Summary of a Forum on Spectrum Management Policy Reform

Committee on Wireless Technology Prospects and Policy Options, National Research Council

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Computer Science and Telecommunications Board

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Preface

Pursuant to a May 29, 2003, executive memorandum, which established a Federal Government Spectrum Task Force and an associated public outreach program, the National Telecommunications and Information Administration convened a series of public forums to bring together a variety of stakeholders to present their views on spectrum management policy. The Computer Science and Telecommunications Board (CSTB) of the National Research Council was asked to convene one of these forums.

CSTB organized a public forum on February 12-13, 2004, at which a variety of government and private sector stakeholders were asked to present their views on spectrum policy (the agenda appears in Appendix A). The forum was organized and this summary report was prepared under the auspices of CSTB's Committee on Wireless Technology Prospects and Policy Options, which is currently also carrying out a comprehensive assessment of wireless technology and application trends and their implications for spectrum management and policy.

Speakers at the forum were given roughly 10 minutes to provide their views on issues identified in the executive memorandum (Box P-1). A brief period was provided at the end of each session for discussion among panelists and for questions from the organizing committee and attendees. Many speakers prepared slides for use in their presentations; copies of most are available from CSTB's Web site, <www.cstb.org>.

This report provides the committee's summary of a number of the remarks made by panelists. Although the summary was prepared by the National Academies based on presentations and discussion at the forum, the comments do not necessarily reflect the view of the committee, nor are they findings or recommendations of the National Academies. The committee's broader consideration of spectrum policy and its findings and recommendations will appear in its final report, to be released in early 2005.

The committee would like to thank all the participants in the forum for their thoughtful presentations. It would also like to thank the National Telecommunications and Information Administration (NTIA) for sponsoring the event, and it extends special thanks to Norbert Schroeder at NTIA for all his help in making the forum possible.

David E. Liddle, *Chair*
Committee on Wireless Technology
Prospects and Policy Options

BOX P-1 Mission and Goals of the Department of Commerce's Spectrum Policy Initiative

Sec. 2. Mission and Goals. The Initiative shall undertake a comprehensive review of spectrum management policies (including any relevant recommendations and findings of the study conducted pursuant to section 214 of the E-Government Act of 2002) with the objective of identifying recommendations for revising policies and procedures to promote more efficient and beneficial use of spectrum without harmful interference to critical incumbent users. The Department of Commerce shall prepare legislative and other recommendations to:

(a) facilitate a modernized and improved spectrum management system;

(b) facilitate policy changes to create incentives for more efficient and beneficial use of spectrum and to provide a higher degree of predictability and certainty in the spectrum management process as it applies to incumbent users;

(c) develop policy tools to streamline the deployment of new and expanded services and technologies, while preserving national security, homeland security, and public safety and encouraging scientific research; and

(d) develop means to address the critical spectrum needs of national security, homeland security, public safety, the federal transportation infrastructure, and science.

SOURCE: Executive Office of the President (EOP), 2003, *Executive Memorandum: Spectrum Policy for the 21st Century*, Washington, D.C., May 29, available online at <http://spectrumreform.ntia.doc.gov/execmemo.htm>.

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Gerald R. Faulhaber, University of Pennsylvania,
Kevin C. Kahn, Intel Corporation,
Dipankar Raychaudhuri, Rutgers University, and
Steven S. Wildman, Michigan State University.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by James J. Mikulski, Motorola (retired). Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

1

Summary of Remarks Made by Forum Panelists

FEDERAL SPECTRUM USERS: DEFENSE, JUSTICE, TRANSPORTATION, AND AVIATION

In Session 1A, panelists from several federal agencies[1] discussed spectrum management from the perspective of the defense, homeland security, justice, transportation, and aviation missions. Speakers made a number of points emphasizing the special nature of federal spectrum use, noting that

- Many federal spectrum applications—such as defense, safety-of-life operations for commercial aviation, and law enforcement and other public safety uses—require very high reliability and interoperability.
- Some federal uses of spectrum are tied to nongovernmental users, which complicates efforts to modernize wireless systems. For example, the Federal Aviation Administration (FAA) cannot easily change some of its services because the costs of new equipment would fall on airlines and pilots.
- Technology changes must often be carefully coordinated to address interdependencies among systems and to align spectrum use with both U.S. and international spectrum allocations.
- New demands for spectrum continue to emerge in the federal government. For example, the Intelligent Vehicle Initiative, which is headed by the National Highway Traffic Safety Administration and the Federal Highway Administration and carried out in partnership with the automobile industry, aims to create a wireless alert system to warn drivers of changing road conditions. Implementation of this and other new transportation systems will depend, in part, on the availability of spectrum.

Regarding the efficiency of federal spectrum use, the panelists noted the following:

- Federal spectrum allocation and assignment processes provide greater flexibility than does the process of allocating and assigning nonfederal spectrum, which tends to be more service- and use-specific. This gives federal users greater freedom, for example, to exploit technological innovation and thus the potential for more efficient use.

[1] Badri Younes, Department of Defense; David G. Boyd, Department of Homeland Security; Merri Jo Gamble, Department of Justice; Tyler Duvall, Department of Transportation; and Donald Willis, Federal Aviation Administration. Biographies for panelists are provided in Appendix C.

- Sharing of spectrum among federal users occurs today. For example, the FAA and Department of Defense (DOD) share spectrum, as the FAA coordinates and authorizes DOD electronic attack exercises and global positioning jamming activities.
- The Integrated Wireless Network Initiative under development by the Departments of Justice, Treasury, and Homeland Security is a good example of a program that seeks to provide interoperability and improve spectral efficiency by building a national land-based, mobile, encrypted radio network to serve the diverse needs of multiple agencies.
- Spectrum sharing is central to the next generation of global positioning systems, for which frequency allocations will support both public- and private-sector use.

Comments by panelists regarding possible changes in spectrum management policy included these:

- Changes to spectrum management policy should balance potential economic benefits against current and future needs of federal users. Potential commercial benefits should be weighed against the operational requirements for protecting health and safety. A panelist also argued that imposing spectrum fees on federal spectrum use would probably not be a useful mechanism for increasing efficiency. It would, for example, be difficult to determine the value of spectrum required for safety-of-life missions.
- A national strategic plan should be created to collectively identify how the federal government could make use of spectrum as efficiently as possible given its operational needs. Based on input from individual agencies, the plan should identify the mission requirements driving spectrum needs and identify new technology under consideration by the agencies. The list of priorities based on federal uses, along with other public and commercial needs, should serve as a basis for spectrum allocation decisions.
- Automation of federal spectrum administrative processes, which would permit spectrum use to be monitored and analyzed in real time, would make spectrum management easier and permit spectrum to be used more effectively and efficiently.
- An integrated testbed should be developed to run trials of new technologies. This would make it easier for government agencies to explore and adopt new technologies and determine future possibilities for spectrum sharing.

FEDERAL SPECTRUM USERS: SCIENTIFIC USES

In Session 1B, panelists from the National Aeronautics and Space Administration (NASA), the National Oceanographic and Atmospheric Administration (NOAA), and the University of California at Berkeley[2] discussed the characteristics of several scientific uses of federal spectrum and implications for spectrum policy. Outlining the characteristics of several scientific uses, the panelists observed that

- Services supporting basic research, science missions to outer space, and weather forecasting require high reliability. Both passive measurements and communications with spacecraft depend on the detection of very weak signals and are highly susceptible to interference.

[2] Scott Pace, National Aeronautics and Space Administration; Richard Barth, National Oceanic and Atmospheric Administration; Karen St. Germain, National Oceanic and Atmospheric Administration; and Don Backer, University of California at Berkeley.

- Radio astronomy and the Earth Exploration Satellite Service (EESS) are both passive spectrum users. Because they are passive observers, they depend on the reception of very weak signals. Each also has to operate in particular spectral bands dictated by physics—emission and absorption in the atmosphere in the case of EESS and emissions of elements, molecules, and stellar objects in the case of radio astronomy.
- EESS data are important for weather forecasting, the development of meteorological and climate models, and other scientific research. EESS measures changes in the natural thermal background and is thus very sensitive to interference. Observations are made globally by a constellation of satellites, which means that spectrum has to be protected worldwide. Because the signals of interest are very weak, the entire allocated bandwidth is used to squeeze out the best possible signal-to-noise ratio.
- Radio astronomy data have been critical to improving our understanding of the universe. The level of tolerable interference for radio astronomy, which measures naturally occurring radiation from outer space, is roughly 10 orders of magnitude below that of remote-sensing systems. Operation depends on dedicated spectrum allocations and geographic protection in the form of radio quiet zones and coordinated operation zones in the vicinity of observatories.
- Satellite-based sensors look down at Earth and thus look at potential interferers, as opposed to radio telescopes, which can look away from interferers.
- Passive uses raise particular concerns about proposals made in the Federal Communications Commission's (FCC's) Spectrum Policy Task Force report.[3] First, remote-sensing systems depend on detecting signals significantly weaker than the existing noise floor level tolerated by commercial systems, raising questions about how one would establish permissible interference levels in remote-sensing bands. Second, passive users cannot be detected for the purpose of dynamically controlling access to unused spectrum.

Speakers noted several efforts to make more efficient use of spectrum:

- New generations of satellite systems launched by NOAA and NASA have increased their bandwidth efficiency. These improvements have been necessary because ongoing improvements to space sensing equipment have increased the volume of data that must be transferred from the satellites to ground stations.
- The consolidation of separate polar weather satellite programs operated by NOAA and DOD into a single system called the National Polar-orbiting Operational Environmental Satellite System (NPOESS) will improve the spectral efficiency of communications with the satellites in the system.

Panelists offered a number of comments about future spectrum policy, including

- Making frequency assignments based on good-neighbor policies that aim to place compatible technologies in adjacent bands of spectrum would be a useful approach.
- The impact on current and future scientific spectrum uses of the cumulative noise floor level increases that may result from policy changes should be considered.
- Different burdens of proof with respect to safety are, appropriately, applied to safety-critical services like communication with spacecraft and to normal commercial services. These differing standards represent an obstacle to shared operation between these services.

[3] Federal Communications Commission (FCC). 2002. *Spectrum Policy Task Force Report,* ET Docket No. 02- 135. FCC, Washington, D.C., November. Available online at <http://www.fcc.gov/sptf/reports.html>.

STATE AND LOCAL GOVERNMENT USERS

In Session 2, public safety professionals and state and local officials[4] discussed public safety communication needs as they relate to current and emerging technologies and spectrum availability. Comments made by panelists include the following:

- The operational needs of public safety (i.e., protection of life and property) cannot be fully served by today's commercial systems. One reason is coverage. Public safety communications requires ubiquitous coverage in rural and wilderness areas that are not well-covered by commercial services. In urban areas, commercial systems do not always reach into subway systems or interiors of buildings despite the density of base stations. Another reason is that public safety communications must be able to handle high-volume surges when and where an emergency occurs, which implies system overprovisioning. Finally, public safety systems must robustly support one-to-many as well as one-to-one communications.
- Emerging technologies, such as microsensor arrays, mobile robots, radio frequency identification systems, and augmented reality technology to overlay visual and audio data onto real-world views for first responders, represent significant opportunities for public safety. Realizing this potential would require the building of new communications networks, would lead to significantly greater demand for public safety spectrum, and would heighten tensions between public safety and commercial uses.
- Interoperability is a major technical and organizational issue. At a technical level it requires coordination and sharing of information about frequency allocations and technology standards. At an organizational level, it requires coordination between local first responders, local elected officials, and state and federal leaders. Current interoperability guidelines produced by the Department of Homeland Security's SAFECOM program and the National Telecommunications and Information Administration (NTIA) have been important steps.
- Local government budgets, which provide most of the funding for public safety communications, are coming under increased pressure. Eighty-three percent of cities are less able to fund operations today than one year ago, according to a survey by the National League of Cities.
- Understanding the nature and limitation of current public safety systems is the biggest challenge facing local elected officials seeking to develop a plan and strategy to mitigate problems.
- Local elected officials have limited time and technical resources to engage in or stay abreast of the numerous activities at the federal level examining public safety issues. However, it is important for local elected officials as well as public safety officials to be involved in these activities.
- Public safety radios are expensive compared with commercial handsets—they cost about $3,000—reflecting their specialized nature and the comparatively small market. If the costs of these radios are to be significantly reduced, greater economies of scale will be necessary.
- Current attempts to provide enhanced services include establishment of a statewide network in New York and a partnership in Washington, D.C., with Motorola and Flarion Technologies that aims to build a broadband data network.
- Using dedicated infrastructure rather than commercial services for public safety services is costly and is one reason that public safety technology lags the state of the art. Yet

[4] Glen Nash, State of California Department of General Services; Capt. Thomas Cowper, New York State Wireless Project; Marilyn Praisner, Montgomery County (Md.) Council; Nancy Jesuale, NetCity Engineering; Robert LeGrande, Office of the Chief Technology Officer, District of Columbia; and Thera Bradshaw, City of Los Angeles.

today's commercial systems have not been designed to meet public safety requirements. One possible remedy is to move to nondedicated spectrum—and possibly nondedicated infrastructure—while providing public safety users with priority access. Implementation would require the incorporation of public safety requirements into the design of new systems and the development of technologies supporting robust authentication of public safety users and priority access to shared networks. Generally, more research is needed on future directions for public safety communications.

- Wide-area mobile data applications will require more spectrum than planned new allocations—4.9 GHz for broadband hotspot and fixed communication and 24 MHz in the 700 MHz band, which may or may not become available in 2006. Use of the 4.9 GHz band is complicated by FCC rules that currently prohibit use of the 802.11j technology currently being developed for use in the Japanese market. The Spectrum Coalition for Public Safety advocates the allocation of an additional 10 MHz in the upper 700 MHz band.

