CONNECTING AND SECURING COMMUNITIES

A GUIDE FOR FEDERAL AGENCIES SUPPORTING RESEARCH, DEVELOPMENT, DEMONSTRATION, AND DEPLOYMENT OF TECHNOLOGY FOR SMART CITIES AND COMMUNITIES

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SMART CITIES & COMMUNITIES TASK FORCE

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About the NITRD Smart Cities and Communities Task Force

The Smart Cities and Communities (SCC) Task Force is a body under the NITRD Cyber-Physical Systems (CPS) Interagency Working Group. The CPS IWG's purpose is to coordinate programs, budgets, and policy recommendations for CPS R&D across the Federal Government. This includes identifying and integrating requirements, facilitating joint program planning, and developing joint strategies for the CPS R&D programs conducted by agency members of the NITRD Subcommittee and CPS IWG. Specifically, the SCC Task Force was created to coordinate Federal action and partnerships with academia, industry, local cities and communities, and other government entities to enable cities and communities of all types in accessing networking and information technologies and services. This access is intended to support cities and communities in developing smart solutions that increase efficiency and reduce costs, create new jobs and improve the economy, enhance safety and security, and meet other needs for their residents and businesses.

About this Document

This guide describes recommended practices and approaches for research, development, coordination, and engagement by Federal agencies in support of U.S. cities and communities expanding their use of digital technologies to build "smart" infrastructure, systems, and services. In developing this guide, the SCC Task Force integrated inputs from relevant Federal agencies and comments from cities and communities, businesses, industry, the scientific community, and the public. The purpose of this document is to guide and coordinate ongoing Federal activities that enhance the efforts of smart cities and communities and private sector partners.

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Executive Summary

Communities in the United States, from rural towns to large cities, are increasingly motivated by a vision in which digital technologies are integrated into infrastructure and services to create new jobs, improve the economy, and enhance safety and security for their residents. Applications include intelligent transportation, autonomous vehicles, smart policing, smart grids, remote healthcare, and more. This vision of smart cities and communities will be realized by empowering Americans to innovate in their local communities, industries, and academic institutions.

To realize the enormous public benefits of smart cities and communities, new capabilities are required in cybersecurity, data access and sharing, machine learning and artificial intelligence, wireless technologies, workforce development, education, and more. Addressing these needs requires cross-sector and cross-government collaboration, experimentation, knowledge sharing, and alignment.

Connecting and Securing Communities: A Guide for Federal Agencies Supporting Research, Development, Demonstration, and Deployment of Technology for Smart Cities and Communities offers a high-level framework of recommended practices and approaches to inform a broad range of smart city/community-related Federal activities. Emphasis is placed on empowering local governments and their stakeholders, including industry, to use partnerships to define and carry out activities that meet shared and individual community needs, and to innovate for the future. Coordinating efforts across Federal agencies will help accelerate the development of smart city/community solutions that maximize the value of investments, optimize benefits to residents, and improve the way infrastructure is designed, built, and maintained.

Smart city/community projects are inherently undertaken at the state and local levels. To be an effective partner in these efforts, Federal agencies must therefore align efforts with state, regional, and local needs, while incorporating appropriate public, private, and public-private partnerships. The Smart Cities and Communities Task Force identified a set of five high-level **Recommended Practices** that can inform Federal agencies in supporting smart city and community efforts:

- Empower local and regional communities to identify their unique needs and develop solutions;
- Accelerate innovation in infrastructure and city/community services;
- Support job growth and drive economic competitiveness;
- Facilitate cross-sector collaboration and bridge existing silos; and
- Boost exports and promote U.S. global leadership.

To assist agencies in Federally funded research, development, and deployment (RD&D) efforts for smart cities/communities technologies that facilitate job growth and economic prosperity, the Smart Cities and Communities Task Force of the Federal Networking and Information Technology Research and Development (NITRD) program identified four **Effective Approaches** that are described below, along with case studies of current and past programs and projects provided as examples to illustrate the approach:

- Promote fundamental R&D and transition innovations to practice for smart cities/communities;
- Facilitate local efforts for secure and resilient infrastructure, systems, and services for smart cities/communities;

- Enable smart cities/communities advances through data and knowledge sharing, best practices, and collaboration; and
- Enable evaluation of progress and long-term growth of smart cities/communities.

This guide envisions Federal agencies working together and engaging with industry, local leaders, civil society, academia, and other key stakeholders. The aim is to accelerate the development and implementation of new discoveries and innovations that enable cities and communities to achieve their local goals and address their most important challenges. Interagency coordination through the National Science and Technology Council will ensure that Federal investments are effectively targeted; States, tribes, and localities are encouraged to self-help; infrastructure investments are well-aligned for sustained and efficient investment; and private sector capabilities are effectively leveraged for success.

1. Introduction

> *We will build gleaming new roads, bridges, highways, railways, and waterways all across our land. And we will do it with American heart, and American hands, and American grit.*
>
> — President Donald J. Trump, February 2018

Communities across America are leading the way towards renewing and revitalizing aging infrastructure to meet the 21st century needs of their residents. Combining innovation in smart infrastructure with new partnerships, local leaders are working to make their communities safer, more resilient, and increasingly livable for residents; as well as more attractive, vibrant, and energizing for businesses. Examples of such locally led innovation from around the country include:

- Independence, Oregon, is leading the Farm-to-Fork project with the Oregon Department of Agriculture, a multinational American technology company, a local produce provider, and a local university, for real-time monitoring and management of transit and storage conditions for high-quality farm produce.[1]
- The Chattanooga Electric Power Board installed more than 6,000 miles of fiber for a communications network that supports not only a resilient smart grid, but also provides ultra-high-speed service to 170,000 homeowners and businesses; attracts new startup companies and academic researchers developing new technology, including for autonomous vehicles;[2] and has factored in an automobile manufacturer's choice of Chattanooga for a billion-dollar factory.[3]
- Denton, Texas, has partnered with the Civil Air Patrol and multiple universities, technology centers, and companies to explore unmanned aerial vehicles (UAVs) as flying cell towers for emergency and disaster relief communications.[4,5,6]
- The City of Newport News, Virginia, and seven other cities and counties in the Hampton Roads area, working with state and academic sector partners, won an innovation prize for their StormSense technology for cloud-enabled flood safety management.[4]
- The Columbus, Ohio, Smart Columbus project has attracted more than 20 private sector partners and over $500 million for its Acceleration Fund to provide equitable access through connected transit, transform mobility through electric and autonomous vehicles, and reduce costs and improve reliability through an advanced smart grid.[7] Researchers at a local university are also creating scalable and adaptable autonomous shuttles to solve first-mile,/last mile challenges in the city.[8,9]

