Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture in the United States

Report adopted as of November 10, 2021

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PART I: EXECUTIVE SUMMARY/INTRODUCTION

The Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture in the United States (also known as the Precision Ag Connectivity Task Force) arose out of the Agriculture Improvement Act of 2018 (2018 Farm Bill). The Task Force's charge is to provide advice and recommendations to the Federal Communications Commission (FCC) and the United States Department of Agriculture (USDA) on how to assess and advance deployment of broadband internet access service on unserved and underserved agricultural land and promote Precision Agriculture for both cropping and husbandry.

The Task Force has four working groups focused in greater detail on specific issues related to Precision Agriculture. These working groups are: 1) Accelerating Broadband Deployment on Unserved Agricultural Lands; 2) Mapping and Analyzing Connectivity on Agricultural Lands; 3) Examining Current and Future Connectivity Demand for Precision Agriculture; and 4) Encouraging Adoption of Precision Agriculture and Availability of High-Quality Jobs on Connected Farms. Each of these working groups has done extensive research and developed recommendations that address current challenges.

Through the collective work of the Precision Ag Connectivity Task Force, the working groups, and conversations with several farmers, ranchers, producers, and those living in rural communities, it is evident that digital infrastructure is tightly linked to the success of this great nation.

Unfortunately, access to this infrastructure is not readily available in rural America which has become a fundamental necessity in the digital world. The challenges facing those without access to digital infrastructure are enormous, including decreased agricultural productivity, education achievement gaps, declining rural communities, lower health care outcomes, hospital closures, crumbling main streets, lack of access to credit, and, paradoxically, the lack of fresh food in America's heartland, among others. Digital connectivity is also directly linked to improved sustainability as farmers today use cutting-edge technologies to enhance decision making and reduce their environmental footprint.

The Precision Ag Connectivity Task Force knows that providing broadband service to unserved and underserved locations is a priority in today's virtual world. Over the last two years, Americans, where possible, have been working, going to school, seeing their doctor, and engaging in the global economy virtually – from their homes or even the parking lots of fast food establishments. However, far too many families are unable to perform these daily activities due to a lack of high-speed broadband service most often referred to in the media as "The Digital Divide".

This Task Force seeks to address these gaps with recommendations that will advise the federal government on ways it can improve access, specifically on rural, agricultural lands. Broadband is the foundational element for all other issues. We need broadband accessibility to better address critical challenges and build economic opportunity, competitiveness, and prosperity. This Precision Ag Connectivity Task Force is doing its part by making this work a priority and addressing the technology and connectivity needs of Precision Agriculture across rural America. The recommendations fall largely within five primary categories with some additional key considerations. The five main priorities that the Task Force recommends are to: 1) Improve federal broadband maps and consistently validate user experiences; 2) Increase incentives and clarify that precision agriculture infrastructure are eligible expenses for federal broadband programs to increase adoption and build out a robust infrastructure; 3) Enhance the high-speed standards to meet the technology needs in agriculture; 4) Improve collaboration between federal agencies and remove regulatory impediments; and 5) Increase digital access to education and training for individuals engaged in farming. Additional consideration should also be given to cyber security concerns and interoperability standards. The following notes provide a summary of the findings from the Precision Ag Connectivity Task Force.

1. Improve federal broadband maps and consistently validate user experiences

a. We recommend that the FCC and the USDA begin working immediately using data sets with the greatest breadth and preeminent industry authority and **derive public-facing FCC broadband availability maps that reflect and confirm the unserved and underserved areas on agricultural lands** based on the current broadband standard for fixed and mobile internet service to facilitate Precision Agriculture practices and adoption.

b. We recommend that the **most recent map for agricultural producers be hosted on the Agricultural Research Service (ARS) website** to include the base layers of National Agricultural Statistics Service (NASS) cropland data and the U.S. Geological Survey (USGS) data on rangeland and 3-D Elevation Program (3DEP) data.

c. With respect to the Broadband Data Collection (BDC)[1], we recommend **a uniform set**

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of practices and validation processes to be developed by the FCC including crowd sourced data validation and on the ground testing mechanisms to verify quality of service against broadband provider claims.** Furthermore, we recommend that the USDA and Extension Service be used to facilitate measurement in this process. Finally, the broadband fabric data must include agricultural structures to which broadband is or would be deployed in addition to the home location, the shop, the office, or the mobile equipment.

d. We recommend that the **broadband availability and quality data be independently verifiable,** using methods consistent across the country. Within this process of verification, the needs of the Native communities should be assessed and met with culturally appropriate and locally accepted approach to gathering accurate data.

2. Increase incentives to build out a robust infrastructure

a. While incentives and subsidies for connectivity deployment continue to be considered, **we recommend that these incentives and subsidies be substantially increased to drive deployment of connectivity**, with an overarching goal of deploying future-proof networks and relying upon various means, terrestrial/non-terrestrial, fixed/mobile platforms as they may be appropriate, and to include other elements to enable Precision Agriculture deployment in the areas of edge computing, private 5G like technology infrastructures, and Precision Agriculture application development. These incentives should be deployed and administered at the most local level possible to ensure that they are efficiently, and effectively utilized, and localized accountability of deployment can be monitored and enforced.

b. The FCC should work with USDA and other relevant agencies to **create incentives for specific types of infrastructure build-out that will support Precision Agriculture networks** and operations, including:

i. Connectivity to rural agriculture land headquarter facilities.

ii. Expansion of middle mile infrastructure.

iii. Deployment of local/last-acre network facilities for use by Precision Agriculture systems and devices.

iv. Clarify that precision agriculture architecture, including edge compute infrastructure and private 5G wireless systems, are eligible expenses for federal broadband programs to increase adoption.

[1] When this document refers to the FCC's Broadband Data Collection (BDC) it is referring to the FCC's ongoing efforts to create new definitive maps of broadband availability based on the requirements of the Broadband Data Act and the FCC's related rulemaking proceeding which is referred to herein as the Digital Opportunity Data Collection proceeding.

3. Enhance the high-speed standards to meet the technology needs in agriculture

a. Given the increasing data flowing to and from agricultural operations because of current and future Precision Agriculture offerings as well as the need to deploy technologies that have an element of future proofing, **we recommend that a broadband definition (both fixed and mobile) be enhanced to higher levels on both the download and upload speeds.** The FCC's current speed benchmark of 25 Mbps download/3 Mbps upload for advanced telecommunications capability is not only low in nature to drive innovation and utilization of Precision Agriculture, but the upload benchmark speed does not account for the vast amounts of data needed to be transferred from the field or farm to the cloud for storage, analysis, and insight generation. As such, the minimum speeds for federal funding should be 100 Mbps download/20 Mbps upload which is consistent with the federal funding requirements passed by Congress in the broadband infrastructure legislation. At this time, symmetrical upload/download should only be considered for broad application terrestrial wireline networks, as symmetrical standards are currently technically impractical for wireless technologies. These offer fiscal efficiency, superior environmental practice, and responsible resource allocation, leading to higher yields of safe, wholesome, and sustainable food, fiber, fauna, and fuel products. The suggestion is not to drive a rigid symmetrical standard but rather to raise the standard on both ends significantly and recognize the uplink capacity is not inferior to downlink needs. This approach should follow the recognition in the Communications Act that universal services are an evolving level of services. Implementation and subsidized investment of on- farm networks and supporting communities and ecosystems is critical to Precision Agriculture adoption as well as the availability of high- quality and digitally dependent jobs.

b. The FCC should **identify, implement, and/or strengthen policies to facilitate use of low, mid, and high-band spectrum** for Precision Agriculture applications, including:

   i. Policies that facilitate access to licensed spectrum in rural areas where that spectrum is underutilized.

   ii. Policies that remove technical impediments to rural agricultural use cases.

   iii. Auction policies that create incentives for bidders to deploy broadband infrastructure in a useful manner (e.g., policies that require bidders to show the long-term sustainability and scalability of their proposed networks).

   iv. Technical policies that improve the performance of rural wireless networks.

4. Improve collaboration between federal agencies and remove regulatory impediments

a. The FCC should work with other federal agencies to **adopt and implement a common set of performance targets and standards** that reflect the specific needs of Precision Agriculture, such as:

   i. Build-out requirements (e.g., in connection with spectrum auctions) based on geographic covered area that comprises croplands or ranch lands vs. covered population.

   ii. Multiple performance targets tailored for specific Precision Agriculture use cases (and reflecting quality metrics such as speed, latency, jitter, and packet loss).

   iii. Service availability metrics (reflecting location- and time-based elements) that can be used in industry-standard propagation models.

b. USDA, NASS, Farm Service Agency (FSA), Risk Management Agency (RMA), Natural Resources Conservation Service (NRCS) and other agencies should **align their existing and individual file management systems to have the capability to receive electronic data layers that are commonly created through the normal course of farm operations.** This improvement of use and incentives for federal reporting and compliance agencies will encourage the adoption of Precision Agriculture and modernize the very systems this Task Force set out to accomplish.

c. The FCC and other stakeholders should **identify and eliminate regulatory impediments** to:

   i. The use of novel business models to support infrastructure and broadband deployment.

   ii. In rural areas where minimum service thresholds have not been met, applicants should have the ability to secure funds from multiple sources across state and federal agencies to support the initial buildout and ongoing infrastructure improvements.

   iii. Regulations pertaining to broadband build-out on tribal lands.

d. The FCC should work with other stakeholders to **prepare "playbooks" to provide appropriate guidance** to relevant stakeholders, such as:

   i. A playbook for the creation and operation of rural community-based, non-profit solutions.

   ii. A playbook for Bureau of Indian Affairs program staff to facilitate build-out on Tribal lands.

