the spectrum that the upgrade would help make available for non-federal use.

Some participants questioned how many federal radio systems are good candidates for this type of exchange. In their view, the cost of upgrading most DoD radar systems is so high as to be prohibitive. Thus, they advised that spectrum reformers should focus on the systems that are in the development pipeline—and making them more efficient—rather than on trying to upgrade the ones that are already in place.

Strategy 4: "Shockwave" Approach for All Spectrum

> *Proposal:* Convert all non-federal site-based assignments into exclusive, flexible-use licenses, and allow licensees to transfer the spectrum usage rights provided in these licenses. Include all federal site-based assignments as well, in keeping with the policy on federal spectrum proposed above.
>
> *Rationale:* Many incumbents in legacy fixed-use bands have little incentive to vacate the spectrum or use it more efficiently because they have no ability to transfer it. If they had rights to the spectrum, they would have an incentive to sell or lease some or all of it or in other ways take steps to use it more efficiently.

"Shockwave" represents the fastest and most efficient way to move legacy bands into the market—hence its name. It could be implemented using the exclusive-use model, the shared-use model or a combination of the two.

Significantly, it avoids the need for auctions, which means it could be carried out far more quickly. This is critical given that the benefits to consumers from additional spectrum are an order of magnitude greater than the auction proceeds. That said, Congress has supported spectrum reform in large part because of the prospects of auction revenue; because it would forego those revenues, this approach would have less appeal to many members. Moreover, because it foregoes the sale (auction) of rights, this approach provides a "windfall" to incumbents, which some Roundtable participants oppose. The FCC's planned incentive auction to free up broadcast spectrum has been criticized on the same grounds.

Facilitating Decentralized Spectrum Management

The group discussed three mechanisms that are designed to overcome the impediments to efficient spectrum usage: interference protection rights, band agents and a fact-based adjudication system. All three are proposed in a recent Brookings Institution paper that was co-authored by one of the Roundtable participants, Pierre de Vries.[31] The common denominator among the mechanisms is that they facilitate more decentralized spectrum management.

Mechanism 1: Interference Protection Rights

> *Proposal:* The FCC (and ideally NTIA) should establish clearly defined interference protection rights that specify the level of aggregate third-party interference that any particular receiver will be expected to tolerate before the radio system can have a claim of harmful interference. One possible next step would be for the FCC to undertake a Notice of Inquiry aimed at developing a formal process for defining such interference protection rights.
>
> *Rationale:* The FCC policy on interference harm is a major impediment to more intensive use of spectrum. The FCC has traditionally regulated radio operation almost entirely through limits on transmitters, an approach that means transmitters must often remedy interference problems that it would be less expensive to fix on the receiver end. At the same time, the expectations for the performance of receivers have been so ambiguous as to create considerable downstream conflict. A set of clearly defined interference protection rights would facilitate private negotiations between spectrum rights holders, thus limiting the need for regulatory intervention, and in doing so help to achieve a more efficient trade-off between the rights of transmitters and those of receivers.

The Roundtable's technical experts made as their principal recommendation that the federal government "instantiate a set of interference protection rights." This is consistent with recommendations issued by the FCC's TAC, the PCAST and other groups. (In addition to reception limits, other terms used for interference protection rights are harm claim thresholds and interference limits.)

Proponents of the shared-use model of spectrum management are particularly supportive of interference protection rights. Such rights are seen as key to an environment in which the FCC no longer has the luxury of being able to place "like services with like services" and must instead place new services in bands not previously allocated to that category of services (i.e., the spectrum-sharing model).[32] In particular, such rights are thought to be essential to the operation of spectrum access systems, which—in order to protect receivers in an automated way—will need an objective statement defining the protection to which the receivers are entitled.

However, some of the people who favor greater reliance on licensed use have concerns about this approach, which they see as an example of "exactitude."[33] They acknowledge that, all else being equal, more clarity is preferable to less clarity. However, perfect clarity is not achievable and additional clarity is costly, as can be seen from commercial contracts. The terms in commercial contracts are often ambiguous because it would be too cumbersome to try to anticipate every possible issue that might come up and specify a resolution to it (e.g., what happens if a branch from my neighbor's tree falls on my gazebo and damages it?). Thus, the parties agree to live with a certain amount of ambiguity and to negotiate and/or adjudicate any issues that the contract doesn't anticipate. Similarly with regulation, some level of ambiguity is unavoidable. Thus, the preferred remedy is to assign exclusive and exhaustive rights, leaving it to the rights holders to negotiate the most efficient trade-offs and to adjudicate any unanticipated issues that arise.

Mechanism 2: Band Agents

> *Proposal:* The FCC and NTIA should facilitate the establishment of band agents that can represent the interests of large groups of fragmented rights holders/licensees, including by taking positions that bind all licensees in the band.
>
> *Rationale:* The fragmentation of spectrum rights makes it difficult for rights holders to reach mutually satisfactory, efficiency-enhancing agreements through direct negotiations with one another or with a third party. This collective-action problem is an impediment to efforts to change the use of a fragmented band. The establishment of band agents would empower end

> users and allow them to consolidate their interests, thus facilitating efficiency-enhancing agreements, including agreements to change spectrum use.