FEDERAL SPECTRUM MANAGEMENT AUTHORITIES

In Session 3, panelists discussed current developments in spectrum policy.[5] Panelists noted that several spectrum reform initiatives were under way:

- Considerable progress has been made recently in several areas. For example, new allocations have been made for ultrawideband, 5 GHz unlicensed, and 70 GHz, 80 GHz, and 90 GHz services, and new allocations are under consideration for third-generation (3G) wireless services. Since the implementation of spectrum auctions, more than 25,000 licenses have been made available and more than $14 billion in revenue has been received by the U.S. Treasury. More flexible services rules and rules encouraging private spectrum transactions have provided additional opportunities and incentives for efficient use.
- The administration's spectrum policy initiative, as outlined in the executive memorandum, will recommend improvements to spectrum management policies and procedures. One particularly useful outcome anticipated from the presidential initiative would be a concise summary of what spectrum users, regulators, and Congress should be doing to improve spectrum policy over the next 5 to 10 years.
- Areas under current FCC consideration include cognitive radios,[6] receiver standards,[7] interference temperature,[8] standards for broadband over power lines,[9] and the identification of

[5] Michael Gallagher, National Telecommunications and Information Administration, Department of Commerce; John Muleta, Wireless Telecommunications Branch, Federal Communications Commission; Julius Knapp, Office of Engineering and Technology, Federal Communications Commission; Andrea Petro, Office of Management and Budget; and David Siddall, Paul, Hastings, Janofsky & Walker LLP.

[6] Federal Communications Commission. 2003. Notice of Proposed Rule-Making and Order. Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies; Authorization and Use of Software Defined Radios. ET Docket No. 03-108, ET Docket No. 00-47 (terminated), FCC 03-322 (rel. December 30). Available online at <http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-03-322A1.pdf>.

[7] Federal Communications Commission. 2003. Notice of Inquiry. Interference Immunity Performance Specifications for Radio Receivers, Review of the Commission's Rules and Policies Affecting the Conversion to Digital Television. ET Docket No. 03-65, MM Docket No. 00-39, FCC 03-54 (rel. March 24). Available online at <http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-03-54A6.pdf >.

[8] Federal Communications Commission. 2003. Notice of Inquiry and Notice of Proposed Rulemaking. Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands.

additional spectrum for advanced wireless services. More spectrum for unlicensed use is being explored in the TV broadcast bands, in bands below 900 MHz, and for the 50-MHz reallocation from federal government use to a mixed-use basis at 3.65 to 3.7 GHz. NTIA is also developing recommendations for the mixed-use band.

- Current legislative proposals include the following: (1) establishing a spectrum reallocation fund that would reimburse federal users that give up spectrum as a way of increasing overall spectral efficiency and encouraging more effective allocation among public and private sector users; (2) authorizing the FCC to charge fees on unauctioned spectrum licenses; and (3) extending the FCC's auction authority, due to expire in 2007.

Panelists also raised a number of questions to be explored further in spectrum management reform initiatives, including these:

- How many of the 90,000 frequency assignments require thorough review, and which areas deserve the highest focus?
- What resources are the agencies that have equity in the spectrum applying to achieve the goals of their mission for a sound spectrum policy?
- Are federal agencies applying sufficient leadership and resources (including information technology) to address oft-cited spectrum challenges? Are the resources comparable to those in the private sector and commensurate with the increasing attention being given to spectrum issues?
- Alternatives to the current public safety business model, which is based on exclusive use of spectrum and self-provisioning, should be considered. Issues to explore include (1) how to separate network access from the provisioning and management of the network, (2) how to increase choice among equipment vendors, and (3) how priority access can be used to provide public safety communications with commercial systems and infrastructure.
- What enables the FCC and NTIA to work well together? What is the value of meeting together on a monthly basis?
- How is interference testing done today? What are its motives, methods, and costs? Would a centralized testing process and facility be useful?
- How does one tell if engineering principles—e.g., interference, harmful interference, signal-to-noise-ratio, noise floor—are being invoked legitimately—or not?
- To what extent can economic incentives replace traditional spectrum planning? To what extent will competition and consumer pressure provide incentives for industry to address interference problems? How much of an incentive does purchasing spectrum rights provide companies to invest in more efficient technologies rather than seeking new allocations?

FREQUENCY MANAGERS AND AMATEUR RADIO

In Session 4, panelists from the Association of Public-Safety Officials, Comsearch, the United Telecom Council, and the American Radio Relay League[10] discussed issues relating to

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ET Docket No. 03-237, FCC 03-289 (rel. November 28). Available online at <http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-03-289A1.pdf>.

[9] Federal Communications Commission. 2004. Notice of Proposed Rule Making. Carrier Current Systems, Including Broadband Over Power Line Systems, Amendment of Part 15 Regarding New Requirements and Measurement Guidelines for Access Broadband. ET Docket No. 03-104, ET Docket No. 04-37, FCC 04-29 (rel. February 23). Available online at <http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-04-29A1.pdf>.

[10] Robert Gurss, Association of Public-Safety Officials; Kenneth Ryan, Comsearch; William Moroney, UTC; and Paul Rinaldo, American Radio Relay League.

frequency management and coordination for public safety, utilities and other critical infrastructure, commercial applications, and amateur radio.

Panelists made several observations about requirements for public safety and critical infrastructure uses of spectrum:

- Voice and data services for the control, operation, and maintenance of utility and other critical infrastructure companies require a very high level of reliability, which has been provided by dedicated networks and radio systems.
- In life-safety applications, efficiency should not be based simply on a measure of users per channel, but rather on how spectrum can best be used to support these missions.

With regard to providing broadband services over power lines, panelists offered contrasting views:

- The utility industry is encouraged about the potential of the technology to offer broadband over power lines and provide an additional true facilities-based competitor in broadband services. The industry is actively examining the interference issues that may result from the service offering, and it is working with groups that could be affected by interference problems.
- Amateur radio operators are concerned about emissions from broadband over power lines. The interference concern is heightened because overhead power lines, many in close proximity to amateur receivers, would act as transmitters. These segments would be resonant at different frequencies depending on their length (e.g., reflecting pole spacing) and thus cannot be planned for or filtered out properly. Because of the high potential for interference, discussions at the FCC have focused on establishing a power limit that would accommodate both uses.

Panelists also offered several suggestions for improving spectrum management policies:

- Amateur radio operators have long made successful use of dynamic frequency assignment by applying a listen-before-transmit rule and asking if a given channel is occupied before transmitting.
- Software tools used by commercial frequency coordination and management organizations, such as geographical information systems and databases, and the best practices of those organizations could be useful in improving the efficiency and effectiveness of federal spectrum management.
- Spectrum policy should provide flexibility to enable interoperability and spectrum sharing between public safety and critical infrastructure users. There is also interest in exploring the deployment of joint radio systems.
- Access to government databases containing nonrestricted data for frequency assignments could improve the identification of relevant licensees and users and the coordination of licenses for commercial services, especially those that are deployed in bands shared with the government.
- Shared databases and common tools could also eventually allow for real-time registration and coordination of commercial services, permitting same-day frequency clearance, deployment, and operation.

CONSUMER ADVOCACY ORGANIZATIONS

In Session 5, panelists from the Consumer Federation of America and the Media Access Project[11] discussed several issues of concern to consumer advocacy organizations with regard to spectrum policy and associated issues of media access. The comments provided by the speakers included these:

- Radio spectrum is a public resource that should be used to promote the widest possible dissemination of information from diverse and even antagonistic sources. Broadcast licensees are supposed to serve the public interest.
- As illustrated by the successful campaign to block low-power FM broadcasting, incumbents tend to act to exclude competing or potentially disruptive technologies and services.
- A balance should be sought between unlicensed spectrum; exclusive licenses by service, such as the family radio service that can only be used for voice services; and other exclusive licensing to ensure that each broadcaster serves the public interest in its own broadcast area..
- The view of spectrum licenses as property rights goes beyond the original premise behind licensing. The granting of exclusive licenses to provide a service to the public reflected the view at the time that this was the only way to make broadcasting economically viable.
- The adoption of secondary markets in spectrum is not likely to increase the number of media voices, as large media firms will be able to outspend new competitors and prevent them from developing competitive services.

CELLULAR CARRIERS

In session 6A, panelists from two national cellular carriers, Cingular Wireless and Verizon Wireless, and an industry association, the Cellular Telecommunications & Internet Association (CTIA),[12] discussed the impact of spectrum policy on cellular voice and data services. Observations made by panelists included these:

- Innovation and investment by cellular carriers have resulted in substantial growth and increased spectral efficiency. Substantial investments in upgraded infrastructure and increased capacity have been necessary to meet subscriber demand within existing spectrum allocations. For example, the number of subscribers has grown by a factor of 12 over the past decade (from 12 million subscribers to over 150 million subscribers), the number of minutes used per subscriber has grown fourfold, and the speed of commercially available data services has increased roughly 100-fold (from 4.8 kbps to over 500 kbps). Only a fourfold increase in spectrum, from 50 MHz to roughly 190 MHz, has been required to achieve these increases (this does not include spectrum to be assigned for 3G services).
- Adding other users to cellular bands would be costly, create potential risks, and not yield customer benefits in the form of new applications or services. It is appropriate to consider ways of exploiting so-called white space, but this is not appropriate for bands where long-term stability is required for investment and innovation to continue. New concepts introduced by the

[11] Harold Feld, Media Access Project, and Mark Cooper, Consumer Federation of America.

[12] Jim Bugel, Cingular Wireless; Jim Smoak, Verizon Wireless; and Diane Cornell, Cellular Telecommunications & Internet Association.

FCC's Spectrum Policy Task Force, such as spectrum sharing, will require careful economic and technological analysis to understand the short- and long-term effects of such changes.

- A mix of licensed and unlicensed spectrum uses is appropriate, and cellular carriers are making use of both today. Exclusive use over a spectrum band for licensed services provides carriers with incentives to invest in infrastructure and to innovate, and it provides carriers with needed protection from interference.
- Both government and commercial spectrum use should be subject to a cost-benefit analysis that includes technical and economic aspects and opportunity costs.
- A useful approach to spectrum management reform would be the establishment of an independent commission of spectrum experts to review spectrum allocations, analogous to the reviews of military facilities conducted under the Base Realignment and Closure Act.
- A longer term for the U.S. ambassador to the World Radiocommunication Conference would allow more attention to be devoted to international harmonization of spectrum allocations. Although technological advances have made it possible to build handsets that can use multiple bands, spectrum allocation differences from country to country add costs and ultimately increase consumer prices.
- Panelists saw opportunities with respect to public safety spectrum use, both to improve the spectral efficiency of these services and to establish new mechanisms for sharing or trading public safety spectrum in exchange for priority access to commercial services.

BROADCASTING SERVICES

In Session 6B, panelists from a broadcast industry association, a broadcaster , and a satellite service provider[13] discussed spectrum policy on terrestrial broadcasting and associated satellite services.

The panelists made the following observations:

- There are long-standing broadcast spectrum sharing arrangements between television broadcasters and other users such as public safety and radio astronomy.
- Investments in digital transmitters by broadcasters are improving spectral efficiency by doubling the number of digital television (DTV) stations in the same amount of spectrum.
- Progress is being made on the transmission side, with digital broadcasting operational at 1,155 digital television stations in 203 television markets, containing 99.4 percent of U.S. television households. In the receiver side, however, digital television penetration is well below 10 percent of households.
- Digital transmission for the broadcasters is expected to generate additional revenue from such services as high-definition television, multicasting, and data transmission and other value-added services.
- Digital repacking efforts aim to move all DTV stations to channels 2 to 51, returning 108 MHz of spectrum to the government. However, repacking has proved challenging in urban areas and is complicated by the existence of low-power television stations and the congressional desire for 175 additional DTV licenses.
- Changing the licensing structure by geographic area and increasing co-location, which would permit greater use of adjacent channels, would promote further efficiency in the broadcast spectrum and would create economic incentives for completing the transition to DTV.
- Although an estimated 85 percent of U.S. households receive a television signal from cable or satellite antennas, roughly 80 million television sets, or one-third of all television sets in

[13] David Donovan, MSTV; Greg Schmidt, LinTV; and Kalpak S. Gude, PanAmSat.

the United States (e.g., second sets in a kitchen or bedroom) receive only over-the-air terrestrial television. The cable and satellite industries also rely on over-the-air television programming that is rebroadcast over those systems.

- Underlay or unlicensed operation in broadcast spectrum should be delayed or prohibited because (1) use of broadcast spectrum will undergo numerous changes as DTV stations are repositioned during digital transition; (2) it will take time to characterize the propagation of new DTV transmissions; (3) receivers, which are provided by the consumer electronic industry and thus have performance characteristics not under the control of broadcasters, are subject to interference from unlicensed devices; (4) no feedback mechanism exists to advise of digital signal degradation; and (5) adding other users to broadcast bands would undesirably constrain the future evolution of television transmission systems.
- Capacity increases being realized by the transition to digital technology for satellite transmissions, permitting six regular digital channels or two HDTV channels as compared with one analog channel per 36 MHz transponder, should not be used to justify the return of spectrum. Instead, such increases should be viewed as providing an opportunity to offer more channels and services, which in turn provides an economic incentive for the investment in the analog-to-digital migration.
- Spectrum policies based on definitions of spectral efficiency that emphasize increasing the number of spectrum users will harm the internal efficiency efforts of existing spectrum users.
- The higher-order modulation schemes that have been employed in satellite communications increase both data rates and spectral efficiency but are more susceptible to interference. Additionally, the smaller earth station antennas currently used by residential users also render satellite links more susceptible to interference than were earlier generations of antennas.

COMMERCIAL AND GOVERNMENT SERVICES AND APPLICATIONS

In Session 6C, panelists from General Dynamics Decision Systems, Boeing, Lockheed Martin, and Iridium[14] discussed commercial and government services and applications. Panelists offered a number of observations about the evolution of wireless technology:

- Even as new technologies and spectrum management policies come into being, legacy devices and associated management policies will still have to be accommodated for some time.
- New adaptive, smart radio technologies—software-defined radios, smart antennas, and intelligent signal processing—can significantly increase the processing gain in the spatial domain but the extent to which they do this will depend on a number of factors, including the band in which they operate, the spectrum environment (propagation environmental condition), cost, application, and platform.
- Many licensed spectrum applications, such as public safety, defense, and some internal corporate business networks, are not market-based, and procuring them from the market would be difficult, as commercial operators would not want to be liable for safety of life and internal business uses that require accuracy 24 hours per day, 7 days per week.

Panelists also offered several observations about current and future policy-making processes:

[14] Bruce Fette, General Dynamics Decision Systems; Thomas Walsh, Boeing; Jennifer Warren, Lockheed Martin; and Pat Mahoney, Iridium.