5. **Increase digital access to education and training for individuals engaged in farming**
    a. The adoption of Precision Agriculture will increase the demand for skilled workers. Technical education curriculums, apprenticeship programs, community colleges, extension and land grant universities provide an avenue to rapidly fill this demand while providing hands on training for a skilled workforce. Increasing access to distance learning, allowing rural citizens to satisfy post-secondary education and college level degrees, more specifically allowing individuals engaged in farming to stay active in operations while achieving their educational goals should be a priority. **We recommend state, local, and federal agencies increase funding for STEM and digital vocational programs at the K-12 and community college levels specifically focused on technology, cyber security, and manufacturing careers in agriculture.**

6. **Other key considerations**
    a. Agriculture is an essential industry and is subject to cyber vulnerabilities: equipment, data layers and supply chain. To accelerate Precision Agriculture adoption and most importantly, as a means of national security, federal cyber security policy should recognize agriculture as critical and essential infrastructure and malicious acts should be treated accordingly. **We recommend that priority be placed on developing Precision Agriculture cyber security specialists** by the USDA, Department of Homeland Security, and President Biden's American Jobs Plan.
    b. As the world looks to agriculture for climate solutions and consumer interest in how, when, and where their bio-based product is grown, **it is imperative a standard for interoperability is established.** One of the key incentives to adopt Precision Agriculture technologies is efficiency of resource use (land, seed, livestock, chemical, machinery, labor, management, and natural resources) and improved interoperability directly impacts the quality of such decisions. Traceability through a supply chain requires interoperability so verified data moves effortlessly as products change hands, processes occur, and services are performed. Increased interoperability will directly result in increased Precision Agriculture adoption, high-quality jobs, and consumer confidence.

Conclusion

The Precision Ag Connectivity Task Force seeks to address several gaps with these recommendations that will improve deployment and access to broadband in rural communities and agricultural lands. Broadband is the foundational element for all other issues. We need it to better address critical challenges and build economic opportunity, competitiveness, and prosperity. Further, the Precision Ag Connectivity Task Force also recognizes that expanding high-speed broadband is a complex issue that carries significant costs.

Nevertheless, given the economic, productivity and quality of life benefits associated with achieving digital connectivity, timely investment is critical. With the collective efforts of the FCC, USDA, and other relevant agencies, we remain encouraged that we can make broadband connectivity available to every corner of our great nation. We ask that that you keep in mind the thousands of families who struggled throughout the pandemic because they had no access to broadband internet. The time is now to invest in our communities.

PART II: DATA AND MAPPING REPORT

The following gaps in data were identified during the investigation of the current state of mapping and broadband availability for agricultural lands.

- Lack of data on broadband coverage on all lands classified agricultural.
- Need to provide accurate broadband maps where producers normally look to find information.
- Besides coverage on ag lands, there is also a need to cover agricultural structures such as grain handling facilities, livestock structures, greenhouses, irrigation systems, etc.
- Need to have independent verification of broadband availability, quality and usability.
- Need to be culturally aware in working with producers in native communities.

Two overarching themes were identified listening to various subject matter specialists. The first is that data that could help improve the mapping of agricultural land broadband coverage, or the lack thereof, are held in separate databases by different agencies in the federal government, but due to privacy related issues it could not be shared or its availability was unknown.
The second identified issue was a lack of both standardized data that is available to the public and definitions and details about the metadata concerning the data. The use of the well-known internal agency acronyms was not helpful in identifying to the public what was contained in the database and what is meant by their use.

From the information collected the following recommendations are respectfully submitted.

Recommendation summary:

1. We recommend that the FCC and the USDA begin working immediately, with the most authoritative data currently available, and derive public facing FCC broadband availability maps that reflect and confirm the unserved and underserved based on the current broadband standard for fixed and mobile internet service on agricultural lands to facilitate precision agricultural practices and adoption.
2. We recommend that the most recent map for agricultural producers be hosted on the ARS website to include the base layers of NASS cropland data, the USGS data on rangeland and 3DEP data.
3. With respect to the BDC, we recommend a uniform set of practices and validation process to be developed by the FCC to verify user experience against broadband provider claims in agricultural areas. Furthermore, we recommend that the USDA and Extension Service be used

to facilitate training on verification and measurement in this process. Finally, the broadband fabric data need to include agricultural structures in addition to the home location and the shop or office.

4. We recommend that the broadband availability and quality data be independently verifiable, using methods consistent across the country.
5. We recommend the next farm bill address the need for precision agriculture data collection funding.
6. Within this process of verification, special attention needs to be given to the Native Communities with culturally appropriate and locally accepted inclusive approach to gathering accurate data.

Additional considerations:

- Create a federal agency working group from USDA, FCC, most notably National Telecommunications and information Administration (NTIA), Federal Aviation Administration (FAA), Bureau of Indian Affairs (BIA), and other relevant agencies with the goal of standardizing, synchronizing all federal maps related to broadband to be current and accurate.
- Create data standards that are public facing describing the metadata in terms that can be understood by non-agency users.
- Working with each State and Tribal Extension Service to understand the agricultural broadband needs.
- Need to provide funding support for BDC relevant to and needed agricultural applications.
- Identify all structures used for radio broadcast, the frequencies in use, and whether such frequencies are being used for last-mile Internet connectivity.
- Work to provide private data holders with relevant information for sharing the data while protecting sources.
- The FSA should be considered as a possible agency to collect data from farmers and ranchers yearly and pass it along to NASS for processing through their current cooperative data agreement. Additional supportive information for our recommendations from subgroups addressing specific focused areas:

Coordinate maps with other agencies

Our focus is on Agriculture and Ranching, and the FCC's Digital Opportunity Data Collection (DODC) proceeding is focused on developing a stand-alone dynamic broadband map. It will be necessary to combine the broadband map that the FCC will develop (including the serviceable location fabric)[2] with existing agricultural maps. To that end, we have the following recommendations.

The NASS Cultivated Land data should be used to determine the base map extent for determining Cultivated Land area for the continental US. The USGS National Land Cover Data (NLCD) should be used to determine the agricultural coverage areas for pasture/grazing, hay from grassland, and cultivated alfalfa hay land. Outside the continental US, the best available agricultural databases will be used to determine land that is in agricultural production.

Supporting considerations:

- To identify the cultivated land, we recommend using the 2020 NASS Cultivated Layer. The NASS Cultivated Layer is based on the most recent five years of Cropland Data Layers (CDL)[3] and assigns each pixel as either cultivated or not cultivated depending on if it was classified as cultivated more than twice in the past five years or if it is only cultivated in the most recent year.
- To identify pasture and livestock grazing land, we recommend using a combination of historical CDLs and the USGS 2016 National Land Cover Database (NLCD 2016)[4].
- Tribal Lands can be identified from a national data layer Data.Gov that is based on TIGER/2017 Census Bureau data.
- Tribal land data should be merged with the Cultivated and Cropland Pasture layers to ensure Tribal Lands are covered in the search for underserved broadband areas.
- Regarding an Alaska land cover data product, we recommend using the 2016 USGS NLCD product over Alaska or the most recent data available. The Alaska product has a cultivated class, pasture/hay class and grassland/herbaceous class. The next update of this product is scheduled for late 2021 at the earliest.

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[2] Presentation by Lynn Follansbee of US Telecom, on the Broadband Serviceable Location Fabric mapping initiative.
[3] Presentation by Rick Mueller USDA/NASS on the Cropland Data Layer Program.
[4] USGS NLCD Program: https://www.sciencedirect.com/science/article/pii/S0924271620300587?via%3Dihub

- The most recent Hawaiian land cover NLCD product is based on 2011 data. The NLCD program will start work on a 2016 Hawaiian product sometime next year. However, there is an alternative land cover product available from the Hawaii Statewide GIS Program/Office of Planning called the 2015 Hawaii Statewide Agricultural Land Use Baseline layer that could be used to validate NLCD data.
- The Puerto Rico NOAA Coastal Change Analysis Program (C-CAP) 30m Land Cover is available at https://www.fisheries.noaa.gov/inport/item/48300. The current data are ten years old and will be replaced once newer information is available. The useful categories for this product are: Pasture/hay, cultivated, and grassland. The resolution is 30m and is consistent with the NASS CDL and USGS NLCD products over the United States, Alaska, and Hawaii.

Add Agriculture Structures to Broadband Data Collection

Use the Broadband Serviceable Location Fabric Machine Learning (ML)/Artificial Intelligence (AI) approach to augment mapping of address location identification and agricultural outbuildings/ infrastructure.

- Ensure that agricultural outbuildings/infrastructure (i.e., barns, sheds, shops, water tank, irrigation systems, grain bins, RTK towers) are included in the broadband serviceable location fabric. *(Note possible data sources: Rural Electrics, state and local property taxing authorities, Natural Resources Conservation Service, and Water Districts)*
- The Commission has already determined in its DODC proceeding that separate maps will be needed for 3G, 4G and 5G mobile services and satellite, fixed services will be required to submit advertised speeds, however, a separate map will also be required for CAT M IoT service, which has a much greater range than traditional 4G / LTE service, on which it is based and any future emergent technologies.
- In the Commission's Third Report and Order in its DODC proceeding the Commission delegated to the Office of Economic Analysis and the Wireless Telecommunications Bureau a pilot program using the US Postal Service delivery vehicles and potentially other governmental sources to verify on-the-ground measurements. While the FCC pilot was completed, we recommend enlisting the aid of local agricultural extension offices in the future, which could train individuals in gathering data for the challenge process.

- Ensure the FCC's broadband serviceable location fabric includes mapping all agricultural structures that includes at least one of the following criteria rather than assuming what structures will and will not require broadband Internet access service.[5]

Primary criteria:

- Structure is located on land zoned Agriculture.
- Structure is classified Agricultural for tax purposes.
- Structure has electricity.

Possible secondary criteria:

- Structure is primary business location for the agricultural operation not including primary residence.
- Structure is surrounded by agricultural land.
- Structure is at least 1000 square feet in size.
- Structure has a water source available.
- Structure is attached to the land.

Map data validation and verification processes and procedures

This recommendation is broken into three parts.

Create a more accurate broadband map showing the broadband serviceable location fabric and network access for both fixed and mobile providers serving the agricultural and rural domains. In addition, crowdsourcing with AI and ML methods for verification of data should be utilized. This could be leveraged through both open source and proprietary data, which will provide a more granular picture of broadband coverage and speeds.

