

Broadband 2021

Report of the Interdisciplinary Workshop on the
Development of a National Broadband Research Agenda

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Broadband 2021 Report

1. Introduction

In June 2016, the Institute for Information Policy (IIP) at Penn State University organized a two-day, interdisciplinary workshop on the technology, utilization, and impacts of high-speed broadband networks, with the goal of identifying a “national broadband research agenda” to advance the deployment, utilization and impact of broadband in the United States. Close to 60 experts drawn from academia and government met at the premises of the National Science Foundation at Arlington, VA for the two-day workshop. This Report presents the preliminary findings of the workshop.

2. Background

In March 2015, a Presidential Memorandum created the Broadband Opportunity Council (BOC), tasked with producing “specific recommendations to increase broadband deployment, competition and adoption within the scope of existing Agency programs, missions and budgets.” Twenty-six executive agencies with some role in broadband deployment, promotion, data collection or research were members of the BOC. The BOC defined its guiding principles as identifying and removing regulatory barriers to the deployment of broadband infrastructures, encouraging public and private investments in networks and services, promoting adoption and meaningful use of broadband, and accomplishing the above in ways that promote the public interest. Agencies who were members of the BOC volunteered to undertake a number of initiatives including efforts to “improve data collection, analysis and research on broadband.”

The National Science Foundation (NSF) and the National Telecommunications and Information Administration (NTIA) undertook to “develop a national research agenda, prototype advanced applications and improve data collection, analysis and research on broadband.” In accordance with this goal, NSF tasked the Institute for Information Policy (IIP) at Penn State University with organizing a national workshop bringing together leading academic scholars and other experts in a workshop to define a national agenda for broadband research.

The workshop was centered on three tracks of discussion: (1) advanced broadband technology, including new networking technologies, applications and services; device accessibility studies; project implementation and evaluation; (2) programs, services and applications that drive broadband usage, including emerging broadband applications, digital literacy programs and community networking; access for disadvantaged populations such as persons with disabilities and tribal reservations; and (3) assessment of economic, social, and educational impacts (including aspects of broadband opportunity related to adoption, availability, and access). Within each track, participants considered broad themes and specific questions for a research agenda; the state of theoretical and methodological knowledge; and the availability, quality and accessibility of data sources to conduct research. To facilitate discussion and interaction, the workshop was divided into three concurrent breakout sessions each focusing on a track, in addition to plenary sessions and keynote speeches. The full program is included as Appendix A.

Participants at the Workshop were drawn primarily from academia, complemented by representation from government agencies, civil society organizations and foundations. In consonance with the aims of the Workshop, we brought together specialists in broadband technologies, usage studies and social/economic impacts. A special effort was made to be geographically representative and demographically inclusive; for example, attendees included representatives from organizations serving minority and tribal populations and persons with disabilities, groups that are generally understood to be underserved by broadband. A full list and brief biographies of all participants is provided in Appendix B.

Three well-respected scholars agreed to serve as the rapporteurs for the three tracks. Rapporteurs were responsible for identifying topics for discussion, structuring the breakout sessions with the assistance of moderators, and compiling the reports on the discussions within their tracks. The Rapporteurs were Professor Jon Peha of Carnegie Mellon University for the Technology Track, Professor Sharon Stover of the University of Texas at Austin for the Usage Track, and Professor Johannes Bauer of Michigan State University for the Impacts Track.

In the sections below, we first delineate “Assumptions Behind a National Broadband Research Agenda” that emerged from discussions at the Broadband 2021 Workshop. Then in separate sections we identify an outline of the national broadband research agenda, constituted of major themes and specific research questions in each of the three tracks. A separate section provides recommendations to executive Agencies regarding steps to facilitate the implementation of the national broadband research agenda. Additional information about the Workshop schedule and participants is provided in Appendices A and B.

3. Assumptions Behind a National Broadband Research Agenda

Inseparable from a national broadband research agenda is a particular conception or vision of the role of broadband in social, economic and political activity, and in our national life in general. This vision is founded on a variety of factors: *a priori* assumptions about the role of technological progress in the improvement of human life and society, normative expectations and ethical norms regarding the ordering of social life, theoretical speculations, historical memory, empirical observations and methodical study. Scholarly research is guided and animated by this vision, and in turn research challenges, tests and eventually modifies our assumptions and expectations regarding the role of broadband in society. The articulation of a national research agenda for broadband therefore has to begin with an examination of our fundamental assumptions and expectations regarding the role of broadband. The following assumptions and expectations were articulated in Workshop discussions.

1. *Broadband is a net positive good, but its effects are neither uniform nor unqualified.*

Though research on the impacts of telecommunications since at least the late 1960s has demonstrated the positive effects of broadband on individual empowerment, economic growth and community development, these effects are not uniform, undifferentiated, or unqualified. Individuals, communities, businesses and economic sectors differ in their ability to benefit from broadband, depending on a number of factors related to individual/community characteristics and environmental factors. Successful incorporation of broadband in daily life, business, and economic activity is dependent on the presence of enabling conditions such as the availability of a digital skills, an educated workforce, managerial talent, and organizational changes.

Not all individuals and communities are likely to place a positive valuation on broadband access. Some individuals and communities may experience a net disutility from broadband access, originating from perceptions of online privacy violations, increased access to harmful content such as pornography, terroristic propaganda, and hate speech. Communities may also experience the loss of economic autonomy, since broadband enables the constitution of larger markets through demand aggregation and expanded distribution networks. Broadband may contribute to growing income inequality, and enhanced connectivity may serve to reinforce existing social structures and beliefs, rather than challenge them.

Research on the economic and social impact of broadband also needs to be updated and strengthened, to ensure that we are studying the effect of broadband technology specifically (and not legacy “connectivity” generally). However, inadequate data sources today hamper this effort.

Balancing both positive and negative impacts, the consensus of the research community is that broadband is a net positive good. Therefore, researchers and policymakers must investigate options to deploy broadband in ways that maximize the benefits while minimizing and compensating for the negative impacts.

2. Programs of broadband deployment are necessary, and need to address persistent impediments to access and usage.

Data demonstrate that all technologies, including broadband and information and communication technologies, have diffused over time with some individuals, businesses, communities and economic sectors being early adopters and others following later. However, some communities have experienced gaps in access and usage that have persisted over time and multiple generations of technology. The diffusion of advanced broadband networks and services has sometimes widened these gaps to the detriment of the economic competitiveness of individuals and communities. The loss of economic competitiveness as a result of gaps in broadband access and usage is sometimes irreversible: for example, the locational choices of firms are made based on access to information infrastructures and a given community may not be able to recover its competitiveness even if it later catches up in terms of its technology infrastructure; we note, however, that such locational path-dependence is a general economic development phenomenon and not unique to the diffusion of broadband. Nonetheless, understanding why and how these gaps occur, and how to address them, may be necessary to achieve inclusive, fair and socially just broadband deployment.

3. Broadband is a platform for innovation, which needs to accommodate not just current needs but also emergent demands.

Broadband has been recognized as a general purpose technology that may be utilized for a variety of economic activities, and as a testbed for innovations in technology, business models and services. A critical mass of users attracts innovators and entrepreneurs on the supply side engendering innovation in services such as education, health care, and other social/public services, and the new products and services the innovators create attract even more users. This virtuous cycle has been characterized as dynamic network externalities. In order to fully benefit from these dynamic effects, network architectures and capabilities have to be sufficiently advanced and flexible. Workshop participants acknowledged the possibility that innovation in technology and services may exacerbate gaps in access and usage, and that those who are digitally excluded are not at the table when innovators and entrepreneurs come up with new technologies and products,

which exacerbates digital inequality. But they characterized this as a necessary consequence of fostering an innovative broadband environment.

4. *Human infrastructures need to keep pace with technological infrastructures to promote inclusive broadband.*

Broadband and the Internet are socio-technical systems. Technological infrastructures alone cannot have the maximum impact on individuals and communities unless accompanied by appropriate human and social infrastructures. Broadband deployment has to parallel the development of services and support functions, content development, digital literacy and job skill training, community informatics, and other capacity generation initiatives in order to enable individuals, communities and businesses to integrate, utilize and benefit from broadband.

5. *Technology, usage and impacts are interrelated domains, and understanding any domain needs careful consideration of the others.*

Technologies, usage patterns and broadband economic and social impacts are often discussed separately, and within separate disciplinary communities—broadly, engineers/computer scientists, social scientists and economists. However, usage patterns are often delimited by technological capabilities, while the uptake of technologies is based on often-unpredictable and sometimes surprising uses invented for them; and economic impacts are premised on both. Workshop participants called for multidisciplinary approaches to understand broadband.

6. *Broadband metrics need to go beyond simple measures of network coverage and availability to include better data on subscriptions and speed, and engage with actual usage contexts.*

Meaningful use of broadband is a complex phenomenon for which network coverage is a necessary but not sufficient condition. It is also premised on the availability of relevant content, affordability, the accessibility of devices and apps, and digital literacy. It also implicates the contexts in which broadband is accessed and used: the social and familial setting, school or work, libraries, public centers, and communities. Research on meaningful use requires rich data on the actual contexts of use. Measuring meaningful use extends beyond the “residential adoption rate” and includes the extent to which businesses are adapting and incorporating broadband technology, and the extent to which the workforce has the skills necessary to employ broadband-enabled tools.

7. *Broadband interventions need to be theoretically informed and evidence-based.*

Research has identified a number of theories, methods and frameworks from fields as diverse as sociology, media studies, psychology, and economics explicating and predicting aspects of broadband such as the uptake of new technologies, usage patterns, and impacts. Workshop participants opined that broadband interventions have to be targeted and calibrated based on the accumulated knowledge about the Internet, interactive technologies, and broadband, and their usage and impacts. More basic scientific work needs to be done on formulating appropriate theories and methodologies to study broadband, and concerns remain about the quality and availability of data.

In the following sections, we present the broad themes of a research agenda that emerged out of Workshop deliberations. For convenience of presentation, we follow the same organization as identified in our charge—Technology, Usage and Impacts, in that order—although even a cursory

examination of the sections is enough to demonstrate that the three tracks are interrelated and several of the Themes cut across two or all three of the tracks.

4. Technology

In this section, we consider aspects of the National Research Agenda related to advanced broadband technologies, including new networking technologies, applications and services; device accessibility studies; and project implementation and evaluation. The presentation is divided into a number of broad themes: for each we present a summary of the workshop discussions pertaining to the theme, and examples of research questions that are motivated by that theme. Recommendations to enable the research community to investigate the questions in this National Research Agenda are reported at the end.

THEME: Technology and Engineering Economics

Workshop participants discussed the importance of cost in the expansion of broadband infrastructure, including both bringing broadband to unserved regions and substantially improving the technical capabilities of broadband infrastructures that have already been deployed. Cost impacts the availability of both new, groundbreaking technologies as well as incremental improvements to relatively mature technologies. The development of new technologies to address small underserved markets, such as those in remote rural areas or for persons with disabilities, must overcome the conundrum that these communities need low cost services, but low cost normally comes only with scale. We also need to consider operating costs (power, maintenance, upgrades, etc.), that can also increase costs especially in rural/remote regions. Research on broadband technologies typically addresses technical design, and how design choices affect capabilities such as the ability to support high data rates, superior user experiences, rapid mobility, or strong security. While technical capabilities are important, more research is needed to understand the evolving engineering-economics of broadband systems as new technologies are deployed. Research will need to separately address the quite different engineering-economic characteristics of broadband infrastructures and broadband applications, which together comprise broadband systems. Such research should assess the potential for novel or emerging approaches to be more cost-effective than, and not just technically superior to, approaches already in use, analyze the potential of ‘design for low cost’ approaches, and design private-public systems that enable development of technologies to close service gaps.

RQ1: What factors should be considered in engineering-economic models of broadband systems that employ novel technical approaches?

RQ2: Are there technical approaches that have the potential to make fixed or mobile broadband systems more cost-effective than they are today?

RQ3: Are there decisions involving technical design, business arrangements, or public policy that would substantially affect the cost-effectiveness of given approaches to the design and operation of broadband systems? Do measures of cost-effectiveness change depending on the setting (e.g.,

remote and rural areas), particularly given differences in business arrangements and public policy that affect these settings?

RQ4: What is the anticipated roadmap for the development and deployment of new fixed and mobile broadband technologies over the next two decades, and what are the implications for access and new services?

RQ5: How are new software-centric broadband networking technologies, such as software defined networking (SDN) and network function virtualization (NFV), likely to be deployed in broadband infrastructure and how what will be the impact on interactions of the players across the end-to-end broadband system.

THEME: Access to Spectrum

As described in the U.S. National Broadband Plan, access to spectrum is a key driver of the growth of broadband systems. Mobile Internet services require spectrum. Even in fixed Internet services, wireless connections are important, from Wi-Fi links used by edge devices to microwave links closer to the core. As demand for spectrum grows among commercial service providers, government agencies, and others, traditional approaches to spectrum management will become increasingly inadequate. We need to find new ways to use spectrum more efficiently, often through new forms of spectrum sharing, and new ways of making more effective use of previously underutilized spectrum. Basic research is needed on approaches that would alleviate the shortage of available spectrum. We also need experimentation to understand the potential impact of new and existing technology, and observation of spectrum usage. Experimentation and observation should take place in a variety of environments, including urban areas, rural areas, and tribal lands. Some of the most important spectrum research and experimentation is highly interdisciplinary, because it may involve advanced wireless technology, economic incentives, and spectrum policy and regulations in complex and intertwined ways. The fact that effective research has to be multidisciplinary creates a challenge for traditional research funding mechanisms that are rooted in a single academic discipline.

Participants felt that there has not been enough collaboration between industrial players involved in new spectrum sharing technologies, and academic experts and the communities that deploy such technologies in situ. There are several industrial players such as Spectrum Bridge and Google that provide TV white spaces spectrum databases. There are other players that build network equipment for shared spectrum access and there are communities that run networks using these experimental technologies (ASA Networks, several communities in Africa through the 4Africa initiative and others). None of these deployments have been studied academically and important lessons may be learned from the evaluation of such real deployments that will advance technology, policy and incentivize mass-production.

RQ1: What wireless technologies and spectrum management approaches would allow more systems to share a given block of spectrum while achieving adequate quality of service for all?

RQ2: What wireless technologies and spectrum management approaches would lead to more effective use of spectrum that may have been underutilized in the past, such as spectrum at high frequencies?

RQ3: What wireless technologies and spectrum management approaches would create appropriate incentives for efficient use of spectrum by users from both the public and private sectors?

RQ4: How will the increasing popularity and allocation of spectrum for unlicensed bands impact future plans for spectrum sharing and rules for coexistence with licensed spectrum bands?

THEME: Edge Empowerment

The term “edge” has multiple meanings, but in this context we refer to devices operated by end users that typically connect to network service providers, such as smartphones, vehicular routers and home routers. Workshop participants discussed the possibility of usable edge empowerment, whereby edge devices are given greater control over various functions rather than networks. After relationships have been established with multiple Internet access providers, edge devices could dynamically manage connections with each, perhaps seamlessly migrating from one cellular carrier to an independent Wi-Fi hotspot to a vehicular network and then to a competing cellular carrier. These same edge devices could also decide to multihome, that is, to connect opportunistically to multiple broadband providers simultaneously. These approaches may benefit users in a number of ways. Dependability could be increased, because devices can remain connected as long as just one of the networks is available. Data rates can be improved by using multiple services simultaneously. Seamless migration and multihoming could also have important economic implications, as it will cause providers of broadband services to compete in new ways.

A related question is whether users will connect all their devices to a broadband provider through a single router, and the Internet access provider will manage this as a single connection, or whether we will move towards per-device connections. ISPs could adopt virtual residential gateways that tailor services on a per device basis, perhaps improving service through customization, although the visibility that ISPs would gain also raises important privacy issues. At the same time, user devices with edge empowerment could migrate individual flows from provider to provider to meet their needs.

RQ1: What technical approaches would be most effective for migration and multihoming?

RQ2: What are the costs, benefits and risks of empowering end user devices to migrate and multihome?

RQ3: How would migration and multihoming affect competition, investment, and innovation?

RQ4: What are the impacts of multihoming and usability for underserved communities?

RQ5: How do current pricing schema affect the development and use of edge and multihoming technologies? What pricing schemes might incentivize more efficient or effective network development?

THEME: Usability

Another form of edge empowerment is to give edge devices rather than content providers greater control over how information is presented to users. For example, in the hands of a hearing-impaired user, an edge device might choose to display video with text captions. In addition to research at the technical level, some new technical approaches will require user studies to investigate how

diverse user groups adapt to integrated services. Better usability could also give users better visibility into and control over how their data is used, thereby improving privacy, and can help enhance security, e.g. by managing software updates effectively while observing other user concerns, such as monthly data quotas.

RQ1: Could new design principles and toolkits help developers create edge devices with more user-friendly interfaces for users?

RQ2: How might these principles and toolkits be used to better meet the needs of individuals with disabilities and other underserved populations?

RQ3: How might these principles and toolkits be used to improve privacy and security?

THEME: Broadband Infrastructure Resilience

Disasters can reduce the functionality of broadband systems or take them down entirely just when communications capacities are needed most. During a disaster and in its aftermath, society depends on a wide range of broadband systems, including the Internet, cellular networks, 911 systems, communications systems used by first responders, broadband systems that support broadcasting and emergency alerts, and broadband systems embedded in critical infrastructure such as the electricity grid. All of these may be in danger during natural disasters, such as hurricanes and earthquakes, and during man-made disasters such as the terrorist attacks that occurred on September 11, 2001. Both forward-looking research and near-term applied research are needed to find ways to make communications systems more useful and resilient when disasters occur. This may include methods of analyzing systems to assess their resilience, methods of making critical system components more reliable when disasters occur, and methods of making entire systems more reliable through fault tolerant designs that allow the systems to operate to the extent possible even with some portions of the system have been destroyed. We must understand the trade-offs between these approaches. For example, research is needed to understand flexible approaches to fault tolerance such as dynamically reconfiguring links if destroyed by a natural disaster, and the trade-offs in cost and scalability between building redundant links versus increasing the reliability of individual links. We must also develop more nuanced understanding of the cost of improved resilience, to support informed decisions about the level of resilience that is appropriate.

