THE NATIONAL BROADBAND RESEARCH AGENDA

KEY PRIORITIES FOR BROADBAND RESEARCH AND DATA

Report prepared by

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Executive Summary

The Information and Communications Technology (ICT) sector has been fertile ground for interdisciplinary research and data collection, management, and analysis. The industry's sheer size, rapid pace of technological innovation, complex regulatory frameworks, and essential roles in personal and business communications have attracted and benefitted from active participation from the research community across various disciplines, including technology, the social and economic sciences, and public policy.

Over the last decade, broadband connectivity (or high-speed Internet) has evolved into a critical enabler for myriad applications now integral to the personal and professional lives of Americans. Broadband has become vital to almost every segment of the Nation's economic and social fabric.[1] The ICT industry accounts for $1 trillion of U.S. Gross Domestic Product, or 7 percent of the Nation's economy.[2] The broadband marketplace has undergone major transformation at all levels. The following statistics illustrate just some of the progress achieved thus far, from various perspectives.

- *Service Providers:* U.S. Internet service providers (ISPs) invested $78 billion of capital expenditures in 2014, and the industry has invested $1.5 trillion since 1996.[3] The U.S. median broadband speed jumped fourfold between 2011 and 2015, standing at 39 megabits per second (Mbps) in September 2015.[4] A variety of public-private partnership models have emerged. Over 50 communities across 19 states have publicly owned networks offering at least 1 Gigabit services.[5]
- *Government:* The benchmark set by the Federal Communications Commission (FCC) for broadband download speeds has increased by a factor of more than six since 2010, from 4 Mbps to 25 Mbps.[6] Beneficiaries of the FCC's Lifeline program stood at 13.4 million in 2014, nearly doubling since 2008.[7] The National Telecommunications and Information Administration's (NTIA's) Broadband Technology Opportunities Program launched the single largest U.S. public investment program for middle-mile networks, investing over $3.5 billion that led to the deployment and upgrade of more than 117,000 network miles.[8]

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[1] Council of Economic Advisers. 2016. Issue Brief: The Digital Divide and Economic Benefits of Broadband Access; available at https://www.whitehouse.gov/sites/default/files/page/files/20160308_broadband_cea_issue_brief.pdf.

[2] Telecommunications Industry Association. 2015. *TIA Policy Innovation Agenda*, "Research and Development"; available at http://www.tiaonline.org/policy/innovation-agenda#R&D.

[3] US Telecom. 2016. "Broadband Investment"; available at http://www.ustelecom.org/broadband-industry/broadband-industry-stats/investment.

[4] FCC. 2016. *Measuring Broadband America, A Report on Consumer Fixed Broadband Performance in the United States*; available at https://www.fcc.gov/reports-research/reports/measuring-broadband-america/measuring-fixed-broadband-report-2016.

[5] ILSR. N.d. Community Network Map; available at https://muninetworks.org/communitymap.

[6] FCC. *Sixth Broadband Deployment Report* (2010) and *2016 Broadband Progress Report* (2016); both available at https://www.fcc.gov/reports-research/reports/broadband-progress-reports.

[7] FCC. 2015. *Universal Service Monitoring Report*; available at https://apps.fcc.gov/edocs_public/attachmatch/DOC-337019A1.pdf. This Federal program to subsidize telephone services for low-income households expanded in 2016 to include subsidies for wireline and wireless broadband.

[8] NTIA. 2016. "Broadband Technology Opportunities Program (BTOP) Quarterly Program Status Report", pp. 1–2; available at https://www.ntia.doc.gov/files/ntia/publications/ntia_btop_28th_qtrly_report_09.12.16.pdf.

- *End Users:* About 53 percent of Americans owned a smartphone in 2015, compared to 27 percent in 2011.[9]

Despite these transformations, 10 percent of Americans lack access to the FCC's prescribed benchmark speeds for broadband of 25 Mbps download and 3 Mbps upload (25/3 Mbps). This divide is more pronounced in rural and Tribal areas, where 39 percent and 41 percent lack such access, respectively.[10] Fewer than 40 percent of Americans have more than one choice of Internet Service Provider. Although over half of Americans own a smartphone, approximately 20 percent of online households rely on mobile data plans alone to go online from home.[11] Over 40 percent of schools, representing nearly half of the nation's students, lack the connectivity to meet the Commission's short-term goal of 100 Mbps per 1,000 students/staff.[12]

The Broadband Opportunity Council noted in its 2015 report that research across broadband deployment, adoption, and competition has not kept pace with the massive digital changes that have come to permeate our economy and society.[13] One of the report's four overarching recommendations was to improve data collection, analysis, and research on broadband. Included in the report was a commitment by NTIA and the National Science Foundation (NSF) to lead the development of a National Broadband Research Agenda (NBRA or Agenda) to address these topics comprehensively. NSF and NTIA engaged the Federal Networking and Information Technology Research and Development (NITRD) Program to assist; the NITRD National Coordination Office established a task force co-chaired by NTIA, NSF, and the U.S. Department of Education (ED) to facilitate the process of gathering Federal agency input in the development of the NBRA. Proposed research and data topics in the Agenda reflect broad input from academia, the public, and Federal staff.

This Agenda provides a synthesis of stakeholder input and a conceptual framework for potential research proposals and data requirements in four key areas related to U.S. R&D in broadband: technology, deployment, adoption, and socioeconomic impacts. It also provides a number of opportunities for Federal support. The NBRA task force is optimistic that findings from these proposed research topics will support the continued dynamic growth of the ICT sector and identify effective strategies to address remaining disparities in broadband access, adoption, and choice in the United States.

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[9] NTIA. 2016. "Digital Nation Data Explorer", Internet-Enabled Mobile Phone Use, Total US; available at https://ntia.doc.gov/data/digital-nation-data-explorer#sel=mobilePhoneUser&demo=&pc=prop&disp=chart.

[10] FCC. 2016. *2016 Broadband Progress Report*; available at https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2016-broadband-progress-report.

[11] G. McHenry (NTIA). 2016. "Evolving Technologies Change the Nature of Internet Use" (blog); available at https://ntia.doc.gov/blog/2016/evolving-technologies-change-nature-internet-use.

[12] FCC. 2016. *2016 Broadband Progress Report.*

[13] Broadband Opportunity Council. 2015 (August 20). *Broadband Opportunity Council Report and Recommendations*; available at https://www.whitehouse.gov/sites/default/files/broadband_opportunity_council_report_final.pdf.

I. Introduction to the National Broadband Research Agenda

I.A Background

I.A.1 Broadband Opportunity Council and its Report to the President

A March 2015 Presidential Memorandum ("Memorandum") titled, “Expanding Broadband Deployment and Adoption by Addressing Regulatory Barriers and Encouraging Investment and Training” stated, “Access to high-speed broadband is no longer a luxury; it is a necessity for American families, businesses, and consumers. Affordable, reliable access to high-speed broadband is critical to U.S. economic growth and competitiveness.”[14]

The Memorandum created the Broadband Opportunity Council ("Council") and tasked it to produce recommendations to increase broadband deployment, competition, and adoption through executive actions within the scope of Federal programs, missions, and budgets. In August 2015, the Council published its *Broadband Opportunity Council Report and Recommendations* ("Report") in response to the Memorandum. One of the Report’s four overarching recommendations was to improve data collection, analysis, and research on broadband. This report noted that “research on broadband deployment, competition, and adoption has not kept pace with the massive digital changes that permeate our economy and society.” It also found the need for more granular data regarding broadband connectivity and usage as they impact stakeholders and their missions, and the need to leverage opportunities for greater interagency collaboration in data collection and analysis efforts.[15]

Also as part of the Council’s response to the mandate of the Memorandum, NTIA and NSF committed to lead the development of a national research agenda focused on broadband. Through the NITRD Program, many Federal agencies have participated in this effort, as reflected throughout this document.

I.A.2 Objectives and Potential Benefits

Objectives

The National Broadband Research Agenda ("NBRA" or "Agenda") aims to present an overall framework for future broadband research that includes identifying (a) promising research areas; (b) requirements for data collection and sharing; (c) opportunities for better alignment and coordination across Federal and external stakeholders; and (d) potential Federal actions (e.g., funding strategies, policy development, and programs) to enhance data collection and research.

[14] President Obama. 2015 (March 23). “Memorandum on Expanding Broadband Deployment and Adoption by Addressing Regulatory Barriers and Encouraging Investment and Training”; available at https://www.gpo.gov/fdsys/pkg/DCPD-201500195/pdf/DCPD-201500195.pdf

[15] Broadband Opportunity Council. 2015 (August 20). *Broadband Opportunity Council Report and Recommendations*; available at https://www.whitehouse.gov/sites/default/files/broadband_opportunity_council_report_final.pdf

Potential Benefits

The Agenda provides foundational research questions and data requirements that are intended to help overcome the systemic disparities in broadband access, adoption, and choices that exist within the United States. In particular, the Agenda aims to identify efforts that will be essential to tackle the most vexing challenges and the key opportunities that remain in removing impediments to broadband access and adoption. The Agenda will support:

- **Identification of key research topics:** The Agenda helps clarify the critical open questions so as to enable members of the research community—across academia, government, industry, and nonprofits—to prioritize their resources and activities in research and data collection.
- **Expanded data collection:** The Agenda identifies data gaps arising from the lack of collection and/or sharing. It creates mechanisms for receiving input from key stakeholders to identify new opportunities to collect information (e.g., through existing survey vehicles). Industry members can identify opportunities to share data in ways that do not undermine competitive positioning and enable firms to benefit from key findings.
- **Increased collaboration:** The outreach process used to gather input from stakeholders fostered useful discussions and should support continued conversations and exchanges of ideas, needs, and opportunities to move forward.
- **Strategic planning:** The Agenda can help Federal agencies, contingent upon resources, to formulate strategies and initiatives moving forward, by identifying new opportunities for data collection, sharing, research funding, and collaboration, or by refocusing existing efforts.

I.B Scope of the Agenda

I.B.1 Stakeholder Input on the Agenda

A key factor in the development of this Agenda was obtaining robust input from a broad set of stakeholders—including academia, commercial entities, nonprofits, the general public, and Federal agency staff—by means of the fora described below. The stakeholders who participated in any of these fora are labeled as "participants" in this document. The Agenda constitutes a compilation of research topics offered by all participants.

"Broadband 2021" National Workshop and Report

Following the Council's report, NSF funded the Institute for Information Policy (IIP) at the Pennsylvania State University to organize a national workshop to bring together leading academic scholars and other experts to begin to define a national agenda for broadband research.[16] Participants at the June 2016 "Broadband 2021" workshop were drawn primarily from academia, complemented by representatives from government agencies, civil society organizations, and foundations. This workshop centered on three tracks of discussion, including advanced broadband technology, adoption and usage, and socioeconomic impact.

[16] See details of the "Broadband 2021" workshop at https://broadband.ist.psu.edu/.

Request for Public Comments

On September 9, 2016, NTIA and NSF issued a public Request for Comments (RFC)[17] to inform the development of the Agenda. The RFC received 49 comments from a broad range of stakeholders (Appendix A). Through this RFC, NTIA and NSF sought recommendations, best practices, and solutions to current challenges with regard to promising research and analytical methodologies; effective approaches for data collection and sharing; opportunities for better alignment and coordination for these research efforts across all Federal and external stakeholders; funding strategies with suggestions for prioritization and public-private resource sharing; and possible changes to Federal policies and programs that could enhance broadband research.

