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Global City Teams Challenge Smart Agriculture and Rural SuperCluster Workshop Report 2020

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Global City Teams Challenge Smart Agriculture and Rural SuperCluster Workshop Report 2020

CYBER-PHYSICAL SYSTEMS

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National Institute of Standards and Technology
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Executive Summary

The National Institute of Standards and Technology (NIST) established the Global City Teams Challenge (GCTC) for communities across the world to use as collaboration platform in their pursuit of deploying Internet of Things (IoT) and Cyber-Physical Systems (CPS) to improve the quality of life for residents. The GCTC's overarching goals are to enable standardization and interoperability for these IoT and CPS, and to make them scalable and replicable for the widest possible use.

The Smart Agriculture and Rural SuperCluster is part of this GCTC effort. On February 19, 2020, this SuperCluster conducted a workshop in Phoenix, Arizona to further refine its blueprint for smart agriculture and rural areas. The workshop ultimately sought to develop a consensus-based smart cities and communities framework and best practices, which could subsequently inform widespread smart agriculture and rural initiatives.

The workshop included five panels, which addressed the following topics: connecting rural places to broadband; smart agriculture; funding and financing; farm field mapping; and improving rural outcomes with broadband access. In each area, experts provided wide-ranging perspectives.

Workshop participants then divided into three groups to discuss challenges for the following areas: smart agriculture, farm field mapping, and improving rural outcomes with broadband access. Spokespersons for each group reported the results to all workshop participants in a plenary session and for possible inclusion in the blueprint and framework.

A month later, the COVID-19 crisis made us even more aware of the criticality of the issues discussed at this meeting, especially broadband connectivity and bandwidth capacity. Closures and stay-at-home directives increased communities' reliance on broadband-enabled platforms. Employers set up remote work protocols, teachers engaged students in video conferencing, and consumers found more ways to shop online with touchless delivery—all for the sake of protecting health and safety.

The COVID-19 pandemic underlined that both rural and urban areas greatly depend on broadband connectivity for distance education, telemedicine, and commerce. This report, along with lessons learned from this pandemic, can inform further pursuit of smart solutions, via broadband connectivity, for agriculture and rural areas.

1. Introduction

In late February 2020, the National Institute of Standards and Technology (NIST) Global City Teams Challenge[1] (GCTC) hosted a Smart Agriculture & Rural Supercluster Workshop in Phoenix, Arizona, USA. This gathering was sponsored by NIST, the National Telecommunications and Information Administration (NTIA), NTCA–The Rural Broadband Association, RTO Wireless, and Telrad Networks. The workshop convened participants from government, industry, and academia to discuss the many benefits and challenges of bringing smart technologies and broadband to more rural areas of the United States.

Barely a month later, the COVID-19 crisis made us even more aware of the criticality of the issues discussed at this meeting, especially regarding broadband connectivity and bandwidth capacity. The benefits of distance education, telemedicine, and broadband-enabled commerce were no longer theoretical explorations.

Rather, closures and stay-at-home directives increased the reliance on broadband-enabled platforms. Employers set up remote work protocols, teachers engaged students in online teaching using video conferencing, and consumers sought online shopping with touchless delivery—all because of the need for health and safety. At the same time, locally-operated, rural broadband providers opened Wi-Fi hotspots, met increasing new home broadband subscription requests, and developed innovative ways to provide hardware and initiate service, all while maintaining technician and customer safety.

We have yet to fully understand the lasting impacts of the COVID-19 crisis. Rather, we have focused on meeting many immediate needs that have arisen as a result of this crisis – to include enabling the widest use of broadband. Support for broadband, which once seemed like abstract advocacy, now is based on extensive practical experience in a time of national emergency. What is apparent is that broadband is a critical tool for communities of all sizes and people of all ages.

This workshop report provides a timely framework for addressing critical issues related to the deployment of broadband and smart technologies in remote and rural areas. This framework complements the lessons learned from the COVID-19 response. Moreover, this framework can serve as a valuable resource for technology innovators, communities, and policymakers, who have brought to prominence the imperative of rural broadband. Together this framework and lessons learned, along with public and private team efforts, can produce manifold benefits in the recovery phase and beyond.

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

2. Smart Agriculture & Rural Supercluster Workshop

2.1. Purpose and Conduct of the Workshop

The Smart Agriculture and Rural SuperCluster Workshop was conceived and planned to further development of a SuperCluster blueprint to contribute to the development of a consensus-based smart cities framework. The workshop focused on best practices for widespread smart agriculture and rural initiatives. The event was held on February 19, 2020, in Phoenix, Arizona, USA.

The workshop began by orienting participants to its purpose and tasks. It primarily consisted of five panels addressing key topics, with experts providing diverse perspectives. Participants then worked in breakout sessions to develop inputs for the SuperCluster blueprint. The workshop also included updates on aspects of smart agriculture research in academia.

Figure 1: Smart Agriculture & Rural SuperCluster Workshop. (Photo by NIST)

2.2. The Smart Agriculture and Rural Blueprint to Date

Josh Seidemann[2] and Mo Shakouri[3] jointly presented a blueprint titled *Rural America, Rural Economies, and Rural Connectivity*[4] published by the Smart Agriculture and Rural SuperCluster in July 2019. The document provides case studies and examples, showing how expanding broadband access to rural communities can improve smart agriculture, healthcare, education, telecommuting, and more. These case studies and examples are intended to aid further study and this workshop should expand on the blueprint.

[2] Vice President of Policy, NTCA-The Rural Broadband Association
[3] Director of Community Broadband at Joint Venture Silicon Valley
[4] https://pages.nist.gov/GCTC/uploads/blueprints/2019-Ag-Rura-Blueprint.pdf?utm_medium=email&utm_campaign=Newsletters&utm_source=sendgrid

Seidemann emphasized the workshop's value; it brings together multiple perspectives on rural communities' widely varying needs. As Seidemann said, "If you've seen one rural area, you've just seen one rural area."

2.3. NIST's Smart Cities and Communities Framework

NIST speaker Sokwoo Rhee outlined the goal for the SuperCluster's blueprint, which will be further developed and included in a consensus-based smart cities and communities framework, guiding widespread smart agriculture and rural initiatives. This framework will be developed, based on blueprints published by SuperClusters, public working groups in the Global City Teams Challenge program.

NIST works with SuperClusters to review each blueprint and promulgate it to smart city and community stakeholders via website and newsletter. These inputs allow NIST and its working group members to develop a consensus-based framework that guides stakeholders—cities, communities, industry, and research agencies—in the planning and implementation of smart solutions.

This blueprint will be incorporated into NIST's series of publications, called Smart Cities and Communities Framework (SCCF).[5] The SCCF is composed of publications in four categories.