RQ1: How do we measure the resilience of broadband systems to disasters? Using these measures, how resilient are important broadband communications systems today?

RQ2: How do we make communities more resilient with broadband systems and better able to respond to disasters?

RQ3: What technical approaches are possible to improve the resilience of broadband systems, and how do they compare with respect to performance effectiveness and cost-effectiveness?

RQ4: What incentives do public and private sector operators of broadband systems have to improve resilience, and how might changes in technology, business practices, or public policy affect these incentives?

RQ5: How might the resilience of broadband systems vary for underserved communities such as Native nations? How might broadband system resilience be improved in cases of communities with unique needs?

THEME: Emergency Communications for Persons with Disabilities and Non-English Speakers

During emergencies, an individual's life may depend on his or her ability to use communications systems. When there is risk of fire or hurricane, everyone should have the ability to access emergency information systems, examples of which include the Integrated Public Alert and Warning System, Wireless Emergency Alerts, and various systems run by local governments and private-sector organizations. It is also important that everyone can call 911 for help. However, applications are not always designed in a way that makes this easy for individuals with disabilities, or for those with low English proficiency. One useful approach for emergency alerts is multimodal communications, whereby information is conveyed in a variety of formats (perhaps including text, audio, video, sirens, flashing lights), so that recipients can choose the format that suits them. Another useful approach is to support real-time conversion, perhaps from audio to text, or from English to Spanish. Technology can also improve our ability to determine who should receive information during an emergency, and to disseminate information more rapidly. Improvements are similarly possible for the 911 system. The U.S. has begun a transition to a next-generation 911 system (NG911). Moving beyond a voice-only system and giving users a choice of media should create new opportunities to improve service for individuals with disabilities, perhaps taking advantage of everything from text messaging to videoconferencing. For both emergency alerts and 911, further work is needed to assess and incrementally improve today's systems, and to seek even better approaches in the future. Work will also be needed to assess the needs of first responders (e.g. FirstNet) as well as the public.

RQ1: How effectively do today's emergency communications systems meet the needs of individuals with disabilities, or with low English proficiency?

RQ2: How can current communications systems be improved to better meet these needs? What are the costs, benefits, and tradeoffs of doing so?

RQ3: What new and emerging technical approaches could lead to better emergency communications for these populations in the long term?

RQ4: How can we provide incentives to deploy the more cost-effective approaches to meeting the needs of persons with disabilities or low English proficiency for emergency communications?

THEME: Trust, Privacy and Security

Concerns over privacy and security cause some individuals to substantially reduce their Internet use, and can lead others to stay away from the Internet entirely. Some workshop participants believe that this effect is even greater among some disadvantaged populations where levels of mistrust are higher, or where arguments for non-centralized control are stronger. (For example, there is widespread demand that tribes should keep their own data and not the federal government.) Thus, one way to expand broadband use is to improve security and privacy protection of devices and applications that use broadband. Such improvements are necessary but not sufficient when the

goal is improving trust. For this, it is also important for users to have some visibility into when their systems and their data are being protected and by whom/which entity or government, and conversely, when they are not protected. Some technical trends may exacerbate privacy and security problems. For example, the emerging Internet of things may bring additional devices that lack strong privacy and security protection, but have access to sensitive information and/or the ability to control devices that affect people's lives. When seeking ways to improve trust, there are complex tradeoffs that must be taken into consideration. For example, trust can often be enhanced by giving end users greater visibility and control over how devices and applications work, but this also increases the burden on users, thereby decreasing usability. It is also important to understand the myriad causes for privacy and security problems, including purely technical challenges, challenges of coordination and possibly standardization across devices and platforms, and lack of incentives for strong security or privacy protection. Beyond user education, are there technologies, applications, and in-home network management tools that can help establish and maintain trust? Investigations need to consider the unique contexts of underserved communities and their relationships with law enforcement and government as part of the trust relationship with broadband infrastructure. Finally, research should examine whether there is a role for policy or standards, similar to those established for flame-retardant fabrics in children's pajamas, which can generate the necessary simplicity and ease-of-decision making for widespread consumer adoption.

RQ1: How can we conceptualize and measure privacy, trust and security in a networked environment, and how well do systems in use today rate?

RQ2: To what extent do issues of trust, privacy and security deter adoption or use of broadband today?

RQ3: What technical changes will help to increase the trust users place in broadband communications systems, devices, and applications?

RQ4: Would changes in technical standards, business practices, or public policies increase incentives to make systems more trustworthy? What governments and agencies standards, protocols, policies and incentives must be changed? For example, what policies can and might tribal governments adopt to improve trust and thus communication?

RQ5: Can we identify best practices or minimum standards of protection that should always be adopted in certain kinds of systems?

RQ6: How will underserved communities adopt and use technical capabilities that are intended to improve trust, privacy and security? What are their unique needs and how should these needs influence design? Which agency standards, protocols, policies and incentives must be changed? For example, what policies can and might tribal governments adopt to improve trust and thus communication?

RQ7: What are the most effective means of consumer education on privacy and security for various user populations? How should effectiveness be evaluated? How should consumer education be made available – as part of school curricula? Other means?

THEME: Measuring User Experience

It is difficult to improve a system's performance if one cannot measure it. With meaningful measurement, it is possible to determine which broadband system is best at meeting the needs of

a given user, and whether systems are improving over time as technology changes. Network engineers typically measure performance in terms of technical parameters such as packet loss, data rate, and latency, but such measures do not always accurately reflect the actual user experience. Measuring user experience requires interdisciplinary research that takes into account how users perceive performance, as well as what can be measured at the network level. The resulting measurements of user experience will necessarily depend on the types of applications that are in use.

RQ1: How should we measure the quality of user experience for a given set of applications that operate over broadband networks?

RQ2: If we seek to maximize the quality of user experience as measured in this way, how would this change the way we design broadband networks, devices and applications?

RQ3: How does the quality of user experience offered by broadband Internet service providers vary from place to place across the nation, e.g. from rural regions to urban regions, or high-income regions to low-income regions? How is it changing over time?

RQ4: What new network management technologies are forecast to define, manage and provide quality of user experience? What are the implications of these new technologies on the overall broadband network architecture and the types of services that can be supported?

THEME: Providing Publicly Available Data about Existing Broadband Infrastructure While Maintaining National Security and Private Sector Competitiveness

Workshop participants believed that government should do more to make data about existing wired and wireless infrastructure available, accurate and up-to-date. While there are great advantages to making such information available to network planners and to researchers, there are sometimes security risks associated with making such information available to adversaries who may wish to intercept communications, jam wireless transmissions, or destroy critical infrastructure. In a competitive broadband market, making this information public may also have a positive or negative impact on competition. Finally, there might be privacy interests in the data. Further research is needed to understand the potential issues surrounding disclosure, and how to address them.

RQ1: How do we assess both the benefits and risks of public disclosure of data on broadband infrastructure and availability?

RQ2: Are there obfuscation strategies that substantially reduce any risks while preserving much of the benefit?

RQ3: What do Native nations want to know about broadband infrastructure and availability on their lands and for their citizens? What might they be giving up if additional data are collected? Who should be studying tribes' broadband infrastructure and availability?

5. Usage

Longstanding interest in access to and use of various technologies has driven a great deal of research and data-gathering. In the domain of computers, the Internet, and digital literacy, such tracking and assessment has been a key input into national thinking about a range of subjects including STEM education, digital literacy, local economic development opportunities, and a range of equity considerations. NTIA and the U.S. Census Bureau began to track patterns of computer ownership, for example, from the mid-1980s, when personal computers began to diffuse into homes. Computer ownership and use emerged in a pattern that would be replicated later on when Internet connectivity was added to the equation: better education and higher income correlated with higher levels of computer ownership as it did eventually with Internet access, adoption and use. NTIA's often-cited surveys and reports provide a chronicle of how these significant technology systems became associated with the digital divide; the Agency's 1995 study *Falling through the Net: A Survey of the "have nots" in Rural and Urban America* makes the connection between the telecommunications policy goal of universal service, with its equity concerns, and the new information environment represented by the "personal computer and modem."¹ Over time, of course, this language slid into "broadband," a term with many connotations that elide technology, capacity, and digital literacy among other things.

While the availability of computers is directly linked to purchasing abilities (i.e., affluence), the opportunity to connect to the Internet and actually make use of its resources reflects a constellation of capabilities and opportunities that include but go beyond income. The discussion in this workshop underscores continuing concerns with the role of geographic place and affordability in the deployment and adoption of broadband, but alongside those factors is the recognition that the very term "broadband" has become shorthand for a group of related ideas spanning the contemporary capacity to engage meaningfully with a broad information environment. Use environments, differential effects on various subgroups and populations, and broad impacts on content domains also constitute vital research interests.

THEME: Alternative definitions of broadband access, adoption and use

Even as computers and modems have been replaced by the generic notion of "access to broadband," what exactly is meant by the term broadband is not consistently defined. Alternative frameworks have been constructed to talk about broadband as a technological threshold, as a set of devices, and as a set of human capabilities often framed in terms of availability, adoption and use of broadband. Policymakers from diverse fields such as housing, health, and telecommunications also have invoked "broadband" in both specific and nonspecific ways. Each frame suggests different issues. The matter of a technology frame may invoke technological standards for data rates and latency, but also raises issues of end-user technologies and how these devices—tablets, smartphones, laptops—influence types of user engagement. A policy frame may be more concerned with the issue of universal service, a longstanding principle in American social history that implies equitable distribution of and access to technological capabilities; considering broadband from this perspective might suggest questions regarding the geographic distribution of wireline and wireless infrastructure and affordability. The idea of "adopting home broadband" for

¹ National Telecommunications and Information Administration (NTIA), *Falling through the Net: A Survey of the "have nots" in Rural and Urban America* (1995). <https://www.ntia.doc.gov/ntiahome/fallingthru.html>

example, raises assumptions about the cultivation and maintenance of digital literacy skills – particularly in the face of evolving software and hardware capabilities.

If we think of broadband as a communication medium, it is clear that not only does it accommodate and alter older media forms and delivery systems such as broadcast, but also it creates entirely new ways to access existing content while likewise creating opportunities to produce and use entirely new content. Broadband as a communications medium affects both privately- and publicly-produced media systems in numerous ways.

Different ways to frame what broadband is or may be can shape our notion of use. Framing “broadband” as a communications medium indicates that research should explore whether the medium is adequately serving the information needs of society, whether gaps in those information needs are present, and how those can be filled. Some consensus or at minimum acknowledgement of the specific frames invoked in our definitions of broadband would be useful in future research.

RQ1: How do different definitions of broadband map to alternative conceptions of uses and outcomes, and how do these definitions evolve over time (broadband as a moving target)?

RQ2: What capabilities are associated with different broadband environments, and for which communities?

RQ3: How do different modes of using broadband affect the practices of people as they seek and locate information for the purposes they desire?

RQ4: How do considerations of equity and economic productivity influence broadband policies and programmatic interventions?

RQ5: How does privately-produced and controlled broadband content restructure other public and private information opportunities that historically were *not* delivered using broadband? What new forms of information or content are catalyzed by broadband, and with what use patterns and outcomes?

RQ6: How do Native nations conceptualize broadband, its use and access? What do tribes want to know about broadband use and access? What kinds of access do they want? What do they want to use it for?

THEME: Models of value and use for broadband

The calculus of how broadband contributes to new information acquisition and behaviors, and how it alters old patterns, goes beyond basic interest in what people are “doing with” their broadband connections. As entirely new use propositions emerge with broadband networks, so too the values that people assign to different activities with those networks may change. Maintaining ties across generations may now entail ensuring that grandparents are able to access and use social media so that they can communicate with grandchildren; grappling with the employment market may likewise necessitate understanding how to access and maneuver across websites with interactive forms and scheduling and testing applications; working in rural regions may escalate the coordination value assigned to mobile broadband access. Different “cultures of use” characterize interactions with broadband.

As broadband becomes embedded in social and organizational infrastructures, people *not* adopting such technologies are disadvantaged in some subtle and some not-so-subtle ways. This implies that a market framework that assumes adopting and using broadband is a matter of choice is in fact inaccurate. We already know that demographics including age, race and ethnicity, income, education, and gender, as well as location, interact with access and use patterns. However, the “it’s their choice” default assumption assigns more responsibility to individuals and families than may be accurate. By the same token, if scholars consider the costs of having an unconnected (or less connected) population, assessments of productivity and economic benefits associated with broadband might look different.

Trust also is recognized as an increasingly important value affecting how one uses, or chooses not to use, the Internet and broadband. A broader media ecology that includes all ages, from millennials to seniors, and that accounts for the value proposition from users’ perspectives could enable us to better apprehend how different social units (individuals, families, groups, communities, and beyond) use broadband.

RQ1: How does the value proposition around broadband vary by gender, income, and demographics? How does it change when considering families, communities, institutions, cities, Native nations and beyond?

RQ2: What are the differences in the use cases for spectrum based networks (including mobile, fixed terrestrial and fixed satellite) as opposed to wireline networks? Grouping them differently, what are the differences in the use cases for mobile networks as opposed to fixed networks (including fixed terrestrial, fixed satellite and wireline)?

RQ3: What are the different broadband “cultures of use?”

RQ4: How do the social values of trust and privacy interact with broadband use?

RQ5: How does enabling users *to create* information alter their information environment in terms of trust and of Internet use patterns?

RQ6: How can the outcomes associated with *not* having access to broadband be assessed? What is the cost of exclusion? What is the opportunity to improve economic outputs and access to social and public services with improved connections for *everyone*?

THEME: Evolving technologies and their availability and use

With the rapid consumer adoption of and industry investment in mobile broadband services, understanding how people use mobile systems has become important in many milieus. For example, educational systems now design for students accessing a range of content on tablets and smartphones; many units of government assume constituents will use mobile media—often but not exclusively broadband media—to access their services. Health care providers are designing for mobile access, with fast and high capacity networks driving their design parameters. What are the use patterns for mobile broadband that interact with content and service paradigms?

The quality of mobility interacts with space and time in ways that challenge assumptions about wireline media. The affordances of mobile media in terms of cost and portability have made them widely attractive to most U.S. population groups; for some, they completely substitute for fixed line broadband. However, mobile broadband, at least currently, cannot convey as much

information as can wireline; mobile services are disadvantaged by data caps and overage charges; and there are disparities between urban and rural regions in terms of the quality (speed, for example) of deployed mobile networks, echoing the same patterns evident with many wireline networks serving different regions. Using wireless data often also entails usability aspects including data caps and affordability. Tribal lands are among the most lacking in well-developed wireline or wireless communication infrastructure.

The uses associated with evolving broadband technologies may offer unexpected challenges and opportunities. For example, persons with disabilities appear to have benefited greatly from new networks that can bypass the need for cumbersome TTY devices and instead communicate in American Sign Language through Video Relay Systems made more common through broadband networks. Finally, the latest generation of streaming services now available to households because of broadband networks has upended many conventional media industry models in terms of economics, participation and content range.

RQ1: How do use patterns differ between mobile broadband and fixed broadband?

RQ2: How do service speeds, service quality, pricing, and geographical reach affect the utilities associated with mobile broadband and consequent use?

RQ3: What is the status of mobile and fixed connectivity for Native nations? How do the availability and use patterns for those communities interact with affordability factors? How might those communities use mobile and fixed connectivity differently from other populations (e.g. access to language learning, connection with non-resident populations)?

RQ4: How can broadband-related technologies (networks, end-user devices) enhance opportunities for persons with disabilities to communicate and best use information resources?

RQ5: How does the public and industrial move to streaming media as opposed to downloading files influence demand and use of broadband? What gatekeeping issues (e.g. copyright, inter-industry practices, interconnection pricing, etc.) are associated with the use of streaming media, and how do we assess their effects on uses?

RQ6: Looking to the future, how might other evolving technologies or interfaces or platforms associated with broadband networks enhance or hinder certain population groups' effective use and access to information resources? For example, how would haptic or oral interactions with networks affect usability?

THEME: International, national, state and tribal-level policy environments

As access to the Internet has brought additional resources to the boundaries of a constantly growing network, the policy environments that shape not only the networks and services themselves but also the content with which they interact has exploded. While Internet policy at one time might have concerned itself with issues of more limited matters of peering and domain name assignment, now it extends to copyright, censorship, security, the conduct of politics and well beyond. Different policy environments have the ability to contour the networks as well as the content and services they provide; some national governments create national firewalls or insist that applications such as Twitter or Facebook alter their terms of service. For some nations, the costs

of *excluding* households or territories from broadband networks are assessed as being so high that they now define access to broadband as a basic right.

On a more regional level, within the United States certain cities and states explicitly promote digital inclusion policies that promote training opportunities and widespread Internet availability through libraries, labs, and other public sites. State, regional and even local policies may influence how, where, when and for what broadband networks are used.

Grappling with the policy environments for broadband necessarily implies characterizing how different political bodies define social goals. As recently as the Open Internet decision in 2015, the Federal Communications Commission (FCC) affirmed a commitment to a fast, fair and open Internet, applying its rules to fixed and mobile broadband service. The implicit element of this decision is simply that free and open communication is important for a variety of purposes. If we assume that broadband infrastructure is similar to other utilities that have warranted some degree of common carriage requirements, we are drawn to questions that assess issues of fairness and free speech and social justice as they relate to broadband services.

RQ1: How do the normative values associated with broadband connectivity in the US compare to those elsewhere?