Plan sampling/drive testing to obtain broadband data relevant to agriculture structures and lands. This process will validate findings and ensure accuracy so that the results are comparative over time. Such field verification efforts can be cost drivers but are a core component of data quality.

Utilize agricultural extension and tribal agricultural extension educators to conduct field surveys. The goal is to ground truth the maps used to validate coverage so funds can be directed to areas identified as unserved/underserved. Precision agriculture relies on fixed and

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[5] *Presentation by Todd Harpest MetaLINK Technologies, Inc. and Joe Carey Trimble Inc presentation on the Broadband Data Act.*

mobile broadband ecosystems, underscoring the need to verify both, especially in the field. The key is having standard testing methods and repeatable results.

Supporting Considerations:

- The most important factors are consistent testing methods and proactive, explicit, strategic sampling – sampling size, geographical spread, conducted throughout the year, at peak times of day for agriculture, yielding verifiable, repeatable results.
- We recognize that there is an important difference between fixed and mobile networks. In a fixed network, whether fiber, cable, or wireless, there is typically some sort of "demarcation point" (typically an Ethernet jack) at which the network performance can be measured. There is no such point for a mobile network. Accurate measurement of mobile Internet performance is difficult and highly technical.
- The technology used for verification should be chosen specifically to match with agricultural needs. We recommend:
    - Open-source testing software and methods
    - On the ground throughput and quality metrics
    - Public reporting and verifiable documentation of test results
    - Independent, verifiable, and unbiased
    - We understand that the FCC's BDC was mandated by Congress and the FCC is tasked with overseeing the BDC, but we recommend that for ground truthing they coordinate with USDA for the field work and appropriate the funding to accomplish the work.

Working with Native Nations

On Native American agricultural lands, build local partnerships with or led by indigenous communities for ground truthing, streamlining the permitting process, and providing federal resources where necessary for mapping, training, and access to broadband.

Supporting Considerations[6]**:**

- Provide the resources to conduct surveys that examine the extent of broadband coverage and available speeds on rural tribal agricultural lands. Designate tribal agricultural extension educators in partnership with tribal colleges and land-grant universities to conduct data gathering and analysis of speeds through ground truthing and crowdsourcing methods funded by federal sources. These educational based entities and their local staff are known and trusted by tribal members to gather data in a culturally sensitive manner.
- USDA-NASS statistics on Native American livestock operations may be underrepresented. Other agencies may have additional data on agricultural land use on native lands. Federal agencies such as USDA NASS, FCC, USGS and BIA should work together with state, local and tribal governments to derive accurate maps of native agricultural lands, particularly domestic livestock grazing lands.

Working with USGS and their 3DEP effort

1. The FCC should work with the USGS to integrate the use of 3DEP data in government and commercial broadband mapping processes.
2. The FCC, through opportunities like the Rural Digital Opportunity Fund, should consider investing in the completion of 3DEP, and promote the collection of Quality Level 1 data, to offer a consistent, reliable, highly accurate terrain dataset for all interested parties to use in preparation for mapping broadband availability for the BDC or other mapping that is funded by FCC.
3. FCC should actively participate in 3DEP governance by assigning representatives to the 3DEP Executive Forum (and/or the 3DEP Federal Interagency Coordinating Committee as it is stood up per the National Landslides Preparedness Act) and Working Group.

Supporting Considerations[7]**:**

- Terrain is a key parameter in modeling the propagation and coverage area of a broadband signal. When complete, the light detection and ranging (lidar) data from the 3D Elevation Program will represent the highest resolution, most accurate national elevation dataset available. This dataset is free to use and standards-based for broad adoption by government

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[6] *Presentation by Loren Birdrattler and Michael Vogt, Blackfeet Agriculture Resource Management Plan on behalf of the Blackfeet Nation. Presentation by Mona Thompson, Cheyenne River Sioux Tribe Telephone Authority.*
[7] *Presentation by Kevin Gallagher USGS on 3DEP.*

and commercial users to play a role in improving maps of broadband accessibility and helping to strengthen the broadband communications network.

- Understanding small variations in terrain is especially important for modeling the performance and attenuation characteristics of higher frequency broadband signals like 5G.
- Lidar is used in signal propagation analyses to determine where broadband signals from communication towers can and cannot reach across the landscape, and for optimal siting of new towers to increase broadband coverage. 3DEP lidar would be a significant improvement in resolution and accuracy over existing national elevation datasets (e.g., SRTM, GLOBE) currently used in RF propagation models.
- As part of the 3D Nation Elevation Requirements and Benefits Study (in progress), the FCC identified requirements for Quality Level 1 data as crucial for performing propagation modeling and analysis of radiofrequency spectrum usage because the behavior of radio waves depends on the topology (clutter) as well as the underlying terrain. Having more accurate lidar information will result in higher confidence in the modeling results.

Funding Agricultural Data Collection

We recommend that language be added to the 2023 reauthorization of the Farm Bill to include the appropriation of funds and the formal authorization of NASS to create a more granular survey to collect additional data on fixed and mobile broadband availability, usage, and current/future needs for precision agriculture operations across their agricultural lands and structures. FCC and USDA NASS should work together to understand broadband performance standards required for widespread adoption for precision agriculture technologies. As an example, the quinquennial ag census, and the biannual USDA Farm Computer Usage & Ownership Survey could be used as the basis to determine future FCC connectivity standards for agricultural operations.

Broadband Maps for various end user groups

This Task Force recommends that the FCC create a public facing tool, likely an interactive map, that depicts areas of the United States and territories lacking access to adequate connectivity to support the bandwidth demands of precision agriculture. The "Negative Space" map should be interactive for users to show areas lacking either fixed and/or mobile connectivity in a geographic area based on the most accurate FCC data sets. Because this tool will be utilized primarily by agricultural stakeholders, we feel the map should focus on land currently in production agriculture.

Several states have created broadband funds for the purpose of providing financial assistance in broadband infrastructure to promote broadband investment for their citizens. The projects are typically funded in part or in full through state and or local governments to connect unserved and underserved lands. The FCC recognizes the benefit in empowering state, local, and tribal entities to determine viable fixed and mobile broadband projects to reach underserved and unserved areas. The Task Force fully supports the FCC's actions empowering the decision-making efforts as close to the stakeholders as possible. However, we feel that the local and state stakeholders lack the resources to accurately identify and validate whether agricultural working lands are served, unserved, or if the federal government has pending funding for a project that may be in the planning stages of construction.

An authoritative, federal, interactive map specifically showing unserved and underserved lands will be a powerful tool to assist local municipalities, state governments, and tribal entities to most efficiently allocate investment dollars from their respective broadband funds to reach more agricultural lands, furthering positive climate, precision agricultural practices.

PART III: ACCELERATING BROADBAND DEPLOYMENT ON UNSERVED AGRICULTURAL LANDS

The Accelerating Deployment Working Group agreed on the recommendations below, which the Task Force adopts.

Recommendations / Rationale for Recommendations

A	The FCC should implement geographic buildout requirements, rather than population-based requirements, tied to spectrum auctions with shorter buildout timelines. 5G funding guidelines should require area-based coverage that includes verified device population and usage data.	- Through spectrum auctions administered by the the FCC, the Federal Government has raised billions of dollars in the auction of spectrum for use across the nation, yet we have not seen equivalent build out in rural ag lands in comparison to that in more densely populated areas. - Often the buildout requirements allow for 10 years to meet auction requirements. Exploring ways to incentivize accelerated buildout timelines to five or fewer years would meet the objective of providing service to unserved areas.

A	Precision Agriculture, by its very nature, will require the use of geographical-based buildout instead of the more traditional approach based on population. The spectrum auctions should include a shorter and more aggressive buildout timeline as positive consideration in winning bids.	- Past auctions had geographic buildout as a focus of winning the spectrum auction over a buildout tied to a percentage of population. This change would better ensure coverage in more sparsely populated areas, such as ag lands. - Consider a dual approach that still requires population targets in urban areas while requiring geographic coverage in rural areas.
B	The FCC and USDA should ensure that Precision Ag standards are established and followed for all elements of the network. Define multiple precision agriculture performance targets comprising speed and quality metrics such as latency, jitter, and packet loss based on the defined broadband needs of actual agricultural use cases, while considering search capacity and seasonal variations, rather than theoretical offering of specific technology types. Define service availability location and time percentage targets that can be used in industry standard radio frequency.	– Establishing standards for precision ag allows for building economies of scale and ensuring that the full ecosystem of precision ag can grow and develop from equipment manufacturers to service providers to farm & ranch applications. - The FCC, USDA and other stakeholders should develop broadband performance targets that specifically reflect the needs of agricultural use cases.

	propagation models for design and measurement of mobile communication systems across agricultural lands. Consider any and all connectivity technologies (fixed, wireless, satellite) that will satisfy the demands of these targets. The FCC include a report on agricultural area coverage as it posts reports on competition on wireline and wireless coverage.	- Several sets of performance targets may be appropriate to account for differences between various use cases (e.g. fixed vs. mobile, consumer Internet access vs. M2M/IoT applications). - The performance characteristics to be measured (speed, latency, etc.) should be based on those that are most salient for the given use case (e.g. some applications may be latency sensitive, where others may be minimally impacted by higher latency). - Specific targets should be tailored to specific use cases (including some use cases may require symmetrical speeds, whereas others benefit from higher allocation to download).
C	Ensure that federal agencies use the same threshold for establishing what is considered to be broadband service, (greater network capacity with a better balance between upload and download speeds) and align all support mechanisms and incentives. Congress should allocate funds to the U.S. Department of Transportation to support infrastructure needed for autonomous vehicle usage at the township and county levels in addition to broader consumer and commercial usage.	– Various federal agencies provide support to build out broadband networks, however the various networks are not in sync with what is considered to meet the threshold of being broadband. A consistent definition would be helpful for ensuring quality networks in rural/ag lands. - The FCC currently acknowledges that a 25/3 Mbps connection meets the threshold for being considered advanced telecommunications capability. However, this threshold has steadily and consistently grown to meet the needs of consumer demand. It is logical to assume that the broadband needs will continue to grow and the supporting networks must have the same scalability.