- Cross-cutting and Foundational Issues: This category addresses all aspects of smart cities and communities' development, such as data, platforms, key performance indicators, municipal IoT, cybersecurity, and privacy.
- Sector-specific Issues: This category addresses smart city and community services, such as smart transportation, public safety, utility, agriculture and rural area, and smart buildings.
- Implementation, Methods, and Approaches: This category includes publications addressing collaboration, innovation capacity building, education, procurement, economic sustainability, and workshop reports.
- Case Studies: While publications in other categories may include case studies, those in this fourth category exclusively address case studies, providing detailed descriptions and analysis for pilots and deployments of smart cities and communities solutions.

2.4. Plenary Panels

2.4.1. Connecting Rural Places to Broadband

In the introduction to the first plenary panel, broadband was described as being similar to electricity: it is foundational, and communities will find it difficult, if not impossible, to function without it. Panel members were asked to address the varying challenges of providing broadband connectivity for given rural areas. They were also asked to address common approaches to enabling it, which included the following:

- Understanding customer needs, which inform services and infrastructure provided;
- Team flexibility and technology options, which are key to achieving connectivity, especially in the last mile and to farmland;

[5] https://www.nist.gov/el/cyber-physical-systems/smart-americaglobal-cities/nist-smart-cities-and-communities-framework

- Various approaches taken by state, tribal, and local governments with respect to funding, use of assets, inclusion programs, participation in public–private partnerships, and more;
- Educating consumers on the technology—many seek to use it but do not always know how to use it or how to use it in a meaningful way;
- Anticipating and forecasting opportunities, provided by new technologies; and
- Various approaches and funding sources used by broadband providers to expand their systems to serve more homes and local institutions.

Connectivity in Minnesota, North Dakota, and South Dakota, by Dave Giles[6]*:* According to the speaker, grants from the Connect America Fund, primarily Phase II, enabled MIDCO[7] to build broadband infrastructure in this three-state area. Low population densities make it difficult for companies to develop successful business models for the area. Presently, MIDCO owns about 10,000 miles of fiber optic networks in the three states, servicing about 400,000 customers, mostly smaller rural communities. It uses whatever tool it can for the last mile in its "fiber to edge-out" effort. MIDCO uses fiber when possible, but also uses copper, microwave, LTE technology, and more. Providers face labor and terrain challenges. North Dakota's oil sector growth has increased labor costs. They also must cover rugged terrain, such as the Black Hills. Addressing gaps requires flexibility in teams and various products, said Giles.

Connectivity in Alaska, by Wanda Tankersley[8]*:* Matanuska Telephone Association[9] (MTA) is a large coop of about 30,000 members, with a service area of about 10,000 square miles, north of Anchorage, Alaska, Tankersley mentioned. MTA primarily runs a telephone and Internet service, owns a wireless Internet service provider, and has fixed wireless technology. The estimated cost to cover the service area with fiber is about $400 million to $500 million—which is costly for 30,000 customers. MTA leverages fiber for middle miles and uses mostly copper for the last mile. Building infrastructure faces multiple challenges due to Alaska's climate and remote location. Transporting materials is expensive, and the cost of network construction is about $132,000 per mile. Mountains and forests pose challenges, and some infrastructure is not accessible via road networks. The construction season is relatively short, running from May to September. Hiring workers with the necessary expertise is also difficult in Alaska.

Connectivity on Tribal Lands, by Traci Morris[10]*:* "It is different in Indian Country," stated Morris, addressing connectivity from the perspective of the American Indian Policy Institute.[11] Tribal lands contain 574 federally recognized tribes, and each has a different form of government.[12] Some tribes are also businesses. Thus, their numerous and varying needs pose challenges for providers. Current regulatory systems also have challenges. Additionally, rugged terrain is a factor. Most end-users have wireless connectivity because that is the only choice available. Solutions based on community needs have been effective, as demonstrated by work with the Southern California Tribal Chairmen's Association.[13]

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[6] General Manager of Fixed Wireless, MIDCO
[7] https://www.midco.com/
[8] Chief Operating Officer for Matanuska Telephone Association
[9] https://www.mtasolutions.com/
[10] Director of the American Indian Policy Institute
[11] https://aipi.asu.edu/
[12] Brian Howard, Traci Morris, "Tribal Technology Assessment: The State of Internet Service on Tribal Lands," July 27, 2019, SSRN. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3427547
[13] https://sctca.net/

Providing New Connectivity, by Jeremiah Marbie[14]: Marbie said Microsoft launched its Airband TV White Space Initiative[15] to close gaps in rural coverage and increase connectivity to the cloud. It uses television spectrum bands not assigned or used by broadcasters. The company sees Airband TV White Space technology as one tool in the toolbox to access the internet when fiber doesn't work and satellite is too expensive. The company has supported Airband TV White Space Internet service providers in about 26 states. Microsoft seeks to understand users' needs to match them with technology that works.

2.4.2. Smart Agriculture

In this panel, several factors were described as driving smart farming, including smart devices that enable faster, better, and cheaper production. The resulting data from smart devices enables data analytics for agriculture, or "Data Agralytics," which could aid predictive farming that reduces its risks (see Figure 2). Broadband is needed for smart agriculture—which will, in turn, impact broadband infrastructure and connectivity.

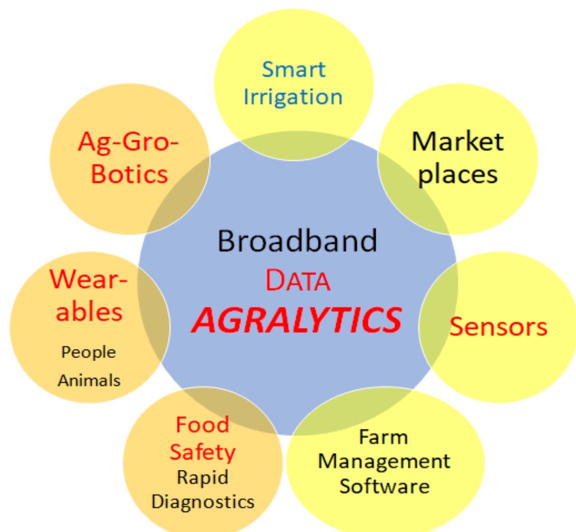

Figure 2: Smart agriculture technologies feeding Data Agralytics, enabling predictive farming (Image used with permission from Robert Tse)

Disruptive Events Driving Smart Agriculture, by Robert Tse[16]*:* According to Tse, disruptive events are driving accelerated innovation and adoption of agriculture technology and Data Agralytics in the food and agriculture system. Several disruptions are pushing technological changes in agriculture. Labor shortages are driving the need to produce more with less labor. Thus, the need and development of "Ag-robotics." Specialty crops (fruits, vegetables, and tree crops) are particularly labor intensive, demanding use of Ag-robotics and other new technologies. For farmland without sufficient rainfall, farming requires more efficient use of water and chemicals through smart irrigation. There is a need for new technology to improve plant hybrids and animal breeds, which could be enabled by smart agriculture. For example, wearable technologies for cows can track fertility cycles, enabling more effective breeding and more efficient management of animal health. New regulations are especially driving the need for Data Agralytics. For example, California mandates water reporting, which could be more easily done by farmers using Data

[14] Director of Digital Transformation, Airband Initiative, at Microsoft
[15] https://www.microsoft.com/en-us/corporate-responsibility/airband/technology
[16] Senior Policy Advisor, Telecommunications, Rural Utilities Service, Rural Development, at U.S. Department of Agriculture

Agralytics, enabled by an app. Disruptive technology has introduced real-time sensor-based farm management.