RQ2: What should be the universal service policy of the future? What mechanisms should be used to define and sustain it? Should we define universal service in terms of technology availability, social use thresholds, or something else? Does the governing statute need to be updated? What research would be helpful to evaluate the impact of universal service policies and to inform policy choices?

RQ3: How does broadband use redefine the communication ecology that is associated with free speech values?

RQ4: What are the regional and local values associated with using broadband as evident in state, city and tribal digital inclusion policies and initiatives? What are the most meaningful metrics associated with assessing their success? What are the implied values associated with the *lack* of state, city, and tribal digital inclusion policies and initiatives?

RQ5: What national and international policies influence the growth and use of broadband? For example, how do national innovation, education and social policies influence broadband use?

RQ6: What is the role of privacy and security, and their related legal and commercial regimes, in how people choose to use broadband services? For example, to what extent do security concerns inhibit certain broadband-based innovations and uses such as those in peer-to-peer environments?

RQ7: What are the strengths and weakness of commercially-provided broadband with respect to the social values articulated in digital inclusion efforts? What is the appropriate and preferred role for public programs in extending access? For example, how might we evaluate the success of the Broadband Technology Opportunities Program (BTOP) and Broadband Initiatives Program (BIP) programs as efforts to expand national broadband infrastructure?

RQ8: How can tribal governments leverage broadband policy-making as an important part of sovereignty and self-determination? What other related policies do tribal governments need to set in order to govern broadband (e.g., data ownership, implications of open data for tribes)?

THEME: Broadband, institutions and digital literacies and readiness

Various new literacies - digital literacy, data literacy, health literacy – are commonly referred to in conjunction with broadband-delivered services. Technology-informed literacies mediate interactions with infrastructures of all sorts whether we are talking about electricity or transportation or broadband. As more of our basic institutions incorporate broadband network-provided access to their information-gathering, records, knowledge and services, the ability to both use those networks and to master the many applications that exploit their resources has grown in importance – and this applies not only to the service user but also the service provider. Whether we refer to them as digital readiness or digital barriers, the literacies that undergird meaningful interaction with the information environment comprise an only partially understood research domain.

Some research on digital literacy has sought to standardize how we measure mastery of the terms and basic interactions with networks; other research instead has sought to identify the specific uses that are meaningful to people, suggesting that broad measures of digital literacy are simply not particularly helpful to people who approach broadband Internet resources from a more instrumental perspective. Context-dependent skills and literacies are not well understood, particularly within discrete social and institutional settings. Still other literacies focus more on information-seeking and evaluation of what one can learn by using broadband-media information. For example, as growing numbers of people seek health information online, the ability to *critically* evaluate search outcomes grows; there is little data on how people search and evaluate health information.

These considerations highlight the importance of understanding how literacies are defined and reinforced by the formal and informal institutions using broadband-delivered resources and services. Education and health are two formal arenas in which literacies are critically important; they have the effect of determining consequential life outcomes. Education and health institutions face both access and readiness barriers. There is scant data on how health institutions are using broadband, what they pay for it, and how its resources are incorporated into their operations. Comparable information about educational institutions is more available, but poorly understood. These formal institutions are migrating toward greater reliance on broadband networks for many elements of their service models. Some unintended consequences of this migration, such as a “homework gap” among children whose households lack home-based broadband, are now evident. Some educational institutions, including community colleges and libraries, may have special roles in cultivating digital literacy for marginalized populations.

A third important formal institutional setting is that of small and medium sized businesses. There too, we lack data on how these businesses use broadband and on their needs and costs. We do know that smaller businesses are under-resourced in terms of network expertise and in terms of understanding how to exploit the opportunities available through broadband, , but do not have the data to quantify and estimate the consequences of this gap. In addition, we do not have reliable data on the “digital skill” needs of businesses and the extent to which they have difficulty finding employees with those skills.

Informal institutions – churches, voluntary organizations, as well as the quasi-formal services and classes provided by formal institutions such as libraries – are important mediating institutions for

broadband services. Among other things, they function as training and support sites for cultivating digital literacy, yet we often know little about the efficacy of their training regimes and settings.

Finally, turning directly to users themselves, the open data movement and participatory cultures that have grown up around the fast access and use associated with ubiquitous broadband have catalyzed different expectations and practices around data. As one participant put it, the top-down model does not describe how many people now interact within their localized and culturally-driven information environments. The use environment once defined in terms of connections is now about data, about people using apps and increasing the flow of data to themselves.

RQ1: How do health and education institutions use broadband networks? What are their broadband needs? How will they be able to shape and to use broadband capabilities in terms of network configurations and in terms of user interactions?

RQ2: What are the security and interoperability requirements for educational and health settings, including the relevant privacy policies now in place and how can we identify key data points and tracking opportunities in terms of performance?

RQ3: What are the assets and vulnerabilities of informal institutions (churches, associations, libraries, museums, etc.) for contributing to digital literacies and meaningful use?

RQ4: How do community institutions, including libraries and museums, mediate digital literacy for children? For adults? To what extent do they contribute to opportunities to access and use broadband? Does their role vary depending on the communities they serve? (For example, libraries are intended to be hubs in areas with low household penetration, which might imply some libraries deserve disproportionate investment.)

RQ5: How do trends in broadband use affect children's abilities to fully participate in the educational process? What are the formal and informal learning environments shaped by broadband networks? Do these environments differ by socioeconomic and ethnic groups?

RQ6: How can we characterize patterns of business Internet use? How can we measure the digital skill needs of businesses in various industry sectors, and the extent to which those needs are being met? What data should be collected routinely, as with the Bureau of Labor Statistics?

RQ7: How do participatory cultures and user capabilities to create information resources alter broadband use trajectories?

RQ8: How do small businesses and nonprofits use broadband? What barriers do they face? What benefits can broadband provide for their customers and clients?

THEME: Metrics for Government Information Portals

Public sector agencies and institutions increasingly rely on utilizing and providing a rich information environment for their internal operations and for communications with and providing services to the rest of the world. Under President Obama, creating the data.gov portal underscored new emphasis on sharing government data, and also created new pressures on agencies to provide data and to insure that it is being used. With the amount and quality of data on government services and their users increasing, there also are new opportunities for agencies to improve their services to target populations, particularly when those populations deal with multiple agencies.

There are unique moments, such as during natural disasters, when government-provided or government-facilitated information is especially important and where the failure or absence of broadband networks is particularly notable. Infrastructure resilience, especially for needed services, must be applied to broadband communication technologies and services even as it is applied to other sorts of infrastructure.

RQ1: Who is using government data portals? How can that use be assessed and calibrated? What mechanisms might improve data sharing and use² of government data by individuals and other organizations, commercial and noncommercial?

RQ2: What are the alternative federal or state or local agency models for educating and diffusing technologies and data? How can best practices be identified?

RQ3: What factors affect how and whether federal agencies share data? How might meta-social impacts from such data sharing be modelled?

RQ4: Can we identify specific instances of wide-ranging government programs such as the Affordable Care Act and evaluate the positive and negative utilities of its online performance? What are the best ways to assess the impact of such online government information programs?

RQ5: What are the costs to government of maintaining off-line versions of everything that's online – basically the direct cost to government from NOT being able to assume everyone is online?

THEME: Equity and the evolving information environment:

Broadband deployment historically has favored certain locations and certain population groups. Participants noted that there is clearly a correlation between systemic social and political exclusion and access to technology. As noted earlier, a similar pattern can be found in actual broadband use. Concerns about a digital divide and inequities resulting from (1) differential opportunities, (2) different capabilities to use broadband networks and (3) different cultures of use all feed information inequities. As societies rely more heavily on information resources for routine tasks and activities, such inequities can have the effect of deepening structural disadvantage. Do certain use patterns or cultures influence social outcomes or one's social network resources? How might we identify "good" use of broadband networks and attendant information sources? For example, there may be equity concerns when smartphone-only users have their content choices restricted due to the "walled gardens" associated with proprietary apps.

RQ1: How do broadband access and use patterns influence opportunities for social mobility? How do advantaged and disadvantaged communities differentially engage the broadband environment?

RQ2: In what ways do racial and ethnic differences and cultures of use distinguish how people use broadband information resources? Are racial and ethnic differences in American Indian, Alaska Native and Native Hawaiian communities further distinguished by differences among tribal cultures and tribal governments?

RQ3: What are the determinants of the digital divide (e.g. by lack of infrastructure, pricing of use, quality of service, etc.)? What are the locational or spatial qualities of the digital divide? Do

² We imply authorized and legal sharing and use.

certain advantages and disadvantages characterize use patterns in rural regions, inner city areas, on American Indian reservations or in Alaska Native villages?

RQ4: How can we foster public hybrid broadband, focusing not only on the technological infrastructure of the network but also situating broadband networks within existing communities as a means to promote digital self-determination for indigenous and other disadvantaged groups?

RQ5: How does differential reliance on mobile broadband-only influence the range of typically-used information resources? How might cheaper hardware and broadband plans and uneven use patterns (dropping on and off paid services, for example) influence use?

RQ6: How can we gauge and differentiate the quality of broadband use from the quantity of broadband use? What does “quality of use” mean, especially considering that user communities may differ in terms of their information needs?

THEME: [Multidisciplinary and Mixed Methods Approaches](#)

While various investigators have either used national datasets (for example, those provided by NTIA, the Census Bureau, or Pew) or have undertaken their own large scale surveys, relatively fewer studies have tackled the many environments in which qualitative and historical data would be particularly useful. There also is a tendency to focus on the grander scale of emerging infrastructures in order to capture their growth and importance; generalizable data from quantitative surveys, for example, can become a gold standard. However, microscale studies can illuminate aspects of broadband infrastructure that are simply not available from those other levels, and they may be particularly good at illuminating some of the disadvantageous, regressive, or contrary experiences, uses and outcomes. Whether through historical, qualitative or other empirical approaches, incorporating methodological pluralism and studying uses in ways and at scales that can investigate some of broadband’s more invisible but still present effects on society would be illuminating.

Gathering data either through ethnographic or other interview-based approaches may take longer, but the rich and deep understandings such data can provide regarding specific populations – particularly populations and experiences often undersampled in larger surveys – can be useful. Indeed, because broadband technology evolves rapidly, the absence of robust and adequate longitudinal datasets, other time-series data, and panel studies may always be constant challenge— as a result, the research community needs to develop and refine mixed approaches to this research. As broadband infrastructure has developed and become integrated and naturalized into so many systems, understanding the dynamic and static information environments we inhabit might best be probed through research methods capable of incorporating time, space, scale and the influence of social organization.

RQ1: In what ways can a socio-technical approach to investigating broadband illuminate some of its unintended consequences and less visible effects? How might longitudinal studies contribute to our understanding of broadband uses outcomes?

RQ2: How can we best understand the stable and changing information environments created by broadband-dependent information systems? What historical data are relevant to responding to this question?

RQ3: How are broadband information environments naturalized or domesticated? What are the processes that individuals and communities go through in adjusting to and incorporating broadband systems? In not incorporating them?

RQ4: What are the relevant cultural dynamics at work with respect to broadband resources, and how do they operate and reproduce communities of practice? For example, how might ethnographic studies contribute to our understanding of ways Native nations use broadband?

RQ5: What methodological approaches can best contribute to our understanding of the nature of and changes in broadband use? What roles do location, time, social and economic status play in broadband utilization? What approaches to microscale studies and focus groups can be employed that will provide us a complete picture of the rapidly-changing environment of broadband usage and technology adoption?

THEME: Collecting and Sharing Usable data

There is broad interest in making sure that data pertinent to our research questions are gathered routinely and with adequate samples. The U.S. now has two recurring survey-based efforts in this regard, including NTIA's long-running series of surveys regarding computer and Internet use,³ and the basic questions on household-level computer ownership and Internet use recently added to the annual American Community Survey (ACS).⁴ However, only the ACS questions are mandated by statute to regularly recur. Additionally, the FCC collects and publishes deployment data twice each year as required by its rules.⁵ This work builds on and continues NTIA's collection of broadband availability data (first as the State Broadband Data and Development Grant Program, later renamed the State Broadband Initiative) which ended in 2014. Regular data-gathering using a standard set of items would be extremely useful and enable the research community to reliably track changes. In this respect, participants regard the Evidence-Based Policymaking Commission Act of 2016 with great interest, and look forward with anticipation to the founding of the Commission of Evidence-Based Policymaking in the executive branch.

Participants all agreed that regular and public data-gathering efforts, using a standard set of items would be extremely useful and enable the research community to reliably track changes. This data collection effort should be open and public, so that individual researchers and institutions that are seeking to study the effectiveness of a particular digital inclusion intervention or policy approach in a community or state can access and utilize the national dataset, as a sort of benchmark.

We acknowledge, along the lines of the earlier research point above, that information beyond what would be available through large sample surveys would be essential to understand the broadband information environment. With regard to deployment data, access to middle mile and last mile

³ NTIA has sponsored, designed, and analyzed results from the Census Bureau-administered Computer and Internet Use Supplement to the Current Population Survey (CPS) on thirteen different occasions since 1994, most recently in July 2015. See <https://ntia.doc.gov/data> for details, reports, and full datasets.

⁴ Questions on computer and Internet use were added to the ACS beginning in 2013. See <https://www.census.gov/acs> for details and data.

⁵ Information about the FCC Form 477 data collection, including rules for which providers are required to file data and information about the data they are required to file, is available at <https://www.fcc.gov/general/form-477-resources-filers>. Deployment are available for download at <https://www.fcc.gov/general/broadband-deployment-data-fcc-form-477>.

network data - especially costs - would be helpful in terms of understanding the possibilities for infrastructures alternative to conventional commercial companies. So too, more granular data – collected at the state level, and the census block level, would be desirable; currently a great deal of the most useful data is aggregated by county, a measurement unit that typically becomes much less useful for rural regions.

Research attention may be directed at the process of data collection itself, and about the types of data that would help address specific questions. For example, researchers may investigate the modalities of collecting household usage data (presumably via a household-level survey). The kinds of applications people use, and on what devices has something to say about the requirements of the network, and may be relevant for some types of research. Real-time network-based measures may be needed to capture not only the types of applications but also the actual frequency of their use may also be useful in some contexts. Researchers may investigate the methods, instruments and frequency of data collection required for these types of data.

There are gaps in broadband data gathering, data curation and analysis. The end to BTOP funding has meant that there is less data available on broadband access, adoption, and use than there was available two years ago, and participants agreed that the government needs to focus on filling this data gap. In addition, we acknowledge that new ways to analyze different sorts of data – especially the data generated by broadband Internet-based networks themselves – are emerging regularly, as are new sampling mechanisms. However, they are not standardized, and are under-evaluated.

Furthermore, specialized populations – persons with disabilities, for example, or Native nations – frequently get short shrift in conventional data gathering efforts, and their numbers in national surveys is too low to provide generalizable results. Many research questions might be answered differently if there were adequate mechanisms to gather data from these groups. Creating testbeds or field laboratories where researchers could experiment with alternative technologies, methods of training, applications, and with certain targeted populations, would be very useful. As it stands, commercial providers such as Facebook appear to have superior research capabilities in important ways, but the data they generate are proprietary. Working with industry to develop methods for researchers to access to such proprietary data could be immensely helpful for many social and broadband use-related questions.

RQ1: What mechanisms would be optimal in order to facilitate national and international data sharing with respect to broadband network users and uses?

RQ2: How can government-maintained (federal, state or local) datasets be made more broadly available and comparable? How can more granular data be gathered pertinent to broadband uses and impacts?

RQ3: What organizational models might excel in sharing relevant broadband data? How do alternative research network models compare in terms of data sharing, undertaking research, and communicating with policy communities?

RQ4: How might we evaluate the utility of working in different ways with relevant policy entities, at the federal, state and local levels?

RQ5: How could the research community best work with the owners and producers of proprietary data relevant to understanding broadband uses and impacts?

RQ6: What do Native nations want to know about broadband infrastructure, availability, and use on their lands and for their citizens? What might they be giving up if additional data are collected? Who should be studying tribes' broadband infrastructure and availability?

6. Impacts

During the past decade, research has deepened our understanding of the potential impacts of broadband on the economy and society. Nonetheless, as the discussions in this track showed, many research deficits continue to exist. This summary organizes the far-reaching exchange into broader themes, synthesizing the main points and concerns of the discussion. Several points were made in multiple contexts and where appropriate some points are mentioned under multiple themes.

The discussions made clear that a research program on the impact of broadband needs to overcome several challenges. Broadband is a general purpose technology (GPT) that supports diverse uses and multiple goals whose relative importance may vary across individuals, uses, organizations, and locations. The relationships between broadband access and use and these outcomes is likely to be complex and multifaceted. These effects likely will unfold at different time scales. An assessment of impact thus will have to deal with varying time lags. Moreover, the effects appear at multiple interrelated levels, ranging from individuals to organizations, communities, regions, the national and potentially global levels. As many initiatives are local and place-based, the question arises of whether we can measure the effects at appropriate levels of granularity and scale.

THEME: Analytical Frames to Assess Broadband Impacts

Broadband affects individuals, organizations, communities, and society at large. It does so in complex ways and at time scales that complicate the assessments of its effects. There is considerable evidence that the availability and use of broadband changes people's lives. Like clean water, broadband is fundamentally important for modern society. Questions such as the growth or employment impacts of broadband may be secondary. (Does it make sense to ask about the growth impacts of clean water?). Broader and different questions may be more appropriate. Thus, the question of what we know about broadband can be framed in different ways. First, at an instrumental level, we can analyze the effects of access to and of the use of existing broadband technologies on productivity, growth, employment, etc. As part of this line of inquiry it will be important to understand for whom these effects materialize, at what timeline, and in which locations. Second, we could also ask about the opportunities that would be opened for individuals, organizations, and communities if there were access to different, better connectivity. Third, we could ask what the economic and social impacts might be if radically different network and service architectures were available and deployed. Only the first set of questions can be answered using historical empirical data. The second and third, forward-looking question requires different forms of analyses such as qualitative methods, scenario-building, and simulation approaches.