C		Scalability in this sense would be related to increasing speeds and capacity on the network as consumer demand increases. Ideally, this would be a fiber optic network, but considering timelines and funding, wireless and satellite options could be used in the interim provided the proper specs for precision ag are met as determined by connectivity needs. - Rural townships and counties rely on federal motor fuel tax to fund local road and bridge maintenance and improvements. Additional funds will be needed to support networks to support autonomous vehicles for field to farm and farm to terminal transport in the future.
D	The FCC should identify and implement policies to facilitate use of low-, mid-, and high-band spectrum for precision agriculture applications, including but not limited to: (i) policies that facilitate access to licensed spectrum in rural areas that may be underutilized; (ii) policies that remove technical impediments to rural agricultural use cases; and (iii) policies that structure future spectrum auctions to increase the likelihood that spectrum can and will be utilized for precision agriculture purposes.	– The FCC has held many spectrum auctions in recent years, and this recommendation would be an inclusion for future spectrum auctions. This spectrum would be used in last acre network deployments.

E	The FCC should strengthen policies that require auction bidders to show the long-term sustainability and scalability, of their proposed networks recognizing the need to raise the bar significantly on both upload and download speeds.	– Broadband network capacity requirements continue to grow exponentially. Therefore, federal funding should support networks that will also scale exponentially and sustain the service for many years. Short-term solutions imply additional funding in regular increments. - Ensure that funding meets a balance between the capital costs to deploy as well as the ongoing costs to maintain, upgrade and support the network. - Ensure the bidders have the capability to deliver the service needed in the committed timeline. Otherwise, rural/ag areas will continue to be unserved and tax-payer dollars could be wasted.
F	The FCC should strengthen policy towards use restrictions of unlicensed spectrum to mitigate unnecessary noise in order to better ensure performance for wireless networks.	– While there are limitations for use of unlicensed spectrum, this is rarely policed at the local level and unnecessary noise can make an unlicensed spectrum unusable. Enhanced monitoring and rapid dispute resolution would allow better use of unlicensed spectrum in the last acre network application.

G	The FCC and USDA should support rural broadband networks by including incentives for connectivity to rural ag land headquarters.	– FCC policy must recognize, consistent with its recent Section 706 reports, that fixed and mobile services are not substitutes but are complementary services needed to support Precision Ag. In the microsystem of a farm this may be seen in the following example: a rancher may rely on remote sensors that track the health, food consumption and activity of its cattle in the field. These will rely on mobile wireless capabilities. At the same time, the rancher may participate in online cattle auctions that rely on high-capacity, low-latency wired broadband services. In this example, the complementary systems of both fixed and mobile services are necessary to support the farm. Moreover, and as expressed in numerous papers and studies, wireless services require wires. At some point, and particularly as 5G is investigated for increasing industrial and other uses, fiber deep into the network will be necessary to provide sufficient backhaul capability. – Headquarters for ag lands can vary substantially between operations and geographic areas from the home-based office to the bin site and input storage areas to the irrigated field or corral. – USDA's programs have been very important to rural broadband growth, from RUS loans to the recent Re-Connect programs with grant and loan components. This recommendation would be to add incentives where farm and ranch headquarters are served by broadband network buildouts.

H	The FCC and USDA should develop policies that incentivize the expansion of middle mile infrastructure leveraging best in class connectivity such as fiberoptic infrastructure.	– Rural fiber networks are one potential solution for middle mile networks to bring the type of capacity of farm headquarter facilities to support future Precision Ag. bandwidth needs. – Bringing fiber to the home, which in many cases serves as the headquarters of a business, in rural America is financially challenging given the economics of building this infrastructure in lower density areas. – High speed cellular networks such as 5G will need to be part of the solution in bringing high speed broadband to rural America. – The current and future evolution of Precision Ag. technology will result in vast amounts of data that will need to be transmitted across the field as well as to the cloud for effective and efficient farm management decision. – Investments made in rural telecommunication networks should be future proofed to have the capacity of support these significant data needs.

I	The FCC and other stakeholders should explore novel business models, including identifying unnecessary regulations that may be impeding the emergence of those models and the promulgation of new regulatory frameworks to facilitate such business models.	– This could include efforts to encourage shared infrastructure models at the middle-mile and last-mile/acre. – Appropriate policies could include further liberalization of the "secondary markets" regimes, and potentially efforts to support wholesale operations that may not fit neatly into federal and state regulatory frameworks. – The FCC's 2.5 GHz recent spectrum auction to tribal entities and existing efforts to raise awareness of the opportunities for tribal entities to become or to cooperate with internet providers is encouraged to continue and to be used as a model for other rural areas.
J	The FCC and USDA should work with stakeholders to build a playbook for the creation and operation of rural community-based, non-profit solutions. An important key to the success of these types of solutions is for the entities involved to leverage the expertise of local, independent, existing operators to build these community-based high-speed networks.	– Strong community-based organizations exist in every rural farm community across America. These include but are not limited to local economic development and community foundations, farm supply cooperatives, rural water districts, rural electric cooperatives, rural cooperative and family-owned telecommunication companies, and county and municipal government entities. – Many examples exist of successful collaborative efforts bringing broadband to rural areas through community-based models. – Many of these initial community efforts fail due to early conflicts that naturally arise when trying to build a community coalition toward a common purpose – often the result of challenges to raise startup capital.

J		- Funding incentives could be developed to assist in bringing together these community organizations. By helping to overcome initial barriers faced in these efforts, more grassroot community-based solutions could be realized. This approach can also utilize groups such as Ag Cooperatives to purchase spectrum for use in last mile applications across farms and ranches. – This collaborative, community-based approach could also be leveraged in the deployment of rural wireless networks by aggregating infrastructure and spectrum across a larger area thus lowering deployment costs.
K	The FCC and USDA should facilitate the ability of parties to obtain funding from multiple sources with one not precluding another.	– FCC, USDA, and some state programs have not allowed recipients of one program to apply for additional funds from a different program. In the case of agricultural lands and many rural areas that are unserved or underserved, applicants should be encouraged to leverage multiple programs to build out and deliver service. – Agencies should explore options for long-term, sustainable funding of network buildout and upgrades that provide affordable, reliable service to precision ag users.

K		– The USDA has achieved great strides through the Rural Utility Service and Rural Development programs. The FSA and NRCS could also serve as direct conduits for funding resources and training to facilitate deployment and adoption of precision ag infrastructure and tools.
L	The USDA should develop policy to support the buildout of local/last acre network to ensure the capability to use Precision Ag systems and devices.	– In addition to existing Rural Utility Service, and Rural Development grant and loan programs, the FSA could facilitate efforts by serving as local contacts and establishing loan or grant criteria for those farms that are seeking to build network infrastructure to support their operations. The NRCS could direct conservation funding to farmers who adopt precision ag to enhance their conservation and nutrient management practices. Land Grant Extension services could enhance training and research in precision ag.
M	The Department of Interior's BIA should conclude review of handbooks for program staff to interpret guidelines for buildout of Internet services, distribute the handbooks and accelerate training to field staff. The FCC and BIA should gather input and act on how to streamline regulations pertaining to broadband buildout on tribal lands.	– In the case of tribal lands, interviews with multiple providers revealed that the cost of building out Internet service can cost up to 30% more on tribal lands due largely to delays in interpreting guidance related to easements and right of ways. – The guidance was revised in 2016 with a rewrite of the Code of Federal Regulations (CFR) 169.26 for citing "telephone and telegraph lines; radio, television, and other communications facilities." – If field staff handbooks and training scheduled for implementation in the spring of 2021 do not show an improvement in efficiency, then the agencies should work together to clarify the CFR for more rapid deployment.

M		of 2021 do not show an improvement in efficiency, then the agencies should work together to clarify the CFR for more rapid deployment.
N	The FCC should ensure that the intent of the Broadband DATA Act is met by expanding proof of service beyond one customer in a census block to a percentage of acres and/or geography as companies report their coverage.	– In some cases, FCC programs deem a block ineligible for support if that block has been listed as having service available within it on a provider's FCC Form 477. Per the FCC Form 477 rules, it is not necessarily the case that a provider can serve the entire area of each of its reported blocks. Providers should show proof of service to more than half the census block area, especially in the case of serving agricultural lands, to move toward the goal of delivering service to more than 95% of agricultural lands. – Weighting of Farms Served when Contemplating High-Cost Support Allocations The USDA ReConnect program includes "weights" that favor areas with farms. While no rural or high-cost universal service support area should be subject to diminished or deprivation of support for lack of farmland, the USDA program indicates that the Federal policymakers have already recognized the role of broadband in farms, and the role of farms in building local communities. Accordingly, the USDA ReConnect program paves the way for the FCC to offer specific consideration in the USF and CAF high-cost programs for farmland. As described above, this may be accomplished by including the cost of connecting farm fields and facilities to broadband.

o Federal cyber security and cyber protection policy, adopted by Congress or developed by agencies, should protect precision ag network infrastructure and data that provide for farm property and its products as well as farm record data to be recognized at a level that is equal to any other independent business entity. It should be recognized that farms and food systems, including their data and records, are a matter of national security. Such property and data should be considered highly sensitive and malicious acts, domestic or international, should be considered a terrorist act in nature.	– A joint federal document "Threats to Precision Agriculture" published by the Department of Homeland Security in 2018 concluded that "most of the threats facing precision agriculture's embedded and digital tools were consistent with threat vectors in all other newly-connected industries... Generally accepted mitigation techniques in other industries were found to be largely sufficient for creating a successful defense-in-depth strategy." – Continual application of the Confidentiality, Integrity, and Availability (CIA) model is needed to prevent disruptions or corruption of data and food security as technologies continue to emerge.