Band agents are a response to the problem of fragmentation. They would be similar to the band managers and frequency coordinators employed in the current regime but with additional powers. Band managers are responsible for managing the interference between operators in a band, and frequency coordinators facilitate the establishment of operating assignments that minimize in-band interference. By contrast, band agents could negotiate adjustments to the operating rules in a given band (known as "alteration rights"), including changes that reflect an agreement with a neighboring operator and that are binding on all licensees in the band.

The group was generally favorable to the idea of band agents, but participants identified three possible concerns. First, as with interference protection rights, some participants view the real problem as poor assignment of spectrum usage rights—fragmentation is only a symptom. If those rights were exclusively and exhaustively assigned, the market would aggregate the fragmented rights "naturally," thus obviating the need for band agents.

Second, some participants cautioned that, by empowering incumbent end users, band agents could make it harder for others whose interests are hostile to those of incumbents. Preston Marshall said that band agents offered a great way to capture incremental improvements, but he argued that advances in wireless have come largely through creative destruction rather than incrementalism. He said the litmus test for this and other options should be, "Does it support creative destruction in the business concepts and business practices of an incumbent group?"

Proponents of the band agent proposal responded that facilitation of changes in spectrum use, including creative destruction, was precisely the goal. They contrasted band agents with band managers and frequency coordinators, whose job is to perpetuate the existing use of a band. However, the proponents acknowledged that the details of the proposal were critical and might still need to be refined.

Third, other participants acknowledged the logic of the band-agent proposal but questioned whether it should be a high priority for spec-

trum management reform. In a number of cases, individual entrepreneurs, companies or trade associations have taken it on themselves to play that role, as Morgan O'Brien did in the case of the 800 MHz SMR bands. More routinely, the FCC identifies the interest groups that speak for the vast majority of the rights holders in a band through its rule-making process. Granted, the FCC still needs to decide what to do about the minority of rights holders who are not represented by those groups, but that will be an issue even with band agents.

The broader point made by the participants who took this perspective is that there is a "*realpolitik* of spectrum." No matter how you deal with spectrum rights and responsibilities in an effort to facilitate changes in the use of a band, at the end of the day, the groups and firms with an interest in that band are going to want to come to the table, and the same issues will need to get resolved. Perhaps the formalization of band agents could facilitate that process somewhat. However, there are other spectrum management reforms that would be more productive.

Mechanism 3: Fact-Based Adjudication

> *Proposal:* The FCC should develop a specialized adjudication function, by (among other things) employing a cadre of administrative judges who would develop factual findings in spectrum disputes. In addition, Congress should establish a Court of Spectrum Claims, to be housed within the existing Court of Claims, to hear spectrum-related cases, including cases that involve the federal government as a party.
>
> *Rationale:* The FCC's existing process for resolving disputes over spectrum usage rights relies heavily on a combination of notice-and-comment rulemaking and high-level negotiations with parties. The process tends to be slow and politically charged; and the rulemaking process, which is designed for making public policy, is not appropriate for handling individual disputes, which should be decided on the basis of objective criteria such as technical efficiency. The proposal would substitute a more fact-based adjudication process in which judges with expertise in spectrum policy would have the resources to adjudicate individual spectrum-related disputes in a timely way. Having such a process will become especially critical if the

> FCC and NTIA adopt a more calibrated system for defining spectrum use rights, such as interference protection rights.

This proposal found broad support among Roundtable participants. Specifically, it brought together those who favor flexible licensed use and those who support shared use (including unlicensed use) as the preferred approach to spectrum management.

To elaborate, those who advocate for spectrum sharing and interference protection rights see fact-based adjudication as a necessary complement. The institution of interference protection rights will necessarily invite disputes among spectrum rights holders. Having an effective adjudication regime in place will serve two key functions. One, the threat of litigation (and the opportunity for discovery) will encourage the parties to reach an agreement without resorting to adjudication. Two, if adjudication becomes necessary, the proposed regime will be able to handle disputes effectively. Moreover, the number of disputes involving the federal government will likely increase insofar as spectrum sharing between federal and non-federal users gains traction. The establishment of a specialized court outside the FCC would allow the federal government to sue or be sued as appropriate.

Those who favor exhaustive assignment of exclusive, flexible spectrum rights (some of whom are skeptical of the need for well-defined interference protection rights) likewise see effective adjudication as an essential element of their preferred approach. This is consistent with Coase's analysis of spectrum management, which pointed to real property as a model, with its reliance on a body of common law that had been built over centuries of adjudication of disputes.

The broad support expressed for this proposal reflected the view of many Roundtable participants that the FCC "has gotten away from the adjudication mindset" that it once displayed. The FCC employs only one or two administrative law judges, and they rarely handle adjudicative proceedings. In the absence of such adjudication, most enforcement decisions are determined by negotiations between the FCC's Enforcement Bureau and the rule-breaking parties. In other cases, disputes that are technical in nature get resolved through a process (notice-and-comment rulemaking) that is designed for making public policy based on public interest considerations.