RQ1: What are the social and economic effects of existing forms of access to and use of existing broadband technologies on individuals, organizations and communities (including Native nations)?

RQ2: How does broadband affect economic growth, productivity, employment and incomes? Are these effects linked to specific affordances and quality of service characteristics of broadband (e.g. speed, price)?

RQ3: Which opportunities would become available for individuals, organizations, and communities (including Native nations) if they had access to different, better connectivity?

RQ4: What might the economic and social impacts be of radically different network and service architectures?

THEME: Transformative Potential of Broadband

An important set of overarching questions discussed by the participants in the track relates to whether or not the transformative promise of broadband is being fulfilled. The National Broadband Plan, BTOP, and other programs have numerous goals for economic development, education, health, government services, civic engagement, and individual empowerment. Knowledge about the positive and negative social and economic effects of broadband is necessary to improve existing public policies and possibly design alternative forms of interventions. Some evidence has been generated in the context of earlier programs (e.g. the BTOP evaluations conducted by ASR Analytics), more and more systematic evidence is needed. One important challenge of such evaluations is to identify the specific ways in which broadband affects outcomes. Much of current research treats broadband as a “black box”, often correlating access to broadband with measures of effects and outcomes. It would be desirable to unpack these relationships and explore more in-depth how individuals and organizations use broadband technology, what the specific barriers to the adoption of new uses and practices are, and what programs are most effective in achieving desirable outcomes. As well, more work is needed in connecting knowledge of the processes through which broadband affects outcomes and recommendations for practice. A comprehensive evaluation of whether or not the transformative potential of broadband has been fulfilled also requires an assessment of the negative and unexpected effects of broadband, many of which are only incompletely understood. These might include the mix of productive and unproductive uses, the extent to which broadband is used mainly for entertainment purposes, political fragmentation, information security breaches, and violations of privacy. Broadband could undermine local small businesses in rural areas by making metropolitan suppliers more readily accessible. It also may include an assessment of the negative consequences of poor connectivity.

RQ1: What are the broader socio-economic impacts of broadband and how can they be assessed in a systematic way? Are there predictable variations in those impacts?

RQ2: What are the actual and potential negative impacts (e.g., entertainment uses, political fragmentation, information security breaches, violations of privacy)? Are any actual or potential impacts more likely to affect given populations, e.g., Native nation citizens?

RQ3: What are the negative consequences of poor connectivity?

RQ4: Have the transformative promises been fulfilled?

THEME: Complementarity Conditions for Harnessing the Benefits of Broadband

Broadband is one important element of the broader information and communication technology (ICT) ecosystem that enables the digital economy. Broadband contributes in direct ways to economic outcomes (e.g. equipment manufacturing and the deployment of infrastructures contribute to GDP and employment). In many other cases additional assets and skills are needed to unleash the full value associated with broadband. Realizing this value for individuals, organizations, and communities then is contingent on such complementary assets as devices, applications, skills, reliable and affordable power supply, and sometimes other infrastructures such as transportation for e-commerce. Absence of such complementary assets can severely constrain the potential benefits of broadband. This is visible in evidence from bringing broadband to tribal lands (where smartphones and computers often are missing), poor city neighborhoods, and rural communities. It was also an observation in many projects funded by BTOP, where the lack of complementary applications limited uses of the broadband platforms. [Historical precedents with rural electrification also point to the importance of complementary goods in diffusion and adoption, in this case electric supply and electrical appliances.] Lastly, lack of appropriate content, such as educational materials, often constrains the benefits of broadband access. In addition to these complementarities related to the ICT ecosystem, the effect and success of projects often is contingent on other complementary institutional arrangements. The benefits of a technical infrastructure will be realized more fully if an appropriate social infrastructure is in place that allows growing projects. There is evidence of a higher success rate of projects given to communities that allow such organic growth. In other cases, the broader legal and regulatory framework needs to be aligned with the goals of broadband, such as in cases where health and insurance regulations prevent reimbursement of tele-visits to doctors. Decisions influencing these complementary assets are often outside the control of broadband policy makers.

RQ1: How can the contributions of complementary assets be assessed?

RQ2: How strong are the complementarities between broadband and different types of complementary assets?

RQ3: What is the contribution of complementary assets to the benefits of broadband?

RQ4: How important are complementary assets for the success of individual projects?

RQ5: Are certain complementarities (e.g., telemedicine, language apps) stronger drivers of inclusion in disadvantaged environments?

THEME: Dynamics of Technology and Digital Divides

Broadband technology is evolving dynamically. During the past 20 years, exponential performance improvements in components, fixed and wireless networking, computing, storage, and devices have supported tremendous increases in technically feasible upload and download speeds. At the same time, the technical architectures of information provision have changed and put additional demands on the network. As solutions move to the cloud, more services are becoming dependent on always-on, reliable connectivity. As services are being configured differently, realizing their benefits will increasingly be contingent on better and more ubiquitous connectivity. One can

expect that technological change will continue with additional challenges to the network infrastructure. Connecting billions of devices in the Internet of Things (IoT), even though each may only have limited bandwidth needs will lead to new demands on networks. The potential of holography and the possibility of non-intrusive brain-to-brain communication all have implications for the requisite broadband infrastructure.

The continued technological dynamic may create a cycle of exclusion that undermines successes achieved with measures of digital inclusion and opens up new waves of digital divides. Consequently, individuals who need information most often have the least access. Similarly, the growth, employment, and civic opportunities of communities will be shaped by how well they manage these transitions to next generation infrastructures and technological architectures. This raises the question whether technology can be customized to the specific needs of a location and how it can be scaled appropriately. It also raises again the question of how technology could be configured differently to maximize benefits to individuals and society. Which designs would provide better access and use to individuals across the life span? Another aspect of rapid and continued technological change is that many potential effects, whether benefits or costs, cannot be known with certainty or not be known at all. Policy makers will have to make decisions under risk and even full uncertainty. Under such conditions, continuous monitoring of effects and continuous adaptation of models will be increasingly important. While policy makers and public decision makers want simple answers the relations involved are complex.

RQ1: What are the implications of continued technological change for broadband networks, users, and for policy makers concerned with access to broadband?

RQ2: How does continuous technological change influence the effects of broadband on individuals and communities?

RQ3: What are the effects of dynamic technological change on the ability of individuals and communities to harness the benefits of advanced communications?

RQ4: What are the effects of the cycle of digital exclusion and inclusion on individuals and communities? How can they be mitigated?

THEME: Specific Social and Economic Impacts of Broadband

There was considerable discussion and agreement on the need to study specific dimensions of the effects of broadband on society in addition to the development of specific applications. Each of these issues has multiple dimensions and can be examined at multiple levels, including individual/behavioral, organizational, community and macro-economic/-societal aspects. In each area there is considerable need for theory formation and empirical research. This discussion generated a large number of potential research questions, including:

RQ1: What are the effects of broadband on employment (see below for more details)?

RQ2: What are the effects of broadband on productivity?

RQ3: How does broadband interact with innovation in businesses of different size (small and medium-sized enterprises, large firms)?

RQ4: What are the effects of broadband on providers of non-profit and public services (e.g., libraries) and their clients?

RQ5: What are the effects of broadband on income?

RQ6: What are the effects of broadband on education (including access to online content in schools, homework and other student activities, distance education, etc.)?

RQ7: What are the effects of broadband on information security?

RQ8: What are the effects of broadband on individuals with disabilities?

RQ9: What are the effects of broadband on social and individual well-being (e.g., self-radicalization, social media and isolation)?

RQ10: What are the effects of broadband on citizen empowerment and the political process?

RQ11: What are the effects of broadband for individual Native nations and Native nations citizens not living on tribal lands?

THEME: Broadband and Labor Demand

One specific impact that was discussed in more detail were the effects of broadband on the labor market. Workshop participants cited research that shows that broadband has an impact on small business startups, contributes to economic growth, and increases household income and expenditures. Other things being equal, all of these contribute to higher labor demand. But broadband also increases productivity by substituting for other production inputs and reducing transaction costs, which may reduce labor demand. The exact impact of broadband on labor demand is not known with enough certainty to guide policy-making.

RQ1: What is the impact of broadband on labor productivity?

RQ2: How does firm size influence broadband-induced productivity changes?

RQ3: How does the educational level of a market influence broadband-induced productivity changes?

RQ4: What types of economic sectors benefit from broadband deployment? Which sectors are negatively affected? Does broadband deployment have differential effects on the labor market in rural and remote areas or in Native nation economies?

THEME: Users and Uses

While factors influencing broadband deployment are better understood, data and hence research on users and uses is more limited. We know little about what users do when they have access to different types of networks: for example, those with access to both fixed and mobile networks might behave differently from those who have access only to mobile networks, or those with access to gigabit networks. Little is also known about how certain types of usage limitations (e.g., data caps on mobile broadband network) affect uses, educational attainment, etc. We know little on the pedagogy of broadband use: how do we teach digital literacy effectively and how can public

institutions (e.g., libraries) take advantage of them? As uses and service differentiate, quality of experience (QoE) may be more important than specific network parameters such as download speed. However, we do not have reliable metrics to measure QoE. For example, how do people experience virtual spaces, how are they generated and shaped by technology and what is the experience of citizens engaging in such spaces?

RQ1: What factors influence Quality of Experience (QoE) and how can it be measured reliably?

RQ2: How are different types of platforms used by users with different types of access platforms?

RQ3: How do the conditions of use of such platforms (e.g. data caps) influence the user experience and outcomes?

RQ4: What are effective pedagogies to teach users and how can public institutions take advantage of them?

THEME: Theoretical and Methodological Foundations

Evaluating the impacts of broadband on short, medium and long time scales raises considerable theoretical and methodological challenges. Some skepticism was expressed as to whether theory was important for practical decision makers and whether they would care at all. Nonetheless, rigorous understanding of the effects of broadband requires solid theories and methods as a precondition to derive clear policy recommendations. As a general purpose technology broadband is rarely a single causal factor that shapes outcomes. Rather it interacts with other factors, such as innovation strategies of businesses, changing patterns of national and international competition, social-demographic developments, and public policies to generate outcomes on productivity, employment, growth, educational attainments, and social inclusion.

Because broadband affects socio-economic systems at multiple levels, rigorous studies will benefit from an application of mixed methods approaches. Qualitative analyses and case studies allow rich and detailed insights but would ideally be complemented by the application of multi-level analyses, reliance on longitudinal data, and examination of panel data. Cross national studies can help shed additional light on the effects of broadband as they allow taking advantage of institutional heterogeneity. However, they introduce additional challenges of measurement and comparison. In some of these areas there is a growing body of research but it is fragmented among several research communities and would benefit from meta-analyses.

An important precondition for rigorous studies is the availability of appropriate data. Given that broadband affects individuals, communities and society at different levels, it will be important to measure at the right scale. Current data collection efforts fall short of the needs of systematic evaluation research (see the further discussion below). Integrating data across different spatial scales and from different sources may be a low hanging fruit to improve the situation. However, in the long run it may be necessary to develop an overarching data collection framework that is appropriate for the needs of evaluating broadband comprehensively. Where empirical data is missing or forward-looking decisions need to be made simulation analyses may allow to parameterize factors and at least develop pattern predictions.

RQ1: How can the interaction effects of the general purpose technology broadband with other factors and their economic and social impacts be modeled?

RQ2: How can the conditions be explored under which broadband has positive effects and those under which negative effects will dominate?

RQ3: How can the dynamic and non-linear effects of broadband on individual/behavioral outcomes be explored?

RQ4: How can the dynamic and non-linear effects of broadband on organizational outcomes be explored?

RQ5: How can the dynamic and non-linear effects of broadband on macro outcomes be explored?

THEME: Data Availability, Collection and Curation

While the discussions generated strong support for the usefulness and relevance of qualitative research methods, including ethnographic approaches and case studies, it also emphasized the need to generate statistical evidence. Knowing the magnitude of effect sizes can help in shaping better and more effective policy programs. Evaluating the impacts of broadband statistically in a theoretically and methodologically rigorous way requires appropriate empirical data to measure the relevant outcomes, the relevant attributes of broadband (availability, speed, prices, etc.) at a level of granularity and scale that is appropriate to the questions studied. The discussion revealed many problems with the currently available empirical information that do not necessarily require new research to address them but it also pointed toward measurement and conceptual issues that might warrant a more systematic research approach.

An urgent issue identified by the participants was a review of the policies that govern the proprietary and confidential nature of certain datasets across multiple federal agencies. In addition, it would be very helpful to link datasets from various agencies. Limited access to data that is available is a major obstacle to more fine-grained analyses that could be overcome in creative ways, for example by creating data enclaves that allow sharing of sensitive data within a closed community of researchers. A second issue identified was the need to collect data that can help evaluate the effects of an intervention into the design and implementation of programs. The relative cost of such efforts will most likely be small compared to the potential gains from learning and the insights for the design of future efforts.

In all cases, a baseline of information is needed. One approach that was discussed was a two-tier approach to data collection and curation, combining a set of general purpose indicators with specialized data collected in the context of specific projects. The general purpose data set would help inform a broad range of impact assessment studies. Currently, relatively good data is available on broadband deployment. However, data on subscribers, uses, prices, network quality and speed, to name but a few, is much more problematic and limited. Often the data is only available from private vendors at costs that are prohibitive to most researchers. Moreover, data definitions frequently change and the quality of the information is difficult to assess, greatly challenging longitudinal and panel studies. Defining the elements of such a general-purpose dataset as well as the definition and effective collection of information will require some conceptual work and creative implementation.

A second tier of tailored data would be collected in the context of specific projects. For example, support to libraries could document more systematically the extent of funding, impacts of funding, and complementary conditions that influence success and failure of projects. In order to create an

evidentiary basis that goes beyond individual projects, data would have to be collected in a coordinated fashion, for example, by using a standardized framework. Such frameworks could emerge from the organizations involved in specific efforts. While many of the proposed initiatives in the area of data collection and curation will not require additional research others would benefit from coordinated efforts to re-think which data should be collected and how that could best be done.

Efforts may also be required to protect indigenous data sovereignty. Research on broadband does not generally take into account Indian Country let alone different tribes. Most national surveys and Census data do not adequately cover Indian Country. They certainly don't distinguish tribe from tribe to provide tribal level data. Because of past misuse of data about Indigenous populations, the unavailability of data aggregated in useful ways for Native nations, and a current movement toward Native nations exploring and exerting sovereignty over data, there are and will be issues particular to the collection and use of data for services and use on Native lands and for Native peoples and sharing that data through open data mechanisms.

RQ1: How would a system of general purpose metrics be structured to serve as a durable base for a broad range of impact evaluations at appropriate scales?

RQ2: Given the general purpose nature of broadband and the widespread reliance on service bundles, how can economically meaningful metrics for prices be determined?

RQ3: How can adjustments for changes in the quality of service be incorporated in the calculation of prices and other general purpose metrics?

RQ4: How can the network infrastructure, devices, and applications be designed to generate data while maintaining appropriate protections of the privacy and confidentiality of users? In Native nation settings, how can the network infrastructure, devices, and applications be designed to generate data while maintaining appropriate protections of the Native nations' sovereignty in relation to data about the nations and their citizens?

THEME: Need for Policy Oriented Research

There was broad agreement that a major goal of a Broadband 2021 research agenda would be to generate actionable research insights. One concern expressed by several participants was whether NSF would fund such applied research given its mission and practice of investing in theoretical research and the development of technology. Administrative analyses as to the effectiveness of programs and the realization of goals will need to be complemented by work using a social welfare approach. While policy research has a long-standing instrumental tradition it might be useful to explicitly investigate the desirable state of broadband deployment and use (that is, have at least a meta-dialogue on what is "good").

One important question in this stream of research is a clear conceptualization of which situations demand policy interventions. Traditional concepts of market failure will need to be modified for the new realities of a highly interrelated and interdependent ICT ecosystem. Many benefits and costs are externalities that materialize away from the organizations that control a decision. For example, does the throttling of bandwidth by a private provider such as Netflix raise policy concerns? Who shall make such decisions? How can effects be assessed meaningfully and determined whether policy intervention is appropriate? We currently only have limited established

practices on how such externalities can be assessed and translated into practical policy. Likewise, in highly interrelated systems, many policies may have indirect and even unanticipated effects. For example, bringing broadband to a rural community may expose local merchants to new forms of online competition and result in their going out of business. How can such potential trade-offs be meaningfully evaluated? There are other policy issues where research is warranted: setting and reviewing impact of universal service targets, impact of regulatory policies or the lack of them on pricing, quality of service, etc.

Many participants recognized the progress achieved in the Broadband Opportunity Council (BOC) and the desirability of coordination across agencies. While there was some unease about the large number of agencies involved and whether this allowed for an efficient and effective orchestration and implementation of policies there was also recognition that assigning tasks to multiple agencies also can unleash initiative and creativity. One challenge in the dynamic ICT ecosystem is that the full effects of policies cannot be anticipated. It therefore may make sense to conduct systematic experiments before policies are being scaled. Such policy design requires conceptual work and a willingness of policy makers and researchers to collaborate in new ways. Systematically done, this would allow assessing the conditions of success and failure and the adaptation of subsequent programs.

RQ1: In the context of dynamically developing technology and an increasingly interrelated ICT ecosystem, what situations warrant policy intervention?

RQ2: What is an efficient level of decentralization of policy tasks and how can policy coordination be achieved effectively? How do we protect Native nations' rights in the process of centralization and decentralization?