Grid Representation of Charge

The following table of recommendations crosschecks the relevance of each recommendation to the charge. A detailed description of each element of the charge is listed below the table.

RECOMMENDATIONS	*FB 3A ii	FB 3A iv	FB 3A vi	Multi Agency Policy	FCC Reg	FCC Spectrum	Joint Expertise
A. The FCC should implement geographic buildout requirements, rather than population-based requirements, tied to spectrum auctions with shorter buildout timelines. Precision Agriculture, by its very nature, will require the use of geographical-based buildout instead of the more traditional approach based on population. The spectrum auctions should include a shorter and more aggressive buildout timeline as positive consideration in winning bids.	x	x		x	x	x	
B. The FCC and USDA should ensure that Precision Ag standards are established and followed for all elements of the network. Define multiple precision agriculture performance targets comprising speed and quality metrics such as latency, jitter, and packet loss based on the defined broadband needs of actual agricultural use cases, while considering search capacity and seasonal variations, rather than theoretical offering of specific technology types. Define service availability location and time percentage targets that can be used in industry standard radio frequency propagation models for design and measurement of mobile communication systems across agricultural lands. Consider any and all connectivity technologies (fixed, wireless, satellite) that will satisfy the demands of these targets.	x	x	x	x		x	
C. Ensure that federal agencies use the same threshold for establishing what is considered to be broadband service (greater network capacity with a better balance between upload and download speeds) and align all support mechanisms and incentives.	x	x		x			
D. The FCC should identify and implement policies to facilitate use of low-, mid-, and high-band spectrum for precision agriculture applications, including but not limited to: (i) policies that facilitate access to licensed spectrum in rural areas that may be underutilized; (ii) policies that remove technical impediments to rural agricultural use cases; and (iii) policies that structure future spectrum auctions to increase the likelihood that spectrum can and will be utilized for precision agriculture purposes.	x	x		x		x	x

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E. The FCC should strengthen policies that require auction bidders to show the long-term sustainability and scalability of their proposed networks recognizing the need to raise the bar significantly on both upload and download speeds.	x	x		x	x	x	
F. The FCC should strengthen policy towards use restrictions of unlicensed spectrum to mitigate unnecessary noise in order to better ensure performance for wireless networks.	x	x		x		x	
G. The FCC and USDA should support rural broadband networks by including incentives for connectivity to rural ag land headquarters.	x	x	x	x		x	x
H. The FCC and USDA should develop policies that incentivize the expansion of middle mile infrastructure leveraging best in class connectivity such as fiberoptic infrastructure.	x	x		x	x		
I. The FCC and other stakeholders should explore novel business models, including by identifying unnecessary regulations that may be impeding the emergence of those models and the promulgation of new regulatory frameworks to facilitate such business models.	x	x	x	x	x	x	
J. The FCC and USDA should work with stakeholders to build a playbook for the creation and operation of rural community-based, non-profit solutions. An important key to the success of these types of solutions is for the entities involved to leverage the expertise of local, independent, existing operators to build these community-based high-speed networks.	x	x		x	x	x	
K. The FCC and USDA should facilitate the ability of parties to obtain funding from multiple sources with one not precluding another	x	x		x			x
L. The USDA should develop policy to support the buildout of local/last acre network to ensure the capability to use Precision Ag systems and devices.	x			x			x
M. The Department of Interior's Bureau of Indian Affairs (BIA) should conclude review of handbooks for program staff to interpret guidelines for buildout of Internet services, distribute the handbooks and accelerate training to field staff. The FCC and BIA should gather input and act on how to streamline regulations pertaining to broadband buildout on tribal lands.	x	x		x	x		x
N. The FCC should ensure that the intent of the Broadband DATA Act is met by expanding proof of service beyond one customer in a census block to a percentage of acres and/or geography as companies report their coverage.		x	x		x	x	x

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O. Federal cyber security and cyber protection policy, adopted by Congress or developed by agencies, should protect precision ag network infrastructure and data that provide for farm property and its products as well as farm record data to be recognized at a level that is equal to any other independent business entity. It should be recognized that farms and food systems, including their data and records, are a matter of national security. Such property and data should be considered highly sensitive and malicious acts, domestic or international, should be considered a terrorist act in nature.		x					x

*Grid Representation of Charge

*FB 3A ii	FB 3A iv	FB 3A vi	FB 3A vi	Multi Agency Policy	FCC reg	FCC spectrum	Joint Expertise

FB 3A ii = 2018 Farm Bill Section 12511 (b)(3)(A)(ii) – Develop policy recommendations to promote the rapid, expanded deployment of broadband Internet access service on unserved agricultural land, with a goal of achieving reliable capabilities on 95 percent of agricultural land in the United States by 2025.

FB 3A iv = 2018 Farm Bill Section 12511 (b)(3)(A)(iv) – Recommend specific new rules or amendments to existing rules of the Commission that the Commission should issue to achieve the goals and purposes of the policy recommendations described in the clause (ii)

FB 3A vi = 2018 Farm Bill Section 12511 (b)(3)(A)(vi) – Recommend specific steps that the Commission should consider to ensure that the expertise of the Secretary and available farm data are reflected in future programs of the Commission dedicated to the infrastructure deployment of broadband Internet access service and to direct available funding to unserved agricultural land where needed.

Multi Agency Policy = Facilitates development of policy recommendations for the Commission, the Department, and federal, state, and local governments intended to promote the acceleration of broadband infrastructure investment on agricultural lands.

FCC Reg = Facilitates the Commission in reducing and/or removing regulatory barriers to broadband infrastructure investment on agricultural lands.

FCC Spectrum = Facilitates the Commission in allocating and licensing spectrum for the purpose of accelerating deployment to unserved agricultural lands.

Joint Expertise = In conjunction with the Mapping & Analyzing Connectivity on Agricultural Lands Working Group, facilitates specific steps the Commission should consider to ensure that the expertise of the Secretary and available farm data are taken into account in Commission policymaking affecting broadband deployment on agricultural lands.

Issues

5G Buildout – In December 2020, the FCC's 5G auction set a record. The concern for rural America is that 5G is expected to build on the foundation of existing networks. Existing networks consistently underdeliver stated capacity on agricultural lands. The future of precision agriculture, in particular the interoperability of equipment manufacturers' data gathering with farm management software and emerging platforms to track environmental practices that will be required for carbon and other eco-related markets are mostly reliant on cellular service for gathering, analyzing and disseminating data.

Accountability – If an auction winner or grantee through any program (Rural Development Opportunity Fund, Connect America, other grants and loans) does not deliver on its commitments, it is unclear when awarded areas will be eligible to compete for additional federal funding. Research the timeline for accountability of 10 years and other requirements to determine impacts on precision agriculture.

Determine how to measure broadband delivery in a way other than people and residences in metrics that capture precision agriculture usage. Collect information from endusers on mapping and precision agriculture needs. Create mechanisms for providers to serve measurable outcomes such as agricultural headquarters. Ensure that spectrum winners, wireless deployments and all technologies account for success of buildout in existing and new areas.

Formalize Existing Relationship – FCC and USDA should enter into a Memorandum of Understanding to fully collaborate on all aspects of rural broadband to support U.S. agriculture. Interagency collaboration has led to several breakthroughs in mapping as well as identified opportunities for fine tuning programs. Rural America and precision agriculture will benefit from ongoing exchange and teamwork between agencies.

Enacting Previous Recommendations – While the group reviewed a range of material, it was noted that several actionable items remained from the Broadband Deployment Advisory Committee's earlier work:

1. The FCC should work, with industry and state/local agencies (or national associations) to develop a broadband readiness checklist.

2. The FCC should either develop or encourage states to develop a process by which localities can certify that they are "broadband ready."
3. Standardized application process across all federal agencies.
4. Historic and environmental review processes should be harmonized across agencies and eliminate duplication of reviews.
5. Name a single point of contact for each federal agency for application review and follow-up and online tracking of the application status.

Funding for Broadband Deployment to Rural Areas to Support Precision Agriculture - Industry practitioners agree that the full potential of precision agriculture can only be realized when robust broadband service is provided to the headquarter level of farms, ranches and other food and fiber supply chain businesses. The primary mechanism for implementing the universal service mandates of the Telecommunications Act of 1996[8] is the Universal Service Fund and Connect America Fund programs that are administered by the FCC. Especially in rural areas served by small, locally operated providers, these programs have enabled admirable broadband achievement. These programs, however, are funded by an assessment on interstate and international end-user telecommunications revenue. As this revenue base is recognized increasingly as shrinking with the expanded adoption of broadband, there is a clear and recognized need to ensure that the funding base for the FCC High Cost Fund is sustainable[9].

[8] Telecommunications Act of 1996, Pub. L. No. 104–104. 110 Stat. 56 (1996). The 1996 Act amended the Communications Act of 1934.
[9] The High Cost Fund is one of four funding mechanisms funded by the Universal Service Fund.

PART IV: EXAMINING CURRENT AND FUTURE CONNECTIVITY DEMAND FOR PRECISION AGRICULTURE.

Introduction and Background

Precision agriculture is the use of technology and data to generate insights that help the Agriculture Community make better decisions and automate practices to increase agricultural productivity, efficiency, and sustainability. Precision agriculture can, among other things, reduce inputs, increase outputs, lower environmental impact, and increase integration and efficiency in the supply chain.

Precision agriculture is critical to the future of agriculture operations on U.S. farms and ranches to meet the United States' needs for food and access to other agriculture-based resources. In order to enable precision agriculture, it is critical that wired and wireless broadband connectivity, edge cloud computing, and private wireless systems be extended to all farms in the United States, including the most rural and remote portions of the country.

It is imperative that precision agriculture architecture be made an eligible expense for federal broadband programs, including for edge computer infrastructure and private 4G/5G wireless systems, among broadband deployment generally, to increase adoption.