[1] https://wiki.modelado.org/Farm_to_Fork_Crop_Tracking

[2] https://www.nsf.gov/awardsearch/showAward?AWD_ID=1647161

[3] https://www.energy.gov/sites/prod/files/2017/01/f34/Final%20SGIG%20Report%20-%202016-12-20_clean.pdf

[4] https://pages.nist.gov/GCTC/action-clusters-2017/

[5] https://www.nsf.gov/awardsearch/showAward?AWD_ID=1622978

[6] https://www.nsf.gov/awardsearch/showAward?AWD_ID=1522458

[7] https://www.columbus.gov/smartcolumbus/home/

[8] https://www.nsf.gov/awardsearch/showAward?AWD_ID=1640308

[9] First mile/last mile refers to the movement of people, goods, or services between a distribution point and an end-user location.

- The City of Ann Arbor and Washtenaw County, Michigan, are piloting a sensor-based stormwater management system developed with a team of university researchers. The system reduces the impacts of flash flooding and utilizes natural water cleaning properties such as sediments settling, to decrease the cost of water management in the region. The system has so far saved the City of Ann Arbor $1 million in stormwater management costs.[10]
- Schenectady, New York, working with multiple technology and power companies, is deploying smart lighting for cost savings coupled with wireless network capabilities to provide equitable Internet access for residents, empower community engagement, extend social services, and expand eHealth access for residents across the community.[11]
- Las Vegas, Nevada, is partnering with the Regional Transportation Commission, a local university, and multiple technology companies and automakers to develop a Connected Vehicle Pilot with a focus on pedestrian safety and traffic flow.[4]
- Nashville, Tennessee, is partnering with researchers through use of a mobile app for multimodal route planning. Emergency responders are working with university researchers to optimize their placement and allocation of resources to improve response times for fire and ambulance services.[12,13]

These projects illustrate the smart community concept—innovative research and development in cutting-edge technologies applied to new and legacy infrastructures with the goal of transforming a community and spurring economic growth. Small towns, farming communities, regional hubs, and urban centers across the Nation are exploring the smart community concept to drive progress in agriculture, transportation, energy, public safety, healthcare, and more.

Smart city/community projects are inherently state and local efforts, but there are many ways for the Federal government to support these efforts, including R&D leading to new innovations, advising on security and resilience, sharing data, and helping to track progress. To be an effective partner, Federal agencies must align their efforts with state, regional, and local needs while incorporating appropriate public-private and public-academic partnerships.

Three ingredients make up the recipe for success in these smart community projects. First, communities are in the lead, combining decision-making authority, connections to residents, and deep, local knowledge to enable effective design and execution of a project that the community embraces. Second, university researchers and businesses are active partners, providing the creativity and expertise for research advances that are translated into action, and the resources and sustainable business models that communities need for progress. Finally, Federal agencies are working behind the scenes—convening, consulting, connecting, and providing funding and other support as catalysts for local progress. This guide provides insights for Federal agencies seeking to adopt and apply these three principles in pursuing smart community goals.

[10] https://www.nsf.gov/awardsearch/showAward?AWD_ID=1737432

[11] http://www.cityofschenectady.com/DocumentCenter/View/1656

[12] https://www.nsf.gov/awardsearch/showAward?AWD_ID=1528799

[13] https://www.nsf.gov/awardsearch/showAward?AWD_ID=1640624

2. Recommended Practices Aligned with Smart City/Community Needs

The Smart Cities and Communities Task Force identified a set of five high-level recommended practices that can inform Federal agencies in supporting smart city and community efforts.

2.1 Empower Local and Regional Communities to Identify their Unique Needs and Develop Solutions

Federal smart city/community activities need to be iteratively informed by cities and communities and should reflect the diverse challenges faced by cities/communities of all types (e.g., rural, suburban, urban, peri-urban, tribal, small, and large).

Local cities/communities with varying needs and resources are embracing the smart city/community concept but are pursuing goals that reflect their different circumstances, needs, and aspirations. No two smart cities/communities are the same. However, there is a consistent vision across cities and communities that leadership lies with the local government to engage residents in identifying city/community goals, setting priorities, evaluating technical options, managing implementation and operations, and assessing progress.

Federal efforts should focus on solutions that are sustainable and readily adaptable to the needs of an individual city or community. Considerations should include privacy and security, social, behavioral, and economic factors (e.g., health, education, and socioeconomic status), effective Internet access, and outreach and educational resources. Finally, Federal support for technologies and programs intended to advance smart city efforts must be designed to work within a wide variety of resource environments, policy settings, and legal and regulatory frameworks.

2.2 Accelerate Innovation in Infrastructure and City/Community Services

Smart city/community innovation may be enabled by accelerating the entire innovation pipeline, from fundamental R&D to testbeds for transitioning research to practice, as well as capacity building to improve existing and new infrastructure, systems, and services, and changing the way infrastructure is designed, built, and maintained. Design considerations include promoting interoperability and integration across sectors and enabling improved security and privacy.

Current smart cities/communities initiatives are fueled by recent advances in information and communications technologies (ICT) combined with the declining prices of such technologies. However, cities/communities are challenged to meet not only today's needs, but also those of tomorrow with changing populations, new economic pressures, and the increased expectations of residents and businesses to continue to improve infrastructure, systems, and services. Meeting tomorrow's needs will require continuing advances in ICT and their adoption in the smart city/community marketplace. Thus, a key role for Federal agencies is in promoting and supporting R&D and transition to practice of innovative, new smart city/community technologies.

2.3 Support Job Growth and Economic Competitiveness

Smart city/community projects can simultaneously improve economic growth, generate job opportunities, and enhance workforce development for upskilling and reskilling.

For a smart city/community project to be sustainable, the city/community needs to achieve economic opportunity and growth, and attract and retain talented individuals, including providing education and training, to help residents understand how to utilize and build on the project and the new jobs and business opportunities created. The challenges in creating measurable benefits for residents and providing for appropriate education and training are best met by a broad, cooperative effort. The Federal Government can play an important role in highlighting successful approaches and facilitating planning and progress on the design, measurement, and workforce challenges and opportunities of a smart city/community project. Examples include:

- Focusing on increasing job availability and access, and skill acquisition to improve worker productivity, performance, and satisfaction;
- Expanding job opportunities for economically disadvantaged communities;
- Providing accessibility for disabled residents, including transportation and services innovations; and
- Expanding technology access in regions without broadband connectivity, thereby growing the economy.