7. Recommendations

In this section, we list the various initiatives that participants in the Broadband 2021 Workshop identified that executive Agencies may take in order to facilitate the National Broadband Research Agenda as identified above. Some of the recommendations call for the continuation or further strengthening of initiatives that federal funding agencies or executive agencies already undertake. Some others may require new activity “within the scope of existing Agency programs, missions and budgets” as called for in the BOC Report and Recommendations. A few of the recommendations call for entirely new programs, procedures and practices to enable the research community to fulfill the expansive research agenda identified in the above pages. Not all recommendations are tied to specific Themes or Research Questions: some of the recommendations such as creating an academic network in support of broadband research and enhancing the quality of data emerged out of the broad discussions at the Workshop.

A. Enhancing Interdisciplinary Research

Participants in all three tracks were close to unanimous in voicing the need for interdisciplinary research to address the problems of digital inclusion. In the technology track for example, participants noted that important spectrum research and experimentation initiatives are often interdisciplinary, involving advanced wireless technology, economic incentives, and spectrum policy and regulations in complex and intertwined ways. In the usage track too, measuring user

experience requires interdisciplinary research that takes into account how users perceive performance, as well as what can be measured at the network level. The resulting measurements of user experience will necessarily depend on the types of applications that are in use. In the impacts track, the technical capabilities of networks and the specific uses to which applications, software and content are put can influence the impacts that are observed. This too calls for interdisciplinary research.

Traditional research funding mechanisms that are rooted in a single academic discipline may not address the need for broadband research. NSF and other funding agencies may want to favorably consider interdisciplinary proposals. Some programs that support interdisciplinary research are already underway, and may be strengthened. For example, the NSF has had an interdisciplinary program called Enhancing Access to the Radio Spectrum (EARS) intended to address some of these issues, which has had its final planned solicitation. Similarly, over the past two years, NSF has had two interdisciplinary solicitations involving directorates from engineering (ENG), computer and information sciences (CSE) and social, behavioral and economic sciences (SBE). The first was Resilient Interdependent Infrastructure Processes and Systems (RIPS) and, the second, Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP). NSF CNS, ENG and SBE should work together with NTIA and FEMA to regularize a program similar to CRISP, focused on the telecommunications infrastructure. It is recommended these program be continued with an eye toward technologies for underserved communities as well as the issues addressed in multiple Themes above.

Recommendation 1: Continue the NSF's interdisciplinary initiatives, such as Enhancing Access to the Radio Spectrum (EARS) program, and initiate others that address items on the broadband research agenda identified in this Report.

Recommendation 2: Increase opportunities for interdisciplinary research and grant-seeking.

B. Creating a National Network or Community of Broadband Scholars

Alongside data-gathering and analysis mechanisms, models that can assist in both forming and supporting a community of scholars examining the broadband technology ecosystem would enable better circulation of knowledge as well as improved opportunities to respond to policy questions related to specific broadband matters. In particular, we need to cultivate a more diverse community of scholars if we are to thoroughly understand the diverse uses and cultures of broadband use in the United States and elsewhere. A Center to coordinate research on broadband was mentioned as a possibility; alternatively, activities might be located within or coordinated by an existing institution, or new institution such as the Commission on Evidence-Based Policymaking established by the Evidence-Based Policymaking Commission Act of 2016.

Recommendation 3: We recommend consideration of a Center model that would undertake data collection and analysis; develop frameworks for sharing data; integrate institutional features to maximize usability, relevance and policy applications; institute a training program that explicitly enhanced the support available for a diverse community of new scholars especially from underrepresented groups, and provide technical assistance to state or local digital inclusion and training initiatives that would like to study the impact of their programmatic interventions.

C. Improving Data Quality and Supporting Wider Sharing of Public and Private Data

Access to data about broadband deployment is important for those trying to expand broadband infrastructure, and for those wanting to do data-driven broadband research. For example, anyone planning to create or expand broadband infrastructure in a remote rural area needs information about the availability and pricing of middle-mile connectivity in the region, and the location of potential interconnection points. In some parts of the country, this information can be difficult to obtain. Better quality data, and wider availability of data will be critically important for the national broadband research agenda, as identified in this Report.

Participants in the workshop raised several ways in which access to information and data might be improved: (1) improving data collection on broadband deployment, (2) initiating special efforts to collect data on underrepresented groups, (3) facilitating information sharing among researchers, and (4) encouraging the private sector to share data with researchers.

C.1 Improving Data Collection on Broadband Deployment.

Researchers who wish to assess the impact of broadband empirically need detailed information on precisely where that infrastructure has been built out and which homes are passed. Researchers who wish to assess the impact of spectrum assignments need detailed information on existing licenses. Thanks to the FCC's Spectrum Dashboard and National Broadband Map, far more of this kind of data is available today than a decade ago. Nevertheless, workshop participants expressed frustration that these resources are too often incomplete, out-of-date, or at a granularity that is coarser than they would like. Data on the prices that consumers pay in different regions for broadband Internet access service would also be useful, and there is no source for this information.

A related issue identified by participants was that policies that govern the proprietary and confidential nature of data prevents data sharing or linking of databases across multiple federal agencies. Though the data already exists, limited access is a major obstacle to more fine-grained analyses. A second issue identified was the need to build the collection of data that can help evaluate the effects of an intervention into the design and implementation of the program. The relative cost of such efforts will most likely be small compared to the potential gains from learning and the insights for the design of future efforts.

Recommendation 4: An information repository of middle-mile broadband infrastructure should be created that would allow researchers to study the extent and impact of this infrastructure on broadband access, usage, and impact.

Recommendation 5: More resources should be allocated towards maintaining the National Broadband Map, Spectrum Dashboard, and other efforts to make information public on broadband resources and availability.

Recommendation 6: Provide funding for a centralized data-sharing infrastructure so individual agencies can make data available without having to incur significant costs themselves

C.2 Initiating Special Efforts to Collect Data on Underrepresented Groups.

Participants expressed the opinion that special efforts have to be made in national surveys to include sufficient number of responses from underrepresented groups, such as persons with disabilities and Native nations' citizens, to provide generalizable results. Data collection efforts have to be respectful of Indigenous data sovereignty. Inadequate coverage of tribal lands in

national surveys and Census data, the aggregation of data without distinguishing between tribes, the unavailability of data aggregated in ways useful for Native nations, etc. were mentioned as problems.

Recommendation 7: Conduct data collection efforts with the active cooperation of Native nations, entities, and communities; create data sharing agreements; recognize and respect tribal sovereignty; determine policy opportunities for tribes to assert sovereignty and self-determination within the broadband sector.

Recommendation 8: Agencies may dedicate additional funding for research on small populations that are not adequately covered in national studies, such as persons with disabilities and tribal populations, and ensure that national surveys use techniques to recruit sufficient number of respondents from these groups to provide generalizable results.

C.3 Facilitating Information Sharing.

Some broadband research generates valuable datasets that could be useful to other researchers, but sharing these datasets can be difficult and labor-intensive. For example, data collected by monitoring network traffic may include sensitive information that should not be shared without removing or anonymizing data that could compromise privacy of network users. Some data is derived in part through partnerships with commercial actors, and datasets should not be shared until proprietary information is removed. Even when all data can be shared, the data may be meaningless to other researchers without thorough documentation and support. Researchers may lack the resources and the incentive to devote time and resources into making their datasets available to others.

Recommendation 9: Funding agencies should provide grants to cover the costs of making datasets available and valuable to the broader research community.

C.4 Encouraging the Private Sector to Share Broadband Data with Researchers

As required by law, the FCC, FTC and other agencies protect the privacy of individuals by limiting the ability of companies to use and disclose sensitive or personally identifiable information. Workshop participants expressed concern that some rules intended to protect consumer privacy might have the unintended side effect of preventing companies from sharing data from broadband systems that could help researchers advance the field. This is currently an issue in an ongoing FCC proceeding on privacy in broadband Internet access services, and the issue is likely to return in many policy debates to come. As the health care industry has shown, with careful consideration and appropriate safeguards, it is often (although not always) possible to provide researchers with the information they need to make good progress without compromising privacy.

Recommendation 10: The FCC and other agencies should consider the impact of their privacy decisions on broadband-related research, and should explicitly solicit the views of individuals with substantial research expertise in the relevant field, before making decisions that would affect the broadband data available to researchers.

Recommendation 11: NSF should develop a framework that would facilitate and encourage private industry to allow researchers to access and study data on broadband usage and impact,

in a way that would protect confidentiality of that data while offering findings that would help grow the broadband ecosystem

D. Other Recommendations

In addition to the major recommendations with broad implications identified above, participants also suggested other initiatives that are more narrowly focused, but offer the promise of improving digital inclusion efforts in substantial ways. These are included not as an exhaustive list of ideas raised by participants, but only a sampling of specific proposals where Agency initiatives are likely to have immediate impact. These include (1) Improving access to spectrum, (2) ensuring broadband infrastructure resilience, and (3) assuring emergency communications for persons with disabilities and Non-English speakers.

D.1 Improving Access to Spectrum

Promoting efficient use of scarce spectrum is a vital goal that can also contribute to greater broadband availability. Improving the efficiency of spectrum use calls for a variety of strategies: basic research on new technologies, experimentation to understand the potential impact of new and existing technologies, observation of spectrum usage, interdisciplinary collaborations combining research on advanced wireless technology, economic incentives, and spectrum policy and regulations, etc.

The community recommends that wireless testbeds be made available to advance new and better ways to access spectrum, especially those that have the potential to expand access to broadband or reduce its cost. This may include experimentation with novel forward-looking techniques to assess whether techniques that have already been established by researchers are ready for technology transfer and widescale deployment. In some cases, new wireless testbeds may be needed. In others, this need can be met by expanding access to existing testbeds.

Recommendation 12: Make wireless testbeds broadly available to advance new and better ways to access spectrum, especially those that have the potential to expand access to broadband or reduce its cost.

D.2 Ensuring Broadband Infrastructure Resilience

Both forward-looking research and near-term applied research are needed to find ways to make communications systems more useful and resilient when natural or man-made disasters occur: including methods of analyzing system resilience, testing critical system components, implementing fault tolerant designs. Research is needed to understand more flexible approaches such as dynamically reconfiguring links if some are destroyed, and building redundant links and adapting to achieve resilience more cost-effectively than by increasing the reliability of individual links. We must also understand the cost of improved resilience, to support informed decisions about the level of resilience that is appropriate.

Recommendation 13: Promote interdisciplinary solicitations focused on the resilience of telecommunications infrastructure

D.2 Assuring Emergency Communications for Persons with Disabilities and non-English Speakers

To ensure that everyone has access to emergency alerts and information and 911, systems such as Integrated Public Alert and Warning System, Wireless Emergency Alerts, and various systems run by local governments and private-sector organizations have to be made accessible to persons with disabilities and non-English Speakers. The U.S. has begun a transition to a next-generation 911 system (NG911). For both emergency alerts and 911, further work is needed to assess and incrementally improve today's systems, and to seek even better approaches in the future.

Recommendation 14: The ability of broadband infrastructures to serve persons with disabilities and non-English speakers in times of disasters should be included in fundamental notions of broadband infrastructure assessment and could be incorporated in an NSF/NTIA/FCC/DHS program.

Appendix A: Workshop Program

Broadband2021
 June 16-17, 2016
 Agenda and Schedule



Thursday, June 16

8:30 am	Registration, check in and coffee
9:00 am	<p>Opening remarks and introductions</p> <ul style="list-style-type: none"> - Carleen Maitland and Krishna Jayakar, IIP Penn State - Jack Brassil, NSF and Francine Alkisswani, NTIA <p>Francine Alkisswani introduces the speakers</p> <ul style="list-style-type: none"> - Erwin P. Gianchandani, NSF - Karen Hansen, NTIA - Keith Marzullo, NITRD <p>Introducing the Rapporteurs and Moderators</p> <ul style="list-style-type: none"> - Rapporteur Technology, Jon Peha, Carnegie Mellon University - Rapporteur Usage, Sharon Strover, University of Texas at Austin - Rapporteur Impacts, Johannes Bauer, Michigan State University - Moderator Technology, Carleen Maitland, IIP Penn State - Moderator Usage, Richard Taylor, University of Hawaii - Moderator Impacts, Krishna Jayakar, IIP Penn State
10:00 am	Coffee Break
10:30 am	<p>Concurrent Breakout Sessions: Defining a Research Agenda [Technology; Usage; Impacts]</p> <p>Examples of questions that may be asked during this session: What research inputs are required to address the short- and long-term needs of technology, utilization and impacts? What critical problems are left unsolved? What types of research are needed in these areas?</p>
12:00 noon	<p>Lunch and Keynote</p> <p>Erica Swanson, Google Fiber</p>
1:45 pm	<p>Concurrent Breakout Sessions: Status of Current Research. [Technology; Usage; Impacts]</p> <p>Examples of questions that may be asked during this session: What is the current state of research on broadband technology, policy, utilization and impacts? What new technologies might have a significant impact on broadband rollout, availability and access? How cost-effective are new technologies in terms of their capacity to increase availability and usage? According to the latest research, what factors drive the adoption of</p>

	broadband and information and communication technologies, and what factors impede adoption? How can unserved and underserved groups such as the urban poor, rural residents, persons with disabilities be enabled to access broadband? What does research say about the effects of broadband on economic growth, individual empowerment and social change?
3:15 pm	Break
3:45 pm	Plenary session review of work in breakouts - Jon Peha, Sharon Strover and Johannes Bauer
5:00 pm	Adjourn
6:30 pm	Reconvene for off-site dinner and discussion

Friday, June 17

8:00 am	Coffee
8:30 am	Concurrent Breakout Sessions: Data, Resources and New Research Directions [Technology; Usage; Impacts] Examples of questions that may be asked during this session: What types of wireless network testbed facilities exist? Are they sufficient? What publicly accessible data sources can help address key questions of broadband utilization and impacts? What are the problems, if any with existing data sources? How may these problems be addressed through better collection, archiving and distribution practices? What other data are required to help analyze and evaluate broadband deployment and impacts?
10:00 am	Coffee Break
10:30 am	Keynote remarks Calvin Johnson , HUD
11:15 am	Plenary session: Defining a Research Agenda – Evolving a consensus - Jon Peha, Sharon Strover and Johannes Bauer
12:30 pm	Networking Lunch
2:15 pm	Plenary session: Drafting the Interim Report (Themes, Sections) - Jon Peha, Sharon Strover and Johannes Bauer
3:45 pm	Break
4:00 pm	Closing Plenary: Summary of workshop; Questions, Dissemination of Report and Next Steps - Carleen Maitland and Krishna Jayakar
5:00 pm	Adjourn

Appendix B: Participant Biographies

Keith Adams has been Assistant Administrator for the Telecommunications Program in the U.S. Department of Agriculture's (USDA) Rural Utility Service (RUS) since July 2013. In this role he manages the Telecommunications Program's loan and grant programs, with an annual budget of almost \$1 billion and a \$4 billion loan portfolio. The Telecommunications Program was further expanded in 2009 under the American Recovery and Reinvestment Act, which authorized \$2.5 billion in budget authority for RUS to provide additional broadband funding through the Broadband Initiatives Program. Under Mr. Adams management, the program has awarded more than \$1 billion to date. As the Assistant Administrator for Telecommunications in the USDA Rural Utility Service, I lead in the furtherance of mission and program goals of expanding broadband services to underserved rural communities through a diverse workforce ranging from managers, loan specialists, and engineers. The position requires close coordination with other Rural Development programs along with a focus towards economic development opportunities in rural America. Keith will be responsible for planning, directing, and coordinating with counterparts at the Department of Commerce's National Telecommunications and Information Administration (NTIA) which serves as the President's Advisor on Telecommunications, the White House's Office of Technology and Science (OSTP), the Federal Communications Commission (FCC) and other Federal, state and local authorities. Mr. Adams tenure with the U.S. Department of Agriculture (USDA) first began in 2001 as a Marketing Specialist with the Foreign Agricultural Service (FAS). His experience also includes time with the U.S. Postal Service, U.S. Small Business Administration and most recently with the U.S. Agency for International Development (USAID). Since 2006, Mr. Adams was the Division Chief in USAID's Office of Food for Peace providing overall leadership for the planning and integration of the day to day operations and budget of the Government's largest resource for food aid and food security assistance effectively working with both private volunteer and International organizations, and other government agencies in achievement of a program valued at over \$2 billion. Mr. Adams holds a Bachelor of Science Degree from Shepherd University, where he majored in Marketing and received his Master of Science (MS) degree from the University of Maryland in 1999. Keith is active in his community serving as Board of Director for his Homeowners Association and serving faithfully at his church. He resides in the suburban Washington DC Metropolitan area with his son.

Francine Alkissawani is a Telecommunications Policy Analyst with the National Telecommunications and Information Administration's (NTIA) BroadbandUSA initiative. During her tenure at NTIA she has been the evaluation specialist for NTIA's Technology Opportunities Program (TOP), a program officer for the TOP information and communications demonstration projects and the Broadband Opportunities Program. Currently she is working with the team assigned to develop a National Broadband Research Agenda as called for in the Broadband Opportunity Council report to the President. Prior to NTIA, she served on the City of Philadelphia Mayor's Telecommunications Advisory Committee, the Pennsylvania Governor's Link-to-Learn Program Task Force, and was a senior evaluator with the U.S. General Accounting Office.