- The current relationship between NTIA and the FCC, which is based in large part on personality and individual working relationships, may not be adequate, especially as increased sharing between federal and nonfederal spectrum users raises jurisdictional questions and otherwise complicates decision making. These complications exist today: For instance, who resolves disputes involving commercial services that have out-of-band impact on government-exclusive bands?
- Increased information on coordination between the Interdepartment Radio Advisory Committee (IRAC) and FCC would be helpful. A public tracking system to monitor the application request process—for example, when the IRAC sends questions to the FCC about an application—would increase confidence that all necessary information has been received, decrease errors, and reduce the time staff spend responding to questions.
- The international dimensions of spectrum decisions, which are not emphasized in the executive memorandum, deserve more attention. For example, domestic decisions can have a significant impact on U.S. licensees that also operate in other countries and have to obtain spectrum assignments or other regulatory approval there as well.
- There is a need to increase U.S. representation in bilateral and international negotiations, which have broad implications for how U.S. allocations and operations are carried out.

TECHNOLOGY, STANDARDS, AND COMMERCIAL R&D

Panelists in Session 7 discussed various ways in which standards setting and technology development relate to spectrum policy.[15] Several speakers addressed the issue of standards, noting that

- Standards-based systems have experienced significant growth in both market size and applications over the past few years, despite the recent downturn in the telecommunications industry. The most notable example is wireless local area networking based on IEEE 802.11 standards.
- Standards do not freeze technology development in time. Standards are constantly evolving as a result of competition among vendors to introduce new and improved technologies and features. Such evolution drives the standards development organizations to continually improve standards to meet the market demand while also maintaining some degree of backward compatibility for current users.
- Although the standards process works well for establishing interoperability between devices built to a common standard, it does not address interoperability or coexistence with *other* systems very well. There is a potential role for regulators here—namely, the establishment of rules covering the coexistence of different standards. These rules should be flexible enough to permit continued technology evolution.

On the subject of licensed and unlicensed spectrum, speakers made several points, including the following:

- Licensed and unlicensed approaches to managing spectrum play useful roles for different technologies and applications, and both support increasing spectral efficiency.

[15] Carl R. Stevenson, Agere Systems; Charles Wheatley, Qualcomm; Gee Rittenhouse, Lucent Laboratories; Kevin Kahn, Intel Corporation; and Carl M. Panasik, Texas Instruments Inc.

- For public safety or homeland security applications, which have demanding requirements, licensed spectrum would offer advantages over unlicensed spectrum because access charges for services have driven efficiency, its reliability is proven, and it leverages world competition to reduce costs. These applications could make use of commercial services if provisions are made for priority access and if liability concerns are addressed.
- Unconstrained interference among different users is possible in unlicensed spectrum, rendering some applications too unreliable. On the other hand, unlicensed spectrum allows new technologies to enter the market quickly and offers new opportunities to provide services, such as wide area networks (WANs).
- Protection for incumbent licensees will remain important.
- Carrier flexibility with respect to the technologies used in their assigned bands is an important enabler of innovation.
- Additional spectrum for unlicensed devices would enable further innovation and use.
- Innovative technology approaches to identify unused spectrum, such as the interference temperature, might not be applicable across all spectrum bands but could serve to identify available spectrum in particular bands with well-defined incumbents.

Views were mixed about the need to increase interference protection for certain unlicensed devices. Some panelists felt the increasing maturity and economic importance of some unlicensed uses may be reason enough to create additional protection for certain devices within unlicensed bands. Others were skeptical about imposing ruled-based enforcement mechanisms on unlicensed devices because new rules could impede innovation and because there are a variety of technical options that could be used to resolve interference problems.

Several international policy issues were addressed by the panelists:

- Encouraging technology neutrality in international allocations would permit operators providing a service, rather than regulators, to determine the best technology architecture to deliver the services and would permit competition on such dimensions as serving more users per megahertz, better quality of service, higher data rates, and the introduction of new services.
- Establishing common worldwide bands for cellular mobile communications would have substantial benefits. Handset designers have found ways of accommodating diverse spectrum allocations, but this has made handsets more complicated than they need to be and has added to their cost. Harmonization would create greater economies of scale for manufacturers, make it more convenient for consumers to use the same device while traveling (especially laptops), and reduce conflicts with regional regulations when portable devices are taken to other countries.

WI-FI AND BROADBAND WIRELESS ACCESS TECHNOLOGIES

In Session 8, panelists from several firms involved in wireless LAN and broadband technologies[16] discussed the implications of these technologies for spectrum management policy. Comments made by panelists included these:

[16] Michael Green, Atheros Communications; Leigh Chinitz, Chief Technical Advisor, Proxim; Siavash Alamouti, Vivato; Duane Buddrius, Alvarion; Bradley Holmes, Arraycomm, Inc.; and Dewayne Hendricks, the Dandin Group.

- Assumptions about spectrum capacity that underlie spectrum management decisions should be carefully examined. Is spectrum really a finite, limited resource (as common wisdom would have it), or is capacity actually infinite, with access constrained by time, geographic location, and frequency?
- The benefits of unlicensed spectrum include the accelerated pace of innovation in wireless communications and the ripple effects of these technologies on other segments of the computing and communications market.
- Measures that would advance unlicensed applications include the allocation of additional spectrum; reuse or shared use of currently underutilized bands; globally harmonized allocations and harmonized technical rules for operation and compliance testing; the use of advanced radio technologies; and a simplified product certification process.
- Wireless broadband could serve as an alternative means of delivering broadband to the 40 percent of households and other underserved groups that are not served by either cable or digital subscriber line (DSL). Roughly 90 percent of these underserved customers are located in rural areas. The following measures would help expand broadband coverage: (1) permit increased transmitter power in unlicensed bands for wireless broadband and (2) identify additional unlicensed spectrum or opportunities for spectrum underlay for wireless broadband.
- Policies should reward more efficient, flexible, and intelligent technologies that permit incremental moves toward a more open, shared approach to spectrum management and allocation. It would, however, be counterproductive to force spectrum users to become more spectrally efficient only to reassign to others the spectrum that was opened up.
- Techniques for spectrum sharing with priority access provide an opportunity to support and enhance national security and public safety applications without requiring separate allocations.
- Smart antenna technologies offer a number of advantages over conventional antennas, including less interference, an increase in bandwidth efficiency and wireless system coverage, and a reduction in the number of standard radios and thus the total energy transmitted. Full exploitation of the technology would be advanced if policy would (1) take account of the antenna gains achieved by smart antennas rather than applying power limits designed for standard antennas systems and (2) emphasize the efficiency of wireless systems rather than individual radios.

GOVERNMENT AND ACADEMIC RESEARCH AND DEVELOPMENT

In Session 9, researchers and research managers from Rutgers, the Massachusetts Institute of Technology, and the Defense Advanced Research Projects Agency (DARPA)[17] discussed several active areas of wireless research and some policy implications.

- Inflexible spectrum policies, which can lead to spot shortages, are the driver for research on dynamic spectrum allocation techniques.
- DARPA's XG program is developing technology to support radios that can dynamically adapt to the spectral and policy environment. One core program component is dynamic spectrum selection based on propagation characteristics, measured spectrum use, and inferred potential interference. The other core component is a policy language to describe rules for spectrum use that allow the regulations in any particular operating environment to be

[17] Preston Marshall, Advanced Technology Office, DARPA; Dipankar Raychaudhuri, Rutgers University; and Moe Win, Massachusetts Institute of Technology.

systematically described and followed by a radio. Results from the XG program will be placed in the public domain with the expectation that the commercial sector will further develop and commercialize the technologies and thus make radios more cost-effective.

- Two areas of research into dynamic frequency allocation are agile radios and cross-layer coordination among radios.
- Agile or cognitive radios are able to select frequencies dynamically across a wide bandwidth and to generate a variety of waveforms.
- Higher layer spectrum coordination protocols, which provide mechanisms for radio devices to observe each other, are a possible enabler for spectrum sharing scenarios such as spectrum underlay or dense unlicensed band deployment. Because interference is a receiver property, spectrum protocols may be needed to overcome the inherent "hidden node" problem, in which two transmitters (no matter how agile) cannot hear each other but still interfere at a receiver that is located between them. Two approaches are being developed to solve this problem. One is a spectrum policy service that uses an Internet connection to provide a network layer service that identifies what is operating within a given locality. Another approach, a spectrum etiquette protocol, would use a common wireless signaling channel rather than an Internet connection. An 802.11-based protocol has already been developed to provide this service. Experiments to reduce interference between Bluetooth and 802.11 transmissions suggest that significant improvements can be made in throughput and quality of service. Either approach would depend on the development of standardized protocols and could leverage the DARPA XG program's work on codifying policy.
- Large-scale trials of alternative cognitive radio and spectrum coordination protocol approaches would help establish the viability of these approaches and provide estimates of the spectral efficiency they could achieve.
- Ultrawideband (UWB) has had a long history with different meanings and definitions. UWB's first use was in the spark gap radios pioneered by Marconi. UWB has come back into play with a recent FCC ruling permitting its use. Today's UWB technology uses very narrow, short pulses for uses such as short-range, high-speed data for broadband access networks. Based on the FCC definition, numerous opportunities exist for the deployment of UWB systems, especially with the wide range of unlicensed spectrum allocation, from 3.1 to 10 GHz. There are no backward compatibility issues because its use has not been permitted until recently.
- FCC rules permit UWB to be used for many applications but interestingly prohibit its use for toys. One current area of interest for UWB is short-range communications within the home.
- Today, UWB is permitted in only one country, the United States, so UWB applications under development will eventually be constrained by allocation decisions and rules established by regulators around the world.

Appendixes

A

Forum Agenda

February 12-13, 2004
Washington, D.C.

THURSDAY, FEBRUARY 12

8:00 a.m. **Registration and Continental Breakfast**

8:30 **Welcome**

Charles Brownstein, Director, Computer Science and Telecommunications Board, National Research Council
David Liddle, Chair, Committee on Wireless Technology Prospects and Policy Options

8:45 **Opening Remarks**

Samuel Bodman, Deputy Secretary, Department of Commerce

Session 1: Federal Spectrum Users

9:00 **1A: Defense, Justice, Transportation, and Aviation**

Moderator: Dale Hatfield, University of Colorado
David G. Boyd, Deputy Director and Research/Development Director for SAFECOM, Department of Homeland Security
Tyler Duvall, Deputy Assistant Secretary of Transportation
Merri Jo Gamble, Spectrum Manager, Department of Justice
Donald Willis, Office of Spectrum Policy and Management, Federal Aviation Administration
Badri Younes, Director, Spectrum Management, Department of Defense

10:15 **Break**

10:30 1B: Scientific Uses

Moderator: David Skellern, Cisco
Don Backer, Professor of Astronomy, University of California at Berkeley, and Chair, NRC Committee on Radio Frequencies
Richard Barth, Office of Radio Frequency, National Oceanic and Atmospheric Administration
Scott Pace, Chief Technologist, National Aeronautics and Space Administration
Karen St. Germain, NPOESS Integrated Program Office, National Oceanic and Atmospheric Administration

11:45 Lunch

Session 2: State and Local Government Users

12:45 p.m. State and Local Government Users

Moderator: David Liddle, U.S. Venture Partners
Thera Bradshaw, Assistant General Manager of Information Technology, City of Los Angeles
Capt. Thomas Cowper, Associate Director, New York State Wireless Project
Nancy Jesuale, President, NetCity Engineering
Robert LeGrande, Agency Liaison, Office of the Chief Technology Officer, District of Columbia
Glen Nash, Senior Telecommunications Engineer, State of California Department of General Services
Marilyn Praisner, Member, Montgomery County (Md.) Council

2:20 Break

Session 3: Federal Spectrum Management Authorities

2:30 Federal Spectrum Management Authorities

Moderator: Yochai Benkler, Yale Law School
Michael Gallagher, Acting Assistant Secretary for Information and Communications, Department of Commerce
Julius Knapp, Deputy Chief, Office of Engineering and Technology, Federal Communications Commission
John Muleta, Chief, Wireless Telecommunications Branch, Federal Communications Commission
Andrea Petro, Program Examiner, Office of Management and Budget
David Siddall, Attorney, Paul, Hastings, Janofsky & Walker LLP

3:50 Break

Session 4: Frequency Managers and Amateur Radio

4:00 Frequency Management and Amateur Radio

Moderator: David Reed, MIT Media Lab and HP Labs
Robert Gurss, Director, Legal and Government Affairs, Association of Public-Safety Officials
William Moroney, President, United Telecom Council
Paul Rinaldo, Chief Technical Officer, American Radio Relay League
Kenneth Ryan, Director, Spectrum Management Solutions, Comsearch

Session 5: Consumers

5:15 Consumer Organizations

Moderator: Yochai Benkler, Yale Law School
Mark Cooper, Director of Research, Consumer Federation of America
Harold Feld, Associate Director, Media Access Project

5:30 Reception

FRIDAY, FEBRUARY 13

8:00 a.m. Registration and Continental Breakfast

Session 6: Carriers and Service Suppliers

8:30 6A: Cellular Carriers

Moderator: Paul Kolodzy, Stevens Institute of Technology
Jim Bugel, Executive Director for Federal Government Affairs, Cingular Wireless
Diane Cornell, Vice President for Regulatory Policy, Cellular Telecommunications & Internet Association
Jim Smoak, Director, Business Development, Verizon Wireless

9:30 6B: Broadcasting Services

Moderator: Paul Kolodzy, Stevens Institute of Technology
David Donovan, President, MSTV
Kalpak S. Gude, Vice President for Government and Regulatory Affairs and Associate General Counsel, PanAmSat
Greg Schmidt, Vice President for New Development and General Counsel, LinTV

10:30 Break

10:45 6C: Commercial and Government Services and Applications

Moderator: Dale Hatfield, University of Colorado
Bruce Fette, Chief Scientist, General Dynamics Decision Systems
Pat Mahoney, Vice President Regulatory and Spectrum Affairs, Iridium
Thomas Walsh, Boeing Space and Communication Spectrum Management
Jennifer Warren, Senior Director, Trade and Regulatory Affairs, Lockheed Martin

11:45 Lunch

Session 7: Technology, Standards, and Commercial R&D

12:45 p.m. Technology, Standards, and Commercial R&D

Moderator: Larry Larson, University of California at San Diego
Kevin Kahn, Intel Fellow and Director, Communications and Interconnect Technology Lab, Intel
Carl M. Panasik, Director, Advanced Architecture, Texas Instruments, Inc.
Gee Rittenhouse, Vice President, The Wireless Research Laboratory, Lucent Laboratories
Carl R. Stevenson, Senior Manager, Standards and Regulatory Affairs, Agere Systems
Charles Wheatley, Senior Vice President for Technology, Qualcomm

Session 8: Wi-Fi and Broadband Wireless Access Technologies

2:00 Wi-Fi and Broadband Wireless Access

Moderator: David Skellern, Cisco
Siavash Alamouti, Chief Technical Officer, Vivato
Duane Buddrius, Director of Product Engineering and Product Management, Alvarion
Leigh Chinitz, Chief Technical Advisor, Proxim
Michael Green, Manager, Global Product Compliance, Atheros Communications
Dewayne Hendricks, Founder, The Dandin Group
Bradley Holmes, Arraycomm, Inc.