2.4 Facilitate Cross-Sector Collaboration and Bridge Existing Silos

Collaboration across domains (e.g., integrating innovations at the nexus of food, energy, and water systems), organizational sectors (e.g., public-private partnerships that bring together government, academia, industry, and nonprofit organizations), and geographic boundaries (e.g., cities/communities, states) can increase efficiency and maximize resources.

The goals of smart city/community projects typically focus on benefits that may not necessarily correspond to technological, geographical, organizational, or disciplinary boundaries. For example, making a city/community more livable and workable crosses sectors from transportation to healthcare and public safety, requires cooperation between the public and private sectors, involves many technologies and a variety of expertise, and requires transitioning research to practice through testing at scale. Similarly, building resilience to large-scale disasters or making progress in transportation, energy, or other large-scale infrastructure projects may not be achieved by a city/community working alone, but may require a regional effort that brings together diverse authorities, entities, and interests.

The challenge for cities and communities lies in spanning traditional boundaries. Interagency coordination and the convening power of Federal agencies can catalyze enhanced cooperation and new partnerships across agencies, sectors, and stakeholders. Figure 1 provides examples of Federal programs that bridge sectors and technology readiness levels, and Section 3 describes a convening role for the Federal Government in bringing together representatives from cities and communities along with innovators from industry and academia to develop replicable solutions that are portable across cities/communities, interoperable across technologies and sectors, cost-effective, and extensible, to allow for growth and evolving needs.

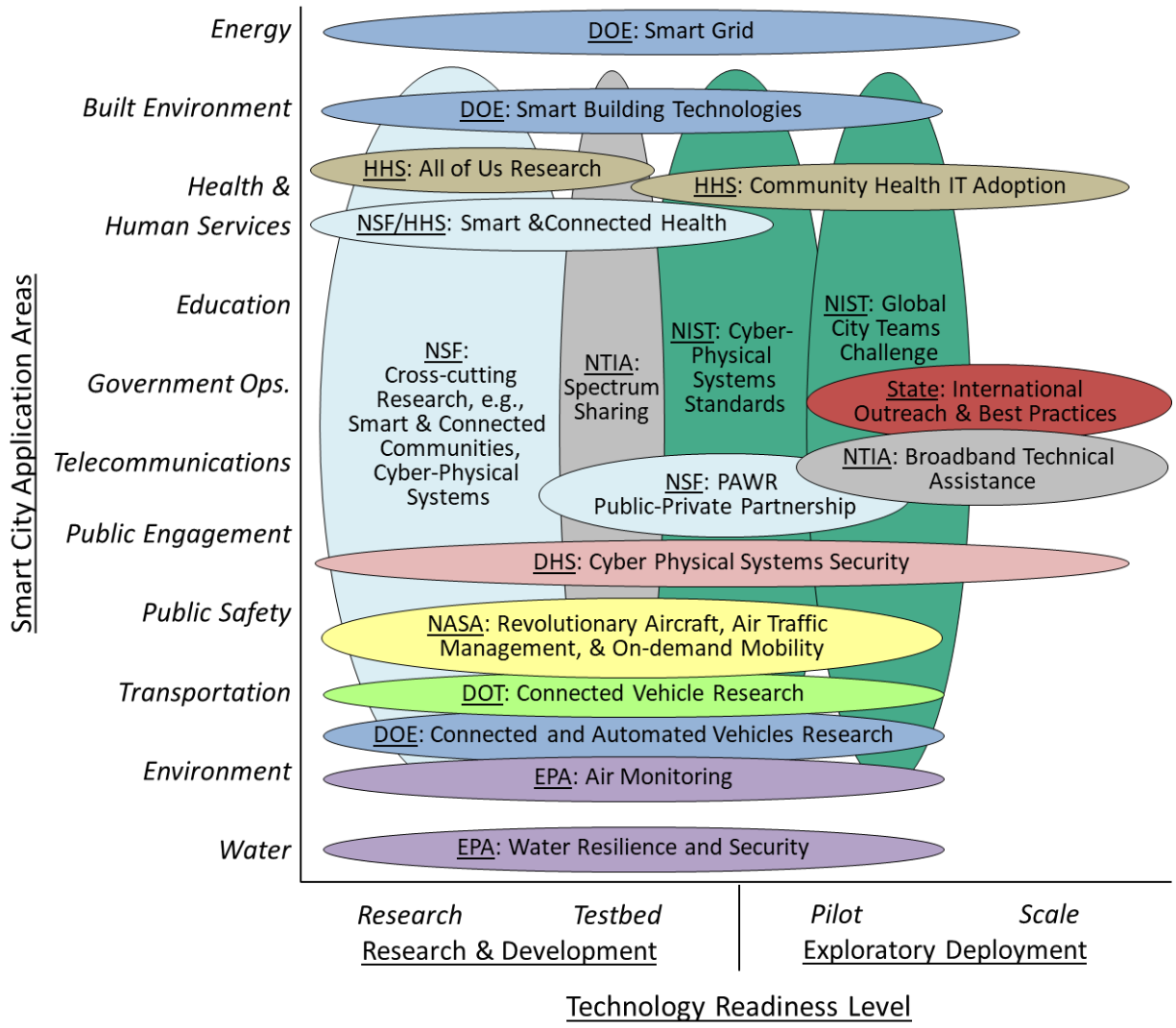

Figure 1: Examples of Federal smart city/community "bridging programs". The image depicts examples of Federal agency-supported smart city/community bridging programs by application area (*vertical axis*) and technology readiness level (*horizontal axis*). Bridging programs are those that cross multiple application areas (*vertically elongated ovals*) and/or span multiple technology readiness levels (*horizontally elongated ovals*).

2.5 Boost Exports and Promote U.S. Leadership

The Federal Government can foster industry-driven standards; sharing of successful practices domestically and internationally; interoperable and replicable solutions to increase global trade, investments, and export opportunities; and provide global leadership for smart cities/communities.