Technology-based precision agriculture enables greater agricultural production, minimizes inputs and costs, and shrinks the environmental footprint. Such smart agriculture results from the Internet of Things (IoT). However, it depends on the availability of broadband as a platform.

A Vision for Smart Agriculture, by Dennis Buckmaster[17]: Buckmaster noted that, at its core, agriculture is logistics—putting the right seed in the right place at the right time, or putting the right food in front of the right cow at the right time of the day. Farmers must make countless decisions in real time, with times varying for each aspect of agriculture. Making those decisions requires information about the fields, animals, machines, facilities, and more. Farmers must also address "what-if" questions, such as, "If the moisture in a field is too high, and it's late in the season, what can be planted?"

Such data-driven decisions can be aided by IoT devices. Sensors indicating nitrate and moisture levels in fields could help decide when to plant, spray, or harvest. With Data Agralytics feeding biophysical models, agriculture could be gamed, allowing "what if" questions to be answered. However, such capabilities depend on a huge amount of data and IoT devices connected to the internet. This requires getting the broadband highway to the farm.

The Manufacturers' Need for Connectivity, by Corina Ardelean[18]: Ardelean explained that AGCO Corporation[19] is a manufacturer of agricultural equipment designed to help farmers increase yields, reduce costs, and achieve more opportunities. That goal depends on connectivity for its machines as well as its customers. Specifically, the company seeks connectivity so that its machines can download data, thus improving operations. It also seeks data analytics for aiding decisions in the moment and in the future. This could reduce labor costs, wait times, and other expenses. The ability to retrieve data is also key to making supply chains more cost-effective, thus getting fresh products to the customer. For example, a new generation of balers will be capable of releasing hay bales with radio-frequency identification tag, enabling geospatial location of each bale. The radio-frequency identification can carry information on relative feed value of the hay, moisture, and other valuable data points. That data enables the dairy producers to optimize nutritional value for their herd and increase milk production. Retrieving this data requires connectivity.

Figure 3: Corina Ardelean of AGCO (Photo by NIST)

Solving User Needs is Key to Solving the Big Broadband Problem, by John Jefferson[20]: Jefferson described rural broadband as being a big problem made up of many small problems. The big problem is largely known: broadband doesn't adequately cover rural areas. The question is how to solve the smaller problems.

[17] Professor of agricultural and biological engineering and Dean's Fellow for Digital Agriculture at Purdue University
[18] Manager of Global Fuse Product Management, Data Integration Logistics, AGCO Corporation
[19] https://www.agcocorp.com/
[20] Managing Partner, Sage Synergies LLC and Cofounder of Insight Labs

This comes down to who is going to use the broadband. There are high and low bandwidth applications, and their uses depend on user needs. It is a matter of understanding the users' needs.

The big problem could be solved by bringing together stakeholder groups. These groups could figure out where demands are and where grants are needed. When stakeholder groups address the smaller problems, they chip away at the bigger problem. For example, if carriers are in the vicinity, it is a matter of understanding their capabilities and matching the appropriate one to the farm's needs. It is also possible to piece together different technologies to create a solution, as exemplified in Minnesota and the Dakotas. Satellite capabilities are also changing, making connectivity available at lower costs. Additionally, there are solutions at the edge, such as fixed wireless.

2.4.3. Funding and Financing

In this panel session, speakers provided details on their respective funding programs for rural telecommunications initiatives and selection criteria.

US Department of Agriculture's Funding Programs for Broadband in Rural Areas, by Robert Tse: Tse described the following USDA efforts:

- The Telecommunications Infrastructure Loans and Guarantees program[21] has $690 million available annually. As a legacy of the telephone era, many applicants are rural phone companies.
- The Rural Broadband Access Loan and Loan Guarantee program[22] will provide $11.2 million in 2020. At the time of the workshop, the program was not open.
- The Community Connect Grants program[23] will have $35 million in 2020. At the time of the workshop, this program was also not yet open.
- The Distance Learning and Telemedicine Grants program[24] had opened at the time of the workshop and has $71 million available in FY 2020. Of this, $12 million and $9.4 million are dedicated to treating opioid addictions and substance abuse disorders, respectively. Due to COVID-19, the program received an additional $25 million in funding. A second window for applications was opened, which closes on July 13, 2020.
- The New Broadband Pilot Program[25] is conducting Reconnect 2, which is providing $550 million. This is a grant, loan, and grant/loan program. Being a pilot, it is more flexible in terms of meeting legislative requirements. In Reconnect 1, a recommendation was made to address precision agriculture and connectivity for farms, which is now recognized in Reconnect 2.

National Science Foundation (NSF) Funding, by David Corman[26]: Corman described NSF[27] funding as focused on projects that go beyond the state of the art, rather than those that simply improve state of the process. These projects have a goal to significantly impact society. For example, NSF funded university research on how to improve communications in tribal communities in Pueblo, New Mexico. NSF has also

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[21] https://www.rd.usda.gov/programs-services/telecommunications-infrastructure-loans-loan-guarantees
[22] https://www.rd.usda.gov/programs-services/rural-broadband-access-loan-and-loan-guarantee
[23] https://www.rd.usda.gov/programs-services/community-connect-grants
[24] https://www.rd.usda.gov/programs-services/distance-learning-telemedicine-grants
[25] https://www.usda.gov/broadband
[26] Program Director at National Science Foundation
[27] https://www.nsf.gov/

funded research on landslide prediction and warning in Sitka, Alaska. For those proposing projects, NSF asks applicants to address the following questions:

- What problems will be solved?
- What are the risks?
- What are the payoffs?
- What are the impacts? Who will be impacted, and how much?
- Who will care if the project succeeds?
- How will success be measured?

Since 2017, NSF has funded 52 projects under the Smart and Connected Communities program,[28] totaling $42 million. They assess such issues as disaster relief and the impact of ride-sharing in a rural area. This year's budget is $40 million, and the awards are highly competitive.