3:15 Break

Session 9: Government and Academic R&D

3:30 Government and Academic R&D

Moderator: Andrea Goldsmith, Stanford
Preston Marshall, Program Manager, Advanced Technology Office, DARPA
Dipankar Raychaudhuri, Professor, Electrical and Computer Engineering, and Director, Wireless Information Network Laboratory, Rutgers University

Moe Win, Charles Stark Draper Assistant Professor of Aeronautics and Astronautics, Massachusetts Institute of Technology

4:15 Closing Remarks

David Liddle, Chair, Committee on Wireless Technology Prospects and Policy Options

4:20 Adjourn

B

List of Slide Presentations

The following presenters used slides in their presentation and made them available to CSTB for public distribution. Copies of these slides can be viewed at CSTB's Web site, <www.cstb.org>. The slides have not been edited, and opinions and statements in them are solely those of the individual persons or participants at the forum and have not necessarily been adopted or endorsed or verified as accurate by the National Academies.

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Richard Barth, Office of Radio Frequency, National Oceanic and Atmospheric Administration
David G. Boyd, Deputy Director and Research/Development Director for SAFECOM, Department of Homeland Security
Thera Bradshaw, Assistant General Manager of Information Technology, City of Los Angeles
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Bruce Fette, Chief Scientist, General Dynamics Decision Systems
Brian Fontes, Vice President for Federal Regulatory Affairs, Cingular Wireless
Merri Jo Gamble, Spectrum Manager, Department of Justice
Michael Green, Manager, Global Product Compliance, Atheros Communications
Kalpak S. Gude, Vice President for Government and Regulatory Affairs, Associate General Counsel, PanAmSat
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Julius Knapp, Deputy Chief, Office of Engineering and Technology, Federal Communications Commission
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Charles Wheatley, Senior Vice President for Technology, Qualcomm
Donald Willis, Office of Spectrum Policy and Management, Federal Aviation Administration
Badri Younes, Director, Spectrum Management, Department of Defense

C

Biographies of Speakers

WELCOME AND OPENING REMARKS

Samuel W. Bodman is the Deputy Secretary of the Department of Commerce. A financier and executive by trade, he is well suited to his role of managing the day-to-day operations of the department, which has 40,000 employees and a $5 billion budget. Dr. Bodman is an engineer by training; he is well qualified for his specific oversight focus on the NOAA, the Patent and Trademark Office, and the National Institute of Standards and Technology. With 31 years of experience in the private sector, Dr. Bodman is a firm believer in the American free enterprise system. His work in the finance industry began when he was a professor at the Massachusetts Institute of Technology and started consulting with the venture capital sector. He and his partners and associates provided financial and managerial support to scores of new business enterprises throughout the United States. Virtually all of these companies had a strong dependence on technology and innovation. Many achieved great financial success and established public markets for their securities. Dr. Bodman holds a B.S. in chemical engineering from Cornell University and an Sc.D. from MIT. He served as an associate professor of chemical engineering at MIT and as technical director of the American Research and Development Corporation, a pioneer venture capital firm. From there, Dr. Bodman went to Fidelity Venture Associates, a division of Fidelity Investments. In 1983 he was named president and chief operating officer of Fidelity Investments and a director of the Fidelity Group of Mutual Funds. In 1987, he joined Cabot Corporation, a Boston-based Fortune 300 company with global business activities in specialty chemicals and materials, where he served as chairman, CEO, and a director. Over the years, he has been a director of many other publicly owned corporations. Dr. Bodman has also been active in public service. He is a former director of MIT's School of Engineering Practice and a former member of the MIT Commission on Education. He was also a member of the Executive and Investment Committees at MIT and the American Academy of Arts and Sciences and was a trustee of the Isabella Stewart Gardner Museum and the New England Aquarium.

Charles N. Brownstein is the director of the Computer Science and Telecommunications Board (CSTB) of the National Academies. He joined the Academies in 2004 from the Corporation for National Research Initiatives (CNRI), where since 1994 he directed the Cross Industry Working Team and did independent research with support from NSF and DARPA. His interests are in innovation, applications and impacts of information technology, Internet performance, and the technology-policy interface. Dr. Brownstein joined CNRI in 1994 after a 20 year career at the National Science Foundation (NSF). There he served in positions including program director for Telecommunications Policy and IT Applications, division

director for Information Science and Technology, deputy assistant director and assistant director of NSF for Computer and Information Science and Engineering (CISE), and director of the Office of Planning and Assessment. His federal achievements are recognized by Presidential Meritorious and Distinguished Senior Executive Service awards and by NSF's Distinguished Service Award. At NSF, he led in the creation of CISE, nurtured the development of NSFnet, and set strategic directions for federal information infrastructure. He was a principal in organizing the inter-agency High Performance Computing and Communications (HPCC) initiative and was executive director of the National Science Board's Special Committee on the Future of NSF. He presided over information technology and policy working groups at the OECD, was founding chair of the Federal Networking Council, and participated on the Board of Regents of the National Library of Medicine. He organized and co-chaired the White House National Performance Review Working Group for Reinventing Government through Information Technology. He was a founding trustee of the Internet Society (ISOC), chaired the Association for Computing Machinery's public policy activity, USACM, and is presently a director of Fortec, which provides the IETF Secretariat. From 1971 to 1975, Dr. Brownstein taught at Lehigh University and was a founder of the Institute of Social and Behavioral Research. There he was principal investigator on NSF and industry-supported research awards on telecommunications policy, information industry innovation, two-way cable field experimentation, and interactive learning technologies. He also taught research design at the University of Michigan's Inter-university Consortium for Social and Political Research. His Ph.D. is in political science, from Florida State University, 1971.

SESSION 1A: FEDERAL SPECTRUM USERS: DEFENSE, JUSTICE, TRANSPORTATION, AND AVIATION

David G. Boyd is deputy director and research and development director for the SAFECOM Program Office at the Department of Homeland Security, where he has been since it was established in March 2003. He is responsible for office operations and for the management or oversight of the operations of all the Homeland Security laboratories. In addition, he is responsible for the national effort to achieve interoperability among communications systems of the nation's first responders at local, state, and federal levels. Dr. Boyd came to Homeland Security from the U.S. Department of Justice, where he was director of science and technology for the National Institute of Justice, the criminal justice research and evaluation agency. His office managed research and development programs in every facet of technology affecting law enforcement and corrections, including the forensic sciences, less-than-lethal technologies, information and communications technologies, concealed weapons and contraband detection, and simulation. His office directed the DNA and forensic laboratory improvement programs, which are designed to strengthen DNA identification and general forensic analysis capabilities in state and local crime laboratories. His office also managed the only voluntary standards development and testing organization for law enforcement and corrections in the United States, and was charged by Congress with the development of proficiency tests for DNA laboratories. Dr. Boyd also served, at the direction of the Attorney General, on the White House National Science and Technology Council, on the National Security Council Committee on Safety and Security of Public Facilities, and as the executive chair of the Justice Department's Technology Policy Council. He has an M.A. in operations research and public policy analysis and a Ph.D. in decision sciences.

Tyler Duvall is the deputy assistant secretary for transportation policy in the Department of Transportation. His portfolio includes economic and strategic analysis; transportation, energy, and the environment; and federal civilian uses of the electromagnetic spectrum, including global positioning systems. Mr. Duvall currently works closely with the assistant secretary for transportation policy and the administrators of the Federal Highway and Federal Transit Administrations in the development of comprehensive surface transportation legislation. In addition, he coordinates the department's

implementation of President Bush's Executive Order to streamline environmental reviews of transportation projects. Before assuming his current role, Duvall was the special assistant to the assistant secretary for transportation policy. In this role, he advised on a broad range of policy and legal issues related to surface transportation, including innovative financing of transportation infrastructure, streamlining environmental review processes, highway safety, freight and goods movement, Amtrak, security, overall program funding, and the oversight of federal funds. Prior to joining USDOT, Mr. Duvall was an associate in the business and finance group of Hogan & Hartson, LLP, of Washington, D.C. There, he represented various public and private companies in mergers, acquisitions, and securities filings. He has a B.A. in economics from Washington and Lee University and a law degree from the University of Virginia.

Merri Jo Gamble is the spectrum manager for the Department of Justice. She has over 30 years experience in the spectrum management field and has served in a variety of positions within the Federal Bureau of Investigation, NTIA, and the Department of Justice. In the area of domestic spectrum management, she is currently the Department of Justice representative on the Interdepartmental Radio Advisory Committee. She has also served as the Department of Justice representative on the Spectrum Planning Subcommittee and on various spectrum management ad hoc and working groups. Her international experience includes participation in bilateral spectrum negotiations with the Mexican government as a subject matter expert on land mobile law enforcement border issues. She participates in activities of the International Telecommunication Union and was recently a delegate and U.S. spokesperson at the World Radiocommunication Conference 2003.

Donald Willis is a manager in the Spectrum Planning and International Division Office at the Federal Aviation Administration. His strategic vision is to protect the aeronautical radio spectrum for the current and future needs of international aviation. After serving in the U.S. Navy from 1966 to 1968, Mr. Willis graduated from Western Washington University in Bellingham, Washington. In 1974, he began his career with the U.S. Air Force as a communications officer. His assignments included command of a communications squadron in Italy and liaison to the Federal Aviation Administration. Mr. Willis's assignments as a spectrum engineer began in 1978 and include having been director for frequency management for the U.S. Air Force in Europe and frequency manager for the Rapid Deployment Joint Task Force, which later became the U.S. Central Command. After retiring from the U.S. Air Force in 1992, he began his career as an electronics engineer at the FAA.

Badri Younes is DOD director for spectrum management and the director of the Defense Spectrum Office, with responsibility for spectrum policy, strategic planning, and implementation at DOD. Under his leadership, the Department has successfully negotiated all the recent win-win agreements with the FCC, NTIA, and the U.S. private sector that have enabled technological innovations to proceed while safeguarding critical military equities. He has successfully led the DOD spectrum management organization to become more proactive in addressing the radio frequency (RF) and spectrum issues facing the department in transforming the military into a network-centric fighting force. Mr. Younes's experience spans over 20 years of microwave and RF systems engineering and technology. Prior to joining the DOD, he managed the RF systems engineering and spectrum management for NASA's Goddard Space Flight Center (GSFC) Space and Ground Networks. While at GSFC, he successfully managed the development and implementation of the hardware systems for NASA's second TDRSS ground terminal. Mr. Younes's career includes 5 years of hands-on work in state-of-the-art technology at the Naval Surface Warfare Center. His primary focus included coding and modulation theory, analog and digital communications, quantum electronics, signal processing, nonlinear mathematics, and neural networks. He has an M.S. in electronic engineering from Catholic University of America.

SESSION 1B: FEDERAL SPECTRUM USERS: SCIENTIFIC USES

Richard Barth is chief of the Radio Frequency Management Division at the U.S. Department of Commerce and director of the department's Office of Radio Frequency Management.

Scott Pace is the chief technologist for space communications in NASA's Office of Space Flight. He is responsible for advising senior NASA management on technical, programmatic, policy, and regulatory issues related to space-based information systems providing communications, navigation, and remote sensing. He is particularly focused on issues related to the global positioning system, active and passive sensor bands, aeronautical safety bands, and dual-use space communications. He represents agency interests in interagency as well as international forums.

Karen St. Germain is with the NPOESS Integrated Program Office at NOAA. Her work has focused on passive polarimetric radiometry of the ocean surface and polar regions, which she continued after several years with the Naval Research Laboratory's Remote Sensing Division. Prior to this Dr. St. Germain was an assistant professor in the Department of Electrical Engineering at the University of Nebraska, Lincoln. She is a member of the American Geophysical Union, the American Association for the Advancement of Science, and the Institute of Electrical and Electronics Engineers. She has a Ph.D. in electrical engineering from the University of Massachusetts, Amherst.

SESSION 2: STATE AND LOCAL GOVERNMENT USERS

Thera Bradshaw is the chief executive officer for the City of Los Angeles Information Technology Agency. Her responsibilities are both internal and external services, including the administration of cable franchises, the education and government television stations, and the 3-1-1 number, "one call to city hall." Before joining the Los Angeles agency, Ms. Bradshaw was executive director of the city and county of San Francisco's Emergency Communications Department. Under her leadership, a new department was created and built from what was traditionally a support service function within the police, public health, and fire departments. From 1990 to 2000, she was responsible for implementing the $200 million dollar capital project improving 9-1-1 emergency communications in San Francisco. Ms. Bradshaw also served as executive director of the Regional Communications Agency of Clark County, Washington, with 42 participating local governments. She pioneered Oregon's first automated, enhanced 9-1-1 system with 14 participating local governments in the Portland metropolitan area in 1986. Ms. Bradshaw's professional leadership extends to state, national, and international roles in appointed and elected positions on a variety of boards and committees. She has authored numerous publications, is an in-demand public speaker, and testified before the U.S. Congress and the FCC. Ms. Bradshaw served from 1999 to 2003 on the Board of Officers and was the 69th President of the Association of Public-Safety Communications Officials International (APCO). APCO is the world's oldest and largest not-for-profit professional organization dedicated to the enhancement of public safety communications, with more than 16,000 members in 34 countries. She also served 7 years on the board of officers for the National 9-1-1 Association (NENA) and was the national president in 1995. Major national policy improving 9-1-1 and public safety communications was accomplished during her tenure. Ms. Bradshaw has received numerous honors, including being named one of the top women of leadership in public safety. Her undergraduate education is from Oregon State University. She is also a graduate of the University of Washington's Graduate School of Public Affairs and the FBI Executive Command College.