Smart cities/communities benefit from a robust technology marketplace that provides for healthy competition and economies of scale that help keep prices low and offer a range of choices and options enabled by interoperability and replicability both domestically and globally. The challenge for cities and communities is that individually they may have only limited influence on the marketplace. Nations around the world are racing to transform their cities and communities and reap the economic and social benefits that smart cities/communities promise, including creation of skilled jobs, new products

and services, and global trade and investment opportunities. Federal agencies have an important role in supporting U.S. leadership in the global smart city/community technology marketplace by promoting innovation and adoption of industry-led standards, assisting U.S. companies access to foreign markets, and ensuring a level-playing field for their products in the global market.

3. Effective Approaches for Federal Smart City/Community Actions

The approaches described in this section provide insights for future Federal agency smart city/community activities, with case studies of current and past Federal agency programs provided as examples to illustrate each approach.

3.1 Promote Fundamental R&D and Transition Innovations to Practice for Smart Cities/Communities

Integrating fields such as human-computer interaction, digital civics, economic geography, and urban policy provide the interdisciplinary approaches necessary for analyzing, evaluating, and developing new models required for smart cities/communities. Investments by Federal agencies that transcend R&D in science and engineering disciplines, cross a broad range of application areas, and include close engagement with cities/communities and their private sector partners are an effective approach to providing the foundation of knowledge for smart city/community solutions. This approach includes fundamental and applied research in cyber-physical systems, artificial intelligence, privacy, big data, and other areas to address challenges such as the following:

- Creating next-generation capabilities that leverage big data techniques and technologies, real-time analytics, decision-making, adaptation, and automation of systems and infrastructure, including cyber-physical systems, to address local needs;
- Investigating scientific and engineering foundations for cybersecurity, privacy, and risk management strategies to enable secure, privacy-sensitive, and resilient smart systems and infrastructure;
- Bolstering the Nation's broadband and wireless network ecosystem and opportunities by exploring new 5G and beyond devices, communication techniques, networks, systems, and services to enhance high-speed, low-cost connectivity and leverage the growing number of connected devices;
- Understanding and integrating the roles of people in smart systems, including social, behavioral, economic, cultural, legal, and ethical factors;
- Advancing the theories of learning and education in science, technology, engineering, and mathematics, including computing, that are enabled by technology innovations, and simultaneously enabling future technology advances to achieve sustainable solutions for local challenges;
- Investigating the differential impacts of technology—including rapidly changing and potentially disruptive technologies—on urban, suburban, and rural communities; and
- Developing real-time models of human behavior, disease occurrence and transmission, and disaster response to optimize healthcare and first-responder resources in dynamic situations.

1. Multi-Institutional Partnerships: The Array of Things

As cities explore smart solutions as part of urban modernization—assessing and leveraging existing expertise, resources, and infrastructure—they may be able to identify emerging challenges and adopt smart city/community innovations. Led by DOE's Argonne National Laboratory, the University of Chicago, and the City of Chicago, and with funding from NSF, the Array of Things exemplifies a successful ongoing and expanding smart city approach.[14] Innovations are being deployed to improve public health and welfare and city operations. Researchers are leveraging city resources, and researchers and city representatives are continually learning from one another.

The Array of Things is a network of interactive, modular sensor boxes being deployed around the City of Chicago. A key element of the system is modularity so that new sensors can be added as needed. Currently, sensors measure temperature, light, carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, sound, particulate matter, and pedestrian and vehicle traffic to better understand their links to health outcomes, transportation safety, and crime. These real-time, location-based data are provided to researchers, policymakers, developers and residents, who are working together to make Chicago healthier and more livable.

3.1.1 Facilitate city/community engagement in an iterative research cycle

Collaboration among researchers and city/community stakeholders is a key element in advancing smart city/community innovation and implementation through research that includes close engagement, well-developed partnerships, and iteration with city/community stakeholders—citizens, practitioners, entrepreneurs, civic leaders, and policymakers—in ways that accelerate innovation, increase the value of investments, and facilitate commercialization and adoption of smart solutions. An effective approach for Federal agencies in facilitating this engagement and the iterative cycle of innovation includes promoting close collaboration among cities, communities, universities, and private sector innovators to define the challenges that cities/communities are facing; pursuing basic research questions based on these challenges; and ensuring that the innovations that result provide the foundations for new technological development and commercialization to meet the real needs of cities and communities nationwide.

2. Interdisciplinary engagement on local challenges: Smart & Connected Communities (S&CC) program

NSF has long supported the basic science and engineering research that lays the foundation of knowledge for smart cities/communities. Programs include, but are not limited to, Big Data, Cyberlearning for Work at the Human-Technology Frontier, Cyber-Physical Systems, Critical Resilient Interdependent Infrastructure Systems and Processes, Secure and Trustworthy Cyberspace, and Smart and Connected Health. The Smart & Connected Communities program uniquely engages communities to help inform research questions and to pilot solutions to local challenges.[15] S&CC proposals require meaningful community engagement as part of the research plan. The S&CC program is highly interdisciplinary, spanning NSF's directorates for Computer and

[14] https://www.nsf.gov/news/special_reports/science_nation/arrayofthings.jsp

[15] https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505364

2. **Interdisciplinary engagement on local challenges: Smart & Connected Communities (S&CC) program**
[*cont'd*.] Information Science and Engineering; Education and Human Resources; Engineering; Geosciences; and Social, Behavioral, and Economic Sciences. Ultimately, the program supports use-inspired fundamental science and engineering research demonstrating two critical components: integrative sociotechnical research and meaningful community engagement.

3.1.2 Support research transition to practice in cities/communities

The transition of research innovations to practice is critical to ensure that smart city/community innovations benefit cities and communities, and their residents, and that they yield the greatest return on investment for the Federal Government. This requires an approach that bridges the chasm between fundamental science and engineering research and full production. Federal agencies must work synergistically with industry, nongovernmental organizations, and other stakeholders to shepherd innovations using transition-to-practice programs to efficiently move research findings to translation and adoption, and fully realize their value. The Platforms for Advanced Wireless Research program, described below, provides an example of fostering at-scale research platforms to test and evaluate innovations while mitigating risk early in the business cycle. Moreover, commercialization programs like the Small Business Innovation Research (SBIR)[16] and Innovation Corps™ (I-Corps™)[17] that span multiple Federal agencies provide mechanisms to foster strong, high-value partnerships with industry and create workforce training and recruiting opportunities, particularly ones that have innovation and entrepreneurship as a focus.