Interagency NBRA Task Force

The National Coordination Office for the NITRD program,[18] in collaboration with NSF and NTIA, established a task force to facilitate the development and writing of the NBRA. The NBRA Task Force reports to the NITRD Large-Scale Networking Interagency Working Group, which supports the coordination of Federal investments in networking R&D. The NBRA Task Force is co-chaired by representatives from NTIA, NSF, and ED. The task force organized a workshop in October 2016 as a forum for agency discussion and identification of critical data, research needs, research opportunities, and key implementation enablers for broadband, such as policy challenges, funding requirements, and coordination opportunities.

I.B.2 Key Subject Areas

The proposed NBRA research topics are divided into four categories, which are detailed in Section II:

- **Broadband technology**: This category encompasses technical issues related to broadband networks, including architecture, software and hardware elements, and transmission technologies. It also includes technical elements related to applications and devices.
- **Broadband deployment**: This category covers subjects related to the planning, deployment, and sustainability of broadband infrastructure. It also includes data and other information, such as mapping, regarding broadband availability.
- **Broadband adoption and digital inclusion**: This category covers challenges and opportunities to foster adoption and meaningful usage of broadband by all types of customers, including residential, business, and community institution patrons.
- **Socioeconomic impacts of broadband**: This category addresses the impacts of broadband on economic and social outcomes. Economic impacts include microeconomic-based indicators at the firm level such as enterprise productivity, competitiveness, financial performance, and quality and efficient delivery of services. Macroeconomic-based indicators include such factors as GDP, employment, and wages. Social dimensions importantly include such dynamics as impacts of broadband availability and use on education, healthcare, workforce preparedness, and access to government services.

[17] NTIA. 2016. "Request for Comments National Broadband Research Agenda"; available at https://www.ntia.doc.gov/request-comments-national-broadband-research-agenda.

[18] NITRD is a Subcommittee of the National Science and Technology Council's Committee on Technology.

Many broadband research topics intersect multiple areas; **cross-cutting topics** are included in the socioeconomic impacts section.

Opportunities for further Federal engagement are discussed in Section III. This includes potential actions that Federal agencies could consider to advance the Agenda, pending availability of resources.

Types of Ideas and Suggestions

The topics proposed in Sections II and III generally reflect one or more of three types of suggestions:

- Relevant research questions;
- Opportunities for data collection and sharing; and/or
- Potential action items for Federal agency support to enable the research and data proposals, such as funding strategies, coordination, or changes to Federal policies and programs to facilitate data collection and research.

Working Definitions

The phrase "broadband research" may have various meanings to different stakeholders. For purposes of being inclusive, a strict interpretation is not offered; nevertheless, the following considerations offer some context.

- *Broadband*: The research and data requirements should be about high-speed access, not simply connectivity. The Agenda applies the FCC's current benchmark for broadband, which is defined as speeds not less than 25 Mbps download and 3 Mbps upload.
- *Research*: For this document, the term research includes fact-finding and analysis activities that can be used to solve challenges and identify opportunities to foster any of the following: advanced technology development; upgrades and deployments of infrastructure to support the escalating thresholds of speed required by residents, businesses, and community institutions; promotion of competition and choice; and support for adoption, inclusion, and meaningful usage.

I.B.3 Framework Used to Prioritize Research Areas and Data Requirements

A national broadband research agenda, by definition, can reflect a vast breadth and depth of research topics; therefore, some level of prioritization is necessary to manage the scope of the discussion. The specific findings and recommendations are intended to reflect the following factors:

1. *Stakeholder Input*: The Agenda reflects a synthesis of the inputs from stakeholders as described in Section I.B.1 above;
2. *Relevance*: The Agenda reflects topics specifically related to research, analysis, and data; and
3. *Impact*: Recommendations reflect a well-defined opportunity, need, or benefit, specifically that the recommendations can help foster competition, innovation, access, adoption, digital inclusion, and the other broad objectives specified in the Council report.

Importantly, this Agenda offers the research community ample room for further prioritization of research topics.

II. Key Findings Regarding NBRA Priorities

Participant inputs (Section I.B.1) towards the development of the Agenda resulted in a broad number of research topics and data requirements; these are reflected in the discussions and charts below in the categories of Broadband Technology, Deployment and Infrastructure, Adoption and Digital Inclusion, and Socioeconomic Impacts.

II.A Broadband Technology

The broadband technology landscape continues to reflect rapid innovation and advancement in platforms, networks, devices, services, and applications. The technical R&D proposals covered in this section are in the areas of emerging broadband infrastructure and systems, broadband infrastructure resilience and public safety, next-generation architectures, and security and privacy. These are neither independent from each other nor completely separate from the other main topics of adoption, deployment, and socioeconomic impacts. For example, architecture intersects security as well as deployment and resilience. Alternatively, strategies for improvement of "quality of experience" (a topic of current academic research) might be classified as either technology-based or adoption-based.

II.A.1 Emerging Broadband Infrastructure and Systems

As noted in the "Broadband 2021" report: "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."[19] Many of the inputs represented in this topic area dealt with wireless technology as a means to lower the cost of deployment, particularly in underserved rural and/or remote areas. Specific technologies called out include millimeter-wave, massive multiple-input–multiple-output (MIMO), hybrid free space optical and RF (radio frequency) systems, and dynamic spectrum allocation. The "Broadband 2021" report also pointed out that some of the most important wireless research and experimentation is highly interdisciplinary, involving a complex interplay among advanced wireless technology, economic incentives, and spectrum policy and regulations.

Key Topics: Emerging Infrastructure & Systems	Agenda Items
Emerging Technologies	• What emerging last- and middle-mile solutions (e.g., dynamic spectrum sharing, power-line communication, drone-based wireless) offer the most promise for reducing the cost of offering broadband services, particularly in low-density, rural, and disadvantaged areas?

[19] Institute for Information Policy, Pennsylvania State University. 2016 (July 25). *Broadband 2021: Report of the Interdisciplinary Workshop on the Development of a National Broadband Research Agenda,* p. 8; available at http://comm.psu.edu/assets/uploads/Broadband_2021.pdf.

	• What wireless technologies, such as millimeter-wave and massive MIMO, will enable access networks to handle much larger numbers of devices per unit area, for example, through densely-packed small cells? • What advantages do free space optical, hybrid optical-RF, and satellite technologies offer in terms of scalability and cost, and in which contexts?
Spectrum Utilization	• How can current spectrum allocations be used more efficiently in various regions and environments, and which currently underused bands can be better utilized? • What techniques can create appropriate incentives for efficient use of spectrum by both the public and private sectors? • What techniques can enable sharing of a given spectrum block (e.g., 3.4–3.6 GHz), while providing seamless data rates of up to 1 Gbps?
Efficiency Drivers	• What cost-effective hardware (i.e., integrated circuit) technologies are needed for long-term scalability? • What innovative technologies can make broadband infrastructure, and the end-user devices, more energy-efficient? • How can technologies be combined to form heterogeneous edge networks that allow network resource usage to be continuously optimized based on application needs, to deliver better user experience at a lower cost of investment? • What factors should be considered in engineering-economic models of broadband systems based on novel technologies, especially models used to quantify and compare the benefits of different technologies?
Measurement and Monitoring	• What technologies and infrastructures are needed to provide an accurate picture of spectrum usage at timescales ranging from milliseconds to months? • How can monitoring technologies and infrastructures enable more effective spectrum sharing techniques and enforcement of spectrum allocation policies?
Quality of Experience	• How can users' overall quality of experience be quantified and measured objectively? • What parameters, both technical (e.g., latency, availability, capacity) and nontechnical, affect users' satisfaction with their service experience? • How does users’ satisfaction with quality of experience vary across regions, applications, and demographics?

II.A.2 Broadband Infrastructure Resilience and Public Safety

Resilience refers to the ability of broadband services to survive, respond to, and recover from adverse events including natural disasters, congestion events, and malicious attacks. Especially during and immediately after a disaster, society depends on reliable access to a wide range of broadband systems, including the Internet, cellular networks, 911 systems, communications systems used by first responders, national security/emergency preparedness systems that support broadcasting and emergency alerts, and broadband systems embedded in critical infrastructure such as the electric power

grid. As infrastructures become more interdependent, assuring continuity of this access becomes a greater challenge. Research in this topic is of importance to the Federal government and myriad partners and stakeholders, including those in State, Territorial, Tribal, and small community localities.

Key Topics: Infrastructure Resilience & Public Safety	Agenda Items
Measuring and Quantifying Resilience	• How should infrastructure resilience be quantified? • How can resilience be measured or estimated, both at time of design and *in situ* for deployed systems? • Using such measures, how resilient are today's deployed broadband systems? • How does resilience vary across regions and service areas (e.g., cities vs. Tribal lands)?
Key Threats and Risks	• What are the major threats to broadband infrastructure (e.g., RF jamming, distributed denial of service (DDoS), spoofing, and event-generated congestion)? Which are the most urgent? • What best practices can be employed to counter each of these major threats? • What sectors or types of networks are most vulnerable to these threats? How can we identify at-risk networks and quantify their levels of risk? • How will the introduction of new technologies affect the resilience of the network, especially emergency communications, in times of network stress? • How can the security and control of the broadband infrastructure supply chain (whether domestic or offshore) be assured?
Public Policy	• What should be the national goals regarding infrastructure resiliency? • What are the roles of government (Federal, State, local) and industry? • What collaboration and partnership opportunities can best bridge the expertise and resources needed across government and industry? • Should the government require a minimum standard of resiliency from commercial service providers? • 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 incentives?
Emergency Preparedness	• How effectively do present and future emergency communication systems serve special-needs populations, such as individuals with disabilities, non-English speakers, and the elderly? • How can emergency preparedness and national security broadband communications be secured and prioritized in emerging wireless broadband infrastructures (e.g., 5th generation ["5G"] wireless systems) during emergencies?
Strategic and Technology Planning	• What technical approaches can improve the resilience of existing infrastructure in a cost-effective way, and how do they compare across all dimensions of interest?

	• How can new deployments be designed to be more resilient? • How can advanced wireless technologies (Section II.A.1) support location services for next-generation 911 (NG-911), to ensure callers can be located when reporting an emergency, especially in rural, Tribal, and other underserved areas?

II.A.3 Next-Generation Architectures

Architecture refers to the totality of functions needed to provide end-to-end broadband services and applications, and how they are organized. This includes not only the design of hardware, software, and protocol standards for carrying bits, but also toolkits and libraries to support applications development, business models (e.g., flat-rate/unlimited access, versus usage caps, versus entirely usage-based payment plans), and implementation techniques such as software-defined networking. Although the current state of the system is fairly homogeneous above the access channel and thus well known—essentially all of the network uses the same suite of protocols: Internet Protocol (IP), Transmission Control Protocol (TCP), User Datagram Protocol (UDP), and Hypertext Transfer Protocol (HTTP)—the burgeoning prevalence of mobile devices, coupled with the trend to connect an ever-increasing number and variety of "things" to the network, brings new challenges with respect to scalability, management, and affordability.