Thomas Cowper, associate director in charge of engineering and technology for the Statewide Wireless Network project within New York State's Office for Technology, is a 20-year veteran of the New York State Police. He spent 9 years in field assignments, including 4 years with the State Police tactical unit,

before becoming directly involved with the development, procurement, and deployment of law enforcement technology. He served as director of communications for the State Police prior to his current assignment. When completed, the Statewide Wireless Network is intended to serve the land mobile radio requirements of 65,000 federal, state, and local public safety users on a single shared network and will be the largest technology procurement in the history of New York State. Capt. Cowper is a member of the Society of Police Futurists International and the FBI's Futures Working Group, two organizations devoted to examining the emerging trends and developments that are changing our world and the manner in which law enforcement and public safety services are delivered. He holds a B.S. in mechanical engineering technology and an M.A. in public administration.

Nancy Jesuale is the president of NetCity Engineering, Inc., a consulting practice dedicated to strategic planning and solution sets for government in public safety and fiber optic telecommunications systems. Current clients of NCE include the City of Los Angeles, the District of Columbia, Portland Community College, and the Center for Wireless Network Security. Ms. Jesuale has worked in local and state government as a telecommunications strategic planner and director of public safety networks, telecommunications networking, and network operations. As program manager for public safety, she is responsible for establishing relationships, research programs, and public policy support for the Wireless Network Security Center (WiNSeC). Most recently Ms. Jesuale was the director of ComNet, a bureau of the city of Portland, Oregon, responsible for all voice, data, and video communications systems in the city and provider of regional communications services for government entities throughout the region.

Robert LeGrande is the deputy chief technology officer in the Office of the Chief Technology Officer (OCTO), District of Columbia government (DC). Mr. LeGrande provides executive leadership for the Wireless Networks Program, the Human Services Modernization Program, the Agency Liaison Group, and the OCTO Chief Information Officer staff. The Wireless Networks Program provides upgrades to the push-to-talk radio networks of the DC Fire Department, the DC Emergency Management System, and the DC Metropolitan Police Department (MPD). He also manages, in conjunction with Washington Metropolitan Area Transit Authority (WMATA), the WMATA Public Radio System Program. This program will expand the upgraded DC Fire, EMS, and MPD push-to-talk radio system to the WMATA tunnel system radio network. Mr. LeGrande oversees the Public Safety Wireless High Speed Data Network Program as well. The program's objective is to construct a broadband wireless network using licensed dedicated spectrum to provide citywide access to mission-critical applications. In this effort, he spearheaded the creation of the Spectrum Coalition for Public Safety to secure 10 MHz of spectrum in the 700 MHz band. He and his team are actively working with legislators to achieve this goal. Additionally, his team is creating the first broadband wireless network for public safety. The network will serve as a testbed for public safety applications and provide all public safety agencies with the insight to key requirements and operational issues regarding broadband applications. He leads the Human Services Modernization Program team, which will upgrade some DC human services IT applications and integrate all of them. He also heads the Agency Liaison Group, which provides IT program direction and support to all district agencies and reviews and approves all DC IT project purchases. Finally, Mr. LeGrande is the deputy responsible for OCTO chief information officer (CIO) staff. This program is responsible for providing CIO leadership and direction to multiple district agencies. Prior to Mr. LeGrande's position with the DC government, he was responsible for overseeing all development of products within the NuVizion portfolio. At Proxicom he served as the managing director for the National Microsoft Practice, with executive oversight responsibilities for a diverse set of program engagements such as www.exxonmobil.com, www.MBCC.com, www.AEAnet.org and www.MERANT.com. Prior to Proxicom, Mr. LeGrande worked as a consultant program manager for MCI's Internet and Intranet Development Group. Here he managed over 18 Web-based projects, including www.MCICENTER.com and MCI's award-winning investor relations Web site. He began his career with Lockheed Martin, where he held positions in configuration management software test and integration engineering and project management on the AN/BSY Submarine Combat System and Vertical Launching System programs. Mr.

LeGrande received his education at Clark Atlanta University, where he graduated with a B.S. in physics and a minor in mathematics.

Glen Nash is senior telecommunications engineer in the State of California Department of General Services.

Marilyn Praisner is the longest serving woman ever on the Montgomery County Council. She is currently in her fourth term representing District 4. Ms. Praisner served as council president in 1993 and 1997 and as vice president in 1992 and 1996. Prior to being elected to the County Council, she worked for the Central Intelligence Agency for 16 years, serving as an analyst, a branch chief, and on the staff of the Deputy Director of Intelligence. A county official known for her national leadership on technology and telecommunications issues, Ms. Praisner has represented local government across this country at numerous technology conferences on public safety communications, cable television, the siting of cellular towers, and rights-of-way management. She has represented local government on public safety communications committees, including the National Task Force on Interoperability (as vice chair of the Governance Subcommittee) and the Department of Homeland Security's Executive Committee for the Public Safety Wireless Network (PSWN) program. She currently serves as a member of the Department's SAFECOM Executive Committee. She also serves on the Homeland Security Task Force of the National Association of Counties (NACo). Ms. Praisner is a Maryland vice chair for Capital Wireless Integrated Network (CapWIN), a public safety communication system for the Washington, D.C., metropolitan area. A member of the board of directors of the NACo, she is in her second term as chair of its Telecommunications and Technology Steering Committee. The immediate past president of the Maryland Association of Counties, she also serves on the Maryland Interoperability Governance Working Group.

SESSION 3: FEDERAL SPECTRUM MANAGEMENT AUTHORITIES

Michael Gallagher is the Acting Assistant Secretary of Commerce for Communications and Information and Acting Administrator of NTIA. He most recently served as the deputy chief of staff for policy and as counselor to the Secretary of Commerce. He was the lead policy advisor to the Secretary and was responsible for the effective coordination of policy initiatives within the Commerce Department and across the administration. As a leading member of the Bush administration's technology team, he has focused on bringing the benefits of new telecommunications technologies to American consumers. Working closely with the FCC and other government agencies, Gallagher directed NTIA's technical study that led to the FCC's approval of ultrawideband, a new technology that could spur the development of devices to underlay the radio frequency spectrum, improving the ability of public safety entities to respond to emergencies. He led NTIA's development of a spectrum allocation plan, paving the way for deployment of advanced mobile telecommunications services known as third-generation (3G). The 3G plan, which identified 90 MHz of radio spectrum for future wireless services, is a significant part of the administration's overall initiative to promote efficient use of the radio spectrum—key to improving the quality of voice and data services and enhancing the delivery of health services. Mr. Gallagher has a B.A. from the University of California at Berkeley and a J.D. from the University of California at Los Angeles.

Julius Knapp is deputy chief of the FCC's Office of Engineering and Technology (OET). Previously he was chief of the policy and rules division for OET and oversaw spectrum allocations and technical rules for radio frequency devices as well as coordination of radio frequency issues with the federal government. Knapp has also served as the chief of the FCC laboratory, where he was responsible for the FCC's equipment authorization program. He held a variety of other positions during his 26 years with the FCC, including heading the Frequency Allocations Branch, where he directed FCC frequency allocation

proceedings for cellular service, private land mobile services, and mobile satellite services. He is a member of the Institute of Electronics and Electrical Engineers and the Electromagnetic Compatibility Society and is a fellow of the Radio Club of America. Mr. Knapp has a B.S. in electrical engineering from the City College of New York.

John Muleta is chief of the Wireless Telecommunications Bureau (WTB) of the Federal Communications Commission, appointed in January 2003. Prior to this appointment, he was the president and CEO of Source 1 Technologies LLC, a privately held systems integration firm in Washington, D.C. Mr. Muleta was also a cofounder of OI Systems, Inc., a Washington-based management consulting firm. He previously served at the FCC, where he held various positions, including deputy bureau chief and chief of the Enforcement Division of the Common Carrier Bureau. After leaving the FCC, Mr. Muleta held the position of president for PSINet Ventures, Inc., and before that, was president of PSINet's Global Facilities Division and the India, Middle East, and Africa Division. He began his career at GTE Corporation and later worked at Coopers & Lybrand Consulting, LLC, before joining the FCC. Mr. Muleta has a B.S. in systems engineering from the University of Virginia School of Engineering and Applied Sciences, and M.B.A. and J.D degrees from the University of Virginia joint degree program.

Andrea Petro is a program examiner at the Office of Management and Budget.

David Siddall is an attorney with the law firm Paul, Hastings, Janofsky, and Walker LLP in Washington, D.C. Mr. Siddall advises and represents a wide range of clients on wireless spectrum and equipment issues before the FCC, Congress, and executive branch agencies. He brings to the table many years of communications policy experience on Capitol Hill and at the FCC before entering private practice, including service as chief of the FCC's spectrum management branch and later as wireless advisor to an FCC commissioner. He was at the heart of the policy debates in the 1990s, when the FCC allocated spectrum and adopted rules to govern a variety of new services such as PCS, digital TV, satellite digital audio radio, and low Earth orbit satellites. Mr. Siddall is admitted to practice before the bars of the District of Columbia and the U.S. Supreme Court. He also is an active member of the Federal Communications Bar Association and the American Bar Association. He is coauthor of the book *FCC Lobbying—A Handbook of Insider Tips and Practical Advice*.

SESSION 4: FREQUENCY MANAGERS AND AMATEUR RADIO

Robert Gurss serves as director of legal and government affairs for the Association of Public-Safety Communications Officials International (APCO). His experience covers all aspects of communications law, including issues related to wireless telecommunications, common carrier, cable, and broadcasting matters. His practice currently focuses on the representation of governmental entities and corporations on wireless telecommunications issues. His expertise includes domestic and international spectrum allocations, transactions involving communications facilities, frequency reallocation negotiations, resolution of interference disputes, complex FCC licensing matters, regulatory compliance issues, rule waivers, equipment standards, tower siting and related environmental assessment issues. Mr. Gurss has been an active participant in the Public Safety Wireless Advisory Committee, the Public Safety National Coordination Committee, the National Public Safety Telecommunications Council, and the National Task Force on Interoperability. He is a frequent speaker on communications law issues and has written the monthly "Washington View" column in *Public Safety Communications* magazine for the past 14 years. Mr. Gurss is a director and past president of the Land Mobile Communications Council, a coalition of major associations representing the interests of wireless telecommunications licensees before the FCC. He has a B.A. and a J.D. from the University of Michigan.

William Moroney is the president, chief executive officer, and member of the board of directors of the United Telecom Council (UTC) and the United Power Line Council (UPLC). UTC is the international trade association representing the telecommunications and IT interests of electric, gas, and water utilities and other critical infrastructure entities. UPLC is a trade association of utilities and technology companies involved in the deployment of broadband over power line (BPL) services. Mr. Moroney has spent the last 20 years as the leader of industry organizations driving technological change and convergence in networking and electronic commerce. Before joining UTC, he served as the chief executive of the MultiMedia Telecommunications Association (MMTA), the Business Quality Messaging Forum (BQM Forum), the Electronic Messaging Association (EMA), the Electronic Funds Transfer Association (EFTA), the National Automated Clearing House Association (NACHA), and his own consulting and financial newsletter publishing company. He also has held public affairs and marketing positions at other trade associations and worked on two presidential campaigns and as a broadcast journalist. Mr. Moroney is a member of the board of directors of the research foundation of the Consumer Energy Council.

Paul Rinaldo is the chief technology officer for the American Radio Relay League, the national association for amateur radio. His current duties include U.S. government relations on domestic and international matters, including the International Telecommunication Union (ITU). He has participated in ITU plenipotentiary conferences, world radio conferences, study groups, working parties, and task groups and in related U.S. preparatory meetings. He currently chairs the ITU-R group charged with technical studies related to the amateur and amateur-satellite services. He chaired ITU groups on wind profiler radar and out-of-band emissions. He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and a member of the Board of the United States ITU Association. Mr. Rinaldo studied radio engineering at Valparaiso Technical Institute.

Kenneth Ryan is director of Spectrum Management Solutions for Comsearch. He is responsible for fixed, satellite, and emerging wireless technologies in engineering, business development, and spectrum management. He is currently working on projects involving federal government wireless initiatives, domestic and international specialized spectrum management services, and emerging wireless services such as Dedicated Short-Range Communications, Enhanced Safety of Vehicles, and satellite Ka-band systems. He is active in the Telecommunications Industry Association and National Spectrum Managers Association. He is a member of the NSMA board of directors and is chairperson for the Satellite Technologies Working Group. He has been working with intersystem interference assessment, satellite Earth station system design, and regulatory consulting for two decades. Mr. Ryan is a professional engineer registered in the state of Virginia. He has a B.S. in electrical engineering from George Mason University and an M.S. in electrical engineering from Virginia Polytechnic Institute.

SESSION 5: CONSUMER ORGANIZATIONS

Mark Cooper is director of research at the Consumer Federation of America, where he has responsibility for energy, telecommunications, and economic policy analysis. He is also director of the Digital Society Project, a Ford Foundation-funded effort to analyze and explain the impact of ongoing technological changes in American society to consumer, low income, and civil rights activists and organizations. He has published in trade and scholarly journals numerous articles on telecommunications and digital society issues, as well as antitrust and energy policy. Dr. Cooper was also a fellow at the Stanford Law School Center for Internet and Society and an associate fellow at the Columbia University Institute on Tele-Information. He is the author of four books, including *Media Ownership and Democracy in the Digital Information Age: Promoting Diversity with First Amendment Principles and Market Structure Analysis* (Center for Internet and Society, 2003). Dr. Cooper has a Ph.D. from Yale University.

Harold Feld, associate director of the Media Access Project, joined MAP after practicing communications, Internet, and energy law at Covington & Burling. He served as co-chair of the Federal Communications Bar Association's Online Committee and has written numerous articles on Internet law and communications policy for trade publications and legal journals. In addition, Mr. Feld clerked for the Hon. John M. Ferren of the District of Columbia Court of Appeals. He has a B.S. from Princeton University and a J.D. from Boston University Law School.