The FCC's critics maintain that the agency exercises too much discretion in its approach to dispute resolution. As noted earlier, technical disputes often get turned into public policy debates. In addition, the FCC at times uses its leverage in one area (e.g., merger approval) to get parties to comply or cooperate in another area (e.g., violation of spectrum license terms).[34] The appeal of a fact-based adjudication process is that the decision makers, namely judges, generally have less discretion than the FCC.

Not all the Roundtable participants shared this perspective. John Leibovitz defended the Commission's use of negotiation and arbitration, especially in cases that involve highly technical disputes. He described the FCC technical staff as "thick-skinned, skeptical people" who have a lot of repeat experience with the different claims that get made and "know how to sort out truth from BS." Moreover, they have an incentive to get the parties to resolve the dispute at the Bureau level.

Some participants also pointed out the need for FCC discretion in certain cases—for example, where there is a public interest element to the dispute or where the two parties in a dispute are unevenly matched in terms of clout and resources. Another participant noted that, in some cases, a strict interpretation of the regulatory rules, which is presumably what an administrative judge would render, is at odds with good public policy. In such cases, even if the FCC were to begin with an adjudicatory proceeding, it might still want to carry out a rulemaking.

A rulemaking is not the only route to good public policy, however. In common law, the process of case-by-case adjudication and resulting precedent yields public policy. Many participants expressed a preference for that approach over rulemaking and negotiations, using existing adjudicatory fora and/or a Court of Spectrum Claims as proposed by de Vries and Weiser.

Endnotes

1. In Auction 97, also known as the AWS-3 auction (for Advanced Wireless Services), the FCC assigned new licenses in the 1695-1710 MHz, 1755-1780 MHz and 2155-2180 MHz bands. The auction began on November 13, 2014, and closed on January 29, 2015, after 341 rounds of bidding. Gross bids totaled $44.9 billion and net bids totaled $41.3 billion—far more than many analysts had predicted. The two largest bidders were AT&T, which spent more than $18 billion, and Verizon, which spent more than $10 billion. There is continued controversy around the role of two small businesses, Northstar Wireless and SNR Wireless, which are majority owned by Dish Networks. The two firms made more than $13 billion in gross bids but are scheduled to pay only around $10 billion if the FCC concludes that they qualify for the Commission's 25 percent discount for small businesses. See the FCC's fact sheet on Auction 97. Available online: http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=97. For more detail on the controversy over Dish Networks, including whether the participation by Northstar and SNR (as well as a third, wholly-owned subsidiary of Dish) served to drive up auction prices to artificial levels, see Phil Goldstein, "Analysis: Dish's AWS-3 Partners Bid Against Each Other, Potentially Pushing Up Prices by $20B," *Fierce Wireless*, February 13, 2015. Available online: http://www.fiercewireless.com/story/analysis-dishs-aws-3-partners-bid-against-each-other-potentially-pushing-pr/2015-02-13. Auction 97 is one of two significant events related to spectrum that has occurred since the Aspen Institute Roundtable on Spectrum Policy met in October 2014. The other event is the FCC's approval, in March 2015 following a two-year proceeding, of the rules creating a Citizens Broadband Radio Service in the 3.5 GHz band. See Section II for a discussion of these path-breaking rules.

2. Some advocates of the spectrum commons, or unlicensed, model reject the implication that it is not market-based. In their view, whereas exclusive licensing creates a market in spectrum rights, unlicensed allocation creates a market in the devices and applications that use spectrum.

3. Although some dismiss this sparring as "sibling rivalry," others recognize it as an important war of ideas. One thought leader sees the intellectual battle between adherents to the property rights and commons models of spectrum governance as the major debate in spectrum policy over the last 15 years. Yochai Benkler, "Open Wireless vs. Licensed Spectrum: Evidence from Market Adoption," *Harvard Journal of Law & Technology*, 26 no. 1 (2012). Another participant has observed that this debate lacks the rancor of other telecommunications policy disputes, in part because the two sides listen to one another and take seriously the criticisms of the other side. Adam D. Thierer, "Three Cheers for the FCC Spectrum Task Force Report," *Techknowledge*, no. 44, (2002). Available online: http://www.cato.org/publications/techknowledge/three-cheers-fcc-spectrum-task-force-report.

4. William J. Baumol and Dorothy Robyn, *Toward an Evolutionary Regime for Spectrum Governance: Licensing or Unrestricted Entry?* (Washington, DC: Brookings Institution Press, 2006): 9–14.

5. Ronald H. Coase, "The Federal Communications Commission," *Journal of Law & Economics* 2 (1959): 1–40.

6. Baumol and Robyn, *Toward an Evolutionary Regime*, 10–11.

7. "CTIA's Annual Survey Says US Wireless Providers Handled 3.2 Trillion Megabytes of Data Traffic in 2013 for a 120 Percent Increase Over 2012," CTIA-The Wireless Association, June 17, 2014. Available online: http://www.ctia.org/resource-library/press-releases/archive/ctia-annual-survey-2013.