Key Topics: Next-Generation Architectures	Agenda Items
Emerging Network Technologies: Value and Impact Measurement	• How can "wireless middle" architectures (e.g., drone-based backhaul) reduce cost of deployment, especially in areas of low user density? • How are emerging software-centric broadband networking technologies, such as software-defined networking (SDN) and network function virtualization (NFV), likely to be deployed in broadband infrastructure? How will such techniques influence the interactions among the players across the end-to-end broadband ecosystem? • Can such techniques provide new incentives or lower costs for broadband deployment? • What effects will transition to next-generation protocols (including Version 6 of the Internet Protocol) in various parts of the infrastructure have on the end-to-end quality of experience of users?
Business Models	• Can new service models (for example, information-centric networking) facilitate, expedite, or enhance the development of applications that are both more usable and more secure? • Would other business models (for example, unbundled access channels and Internet service) provide better security, greater flexibility, and more incentives for innovation?
Edge Models	• What technical approaches would be most effective for migration and multihoming (i.e., allowing devices to rapidly switch between providers or technologies) of hosts or computer networks to more than one network in order to increase reliability, performance, or cost savings? • What are the costs, benefits, and risks of empowering end-user devices to migrate, multihome, and/or switch between access technologies?

	• How would migration and multihoming affect competition, investment, and innovation? • What are the impacts of multihoming and usability for underserved communities? • How do current pricing schemes affect the development and use of novel edge technologies and multihoming? What pricing schemes might incentivize more efficient or effective network development?

II.A.4 Security and Privacy

As more and more personal, business, and government activities depend on digital connectivity, the security and privacy characteristics of broadband applications and infrastructure become more and more critical. Indeed, concerns over security and privacy may cause some people to limit their use of the network and cause others to avoid it entirely. This aspect is covered in more detail in Section II.C.2. Unfortunately, the protocols on which the Internet has been built over the last three decades were, with few exceptions, not designed with security and privacy in mind, and it has proven very difficult to retrofit these properties. The problem is complex and the issues are systemic. They range from the insecurity of devices such as those marketed for the "Internet of Things," to the lack of incentives for either vendors or users to improve security, to the fundamental tension between accountability (which requires robust, unforgeable identities) and privacy (which requires ambiguity with respect to identity), to the inability of even technically savvy users to determine whether their home networks are secure. The topics described below align with recent Federal strategic plans for cybersecurity and privacy.[20]

Key Topics: Security and Privacy	Agenda Items
Measuring Privacy and Trust	• How can privacy, trust, and security in a networked environment be conceptualized and measured; how well do systems now in use perform? • How can we quantify and measure the effect of component usability on overall security?
Role of Technology in Privacy and Trust	• What best practices or minimum standards of protection should be adopted in certain environments (e.g., home networks) to improve security of the overall broadband system? How might such practices be encouraged or enforced? • What technical changes will help to increase the trust users place in broadband communications systems, devices, and applications, especially in underserved and disadvantaged communities? • Could changes in technical standards, business practices, or public policies increase incentives to make systems more trustworthy?

[20] See the *2016 Federal Cybersecurity Research and Development Strategic Plan*, available at https://www.whitehouse.gov/sites/whitehouse.gov/files/documents/2016_Federal_Cybersecurity_Research_and_Development_Stratgeic_Plan.pdf; and *2016 National Privacy Research Strategy*, available at https://www.whitehouse.gov/sites/default/files/nprs_nstc_review_final.pdf.

Role of Policy	• What government-wide and individual agency standards, protocols, policies, and incentives can improve the security and trustworthiness of the system? For example, what policies might Tribal governments adopt to improve trust in broadband and enable better communication within Tribal communities? • How can we simplify privacy and security policy reporting and increase user knowledge and comprehension of such policies?

II.B Broadband Deployment and Infrastructure

The size and scale of U.S. broadband infrastructure has advanced considerably over the last decade through vigorous investments from the private sector and government financial assistance programs; technology advancements across wireline and wireless systems (e.g., Data over Cable Service Interface Specification—DOCSIS 3.1—and 4G Long Term Evolution—4G LTE); measures to address entry and expansion barriers; and increased private and public collaboration.

However, approximately 10 percent of Americans lack access to fixed services that deliver the FCC's prescribed benchmark for minimum broadband (25/3 Mbps download/upload).[21] The rural divide is more pronounced, because 39 percent of rural households lack such access, compared to 4 percent of urban households. An even more profound statistic is that 20 percent of rural Americans lack access even to the FCC's prior minimum benchmark of 4/1 Mbps, and 33 percent lack access to the 10/1 Mbps speeds required by the FCC's Connect America Fund. Choices are limited even when broadband services are available. Fewer than 40 percent of Americans have more than one choice of broadband service provider. Moreover, four in 10 Americans live in areas where very-high-speed broadband service—100 Mbps or greater—is completely unavailable. About 41 percent of Americans living on Tribal lands lack access to 25/3 Mbps broadband; of those who live in *rural* Tribal lands, fully 68 percent lack access. The gaps also pertain to community institutions, where broadband is a key enabler for their missions. For example, approximately 19 percent of schools lack the speed connectivity to address the Commission's short-term goal of 100 Mbps per 1,000 students and staff.

The themes under this category include research and data that can help inform and foster actions to drive greater deployment and choice and that assess or predict the potential impacts of related policies. Key topics include:

- *Broadband availability data*: The collection and sharing of data regarding the availability of broadband technologies, speeds, and providers;
- *Low-cost solutions*: Low-cost technology solutions that can significantly lower upfront capital costs and/or recurring operating expenses;
- *Financing programs and solutions*: Sources of financing that involve lower borrowing costs and/or longer payback periods, and government programs that can help attract private investment by addressing key business case risk;

[21] All statistics in this paragraph are from FCC. 2016. *2016 Broadband Progress Report*; available at https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2016-broadband-progress-report2016.

- *Business models and public–private partnerships*: Opportunities for public and commercial stakeholders to share risks, rewards, and responsibilities across the ownership, planning, deployment, and operations of a broadband network; and
- *Market expansion and/or entry barriers*: Best practices and strategies to overcome critical obstacles that increase the time and costs for incumbents to expand their networks, and/or prevent a potential new provider from entering a new market.

II.B.1 Broadband Availability Data: Technologies, Speeds, and Providers

Granular data regarding availability of broadband technologies, speeds, and service providers play a critical role across a wide spectrum of broadband research and analysis requirements, as noted below.

FCC 477 Data. The FCC collects broadband speed data at the census block level as part of its "Form 477" reporting requirement for all facilities-based service providers for schools, libraries, community centers, and others. The FCC collects and publishes this broadband deployment data twice each year.[22]

National Broadband Map. NTIA and the FCC launched the National Broadband Map (http://www.broadbandmap.gov) in 2011 and updated it biannually through 2014. The map depicts broadband availability by technology, maximum advertised speeds, and provider names. The data sets used to populate the National Broadband Map were collected by the 56 states and territories funded by grants through NTIA's State Broadband Initiative. The program posted its final data update in March 2015. NTIA subsequently transitioned the map to the FCC. The FCC has not yet updated the National Broadband Map due to budgetary constraints, but it does have much of the data necessary to do so through its Form 477 data program.

Census Data. The U.S. Census Bureau's American Community Survey (ACS) provides another major data source regarding household access to the Internet. It has the advantage of a large sample size of 3.5 million housing units each year. ACS surveys have sampled computer and Internet use annually since 2013, providing data on the scope and geographic coverage of Internet access. The ACS data is complemented by information from the Current Population Survey (CPS) Computer and Internet Use Supplement. While the CPS is smaller in size than the ACS, it provides essential detail on how people use the Internet and for what purposes, as discussed in Section II.C.1. Participants submitted a variety of research and data requirements for broadband availability, as follows.

Key Topics: Broadband Availability Data	Agenda Items
National Broadband Map	• Many stakeholders requested that the FCC should update the National Broadband Map with the FCC 477 data. If the FCC does not update the map, what alternative approaches and business models should be considered so a trusted third party (private, nonprofit, or academic) publishes and updates the map? • Would a mapping interface help service providers decrease the number of filing errors in their 477 data submissions, because

[22] FCC Form 477 data collection Information is available at https://www.fcc.gov/general/form-477- resources-filers.

	availability data could be visualized? Would a map offer a more effective way to see incremental changes over reporting periods?
Key Limitations Regarding FCC 477 Data	• How can the FCC address the issue that data reporting at the level of large census blocks may overstate availability or quality when broadband technologies or speeds are not uniform throughout the block (e.g., break large census blocks into smaller subsets)?
Data Regarding Backbone and Middle-Mile Networks	• What critical research areas could be pursued with data regarding locations and speeds of backbone and middle-mile network facilities? What specific data would be useful regarding such facilities? • How should such information be collected (e.g., point-to-point community spans)? • What are the key challenges and concerns with the government requiring the filing of such information from backbone and middle-mile service providers? How can these concerns be addressed?

II.B.2 Low-Cost Solutions

The capital-intensive nature of building broadband infrastructure has complicated the development of business cases that earn a positive return on investment and are sustainable. The challenges are of paramount importance to rural communities, where low population densities prevent the high upfront costs from being scaled across a wide subscriber base. Thus, research into low-cost strategies—both capital and operating cost strategies—continues to warrant significant attention. Key research and data opportunities are delineated below.

Key Topics: Low-Cost Solutions	Agenda Items
Low Cost Technologies	• What factors (public policy, business arrangements, etc.) can substantially impact the technical design to enable significant capital and operating cost efficiency?
Upgrades to Existing Infrastructure	• What emerging technologies can significantly improve speeds over legacy copper-based facilities? • How can the trade-offs be quantified when service providers upgrade rural networks to meet minimum broadband speed thresholds, considering that these improved speeds may likely fall below future increases in the benchmarks?
Government Sponsorship and Funding of Low-Cost Solutions	• Given the variety of federally sponsored research programs looking into advanced wireless and wireline networking solutions, are there specific topics that warrant greater attention to help foster low-cost solutions?
Opportunities to Lower Operating Expenses	• What are the biggest opportunities to significantly lower network operating costs (e.g., power, maintenance, upgrades)? • How can advances in solar energy be further incorporated into broadband technology networks to reduce energy costs and increase environmental sustainability, and into advanced networks to areas where power limitations previously thwarted deployment?

II.B.3 Financing Approaches for Challenging Business Cases

The sources of investment capital, and the associated terms and conditions, have a significant impact on broadband deployment. They affect the cost of capital and the time horizon for achieving key financial targets. Collectively, they influence feasibility for a business plan and may stymie abilities to raise financing for low-density, unserved, and underserved communities. They also influence business model types, including such elements as technology, ownership structure, partnership structure, roles for public-private collaboration, services, pricing, prelaunch threshold requirements, and overall sustainability.

The research and data on cheaper types of capital warrant greater attention. For example, whereas the interest rates on municipal bonds and government-provided loans are generally lower than the interest rates on commercial bonds and loans, securing such financing can still be a roadblock for deployment. Tax credits for infrastructure investments can help elevate the returns and may provide enough incentive to attract private capital. Government subsidy and grant programs reduce risks and may help incentivize private capital to enter the market; more data on such impacts are desired. Key research and data requirements on financing are delineated below.