SESSION 6A: CARRIERS

Jim Bugel, executive director for Federal Government Affairs/National Security for Cingular Wireless LLC, is responsible for federal regulatory policy and strategic planning for Cingular Wireless. Mr. Bugel brings to the federal regulatory environment years of experience in the wireless industry. He has held management and leadership positions in the operations, marketing, and finance sectors of the company. In Washington, D.C., Mr. Bugel is actively involved in federal spectrum management issues at both the Federal Communications Commission and National Telecommunications and Information Administration. His added responsibilities include the newly created Department of Homeland Security, where he is Cingular's representative on matters relating to homeland security. Prior to the formation of Cingular Wireless, Mr. Bugel was with BellSouth. Mr. Bugel received his Bachelors in Business Science from Miami University in Oxford, Ohio.

Diane Cornell is vice president for regulatory policy at the Cellular Telecommunications & Internet Association (CTIA). She is responsible for coordinating regulatory issues affecting the mobile wireless industry. Since joining CTIA Ms. Cornell has worked on a wide range of issues involving spectrum, universal service, and regulatory mandates. She previously worked at the FCC in a number of positions. Her last position at the FCC was as associate chief in the Wireless Telecommunications Bureau, where she served as chief of staff. There she was involved in a wide range of wireless communications issues, including various spectrum-related rulemakings and issues involving third-generation mobile systems. As chief of the Telecommunications Division of the International Bureau and chief of the International Policy Division of the Common Carrier Bureau, she was responsible for international policy rulemakings, facilities and service authorizations, and multilateral and bilateral conferences. Before joining the FCC, Ms. Cornell was a senior associate specializing in telecommunications with the law firm of Squire, Sanders and Dempsey in Washington, D.C. She is currently an officer of the Federal Communications Bar Association. Ms. Cornell has a B.A. from Wesleyan University and a J.D. from the University of Pennsylvania.

Jim Smoak, director of business development, Verizon Wireless, has been in the wireless industry for over 10 years. He has held several positions in sales, training, customer service, engineering, and product development. Mr. Smoak currently works in the wireless data and multimedia department and is a director within the business development function. Some of his larger responsibilities include the company's efforts around location-based services and smart devices, and he is responsible for the company's marketing relationship with Microsoft Corporation.

SESSION 6B: BROADCASTING SERVICES

David Donovan is president of the Association for Maximum Service Television, Inc. (MSTV). MSTV is a 48-year old national association of over 430 local television stations dedicated to promoting the

technical quality of free, local, over-the-air television service and has taken a leading role in the transition to digital television service. Mr. Donovan has nearly 20 years of broadcast regulatory and policy experience, and prior to accepting the position of MSTV president, he served as the vice president for legal and legislative affairs for the Association of Local Television Stations, Inc. (ALTV). He has also served as the mass media legal advisor to two FCC commissioners, as well as legal advisor to the chief of the Mass Media Bureau. Mr. Donovan came to the FCC from Boston, where he was in the private practice of law. He also served as law clerk to the Judicial Council of Massachusetts. He has a B.A. and an M.A. in communications from the University of Massachusetts, Amherst, and a J.D. from Suffolk University Law School.

Kalpak Gude is vice president for government regulatory affairs and associate general counsel of PanAmSat. PanAmSat is a leading commercial provider of global satellite communications services in both video (including cable television program distribution, direct-to-home television, and special events coverage) and data (including VSAT networks and Internet backbone connectivity). His responsibilities include leading the corporate effort on global and domestic regulatory affairs, which entail management of PanAmSat's international market entry, global licensing, and international policy efforts, along with legislative, regulatory policy, and licensing issues before the U.S. government. His work also focuses on corporate compliance with U.S. export control regulations and international spectrum management issues. These responsibilities include management of PanAmSat's regulatory efforts at the ITU and global compliance with ITU regulations. Mr. Gude worked as counsel on the U.S. Senate Committee on Commerce, Science, and Transportation, as well as the Subcommittee on Communications before joining PanAmSat. There, he focused on areas of telecommunications, the Internet, and satellites. Prior to his work with the U.S. Senate, he was an attorney/advisor in the Policy and Program Planning Division, Common Carrier Bureau of the FCC, where he focused on local telecommunications competition and was one of the primary authors of the FCC's local competition rules implementing the 1996 Telecommunications Act. Mr. Gude has a B.S. in electrical engineering from the Rochester Institute of Technology and a J.D. from the Indiana University School of Law, Bloomington.

Greg Schmidt is vice president for new development and general counsel of LIN Television Corporation, where he oversees legal and regulatory operations. Mr. Schmidt came to LINTV from his partnership in the Washington law firm of Covington & Burling, where he practiced communications law for 15 years. At C&B, he represented a wide variety of mid-sized broadcast companies, including LINTV, as well as television trade associations, including the CBS Television Network Affiliates Association and the Association for Maximum Service Television (MSTV). While representing MSTV, Mr. Schmidt helped craft the industry's initial regulatory strategy for the transition to digital television. As interim co-president of MSTV, he assisted in the completion of the industry's reevaluation of its digital transmission standard. He is currently on the boards of the Media Institute and the Washington International School and has served on the executive committee and as chairman of various committees of the Federal Communications Bar Association. Prior to his work with C&B, he served as a clerk and as deputy supervising staff attorney for the United States Court of Appeals for the Ninth Circuit. He has a B.A. from Swarthmore College and a J.D. from Stanford University.

SESSION 6C: COMMERCIAL AND GOVERNMENT SERVICES AND APPLICATIONS

Bruce Fette is chief scientist of the ISSPD division of General Dynamics Decision Systems, working in advanced signal processing for telephony and RF communications. Dr. Fette has acquired 35 patents, is a member of the Motorola Science Advisory Board, a Motorola Dan Nobel fellow, and has been given the Distinguished Innovator Award. He has worked with the SDR Forum from its inception, currently as technical chair, and is a panelist for the IEEE Conference on Acoustics Speech and Signal Processing

Industrial Technology Track. Dr. Fette also is currently heading the General Dynamics Signal Processing Center of Excellence. He has a B.S.E.E. from the University of Cincinnati and M.S.E.E. and Ph.D. degrees from Arizona State University.

Pat Mahoney is the vice president for regulatory and spectrum affairs for Iridium Satellite LLC, the owner and operator of the Iridium Mobile Satellite System. In this position, she is responsible for the coordination of spectrum and regulatory issues impacting the Iridium satellite system, as well as the management of spectrum and service authorizations necessary for operation in various countries in which Iridium provides service. Mahoney has over 24 years experience as an attorney in the communications field, specializing in regulatory matters, licensing, and spectrum, including 5 years at Iridium LLC, the predecessor of Iridium Satellite, LLC. Immediately prior to joining Iridium Satellite LLC, she was vice president at Final Analysis, one of the licensed "Little LEO" MSS systems, establishing and directing the domestic and international regulatory policies and government affairs activities of that company. Ms. Mahoney began her communications regulatory career at the communications law firm of Fletcher Heald and Hildreth, where she practiced for 16 years and was a partner. She has also served the satellite industry in a number of leadership positions. She is a former chair of the Satellite Industry Association, an industry trade association in the United States. She served on the FCC Advisory Committee for the ITU's 2003 World Radio Conference and was vice chair of the its Informal Working Group on MSS, including GPS. She was also one of three U.S. satellite industry representatives on an international task force of leaders of government, industry, and the science community established by the OECD to address the impact of low Earth orbit satellites on the future of radio astronomy.

Thomas Walsh is with Boeing Space and Communication Spectrum Management.

Jennifer Warren is senior director of Trade and Regulatory Affairs in Lockheed Martin's Washington, D.C., operations, responsible for developing and implementing corporate domestic and international policy and regulatory strategies, with a particular emphasis on spectrum management, IT policy/regulation, and satellite policies. In addition, she handles day-to-day government and regulatory responsibilities associated with these issues. Prior to joining Lockheed Martin's Space and Strategic Missiles Sector, Ms. Warren was at the FCC in numerous positions, including senior legal advisor to the chief of the International Bureau and, finally, assistant chief of the Wireless Telecommunications Bureau. Before joining the FCC, she interned at the Commission of the European Communities in Brussels, at both legal services and the Directorate General for Competition, focusing on a range of EU activities with Japan and the United States, including the U.S.-EU cooperation agreement on antitrust matters. Since entering the field of international telecommunications, Ms. Warren has served both as a government and private representative on U.S. delegations to numerous international conferences, including the ITU Plenipotentiary Conferences and World Radio Conferences. She also served as vice chair of the FCC's Federal Advisory Committee for WRC-03 (WAC-03) and currently is vice chair of the TIA's Spectrum Policy Working Group, co-chair of the Satellite Industry Association's Regulatory Working Group, and chair of Industry Working Group-1 of the FCC's WAC-07. Ms. Warren has a B.S. in languages and a J.D., both from Georgetown University.

SESSION 7: TECHNOLOGY, STANDARDS, AND COMMERCIAL R&D

Kevin Kahn is an Intel senior fellow and currently the director of the Communications Technology Lab, an advanced development and research lab in Intel's Corporate Technology Group responsible for radio, optical, and copper physical layer technologies. He helps drive communications strategies and policy for the corporation. Some of his current primary focuses are broadband access to the home, wireless LANs and PANs, spectrum policy, and related Internet issues. He also coordinates Intel RF technical directions across divisions and chairs the Intel Communications Research Council, which oversees research activities between Intel and academic programs. Dr. Kahn serves on the FCC Technological Advisory Council, the National Science Foundation's Engineering Advisory Council, and on various academic

advisory committees. Throughout his work with Intel, he has worked in system software development, operating systems, processor architecture, and various strategic planning roles. He has held both management and senior individual contributor roles. Dr. Kahn holds a B.Sc. in mathematics from Manhattan College and M.S. and Ph.D. degrees in computer science from Purdue University.

Carl Panasik is director of the advanced architectures team for Texas Instruments (TI) and is also currently a distinguished member of technical staff. He is responsible for U.S.-based research initiatives in the Wireless Terminals Business Unit and is chair of the Wireless Intellectual Property Rights Committee. The team develops wireless communications systems utilizing smart handsets. Dr. Panasik is TI's early adopter for ultrawideband communications. He has worked on software-defined radio architectures and digital signal processor-enhanced cellular power amplifiers that are designed for next-generation handsets. Prior to his current position, Dr. Panasik was program manager for the TI Odyssey Program, where he directed technology development for 2.5 and 3G Internet-ready handsets that will allow consumers to view streaming audio and video. This research effort covered adaptive antennas, multiband RF, baseband architecture, process technology, applications software, and other areas. Previously, Dr. Panasik was the manager for the Wireless Data Research program, where he supported the TI Notebook division in the development of wireless meeting rooms and classrooms. He also was the program manager for the TI programmable transversal filter research contract for the U.S. Department of Defense. Dr. Panasik is a senior member of the IEEE and a certified professional engineer in the state of Texas. He holds 13 patents with over 30 patents pending. Dr. Pansik has a B.S. in electrical engineering from Cleveland State University and M.S. and Ph.D. degrees from the University of Illinois.

George (Gee) Rittenhouse is vice president of the Wireless Research Laboratories at Lucent Technologies, where he has headed several projects, including MIMO system development, network optimization, wireless IP networks, and fourth-generation wireless. He joined Bell Laboratories as a member of technical staff, where he developed a high-speed 0.1 μm NMOS process for optical networking. He later joined the Wireless Research Laboratory at Bell Laboratories, where his research focused on RF front-end radio architectures and cellular system engineering. He has written for numerous publications and holds patents in wireless systems and circuits. He has also received the Bell Labs fellow award. Dr. Rittenhouse holds a B.S. in physics from the University of California at Los Angeles and a Ph.D. in electrical engineering and computer science from the Massachusetts Institute of Technology.

Carl Stevenson is senior manager for standards and regulatory affairs at Agere Systems, with experience in the design and development of RF communications systems and equipment. He is a senior member of the IEEE, a member of the IEEE Standards Association, a fellow of the Radio Club of America, chair of the IEEE 802.18 Radio Regulatory Technical Advisory Group, and chair of the Wi-Fi Alliance Regulatory Committee.

Charles Wheatley is senior vice president for technology at Qualcomm, concentrating equally on RF hardware design, system design, field testing, and standards development. He has been working on various aspects of CDMA as applied to cellular/personal communications since its inception. He has been involved with spread spectrum systems for over 40 years, including both frequency hopping and direct sequence systems. At Rockwell International, he contributed to the GPS on various terminal designs and was also responsible for technical aspects of GPS's spaceborne rubidium frequency standard. After he moved to Linkabit, he contributed to RF and system aspects of the Milstar program. Dr. Wheatley is an IEEE fellow and holds over 50 patents on various techniques and devices, mostly related to communications and navigation. He holds a B.S. in physics from the California Institute of Technology, an M.S. in electrical engineering from the University of Southern California, and a Ph.D. in electrical engineering from the University of California at Los Angeles.

SESSION 8: WI-FI AND BROADBAND WIRELESS ACCESS TECHNOLOGIES

Siavash Alamouti is vice president for advanced development at Vivato, where he has been a pioneer in wireless technologies. Best known as the inventor of the Alamouti Code, the first multiple-input-multiple-output (MIMO) code adopted for a wireless standard, his research and development efforts have been recognized by the IEEE Communications Society as among the most influential in the organization's history. Since joining Vivato, Mr. Alamouti has helped revolutionize the use of smart antenna technology in Wi-Fi infrastructure systems and was instrumental in building the first Wi-Fi switch. Prior to joining Vivato, he made contributions in specifying methodologies and developing design libraries for third-generation wireless communications systems, wireless local area network (WLAN) systems and smart antennae at Cadence Design Systems. Mr. Alamouti began his career developing and designing physical and media access control (MAC) layer technologies at MPR Teltech and AT&T Wireless. In addition to his professional duties, Mr. Alamouti serves as a technical advisor to both the Harvard Broadband Communications Laboratory (HBBCL) and Morpho Technologies. He has published more than 100 papers and technical reports and has received more than 10 patents for his innovations in the field of wireless communications. Mr. Alamouti holds B.A.Sc. and M.A.Sc. degrees in electrical engineering from the University of British Columbia.