Johannes M. Bauer is a Professor in the Department of Media and Information at Michigan State University. Since January 2013 he also serves as the Department Chair. He is trained as an engineer and economist, holding MA and PhD degrees in economics from the Vienna University of Economics and Business Administration, Austria. His experience at MSU is complemented by extended stays as a visiting professor at the Technical University of Delft, Netherlands (2000-2001), the University of Konstanz, Germany (Summer 2010), and most recently the University of

Zurich, Switzerland (2012). His research covers a wide range of issues related to innovation in information and communication technology industries (ICT), business models of national and global players, as well as the public policy and governance challenges of harnessing the full benefits of ICT for society. He also has developed and used computational methods to examine the effects of governance on advanced communications infrastructure and applied big data analytical methods to problems of information security. Dr. Bauer is a frequent speaker at international conferences and has served as an advisor to public and private sector organizations in North and South America, Europe, and Asia

Samantha Becker, MLIS, MPA, is the Principal Research Scientist for the TASCHA | U.S. Impact Study Research Group at the University of Washington Information School. Her research focuses on digital inclusion programs and policies, with an emphasis on community technology and public libraries. She was co-author of the first large-scale study of the impact of public access technology in public libraries, *Opportunity for All: How the American Public Benefits from Internet Access at U.S. Libraries* and also coauthored *Building Digital Communities A Framework for Action*, a tool to help assess communities and help them work towards becoming digitally inclusive. Her work is focused on helping the digital inclusion community leverage data to improve outcomes for people left behind by technology advancements and support excellence in programs that help bridge the digital divide. She is particularly interested in the adoption of common metrics and understanding barriers to effective use of technology.

Doug Brake is a telecommunications policy analyst at the Information Technology and Innovation Foundation. He specializes in broadband policy, wireless enforcement, and spectrum-sharing mechanisms. He previously served as a research assistant at the Silicon Flatirons Center at the University of Colorado, where he sought to improve policy surrounding wireless enforcement, interference limits, and gigabit network deployment. Prior to that, he served as a Hatfield scholar at the Federal Communications Commission, assisting with the implementation of the advanced communications services section of the 21st Century Communications and Video Accessibility Act. Brake holds a law degree from the University of Colorado Law School and a bachelor's degree in English literature and philosophy from Macalester College. His research areas include broadband and wireless.

Jack Brassil currently serves as a Program Director in the Division of Computer and Network Systems at the National Science Foundation in Arlington, Virginia, USA. His program responsibilities include the networking research core program (NeTS) and experimental networking and computing research infrastructure (e.g., GENI, US Ignite, NSFFutureCloud). Dr. Brassil has performed and managed computing and networking research for over 25 years, is a Senior Scholar in the Department of Computer Science at Princeton University (on leave), and is a Fellow of the IEEE.

Justin S. Brown is an assistant professor in the Zimmerman School of Advertising & Mass Communications at the University of South Florida, teaching courses in telecommunications, law and research methods. His research focuses on telecommunications law and policy issues including broadband deployment and new media. He has made numerous research presentations at conferences organized by the International Communications Association (ICA), American Educators in Journalism & Mass Communication (AEJMC), Broadcast Education Association (BEA) and the Telecommunication Policy Research Conference (TPRC). His research is represented in such publications as *Cardozo Arts & Entertainment Law Journal*, *Communication*

Research, Communication Law & Policy, Federal Communications Law Journal, Cornell Journal of Law & Public Policy, IDEA: Intellectual Property Law Review, Journalism & Mass Communication Quarterly and *info: The journal of policy, regulation and strategy for telecommunications, information and media*. Justin is currently serving as the MCI Communications Congressional Fellow, working in the office of Sen. Brian Schatz (DHI) to help support his role as ranking minority member of the Communications, Technology, Innovation and the Internet subcommittee. He earned his B.S. (Journalism) from the University of Oregon, and both his M.A. (Telecommunication Studies) and Ph.D. (Mass Communication) from Penn State University.

Jay Chen is an assistant professor of Computer Science at NYU Abu Dhabi and the Co-Director of the Design Technology Lab. His research is in the area of information and communication technologies for development (ICTD), a rich seam at the intersection of technical systems and social systems. His work focuses on 'incidental interventions', technology interventions that leverage people's existing behaviors or latent aspirations in order to encourage technology adoption in developing regions. He is a research assistant professor at the NYU Polytechnic School of Engineering and a member of the Center for Technology and Economic Development (CTED). B.S., B.A., M.S. University of California (San Diego); Ph.D. New York University.

David Clark is a Senior Research Scientist at the MIT Computer Science and Artificial Intelligence Laboratory, where he has worked since receiving his Ph.D. there in 1973. Since the mid 70s, Dr. Clark has been leading the development of the Internet; from 1981-1989 he acted as Chief Protocol Architect in this development, and chaired the Internet Activities Board. His current research looks at re-definition of the architectural underpinnings of the Internet, and the relation of technology and architecture to economic, societal and policy considerations. He is helping the U.S. National Science Foundation organize their Future Internet Design program. He is past chairman of the Computer Science and Telecommunications Board of the National Academies, and has contributed to a number of studies on the societal and policy impact of computer communications. He is co-director of the MIT Communications Futures Program, a project for industry collaboration and coordination along the communications value chain.

Leah Davis is a Senior Research Associate with the Center for Digital Inclusion (CDI) in the Graduate School of Library and Information Science, University of Illinois, Urbana-Champaign. Leah's role at CDI is to lead research and provide expertise on community projects. She helped lead completion of the Inclusive Gigabit Libraries project funded by the Institute of Museum and Library Services. Leah was a consultant and field lead for the evaluation of the Broadband Technology Opportunities Program of the National Telecommunications and Information Administration, U.S. Department of Commerce. In addition, she has been a principal investigator conducting and administering research projects on information and communication technology use in the nonprofit and public sectors. Leah is currently engaged in research analyzing information technology and knowledge sharing among public sector organizations and social networks, as well as broadband adoption and digital inclusion. She participated as a delegate for the National Academy of Public Administration consultation with the Ghana Public Services Commission to improve e-governance services in Accra, Ghana. Leah received her Ph.D. from the School of Public and Environmental Affairs at Indiana University, where she studied policy analysis and public management. She completed a minor in information science from the School of Library and Information Science at Indiana University.

Tawanna Dillahunt is an Assistant Professor at the University of Michigan's School of Information (UMSI) and holds a courtesy appointment with the Electrical Engineering and Computer Science (EECS) department. Tawanna leads the Social Innovations Group at UMSI and her research interests lie at the intersection of human-computer interaction, ubiquitous computing, and social computing. She is primarily interested in identifying how theories from the social sciences can be used to design technologies that have a positive impact on group and individual behavior. With the narrowing of the digital divide, the ubiquity of smart devices and mobile hotspots in common places in the U.S. (e.g., libraries, community centers, and even McDonald's) she sees an urgent need to explore the use of these technologies for those that stand the most to gain from these resources. Therefore, she designs, builds, enhances and deploy innovative technologies that solve real-world problems, particularly in underserved communities. Dr. Dillahunt holds a M.S. and Ph.D. in Human-Computer Interaction from Carnegie Mellon University, a M.S. in Computer Science from the Oregon Graduate Institute School of Science and Engineering (now a part of the Oregon Health and Science University in Portland, OR), and a B.S. in Computer Engineering from North Carolina State University. She was also a software engineer at Intel Corporation for several years.

William H. Dutton is the Quello Professor of Media and Information Policy in the Department of Media and Information, College of Communication Arts and Sciences at Michigan State University, where he is Director of the Quello Center. Prior to this appointment, Bill was Professor of Internet Studies at the Oxford Internet Institute, University of Oxford, where he was the Founding Director of the OII and a Fellow of Balliol College. Bill received a Lifetime Achievement Award for his role as Founding Director of the OII. He is also the recipient of the International Communication Association's (ICA) first Fred Williams' award for contributions to the study of communication and technology, the William F. Ogburn Lifetime Achievement Award from the Communication and Information Technologies Section of the American Sociological Association in 2014, and was named an ICA Fellow in 2015. Bill is presently a co-principal investigator in the UK FCO supported Global Cyber Security Capacity Project, and developing a set of projects on digital inequalities and their implications in Detroit, Michigan, and the United States.

Valerie Fast Horse has worked for the Coeur d'Alene Tribe as the Director of IT for the past 16 years. She has four programs within her Department: IT- Government Services, Geographic Information Systems (GIS), Red-Spectrum Communications (the Tribe's broadband provider), and KWIS 88.3 FM (the Tribe's radio station). In 2005 she successfully planned and implemented a \$2.8 million broadband grant to build a Tribal Community Technology Center and deploy a wireless ISP (Red-Spectrum) to bring broadband services to residents of the Coeur d'Alene Reservation for the first time. More recently in 2015 she completed a \$10.2 million fiber-to-the-home project that included construction of 121 route miles of fiber, 1 new wireless tower, and equipment upgrades to 5 existing towers & access points. Through these efforts the Tribe is able to reach over 3,000 homes with either fiber or wireless connections. Fast Horse is a former elected tribal leader and served six years as a Tribal Council member. In 2011 she was appointed to serve on the FCC-Native Nations Broadband Task Force. Also in 2011 she was selected as one of the 15 positive female role models nominated for changing the course of history in the state of Idaho and received the Idaho "Women Making History" award by the Boise State Women's Center.

Nick Feamster is a professor in the Computer Science Department at Princeton University and the Acting Director of the Princeton University Center for Information Technology Policy (CITP).

Before joining the faculty at Princeton, he was a professor in the School of Computer Science at Georgia Tech. He received his Ph.D. in Computer science from MIT in 2005, and his S.B. and M.Eng. degrees in Electrical Engineering and Computer Science from MIT in 2000 and 2001, respectively. His research focuses on many aspects of computer networking and networked systems, with a focus on network operations, network security, and censorship-resistant communication systems. In December 2008, he received the Presidential Early Career Award for Scientists and Engineers (PECASE) for his contributions to cybersecurity, notably spam filtering. His honors include the Technology Review 35 "Top Young Innovators Under 35" award, the ACM SIGCOMM Rising Star Award, a Sloan Research Fellowship, the NSF CAREER award, the IBM Faculty Fellowship, the IRTF Applied Networking Research Prize, and award papers at the SIGCOMM Internet Measurement Conference (measuring Web performance bottlenecks), SIGCOMM (network-level behavior of spammers), the NSDI conference (fault detection in router configuration), Usenix Security (circumventing web censorship using Infranet), and Usenix Security (web cookie analysis).

Kenneth Flamm is a Professor and holder of the Dean Rusk Chair at the LBJ School of Public Affairs at the University of Texas at Austin. He is an honors graduate of Stanford University and received a Ph.D. in economics from MIT. From 1993 to 1995, Dr. Flamm served as Principal Deputy Assistant Secretary of Defense for Economic Security and Special Assistant to the Deputy Secretary of Defense for Dual Use Technology Policy, and was awarded the Distinguished Public Service Medal by the Secretary of Defense for his work at DoD. Prior to, and after his service at the Defense Department, he spent eleven years as a Senior Fellow in the Foreign Policy Studies Program at the Brookings Institution. Dr. Flamm has been a professor of economics at the Instituto Tecnológico A. de México in Mexico City, the University of Massachusetts, and George Washington University. Flamm has been elected to membership in the Conference on Research on Income and Wealth, has served as vice-chair of the National Research Council's Panel on Comparative Innovation Policy, and as a member of its Science, Technology, and Economic Policy Board, its Committee on Assessing the Need for a Defense Stockpile, its assessment panel on the Small Business Innovation Research Program, its Committee on the Rationale and Goals of the U.S. Civil Space Program, its Committee on the Future of Supercomputing, and its Steering Group on Measuring and Sustaining the New Economy. He has served as member and Chair of the NATO Science Committee's Panel for Science and Technology Policy and Organization, and as a member of the Federal Networking Council Advisory Committee, the OECD's Expert Working Party on High Performance Computers and Communications, various advisory committees and study groups of the National Science Foundation, the Council on Foreign Relations, the Defense Science Board, and the U.S. Congress' Office of Technology Assessment, and as a consultant to various government agencies, international organizations, and private corporations. Dr. Flamm is the author of numerous articles and books on the dynamics of global competition in high technology industries, including studies of broadband adoption and diffusion, and the computer, semiconductor, Internet, and telecommunications industries.

Jon Gant is a national leader in the areas of digital inclusion and broadband adoption. Jon is currently a professor at the Graduate School of Library and Information Science at the University of Illinois at Urbana-Champaign where he serves as the founding Director of the Center for Digital Inclusion (CDI). Under Jon's leadership, CDI examines the social and economic impact of information and communication technologies globally. Jon is the principal investigator for the Illinois Digital Innovation Leadership Program. This is a collaboration with University of Illinois

Extension and the Champaign-Urbana Community Fab Lab to build local high tech hubs in Illinois based to support digital fabrication, digital media production and data analytics. CDI is currently developing new research on smart cities/communities and next-generation Internet applications to serve the public. Since 2009, Jon served as a director of Urbana-Champaign Big Broadband (UC2B), a University of Illinois-led intergovernmental consortium with the City of Urbana and City of Champaign operating an Internet service provider startup providing gigabit speed Internet access serving households, businesses and community anchor institutions in Urban-Champaign, IL. UC2B received a \$22 million Broadband Technology Opportunity Program grant to construct a 187-mile fiber-optic broadband network infrastructure. Jon served as director for business development and was responsible for designing and implementing an innovative data analytics approach for business development, network engineering and construction, and customer relationship management. Since the completion of the BTOP grant in 2014, UC2B is now a not-for-profit ISP. UC2B is partnering with ITV-3 to expand gigabit services, voice and video to households in Urbana-Champaign. Jon serves currently as the Chairperson of the UC2B Board of Directors . Jon served as a research director for the evaluation of the Department of Commerce's Broadband Technology Opportunity Program (BTOP) as a consultant with ASR Analytics. Jon collaborated with the evaluation team to develop the mixed method research design, train and mentor the research and data analytics team, lead site visits, conduct interviews, brief senior NTIA officials, analyze the social and economic impacts, and co-author the case studies and final reports. The Institute of Museum and Library Services, the Organization for Economic Coordination and Development, the International Telecommunication Union, the State of Illinois, Partnership for a Connected Illinois, the American Library Association, and the National Science Foundation, among others, have funded Jon's research. Jon received his M.S. and Ph.D. degrees from Heinz College at Carnegie Mellon University, where he studied public policy and information management. Jon earned his undergraduate degree from the University of Michigan.

Rafi Goldberg is a technology-centric policy analyst with experience in research, politics, and both federal and state government. He is currently a Telecommunications Policy Analyst at the National Telecommunications and Information Administration (NTIA), the Commerce Department agency that advises the President on Internet and communications policies. The broad scope of his work at NTIA includes examining data on computer and Internet use in the United States, as well as analyzing policy issues ranging from intellectual property to mobile device portability. Rafi has experience with a broad range of contemporary policy questions, including network neutrality, universal service, and competition issues. Rafi earned a Master of Public Policy degree at Georgetown University in 2011, with a concentration in environmental and regulatory policy. For his master's thesis, "Broadband Use and Civic Engagement," Rafi analyzed survey data to find that broadband Internet use is a positive indicator of several forms of participation in civic life. Prior to attending graduate school, Rafi served in the Office of Massachusetts Governor Deval L. Patrick, where his primary task was vetting candidates for appointment to high-level Executive Branch positions. While at the Governor's Office, he led the development of a transparency-enhancing web site that details all seven hundred state boards and commissions to which the Governor makes appointments, and enables interested constituents to apply online for open positions. Rafi is a proud alumnus of Tufts University, from which he graduated in 2006 with a BA in Political Science. At Tufts, he successfully advocated for, and worked on the implementation of, a fund that awards stipends to students undertaking unpaid summer internships in public service.

Tony H. Grubestic is the College Professor of Policy Analytics at Arizona State University, where he is also Director of the Center for Spatial Reasoning & Policy Analytics. He has previously held academic appointments at Drexel University, Indiana University and the University of Cincinnati. Grubestic is editor of *International Regional Science Review* and associate editor for *Telematics and Informatics*. His research and teaching interests are in geographic information science, regional development and public policy evaluation. Author of over 120 research publications, his recent work focuses on spatial analytics and data uncertainty, neighborhood dynamics, telecommunications policy and air transportation systems. Grubestic obtained a B.A. in Political Science from Willamette University, a B.S. in Geography from the University of Wisconsin-Whitewater, a M.A. in Geography from the University of Akron, and a Ph.D. in Geographic Information Science from Ohio State University. His most recent book, *Broadband Telecommunications and Regional Development*, is now available from Routledge: <https://www.routledge.com/products/9781138013919>. For more details, see <http://www.tonygrubestic.net>

Karen Hanson is the Director of Partnerships and Interagency Affairs for BroadbandUSA with the National Telecommunications and Information Administration (NTIA) at the U.S. Department of Commerce. Karen is responsible for promoting partnerships with BroadbandUSA and coordinating NTIA's interagency efforts to promote broadband adoption and deployment. Karen also manages NTIA's work on the Broadband Opportunity Council (BOC), an interagency working group established by President Obama in 2015. Karen's background includes experience in the nonprofit, philanthropic, and private sectors. She graduated from Duke University with a B.A. in Public Policy Studies and has an MBA from the Marshall School of Business at the University of Southern California.

John B. Horrigan is a Senior Researcher at the Pew Research Center where he focuses on libraries, communities, and technology adoption. He rejoined the Pew Research Center in January 2015, having been with Pew before from 2000 to 2009. In 2009, he joined the leadership team at the Federal Communications Commission and he led development of the broadband adoption and usage portion of the National Broadband Plan. He is a nationally recognized leader on home broadband adoption patterns, the impact of connectivity on individuals, and strategies for closing adoption gaps. At Pew, he has authored recent reports on broadband adoption and lifelong learning and technology. As a consultant, Horrigan is author of landmark reports on Comcast's Internet Essentials program. The reports, "The Essentials of Connectivity" and "Deepening Ties" demonstrate the impact of online access for low-income families with children and make recommendations on how to accelerate broadband adoption and usage. Horrigan has a Ph.D. in public policy from the University of Texas at Austin and his undergraduate degree from the University of Virginia.