Key Topics: Financing	Agenda Items
Municipal Bond Financing	• Given that many communities may lack a credit rating, or lack the experience and understanding to raise municipal bonds (e.g., general-obligation or tax-based bonds), what best practices and strategies can help communities and financial institutions foster greater bond activity? • What local, State, and Federal government policies can support and foster such financing?
Tax Credit Programs	• What are the key metrics regarding the role of New Market Tax Credits on broadband deployment to date (e.g., capital dollars, miles deployed, technology, locations, or expansion)? • How have credit-supported networks contributed to economic development?
FCC Healthcare Connect Fund	• What new data metrics should the FCC consider collecting from beneficiaries of the Healthcare Connect Fund regarding services and applications used by healthcare providers and patients and their impact on a variety of metrics used to measure patient outcomes?
E-Rate Programs	• What new data metrics should the FCC consider collecting from schools receiving E-Rate support (for discounts to assist U.S. schools and libraries to obtain affordable telecommunications and Internet access) regarding a host of critical data points, including teacher use of online content, student use of Internet-based courses, connection speeds, and impacts on student performance?
Infrastructure Bank	• What are best practices regarding the creation of an infrastructure bank with regard to broadband deployment, e.g., eligibility, funding criteria, and financing parameters?

II.B.4 Public-Private Partnerships

Public-private partnership (PPP) models aim to reduce a variety of financial and operating risks in order to attract private partners. A wide variety of PPP arrangements have been used to bring broadband to unserved and underserved communities. These models recognize the unique strengths and resources of the commercial sector, public entities, nonprofits, and community leaders. These partnerships vary with regard to network ownership and financing, but also in the roles they play with regard to construction, operations, marketing, and overall sustainability.

Analysts across the stakeholder spectrum have studied and written much about the variety of PPP business models, best practices, key risks, overall impacts, etc.[23] Their benefits and limitations are, nevertheless, widely debated. The discussions regarding the development of a national infrastructure bank will invite further debate regarding the key merits, limitations, and risks of PPPs.

Key Topics: Public-Private Partnerships	Agenda Items
Performance Measurement and Impact Evaluation	• How can government agencies that support PPPs measure the return on their financial investment and/or other contributed resources? What methodologies can be applied, given the variety of PPP models (e.g., subsidy contribution, joint-ownership and operated, concession, management contract, etc.)? • Given the financial assistance provided by local, State and Federal government programs in funding various PPPs, what data should be collected to better understand the value of PPP models?
Information Sharing	• How can public sector entities more effectively share the details of their sponsored PPP arrangements with the research community? • What specific data points are most valuable to the research community?
Demand Aggregation	• What are the best practices to foster demand aggregation and therefore contribute to the economic feasibility of a business case in unserved and/or underserved communities? • Given the movement by many communities to plan and deploy a range of "Smart City" solutions, how can these initiatives encourage the deployment of advanced networks that serve the broader community?
Best Practices from Other Industries	• Given that other sectors (e.g., transportation, energy) have a longer track record in PPP deployment, what best practices can be applied to the broadband sector? • What performance metrics, research methodologies, impact/outcome frameworks, etc., are relevant to the broadband PPP landscape?

[23] P. Lucey and C. Mitchell. 2016. Successful Strategies for Broadband Public-Private Partnerships (Minneapolis, MN: Institute for Local Self-Reliance); available at https://ilsr.org/wp-content/uploads/downloads/2016/08/PPP-Report-2016-1.pdf. Also, World Bank Group, 2014. *Public-Private Partnerships Reference Guide: Version 2.0*; available at http://ppp.worldbank.org/public-private-partnership/library/public-private-partnerships-reference-guide-version-20.

Emerging Models for Public–Private Collaboration on Smart City Solutions	• What are some best practices and frameworks regarding how the broadband-enabled "Smart City" solutions and strategies can attract additional resources and capital from private and public entities for electrical grid platforms, lighting, video surveillance, traffic analytics, parking, environmental sensing, etc.?

II.B.5 Market Entry and Expansion Barriers

A variety of market entry and/or expansion barriers to broadband deployment prevent new broadband providers from competing or incumbents from expanding and upgrading their facilities. These barriers include regulatory (e.g., permits), competitive (e.g., pole attachments), economic (e.g., unprofitable business cases), and capital challenges (e.g., access to low-cost financing). Although these have been studied and policies and programs have targeted many of these barriers, these challenges continue to warrant further research, especially to provide case studies that illustrate specific community-based challenges and customized solutions.

Key Topics: Barriers to Market Entry & Expansion	Agenda Items
Regulatory Barriers and/or Opportunities	• What best practices have State and local governments used to highlight the inventory of utility poles, conduit, and utility lines (e.g., water, gas, electric), and to provide access to such facilities? • What key factors have led State and local governments to modify local laws or ordinances to accommodate enhanced broadband infrastructure? • What strategies have been used effectively by State and local governments to promote "dig once" practices?
Competitive Barriers	• What impacts do vertical consolidations between middle-mile and last-mile providers have on competition for broadband services? • What emerging practices by incumbent broadband providers may be considered anticompetitive?
Business Case and/or Economic Barriers	• What are best practices for demand aggregation? • How have open access requirements for last-mile networks fared at stimulating competition by non-facility-based owners? • What specific terms and conditions can make open access requirements more conducive to competition? • Although much research has been performed on price elasticity and broadband adoption, how do these findings apply as advanced speeds are launched or as new usages such as "over-the-top" video become increasingly widespread?
Financial Capital Barriers	• What are the critical barriers to private investment capital? • What policy changes can be made to Federal loan programs (e.g., USDA's Rural Utilities Service programs) to further foster broadband deployment in unserved and underserved areas?

II.C Broadband Adoption and Digital Inclusion

Approximately 33 million U.S. households, or 27 percent, had not adopted residential broadband Internet service as of July 2015; even more significant, 20 percent of all U.S. households were offline entirely, lacking a single member using the Internet from any location.[24] The lack of adoption is most pronounced in rural communities and low-income population segments. For example, 69 percent of rural residents used the Internet compared to 75 percent of urban residents. Nationally, Americans with family incomes between $75,000 and $99,999 per year adopted the Internet at an 83 percent rate, compared to 70 percent of those in the $25,000 to $49,999 income range.[25] These disparities were even higher among low-income rural residents. Overall, vulnerable population segments (see Section II.C.7) continue to have lower rates of adoption and use of Internet-based services and applications.

The lack of good data on adoption and usage by business segments, especially small businesses, warrants additional data gathering and analysis, given the increasing importance of enterprise applications that drive productivity and performance. The key themes in research proposals and needed data sets vis-à-vis broadband adoption are wide-ranging: (1) adoption and usage data for population segments such as households, businesses, and vulnerable populations; (2) privacy and security challenges to adoption and meaningful usage; (3) impacts of pricing on adoption and usage; (4) impediments and opportunities to foster meaningful usage and digital inclusion; (5) enterprise and small business access and adoption, and resulting socioeconomic impact; (6) expansion of broadband to select prison populations; and (7) vulnerable population segments, especially individuals with disabilities and seniors.

II.C.1 Datasets on Broadband Adoption

Participants requested that the Agenda continue to build upon existing data collection efforts regarding adoption and usage.

Current Population Survey (CPS). The major national source of data on Internet usage and devices comes from the U.S. Census Bureau's Current Population Survey. NTIA sponsors the CPS Computer and Internet Use Supplement as the basis for its *Digital Nation* series of reports to understand the factors driving American usage of the Internet, as well barriers to usage.[26] The most recent survey (July 2015) asked 50 questions about technologies, devices, locations, online activities, and reasons for not adopting. It also gathered data on privacy and security concerns. The CPS sample size of roughly 53,000 households allows NTIA to break out results by demographics like age, race, income, and education, as well as by state of residence. The next survey is slated for November 2017.

Data Central. In 2015, NTIA launched its Data Central website (https://ntia.doc.gov/data) to allow the public access to data sets on computer and Internet use. During the first year alone, Data Central

[24] M. Lewis. 2016 (Sept. 28). "Digitally Unconnected in the U.S.: Who's Not Online and Why?" (blog); available at https://www.ntia.doc.gov/blog/2016/digitally-unconnected-us-who-s-not-online-and-why.

[25] E. Carlson and J. Goss. 2016. "The State of the Urban/Rural Digital Divide" (blog); available at https://www.ntia.doc.gov/blog/2016/state-urbanrural-digital-divide.

[26] NTIA. N.d. "Data Central" (Digital Nation Blog); available at https://www.ntia.doc.gov/category/data-central. The Census Bureau has periodically asked questions about computer use in the CPS since 1984 and about Internet access since 1997. NTIA began sponsoring a full CPS Supplement in 1994.

accounted for over 48,000 page views, and users viewed NTIA's Data Explorer visualization tool nearly 4,000 times. NTIA publishes full datasets along with technical documentation and sample code in its Research Center, enabling outside researchers to easily get started using NTIA data in their own studies.

Potential Census Project. There is little research directly comparing deployment data collected from Internet service providers (ISPs) to adoption data from household surveys. Merged datasets would enable evaluation of strengths and weaknesses of adoption data and validation of the data collected as part of the U.S. Census Bureau's ACS surveys. Also, Federal data is available on both deployment and adoption that can be used for comparison research. One project proposed by Census (subject to the availability of funding) would merge publicly available FCC 477 data and internal ACS data at the block level using detailed geographic identifiers on both files. This would allow expanded assessment and validation of the ACS data, potential mitigation of errors and weaknesses in the ACS, and generation of a more reliable picture of the socioeconomic correlates of Internet availability and use than are currently possible.

Key Topics: Datasets on Adoption	Agenda Items
CPS Computer and Internet Use Supplement – Data Requirements	• Consider approaches to build upon the existing robust data collection efforts on adoption and usage. • Determine the extent to which households report (in the American Community Survey) paying for Internet services not actually available in their areas, including overall service and specific types of service (i.e., fixed broadband, mobile broadband, and satellite).
Research Methodologies	• Find opportunities to conduct longitudinal research that follows individuals' adoption and usage on broadband technology, which can clarify the factors underlying broadband adoption and usage—including proximity to broadband infrastructure, socioeconomic status, personal interests, and life circumstances.

II.C.2 Privacy and Security Challenges to Adoption and Meaningful Usage

The increasing frequency of large data breaches has elevated issues of online trust and privacy. The hesitancy to trust data to third parties can lead to what could be described as a *self-imposed* digital divide, where individuals purposefully abstain or reduce participation in broadband activities due to their distrusts. The negative impacts of this situation can be as detrimental in all socioeconomic sectors as individuals not having access to broadband. Additional measures are needed to improve trust and enforce concerns of individual privacy. (See also Section II.A.4 for Technology aspects of this issue.)

Key Topics: Privacy and Security Challenges	Agenda Items
Deterrence to Adoption and Usage	• To what extent do perceived and actual threats to privacy and cyber security deter adoption of broadband? • What types of applications are less used by those worried about privacy and cybersecurity risks? • Which population segments are most impacted by such risks?

	• How can their impact on broadband usage be measured and quantified?
Education and Awareness	• What are the best practices to help the different segments of end-users understand and manage these risks related to privacy and security? • Which adoption programs may constitute informative case studies on such best practices? • What are the most effective means of consumer education on privacy and security for various user populations?

II.C.3 Impacts of Pricing: Key Research and Data Requirements

Broadband pricing influences many of the research themes in the Agenda. Although pricing is not a singular determinant, pricing when combined with other variables can help inform researchers in their evaluation and analyses of competitiveness, adoption barriers, business cases for deployment, public policy impact, etc.

Participants acknowledged the complexity of collecting and analyzing pricing data. Internet services fees are often masked due to bundled service packages, special fees (e.g., activation and equipment fees), upfront and/or recurring discounts, and special costs such as data overages. Stakeholder input indicated that having granular pricing data would enable researchers to study and analyze the impact of pricing on many themes noted in the Agenda.