Duane Buddrius, director of product engineering and product management for Alvarion Inc., has been instrumental in Alvarion's extraordinary growth, contributing heavily to the development of new products for the 2.4-GHz, 5-GHz, and 900-MHz markets as well as managing the product life cycles for the North American Division. He pioneered the unlicensed band direct sequence and frequency hopping spread spectrum markets, working in systems engineering, research and development, and marketing. Mr. Buddrius has participated in IEEE 802.11 wireless standards development, FCC rule-making procedures, and in the WLANA, Wi-Fi, and WiMAX industry associations. Prior to Alvarion, Mr. Buddrius held positions as director of engineering and director of product development at Solectek Corporation and at other players in the wireless industry.

Leigh Chinitz is the chief technical officer for the Wireless LAN Division of Proxim Corporation. His responsibilities include setting and leading technology directions across the Proxim LAN Division and driving the overall software and hardware architecture and technology roadmaps. In addition, his position entails participation in many technical, regulatory, and standards organizations. Previously he was the chair of the technical committee within the HomeRF Working Group, and currently he is an active participant in the 802.11 standards committees. Prior to joining Proxim he worked in systems technology research for Motorola and later was responsible for coordinating Motorola's participation in FCC rule-making proceedings as part of Motorola's government relations organization. Mr. Chintz holds a B.S. in physics from Yale University and an M.S. in physics from the University of Virginia.

Michael Green, manager of Global Product Compliance at Atheros Communications, is responsible for regulatory approvals of 802.11a, b, and g products. Over the past 2 years he has lobbied spectrum regulators in the United States, Asia, and Europe to remove barriers to use of the 5-GHz bands and participated in the U.S. and European preparation for the World Radio Conference 2003, which has resulted in a global allocation of 455 MHz of spectrum for use by wireless LAN devices. He formerly worked at 3Com Corporation as manager of the regulatory affairs and approvals group responsible for global approvals of all product categories and as a wireless product manager.

Dewayne Hendricks is currently CEO of the Dandin Group, Inc., based in Fremont, California. The Dandin Group offers a comprehensive range of products and services, including research and product development, for wireless communications via the Internet. The Dandin Group will begin to deploy the first exclusively wireless Internet-based communications system, including voice, data, and video, in

Tonga later this year. He is also an active member of the FCC Technological Advisory Council. Prior to forming the Dandin Group, he was the general manager of the Wireless Business Unit for Com21, Inc. He joined Com21 following an opportunity to participate as the co-principal investigator in the NSF's Wireless Field Tests for Education project. The project successfully connected remote educational institutions to the Internet. The test sites ranged from rural primary schools in Colorado to a university in Ulaan Baatar, Mongolia. Mr. Hendricks was the CEO and cofounder of Tetherless Access Ltd., one of the first companies to develop and deploy Part 15 unlicensed wireless metropolitan area data networks using the TCP/IP protocols. He has participated in the installation of these networks in other parts of the world, including Kenya, Tonga, Mexico, Canada, and Mongolia. In 1986, he ported the popular KA9Q Internet Protocol package to the Macintosh, allowing the Macintosh platform to be used in packet radio networks. Today, thousands of amateur radio operators worldwide use the NET/Mac system he developed to participate in the global packet radio Internet. This system continues to be developed and deployed by the amateur radio service. He has been involved with radio since receiving his amateur radio operator's license as a teen. Mr. Hendricks currently holds official positions in several national nonprofit amateur radio organizations and is a director of the Wireless Communications Alliance, an industry group representing manufacturers in the unlicensed radio industry.

Bradley Holmes is with Arraycomm, Inc.

SESSION 9: GOVERNMENT AND ACADEMIC R&D

Preston F. Marshall has an almost 30-year background in communications, software and hardware development, and system development. Currently he is with DARPA's Advanced Technology Office, and serves as program manager for the neXt Generation (XG) Communications, WolfPack, and Connectionless networking programs, as well as several smaller efforts. The XG program is developing technology to provide adaptive spectrum algorithms, waveforms, and media access in an integrated, open product. The WolfPack program is developing an electronic and signal intelligence/communications and radar denial system that uses a distributed network of forward-positioned, Coke-can-sized devices and networks the multiple assets to achieve order-of-magnitude increases in capability over conventional standoff technology. Mr. Marshall previously was employed by a number of defense electronics companies and participated in the Trident submarine, missile defense, B-1B electronic countermeasures and acoustic processing programs, and he has supported several Office of the Secretary of Defense offices in the area of spectrum-related policy and technology. Mr. Marshall holds B.S.E.E and M.S. degrees in information science from Lehigh University.

Dipankar Raychaudhuri is a professor of electrical and computer engineering and director of the Wireless Information Network Lab (WINLAB) at Rutgers University. As WINLAB's director, he is responsible for a cooperative industry-university research center with focus on next-generation wireless technologies. WINLAB's current research scope includes topics such as RF/sensor devices, UWB, future 3G and WLAN systems, spectrum management, ad hoc networks, and pervasive computing. Prior to WINLAB, he held progressively responsible corporate R&D positions in telecom and networking, including chief scientist for Iospan Wireless, assistant general manager and department head of systems architecture for NEC USA C&C Research Laboratories, and head of broadband communications research for the Sarnoff Corporation. Research and development highlights include the multimodal sensor-on-silicon center of excellence (MUSE), hierarchical self-organizing ad hoc wireless network for sensors and 4G, and AirBurst, a MIMO/OFDM system for broadband fixed wireless access. Dr. Raychaudhuri holds 10 patents on various topics, including broadband wireless networks, MAC protocols, digital video, and VSAT networks. A past vice-chair of the Wireless ATM Working Group of the ATM Forum, he is also an IEEE fellow and editor of IEEE Multimedia and ACM M2CR. He holds a B.Tech. in electronics and

electrical communications from the Indian Institute of Technology at Kharagpur and M.S. and Ph.D. degrees in electrical engineering from SUNY at Stony Brook.

Moe Z. Win has been since 2002 with the Department of Aeronautics and Astronautics and the Laboratory for Information and Decision Systems at the Massachusetts Institute of Technology, where he holds the Charles Stark Draper Chair. His main research interests are the application of mathematical and statistical theories to communication, detection, and estimation problems. Specific current research topics include measurement and modeling of time-varying channels, design and analysis of multiple antenna systems, ultrawide bandwidth communications systems, optical communications systems, and space communications systems. From 1998 to 2002, he was with the Wireless Systems Research Department at AT&T Laboratories–Research. From 1994 to 1997, he was a research assistant with the Communication Sciences Institute at the University of Southern California (USC), where he played a key role in the successful creation of the Ultra-Wideband Radio Laboratory. In 1987, Dr. Win was at the Jet Propulsion Laboratory of the California Institute of Technology, where he performed research on digital communications and optical systems for NASA space exploration missions. He currently serves as the technical program chair for the IEEE Communication Theory Symposium of ICC-2004. He served as the technical program chair for the IEEE Communication Theory Symposium of Globecom-2000 and the IEEE Conference on Ultra Wideband Systems and Technologies in 2002, technical program vice-chair for the IEEE International Conference on Communications in 2002, and the tutorial chair for the IEEE Semiannual International Vehicular Technology Conference in fall 2001. He is the secretary for the Radio Communications Technical Committee of the IEEE Communications Society. Dr. Win currently serves as area editor for *Modulation and Signal Design* and as editor for *Wideband Wireless and Diversity*, both for *IEEE Transactions on Communications*. He served as the editor for *Equalization and Diversity* from July 1998 to June 2003 for the *IEEE Transactions on Communications* and as a guest editor for the 2002 *IEEE Journal on Selected Areas in Communications* special issue on Ultra-Wideband Radio in Multiaccess Wireless Communications. Dr. Win was awarded a B.S. from Texas A&M University in 1987 and an M.S. degree from the University of Southern California at Los Angeles in 1989, both in electrical engineering. As a Presidential Fellow at USC, he received both an M.S. degree in applied mathematics and a Ph.D. degree in electrical engineering in 1998.

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Biographies of Committee and Staff Members

David E. Liddle, *Chair*, is a general partner in the firm U.S. Venture Partners, a leading Silicon Valley venture capital firm that specializes in building companies from an early stage in digital communications, networking, wireless communications, semiconductors, technical software, and e-health. He retired in December 1999 after 8 years as CEO of Interval Research Corporation. During and after his education (B.S. and E.E., University of Michigan; Ph.D., computer science, University of Toledo), Dr. Liddle has spent his professional career developing technologies for interaction and communication in activities spanning research, development, management, and entrepreneurship. First, he spent 10 years at the Xerox Palo Alto Research Center and the Xerox Information Products Group, where he was responsible for the first commercial implementation of the graphical user interface and local area networking. He then founded Metaphor Computer Systems, whose technology was adopted by IBM and the company ultimately acquired by IBM in 1991. In 1992, Dr. Liddle co-founded Interval Research Corporation with Paul Allen. During his tenure, the company formed six new companies and several joint ventures based on the research conducted at Interval. Dr. Liddle is a consulting professor of computer science at Stanford University. He has served as a director at Sybase, Broderbund Software, Metricom, Starwave, and Ticketmaster; he is currently a director with the New York Times Company, in addition to numerous early-stage companies. He was honored as a distinguished alumnus from the University of Michigan and is a member of the national advisory committee at the College of Engineering of that university. He is also a member of the advisory committee of the School of Engineering at Stanford University and of the College of Engineering at the University of California, Berkeley. He has been elected a senior fellow of the Royal College of Art for his contributions to human-computer interaction. His current technology and investment interests are particularly focused on signal processing, with emphasis on wireless communications.

Yochai Benkler is a professor of law at Yale Law School. His research focuses on the effects of laws that regulate information production and exchange on the distribution of control over information flows, knowledge, and culture in the digital environment. His particular focus has been the neglected role of commons-based approaches toward management of resources in the digitally networked environment. He has written about the economics and political theory of rules governing telecommunications infrastructure, with a special emphasis on wireless communications, rules governing private control over information, in particular intellectual property, and of relevant aspects of U.S. constitutional law. Previously, Mr. Benkler had been a professor at New York University School of Law, where he was director of the Engelberg Center for Innovation Law and Policy and of the Information Law Institute. Mr. Benkler received his J.D from Harvard Law School and his LL.B. from Tel Aviv University.

David Borth is an expert on wireless communications, with insight into national security as well as commercial needs. He is corporate vice president and director of the Communications Research Laboratories of Motorola, a part of the company's research arm, Motorola Labs. Dr. Borth joined Motorola in 1980 as a member of the Systems Research Laboratory in corporate research and development. As a member of that organization, he has conducted research on digital modulation techniques, adaptive digital signal processing methods applied to communication systems, and personal communication systems, including both cellular and PCS systems. He has contributed to Motorola's implementations of the GSM, TDMA (IS-54/IS-136), and CDMA (IS-95) digital cellular systems. In his current role, he manages a multinational (United States, Australia, France, Japan, United Kingdom) organization focusing on all aspects of communication systems, ranging from theoretical systems studies to system and subsystem analysis and implementation to integrated circuit designs. Dr. Borth received his B.S., M.S., and Ph.D. degrees in electrical engineering from the University of Illinois at Urbana-Champaign. Previously, he was a member of the technical staff of the systems division of Watkins-Johnson Company and an assistant professor in the School of Electrical Engineering, Georgia Institute of Technology. Dr. Borth is a member of Motorola's Science Advisory Board Associates and has been elected a Dan Noble Fellow, Motorola's highest honorary technical award. He has been issued 31 patents and has authored or co-authored chapters of five books in addition to 25 publications. He received the Distinguished Alumnus Award from the University of Illinois Electrical and Computer Engineering Alumni Association and was elected a fellow of the Institute of Electrical and Electronics Engineers for his contributions to the design and development of wireless telecommunication systems. He is a registered professional engineer in the state of Illinois. Dr. Borth was a member of the Computer Science and Telecommunications Board from 2000 to 2003. He also served on the CSTB committee that produced the report *Information Technology for Counter-Terrorism: Immediate Action and Future Possibilities* (2003).

Robert W. Brodersen is the John R. Whinnery Distinguished Professor in the Department of Electrical Engineering and Computer Science at the University of California at Berkeley. He is also the co-scientific director of the Berkeley Wireless Research Center, where his research focus is the application of integrated circuits to personal communication systems, with emphasis on wireless communications and low-power design. Dr. Brodersen's research is focused in the areas of low power design and wireless communications and the CAD tools necessary to support these activities. He has won best paper awards for a number of journal and conference papers in the areas of integrated circuit design, CAD, and communications, including the W.G. Baker Award in 1979. In 1982 he became a fellow of the IEEE. He was corecipient of the IEEE Morris K. Liebmann Award in 1983. He received technical achievement awards in the IEEE Circuits and Systems Society in 1986, from the Signal Processing Society in 1991, and in 1999 from the ACM Special Interest Group in Mobile Computing. Dr. Brodersen was elected a member of the National Academy of Engineering in 1988. In 1996, he received the IEEE Solid State Circuits Award. He was awarded an honorary doctorate from the University of Lund, Sweden, in 1999, and in 2000 he received the Millennium Award from the Circuits and Systems Society and the Golden Jubilee Award from the IEEE. In 2001 he was awarded the Lewis Winner Award for outstanding paper at the IEEE International Solid-State Circuits Conference. He has served on the editorial board or as reviewer for numerous scholarly journals and publications, including the *IEEE Journal of Solid-State Circuits*, *IEEE Transactions on VLSI Systems*, *IEEE Personal Communications Magazine,* and *Wireless Personal Communications* (Kluwer Press). He is the author or co-author of over 60 journal publications; 120 published conference papers; and author, co-author, editor, or contributor to 14 books, including *An Anatomy of a Silicon Compiler* (1992, Kluwer Academic Publishers) and *Low Power Digital CMOS Design* (1995, Kluwer Academic Publishers). He received his Ph.D. degree in engineering from the Massachusetts Institute of Technology in 1972.