CoBank's Lending for Rural Projects, by Sarah Tyree[29]: Tyree explained that CoBank[30] is one of the largest providers of credit to the U.S. rural economy and one of the world's 50 most credit-worthy institutions. It is part of the Farm Credit System, set up by Congress, which also directs who CoBank can lend to. CoBank is a cooperative (or coop), meaning that it is owned and governed by its customers.

CoBank lends to operations that can show a record of cash flow over several years. It does not lend to start-ups. Agribusiness comprises about 28% of CoBank's business, rural infrastructure comprises 21%, and farm credit banking comprises 51%. Regarding rural infrastructure, CoBank lends to rural electrification and rural water coops. Regarding telecommunications, CoBank lends to companies in all aspects of rural telecommunications, such as those providing fiber transport, wireless, and data centers.

How Grants Have Benefitted the Navajo Nation, by Monroe Keedo[31]: Keedo said that, in 2010, the Navajo National Middle Mile/Last Mile Project[32] applied for a $32 million grant under the American Recovery and Reinvestment Act of 2009.[33] To obtain the grant, the project had to raise $10 million in matching funds. Being a partner in the project and a semi-autonomous entity, the Navajo Tribal Utility Authority[34] (NTUA) was able to raise the $10 million, working with the Navajo people more easily than could its government, which must follow extensive regulations.

The project built fiber optic and microwave infrastructure and then partnered with Commnet Wireless[35] to provide wireless broadband to the homes. In the first three years, the project laid 550 miles of fiber on the Navajo Nation and built 59 towers. Today, the Nation has over 800 miles of fiber and 110 towers. The project also provided 4G LTE services. The result was major change for the Navajo Nation in terms of telecommunications and the ability for more tribal members to access 911 for emergency services.

[28] https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505364
[29] Vice President of Policy and Public Affairs at CoBank
[30] https://www.cobank.com/
[31] Research and Development Engineer at Navajo Tribal Utility Authority
[32] https://www.ntia.doc.gov/legacy/broadbandgrants/factsheets/NavajoTribalUtilityAuthority.pdf
[33] https://www.ntia.doc.gov/page/2011/american-recovery-and-reinvestment-act-2009
[34] http://www.ntua.com/
[35] https://www.commnetwireless.com/

Despite such projects, many on Navajo tribal lands still lack broadband access. Thus, the NTUA seeks partnerships to help change this situation. It also is a partner in other projects, which have received several grants from the Federal Communications Commission (FCC). Keedo asserted that only 0.6% of FCC telecommunications funding has gone to Indian lands. Some grant programs are difficult to apply for, as they require matching funds, which are hard for tribes to secure. Keedo also asserted that the same is true for Rural Utilities Services. Only 11% of its telecommunications funding goes to Indian lands. NTUA also partnered on a grant to extend connectivity provided by the State of Arizona.

Figure 4: Monroe Keedo of Navajo Tribal Utility Authority (Photo by NIST)

Another problem in getting grants is meeting the demand for a project to show a design. This also depends on an understanding of user needs. The problem is, many on tribal lands have never had broadband and so are unaware of its benefits. Obtaining grants means educating people on its uses, which drives design. Grant programs also want to see sustainability, which many tribal governments lack the financial means to demonstrate.

2.4.4. Farm Field Mapping

In this panel session, participants discussed the need for better broadband mapping in rural areas. The Federal Communications Commission's broadband mapping is focused on people and houses. However, concerns have arisen over the coverage needed for precision agriculture, as indicated by comments received by the U.S. Department of Agriculture. For example, the state of Mississippi measured and found a 50% difference from what the FCC had mapped for the state's broadband coverage. Without accurate farm field mapping, it is difficult to allocate resources for broadband coverage effectively. The following are varying perspectives on such mapping.

Broadband coverage measured in Yolo County, CA, by Tyler Boyle[36]: Boyle presented that the Geographical Information Center[37] at California State University, Chico, measured the broadband coverage in Yolo County. The California Public Utilities Commission (CPUC) developed an Android mobile app called CalSPEED[38] to measure mobile broadband performance in urban and rural areas. Initially, researchers with the apps drove the streets of Yolo County, measuring throughput and latency at more than 150 sites in its agricultural lands. They then focused on taking more precise measurements in fields at seven farms, finding huge variations in service. At one vineyard, for example, much of the field had no service, while other parts of it had download speeds varying from three to 32 megabits per second (see Figure 5). Most fields had an average download speed of about 3 megabits per second and a 10% failure rate. Landowners indicated that the service would not support smart agriculture.

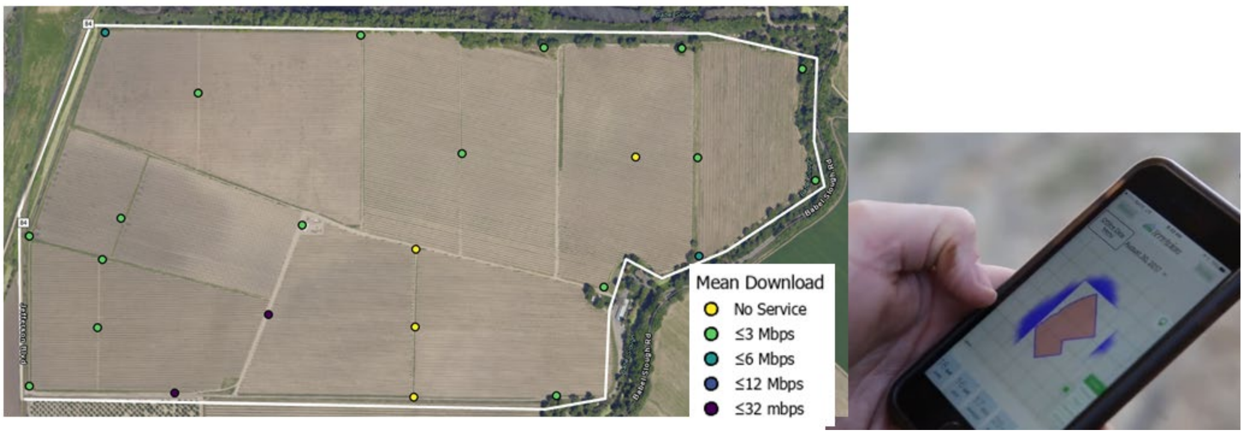


Figure 5: Varying broadband performance in a field in Yolo County, CA, measured with CalSPEED app (Images used with permission from Tyler Boyle)

The Challenges of Providing Broadband Maps in Agriculture Areas, by Joe Carey[39]: Carey explained that his employer, Trimble, Inc.[40], provides services such as connected farming, with the goal to enable farmers to download data and services. However, connected farming works well near cities and interstates, but much less so in other areas. Getting broadband maps to farmers, and showing them where connected farming is possible, entails several challenges, which include the following:

- Radio is unpredictable due to reflection off snow and water and absorption by foliage.
- A Cat M1 modem for LTE will get a different map than one that a Cat 1 modem gets.
- The type and height of an antenna above the ground will impact the type of map that users will receive.
- Antenna movement, even by an inch, can cause "fast fading," impacting the maps that users get.