Heather E. Hudson is Affiliate Professor of Communications Policy at the Institute of Social and Economic Research (ISER), University of Alaska, Anchorage. She was previously Director of ISER and founding Director of the Telecommunications Management and Policy Program at the University of San Francisco. Her research focuses on applications of information and communication technologies for socioeconomic development, regulatory issues, and policies and strategies to extend affordable access to communications, particularly in rural and developing regions. She has planned and evaluated communication projects in Alaska and northern Canada and more than 50 developing countries and emerging economies. Dr. Hudson is the author of numerous articles and several books and is the recipient of two Fulbright awards and a Sloan

Industry Fellowship. She has consulted for international organizations, government agencies, the private sector, and consumer and indigenous organizations, and has testified before regulators in the U.S. and Canada. Her latest book is *Connecting Alaskans: Telecommunications in Alaska from Telegraph to Broadband* (University of Alaska Press, 2015). Her recent activities include research on Internet and broadband usage in indigenous communities in Alaska and northern Canada, testimony on behalf of First Nations communication organizations on broadband as a basic service in Canada, and particularly NTIA's FirstNet Public Safety Advisory Council.

Krishna Jayakar is an associate professor in the Department of Telecommunications, the co-Director of the Institute for Information Policy, and the Coordinator for the intercollege Information and Communication Technologies for Development (ICT4D) Consortium at Penn State University. He has published close to fifty journal articles and book chapters and made around a 100 peer-reviewed conference presentations and invited talks on telecommunications policy and media economics, specializing in universal access to telecommunications. He serves on the visiting faculty of two Chinese universities and as Visiting Professor at the School of International Affairs at Penn State. He is the Co-Editor of the *Journal of Information Policy* and serves on the board of editors of *The Information Society* journal. Dr. Jayakar's research has been supported by grants from the Pacific Telecommunications Council, Time Warner Cable, the Free Press Foundation, AT&T etc. He teaches course in telecommunications management and media economics. Before joining academics, Dr. Jayakar was a research officer in India's Ministry of Information and Broadcasting, drafting research reports and position papers on media policy. Dr. Jayakar received his undergraduate degree in engineering from the Institute of Technology-BHU, India, and masters and PhD from Indiana University, Bloomington.

Calvin Johnson is a Deputy Assistant Secretary at the U.S. Department Housing and Urban Development (Policy Development and Research/Office of Research, Evaluation, and Monitoring [OREM]). OREM is responsible for conducting demonstrations, evaluations, and analyses across a variety of topics to include housing assistance programs, the intersection of housing and health, homelessness, community development, building technology, renewable energy, and disaster and community resiliency. Prior to joining HUD, he held the position of Associate Director for the Office of Research and Evaluation at the Court Services and Offender Supervision Agency for the District of Columbia where he was responsible for the predictive analytics in the areas of offender compliance and preventive interventions intended to mitigate identified social and behavioral risks. His other prior research experiences include positions held at the University of Pennsylvania, The Executive Office of the Mayor of the District of Columbia, and The Urban Institute where he was responsible for leading evaluations of crime control and prevention policy studies and place-based initiatives. He received his BA in Sociology from Eastern Washington University, his MA in Sociology from Temple University, and his PhD in Criminology and Criminal Justice from the University of Maryland at College Park.

Grace Kena is an Education Statistician at the National Center for Education Statistics (NCES) housed within the Institute of Education Sciences at the U.S. Department of Education. Grace works within the Annual Reports Program at NCES, where she effectively leads and provides analytic guidance and input for a number of complex and high-profile projects and efforts. Grace's knowledge of issues spans the education spectrum, ranging from early childhood to postsecondary education and beyond. She is currently the project lead for one of the Center's flagship reports, the Congressionally mandated *Condition of Education* which is released annually. She also supports the NCES Commissioner on various special projects, including developing presentations and

talking points, and providing input for both one-time and ongoing initiatives. Grace has a bachelor's degree from The University of Chicago in a concentration titled the history, philosophy, and social studies of science and medicine. She also has a master's degree in public policy from Duke University. Grace has particular interest in enhancing education outcomes for underprivileged and underserved youth and in using data to advance programmatic and policy efforts.

Tom Koutsky serves as Chief Policy Counsel for Connected Nation. Tom has published numerous articles on broadband policy, the economics of telecommunications networks, the effectiveness of public policy on broadband adoption, telecommunications competition policy, universal service, and network interconnection and access policies. Tom served at the Federal Communications Commission as a senior advisor on the team that wrote the first U.S. National Broadband Plan. For the Plan, Tom focused on policy recommendations related to federal, state, and local policies, network infrastructure, the law and economics of middle mile connectivity, wholesale competition rules, and policy and universal service and access charge reform. Prior to his involvement with the National Broadband Plan, Tom served as chair of the FCC's North American Numbering Council, and was a resident scholar for the Phoenix Center for Advanced Legal and Economic Public Policy Studies. Tom holds a juris doctorate from University of Chicago Law School and a bachelor of arts in political science from the University of Illinois.

William Lehr is a telecommunications/Internet industry economist and policy analyst with over twenty-five years of experience in academic research and industry consulting. He is currently a research scientist in the Computer Science and Artificial Intelligence Laboratory (CSAIL) at the Massachusetts Institute of Technology (MIT). Dr. Lehr's research focuses on the economic and policy implications of broadband Internet access, next generation Internet architecture, and the evolution of wireless technology. In addition to his academic research, Dr. Lehr regularly advises senior executives and policymakers in the U.S. and abroad on business strategy and policy matters of relevance to the communications and information technology industries. Dr. Lehr holds a PhD in Economics from Stanford, an MBA in Finance from the Wharton School, and MSE, BA, and BS degrees from the University of Pennsylvania.

Maureen Lewis joined the National Telecommunications and Information Administration (NTIA) as the Director of Minority Telecommunications Development in 2000. NTIA, an agency of the U. S. Department of Commerce, is the executive branch agency principally responsible for advising the President on telecommunications and information policy. In her role, Ms. Lewis develops and advocates policies to promote minority ownership of media and telecommunications enterprises and affordable access to information technology. She is also a member of NTIA's domestic policy team that researches computer and Internet use for the agency's "Exploring the Digital Nation" reports. An alumna of Georgetown University Law Center and Spelman College, Ms. Lewis began her legal career as an antitrust attorney at the Federal Trade Commission and then as an advisor to a commissioner. She next served as senior counsel for Howard University and then as general counsel for a non-profit advocacy organization urging ubiquitous, affordable broadband access throughout the nation. Ms. Lewis is a member of the bar of the District of Columbia and of the United States Supreme Court.

Mark Lloyd is a professor of communication at the USC-Annenberg School of Journalism and Communication. Lloyd's academic career includes two years as a visiting scholar at MIT, where he conducted research into the communications ecology of Cambridge, MA. Lloyd has also taught

at the Georgetown University Public Policy Institute, and lectured at Harvard, UCLA, Penn State and other institutions in the U.S. and abroad. From 2009- 2012 he served as an associate general counsel at the Federal Communications Commission, where he helped design and promote research to inform the national broadband plan and the report on the critical information needs of the public. Previously, Lloyd has been the General Counsel of the Benton Foundation. Before becoming a communications lawyer, Lloyd was an Emmy Award-winning broadcast journalist, including work at NBC and CNN. He is a graduate of the University of Michigan-Ann Arbor, and the Georgetown University Law Center.

Carleen Maitland is co-Director of the Institute for Information Policy and Associate Professor in the College of Information Sciences and Technology at Penn State University, USA. Her expertise includes analyses of information and communication technology (ICT) use in international organizations, particularly those involved in fostering economic and social development as well as humanitarian relief. Her work has been carried out in the U.S., Europe, Africa and the Middle East, while working with several UN organizations, Save the Children, and the U.S. State Department, just to name a few. Current projects include analyses of ICT use by and for refugees with the UN Refugee Agency (UNHCR) as well as the potential of white space technologies to extend service to rural populations in Native American communities. Outcomes from her work, including over 100 refereed publications and presentations have appeared in outlets such as the Journal of Information Technology, The Information Society, Telecommunications Policy, and Information Systems Frontiers. Her research has been supported by the National Science Foundation, the European Commission, the U.S. Department of Commerce, and IBM, among others. She received a Ph.D. in the Economics of Infrastructures from Delft University of Technology, the Netherlands, in 2001 as well as undergraduate and graduate degrees in engineering from Worcester Polytechnic Institute and Stanford University. Also, from 2010-2012 she served as a Program Manager in the U.S. National Science Foundation, both in the Office of International Science and Engineering and the Office of Cyberinfrastructure.

Keith Marzullo is the Director of the Federal Networking and Information Technology Research and Development (NITRD) National Coordination Office (NCO). He also serves as the Co-chair of the NITRD Subcommittee of the National Science and Technology Council (NSTC) Committee on Technology (CoT), where he oversees the operations and activities of the NITRD Program. The NCO reports to the Office of Science and Technology Policy (OSTP), Executive Office of the President. Dr. Marzullo joins NITRD NCO from the National Science Foundation (NSF), where he served as the Division Director for the Computer and Network Systems (CNS) Division in the Computer & Information Science & Engineering (CISE) Directorate. He also served as Co-Chair of the NITRD Cybersecurity and Cyber Physical Systems R&D Senior Steering Groups. Prior to joining NSF, Dr. Marzullo was a faculty member at the University of California, San Diego's Computer Science and Engineering Department, and served as the Department Chair from 2006-2010. Dr. Marzullo received his Ph.D. in Electrical Engineering from Stanford University, where he developed the Xerox Research Internet Clock Synchronization protocol, one of the first practical fault-tolerant protocols for keeping widely-distributed clocks synchronized with each other.

Grant Miller has worked for 18 years as the coordinator of Large Scale Networking (LSN) and High End Computing (HEC) at the National Coordination Office (NCO) supporting the NITRD Subcommittee of the National Science and Technology Council (NSTC). The LSN develops common approaches across the Federal agencies for R&D plans for advanced networking

programs and testbeds. Grant coordinates the Joint Engineering Team of the LSN which provides connectivity and performance of research and development networks, network testbeds, and prototypes of new networking technology. Mr. Miller coordinates the Middleware and Grid Interagency Coordination (MAGIC) Team that provides grid and cloud networking environments to support science R&D research and it facilitates the development of common approaches to Identity Management for science cooperation in cloud and grid environments. Mr. Miller coordinates the JET Big Data demonstrations that provide demonstrations of leading edge networking technology for big data applications at the annual Supercomputing Conference. Miller is the coordinator for the Federal agency Smart Cities Task Force that is promoting development and use of broadband and wireless technologies for Smart Cities.

Helena Mitchell is a *Regents' Researcher*, the highest status bestowed by the Board of Regents, which governs the University System of Georgia. In tandem, Dr. Mitchell is Executive Director of the Center for Advanced Communications Policy at the Georgia Institute of Technology. Since 2001 she has been the Principal Investigator for the Rehabilitation Engineering Research Center for Wireless Technologies (Wireless RERC) funded to research, evaluate and develop innovative wireless technologies and products that promote equitable access. Her areas of expertise include broadband and wireless communications, emergency/public safety communications, spectrum management, regulatory policy, and universal service to vulnerable populations. Dr. Mitchell has held senior positions at the Federal Communications Commission (FCC), where she was Associate Chief, Strategic Communications for the Office of Engineering and Technology and earlier was chief of the Emergency Broadcast System, and the first chief of the Emergency Alert System (EAS). Helena previously headed the telecommunications development programs for the National Telecommunications and Information Administration (NTIA), of the U.S. Department of Commerce. Helena has and continues to serve on a wide variety of community, industry and academic advisory councils and boards.

Traci Morris is the Director of Arizona State University's American Indian Policy Institute and a member of the Chickasaw nation of Oklahoma. Her work and research focuses on the digital divide (or divides), digital inclusion, internet use, and development of broadband in Indian Country and she has advocated for digital inclusion at the Federal Communications Commission and on Capitol Hill. Morris has worked with Native American Tribes, tribal businesses, native American non profits, native media makers, and artists and galleries.

Karen Mossberger is Professor and Director of the School of Public Affairs at Arizona State University. Her research interests include digital inequality, broadband evaluation, e-government, and urban policy. With Caroline Tolbert of the University of Iowa, she was part of a National Science Foundation grant to estimate Internet (including broadband) use for states, cities, metros and counties from 1997-2012 using the Current Population Survey. The team also created estimates for the 2013 and 2014 American Community Survey for Internet use by race, ethnicity, education, employment, and other factors. The data is available at ASU at <https://policyinformatics.asu.edu/broadbanddata-portal/home>. Using neighborhood-level estimates from 3 citywide surveys, Mossberger and colleagues conducted a multi-year evaluation of the Smart Communities BTOP program that found significantly higher increases in Internet use in the 9 low and moderate-income Chicago neighborhoods participating in the program, compared to other Chicago community areas. She is also co-editing a book on the evaluation of policy impacts of broadband, as a result of a national research roundtable held at the MacArthur Foundation. Recent projects include collaboration with Traci Morris and Nicholet Deschines to

examine urban and rural differences in Internet use for American Indians and Alaska Natives. Her co-authored books include *Digital Cities: The Internet and the Geography of Opportunity* (Mossberger, Tolbert, and Franko 2013, Oxford University Press), *Digital Citizenship: The Internet, Society and Participation* (Mossberger, Tolbert and McNeal 2008, MIT Press) and *Virtual Inequality: Beyond the Digital Divide* (Mossberger, Tolbert and Stansbury 2003, Georgetown University Press). Her work on Internet use has been supported by the National Science Foundation, U.S. Department of Housing and Urban Development, John D. and Catherine T. MacArthur Foundation, Smith Richardson Foundation, and Partnership for a Connected Illinois, among others. She was the 2014-2015 President of the Information Technology and Politics section of the American Political Science Association.

Jon Peha is a Professor at Carnegie Mellon University who has addressed information networks in industry, government, and academia. In government, he served at the Federal Communications Commission as Chief Technologist, in the White House as Assistant Director of the Office of Science & Technology Policy, in the House Energy & Commerce Committee, and at USAID where he helped launch and lead a US Government interagency program to assist developing countries with information infrastructure. In industry, he has been Chief Technical Officer for three high-tech companies, and a member of technical staff at SRI International, AT&T Bell Laboratories, and Microsoft. At Carnegie Mellon, he is a Professor in the Dept. of Engineering & Public Policy and the Dept. of Electrical & Computer Engineering, and former Associate Director of the university's Center for Wireless & Broadband Networking. His research spans technical and policy issues of information networks. Dr. Peha holds a PhD in electrical engineering from Stanford, and a BS from Brown. He is an *IEEE Fellow* and an *AAAS Fellow*, and was selected by AAAS as one of 40 "Featured AAAS Science and Technology Policy Fellows" of the last 40 years ("40@40"). Dr. Peha has received the FCC's "Excellence in Engineering Award," the IEEE Communications Society TCCN Publication Award for career contributions, and the Brown Engineering Medal.

Stephanie Carroll Rainie (Ahtna Athabascan) is Assistant Research Professor, Udall Center for Studies in Public Policy; Associate Director and Manager, Tribal Health Program for the Native Nations Institute (NNI) in the Udall Center for Studies in Public Policy; Assistant Professor in the Public Health Policy and Management Program at the Community, Environment and Policy Department (CEP), Mel and Enid Zuckerman College of Public Health (MEZCOPH); and Assistant Director for the Center for Indigenous Environmental Health Research (CIEHR) at the University of Arizona (UA). Stephanie's research explores the links between governance, health care, the environment, and community wellness. She collaborates with a community of tribal leaders and program staff, researchers, and students at the UA's NNI and CIEHR, and elsewhere. She is the co-founder of the US Indigenous Data Sovereignty Network, a founding member of the International Indigenous Data Sovereignty Network, and on the faculty advisory board for the University of Arizona's Center for Digital Society and Data Studies. She received her AB from Cornell University and MPH and DrPH from the University of Arizona.

David Reed is currently Director of the Interdisciplinary Telecom Program at the University of Colorado Boulder. He also is a Senior Fellow, Silicon Flatirons Center for Law, Technology, and Entrepreneurship at the CU Law School. Dr. Reed's research interests include telecommunications technology, policy, and economics: Applying interdisciplinary research methods to examine the evolution of telecommunications infrastructure to advanced wireless and broadband platforms and the resulting implications on business strategy or public policy objectives. Dr. Reed was the Chief

Technology Officer and Chief Strategy Officer at Cable Television Laboratories where he led R&D projects covering a wide range of technologies relevant to the cable industry such as application platforms, business services, voice-over-IP, and broadband delivery systems. Dr. Reed also has been a Telecommunications Policy Analyst in the Office of Plans and Policy at the Federal Communications Commission where he worked on cabletelco competition, personal communications services (PCS), and spectrum auction policies.

Robert Rhoads is a Branch Chief within the U.S. Department of Homeland Security's Office of Emergency Communications (OEC). Mr. Rhoads is responsible for supporting OEC in its mission to accelerate and attain operable and interoperable emergency communications among public safety agencies and across Federal, State, local and tribal governments nationwide. The Partnerships Branch, which Mr. Rhoads leads, provides support to SAFECOM, the National Council of Statewide Interoperable Coordinators (NCSWIC), the Emergency Communications Preparedness Center, (ECPC) the National Public Safety Telecommunications Council (NPSTC). These groups focus on improving emergency communications capabilities and work to inform and provide recommendations to all disciplines across all levels of government. Throughout his career at DHS, Mr. Rhoads has served on committees and working groups representing DHS, including the most recent FCC Task Force on Optimization of PSAP Architecture, the NPSTC Assessment of Future Spectrum and Technology, the FCC Technical Advisory Board for First Responder Interoperability, and the NPSTC Broadband High Level Launch Requirements. Prior to serving in DHS, Mr. Rhoads served nearly 30 years Fairfax County, Virginia Fire and Rescue Department before retiring as a Battalion Fire Chief in 2008. He has also worked as an engineer in the private sector. His achievements as an engineer include requirements development, integrating, testing, and demonstrating public safety systems and applications.