Key Topics: Impacts of Pricing	Agenda Items
Pricing Data	• How should those Federal agencies with financial assistance programs (e.g., FCC, RUS) leverage their roles to collect pricing and marketing data?
Price Elasticity of Broadband Service Demand	• What is the price elasticity of demand across various customer segments with lower adoption rates, e.g., low-income, rural, Tribal, people with disabilities, and seniors? • How does the price elasticity of demand change across adopters as Internet speed tiers increase? • How will price elasticity change as new services and applications are increasingly adopted, such as “over the top” video? • While affordability ranks as a top adoption barrier, what price point would be affordable and drive adoption for various segments of low adopters? • For price-sensitive customers, to what extent is price an issue relative to service plans with potential variances (e.g., data overage charges, periodic price hikes)?
Middle-Mile Pricing and Impact on Last-Mile	• How do the various pricing strategies, contract terms, and service offerings set by middle-mile network providers (e.g., indefeasible rights of use [IRUs] for dark fiber, trade-offs between recurring and nonrecurring charges) impact the cost structure, pricing policies, and overall marketing strategy of last-mile providers?

Marketing Strategies & Impact on Adoption	• How do data caps impact adoption for both fixed and mobile networks? • How do "zero-rating" plans impact broadband adoption and usage?
Price Assistance Programs	• How effective is the FCC Lifeline program in fostering long-term broadband adoption? • To what extent do such programs foster greater adoption when blended with other initiatives to foster adoption (e.g., digital literacy, application training, etc.)?

II.C.4 Meaningful Usage and Digital Inclusion

Research on the digital divide has historically centered on lack of access and adoption. As progress continues on those fronts, an emerging area of research is the evaluation and measurement of whether end-users are taking advantage of the applications and services enabled by high-speed Internet. Meaningful usage is influenced by many factors that promote initial adoption, including digital literacy, accessibility to devices, and awareness. The disparities in meaningful usage and digital inclusion constitute a type of digital divide that is not binary in nature—i.e., the choices are not simply adoption versus non-adoption. The "Broadband 2021" report noted that research on meaningful use requires rich data on the actual contexts of use and understanding of the user experience.

The most recent FCC *Measuring Broadband America* report illustrates another dimension of the digital divide between low bandwidth vs. high bandwidth customers.[27] Specifically, customers purchasing download speeds between 15 Mbps to 50 Mbps were more likely to have migrated toward higher service tiers than customers purchasing plans for less than 15 Mbps—offered mostly by digital subscriber line (DSL) services—where only a few percent migrated within the following year to a service tier with a higher download speed.

Key Topics: Meaningful Usage and Digital Inclusion	Agenda Items
Best Practices to Foster Meaningful Usage	• How can we best quantify "meaningful use" of the Internet in terms of online behavior and/or outcomes? • What best practices have proven to drive meaningful usage in various end-user groups, especially vulnerable populations with lower adoption rates? • Given that meaningful usage is driven by many factors, which vary across not just end-user segments but individuals, what best practices can be taken to create a "menu" of strategies to foster meaningful usage? What factors must be known about the end-user in order to develop the most appropriate "menu"?

[27] FCC. 2016. "Measuring Broadband America 2016 Fixed Broadband Report"; available at https://www.fcc.gov/reports-research/reports/measuring-broadband-america/measuring-fixed-broadband-report-2016.

Mobile Subscription Services and Meaningful Usage	• To what extent do Americans with smartphones who do not use fixed home Internet access services at home not take full advantage of available services and experiences due to concerns about coverage, reliability, ease of use, subscription pricing, data usage caps, relatively lower speeds, etc. • What percentage of first-time broadband adopters is relying on mobile services exclusively for broadband access? • Given continuing enhancements in the capabilities of mobile devices (smartphones, tablets), what frameworks and methodologies can be applied to evaluate whether mobile service constitutes a substitute for rather than a complement to fixed broadband services, especially across different user segments?
Demographic Perspectives	• In what ways do racial and ethnic differences and cultures of use distinguish how people use broadband information resources? • What data-driven efforts should be created to address digital inequality that is responsive and locally relevant to the children and families who face these challenges?
User Experience	• What are some best practices that can foster collaboration between private-sector entities—such as ISPs, device manufacturers, and application developers—that have vast knowledge about the user experience, and nonprofits, academia, and the government that have programs to encourage meaningful usage? • What are the critical factors affecting user experience for users who exhibit relatively low usage?
Role of Community Anchor Institutions (CAIs)	• What are the best practices and challenges regarding how community anchor institutions, such as schools, libraries, health providers, community centers, public housing, and public media, can promote meaningful usage?

II.C.5 Enterprise/Small Business: Access, Adoption, and Socioeconomic Impact

High-speed Internet services and applications play a critical role in helping businesses reach their highest potential to perform, compete, and earn. Goals for businesses that use online applications include increasing sales efficiency, reaching target markets, expanding geographic reach, reducing operating costs, and enhancing the brand. Unfortunately, many businesses lack access to, or cannot afford, the advanced speeds required by a host of bandwidth-intensive applications, such as cloud storage solutions. Many others, especially small businesses, fail to take full advantage of network applications, thus putting them at a competitive disadvantage. One report found that smaller businesses are less likely than larger ones to fully understand the benefits of the Internet.[28]

[28] M. Curri. 2015 (Nov.-Dec.). "Small Businesses and the Digital Divide", *Broadband Communities*; available at http://www.bbcmag.com/2015mags/Nov_Dec/BBC_Nov15_SmallBusinesses.pdf.

The FCC Form 477 data requires facilities-based providers to report maximum advertised speeds for each technology to all end-user locations, including businesses. The data and research gaps pertain to questions about barriers and drivers regarding adoption and meaningful usage, the latter being defined as taking full advantage of the benefits of Internet applications. These challenges are particularly relevant to small businesses, which generated 60 percent of new jobs in the economic recovery, mid-2009 to mid-2013.[29]

Key Topics: Business Customers	Agenda Items
Availability	• As more businesses use specialized services (e.g., managed services and dedicated links), what indicators other than speed and technology should the FCC consider collecting for the business customer segment?
Adoption and Digital Inclusion	• What are the key adoption barriers for business customers, including the small business segment? • What are the critical barriers and opportunities impacting meaningful usage? • Given the highly diverse range of small businesses (e.g., industry, size), what specific types of research and data gathering should be prioritized that can provide insight across this variety of small businesses?
Data and Measurement	• How can meaningful usage and digital inclusion be measured for the business segment? • What data should be collected routinely, including by the Bureau of Labor Statistics?

II.C.6 Internet Access for Prisoners: Opportunities to Reduce Recidivism While Managing Security Risks

The benefits and risks of providing Internet access to segments of the incarcerated population warrants greater research and data collection. Over 95 percent of all State prisoners who leave prison are released back into their communities.[30] According to the Bureau of Justice Statistics, about two-thirds and three-quarters of released prisoners are re-arrested within three and five years of release, respectively.[31] Most released prisoners struggle to support themselves, due to challenges in finding employment and acquiring skills and education. Employability is difficult due to the stigma of having a criminal conviction, coupled with a dearth of educational credentialing, as 40 percent of prison and jail inmates lack a high school diploma. Mental illness and substance abuse (both before prison entry and after release) further contribute to unemployment and difficulties in community reentry.

[29] U.S. Small Business Administration Office of Advocacy, N.d. "Frequently Asked Questions"; available at https://sba.gov/sites/default/files/FAQ_March_2014_0.pdf.

[30] Bureau of Justice Statistics (BJS). (Accessed December 2015). "Reentry Trends in the United States"; available at http://www.bjs.gov/content/reentry/reentry.cfm.

[31] BJS. 2014. "Recidivism of Prisoners Released in 30 States in 2005: Patterns from 2005 to 2010 – Update"; available at http://www.bjs.gov/index.cfm?ty=pbdetail&iid=4986.

Broadband technology and its applications offer great potential to help address these difficulties. For example, online courses, e-healthcare applications, self-help and faith-based websites, and controlled social media applications may play critical roles in personal and professional development as well as employment. Moreover, Internet access can help increase knowledge about and competency in this critical technology, which can further improve transition to life in the community. Very few states offer Internet access to inmates, and this access is controlled for the few that do. These limitations are based on prisoner risk level (e.g., minimum-security inmates); release time (e.g., close proximity to release date); and/or access function (e.g., job search).

The answers to the following research questions can help guide policymakers, corrections professionals, technologists, academics, and other stakeholders to understand the benefits and risks of making Internet access a component of a prisoner's rehabilitation program.

Key Topics: Access by Prison Populations	Agenda Items
Broadband Availability	• What number and percentage of Federal and State prisons have access to broadband networks? • How many Federal and State prisons are located in unserved and underserved areas? What other impediments prevent prisons from having high-speed Internet access?
Broadband Usage by Prisoners	• How many State and Federal prisons offer Internet access to their inmate populations? • What are the advantages and disadvantages of providing such access? • Do offense level, time until release, or other variables dictate participation in Internet based programming (e.g., nonviolent offenders, close proximity to release date)? • Which applications have been or are being used, especially in terms of education, workforce preparation, healthcare, social media, communication, faith/motivation, etc.? • Are these the same tools used in community-based programs? Are there data sharing agreements between facility- and community-based providers? • What are the key barriers to adoption of relevant applications (e.g., digital literacy, relevance, cost, security); how can these barriers be addressed?
Security and Safety	• What are the risks in having prisoners engage in controlled access to relevant online applications? • What technology solutions are available to limit access to banned uses (e.g., communication with other prisons or the public, accessing inappropriate content, etc.)? • Which of these security and safety risks can be solved by technology? Prison management practices? Other strategies? • How can prison management work with technology vendors and service providers to address these issues? How can prison and

	correctional management work with facility staff to address these issues? What training is needed? • Should any specific segments of the prison population be denied Internet access completely? If so, why?
Impact Evaluation (Economic, Social, Personal)	• Which specific applications offer the greatest value to prisoners for their post-prison lives? What applications can allow for developing or joining longitudinal tracking systems to follow up on incarcerated individuals returning to the community? • What has been the impact to those prisoners who have had meaningful usage of the Internet with regard to key indicators, including employment, workforce reentry, education achievement, family and community engagement, and social assimilation? • How can such applications impact recidivism?

II.C.7 Vulnerable Population Segments

Stakeholder input on vulnerable population segments was focused on people with disabilities and the senior population. Other vulnerable population segments include low-income, rural, and nonfluent-English-speaking individuals.

People with Disabilities

As of 2010, over 57 million Americans lived with disabilities.[32] This number is likely to grow rapidly as the baby boomer generation ages. Statistics about broadband use by persons with disabilities are incomplete and merit further research, given indications that this group lags behind the population as a whole in terms of access and usage.[33] Research has focused both on impediments to Internet and computer usage for persons with disabilities, and on opportunities arising from technology solutions, awareness, and training. Benefits of broadband to this population include greatly improved voice-command capabilities in devices and better employment opportunities; challenges include the extra costs for screen readers and other assistive technologies.

Higher speeds at affordable price points can foster greater innovation in the development of assistive applications. Many such applications work better with higher speeds, such as streaming video or text-reading applications. Video-relay services, which require high-speed Internet to run, allow people who are deaf to have phone conversations in sign language by means of an in-person or online interpreter. Moreover, online education and telemedicine offer significant benefits to individuals with disabilities.