There are possibilities for addressing these variables in broadband mapping. A state-of-the-art network analyzer costs about $20,000 and requires a very skilled engineer to interpret data. However, university

[36] Senior GIS Analyst, Geographical Information Center (GIC) at California State University, Chico
[37] https://www.gic.csuchico.edu/
[38] http://www.tellusventure.com/downloads/cpuc/calspeed/biba_webinar_calspeed_measurement_6feb2019.pdf
[39] Director of Wireless Strategy, Natural Resources Sector, at Trimble, Inc.
[40] https://www.trimble.com/

researchers are proposing the development of a software-defined radio that can do the same thing for users for only a few hundred dollars.

Network Providers' Needing Maps of Unserved Agricultural Lands, by Melissa Clawson[41]: According to Clawson, Geolinks[42] is a provider of point-to-point wireless networks that may be installed instead of fiber optics networks. It uses microwaves to deliver the last mile of service to a parabolic antenna. The company has been successful in securing grants for providing service to difficult areas and seeks to do the same for agricultural lands. The problem, however, is that FCC's broadband maps show homes and population densities but not the locations of farms. The company is in need of maps showing agricultural lands that are not served, or that are underserved, so that it can focus its efforts.

2.4.5. Improving Rural Outcomes with Broadband Access

In addition to explaining what improved outcomes with broadband access in rural areas would look like, panel members provided approaches to achieve them and the partnerships enabling them.

Figure 6: Outcomes Panel (left to right): Matthew Rantanen, Catherine Moyer, Sarah Tyree, Dominic Papa (Photo by NIST)

Outcomes on Tribal Lands, by Matthew Rantanen[43]: Rantanen explained that when network providers began establishing infrastructure across the US, they avoided difficult areas, such as the Sierras and tribal lands, because they lacked knowledge of how to work with tribal governments. Consequently, there were 8,000 missing middle miles to 320 tribal lands in the 48 contiguous states. The estimated cost for fiber to cover these middle miles is about $1.5 billion.

As a result of several initiatives by the Southern California Tribal Chairmen's Association[44] since 2001, broadband networks were extended to 20 tribes in California, covering an area of 650 miles. These efforts

[41] General Counsel and Vice President of Government Affairs and Education, at GeoLinks
[42] https://geolinks.com/
[43] Director of Technology at the Southern California Tribal Chairmen's Association
[44] https://sctca.net/

initially were focused on connecting networks with libraries, then tribal community centers, followed by municipal centers and homes. This has had an impact. "In the 19 years I've been there, I've seen kids born there and go off to college, because they have had Internet and thus were exposed to higher education," said Rantanen. However, such initiatives are only the first phase. Many who leave tribal lands to pursue higher education do not return. Thus, tribal lands are losing their next generation of thinkers.

More is needed to increase connectivity and opportunities on tribal lands. Recently, the FCC gave tribal lands priority in accessing the FM radio spectrum, with no fees and no external competition. Today, these lands have 75 stations. The FCC is also giving them priority access to 2.5 GHz licenses. Addressing the need for partnerships, Rantanen noted that these successes and more resulted from the Southern California Tribal Chairmen's Association work with over 160 organizations.

Outcomes of Telehealth Pilots, by Sarah Tyree: Tyree further explained that CoBank lends to broadband providers, seeking to connect rural areas. The challenge, however, is securing additional funding from other sources for initiatives, covering areas with low population densities. Thus, CoBank seeks initiatives that can show potential benefits for such areas, and, thus, qualify for help from the Universal Service Fund.[45]

Based on a Mississippi State University study on a telehealth pilot, CoBank and partners replicated the pilot in rural southwest Georgia. It connected 100 patients with uncontrollable type 2 diabetes facing risks of loss of sight and amputation. Each day, patients reported on their sleep, blood sugar levels, diet, and walking. Remote healthcare providers advised them on adjustments to intake and habits. The results were significant. Fifty of the patients decreased their blood sugar levels by 2.5% on average. Patient surveys were even more remarkable. Tyree quoted patients as saying, "This is the first time I have felt loved by my healthcare provider" and "I am minding my 'Ps & Qs' because I know someone is out there." Cost analysis also revealed savings of almost $4,000 per patient each month.

The pilot was described as having additional results. The hospital in Macon, GA, adopted this connectivity to expand their treatment to 400 patients, also receiving reimbursements per patient on a monthly basis. The project also found that most patients preferred use of smartphones, as opposed to tablet computers. Additionally, the most compliant patients were those over 60 years of age. Subsequently, CoBank is pursuing other telehealth initiatives, such as reducing risks to women in rural areas, who have a greater chance of dying during pregnancy than their mothers did.

Pursuing Transformational Outcomes—Smart Region and Smart State, by Dominic Papa[46]: The Arizona Commerce Authority[47]—a public-private sector partnership—has established the "Smart Region Consortium."[48] It is a permanent platform that allows governments, industry, and research institutions to collaboratively design and develop pilots that address seemingly insurmountable challenges, cutting across multiple local jurisdictions, such as connecting broadband in rural areas. This smart region approach is seen as enabling solutions on a larger scale than if pursued by individual municipalities. For now, the Smart Region Consortium is focused on the Phoenix metropolitan area, including the 22 nearby cities and towns. The Arizona Commerce Authority is expanding collaborative efforts to form a Smart State effort

[45] https://www.fcc.gov/general/universal-service-fund
[46] Vice President, Smart State Initiatives, Arizona Commerce Authority
[47] https://www.azcommerce.com/
[48] https://www.azidp.com/the-smart-region/

encompassing the other cities and areas in Arizona. This statewide collaboration is exemplified by the Institute of Automated Mobility,[49] established by the governor of Arizona.

The Precision Agriculture Connectivity Task Force, by Catherine Moyer[50]: According to Moyer, the 2018 Farm Bill established the Precision Ag Connectivity Task Force.[51] Its purpose is to provide the FCC with advice and recommendations on how to advance broadband access for unserved agriculture lands and thus promote precision agriculture. The FCC has the authority to consult with the Department of Agriculture regarding related issues. The Task Force's objectives are to:

- Identify and measure gaps in the availability of broadband.
- Develop policies promoting reliable broadband for 95% of agricultural lands by 2025.
- Encourage adoption of broadband on farms and ranches and promote precision agriculture.
- Accelerate deployment on unserved agriculture lands.