David D. Clark graduated from Swarthmore College in 1966 and received his Ph.D. from the Massachusetts Institute of Technology in 1973. He has worked since then at the MIT Laboratory for

Computer Science, where he is currently a senior research scientist in charge of the Advanced Network Architecture Group. Dr. Clark's research interests include networks, network protocols, operating systems, distributed systems, and computer and communications security. After receiving his Ph.D., he worked on the early stages of the ARPANET and on the development of token ring local area network technology. Since the mid-1970s, Dr. Clark has been involved in the development of the Internet. From 1981 to 1989, he acted as chief protocol architect in this development and chaired the Internet Activities Board. His current research area is protocols and architectures for very large and very high speed networks. Specific activities include extensions to the Internet to support real-time traffic, explicit allocation of service, pricing, and new network technologies. In the security area, Dr. Clark participated in the early development of the multilevel secure Multics operating system. He developed an information security model that stresses integrity of data rather than disclosure control. Dr. Clark is a fellow of the ACM and the IEEE and is a member of the National Academy of Engineering. He received the ACM SIGCOMM award and the IEEE award in international communications, as well as the IEEE Hamming Award for his work on the Internet. He is a consultant to a number of companies and serves on a number of technical advisory boards. Dr. Clark is currently chair of the CSTB (term ending June 30, 2004). He chaired the committee that produced the CSTB report *Computers at Risk: Safe Computing in the Information Age* and served on the committees that produced several other CSTB reports.

Thomas (Ted) E. Darcie received his Ph.D. in aerospace physics from the University of Toronto in 1982. Currently, he is a professor at the University of Victoria, British Columbia, holding a Tier 1 Canada Research Chair in Optical Systems for Communications, Imaging, and Sensing. Previously he worked at AT&T Bell Laboratories, where he joined the technical staff to study a wide variety of topics related to light-wave telecommunications, including fiber fabrication processes, semiconductor lasers, optical amplifiers, and numerous modulation and multiplexing techniques. He has been a lead figure in the development of light-wave systems for analog applications in cable television and wireless systems. As head of access communications research at AT&T Bell Laboratories (1989-1995), Dr. Darcie was responsible for technology innovation in wireless, light-wave, and hybrid fiber-coax systems. He has authored over 100 technical publications and 25 patents spanning this broad set of technologies. From 1995 to 2002, he was vice president at AT&T Laboratories, in charge of communications infrastructure research. His research laboratory provided technology support for AT&T's diverse requirements in optical networking, broadband access, fixed wireless access, wireless LAN, and cellular systems. His team worked closely with AT&T businesses to provide technical expertise and vision and has numerous programs devoted to the evolution of mobile and broadband services, applications, and technologies. From 2002 to 2003, he was vice president for AT&T Labs' Network Architecture and Strategic Operations Planning, with responsibility for connecting innovative network technologies with opportunities within AT&T's network. Dr. Darcie is an AT&T fellow, a fellow of the IEEE, and is currently a member of the Computer Science and Telecommunications Board.

Andrea Goldsmith received B.S., M.S., and Ph.D. degrees in electrical engineering from the University of California at Berkeley in 1986, 1991, and 1994, respectively. She was an assistant professor in the department of electrical engineering at Caltech from 1994 to 1999. In 1999, she joined the electrical engineering department at Stanford University, where she is currently an associate professor. Her industry experience includes affiliation with Maxim Technologies (1986-1990), where she worked on packet radio and satellite communication systems, and with AT&T Bell Laboratories (1991-1992), where she worked on microcell modeling and channel estimation. Dr. Goldsmith's research includes work on the capacity of wireless channels and networks; wireless information and communication theory; multiantenna wireless systems; energy-constrained communications; communications for distributed control; cross-layer design for cellular systems ad hoc wireless networks; and sensor networks. Dr. Goldsmith holds the Bredt Faculty Development Scholar Chair at Stanford and is a recipient of the National Academy of Engineering Gilbreth Lectureship, Stanford's Terman Faculty Fellowship, a National Science Foundation CAREER Development Award, the Office of Naval Research Young

Investigator Award, a National Semiconductor Faculty Development Award, an Okawa Foundation Award, and the David Griep Memorial Prize from the University of California at Berkeley. She was an editor for the *IEEE Transactions on Communications* from 1995 to 2001 and has been an editor for the *IEEE Wireless Communications* magazine since 1995. She is also an elected member of Stanford's faculty senate and the IEEE Information Theory Society Board of Governors. Dr. Goldsmith served on the CSTB committee that produced the report *Evolution of Untethered Communications* (1997).

Dale N. Hatfield is currently an independent consultant and adjunct professor in the Department of Interdisciplinary Telecommunications at the University of Colorado at Boulder (CU). Between December 2000 and April 2002, Mr. Hatfield served as chair of the department. Prior to joining CU, Mr. Hatfield was the chief of the Office of Engineering and Technology at the FCC and immediately before that was chief technologist at the commission. Before joining the FCC in December 1997, he was CEO of Mr. Hatfield Associates, Inc., a multidisciplinary telecommunications consulting firm in Boulder, Colorado, for 15 years. Before that, Mr. Hatfield was deputy Assistant Secretary of Commerce for Communications and Information and deputy administrator of the NTIA. Before moving to NTIA, Mr. Hatfield was chief of the Office of Plans and Policy at the FCC. In 1973 Mr. Hatfield received a Department of Commerce Silver Medal for contributions to domestic communications satellite policy, and in 1999 he received the Attorney General's Distinguished Service Award. In 2000, he received the PCIA Foundation's Eugene C. Bowler award for exceptional professionalism and dedication in government service and the FCC's Gold Medal Award for distinguished service. More recently, he received the distinguished engineer award from the University of Colorado at Boulder. He currently is a fellow of the Radio Club of America. In February 2001, the FTC appointed Mr. Hatfield as monitor trustee in the AOL/Time Warner merger. Currently, Mr. Hatfield is serving on the board of directors of Crown Castle International and KBDI TV-12 public television in Denver. He holds a B.S. in electrical engineering from Case Institute of Technology and an M.S. in industrial management from Purdue University.

Michael Katz is the Edward J. and Mollie Arnold Professor of Business Administration of the Haas Economic Analysis and Policy Group and Director of the Center for Telecommunications and Digital Convergence at the University of California at Berkeley. From 2001 to 2002, he was Deputy Assistant Attorney General for economic analysis in the Antitrust Division of the Department of Justice. From 1994 to 1996, he was chief economist at the Federal Communications Commission. Dr. Katz is co-editor of *California Management Review* and *Journal of Economics and Management Strategy*. He is a former member of the Computer Science and Telecommunications Board of the National Research Council. He received his Ph.D. in economics from Oxford University.

Paul J. Kolodzy is director of the Wireless Network Security Center (WiNSeC), a new research facility at Stevens Institute of Technology that will draw on wide-ranging expertise to design, develop, and evaluate technology for the secure transmission of voice, video, and data. He is also is a professor in the schools of Engineering and Technology Management at Stevens. Previously, Dr. Kolodzy had been appointed as the senior spectrum policy advisor at the FCC, and he was also chair of the FCC's newly created Spectrum Policy Task Force, which was charged with examining spectrum allocation processes and other issues so that spectrum can be put to the highest and best use in a timely manner. Before joining the FCC, Dr. Kolodzy served as a program manager within the Advanced Technology Office at DARPA in the Department of Defense. At DARPA, he oversaw the development of next-generation communications technology, which included the neXt Generation Communications (XG) initiative. The XG project is developing technology that has the potential to fundamentally change the manner which spectrum is allocated and assigned. Dr. Kolodzy has also held positions at MIT's Lincoln Laboratory and Lockheed Martin Corporation in the development and management of advanced signal processing, RF, and EO systems. He received a B.S. from Purdue University in chemical engineering and an M.S. and a Ph.D. in chemical engineering from Case Western Reserve University. His doctoral work focused on

laser measurement systems.

Larry Larson is professor of electrical and computer engineering and director of the Center for Wireless Communications at the University of California, San Diego (UCSD). Dr. Larson's research ranges from electronic circuits and systems to electronic devices and materials. He develops high-speed circuits based on InP (indium phosphide) and GaAs (gallium arsenide) as well as silicon-germanium and CMOS technology. He also explores applications for micromachining technology in the manufacture of high-speed integrated circuits and studies new packaging technology for them. Dr. Larson's current research is specifically also focused on low-power circuit design and RF design techniques for wireless communications. He recently completed *CDMA Mobile Radio Design*, a book on how to design the hardware and software for wireless handsets based on code-division multiple access technology. CDMA is the foundation of all third-generation wireless technologies, including Europe's W-CDMA standard and CDMA2000. As director of the industry-sponsored Center for Wireless Communications (CWC) at UCSD, Dr. Larson is in a unique position to comment on the development and deployment of 3G wireless, including new generations of circuits. He oversees a wide range of ongoing research projects, with funding from CWC's 17 corporate members. He is the first holder of the Communications Industry endowed chair at the Jacobs School. He joined the UCSD faculty in 1996, after a 16-year career at Hughes Research Laboratories, where he pioneered the development of analog integrated circuits and low-noise HEMTs in III-V technology, as well as microwave integrated circuits in SiGe HBT technology and RF MEMs technology. Dr. Larson received his Ph.D. from the University of California at Los Angeles in 1986. He is an IEEE fellow and co-winner of the 1996 Hughes Electronics Lawrence Hyland Patent Award and the 1999 IBM Microelectronics Excellence Award.

David P. Reed is a fellow at HP Labs and an adjunct professor at the MIT Media Laboratory. Dr. Reed's work focuses on using digital technology to transform the design of technological, business, and social systems. His current explorations center on exploiting new information technologies that enable people to be more effective, including mobile computing; highly scalable wireless networking; group information sharing; pervasive networking; video media processing; and infrastructures for electronic commerce. Dr. Reed spent 4 years at Interval Research Corporation, exploring portable and consumer media technology. For 7 years prior to joining Interval, Dr. Reed was vice president and chief scientist for Lotus Development Corporation, where he led the design and implementation of key products, including 1-2-3, and technical business strategy. Dr. Reed was also a professor in MIT's Laboratory for Computer Science. He is co-inventor of the end-to-end argument, often called the fundamental architectural principle of the Internet. Dr. Reed holds a B.S. in electrical engineering and M.S and Ph.D. degrees in computer science and engineering from MIT.

Gregory L. Rosston is the deputy director of the Stanford Institute for Economic Policy Research. His research focuses on industrial organization, antitrust, and regulation. He has written numerous articles on competition in local telecommunications, implementation of the Telecommunications Act of 1996, auctions, and spectrum policy. He has also co-edited two books, including *Interconnection and the Internet: Selected Papers from the 1996 Telecommunications Policy Research Conference*. Prior to joining Stanford University, Dr. Rosston served as deputy chief economist of the FCC. At the FCC, he helped to implement the Telecommunications Act. In this work, he helped to design and write the rules the commission adopted as a framework to encourage efficient competition in telecommunications markets. He also helped with the design and implementation of the FCC's spectrum auctions. Dr. Rosston received his Ph.D. in economics from Stanford University and his A.B. in economics from the University of California at Berkeley.

David Skellern is currently the technology director for Cisco's Wireless Networking Business Unit. He has been a consultant for leading companies in the United States, Europe, and Japan on the development of multiservice and broadband communications networks. He held a senior staff faculty

position at HP Laboratories from 1993 to 1999. In 1989, Dr. Skellern joined Macquarie University as professor of electronics. While at Macquarie University, he worked to develop the core technologies that led to the formation of Radiata Communications Pty Ltd. in 1997. He received B.Sc. (1972), B.E. (1974), and Ph.D. (1985) degrees from the University of Sydney.

STAFF

Jon Eisenberg, study director, is a senior program officer with the Computer Science and Telecommunications Board of the National Research Council. At CSTB, he has been study director for a diverse body of work, including a series of studies exploring networking technologies and Internet and broadband policy. Current studies include an examination of emerging wireless technologies and spectrum policy and a review of the National Archives and Records Administration's digital materials preservation strategy. From 1995 to 1997, Dr. Eisenberg was an AAAS Science, Engineering, and Diplomacy Fellow at the U.S. Agency for International Development, where he worked on environmental management, technology transfer, and telecommunications policy issues. He received his Ph.D. in physics from the University of Washington in 1996 and B.S. in physics with honors from the University of Massachusetts at Amherst in 1988.

Julie Esanu is a program officer for the Office of International Scientific and Technical Information Programs (ISTIP) at the National Academies. Her emphasis is policy and management issues related to digital scientific and technical data and information, primarily through the support of the U.S. National Committee for the Committee on Data for Science and Technology (CODATA), an interdisciplinary committee of the International Council of Science. Ms. Esanu is the coeditor of two recent and related National Academies reports, including *Open Access and the Public Domain in Digital Data for Science: Proceedings of a Symposium* (National Academies Press, forthcoming) and *The Role of Scientific and Technical Data and Information in the Public Domain: Proceedings of a Symposium* (NAP, 2003). She worked with the Computer Science and Telecommunications Board to convene a workshop on the spectrum management policy reform and has provided program and research support to other National Academies' projects examining the role of remote sensing research and applications; reviewing C4I planning for the Department of Defense; assessing research programs at the Army Research Laboratory; and examining the allocation of federal research and development funds. Ms. Esanu received her bachelor's degree in political science and international affairs from the George Washington University.

Kristen Batch is a research associate with the Computer Science and Telecommunications Board of the National Research Council. She is involved with the project focusing on wireless communication technologies and telecommunications research and development. While pursuing an M.A. in international communications from American University, she interned at the NTIA, in the Office of International Affairs, and at the Center for Strategic and International Studies, in the Technology and Public Policy Program. She also earned a B.A. from Carnegie Mellon University in literary and cultural studies and Spanish and received two travel grants to conduct independent research in Spain.

Margaret Marsh Huynh is a senior program assistant with the Computer Science and Telecommunications Board of the National Research Council since January 1999 supporting several projects. She is currently supporting The Future of Supercomputing, Wireless Technology Prospects and Policy Options, and Internet Searching and the Domain Name System: Technical Alternatives and Policy Implications. She previously worked on the projects that produced the reports *Beyond Productivity: Information Technology, Innovation, and Creativity*; *IT Roadmap to a Geospatial Future*; *Building a Workforce for the Information Economy*; and *The Digital Dilemma: Intellectual Property in the*

Information Age. Ms. Huynh also assisted with the project Exploring Information Technology Issues for the Behavioral and Social Sciences (Digital Divide and Democracy). She assists on other projects as needed. Prior to coming to the NRC, Ms. Huynh worked as a meeting assistant at Management for Meetings and from September 1996 to April 1998 as a meeting assistant at the American Society for Civil Engineers. Ms. Huynh has a B.A. (1990) in liberal studies with minors in sociology and psychology from Salisbury State University, Maryland.