[32] M. W. Brault. 2012. *Americans with Disabilities: 2010*. Current Population Reports P70-131 (Washington, DC: Census Bureau); available at http://www.census.gov/prod/2012pubs/p70-131.pdf; Also, NTIA. 2016. "Digital Nation Data Explorer" (Disability Status); available at https://ntia.doc.gov/data/digital-nation-data-explorer#sel=internetUser&demo=disability&pc=prop&disp=chart.

[33] Communications Workers of America. (Accessed Dec. 2016). "High-Speed Internet and People with Disabilities"; available at http://files.cwa-union.org/speedmatters/FactSheets/SpeedMatters_Disabilities.pdf?nocdn=1; also, E. Lyle. 2010. A Giant Leap & A Big Deal: Delivering on the Promise of Equal Access to Broadband for People with Disabilities (Washington, DC: FCC, OBI Working Paper Series No. 2), p. 6; available at https://apps.fcc.gov/edocs_public/attachmatch/DOC-297713A1.pdf.

Participants suggested several areas of research to better understand the experiences of persons with disabilities regarding broadband access and usage, as delineated below.

Key Topics: People with Disabilities	Agenda Items
Adoption and Usage	• What are the challenges with regard to adoption and meaningful usage for the different segments of people with disabilities? (Note: The U.S. Census Bureau categorizes disabilities into six groups of challenges: sensory, physical, mental, self-care, go-outside-the-home, and employment)?[34] • What are the best practices for fostering and sustaining adoption and meaningful usage? • Despite many case studies in this area, what specific areas need to be developed regarding challenges, solutions, and impacts?
Technology	• Which areas of technology development are lagging with regard to the development of innovative solutions for disabled individuals (e.g., new user interfaces and applications)? • Could new design principles and toolkits help developers create edge devices with interfaces that better meet the needs of individuals with disabilities? • What particular disabilities require greater research into the dynamics of broadband adoption and usage, or create opportunities to develop new technologies and applications?
Public Safety	• How effectively do today's emergency communications systems meet the needs of individuals with disabilities, seniors, or low English proficiency? • How can current communications systems be improved to better meet these needs? What are the costs, benefits, and tradeoffs of doing so? • What new and emerging technical approaches could lead to better emergency communications for these populations in the long term? • What incentives can be provided to service providers to deploy the most cost-effective approaches to meeting the needs of persons with disabilities or low English proficiency for emergency communications?

Seniors

Seniors represent the largest and fastest-growing segment of the U.S. population, and the broadband adoption rates for this cohort are among the lowest. Just 53 percent of people ages 65 and older used the Internet at home in 2015.[35] Adoption rates fall dramatically in higher-age segments of the senior population. Recent work suggests that concerns about privacy and confidentiality may be significant

[34] U.S. Census Bureau. (Accessed January 2017). American Community Survey, "History"; available at http://www.census.gov/people/disability/methodology/acs.html.

[35] NTIA. 2016. "Digital Nation Data Explorer"; available at https://ntia.doc.gov/data/digital-nation-data-explorer#sel=homeInternetUser&demo=age&pc=prop&disp=chart.

barriers to adoption and use of technology by these populations. Some surveys have shown that seniors are more concerned about these issues than younger age groups, although they also seem to be less informed about how best to safeguard their privacy.

Key Topics: Seniors	Agenda Items
Adoption and Usage	• What are the challenges with regard to adoption and meaningful usage for different age segments of the senior population? • What best practices have proven to drive sustainable adoption and meaningful usage by seniors in different age segments?
Technology	• Which areas of technology development are lagging with regard to the development of innovative solutions for seniors (e.g., new user interfaces and applications)? • Could new design principles and toolkits help developers create devices (e.g., home routers, tablets) with more user-friendly interfaces for seniors? • What models of technology adoption and usage can be applied to seniors, given the unique circumstances that apply to elderly populations?
Impact	• How have healthcare applications that are used by seniors impacted outcomes related to their health? • How have social media tools used by seniors impacted outcomes related to family and community engagement? • What areas warrant greater evaluation of usage and impact?

II.D Socioeconomic Impacts of Broadband

The socioeconomic impacts of broadband on society are multilayered and complex. Research into the positive and negative social and economic effects of broadband on various populations is needed to improve existing public policies and design possible interventions. As noted in the "Broadband 2021" report, systemic data is needed, both quantitative and qualitative. Key research themes across subtopics include:

- Establish consistent or generally accepted models and methodologies for assessing economic and social impacts;
- Identify the roles of anchor institutions and community organizations in supporting long-term social and economic development goals through their broadband adoption and utilization programs;
- Research and document the social and economic benefits of targeted broadband adoption efforts;
- Study the impact of broadband on employment, productivity, and wages, not just on GDP growth;
- Research the socioeconomic opportunities and barriers for underserved and rural populations; and
- Study the social and economic impacts of Federal programs seeking to foster broadband access, adoption, or competition.

II.D.1 Economic Impacts

The national and local economic impacts of information and communication technologies have been a long-standing focus for researchers. The rapid rise in broadband access and adoption, and innovation across devices and applications, have been evaluated at many levels, including (a) macroeconomic impacts of broadband on GDP growth, productivity, employment, etc.; (b) microeconomic impacts at the firm level with regard to productivity, efficiency, competitiveness, innovation, growth, etc.; (c) consumer-level impacts with regard to individual productivity, employment standing, and consumer surplus; (d) capital investment impacts on direct, indirect, and induced jobs; and (e) spillover effects, including negative consequences from disruptions such as unemployment (e.g., due to outsourcing, productivity), disadvantages for unserved communities, and others. These studies have used a combination of econometric analyses and case studies. The collective findings generally support the view that broadband has a significant economic impact.[36]

The next wave of economic research will need to reflect situational factors such as technology advancements, innovations across application and device layers, applications, and the increasing digital divide in terms of both access and adoption of these higher speeds across all user levels—households, firms, and community institutions. McKinsey notes that the potential annual economic impact of the Internet of Things (IoT) sector could range from $3.9 trillion to $11.1 trillion globally by 2025,[37] and many IoT-related applications (e.g., smart cities, smart homes) already are in the early stages of development.

Key Topics: Economic Impacts	Agenda Items
Higher Speeds	• What is the incremental economic value as both supply and demand of high-speed Internet jumps to higher speeds (e.g., 100 Mbps, 1 Gbps, and beyond)? • How can the economic impact of innovations enabled by advanced speeds (e.g., 1 Gbps for firms and community institutions, 100 Mbps for households) be measured?
Internet of Things	• What data are required to measure the economic impacts of the Internet of Things (IoT) sector? • Given that many IoT applications are dependent upon large data sets, what actions can governments take to address security and privacy risks? • What standards regarding enablement of interoperability of IoT devices and systems are required, and how can the government support standards development?

[36] ITU. 2012. *The Impact of Broadband on the Economy: Research to Date and Policy Issues*; available at https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf.
[37] McKinsey Global Institute. 2015. *The Internet of Things: Mapping the Value Beyond the Hype;* available at http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world.

Data Requirements	• Given that many economic impacts of capital investments have taken place over a lengthy timeframe, how can governments play a more effective role in collecting and sharing time-series data, especially from Federal investment programs?
Community Assessment	• Study local and regional effects of broadband access and adoption not solely with reference to a given community, but also with reference to neighboring communities, to ensure measurement of actual economic growth rather than economic migration.

II.D.2 Broadband and Education

Although K-12 educational institutions have made great progress in the past few years with regard to broadband connectivity, there is still considerable work to be done to ensure equitable access. The modernization of the FCC's Universal Service Program for Schools and Libraries (known as E-Rate)[38] prioritizes broadband connectivity to and through school buildings and is a valuable funding source for many schools and local educational agencies (LEAs). However, there are still schools that do not meet the FCC's minimum short-term bandwidth recommendations of 100 Mbps per 1000 students, especially in rural areas and on Tribal lands.[39]

Educational institutions have a key role to play in developing the digital literacy skills needed for workforce and college success. The benefits of a digitally literate population are diverse and cross-cutting on both the individual and societal levels. Business development, employment, healthcare, criminal justice, and social work are just a few of the many areas impacted. The NBRA, therefore, emphasizes research on the impact of broadband in poor and traditionally underserved communities and on identifying best practices for ensuring digital equity.

There is very little research data about the ways in which robust connectivity, well-implemented instructional technology initiatives, and at-home student connectivity directly impact academic achievement and workforce preparedness. Additional research is needed to better guide government agencies in providing technical assistance and support to schools and school districts and to help evaluate the effectiveness of initiatives related to education technology.

Federal funding for education technology and broadband research will be key to the successful evaluation and implementation of existing and future education-technology-related programs. This will enable the government to provide technical assistance, highlight best practices, and target communication strategies to assist schools and LEAs. As part of these processes:

- Data should be collected and shared publicly and across agencies;
- Data collection on implementation and intervention evaluations should be built into the design of agency programs to develop evidence-based policy and future program planning;

[38] FCC. (Accessed Dec. 2016). "Universal Service Program for Schools and Libraries (E-Rate)"; available at https://www.fcc.gov/general/universal-service-program-schools-and-libraries-e-rate.
[39] FCC. 2016 (Jan. 29). *2016 Broadband Progress Report* (GN Docket No. 15-191) and references therein; available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-6A1.pdf.

- Funding agencies should help support the costs of making datasets available to the broader research community; and
- Methods to promote sharing of the FCC's E-Rate data with researchers, policymakers, and other key influencers should be identified.

Key Topics: Education	Agenda Items
Broadband Access	• Do broadband speeds in classrooms match expectations, or do internal (e.g., within a school building) infrastructure challenges impede broadband performance? • Why don't some eligible schools and LEAs apply for E-Rate funding? What technical assistance and support will encourage them to apply? • What strategies have schools in underserved areas used to acquire broadband access (community/municipal partnerships, cutting-edge technologies, self-provisioning, etc.), and how can these be scaled?
Broadband Usage	• How is broadband connectivity being used in schools? Are students learning how to use technology as a tool to engage in productive lifelong learning, or are they simply consuming passive content? • What technologies are deployed in classrooms; how are they used? • How does broadband access impact student learning outcomes, graduation rates, and student engagement in the learning process?
Broadband Technical Assistance	• What technical assistance do schools and LEAs need to bring adequate broadband connectivity to school buildings, especially in rural, Tribal, and underserved areas? • How can schools and LEAs ensure that this connectivity is best leveraged to enhance academic performance and develop the digital literacy skills needed for workforce and college success?
Home Broadband for Students	• How does access to broadband at home affect academic performance? • In what ways does having school-age children motivate families to engage in meaningful adoption of broadband, and how can schools facilitate this? • How are schools partnering with government agencies, nonprofits, and anchor institutions such as libraries to help address the "homework gap" between students who have and don't have Internet access?
Schools as Anchor Institutions	• What is the role of schools in promoting Internet access throughout the community? What are best practices for schools seeking to leverage their broadband connectivity to assist the broader community? • How can government best promote and support the further adoption of broadband for the purposes of enhancing teaching and learning?

II.D.3 Broadband and Workforce Development

The public workforce development system in the United States is highly decentralized, with the decision-making for infrastructure-related investments largely determined by business-led Workforce Development Boards and management of individual Department of Labor American Job Centers (AJCs, also known as

One-Stop Career Centers) that provide resource rooms for job seekers. Information regarding the "technical scaffolding" provided for these resource rooms by the funding agencies of the Workforce Innovation and Opportunity Act (WIOA)—DOL, ED, HUD, HHS, and USDA—is limited and anecdotal.