This section examines the following critical questions:

- The current and future connectivity needs for precision agriculture in terms of coverage, speed, monthly usage, latency, and other factors; the technologies available to meet those needs; and the advantages and limitations of those technologies;
- Whether and how connectivity needs vary by agricultural product geography and other factors;
- How and why demand for precision agriculture needs may change over time due to, for example, population increases and shifts, environmental challenges, changes in diets, and increased demand for knowing where food is sourced; and
- Whether the amount or type of connectivity available is shifting or will shift the choices of agricultural producers—for instance, from growing one crop or crop type to another.

This section also details the current and projected future connectivity needs of agricultural operations, farmers, and ranchers (the "Agriculture Community") and identifies the benefits of communications technologies that can meet these needs today and in the future. This includes ensuring that the communications networks, including 5G and beyond, are designed to meet the current and future needs of the Agriculture Community.

It is important to recognize that many areas of agriculture are currently using aspects of precision agriculture technologies and practices and that the use of precision agriculture technologies is growing. It is also important to note that precision agriculture is not one thing, but a continuum of evolving tools and practices to improve efficiency and increase outputs. Connectivity is to precision agriculture as water is to life. Life can flourish without significant water, but when water is abundant, life thrives. Today, our use of mostly disconnected technologies has improved agriculture outputs and reduced environmental impacts; however, when connectivity is introduced, existing opportunities will be realized and new opportunities will emerge. We are in the infancy of precision agriculture.

The case for action to ensure connectivity for precision agriculture technology use by the Agriculture Community is clear and compelling and requires immediate action. The current and future use cases we examined in this report demonstrate the requirements necessary for the United States to close the connectivity gap and improve connectivity performance throughout rural America, especially on agricultural lands.

To reinforce the case for connectivity now to support precision agriculture in the future, this report provides an overview of current and future demand for precision agriculture technologies and applications across three main agriculture sectors: 1) row crops and broad acre crops, 2) livestock, and 3) specialty crop production.[10]

We then focus on the state of communications technology to meet these demands, including both narrowband and broadband connectivity solutions, and share use cases to demonstrate the role of connectivity in enabling precision agriculture to ensure that our farmers and ranchers can meet the demands for food and fuel today and in the future. Our report concludes with an overview of the benefits of connectivity and our recommendations.

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[10] The following definitions are used for each agriculture status:

1. Row crops and broad acre: These are crops that grow in rows and large-scale crops (e.g., wheat).
2. Livestock: This is farming that focuses on raising livestock such as cows, pigs, and goats.
3. Specialty crops: These are fruits and vegetables, tree nuts, dried fruits, and horticulture and nursery crops, including nursery crops that require special treatment.

One note: The Task Force prepared and released a survey to farmers, technologists, and service providers to determine the current and future connectivity requirements for precision agriculture. Unfortunately, the response to the survey was low and provided little helpful data.[11] As discussed in the recommendations, the Task Force urges further government agency or peer reviewed third-party research of actual bandwidth demand per connected piece of farm equipment/device, aggregate bandwidth demand by farm type and size, and a future demand forecast. Collecting this data bi-annually will help determine broadband performance standards for government funding and related programs. A primary reason behind obtaining this data is to capture the anticipated growth of precision agriculture and ensure that connectivity supply meets connectivity demand.

Overview of the Need for Connectivity to Meet Precision Agriculture Requirements

The need for connectivity for precision agriculture is clear when considering current and future food demand and demand for agricultural resources, such as corn for ethanol, in the United States. The U.S. Census Bureau projects that the U.S. population will increase by 79 million in the next 40 years—from about 326 million to 404 million between 2017 and 2060.[12] This means that the number of people living across the United States who need to be fed is growing exponentially, and food production has to match this need to ensure U.S. food security. In addition, the need for agricultural products to support other requirements, such as fuel, continues to grow.

The USDA found that about 52% of the 2012 U.S. land base is used for agricultural purposes, including cropping, grazing (on pasture, on range, and in forests), and farmsteads/farm roads.[13] With the continued population growth and development of the United States, as shown in **Figure 1**, the amount of land base for agriculture purposes will likely decrease, not increase. This means that the Agriculture Community must become more productive and efficient to meet increased demand in the United States for food and other resources.

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[11] Because of Federal Advisory Committee legal constraints, we could only send the survey to an extremely limited number of people.
[12] https://www.census.gov/content/dam/Census/library/publications/2020/demo/p25-1144.pdf
[13] Major Uses of Land in the United States, 2012, Bigelow, D.P. & Borchers, A. (August 2017, United States Department of Agriculture, Economic Research Service) Website link: https://www.ers.usda.gov/webdocs/publications/84880/eib-178.pdf?v=0#:~:text=Major%20land%20uses%20in%202012,14%20percent)%2C%20miscellaneous%20uses%20(

In addition, as shown in **Figure 2**, food security is a problem in the United States that will only worsen as the U.S. population increases.[14] While the USDA diagram shows that food security peaked in 2011, with unexpected events like the COVID-19 pandemic and continued population growth, we expect food security to be an ongoing issue. This has become especially evident during the COVID-19 pandemic.

When increased food demand is combined with the growth of food waste, it is clear that the U.S. has a major problem that must be addressed now. Growing concerns about the future of food security in this country and the need for agricultural resources for fuel and other critical supplies (e.g., paper) calls for the widespread use of precision agriculture technologies and practices by our Agriculture Community.

By increasing the use of precision agriculture, the U.S. can, among other things, improve food security, meet the growing demand for food, reduce the environmental impact of agricultural practices, reduce food waste, improve the profitability of U.S. agriculture, increase skilled labor demand to support the farm (but not necessarily on the farm), deliver food where it needs to go to fight domestic hunger, and increase U.S. competitiveness internationally.

For precision agriculture to be successfully adopted by the Agriculture Community, it is critical for there to be reliable connectivity across operations on farms and ranches. The value of technologies deployed in agriculture is amplified exponentially when connected, allowing data to flow. Accordingly, connectivity is the enabling fabric of precision agriculture.

And yet, there is no magic wand for delivering connectivity to enable precision agriculture. The economics of terrestrial broadband deployment and faster connectivity options for rural communities and areas of high agricultural production can be prohibitive. If it were not so, much greater deployment to these rural areas and increased choices would have been seen by now. In addition, the Agriculture Community has been slow to adopt non-terrestrial technologies, such as satellite.

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[14] Food Security and Nutrition Assistance, 2020 (September 2020, United States Department of Agriculture, Economic Research Service, contact: Morrison, R.M.)
Website link: https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/food-security-and-nutrition-assistance/#:~:text=ERS%20monitors%20the%20food%20security,an%20annual%2C%20nationally%20representative%20survey.&text=Reliable%20monitoring%20of%20food%20security,aimed%20at%20reducing%20food%20insecurity.

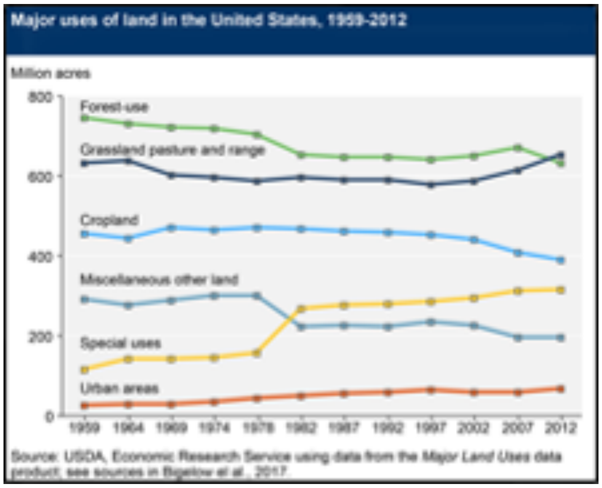

Figure 1. Major Uses of Land in the United States, 1959–2012

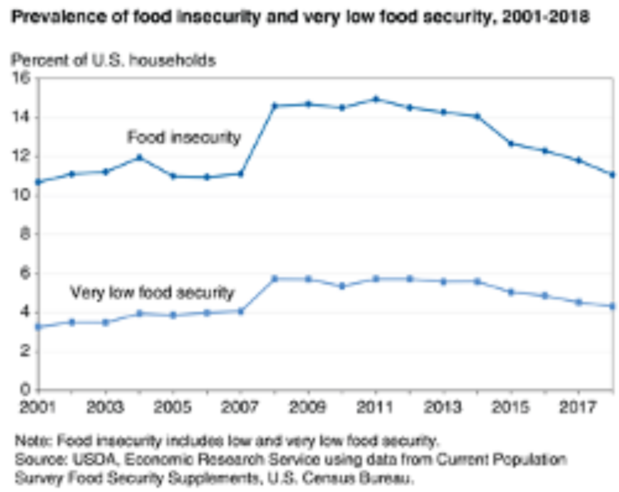

Figure 2. USDA Prevalence of Food Insecurity as of 2018

For the United States to improve food security for the U.S. population and meet other goals for the Agriculture Community and rural America, federal policy must enable the adoption of precision agriculture. As with other high-cost areas, policies that promote broadband connectivity across as much agricultural land as possible, including high-speed connectivity, are essential. It is encouraging that the FCC and the USDA have begun to recognize the unique connectivity needs of agricultural producers. Programs and funding dedicated to expanding rural broadband should take into consideration the connectivity gaps in farming operations, including farm buildings; ranchlands; and croplands where systems, sensors, and equipment operate.

In addition, connections via satellites or drones need to be examined, especially in areas where filling the connectivity gap is especially challenging because of cost, distance, and terrain. In addition, other models—including not-for-profit entities, such as cooperatives—may be more successful in bringing the agricultural community the connectivity it requires.

Overview of Uses of Precision Agriculture Today

"Reliable, High-Speed Broadband e-Connectivity is Essential to Enhanced Agricultural Production."
– *USDA Report on Rural Broadband and Benefits of Next Generation Precision Agriculture*

"Generations ago, the federal government recognized that without affordable access to electricity, Americans couldn't fully participate in modern society and the modern economy.