8. CTIA-The Wireless Association, *Annual Wireless Industry Survey*, 2014. Available online: http://www.ctia.org/your-wireless-life/how-wireless-works/annual-wireless-industry-survey.

9. FCC Spectrum Policy Task Force, *Report of the Unlicensed Devices and Experimental Licenses Working Group*, November 15, 2002. Available online: http://transition.fcc.gov/sptf/files/E&UWGFinalReport.pdf. These bands were already being used for non-communications purposes and thus were less susceptible to harmful interference. Moreover, they provided sufficient bandwidth to allow for the development of devices that could deliver high data rates.

10. For an inventory of unlicensed spectrum, see Table 2 in Coleman Bazelon, "Licensed or Unlicensed: The Economic Considerations in Incremental Spectrum Allocations," *Communications Magazine*, 47 no. 3 (2009): 113.

11. Yochai Benkler, "Overcoming Agoraphobia: Building the Commons of the Digitally Networked Environment," *Harvard Journal of Law & Technology*, 11 no. 2 (1998): 287–400.

12. Peter Rysavy, "Will LTE in Unlicensed Spectrum Unlock a Vast Store of Mobile Broadband Capacity?" *MIMOWorld*, June 5, 2014. Available online: http://www.mimoworld.com/?p=2377. See also Preston Marshall, "The View Ahead: Technology Opportunities." Paper presented at Looking Back to Look Forward: The Next Ten Years of Spectrum Policy Washington, DC, November 2012. Available online: http://www.siliconflatirons.com/documents/conferences/2012.11.13%20Spectrum/PositionPapers/Marshall_TheViewAhead.html.

13. For an analysis of the factors driving the move to smaller-cell architectures, see John Chapin and William Lehr, "Mobile Broadband Growth, Spectrum Scarcity and Sustainable Competition." Paper presented at the 39th Research Conference on Communication, Information and Internet Policy (2011 TPRC), Arlington, VA, September 2011. Available online: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1992423; and William Lehr and Miguel Oliver, "Small Cells and the Mobile Broadband Ecosystem." Paper presented at the 25th European Regional Conference of the International Communications Society (Euro ITS2014), Brussels, June 2014. Available online: http://econpapers.repec.org/paper/zbwitse14/101406.htm.

14. This was one of several actions that the Commission took to refine the LSA/ASA model. See MIT Communications Futures Program, Spectrum Working Group, *Toward More Efficient Spectrum Management: New Models for Protected Shared Access*, Cambridge, MA 2014. Available online: http://cfp.mit.edu/publications/CFP_Papers/CFP%20Spectrum%20Sharing%20Paper%202014.pdf.

15. FCC, *In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, GN Docket No. 12-354, Notice of Proposed Rulemaking and Order, (Rel. December 12, 2012). See also, FCC, *In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, GN Docket No. 12-354, Further Notice of Proposed Rule-making (Rel. April 23, 2014).

16. FCC, *In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, GN Docket No. 12-354, Report and Order and Second Further Notice of Proposed Rulemaking (Rel. April 21, 2015). Available online: http://www.fcc.gov/document/citizens-broadband-radio-service-ro.

17. "FCC Proposes New Approach to Spectrum Management," *CommLawBlog*, April 27, 2014. Available online: http://www.commlawblog.com/2014/04/articles/unlicensed-operations-and-emer/fcc-proposes-new-approach-to-spectrum-management/.

18. Thomas W. Hazlett, "The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's 'Big Joke': An Essay on Airwave Allocation Policy," *Harvard Journal of Law & Technology*, 14 no. 2 (2001): 387–388.

19. Thomas W. Hazlett and Brent Skorup, "Tragedy of the Regulatory Commons: LightSquared and the Miss-ing Spectrum Rights," *Duke Law & Technology Review*, 13 no. 1 (2014). Available online: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2544673. For one source of the $4 billion figure (a figure that Hazlett and Skorup cite), see Michael Bathon, "LightSquared Files Bankruptcy After Network Blocked," *Bloomberg Business*, May 15, 2012. Available online: http://www.bloomberg.com/news/articles/2012-05-14/lightsquared-failed-wireless-venture-files-for-bankruptcy.

20. Jean Pierre de Vries, "Optimizing Receiver Performance Using Interference Limits." Paper presented at 2012 TPRC, Arlington, VA, November 2012. Available online: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2018080.

21. Peter A. Tenhula, "Enforcement of Spectrum Usage Rights: Fair and Expedient Resolution of 'Interference' Disputes." Paper presented at 2012 TPRC, Arlington, VA, August 2012. Available online: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2032312.

22. See Thomas W. Hazlett, "Efficient Spectrum Reallocation with Hold-Ups and Without Nirvana," George Mason Law & Economics Research Paper No. 14–16, June 2014. Available online: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2440003. For additional analysis of transition mechanisms, generally, and overlays, specifically, see FCC Spectrum Policy Task Force, "Report," ET Docket No. 02-135 (November 2002): 46–51. Available online: https://apps.fcc.gov/edocs_public/attachmatch/DOC-228542A1.pdf.