The Department of Labor targets annual funding under WIOA to Native American organizations across the United States to prepare both adults and young people to successfully enter the labor market. The presence (and speed) of Internet access on Tribal lands can be a significant factor in ensuring that this population has equity in accessing employment and educational services.

Broadband research will help inform the ability of Federal funders to share information and impact the technology-based delivery of educational services and content, especially in AJC resource rooms and distance learning centers.

Key Topics: Workforce Development	Agenda Items
Broadband Access	• What percentage of the 2,400 AJCs currently have access to broadband networks? • Is there "rough equivalence" between urban and rural jobs centers in terms of broadband access? • What is the broadband penetration for the workforce development organizations that serve the Native American population?
Broadband Emphasis	• Are there significant differences in the "emphasis" provided by individual States in their local planning guidance regarding the value of increased technology and broadband deployment in the jobs centers?
Broadband Usage and Digital Literacy	• What patterns of usage are common in American Jobs Centers and Tribal organizations (i.e., data similar to that collected in NTIA and Census Bureau surveys)? • To what extent do AJCs and local programs provide resources and curricula aimed at improving digital literacy? To what extent are they successful? • How does broadband access impact the availability and success of adult digital literacy initiatives? • What broadband-related Federal reporting under WIOA will provide information on credentials and certificates that are obtained by program participants?
Broadband Use by Prisoners and Former Inmates (see also Section II.C.6)	• How does broadband availability in One-Stop Career Centers located in prisons assist men and women who will soon be released in preparing for the local labor markets to which they return?

II.D.4 Broadband and Healthcare

Broadband has drastically changed the way patients consume and access health information and services, with an unprecedented amount of health information available to consumers online and the advent of telemedicine and electronic health records allowing for a significant expansion of care.

Healthcare and telemedicine are increasingly important to various American demographics, including rural residents and retiring baby boomers whose healthcare needs may be already unmet and/or are increasing. The ability of broadband to assist in both healthcare diagnostics and delivery holds significant promise for improvement in this realm. All stakeholders can benefit from additional research into the salutary impacts of broadband on healthcare, especially in rural, remote, and other underserved communities.

In an August 2016 report to Congress on E-health and Telemedicine, the U.S. Department of Health and Human Services noted that payment reform, state licensure barriers, and the lack of ubiquitous high-speed broadband in rural areas are barriers to the growth of telemedicine. Healthcare consumers and providers would benefit from research in these areas, as well as into issues related to privacy and security standards. An additional area of research that would benefit residents of Tribal lands are the geographical, funding, and administrative challenges that make it difficult for telecommunications companies to build broadband infrastructure on Tribal lands.

Key Topics: Healthcare	Agenda Items
Broadband Usage	• How do health institutions use broadband networks? What are their broadband needs? • What are the security and interoperability requirements specific to health settings, including the relevant privacy policies now in place, and how can key data points and tracking opportunities be identified in terms of performance?
Health Outcomes	• What are broadband's impacts on health outcomes? Do they differ across demographics, regions, or other factors? • How does broadband impact individuals' access to health services, especially in rural areas? • How can connectivity lead to better health outcomes while driving down health-related costs for municipalities or other payers?
Telemedicine	• What are the impacts of broadband on telemedicine, especially in rural areas? What are the potential costs and cost savings, both for the patient and the health institution (e.g., travel)? How can telemedicine improve access to digital health services such as remote patient monitoring? • How can targeted policymaking and public-private partnerships be used to facilitate the deployment of broadband to unserved areas of the country and to educate consumers about telemedicine?

II.D.5 Other Impacts

The "Broadband 2021" report noted that in order for individuals, communities, and businesses to integrate, utilize, and benefit from broadband availability, service, support, and digital literacy,

education must parallel broadband deployment.[40] Capacity building around broadband uptake and utilization is not the responsibility of any single entity; rather, a community-based approach that involves a cross-section of governmental and community organizations working together is better positioned for success. Therefore, cross-disciplinary research, particularly across the fields of education, social work, community health, workforce development, local government, and library and information science, is needed to better understand and address the financial, social, and institutional barriers to broadband adoption and usage.

Key Topics: Other Impacts	Agenda Items
Civic Engagement	• What are the effects of broadband on citizen empowerment and the political process? • What applications related to civic engagement have been widely used, and what have been the impacts? • How does broadband availability impact knowledge and uptake of government services, such as housing assistance, Federal benefits, the USDA Supplemental Nutrition Assistance Program (SNAP) program, Social Security, and unemployment? Can the government collect and disseminate better data for online adoption or enrollment in government services? • What are the effects of broadband on providers of nonprofit and public services (e.g., libraries) and their clients? • What opportunities exist to improve economic outputs and access to social and public service with improved connections for all?
Digital Literacy	• What are the core competencies that comprise basic digital literacy? • What are the characteristics of and pedagogical approaches behind successful digital literacy programs? How is this success measured? • What are the social and cultural impediments to fostering meaningful digital usage by underserved communities; how can they be overcome? • What are the causal links between digital inclusion and improved social outcomes, including educational attainment, social mobility, and financial literacy? • How do digital skill gaps impact employability? Are students leaving school with the digital literacy skills needed for workforce success? How does this impact business growth?
Social Impacts	• What are the social and economic effects of broadband access on individuals, families, organizations, and communities (including Tribal nations)? What are the impacts of exclusion? • How do broadband access and use patterns influence opportunities for social mobility?

[40] Institute for Information Policy, Pennsylvania State University. 2016 (July 25). *Broadband 2021: Report of the Interdisciplinary Workshop on the Development of a National Broadband Research Agenda*, p. 7; available at http://comm.psu.edu/assets/uploads/Broadband_2021.pdf.

	• What demographic factors contribute to the digital divide, especially among different racial and ethnic groups? • What opportunities would become available for individuals, organizations, and communities (including Tribal nations) if they had access to broadband or had better connectivity?
Employment	• What are the effects of broadband on employment? • What are the effects of broadband on productivity? • How does the educational level of a market influence broadband-induced productivity changes? • What are the effects of broadband access on income? • What opportunities would become available for individuals, organizations, and communities if they had access to different, better connectivity?
Community Anchor Institutions	• How does broadband access impact providers of nonprofit and public services (e.g., libraries) and their clients? • Agencies should fund cross-disciplinary research, particularly across the fields of education, social work, community health, and library and information science, to deepen understanding of the non-price barriers to broadband adoption and usage. • How can community anchor institutions such as libraries, schools, and health providers be leveraged to bring broadband access to underserved areas and increase community uptake of digital services?
Negative Consequences of Broadband	• How can outcomes associated with not having broadband access be assessed? • What are the actual and potential negative impacts of broadband (e.g., entertainment, political fragmentation, radicalization, information security breaches, and privacy violations)? Are any specific actual or potential impacts more likely to affect specific populations? • How do societal expectations of universal broadband access negatively impact low-income families (e.g., electronic-only forms being required for employment and other social assistance and college financial aid)?

III. Federal Support Opportunities and Next Steps

III.A Opportunities for Continued Federal Engagement

III.A.1 Evaluating Policy and Program Impact

All levels of government—Federal, State, and local—have been active in developing policies and programs to foster broadband access, adoption, and competition over the past decade and beyond. Federal investments alone have led to the deployment and upgrade of more than 117,000 network-miles since 2009.[41] The FCC created the Connect America Fund[42] to reform and modernize the universal service and intercarrier compensation programs and target the subsidies to capital investment in faster networks rather than support operating expenses of legacy networks. In addition, in March 2016, the FCC modernized the Lifeline subsidy program to include wireline and wireless broadband services.[43] In July 2015, the U.S. Department of Housing and Urban Development started ConnectHome,[44] which is a public-private partnership to expand broadband to hundreds of thousands of low-income households.

Evaluation of the effectiveness of the various programs is crucial for all stakeholders to make the best use of their resources. Moreover, the research community has an interest in evaluating policies and programs across various dimensions. In the near term, evaluation involves the examination of program implementation, such as the resources, processes, and procedures used to execute the initiative. In the long term, evaluation involves the measurement of impacts and outcomes of particular policies or programs, where the analysis looks at changes relative to not having the particular policies or programs. For example, NTIA reserved a portion of funds from the American Recovery and Reinvestment Act of 2009 Broadband Technology Opportunities Program (BTOP) to hire a third-party research firm to evaluate the impact of the BTOP program and how goals were met.

The robust level of public activity promoting equality of broadband access has raised a number of questions and research opportunities, especially in these areas: measuring effectiveness of policies and programs, downstream impacts of government involvement on private sector investment, and opportunities for the research community to contribute and share findings with policymakers before programs are scaled up.

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[41] NTIA. 2016. "Broadband Technology Opportunities Program (BTOP) Quarterly Program Status Report", pp. 1–2; available at https://www.ntia.doc.gov/files/ntia/publications/ntia_btop_30th_qtrly_report.pdf.

[42] FCC Wireline Competition Bureau. 2012. "FCC Launches Connect America Fund" (blog); available at https://www.fcc.gov/news-events/blog/2012/04/25/fcc-launches-connect-america-fund, and 2016. Public Notice of Support Amounts Offered to Rate-Of-Return Carriers to Expand Rural Broadband (WC Docket No. 10-90); available at https://apps.fcc.gov/edocs_public/attachmatch/DA-16-869A1_Rcd.pdf.

[43] FCC. 2016. "Lifeline Support for Affordable Communications"; available at https://www.fcc.gov/consumers/guides/lifeline-support-affordable-communications.

[44] EveryoneOn. 2015. "ConnectHome"; available at http://everyoneon.org/connecthome/.

Key Topics: Evaluating Policy & Program Impact	Agenda Items
Measuring Policy and Program Effectiveness	• Should Federal investment programs specifically delineate measurable objectives and outcomes? • If so, what are the key metrics that should be monitored for subsidy programs? Loan programs? • Should Federal broadband investment programs reserve some funding for independent firms to conduct research and analysis regarding impacts and outcomes, similar to NTIA's BTOP Program? • How can the research community be more involved in developing case study-based research regarding the outcomes of Federal investment policies and programs? • Given the long-term nature of capital investment, what is a fair length of time that should be allowed before meaningful analysis is done on impacts and outcomes?
Downstream Impacts of Investment Programs	• What are the major unintended consequences of government financial assistance programs that target unserved and underserved areas? • Under what circumstances can such programs stifle, freeze, or encourage private sector investment?
Collaboration with Research Community	• What are best practices regarding how such programs can be designed and tested before expanding their adoption? • How can government agencies be more responsive in collecting and sharing data with the research community? How can the research community be more responsive with regard to providing data requirements, sharing methodologies, and sharing findings?

III.A.2 Standardizing Terminology

The rapid changes in the technology sector often imply that "working" or "official" definitions may lose relevance over time. For example, the FCC has quadrupled its benchmark for minimum broadband speeds, raising it from 4/1 Mbps to 25/3 Mbps for download-upload between 2008 and 2015.

"Adoption" has generally meant a binary categorization of whether someone is using the Internet or not. Other terms such as "meaningful usage" and "digital inclusion" represent concepts or frameworks. Some terms such as "unserved" or "underserved" have tight definitions but are not applied consistently. Achieving interagency consensus on terminology can be useful, particularly as it relates to data collection and reporting.

Key Topics: Standardizing Terminology	Agenda Items
Impact of Definition Variance	• Which commonly used terms across the broadband landscape have the most variation in meaning? • How do such variations adversely impact, or benefit, the research community?