3. **Public-private partnerships for R&D Infrastructure: Platforms for Advanced Wireless Research (PAWR)**
Beginning in FY 2017, NSF and a consortium of over 25 companies and technology associations in the wireless sector initiated funding for the design, development, deployment, and initial operation of a set of Platforms for Advanced Wireless Research.[18] This NSF-led public-private partnership aims to advance the development of next-generation wireless technologies and services beyond 5G, providing the high-speed, high-capacity connectivity that is a crucial part of the infrastructure for smart city/community solutions, including vehicle-to-vehicle communication and disaster preparedness and response. NSF is investing $50 million over seven years, to be matched by an additional $50 million in cash and in-kind contributions committed by the industry partners, toward four city-scale wireless research platforms. Each platform will deploy an infrastructure focused on one or more aspects of wireless technologies and services (e.g., dynamic spectrum access, mobility at scale, or measurement), allowing academic researchers, entrepreneurs, and wireless companies to design, test, prove, and refine advanced technologies and algorithms in real-world settings. Innovations that result from PAWR have great potential to positively impact future generations of wireless networks and associated smart city/community applications.

[16] https://www.sbir.gov/

[17] https://www.nsf.gov/news/special_reports/i-corps/; https://sbir.cancer.gov/programseducation/icorps

[18] https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505316

3.1.3 Accelerate local solutions using community-centric programs

The Federal Government can use pilot projects, challenges, prize competitions, and other programs in cities and communities to leverage new technology to address local priorities. Such programs can broaden the impacts of innovation and help integrate smart technologies across application areas relevant to cities/communities. Federal agencies may apply this community-centric approach in everything ranging from a fundamental R&D mode that includes pilot projects that allow research results to be applied and adopted by local and regional governments (e.g., public-private-university partnerships through NSF's S&CC Program as described in Case Study 2, above), to a development and deployment mode that amplifies the Federal investment by attracting public and private partners (e.g., the U.S. DOT Smart City Challenge described in Case Study 4 below).

4. Challenges and competitions to generate investment and increase impact: Smart City Challenge

DOT issued the Smart City Challenge[19] to encourage cities to propose holistic approaches to improving surface transportation performance within a city and integrate transportation with other smart city application areas such as public safety, public services, and energy efficiency. Seventy-eight cities/communities responded with their visions for using emerging data, technologies, and applications to address daunting transportation challenges and demonstrate how their smart city/community will reduce congestion, keep travelers safe, protect the environment, connect underserved communities, and support economic vitality. Their responses blended 12 vision elements that addressed technologies, people, and data. Smart technologies such as connected/automated vehicles and sensor-based infrastructure linked citizens to opportunities and focused on mobility services and choices. DOT's $40 million challenge has resulted in public and private partners leveraging $500 million in additional resources to support the seven finalist cities.

3.2 Facilitate Local Efforts for Secure and Resilient Infrastructure, Systems, and Services for Smart Cities/Communities

As connectivity and interdependencies of smart city/community solutions increase, cities/communities will need to manage risk by increasing the security, reliability, resiliency, and efficiency of critical infrastructure, systems, and services for long-term value. These efforts are important to reduce the cost of hazards and malfunctions in terms of lives, livelihoods, and quality of life. This section describes approaches Federal agencies can use to help cities/communities mitigate these risks.

3.2.1 Enable cities/communities to assess, leverage, and enhance existing infrastructure, systems, and services

Cities and communities have already invested substantially in their current infrastructure. It is therefore important for them to find ways to leverage existing and legacy infrastructure, systems, and services to increase infrastructure efficiency, security, reliability, and resiliency. Federal agencies can support cities and communities in innovative efforts to enhance existing critical infrastructures. These efforts include broad partnerships for resilience at state and regional levels, as illustrated in Case Study 5 below, or community-focused projects. In an example of the latter, university researchers are partnering

[19] https://www.transportation.gov/smartcity/

with the Nashville Metropolitan Police Department and the Nashville Fire Department to develop tools to improve existing emergency response infrastructure and services.[12,13] With NSF funding, the team is developing a Smart City Emergency Response Hub, a next-generation system that anticipates incidents and allocates resources efficiently, securely, and reliably.

5. Multiagency collaboration with local/regional governments: Wide Area Recovery and Resiliency Program (WARRP)

The Wide Area Recovery and Resiliency Program,[20] a partnership between the U.S. Department of Energy's Pacific Northwest National Laboratory, DHS, the State of Colorado, and the City of Denver, has created a framework for urban areas, critical infrastructures, and military installations to enhance wide-area recovery efforts in response to chemical, biological, radiological, or nuclear (CBRN) events. The document provides an all-hazards framework to enable critical recovery decisions at a regional level and to provide context to local jurisdictions to develop their own operational recovery plans and ensure a timely return of basic services and social and economic order. Additionally, with FEMA, an urban area recovery planning aid was developed as a guide to inform the development of recovery plans and strategies in response to CBRN events. In addition to DOE, DHS, and FEMA, CDC, EPA, HHS, and DOD were also involved in the work, along with local and state authorities. The resources have been made available to other cities as well.

3.2.2 Support cities/communities in designing new secure and resilient infrastructure, systems, and services

In designing and building new infrastructure, systems, and services, security and resiliency should be key concerns addressed at design time and throughout the system lifecycle, rather than as add-ons. Federal agencies can assist and encourage cities and communities in developing innovative concepts for designed-in security and resilience that are effective while also ensuring that project costs are feasible within constrained city/community budgets.

Examples of this approach include NSF's Smart and Connected Communities Program (Case Study 2, Section 3.1.1), which supports integrative research projects that pair advances in technological and social dimensions with meaningful community engagement, including a range of projects for resilient infrastructure, systems, and services, and NIST's Internet of Things[21] (IoT)-Enabled Smart City Framework,[22] which provides both a logical structure and tools to facilitate effective planning for community resilience through smart city technologies. Case Study 6 below describes the interagency approach of DHS's Cyber Security Division, including the NIST- and DHS-led Smart and Secure Cities and Communities Challenge.[23]

[20] http://nwrtc.pnnl.gov/projects/programs.stm

[21] https://www.iso.org/files/live/sites/isoorg/files/developing_standards/docs/en/internet_of_things_report-jtc1.pdf

[22] https://pages.nist.gov/smartcitiesarchitecture/

[23] https://pages.nist.gov/GCTC/event/gctc-kickoff-2018/

6. Promote coordinated R&D programs: DHS Cyber Security Division (CSD)

The DHS Science and Technology Directorate's Cybersecurity Division, part of the Homeland Security Advanced Research Projects Agency, supports several major programs focused on developing the cybersecurity capabilities needed by critical infrastructure organizations across the Nation. These include Cybersecurity for Oil & Gas Systems (COGS, also called LOGIIC); Cyber Resilient Energy Delivery Consortium (CRED-C, formerly TCIP-G); the Cyber-Physical Systems program and its Automotive and Medical Device Consortia efforts; Critical Infrastructure Design and Adaptive Resilient Systems (CIDARS); and the Next Generation Cyber Infrastructure (NGCI) Apex program, focused on financial services organizations and infrastructures. All of these programs/projects develop and execute collaborative R&D projects to improve cybersecurity in critical infrastructures, working closely with other Cabinet-level agencies and technical regulatory organizations. For example, CSD and NIST are currently working to leverage some of these efforts and insights to the benefit of cities and communities, where many of these critical infrastructure systems come together, through the 2018 Smart and Secure Cities and Communities Challenge.