23. Communications with Henry McCreary, Director of PTC Communications at CSX and President of PTC-220 LLC, April 2015.

24. *Ibid.*

25. American Public Transportation Association, "Positive Train Control," Legislative Issue Brief, March 8, 2015. Available online: http://www.apta.com/mc/legislative/previous/2014/program/Documents/Letterhead_PTC%20Issue%20Brief.pdf. Separately, the freight railroads are supporting legislation that would delay the statutory deadline for implementation of PTC. Jeff Berman, "AAR Welcomes Renewed Call for Positive Train Control Implementation Extension," *Logistics Management*, March 5, 2015. Available online: http://www.logisticsmgmt.com/article/aar_welcomes_renewed_call_for_positive_train_control_implementation_extensi. One respected rail safety expert has criticized the freight rail industry's system architecture for PTC, which will require the placement of a radio at the site of every existing wayside signal (40,000 sites). In his view—a view that others contest—this spectrum-intensive approach will raise the cost and reduce the operational benefits of PTC by tying it to outmoded, electro-mechanical signals rather than integrating it with other critical information systems. Communications with Steven Ditmeyer, Adjunct Professor, Michigan State University, April 2015.

26. Thomas W. Hazlett, "Katrina's Radio Silence," *Financial Times*, October 26, 2005. Available online: http://www.ft.com/intl/cms/s/2/8defb2f6-4486-11da-a5f0-00000e2511c8.html#axzz3UBL0Los1.

27. Jean Pierre de Vries, "How I Learned to Stop Worrying and Love Interference: Using Well-Defined Radio Rights to Boost Concurrent Operation," September 2010. Available online: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1672375.

28. Dorothy Robyn, "Buildings and Bandwidth: Lessons for Spectrum Policy from Federal Property Management," Washington, DC: Brookings Institution, 2014. Available online: http://www.brookings.edu/research/papers/2014/09/23-buildings-bandwidth-spectrum-property.

29. Ibid, 14.

30. "GSA Seeks Ideas for First-Of-Its-Kind Redevelopment of Volpe Center," August 26, 2014. Available online: http://www.gsa.gov/portal/content/196375. See also Katharine Q. Seelye, "Space Age Relic Enters Astronomical Real Estate Market," *New York Times*, February 6, 2015. Available online: http://www.nytimes.com/2015/02/07/us/space-age-relic-enters-astronomical-real-estate-market.html?_r=0. For background on GSA's exchange authority, see "Federal Real Property: GSA Should Better Target Its Use of Swap-Construct Exchanges," GAO-14-586, July 2014. Available online: http://www.gao.gov/products/GAO-14-586.

31. J. Pierre de Vries and Philip J. Weiser, "Unlocking Spectrum Value through Improved Allocation, Assignment, and Adjudication of Spectrum Rights." Discussion Paper 2014-01, Brookings Institution, the Hamilton Project, Washington, DC, March 2014. Available online: http://www.brookings.edu/research/papers/2014/03/24-unlocking-spectrum-value-through-improved-allocation-de-vries-weiser.

32. FCC Technological Advisory Council, Receivers and Spectrum Working Group, "Interference Limits Policy: The Use of Harm Claim Thresholds to Improve the Interference Tolerance of Wireless Systems," White Paper Version 1.0, February 6, 2013: 3.

33. Thomas W. Hazlett and Sarah Oh, "Exactitude in Defining Rights: Radio Spectrum and the 'Harmful Interference' Conundrum," *Berkeley Technology Law Journal*, 28 (2013). Available online: http://scholarship.law.berkeley.edu/btlj/vol28/iss1/6/.

34. See, for example, the discussion of the Sirius-XM case in de Vries and Weiser, "Unlocking Spectrum Value," 14.

APPENDIX

Moving Towards General Purpose Spectrum

Queenstown, Maryland
October 22-24, 2014

Roundtable Participants

Coleman Bazelon
Principal
The Brattle Group

Vanu Bose
Chief Executive Officer & President
Vanu, Inc.

Paula Boyd
Director of Government and Regulatory Affairs
Microsoft

Doug Brake
Telecommunications Policy Analyst
Information Technology and Innovation Foundation

Mary Brown
Senior Director
Technology and Spectrum Policy, Global Policy and Government Affairs
Cisco Systems

Michael Calabrese
Director, Wireless Future Program
New America Foundation

Jonathan Chaplin
Managing Partner
New Street Research

Jacqueline Clary
Senior Counsel & Policy Fellow
Minority Media and Telecommunications Council

Pierre de Vries
Senior Adjunct Fellow and
Co-Director of the Spectrum Policy Initiative
Silicon Flatirons Center
University of Colorado

Harold Feld
Senior Vice President
Public Knowledge

Note: Titles and affiliations are as of the date of the conference.