The Task Force, which lasts until the end of 2021, faces a very aggressive timeline. However, its establishment highlights the importance of connectivity for agriculture. Many have previously discussed the importance of broadband for rural areas, but agriculture has received little attention. Precision agriculture and the increasing data it requires have received even less attention. Increased connectivity is needed to keep future generations in rural areas so that they will take over and run the farms.

Referring to partnerships, Moyer stated that the Task Force's success will greatly depend on working relationships. From a provider's perspective, Moyer stated that Pioneer Communications often partners with electric coops when they build infrastructure into rural areas, thus allowing extension of broadband coverage.

2.5. Breakout Sessions: Inputs for Blueprint and NIST Framework

Workshop participants were divided into groups to discuss several topics for the SuperCluster blueprint for agriculture and rural areas, as input to the NIST Smart Cities and Communities Framework.

2.5.1. Group 1 – Smart Agriculture

According to the participants in the smart agriculture discussion, moderated by Dennis Buckmaster, agriculture varies in terms of products, including livestock, wide-acre crops, and high-value crops. Agriculture also includes many processes beyond the farm gate; the supply chain for food and other agricultural products could be improved with enhanced connectivity and interoperability among systems. There are instances in which low-tech approaches can succeed (e.g., niche markets), but high-tech approaches are needed in larger and more complex systems. Agriculturalists always bear risk, and smart agriculture should lead to reduced variability, increased resilience, improved sustainability, and improved quality of life.

Regardless of what is grown, produced, transported, and processed, smart agriculture should measure the common elements—the "whats"—that are needed to reduce risks and ensure a minimum viable product.

[49] https://www.aztechcouncil.org/institute-for-automated-mobility-created-with-intel-at-helm/
[50] CEO, Pioneer Communications
[51] https://www.fcc.gov/task-force-reviewing-connectivity-and-technology-needs-precision-agriculture-united-states

This includes measuring and tracking land, labor, input resources data required for automation, and, certainly, market demand and prices. Smart agriculture involves appropriate location, timing, and accuracy of these measurements.

2.5.2. Group 2 – Farm Field Mapping

According to the participants in the farm field mapping discussion, moderated by Tyler Boyle, the availability of data regarding connectivity in farming/field areas is relatively poor. Crowdsourcing could be used to improve the availability of data. Specifically, property owners and organizations such as 4-H[52] could be encouraged to download crowdsourcing apps to measure radio signal strength on properties.

Another possible improvement could come from questions added to map survey requirements regarding connectivity in their fields. This survey would also encourage participation in crowdsourcing measurement efforts. Additionally, incentives could be provided for graduate students or a “hack-a-thon” to develop an affordable unit—hardware and software—to measure wireless signals for large areas. Conceivably, drones, 4-H groups, broadband consortia, or even mail trucks could deploy this unit to collect data. Machinery that traverses these fields a few times a year can also be used to gather data.

2.5.3. Group 3 – Improving Rural Outcomes with Broadband Access

According to the participants in the broadband access discussion, moderated by Jean Rice[53], there are several possibilities for connectivity with wireless networks, including satellites, cellular technologies, aerial drones, aerostats, and fiber optics. Each has advantages and disadvantages. Each requires partnerships established in advance, enabling cybersecurity and privacy, and regulations, scaling up from local, tribal, state, and federal levels.

Each also requires financing. Many initiatives are established and continue operations using grants. This approach carries an inherent risk of service disruption in the event a grant is not received. Such initiatives should build in funding for sustainability beyond grants. In the case of loans, such as from CoBank, lenders require evidence of active capital for a return on investments. Other options for making construction economical in rural and remote areas are grant or subsidy programs available from federal and state sources.

The challenge of developing a good business case for rural areas is low population density. There are network services that people would pay for, such as telehealth. Such network services would also improve quality of life and outcomes. A case study suggests that providing network access to students at home helps increase the graduation rate.[54]

Lastly, many areas are heading for “data everywhere and users everywhere.” There are no boundaries for either. Technology is thus needed to address this challenge and provide opportunities.

2.6. Research Updates

The workshop included presentations on aspects of smart agriculture research in academia. Researchers from Iowa State University and Purdue University presented their work.

[52] https://4-h.org/
[53] Senior Program Specialist at the National Telecommunication and Information Administration
[54] “Cradlepoint Helps California School District Ensure No Child Is Left Offline” (Cradlepoint, 2016), https://www.cosn.org/sites/default/files/Coachella-Customer-Success-Story.pdf

2.6.1. Pursuing Connectivity Solutions in Rural Areas

As part of the NSF CyNet project,[55] Iowa State University (ISU) researchers deployed software-defined radio access networks in the ISU Curtiss Research Farm and ISU Research Park and connected them to the campus fiber networks and cloud centers (see Figure 7). Researchers in wireless networking, smart agriculture, and smart transportation are using CyNet as a living lab to develop wireless and application solutions for smart and connected rural communities. In particular, CyNet enables the study of rural connectivity solutions and their applications, with a special focus on:

- Convergence of open-source, software-defined wireless, fiber, and edge/cloud computing infrastructures;
- Data analytics; and
- Applications in different domains, such as smart agriculture and smart transportation.