3.2.3 Foster smart infrastructure, systems, and services with long-term capacity

Cities and communities often face tight budgets that can severely constrain options in infrastructure investments. Making strategic, forward-looking decisions now enables cities and communities to be better prepared for future growth and changes in technology. Federal agencies can provide technical assistance to cities, communities, and industry to facilitate public-private partnerships, determine ways to build for future capacity, and enable collaboration across sectors to create more resilient, interoperable systems that provide cost-effective, key services. NTIA's BroadbandUSA,[24] which has provided technical assistance on the lifecycle of broadband and smart cities issues, is one example of an integrated approach across multiple service sectors to develop intelligent, cost-effective solutions that satisfy user demand for services in cities and communities.

7. Promote development and deployment of intelligent infrastructure: Smart Grid

Early-stage research in innovative technologies that show promise in harnessing American energy resources safely and efficiently can enable cities and communities to meet the growing energy needs central to their smart city/community solutions. DOE and NIST are leading complementary programs that together are providing the foundation for a smart grid of the future that will improve reliability, operational efficiency, resilience, and outage recovery. DOE's Smart Grid program is developing innovative technologies, tools, and techniques to move to a modern electric grid distribution and delivery system.[25] DOE is pursuing strategic investments to realize the capabilities necessary to meet the Nation's evolving electricity needs. These needs include accommodating increasing customer-owned distributed power generation (such as solar photovoltaics); supporting the shift towards the electrification of transportation systems and vehicles; enabling greater customer choice and control over electricity consumption; being more resilient to extreme weather conditions; reducing the duration and number of outages; and, at the same time, maintaining affordability.

[24] https://broadbandusa.ntia.doc.gov/

[25] https://energy.gov/oe/services/technology-development/smart-grid

7. Promote development and deployment of intelligent infrastructure: Smart Grid
[*cont'd*.] NIST's Smart Grid program complements DOE's efforts with an emphasis on measurement methods, best practices, and guidelines for interoperable smart grid technologies that enhance safety, security, resilience, and reliability, and enable new architectures for the electric grid of the future that may support new energy resources, stakeholders, and market models.[26]

3.3 Enable Smart Cities/Communities Advances through Data and Knowledge Sharing, Best Practices, and Collaboration

Knowledge sharing and collaboration could enable replication and scaling of smart solutions across cities and communities both in the United States and globally. Data sharing and interoperability are critical, as data are a foundation for improved decision making. Challenges to data and knowledge sharing, best practices, and collaboration are being addressed by a range of standards development organizations, industry and community consortia, nonprofit organizations, and others. Federal agencies can facilitate those efforts.

By their very nature, smart city/community goals require the analysis of varying data types from many different sources. Federal agency support and engagement is an important part of incentivizing secure, privacy-preserving data sharing, and promoting data interoperability. Agencies can promote best practices for sharing of data in ways that promote innovation, entrepreneurship, and exports, consistent with the Federal priority to leverage data as a strategic asset under the President's Performance Management Agenda.[27]

3.3.1 Advance secure, privacy-preserving data sharing and interoperability

The technologies and policies for the collection, storage, exchange, security, and use of public data, particularly public-sector IoT data, both within and outside city/community systems, are critical for the broad deployment of smart city/community solutions. Many cities have successfully implemented data management and open data solutions for public data. However, a comprehensive strategy is not yet available for enabling access and use of data from myriad and heterogeneous sources and applications.

One role for Federal agencies is in supporting projects that demonstrate best practices for secure data preservation and access. For example, DHS funded the development of the National Capital Region Geospatial Data Exchange,[28] which comprises a system and procedures for secure, flexible, and standardized sharing of critical mapped information in the Washington, DC, metropolitan area by National Capital Region partners at the state and local levels.

Another role for agencies is in integrating mechanisms for privacy-preserving sharing of data for use within and across smart city/community infrastructure systems and services. NIH launched the "All of Us" Research Program to gain better insights into the biological, environmental, and behavioral factors that drive disease.[29] The program is simultaneously addressing the challenges of making data from

[26] https://www.nist.gov/engineering-laboratory/smart-grid

[27] https://www.performance.gov/CAP/CAP_goal_2.html

[28] https://octo.dc.gov/page/ncr-gdx

[29] https://allofus.nih.gov/

potentially one million participants available to researchers across providers and sectors while securely managing highly sensitive individual health information.

Finally, agencies working together with academic and industry partners can facilitate the development and dissemination of best practices, guidelines, and standards for interoperability. For example, Federal agencies may promote best practices by sharing their data from smart city/community applications in standards-based, well-documented, interoperable forms. In addition, they can facilitate public-private partnerships to help make data more interoperable and promote data sharing across sectors, technology platforms, and application areas.

8. Promote data access and interoperability: CitySDK and First Responders Group

By working with local leaders, Federal agencies can facilitate interoperable solutions that bridge sectors, organizations, and technologies for key community needs. The U.S. Census Bureau's open-source city software development kit (CitySDK) project makes valuable data and application (app) development accessible by communities and civic innovators.[30] To help incubate new apps that are based on open data, including smart cities/communities apps with broad civic benefits, the Census Bureau launched a pilot program of data innovation workshops, delivered in close collaboration with city experts, to help solve the most pressing local issues. The pilot program helps bridge the data production and management gap between Federal, state, and city data, and extends to national scale through the Census Bureau's State Data Center Program. One key focus of the CitySDK pilot is helping cities break down data silos to aid in smarter disaster response.