Charlie Firestone
Executive Director
Communications and Society Program
The Aspen Institute

Thomas Hazlett
Hugh H. Macaulay Endowed Professor of Economics
Clemson University

John Kuzin
Senior Director, Regulatory
Qualcomm Incorporated

William Lehr
Economist & Research Scientist
Massachusetts Institute of Technology

John Leibovitz
Special Advisor to the Chairman for Spectrum Policy
and
Deputy Bureau Chief
Wireless Telecommunications Bureau
Federal Communications Commission

Preston Marshall
Principle Wireless Architect
Google Access

Tom Nagel
Senior Vice President, Strategic Initiatives
Comcast Corporation

Terri Natoli
Vice President
Regulatory Affairs and Government Relations
Time Warner Cable

Jon Peha
Full Professor
Carnegie Mellon University

Peter Pitsch
Executive Director, Communications Policy
and
Associate General Counsel
Intel Corporation

Carl Povelites
Assistant Vice President, Public Policy
AT&T Services, Inc.

Charla Rath
Vice President, Wireless Policy Development
Verizon Communications

Dennis Roberson
Vice Provost for Research
Illinois Institute of Technology

Dorothy Robyn
Independent Writer/Consultant

Steve Sharkey
Senior Director
Chief Engineering and Technology Policy
T-Mobile

Note: Titles and affiliations are as of the date of the conference.

Peter Tenhula
Acting Deputy Associate
Administrator for Spectrum
Management
Office of Spectrum Management
National Telecommunications
and Information Administration
U.S. Department of Commerce

Staff:

Ian Smalley
Senior Project Manager
Communications and Society
Program
The Aspen Institute

Note: Titles and affiliations are as of the date of the conference.

About the Author

Dorothy Robyn is a public policy expert who writes and consults on policy issues related to energy, infrastructure and telecommunications. She has 30 years of experience in government, academia and consulting. From 2012 to 2014, Dr. Robyn was the Commissioner of the Public Buildings Service (PBS) in the U.S. General Services Administration. PBS is the real estate arm of the federal government. From 2009 to 2012, she was the Deputy Under Secretary of Defense for Installations & Environment in the Department of Defense, where she provided Department-wide oversight of U.S. military bases around the world. From 1993 to 2001, she served as Special Assistant to the President for Economic Policy on the staff of the White House National Economic Council. Dr. Robyn previously was an assistant professor at Harvard's Kennedy School of Government, and a Principal with The Brattle Group, an economic consultancy. She has an MPP and a Ph.D. in public policy from the University of California, Berkeley. She is the author of *Braking the Special Interests: Trucking Deregulation and the Politics of Policy Reform* (University of Chicago Press, 1987) and co-author, with William J. Baumol, of *Toward an Evolutionary Regime for Spectrum Governance: Licensed or Unrestricted Entry* (Brookings Press, 2006).

About the Communications and Society Program

www.aspeninstitute.org/c&s

The Communications and Society Program is an active venue for framing policies and developing recommendations in the information and communications fields. We provide a multidisciplinary space where veteran and emerging decision-makers can develop new approaches and suggestions for communications policy. The Program enables global leaders and experts to explore new concepts, exchange insights, develop meaningful networks, and find personal growth, all for the betterment of society.

The Program's projects range across many areas of information, communications, and media policy. Our activities focus on issues of open and innovative governance, public diplomacy, institutional innovation, broadband and spectrum management, as well as the future of content, issues of race and diversity, and the free flow of digital goods, services, and ideas across borders.

Most conferences employ the signature Aspen Institute seminar format: approximately 25 leaders from diverse disciplines and perspectives engaged in a moderated roundtable dialogue, with the goal of driving the agenda to specific conclusions and recommendations. The program distributes our conference reports and other materials to key policymakers, opinion leaders, and the public in the United States and around the world. We also use the Internet and social media to inform and ignite broader conversations that foster greater participation in the democratic process.

The Program's Executive Director is Charles M. Firestone. He has served in this capacity since 1989 and also as Executive Vice President of the Aspen Institute. Prior to joining the Aspen Institute, Mr. Firestone was a communications attorney and law professor who has argued cases before the United States Supreme Court. He is a former director of the UCLA Communications Law Program, first president of the Los Angeles Board of Telecommunications Commissioners, and an appellate attorney for the U.S. Federal Communications Commission.

Select Publications from the Aspen Institute Communications Policy Project

The Atomic Age of Data: Policies for the Internet of Things, by Ellen P. Goodman

The Twenty-Ninth Annual Aspen Institute Conference on Communications Policy, titled "Developing Policies for the Internet of Things," took place August 13-16, 2014 in Aspen, CO. As the world becomes increasingly connected and more objects become embedded with sensors, the Internet of Things is poised to explode, with estimates of 25 billion connected devices by 2020. 35 knowledgeable participants gathered to examine how specifically should communications policies accommodate the new Internet of Everything? This report explores the nascent promises and challenges of the IoT. In examining the interplay between the vast increase in data created on the Internet of Things (IoT), and the resultant strain on the networks that carry this information, and the group came to a realization. Data needs to be thought of as "infrastructure." 2015, 72 pages, ISBN Paper: 0-89843-623-0, $12.00