	• Which, if any, of these terms require standardization of their meaning? • Which terms are best suited to be regarded as concepts and frameworks? If so, would these concepts and frameworks benefit from having greater consensus with regard to their meaning?
Role of Government	• What should the role of the Federal government be in fostering standardization of terms for those that would most benefit from uniformity? • What are the benefits and limitations of having uniform definitions of commonly used terms across Federal programs?
Affordability	• The World Bank defines "affordable" broadband as being a percentage of income. Should there be a minimum index for affordability?

III.A.3 Sharing Federal Broadband Data and Research

Stakeholder input to the Agenda discussed both the challenges and the opportunities of having effective and efficient access to federally collected data. Participants noted that, in general, the default option should always be making any nonproprietary data open, transparent, and easily accessible. A particular challenge they noted is data sets marked as proprietary or confidential. Limiting access to existing data that are available is an obstacle to more fine-grained analyses that could be overcome in creative ways, e.g., by creating data enclaves to allow sharing of sensitive data within a closed community of researchers.

One specific opportunity has been the creation of centralized data portals. The Data.gov portal has provided new emphasis on sharing of government data. Moreover, several Federal agencies (e.g., FCC, RUS, NTIA, HUD, and NSF) have separate robust portals with granular information about their own policies, beneficiaries, reports, data, etc. These resources can empower individual researchers and institutions. Some stakeholders suggested that a centralized portal for all federally sponsored research and data collected as related to broadband could be useful. Relevant questions are specified below.

Key Topics: Centralized Data Portals	Agenda Items
Proprietary Data Collected by Federal Government	• Should the government provide a list of all the data sets that are kept confidential? • How can the government create data enclaves that allow sharing of sensitive data within a closed community of researchers?
Publicly Available Datasets	• What are the challenges of accessing publicly available datasets? How could these challenges be addressed? • What mechanisms might improve data sharing and use of government data by individuals and other organizations, commercial and noncommercial? • How can government-maintained (Federal, State, or local) datasets be made more broadly available and comparable? • Federal agencies with funding programs should consider identifying approaches to develop a centralized database that reflects the inventory of all network assets built via Federal funds.

Best Practices	• What are the advantages and disadvantages of having one particular agency create a portal that houses all broadband data collected, or at least links to them? • Should there be designated funding for data collection and sharing in Federal program budgets? • What are the various Federal, State, or local agency models for educating and diffusing technologies and data? • How do alternative research network models compare in terms of data sharing, undertaking research, and communicating with policy communities?

III.A.4 Sharing Proprietary Data

A great deal of data collection and research takes place within private entities, where the findings can lead to competitive advantages with regard to better technology, products and services, marketing practices, etc. However, these data also can be relevant to helping answer key questions that are unrelated to competitive position or strategy. For example, "Broadband 2021" participants noted that data from social media companies (e.g., Facebook and Twitter) potentially contain information on mobile broadband coverage and usage and the quality and frequency of mobile broadband access nationwide. They suggested that there may be opportunities to fold these private data into secure databases that could be accessed and used by researchers seeking to study these trends.

Key Topics: Sharing Proprietary Data	Agenda Items
Critical Proprietary Data Sets	• What private data sets could significantly assist the research community in helping answer many of the research questions or address the data requirements listed in the Agenda?
Strategies and Best Practices	• What creative means can the government use to support sharing of sensitive data within a closed community of researchers? • What best practices have been employed by private firms and the research community to facilitate data sharing and analysis without revealing or impacting the competitive positions of firms agreeing to provide such data?

III.A.5 Fostering Increased Collaboration throughout the Research Community

A key purpose of the Agenda, and the process used to develop it, is to foster collaboration across the research community. A common theme in this Agenda is that many of the research questions and data sets cascade across technology, deployment, adoption, and impact. The "Broadband 2021" report noted that attendees were almost "unanimous in voicing the need for interdisciplinary research." They cited that most spectrum research and experimentation require intertwining findings across technology, economic incentives, spectrum policy, and regulation. Thus, a key aspect is to encourage the convergence across broadband services and technologies and more clearly identify the challenges that remain in terms of access, adoption, and inclusion. Moreover, much of this Agenda can be acted upon

by non-Federal actors, i.e., academic and industry researchers, private foundations, etc.; their participation and follow-up will be crucial in the prioritization, planning, and enactment of effective research and data gathering proposals.

Key Topics: Fostering Collaboration Across Agencies and Disciplines	Agenda Items
Intra-Agency Collaboration	• What best practices can Federal agencies pursue to foster internal collaboration among all the agencies that work on broadband programs and policies?
External Collaboration with Federal Government	• What best practices can Federal agencies pursue to foster collaboration with the research community? • How can major policies and programs be designed in greater collaboration with the research community?
Community of Researchers	• What strategies can foster a national network community for broadband scholars?
Fostering Interdisciplinary Research	• How can existing federally funded research programs foster interdisciplinary collaboration? • What policies and programs can the Federal government pursue to promote interdisciplinary research among external stakeholders? • What best practices are used by Federal agencies to foster interdisciplinary research outside ICT that could be extended to ICT?

III.B Moving Forward via NITRD

The NITRD Program, comprising more than 20 U.S. government departments, agencies, and offices, enables coordination of Federal plans and programs in support of networking and information technology (IT) research and development. Chartered by the High Performance Computing Act of 1991 as amended through P.L. 114–329, enacted January 6, 2017,[45] NITRD promotes this coordination of networking and IT R&D to support the mission requirements of the participating agencies and to assure the continuing U.S. technological leadership to meet the needs of the Nation's research, societal, and commercial sectors. As noted In Section I.B, NITRD established a task force comprising NITRD members and other Federal departments, agencies, and offices to lead the development of this Agenda. Further coordination by these same agencies is needed to support the implementation of this Agenda. In this regard, the NITRD task force is expected to continue leading development of the Agenda, reporting to the NITRD Large Scale Networking (LSN) Interagency Working Group (IWG).

[45] NITRD, 2017. "Networking and Information Technology Research and Development Modernization Act of 2016" (Public Law 114-329, SEC. 105); available at https://www.congress.gov/bill/114th-congress/senate-bill/3084/text#toc-idB56FB943F79348E9AEE03036E5C90675.

In preparing this Agenda, the NITRD task force sought to synthesize and catalog inputs from academia, the public, and Federal staff about key research challenges and opportunities for broadband. Going forward, Federal agencies can support this Agenda through a number of actions, such as the following:

- **Expanding collaboration and community:** Foster cross-sector (government, academia, and industry) discussions to catalyze new collaborations and grow capacity in the research community to address the broadband research challenges outlined in this Agenda;
- **Inventorying existing data:** Invite agencies to consider whether they have existing data that can support the broadband research questions; continue efforts to create an inventory of all broadband data collected by Federal agencies;
- **Expanding reporting:** Invite agencies to consider whether existing data collection and reporting efforts can be expanded to address data requirements; and
- **Improving interagency collaboration:** Through the NITRD NBRA task force, enable greater interagency collaboration about Federal agencies' programs and associated milestones.

Appendixes

A. List of Respondents to the Request for Comments

Submitting Individual or Entity	Entity Type
American Planning Association	Nonprofit/Trade Association
Anonymous	Individual
Artschwager, Eva	Individual
Barbara Bush Foundation for Family Literacy and Digital Promise	Nonprofit/Foundation
Benton Foundation	Nonprofit/Foundation
Berkman Klein Center for Internet & Society, Harvard University	Nonprofit/IHE
City of Chicago	City Government
City of Seattle	City Government
Competitive Carriers Association	Nonprofit/Trade Association
Connected Nation, Inc.	Nonprofit/Foundation
Connecting For Good	Nonprofit
Consortium for School Networking, and State Educational Technology Directors Association*	Nonprofit/Consortium
CTIA	Nonprofit/Trade Association
EveryoneOn	Nonprofit
Extension Service Partnership	Nonprofit/IHE
Fiber to the Home Council	Nonprofit
Georgia Institute of Technology	Nonprofit/IHE
Gepper, Jeffrey, and Lucchesi, Juliana*	Individual
Gonzales, Amy	Individual
Greenlining Institute	Nonprofit
Gusman, Joe	Individual
Information Technology and Innovation Foundation	Nonprofit/Foundation
Kennedy, Deborah	Individual
The Leadership Conference on Civil and Human Rights	Nonprofit/Coalition
Lone Eagle Consulting	For profit
Mandelbaum, Richard	Individual
McDonough, Carol	Individual
Measurement Lab (M-Lab)	Consortium
Mobile Beacon	For profit

Submitting Individual or Entity	Entity Type
National Digital Inclusion Alliance (NDIA)	Nonprofit Coalition
North Carolina Broadband Infrastructure Office	State Government
NTCA–The Rural Broadband Association	Nonprofit/Trade Association
Office of Adult Education, City of Philadelphia	City Government
Partnership for Progress on the Digital Divide	Nonprofit/Consortium
ProLiteracy	Nonprofit
Reder, Stephen	Individual
Rosen, David	Individual
Sandia National Laboratories	Federal Laboratory
Schools, Health & Libraries Broadband Coalition; Consortium for School Networking; Education Networks of America; OneNet*	Nonprofit/Consortium
TechFreedom	Nonprofit
Technology Policy Institute	Nonprofit
TW	Individual
United States Telecom Association	Nonprofit/Trade Association
University of Missouri Geographic Resources Center	Nonprofit/IHE
Utah Governor's Office of Economic Development	State Government
Wireless Infrastructure Association	Nonprofit/Trade Association

* Single responses to the RFC by two or more parties.

B. List of Acronyms

ACS	American Community Survey (FCC)
AJC	American Job Center
ARRA	American Recovery and Reinvestment Act of 2009
BJS	Bureau of Justice Statistics
BOC	Broadband Opportunity Council
Broadband 2021	Workshop and final report of the July 2015 Interdisciplinary Workshop on the Development of a National Broadband Research Agenda, sponsored by The Pennsylvania State University Institute for Information Policy
BTOP	Broadband Technology Opportunities Program (NTIA)
CPS	Current Population Survey
DHS OEC	Department of Homeland Security Office of Emergency Communications
DOL	Department of Labor
DSL	Digital subscriber line
ED	Department of Education
FCC	Federal Communications Commission
HHS	Department of Health and Human Services
HUD	Department of Housing and Urban Development
ICT	Information, Communications, and Technology sector
IIP	Institute for Information Policy (Penn State University)
IT	Information technology
LEA	Local educational agencies
LTE	(Wireless)
MIMO	Multiple-input–multiple-output
NBRA or Agenda	National Broadband Research Agenda
NFV	Network function virtualization
NITRD	National Networking and Information Technology Research and Development Program (of the NSTC Committee on Technology, NITRD Subcommittee)
NSF	National Science Foundation
NSTC	National Science and Technology Council
NTIA	National Telecommunications and Information Association (DOC)
OMB	Office of Management and Budget
PPP	Public-private partnership

RERC	Rehabilitation Engineering Research Center
RF	Radio frequency
RFC	Request for Comments
RUS	Rural Utilities Service (USDA)
SDN	Software-defined networking
SHLB	Schools, Health & Libraries Broadband Coalition
SNAP	Supplemental Nutrition Assistance Program (USDA)
TIA	Telecommunications Industry Association
USAC	Universal Service Administration Company (FCC E-rate program manager)
USDA	U.S. Department of Agriculture
VRS	Video relay services
WIOA	Workforce Innovation and Opportunity Act