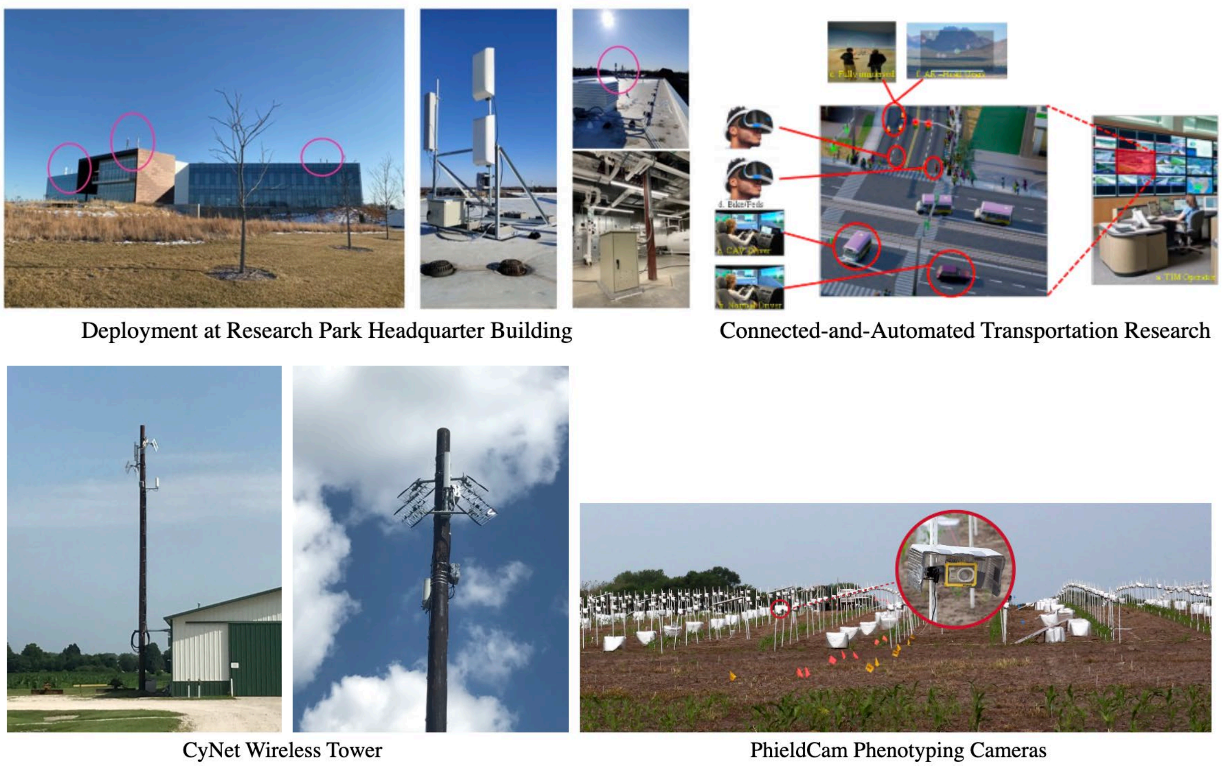


Figure 7: Iowa State University's software-defined radio access networks (Images used with permission from Hongwei Zhang, Iowa State University)

2.6.2. Assessing Data Relays in Rural Areas

Yaguang Zhang[56] presented the latest developments at Purdue University for a large-scale cellular coverage analysis project. This project focused on modeling the blockage and coverage conditions for unmanned aerial vehicle (UAV) data relay via channel modeling. The research team has quantified the cellular data coverage improvement when the 4G LTE system is relayed by UAVs over large geographic areas of interest

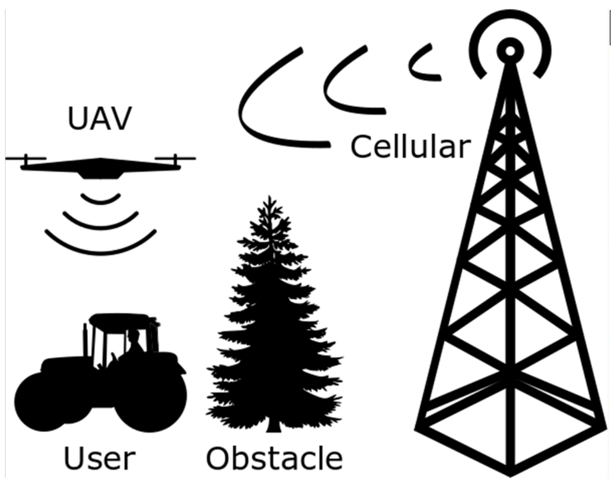
[55] https://www.ece.iastate.edu/~hongwei/group/projects/CyNet.html

[56] Ph.D. Candidate at Purdue University

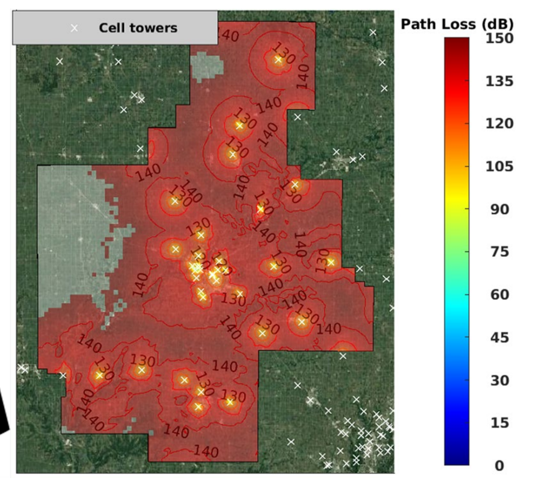
(up to the whole state of Indiana). Data layers regarding terrain and LiDAR-based elevation and cell tower layout were utilized to render the analysis realistic. This simulation yields connectivity performance improvements with deployment of UAV data relay systems (see Figure 8).

Their work proposed algorithms for blockage and path loss maps with fixed-height relay UAVs. The blockage maps were generated based on high-resolution LiDAR data and were used to locate regions with line-of-sight obstructions. On the other hand, path loss maps generated from terrain elevation data were used to identify regions with satisfactory coverage conditions. Novel procedures on result visualization and analysis also provided for system-level performance evaluation. Their analyses showed that a coverage ratio gain over 40% can be achieved at a drone height of 100 m, compared to a typical pedestrian height of 1.5 m, for Indiana. More details can be found in their IEEE paper[57].

The flexibility of extending wireless communication coverage via UAV data relay is extremely valuable for digital agriculture applications in rural areas, especially for those where network coverage is sparse or nonexistent. Purdue researchers are using these simulation results to chart area coverage differences when the relay is blocked by structures and obstacles and when UAVs could be used to avoid them. Their goal is to optimize the UAV deployment locations with simulations to provide configuration and performance references on real-life UAV data relay systems. A similar approach could also be used to optimize the deployment of aerostats or cell towers on wheels.



A typical UAV data relay scenario for agriculture



Path loss map for the WHIN area with UAVs at 30 m

Figure 8: Illustrations for UAV data relay coverage analyses
(Images used with permission from Yaguang Zhang)

[57] Y. Zhang, T. Arakawa, J. V. Krogmeier, C. R. Anderson, D. J. Love, and D. R. Buckmaster, "Large-Scale Cellular Coverage Analyses for UAV Data Relay via Channel Modeling," to appear in *2020 IEEE International Conference on Communications (ICC). IEEE.*

3. Conclusions

The Smart Agriculture and Rural SuperCluster workshop brought together various perspectives, which introduced success stories related to broadband access in the U.S. Participants described the potential benefits of improved rural broadband access, which are diverse and include increased agricultural productivity, environmental monitoring, education, healthcare, logistics for all businesses, and general quality of life. This potential, coupled with successes to date, gives hope to residents of regions and localities, which have yet to gain satisfactory broadband access. Equally important, this workshop identified lessons learned from overcoming past challenges and considered how they inform further expansion of broadband access and smart solutions for agriculture and rural areas.