Video Veritas: Building a 21st Century Video Platform for a High-Performance Society, by John B. Horrigan

The Twenty-Eighth Annual Aspen Institute Conference on Communications Policy focused on the future of video regulation. The resulting report, written by John B. Horrigan, looks at the changing landscape of video regulation and the fundamental shift in how video is being viewed. While cable and broadcast television continue to be the dominant modes of transmission, over the top delivery of content via the Internet provides new ways to distribute personalized and targeted programming directly to the viewer. This, and the proliferation of mobile devices and tablets can deliver video to the viewer anywhere, anytime. As a result, the advertising-based broadcast business model is undergoing significant challenge and change. This report examines the evolving video ecosystem and offers recommendations for policy that can accommodate the new video market. 2014, 54 pages, ISBN Paper: 0-89843-603-6, $12.00

Spectrum as a Resource for Enabling Innovation Policy, by William Webb

The 2012 Aspen Institute Roundtable on Spectrum Policy (AIRS) convened shortly after the presidential election to consider ways that spectrum policy could improve the economy through innovation. The 32 leading communications policy experts in attendance focused on how spectrum policies could help create an environment that makes it easier to use spectrum as a resource for innovative new goods and services. The participants first identified problems facing new entry and innovation today, and then recommended solutions, looking specifically at the interstices among licensed and unlicensed approaches, spectrum sharing and flexibility, and new institutional arrangements to manage these solutions. The report, written by British spectrum expert William Webb, sets forth 11 recommendations that he gleaned from the conference dialogue to guide future spectrum policy development with regard to facilitating innovation. 2013, 45 pages, ISBN Paper: 0-89843-584-6, $12.00

Rethinking Communications Regulation, by Richard Adler

As the Internet and other information and communications technologies grow exponentially, and as a new ecosystem is emerging that could conflate previously distinct methods of communication into a single digital medium, questions arise as to whether the traditional silos of regulation are still appropriate. The report resulting from the 27th Annual Aspen Institute Communications Policy Conference addresses the overarching concern as to whether the Communications Act needs a radical revision. Written by rapporteur Richard Adler, the report considers the key goals of a new communications regime and offers regulatory and non-regulatory approaches for achieving these goals in a digitally connected world. 2013, 65 pages, ISBN Paper: 0-89843-583-8, $12.00

The Reallocation Imperative: A New Vision for Spectrum Policy, by Preston Marshall

The report resulting from the 2011 Aspen Institute Roundtable on Spectrum Policy addresses new ways of allocating, clearing, using and/or sharing spectrum controlled by private parties and government agencies. Written by rapporteur Preston Marshall, the report attempts to step back and establish a broad vision for reallocating spectrum in the United States in the public interest, discussing new approaches that will

facilitate more effective and efficient spectrum use. A number of recommendations are laid forth to guide future spectrum policy development, Congressional actions, and technology explorations. 2012, 54 pages, ISBN Paper: 0-89843-570-6, $12.00

Updating Rules of the Digital Road: Privacy, Security, Intellectual Property, by Richard Adler

Given the current growth and importance of the Internet, the report of the 2011 Aspen Institute Conference on Communications Policy titled *Updating Rules of the Digital Road: Privacy, Security, Intellectual Property*, highlights the elements that will allow for greater use of broadband as the common medium: security, privacy and intellectual property regulation. Written by rapporteur Richard Adler, the report explores a range of threats that plague the use of today's communications media and provides a series of recommendations which aim to ensure that users' communications are secure, private and protected.

The report reflects the issues and ideas raised by business leaders, academics, and policy experts at the Twenty-Sixth Annual Aspen Institute Conference on Communications Policy. 2012, 70 pages, ISBN Paper: 0-89843-563-3, $12.00

Spectrum for the Next Generation of Wireless, by Mark MacCarthy

Spectrum for the Next Generation of Wireless explores possible sources of spectrum, looking specifically at incentives or other measures to assure that spectrum finds its highest and best use. It includes a number of recommendations, both private and federal, of where and how spectrum can be repurposed for wireless use. In November 2010, the Aspen Institute Communications and Society Program convened the Aspen Institute Roundtable on Spectrum Policy, where 31 experts and leaders addressed the consequences and solutions to the increasing demand for spectrum. Spectrum for the Next Generation of Wireless is the report resulting from the Roundtable discussions. 2011, 68 pages, ISBN Paper: 0-89843-551-X, $12.00

Rewriting Broadband Regulation, by David Bollier

The report of the 25th Annual Aspen Institute Conference on Communications Policy in Aspen, Colorado, considers how the United States should reform its broadband regulatory system. Participants looked at international models and examples and examined how data

and communications should be protected in the international arena. The resulting report explores a range of policies for U.S. broadband regulation, many of them derivative of the National Broadband Plan adopted by the Federal Communications Commission only a few months before the conference.