DHS Science and Technology Directorate's First Responders Group is exploring the need for diverse types of geospatial data for emergency response in future cities and communities.[31] The group is exploring how better access to a diversity of interoperable data sources and powerful analytics could inform and protect the safety of firefighters responding to an incident; enable next-generation, more intelligent firefighting systems; and allow safer and more efficient evacuation in the event of a disaster.

3.3.2 Facilitate replication and scaling through best practices

Federal agencies have a role in helping cities identify best practices and boost replication and scaling across geographic boundaries by facilitating multi-city programs. Areas where best practices may improve scaling include intelligent transportation systems that cross geographic boundaries; remote-access healthcare systems that work in any location; and regional air quality improvements through coordinated local action. By bringing multiple Federal agencies together with local governments, academia, industry, and nonprofit stakeholders to collaborate on shared solutions broadly adoptable by many cities and communities, agencies can leverage each other's investments and reduce barriers to the adoption of such solutions. Through best practices and economies of scale, more cities and communities of all types can leverage, scale, and replicate each other's successes.

[30] https://uscensusbureau.github.io/citysdk/

[31] https://www.dhs.gov/science-and-technology/first-responders

9. Convene stakeholders to enable collaboration: NIST's Global City Teams Challenge (GCTC)

NIST's Global City Teams Challenge is a collaborative platform to promote replicable, scalable, and sustainable models for incubation and deployment of interoperable, standards-based IoT solutions and demonstration of their measurable benefits in smart cities and communities across the Nation and around the world.[32] More than 100 "Action Clusters", or teams of diverse stakeholders with a common objective, representing collectively more than 150 cities and over 400 companies, universities, and other organizations worldwide, have participated in the Challenge. GCTC has also catalyzed the formation of multi-team "SuperClusters" that bring together multiple Action Clusters to take on grand challenges in areas such as Transportation, City Platform/Dashboard, Public Safety, Energy/Water/Waste Management, Wireless Access, Data Governance and Exchange, and Agricultural and Rural Applications. The GCTC SuperClusters bring together groups of communities formed around lead cities and private sector partners to work with NIST and its collaborators, including DOT, DHS, NSF, EPA, DOS, ITA, and NTIA, to develop "blueprints" for shared solutions that will be collaboratively implemented and replicated in multiple cities and communities. NIST and DHS S&T are also working as partners in GCTC's Smart and Secure Cities and Communities Challenge highlighting designed-in cybersecurity and privacy in smart city/community applications.

3.3.3 Foster global collaboration to drive innovation

While cities and communities have unique characteristics, they often face common challenges regionally and globally, including responding to natural and man-made disasters, providing access to safe sanitation and potable water, reducing crime, and implementing effective cybersecurity. By engaging internationally, for example through programs like NSF's S&CC program (see Case Study 2, Section 3.1.1) and NIST's GCTC (see Case Study 9, Section 3.3.2), or in fundamental research that addresses global problems, agencies can enable technologists and researchers to share innovations and new approaches to common problems while ensuring continued U.S. leadership and global advantage. In one example, the Array of Things project (see Case Study 1, Section 3.1), with NSF support and DOE National Laboratory participation, is expanding its reach to other parts of the world to understand the impact of different physical environments on the reliability of its technology, and to create a network of users who can share data, information, and approaches.

3.3.4 Boost global technology trade and investment opportunities

Global trade, investments, and export opportunities in smart cities/communities technologies developed by U.S. industry are supported by sharing best practices and promoting interoperable technology with other governments. The trade promotion activities of the ITA are supported by the efforts of NIST and other Federal agencies on joint implementation of best practices across global borders, which helps ITA's trade policy assist U.S. companies with market access challenges.[33]

[32] https://pages.nist.gov/GCTC/

[33] https://www.export.gov/smartcities

3.4 Enable Evaluation of Progress and Long-Term Growth of Smart Cities/Communities

Long-term growth and sustainability of smart cities/communities initiatives requires evaluating progress, demonstrating benefit, and investing in human capital. Federal agencies, working with state, local, academic, and industry partners, can contribute to developing standards, metrics, and economic models for evaluation that can be easily adapted at the local level. In addition, long-term sustainability depends on workforce training and communicating successes to all stakeholders, including the public.

3.4.1 Promote standards and best practices

Key features of an effective smart city/community system are interoperability, replicability, scalability, extensibility, and ability to update. Interoperability enables modular designs that allow cities/communities to build solutions in manageable budget increments and enable options and choices among competing solutions. Replication and scalability allow cities/communities of all sizes and types to adopt successful solutions deployed in other cities and communities. Extensibility allows cities/communities to plan for future growth and evolving needs. Updating capabilities ensure that smart infrastructure systems that may be deployed for decades can be renewed as technology evolves. All these features require an underlying foundation of voluntary, consensus-based standards, architectures, and best practices that emerge through industry-led processes, along with a robust testing and certification capacity that supports these standards.

Federal agencies can play an effective role in promoting the emergence of global smart cities/communities standards and best practices by providing relevant technical expertise, engaging effectively with cities/communities, and facilitating industry-led processes that produce consensus results for voluntary adoption that are technology- and business-model-neutral. These activities seed private-sector testing and certification capacity for smart city/community technologies accreditation.

10. Promote development of global standards and best practices: Internet of Things-Enabled Smart City Framework

The IoT-Enabled Smart City Framework provides a consensus framework of common architectural features to enable smart city solutions that are interoperable, portable, extensible, and cost-effective.[22] Development and implementation of smart city solutions is an international effort, and to that end, NIST and its collaborators convened an international coalition dedicated to developing the framework. Through an open, technical working group studying real-world smart city applications and architectures, this coalition identified pivotal points of interoperability where emerging alignment on best practices and standards could enable a landscape of diverse, but interoperable, smart city solutions. Coalition members include the American National Standards Institute; the U.S. Green Building Council; the Telecommunications Industry Association (TIA); the Republic of Korea's Ministry of Science, Information and Communications Technologies, and Future Planning; the Italian National Agency for New Technologies, Energy, and Sustainable Economic Development; the European Telecommunications Standards Institute; and the FIWARE Foundation.

3.4.2 Support economic models for evaluation

With cities and communities adopting complex, systems-of-systems approaches to community management, city-/community-scale economic models are increasingly important. Such economic

models offer a means to evaluate and demonstrate impact and return on investment for smart city/community initiatives, evaluate progress in real time and adjust as needed, assess total lifecycle costs from design through retirement, and plan investments for the future. These capabilities require an underlying framework of metrics and measurement methods, including quantifiable key performance indicators, and Federal agencies can facilitate their development. In doing so, unique characteristics of cities and communities should be considered to ensure that models and methods are easily adaptable to the local level.