Participants noted that a starting point that many assume is resolved—but evidence proves otherwise—is accurately mapping connectivity (cellular, fiber, WiFi, etc.). This mapping has, historically, had limitations. Regional maps have been very inaccurate at local levels, and at micro-local levels, such as along a road, can be significantly inaccurate. Collection of improved data could be achieved by capitalizing on ongoing "business" operations, like mail and package deliveries, farming, as well as, crowdsourcing. These efforts could determine access characteristics such as radio signal strength and data speed.

Several participants emphasized the importance of clarifying stakeholder and customer needs prior to establishing broadband connectivity in remote areas. This clarification includes use cases for access. It also requires specifying coverage, like whether it is for concentrated homes and businesses, sparse residences, or land areas where agricultural activities occur. As use cases and the benefits are identified, the degree of latency should be considered, as it influences technical solutions. While no single solutions exist for technology or financing, needs assessments significantly influence both.

Furthermore, participants noted that selection of the best solutions requires decision makers to have knowledge of all technical and financial options' strengths, weaknesses, attributes. Alaskan experience shows that high-quality internet connectivity solutions can be deployed in the most challenging environments, involving distance, climate, and terrain. The tribal lands experience shows that partnerships can lead to a significant influx of funding and that a combination of connectivity technologies can increase access and serve large areas in a short period. Yet, participants asserted that funding often has constraints that make equitable distribution of resources difficult, and the all-important business case sometimes seems elusive.

Acknowledgements

The authors acknowledge the valuable contributions of all workshop speakers and participants. Appreciation is extended to NTCA–The Rural Broadband Association, RTO Wireless, and Telrad Networks for their support. Tom Linn is recognized for taking detailed notes of the workshop and assisting with the report.

Appendix A: Workshop Agenda

Smart Agriculture & Rural Supercluster Workshop

Smart technologies are igniting rural economic development, improving health care and education, and improving farming and ranching production. The Global City Team Challenge (GCTC) Agriculture and Rural Broadband SuperCluster encourages collaboration on innovative agtech and rural projects and released a blueprint for rural communities in July 2019.

Stay tuned with this effort at: **https://pages.nist.gov/GCTC/super-clusters/**

Tue, February 18th, 2020 – Phoenix AZ

3:30 pm Field Trip to Gila River Telecommunications

Wed, February 19, 2020

9:00 a.m. Welcome and Introductions
Josh Seidemann, VP Policy, NTCA–The Rural Broadband Association
Jean Rice, Senior Broadband Specialist, National Telecommunication and Information Administration
Mo Shakouri, Dir Community Broadband Initiative, Joint Venture Silicon Valley

9:15 a.m. Introduction to the NIST Smart Cities and Communities Framework
Sokwoo Rhee, Associate Director for Cyber-Physical Systems Innovation, National Institute of Standards and Technology

9:40 a.m. Overview of Smart Ag & Rural Supercluster Blueprint
Josh Seidemann, VP Policy, NTCA–The Rural Broadband Association
Mo Shakouri, Dir Community Broadband Initiative, Joint Venture Silicon Valley

9:50 a.m. **Jeff Sobotka**, VP – State Broadband Director, Arizona Commerce Authority

10:00 a.m. Panel: Connecting Rural Places to Broadband
Moderator: **Josh Seidemann**, VP Policy, NTCA–The Rural Broadband Association
Traci Morris, Director of the American Indian Policy Institute
Wanda Tankersley, COO of Matanuska Telephone Association in Palmer, Alaska
Dave Giles, General Manager Fixed Wireless, MIDCO
Jeremiah Marble, Director of Digital Transformation, Airband Initiative, Microsoft

11:00 a.m. Panel: Smart Agriculture - What is it, who is using it, and how?
Moderator: **Mo Shakouri,** Dir Community Broadband Initiative, Joint Venture Silicon Valley
Robert Tse, Senior Policy Advisor Assistant Administrator's Office, Telecommunications Program, Rural Utilities Service, Rural Development, United States Department of Agriculture
Dennis Buckmaster, Professor of Agricultural & Biological Engineering, Dean's Fellow for Digital Agriculture, Purdue University
Corina Ardelean, Manager, Global Fuse Product Management, Data Integration Logistics, AGCO Corporation
John Jefferson, AgTech, Strategic Partnership, Program Management Managing Partner-Sage Synergies LLC, Co-Founder – Insight Labs

Noon Lunch Break

12:15 p.m. **Deploying Aerostats for Wireless Networks** by Steve Hubbard, CEO, RTO Wireless

12:30 p.m. Funding and Financing Panel (Federal and State)
Moderator: **Dennis Buckmaster**, Professor of Agricultural & Biological Engineering, Dean's Fellow for Digital Agriculture, Purdue University
Robert Tse, Senior Policy Advisor Assistant Administrator's Office, Telecommunications Program, Rural Utilities Service, Rural Development, United States Department of Agriculture
David Corman, Program Director, National Science Foundation
Sarah Tyree, VP Policy and Public Affairs, CoBank
Monroe Keedo, Navajo Tribal Utility Authority

1:30 p.m. Farm Field Mapping

Moderator: **Robert Tse**, Senior Policy Advisor Assistant Administrator's Office, Telecommunications Program, Rural Utilities Service, Rural Development, United States Department of Agriculture
Tyler Boyle, Senior GIS Analyst, Geographical Information Center (GIC), California State University, Chico
Joe Carey, Director, Wireless Strategy, Natural Resources Sector, Trimble, Inc.
Melissa Slawson, General Counsel and Vice President of Government Affairs and Education, GeoLinks
Tyler Boyle, Senior GIS Analyst, Geographical Information Center (GIC), California State University, Chico

2:00 p.m. Break

2:15 p.m. Topical Breakout Sessions to Populate the Blueprint and Framework with Examples

Group 1: Smart Agriculture – Moderator: **Dennis Buckmaster**
Group 2: Farm Field Mapping – Moderator: **Robert Tse**
Group 3: Rural Connectivity, Improving Rural Outcomes & Quality of Life – Moderator: **Jean Rice**

3:30 p.m. Report Out
Moderator: **Sokwoo Rhee**, National Institute for Standards and Technology

4:00 p.m. Panel: Improving Rural Outcomes with Broadband Access
Moderator: **Jean Rice**, Senior Broadband Specialist, National Telecommunication and Information Administration
Dominic Papa, VP, Smart State Initiatives, Arizona Commerce Authority
Matthew Ratanan, Director of Technology, Southern California Chairman's Association
Sarah Tyree, VP Policy and Public Affairs, CoBank
Catherine Moyer, CEO of Pioneer Communications

5:00 p.m. Rural Connectivity Case Studies
Hongwei Zhang, Associate Professor, Iowa State University
Yaguang Zhang, PhD Candidate, Purdue University

5:30 p.m. Close