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Broadband internet is the new electricity. It is necessary for Americans to do their jobs, to participate equally in school learning and health care, and to stay connected."
– *Secretary of Agriculture Tom Vilsack*

"When we are able to deploy broadband ubiquitously, think of all the things we will be able to design, harvest, and develop ... Broadband in rural America will be as transformative in the 21st century as rural electrification was in the last century."
– *Former U.S. Secretary of Agriculture Sonny Perdue*

Agriculture production in the U.S. continues to be a knowledge- and data-driven effort that enables the best results for farmers, ranchers, and their consumers. Historically, U.S. farmers and ranchers have kept detailed records to document how they operated (e.g., farming or ranching practices) so that they can utilize past achievements to improve future operational improvements. Precision agriculture, using broadband, narrowband, and sensor technologies, allows producers to generate greater amounts of data on a much more granular scale, creating better insights for making decisions. The end goal of this effort is increasing quantity and quality while ensuring cost efficiency in production and supply chains and reducing environmental impacts of agriculture operations. There are two basic connectivity profiles this Committee has identified that facilitate current technology use and continued adoption.

Table 1. Connectivity Profile

	Low-Speed, Broad Coverage	High-Speed, Centralized
Geographic Coverage	Large areas (e.g., agricultural fields)	Targeted agricultural operational headquarters, such as a farm or ranch operations center—typically, one site per producer
Network Speed	Slow (<5 Mbps)	Broadband and faster (100+ Mbps)
Network Latency	High latency is tolerable (for now)	Low latency
Upload/Download Speeds	Asymmetrical (faster download and slower upload) Expect small upload and downloads over time from many sensors and field devices.	Symmetrical (same download and upload speeds) Expect large upload and downloads to support processing of large data files and online visualizations, training, and support.
Usage	• Transmit sensor data from fields • System automation and monitoring • Mobile access to systems and data for workers and decision-makers	• Farm-level data aggregation and modeling • Raw data uploads for processing (drone and other sensor data) • Training and system support

There are two basic connectivity profiles this committee has identified that facilitate current technology use and continued adoption.

Below, we set forth, by sector, how current and emerging communications technologies can support the adoption of precision agriculture technologies and practices that the U.S. Agriculture Community needs to thrive, stay globally competitive, and ensure that the U.S. agriculture supply chain is safe and secure.

Row Crop and Broad Acre Farming

Row crop and broad acre farming involve operations that rely on self-propelled equipment (e.g., tractors and irrigation equipment). Large-scale corn, soybean, sorghum, cotton and wheat farmers—who use equipment for planting, irrigating, protecting, harvesting, transporting, and storing large amounts of product—were among the first adopters of precision agriculture technologies and connected machines.

Precision agriculture has brought many benefits to these farms. For example, with a combination of GPS guidance and computer vision, tractors can operate across large tracts of land while ensuring precise and accurate field management. Harvesters and offloading systems, both equipped with sensors and machine-to-machine communication, are able to work in tandem by communicating how much is being harvested and the capacity of the offloading system to the operations manager in real time. This work has traditionally been done manually, but the introduction of automation has allowed this work to be done more cost-effectively and efficiently, reducing labor and harvesting costs over the long-term and preventing wasteful grain spillage. As newer connected machines gain access to greater broadband speeds and capabilities, these farming operations will continue to gain additional cost and resource efficiencies.

Through the use of connected machines, agricultural activities (such as soil preparation, planting, crop protection, and harvesting) can be executed while farm managers remotely monitor metrics for job progress and quality. This connectivity can enable just-in-time refueling, refilling of products, and fleet management for optimal execution throughout the day and season. Additionally, the performance and quality of the job can be monitored for possible improvements through the tracking of key metrics, such as seed singulation, grain quality, and grain losses. If parameters fall outside a specific range, alerts are sent wirelessly from the machine to support staff, allowing them to improve the settings of the machines during the operation, sometimes even remotely.

Additionally, remote monitoring of stored commodities after a harvest can improve product quality through continuous monitoring of temperature, moisture content, and carbon dioxide. These systems use collected data, environmental sensors, and commodity-specific algorithms to control aeration systems that maintain or improve the quality of the stored commodity. Broadband connections and cloud-based systems allow efficient real-time access to inventory and markets. This data can be accessed remotely from multiple locations and devices. Access to real-time data allows sales, trades, and shipments to be made in the most cost-efficient, timely, and profitable manner for the operation.

In addition, given the high variability in field characteristics, weather patterns, and crop inputs for production, the utilization of near-real-time information to make decisions on how to adjust the seasonal plan or the plan for next season can make the difference for strong output and overall sustainable profitability. For example, producers can use this information to analyze the performance of this season's crop and make decisions on fertilizer and seed selection for both the current crop and next season's crop from the seat of a harvester. For agriculture operations without access to the required connectivity, producers must either wait until the end of the day when they can manually transfer downloaded information to their trusted advisors or until after the year's harvest is completed. Accordingly, connectivity that supports precision agriculture can be transformative for row crop and broad acre farming.

Dr. Wesley Porter, University of Georgia, professor of Precision Agriculture and Irrigation, shared his thoughts on workforce inefficiencies in broad acre farming with the Connectivity Needs working group. Dr. Porter described common pain points caused by lack of connectivity during the retrieval of data from production practices and stressed the need for advanced data analysis of field conditions and the ability to process data in real time on field equipment to make production decisions.

Due to the lack of broadband access, it is common for farmers to carry a mobile Wi-Fi device during farm operations to connect precision agriculture devices through their mobile phone for data transfer or GPS correction for agricultural vehicles. Dr. Porter expanded on issues caused by limited-to-no broadband access. Many sensors used for irrigation scheduling need to collect data, and machinery sensors collect production data at a high rate, which can be valuable to producers for making in-season decisions. "This data needs to be updated frequently to be of use—thus, having access to connectivity at the farm level would be optimal."

Dr. Porter also highlighted the benefits that precision agriculture can have on workforce productivity and operational cost reduction. First, traveling to multiple sites to manually collect data consumes hourly labor and fuel—in some cases, people will need to travel as far as 150 miles one way. Second, it costs approximately $25 per month per soil moisture sensor to transfer the data from the field to the cloud on a daily basis. Dr. Porter stated, "In a typical field, three sensors are usually utilized, so this would cost $75 per month per field." Typically, the sensors are installed for 5 to 6 months per year, costing up to $450 per year per field for data management. However, Dr. Porter added, "Sensors can have cost savings of up to $20 per acre when properly utilized."

Livestock

Livestock farming has very different requirements than row crop and broad acre farming, as animals generally require higher levels of care than crops. For example, the dairy industry has embraced smart machines and sensors to help monitor the amount of feed consumed and the quantity of milk generated at an individual animal level. This, combined with sensors to track key indicators of animal health, has allowed for significantly improved milk production and has greatly increased animal health and welfare. Infections and other health issues can be identified early by smart machines and animal health sensors, allowing for treatment with minimal impact to both the animals and milk production. These same capabilities scale well to large operations, where a cow or another animal may go days without human interaction. These systems also generate large amounts of data that must be gathered and processed on a regular basis to identify animal-level trends, which requires high-speed broadband connections.

Robots are also used in the livestock industry. For example, robots that function 24 hours a day can enable cows to come and go from automated milking machines for a more natural and self regulated low-stress environment, improving milk quality and quantity. These robots perform pre- and post-milking cleaning activities every time the animal is serviced, ensuring that industry cleaning standards are met and documented at every servicing.

Tracking movement, behavioral, and biometric data from livestock via sensors feeding real-time information systems gives farmers access to precise data, allowing them to better pinpoint which animals may need specific attention or care. Once activated, control and tracking systems report the data to the cloud at regular intervals for big data analysis and access by livestock managers on a dashboard.

In addition, new tools integrate big data solutions into livestock management to help producers increase sustainability and profitability through wireless communications-enabled devices that work with scale systems to automate the feed delivery process. This allows livestock managers to track every pound of feed delivered to manage inventory and farm costs. Accordingly, connectivity to utilize precision agriculture for livestock is critical on many fronts, including the health and welfare of the animals.

Table 2 provides examples of how precision agriculture meets livestock needs today.[15]

Table 2. Precision Agriculture Livestock Activities by Relative Bandwidth

Livestock Type	Low* • Less than 512 kbps DL • Less than 128 kbps UL • Latency greater than 100 ms	Medium* • 5 to 25 Mbps DL • 1 to 5 Mbps UL • Latency 50 to 100 ms	High* • 25 to 100 Mbps DL • 5 to 20 Mbps UL • Latency less than 50 ms
Meat/Beef			
Free-range grazing	• Estrus detection	• Activity monitoring • Rumination/Grazing (research focused)	• Body scanner
Feed lots	• Activity monitoring • Movement monitoring (time and distance/proximity to feed bunk)		• Automated BCS scores • Feed intake
Dairy			
Replacement calves	• ID tags, birth weight, calving ease	• Vet data, pedigree, records, automated calf feeding	
Production cows	• Productivity (lbs. of milk)	• Robotic systems (fat/protein content), health, rumination monitoring (accelerometer, etc.) • Carbon monitoring	• Automated BCS scoring, eating and rumination monitoring using AI/ML, remote health/vets, and remote nutritionists
Dry cows	• Estrus monitoring		• Feed monitoring
Milk monitoring	• Bulk tank monitoring • Milk transport		

[15] Speed and bandwidth criteria developed from the following sources: Ericsson, Fierce Summer Blitz 5G and Fixed Wireless Opportunity, Aug. 03, 2021, Ericsson Mobility Report, 2021, Ookla, United States Mobile and Fixed Broadband Internet Speeds, 2021

Livestock Type	**Low*** • Less than 512 kbps DL • Less than 128 kbps UL • Latency greater than 100 ms	**Medium*** • 5 to 25 Mbps DL • 1 to 5 Mbps UL • Latency 50 to 100 ms	**High*** • 25 to 100 Mbps DL • 5 to 20 Mbps UL • Latency less than 50 ms
Poultry			
Layers	• Climate control	• Audio monitoring for chicken health	• Multiple cameras for live monitoring
Swine			
Gestation			• Genomic research
Farrowing/Nursing	• Temperature and climate monitoring	• Feed intake	• Lactation feed monitoring
Growing & Finishing		• Precision feed management	• Health monitoring
Aquaculture			
Salmon		• Acoustic feed monitoring	• Video feed monitoring • Drones for tracking