11. Assess the impact of investments: Broadband Technology Opportunities Program (BTOP) Evaluation Study

Metrics and methods are needed to evaluate the economic impacts on cities and communities that result from investments in intelligent infrastructure. To that end, NTIA contracted ASR Analytics, LLC, to conduct an independent evaluation of the long-term economic and social impacts of the Broadband Technology Opportunities Program,[34] which awarded $4 billion in American Reinvestment and Recovery Act grants. Among the analyses was an evaluation of the impact of BTOP infrastructure spending on gross domestic product (GDP) in the areas served by the new broadband infrastructure. Study leads used existing literature on the economic impact of broadband to estimate changes in both annual economic output and employment. For the base case of a 2.0 percent increase in broadband availability, BTOP infrastructure spending was expected to yield $5.7 billion in increased output annually. The additional broadband infrastructure provided by BTOP was also expected to create more than 22,000 long-term jobs and generate more than $1 billion in additional household income each year.

3.4.3 Facilitate long-term sustainability by boosting human capital

The long-term sustainability of smart cities/communities requires a population and workforce that are motivated and empowered to tackle local challenges through communication, education, and workforce development, transitioning, and retraining. These activities may include information and educational resources for municipal leaders on smart cities/communities technologies, for industry leaders on partnerships with cities/communities, and for residents about the use and value of smart solutions. Public participation in scientific research (e.g., citizen science and crowdsourcing) offers a valuable means for engaging residents. For example, residents may work collaboratively to solve local problems through collection and analysis of local data, which may aid in enhancing buy-in, acceptance, and effective governance around the technologies.

The smart city/community arena offers a unique opportunity for Federal agencies to engage with residents and students in partnership with local and regional educational institutions. In one such example, through the NSF-funded Water Awareness Research and Education (WARE) program,[35] K–12 teachers and students worked alongside university faculty and students to install and retrofit smart infrastructure to alleviate flooding, improve nutrient management, and execute project-based learning activities for all involved.

[34] https://www.ntia.doc.gov/files/ntia/publications/asr_final_report.pdf

[35] https://www.nsf.gov/awardsearch/showAward?AWD_ID=1200682

12. Build a workforce through partnerships: NIST's National Initiative for Cybersecurity Education (NICE) and NSF's Cyberlearning for Work at the Human-Technology Frontier

An effective approach to developing a smart city/community workforce is through partnerships between workers, community leaders, educators, industry, and government. The National Initiative for Cybersecurity Education (NICE),[36] led by NIST, is a partnership between government, academia, and the private sector with a mission of energizing and promoting a robust network and an ecosystem of cybersecurity education, training, and workforce development. NICE fulfills this mission by coordinating with government, academic, and industry partners to build on existing successful programs, facilitate change and innovation, and bring leadership and vision to increase the number of skilled cybersecurity professionals helping to keep the Nation secure.

Additionally, agencies can promote the development of educational resources for a well-trained workforce and an informed citizenry, which are among the essential foundations of a successful smart city/community effort. NSF has supported interdisciplinary research on learning in many programs over many decades, especially in cross-directorate investments. In the Cyberlearning for Work at the Human-Technology Frontier program,[37] four NSF directorates (Computer and Information Science and Engineering; Education and Human Resources; Social, Behavioral, and Economic Sciences; and Engineering) fund projects that exploit emerging technologies to advance learning in multiple contexts. Increasingly, the Cyberlearning for Work at the Human-Technology Frontier program is integrating what is known about how people learn with the opportunities offered by new and emerging technologies to prepare individuals across their lifespans with needed skills.

3.4.4 Communicate successes and lessons learned through cross-sector platforms

Progress across the full city and community landscape can be accelerated by broadly communicating the successes and lessons-learned in smart city/community innovations. Key to these successes have been partnerships that bring cities and communities together with academia, industry, nonprofit organizations, and others to work on innovative solutions that benefit residents. Federal agencies can facilitate communication by providing mechanisms for coordinating and sharing cross-sector, cross-stakeholder innovations and supporting efforts that build partnership capacity and maximize benefits through strong collaborative efforts.

In addition to communicating successes and lessons learned between smart city/community stakeholders in academia, industry, and government, Federal agencies have a role to play in elevating smart city/community efforts for public awareness more broadly. Highlighting city/community challenges and smart city/community solutions to diverse audiences, including the public, promotes inclusive, equitable, and sustainable progress.

[36] https://www.nist.gov/itl/applied-cybersecurity/nice

[37] https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504984

13. Stakeholder engagement opportunities: US Ignite Application Summit

NSF launched and continues to support US Ignite,[38] a public-private partnership seeking to connect "islands" of broadband across the Nation and demonstrate the potential of game-changing new applications that take advantage of smart, ultra-high-speed connections.[39] There are currently 25 US Ignite cities and communities across the Nation that have deployed connections with speeds over 1 gigabit per second to homes and businesses, and over 99 application prototypes that leverage these advanced networks are currently being developed or are in use. Since inception, every summer, the US Ignite Application Summit brings together computing researchers, software and application developers, entrepreneurs, innovators, investors, industry executives, and civic leaders to showcase the emerging content-rich, high-bandwidth, dynamic, secure, and reliable apps; identify opportunities for cross-city/community expansion of emerging apps; and catalyze new collaborations and partnerships for furthering the US Ignite ecosystem.

4. Summary

This document, *Connecting and Securing Communities: A Guide for Federal Agencies Supporting Research, Development, Demonstration, and Deployment of Technology for Smart Cities and Communities*, offers recommended practices and effective approaches for Federal agencies in pursuing smart cities/communities goals that are informed by and responsive to the needs of the full spectrum of stakeholders. Its recommended practices span sectors (e.g., academia, government, and industry); application areas (e.g., transportation, energy, networking, and health); and geographic boundaries (i.e., across communities, cities, states, nations, and regions).

Implementing the approaches in this guide requires close coordination among Federal agencies as well as with city and community stakeholders. The NITRD Subcommittee will continue its mission to provide an ongoing forum for interagency coordination. Through this cooperation, agencies will ensure that Federal investments are effectively targeted; that States, tribes, and localities are encouraged to self-help; infrastructure investments are well-aligned for sustained and efficient investment; and the capabilities of the private sector are effectively leveraged for success.

[38] https://www.us-ignite.org/

[39] https://www.us-ignite.org/apps/