Participants also ventured into new and interesting territory with the novel concept of "digital embassies." They saw this as a way of dealing with jurisdictional issues associated with the treatment and protection of data in the cloud, i.e., data that is provided in one country but stored or manipulated in another. The concept is that the data would be treated throughout as if it were in a kind of virtual embassy, where the citizenship of the data (i.e., legal treatment) goes along with the data. This policy seed has since been cultivated in various other regulatory environments. 2011, 37 Pages, ISBN Paper: 0-89843-548-X, $12.00

Scenarios for a National Broadband Policy, by David Bollier

The report of the 24th Annual Aspen Institute Conference on Communications Policy in Aspen, Colorado, captures the scenario building process that participants used to map four imaginary scenarios of how the economy and society might evolve in the future, and the implications for broadband policy. It identifies how certain trends—economic, political, cultural, and technological—might require specific types of government policy intervention or action. 2010, 52 pages, ISBN Paper: 0-89843-517-X, $12.00

Rethinking Spectrum Policy: A Fiber Intensive Wireless Architecture, by Mark MacCarthy

Rethinking Spectrum Policy: A Fiber Intensive Wireless Architecture is the report resulting from the Aspen Institute Roundtable on Spectrum Policy, held at the Aspen Wye River Conference Center in November 2009. Written by rapporteur Mark MacCarthy, the report captures the insights of the participants, exploring innovative ways to respond to the projections of exponential growth in the demand for wireless services and additional spectrum. In addition to discussing spectrum reallocations, improved receivers, shared use and secondary markets as important components for meeting demand, the report also examines opportunities for changes in network architecture, such as shifting the mix between fiber and wireless. 2010, 58 pages, ISBN Paper: 0-89843-520-X, $12.00

ICT: The 21st Century Transitional Initiative, by Simon Wilkie

The report of the 23rd Annual Aspen Institute Conference on Communications Policy in Aspen, Colorado addresses how the United States can leverage information and communications technologies (ICT) to help stimulate the economy and establish long-term economic growth. The report, written by Roundtable rapporteur Simon Wilkie, details the Aspen Plan, as developed in the summer of 2008, prior to the economic meltdown beginning in September 2008 and prior to the election of Barack Obama as President. The Plan recommends how the Federal Government—through executive leadership, government services and investment—can leverage ICTs to serve the double bottom line of stimulating the economy and serving crucial social needs such as energy efficiency and environmental stewardship. 2009, 80 pages, ISBN Paper: 0-89843-500-5, $12.00

A Framework for a National Broadband Policy, by Philip J. Weiser

While the importance of broadband access to functioning modern society is now clear, millions of Americans remain unconnected, and Washington has not yet presented any clear plan for fixing the problem.

Condensing discussions from the 2008 Conference on Communications Policy and Aspen Institute Roundtable on Spectrum Policy (AIRS) into a single report, Professor Philip Weiser of the University of Colorado at Boulder offers a series of specific and concrete policy recommendations for expanding access, affordability, and adoption of broadband in the United States. 2008, 94 pages, ISBN Paper: 0-89843-484-X, $12.00

The Future of Video: New Approaches to Communications Regulation, by Philip J. Weiser

As the converged worlds of telecommunications and information are changing the way most Americans receive and relate to video entertainment and information, the regulatory regimes governing their delivery have not changed in tune with the times. These changes raise several crucial questions: Is there a comprehensive way to consider the next generation of video delivery? What needs to change to bring about a regulatory regime appropriate to the new world of video? The report of the 21st Annual Conference on Communications Policy in Aspen, Colorado, outlines a series of important issues related to the emergence of a new video marketplace based on the promise of Internet technology and offers recommendations for guiding it into the years ahead. 2006, 70 pages, ISBN Paper: 0-89843-458-0, $12.00

Clearing the Air: Convergence and the Safety Enterprise, by Philip J. Weiser

The report describes the communications problems facing the safety enterprise community and their potential solutions. The report offers several steps toward a solution, focusing on integrating communications across the safety sector on an Internet-Protocol-based backbone network, which could include existing radio systems and thus make systems more dependable during emergencies and reduce costs by taking advantage of economies of scale. The conference participants stressed that the greatest barriers to these advances were not due to lagging technology but to cultural reluctance in adopting recent advances. Writes Weiser, "The public safety community should migrate away from its traditional reliance on specialized equipment and embrace an integrated broadband infrastructure that will leverage technological innovations routinely being used in commercial sectors and the military." 2006, 55 pages, ISBN Paper: 0-89843-4, $12.00

Reforming Telecommunications Regulation, by Robert M. Entman

The report of the 19th Annual Aspen Institute Conference on Telecommunications Policy describes how the telecommunications regulatory regime in the United States will need to change as a result of technological advances and competition among broadband digital subscriber lines (DSL), cable modems, and other players, such as wireless broadband providers. The report proposes major revisions of the Communications Act and FCC regulations and suggests an interim transitional scheme toward ultimate deregulation of basic telecommunications, revising the current method for universal service subsidies, and changing the way regulators look at rural communications. 2005, 47 pages, ISBN Paper: 0-89843-428-9, $12.00

Reports can be ordered online at *www.aspeninstitute.org/publications* or by sending an email request to *publications@aspeninstitute.org.*