Steve Rosenberg has been the Chief Data Officer for the Wireline Competition Bureau at the Federal Communications Commission since the spring of 2010. His focus is on improving the collection, analysis and dissemination of data to inform policy-making in the bureau. Steve first joined the FCC in July, 2009 as part of the team working to create the National Broadband Plan, where he worked to quantify broadband availability and the costs associated with providing universal broadband access. Prior to joining the Commission, Steve worked in the telecom practice at McKinsey & Company before working at The Advisory Board, serving not-for-profits in the healthcare and education sectors. He earned a Ph.D. in Physics from UCLA in 1999.

Leila Samy leads the U.S. Department of Health and Human Services' (HHS) White House Rural Council initiatives addressing top challenges facing health care organizations serving rural communities and Veterans, including financing, broadband and workforce challenges. Ms Samy builds coalitions with leaders from state and local governments, academia, as well as practitioners and vendors in the health care, technology and telecommunications industries to expand access to financing and adoption of technology by rural health care providers. A trusted transformer, Ms. Samy has been with HHS since 2007, building public/private coalitions, launching pilot projects and scaling successful models across the US.

Harmeet Sawhney is Professor in the Media School at Indiana University, Bloomington. His research interests focus on how telecommunications networks are envisioned and created. His research articles appear in *Telecommunications Policy*; *Journal of Broadcasting & Electronic Media*; *Media, Culture, & Society*; *Info*; *Prometheus*; *Culture, Theory & Critique*; *Entrepreneurship & Regional Development*; *Popular Communication*; *Communication*

Monographs; Annual Review of Information Science & Technology; Science Technology & Society; The Information Society and book chapters in edited volumes. He has been visiting faculty at University of Michigan, National University of Singapore, London School of Economics, and Stanhope Center for Communications Policy Research, London. He is currently serving as the Editor-in-Chief of *The Information Society*.

Jorge Reina Schement serves as Vice Chancellor, Rutgers University New Brunswick. He is Distinguished Professor of Communication Policy, and author of over 250 books, papers, and articles. A Latino from South Texas, his research focuses on the social and policy implications of the production and consumption of information, especially as they relate to ethnic minorities. He conducted the first study of the impact of minority ownership in broadcasting, and conducted the original research that led to recognition of the Digital Divide. His studies of minority ownership contributed to the Supreme Court's decision in *Metro Broadcasting, Inc. v. F.C.C. et al.* He authored the telecommunications policy agenda for the Congressional Hispanic Caucus. He is a founding member of the FCC Federal Advisory Committee on Diversity in the Digital Age, and a member of the FCC Transition Team for the Obama administration.

Marvin Sirbu is Professor of Engineering and Public Policy, Industrial Administration, and Electrical and Computer Engineering at Carnegie Mellon University, and founder of Carnegie Mellon's Information Networking Institute. Professor Sirbu's interests are in telecommunications and information technology, policy and management. Recent research has focused on local broadband access competition; economic impacts of broadband; future Internet architecture; network neutrality; and spectrum policy. Professor Sirbu received S.B., S.M. and ScD degrees from MIT. Prior to moving to CMU in 1985, Professor Sirbu taught at MIT's Sloan School of Management, and directed its Research Program in Communications Policy. He has served on the FCC Technological Advisory Committee, numerous panels for the U.S. National Research Council and the Office of Technology Assessment, and on the boards of several telecom related corporations. He holds two patents in the area of electronic commerce.

Darrell Smith is a Program Lead for the Emergency Communications Preparedness Center (ECPC) for the Department of Homeland Security (DHS) Office of Emergency Communications (OEC). In this role, he coordinates information sharing with Federal government stakeholders regarding emergency communications and interoperability issues which affect policy and operations at all levels of the Federal government. He is also the designated co-chair of the Accelerating Broadband Infrastructure Deployment Working Group, as established by Executive Order 13616. As the co-chair, he coordinates with Federal departments and agencies to develop and implement a strategy to facilitate the timely and efficient deployment of broadband facilities on Federal lands, buildings, rights of way, and federally assisted highways. Prior to joining OEC, Mr. Smith was with the Department of the Treasury's Wireless Management Office, overseeing the implementation of a commercial wireless services acquisition effort, and was acting branch chief of the Department of State's Radio Program Office. Before entering the Federal Government, he was enlisted in the U.S. Army as a radio repair specialist in the Signal Corps.

Sharon Strover is the Philip G. Warner Regents Professor in Communication and former Chair of the Radio-TV-Film Department at the University of Texas where she now directs the Technology and Information Policy Institute. Her recent research projects examine policy responses to the digital divide, internationally as well as domestically; the economic benefits of broadband, particularly in rural areas; the role of libraries in local information environments; and

the use of various digital media devices and platforms. She also directs an international Digital Media program as part of a broader collaboration effort between the University of Texas at Austin and the government of Portugal, a multiyear project that includes developing doctoral programs in digital media and sponsoring research in immersive technologies. Dr. Strover has worked with several international, national and regional government agencies and nonprofits on communications policy issues, including the U.S. Department of Agriculture's Rural Utilities Service, the Center for Rural Strategies, the Benton Foundation, the Center for Rural Strategies, the European Union, The Appalachian Regional Commission, the Rural Policy Institute, the Ford Foundation, and the European Union.

Erica Swanson is Head of Community Impact Investments & Programs at Google Fiber. She leads the team responsible for developing and delivering a range of social impact investments and community engagement strategies in Google Fiber cities. A key area of focus is partnering with local leaders to advance digital equity. Before joining Fiber, Erica directed Google's partnerships with national advocacy organizations, in support of public policies that advance a free and open Internet. She came to Google from The Leadership Conference on Civil and Human Rights, where she led coalition outreach efforts on issues ranging from voting rights to media justice. Her earlier work spans all levels of American federalism: working for a U.S. Senator; with a bipartisan network of state legislators; for a county-level political party; and as a grassroots organizer. Erica's M.A. is in public policy and women's studies from The George Washington University.

Sandeep Taxali serves as a senior policy analyst and broadband development officer at NTIA. He played an integral role in starting up the BTOP program, and led a team to review over \$1 billion in infrastructure funding requests for middle- and last-mile networks. He has managed a portfolio of 18 grants representing over \$600 million in capital funding. As part of NTIA's emerging BroadbandUSA effort, Sandeep provides technical assistance to communities and key stakeholders seeking to develop public private partnerships. Prior to NTIA, he directed C-Level sponsored strategy engagements in the telecommunications sector while at a management consulting firm. His work involved the development of comprehensive business cases and go-to-market strategies for corporate investments spanning up to \$2 billion. He had spent over three years at the FCC as part of a rotational analyst program sponsored by Chairman Reed Hundt's office, and led the market and economic assessment for a variety of proceedings at the Wireless and International Bureaus, including the Comsat Non-Dominance Order. He also served as a speechwriter at the FCC, and contributed to Vice President Al Gore's speech at the International Telecommunications Union Plenipotentiary Conference. He is a CPA, and also holds a MBA and MPP.

Richard D. Taylor, since August 2015, has been Distinguished Professor in Residence in the College of Social Sciences at the University of Hawai'i at Mānoa. He is co-Editor-in-Chief of the Journal of Information Policy and co-Director Emeritus of the Penn State Institute for Information Policy. He is Palmer Chair Professor of Telecommunications Studies and Law Emeritus at Penn State. He is former President and Chairman of the Board of the Pacific Telecommunications Council, and a former member of the Board of TPRC. Prior going to Penn State in 1989 he was V.P.-Corporate Counsel at Warner Cable Communications. He holds a law degree from New York University School of Law and a doctorate from Columbia University. He is a member of the American Bar Association, the New York State Bar Association and the Federal Communications Bar Association.

Emy Tseng is currently a Senior Broadband Program Specialist with National Telecommunications and Information Administration (NTIA). Her policy and technical assistance work focuses on furthering broadband adoption and digital inclusion in communities throughout the U.S. Formerly as a Federal Program Officer, she oversaw a Broadband Technology Opportunities Program (BTOP) \$114M grant portfolio of Public Computing Centers (PCC) and Sustainable Broadband Adoption (SBA) projects - working mainly with urban local governments and K-12 technology and education programs. Tseng is also an Affiliate at the Berkman Center for Internet and Society at Harvard University. Her work at the Center focuses on Inclusive Innovation - how marginalized communities adopt, shape and create technology in ways that reflect community needs and values. She leads the Inclusive Innovation Working Group and curates the Inclusive Innovation talk series as part of Berkman's lunchtime public talks and webcasts. Prior to NTIA, Emy worked for the City and County of San Francisco as the Project Director of the San Francisco Digital Inclusion Program - a citywide initiative to promote broadband adoption and digital literacy in the City's disadvantaged communities. In that capacity, she was appointed to serve on the first California Broadband Task Force. Previously, Emy was the Senior Policy Advisor at Zerodivide.org, Managing Director of Innovation Funders Network, a Council of Foundations affinity group, and a Program Associate at the Ford Foundation on communications policy. At Massachusetts Institute of Technology (MIT), she conducted research on broadband policy, open access, municipal networking and Fiber to the Home (FTTH). She previously worked in the software industry as an engineer, project manager and software architect. Emy has a Masters of Science degree in Technology and Policy (TPP) from MIT, and a Bachelor of Science degree in Math/Physics from Brown University.

Nicol Turner-Lee is Vice President and Chief Research and Policy Officer for the Multicultural Media, Telecom and Internet Council (MMTC), a 30-year old minority media advocacy organization, where she is responsible for designing and implementing its research and policy agenda. She architects the policy and research agenda and works with civil rights, government, corporations and other stakeholders to strategize and operationalize MMTC's work. Before joining MMTC, she was President and CEO of the National Association for Multi-ethnicity in Communications (NAMIC), a national membership association that educates, advocates and empowers for multi-ethnic diversity in the communications industry through pipeline development, hiring and retention. Prior to NAMIC, Dr. Turner-Lee was Vice President and the first Director of the Media and Technology Institute for the Joint Center for Political and Economic Studies, one of the nation's leading research and public policy institutions whose work focuses on issues of concern to African Americans and other people of color. At the Joint Center, Dr. Turner-Lee created the first "National Minority Broadband Adoption Study" that was cited in the Federal Communications Commission's congressionally mandated National Broadband Plan as well as a subsequent report detailing the information needs of communities. Dr. Turner-Lee was recently appointed to the U.S. State Department's Advisory Committee on International Communications and Information Policy (ACICIP) by Ambassador Daniel A. Sepulveda. She also serves on the Apple ConnectEd Advisory Board and is a Visiting Researcher at the Center for Gender Equity in STEM for Women and Girls at Arizona State University. In 2011, Dr. Turner-Lee was appointed to the Federal Advisory Committee on Diversity in the Digital Age by former FCC Chairman Julius Genachowski. Last year, Dr. Turner-Lee was given the Lifetime Achievement Award for leadership in media and technology by the Rainbow PUSH Coalition and she received the Partner in Service Award from the Sigma Rho fraternity. Prior to this, she has been honored by the Alliance for Women in Media as one of their 60 most inspiring women in media, by CableFax as one of the

Most Influential Minorities in Cable and one of the Most Powerful Women in Cable, by MMTC for its Extraordinary Service Award, by Multichannel News as one of their “Women to Watch,” and other organizations for her extraordinary service. She has also been selected twice by Time Warner Cable as one of four participants in their signature Digital Research Program. Her other recent recognitions have come from the National Organization of Black Elected Legislative (NOBEL) Women, and the National Coalition of 100 Black Women-Northern VA Chapter. Dr. Turner-Lee is actively engaged on local and national boards and advisory committees. She is Secretary for TPRC (a national research collaborative focused on information policy), the Chairwoman for the Rainbow PUSH Coalition’s Public Policy Institute and STEM4US, a Washington-based non-profit working to accelerate diversity in the fields of science, technology, engineering and math. She also sits on the Board of Directors for the Washington Literacy Center that works to end adult illiteracy in the DC area. Dr. Turner-Lee is also the author of several publications with two forthcoming on lifeline program reform and zero ratings. She is also a sought out speaker and panelist on media, telecommunications and high tech industries. She graduated with honors from Colgate University, has a doctorate in Sociology from Northwestern University and a Certificate in Nonprofit Management from the University of Illinois-Chicago. She is the proud mother of Keith and Chloe and serves as Secretary of her son’s local Boy Scouts troop.

Kristene Unsworth is an assistant professor in the College of Computing and Informatics at Drexel University in Philadelphia. She is also an affiliated faculty member in Drexel’s Science, Technology, and Society program and the Center for Public Policy. Her work focuses on information policy and ethics in relation to civil society and government.

Morgan Vigil is a Ph.D. candidate in the department of computer science at UC Santa Barbara. Her research has focused on designing network systems for challenged environments and her dissertation work specifically addresses issues of Internet accessibility in Indian Country. She serves as a member on the board of directors at American Indian Health & Services in Santa Barbara, a non-profit community health clinic that serves the American Indian population in Santa Barbara, Santa Ynez, and Ventura counties. She is committed to interdisciplinary research that brings a network scientific approach to technical innovation, policy reformation, and community-centric solutions.

Scott Wallsten is an economist with expertise in industrial organization and public policy. His research focuses on telecommunications, regulation, competition, and technology policy. His research has been published in numerous academic journals and his commentaries have appeared in newspapers and news magazines around the world. He holds a Ph.D. in economics from Stanford University. He is vice president for research and a senior fellow at the Technology Policy Institute and a senior policy scholar at the Georgetown Center for Business and Public Policy. He was the economics director for the FCC's National Broadband Plan and has been a lecturer in Stanford University's public policy program, director of communications policy studies and senior fellow at the Progress & Freedom Foundation, a senior fellow at the AEI – Brookings Joint Center for Regulatory Studies and a resident scholar at the American Enterprise Institute, an economist at The World Bank, a scholar at the Stanford Institute for Economic Policy Research, and a staff economist at the U.S. President’s Council of Economic Advisers.

Nancy Weiss serves as General Counsel of the U.S. Institute of Museum and Library Services (IMLS) and a member of the Senior Executive Service. IMLS's mission is to promote museum, library, and information services to meet the information, education, research, social, and

economic needs of the nation. IMLS supports the 35,000 museums and 123,000 libraries within the United States through research, policy development, and programs of financial assistance. Nancy is also Secretary to the National Museum and Library Services Board, a presidentially-appointed policy advisory board. She has played a key role in drafting international instruments pertaining to copyright and digital content, cultural activity and expression, human rights, and information policy. As Senior Advisor to the Chief Technology Officer of the United States, at the White House Office of Science and Technology Policy, she has helped develop and implement intellectual property and innovation policy. Prior to joining IMLS, Nancy served as Deputy General Counsel of the National Endowment for the Humanities, where she also provided counsel to the Arts and Artifacts Indemnity Program (which helps defray the costs associated with international museum exhibitions) and represented the agency on the National Archives Trust Fund Board. Earlier in her career, she practiced litigation and media law at Williams and Connolly in Washington D.C., held a legal research fellowship in New Delhi, India, and held a federal judicial clerkship with the Hon. William W Schwarzer (N.D. California and Director of the Federal Judicial Center). Nancy graduated with honors from the University of Michigan Law School, and phi beta kappa with a degree in Economics from the Wharton School of the University of Pennsylvania. She has been admitted to the bars of California and the District of Columbia.

Jenifer Sunrise Winter is an Associate Professor in the School of Communications at the University of Hawai'i at Mānoa and an affiliate of the Hawaii Research Center for Futures Studies. Dr. Winter's research focuses on communication rights in network societies – in particular digital inequalities, algorithmic discrimination, and privacy in the context of big data and the Internet of Things. She also focuses on broadband development's role in improving the quality of life and enabling self-determination in indigenous communities, exploring the potential for community-initiated broadband projects that will strengthen community input in the planning and management of broadband networks and services. Related research addresses broadband access rights, community informatics, and the Internet as a support for democratic institutions and publics. She has recently co-edited *The Future Internet: Alternative Visions* (Springer) and has authored dozens of journal articles, book chapters, and conference papers addressing emerging policy issues related to the Internet. She is a four-time attendee of the National Science Foundation's WISE Institute, Team for Research in Ubiquitous Secure Technology.

Lynette (Kvasny) Yarger is an Associate Professor in the College of Information Sciences and Technology. She earned her Ph.D. in Computer Information Systems from the Robinson College of Business at Georgia State University. Her research focuses on how and why historically underserved groups use information and communication technologies. She has designed, implemented and assessed community computing projects in economically challenged neighborhoods in Atlanta, West Philadelphia, and Harrisburg. She is also a co-founder of MyHealthImpactNetwork, a social network platform that focuses on health and social media interventions for African American collegians. Her current research examines the performance of racial and gender identities in the construction of health information by African American teens and young adults, and the IT career pathways of African American males. Her research has been published in the *Journal of the American Medical Informatics Association*, *The Information Society*, *Information Systems Journal*, the *Journal of Computer Mediated Communication*, and *New Media and Society*. Dr. Yarger's research has been supported by the National Science Foundation (including the prestigious NSF Career Award), Oracle Help Us Help Foundation,

AmeriCorps VISTA, the Penn State Africana Research Center, and the Penn State Children, Youth and Family Consortium.

Mariya Zheleva is an assistant professor in the Department of Computer Science at University at Albany SUNY. Prior to joining the tenure-track faculty in 2016, she was a visiting assistant professor at the University. She completed her PhD in Computer Science at University of California Santa Barbara in 2014. Mariya's research interest is in the intersection of wireless networks and Information and Communication Technology for Development. She has done work on small local cellular networks, Dynamic Spectrum Access, spectrum management and sensing and network performance and characterization. Her work was published in top-tier conferences, interdisciplinary journals and featured in popular media. Mariya is currently serving on the organizing committee of DySPAN2017 and on the technical program committees of ICTD, ACM DEV and WWW.