* *Speeds are measured per device. Most agricultural producers use many of these devices on a single Internet connection.*

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Specialty Crops

Specialty crops—such as vegetables, fruits, nuts, and other nursery crops—are often delicate products or high-density crops that rely on a large labor force and various types of connectivity technologies for management and harvesting. Irrigation has been a key requirement for these crops to be successful. Historically, large swaths of land and rows of specialty crops would need to be watered at the same time. However, precision agriculture can bring a higher level of accuracy to the management of these often-sensitive crops. For example, sensors contained in smart machines can monitor soil moisture at the plant level. Routine checks of pressure variation in leaves and ambient temperature can ensure that crops are optimally hydrated and water is only consumed when needed. With this information, smart irrigation systems can determine when to start and stop watering much smaller sections of crops. More efficient irrigation is also a useful method of water conservation and can assist when areas of the country are facing a drought, such as what the western United States is currently experiencing. This level of detail can only be achieved when sensors and control systems can communicate on a regular basis. Moreover, precision agriculture use cases can be fully unlocked with the availability of high-band, ultra low-latency networks to support mission-critical services and Low-Power Wide-Area. Network (LPWAN) satellite-based or low/mid-band spectrum to support massive Internet of Things (IoT) sensors.

Combining data from radar networks (temperature, precipitation, wind speed, and humidity) and a multitude of property-type sensors can inform not only irrigation but also pest and disease prevention, predictive analytics for crop loads, and inventory management. Specialty crops grown in tightly controlled areas, including vertical greenhouses, rely on IoT sensors and 2 way devices to monitor and control greenhouse climate and increase crop cycles annually (up to 12 per year), including decision support for times to plant, distribute nutrients, provide prescriptive maintenance, and harvest. Deploying computer vision and sensors indoors (e.g., vertical greenhouses) and connected with equipment decreases repair costs, extends equipment life, and can result in multi-billion-dollar savings to U.S. farmers.

The deployment of smart and autonomous machines that incorporate sensor technologies, analytics platforms, and access to third-party data sources can greatly improve performance efficiencies, yields, and inventory management while avoiding spoilage losses. With many fruits decaying 10% per hour in sunlight, decisions on picking, transport, and storage must be made in real time. During production, these integrated platforms can drive decisions based on weather, disease, insect population, moisture density, and ripeness, triggering smart systems and robots to maximize the harvest of precious fruit at the point of demand.

In the near future, machines and robots will have greater value creation potential in the United States versus less developed regions as broadband or mid/high-band connectivity and next generation machines become generally available. For example, autonomous machines operate fewer hours when compared to human-operated machines; therefore, they will consume less fuel and require fewer maintenance events.

There are many machine-learning and robot solutions for the fruit industry that rely on real-time data, necessitating reliable connectivity. Machine learning can be used to identify and measure the ripeness of fruit with 3D modeling to track harvest progress. Robots using software for fruit identification and classification can reduce fruit decay by reducing the hours fruit spends in the sun before shipping. Paired color and stereo cameras can be used to locate ripe fruit and follow the harvesting process with an autonomous ground robot with a fruit sucking vacuum in real time. Computer vision with sensors can also be used for harvesting by guiding a robot arm to the position of the detected fruit without damaging the tree or bruising the fruit at the point of harvest.

Robotic components are also used to remove leaves from harvested fruit. Once picked and sorted, decision-support systems assist in proper storage to minimize fruit decay and determine the optimal time to transport the product to cold storage. These real-time decision-support systems not only track inventory but can also include fleet management analytics to assist in conducting cost-benefit analyses of sending a partially or fully loaded truck to cold storage. Sensors in shipping containers provide quality assurance by sending alerts for temperature and pressure changes. Holistically, proper connectivity can enable fee-based agritech solution providers to offer technology and data packages to farmers seeking to reduce risk and initial capital outlay while increasing yields and profits.

In the nursery sector, robots are being used effectively to automate transplanting of seedlings into larger pots, to move plants across conveyers to be scanned by sensors to assess health and apply treatment if needed, and to space out plants so they have room to grow. These tasks are tremendously tedious and perfect for robots; however, these robots require broadband or mid/high-band connectivity to access centralized data to effectively evaluate the large variety of crops at a nursery. Autonomous ground robots can be used to scan and assess the current opportunity to harvest specialty crops from the greenhouse to the fields. This includes cameras and sensors linked to learning software. From a preventive maintenance standpoint, weeding robots use intelligence to evaluate between weeds and plants before taking action.

Tracking and inventory are critical for all specialty crops. In the nursery sector, thousands of plants can be moved at any given time. Tracking these movements at the plant level can help optimize product movements. In both nursery and fruit and vegetable areas, inventory management of product at its various stages can be critical to support destination markets, such as big-box chains, in maintaining inventory.

This is especially challenging due to the huge variety of plants produced. We have also begun to see an increase in these sectors of integration with direct-to-consumer demand. Both destination markets and direct-to-consumer demand can provide critical alerts to the farms on when to pick or harvest. This level of tracking can also track product attributes back to the farmland for regulatory, imagery, and reporting purposes. Moreover, data input can be used for Community Supported Agriculture (CSA), week-to-week buyer demand, and supply availability on e-commerce platforms.

Farmers also seek reliability and a better digital experience in their own buying journey, as 57% prefer a smartphone or tablet to research and purchase products, and 45% who do not purchase online say they will consider it in the future.[16] Accordingly, connectivity to support precision agriculture is a key requirement for the success of specialty crops.

[16] McKinsey Chemical & Agriculture Digital Customer Decision Survey, 2018

Table 3 shows the requirements for communications technology in terms of speeds for different aspects of specialty crop farming.

Table 3. *Precision Agriculture Specialty Crop Activities by Relative Speed*

Bandwidth	Low * • Less than 512 kbps DL • Less than 128 kbps UL • Latency greater than 100 ms	Medium * • 5 to 25 Mbps DL • 1 to 5 Mbps UL • Latency 50 to 100 ms	High * • 25 to 100 Mbps DL • 5 to 20 Mbps UL • Latency less than 50 ms
Fruit/Nut Trees			
Weather Modeling	Bioimpedance sensors, meteorological sensors, moisture sensors, temperature sensors, and rain gauges		3D digital surface models with Unmanned Aerial Vehicle (UAV)/satellite and use of object-based image analysis techniques
Machine Learning and Visioning	Dendrometers, photometric sensors, photosynthesis sensors, leaf area index sensors, and accelerometers	Fruit grading QA/QC platforms and optical sensors (hyperspectral, multispectral, fluorescence, and thermal) and field data analytics for fertilization	High-resolution imaging sensors with computer visioning to capture the amount of light energy released by a plant and precision controls for vehicle-to-vehicle connections
Outdoor Smart Irrigation	Chlorophyll meters, biological sensors, hygrometers, temperature sensors, and Micro-Electromechanical System (MEMS) sensors	Water content and irrigation management system	Gateway appliance to support aggregate data from smart sensors to the cloud
Robotic Harvesting	MEMS, navigation/obstacle sensors, Leaf Area Index (LAI) sensors, GPS, position sensors, and accelerometers	Range finders and optical cameras	Image processing (vision sensors/LiDAR) and algorithms for picking, automatic harvesting (fruit detection, location detection, and the physical harvesting equipment to grasp and detach fruit from the plant), UAVs and imaging, Robotics and Autonomous Systems (RAS), and Convolution Neural Network (CNN) for analyzing visual imagery

Bandwidth	Low * • Less than 512 kbps DL • Less than 128 kbps UL • Latency greater than 100 ms	Medium * • 5 to 25 Mbps DL • 1 to 5 Mbps UL • Latency 50 to 100 ms	High * • 25 to 100 Mbps DL • 5 to 20 Mbps UL • Latency less than 50 ms
Vegetables			
Frost Detection	Temperature sensors, leaf wetness sensors, and airflow sensors	Gateway appliance (point-to-multipoint, and low-power sensors)	
Pest Prevention	Weed seekers, chemical analyzers, microorganism sensors, and position sensors	Pest and disease image sensors and low-resolution image sensors for assessing crops across a large area	Point-to-multipoint aggregation, drone surveillance, and image analysis for pest prevention
Ground Harvesting	MEMS, navigation/obstacle sensors, GPS, and position sensors	Range finders	Navigation using RAS, autonomous ground vehicles, and CNN for analyzing visual imagery with single-shot multi-box detector
Ground Input Use and Management	Various property-type sensors and MEMS	Data-driven decision support systems, optical cameras, and nutrient distribution equipment	Gateway appliance to support aggregate data from smart sensors to the cloud
Nurseries/Greenhouses			
Indoor Smart Irrigation	Water probes, meteorological sensors, moisture sensors, and airflow sensors	Evapotranspiration (ET) controllers and two-way communication from local weather data to adjust irrigation schedules	Gateway appliance to support aggregate data from smart sensors to cloud
Food Waste Management	Biosensors (chemical/gas), level sensors, microorganism sensors, and blockchain	Applications to analyze vegetative health and integration with direct consumer	Image sensors and RAS

Bandwidth	Low * • Less than 512 kbps DL • Less than 128 kbps UL • Latency greater than 100 ms	Medium * • 5 to 25 Mbps DL • 1 to 5 Mbps UL • Latency 50 to 100 ms	High * • 25 to 100 Mbps DL • 5 to 20 Mbps UL • Latency less than 50 ms
		demand to know when to pick	
Storage Monitoring	Temperature sensors, pressure sensors, and level sensors (silos)	Gateway appliance to support aggregate data from sensors from cold storage, supply chain management platforms imagery, and fleet management and reporting tools	Autonomous ground vehicles (real-time picking and fruit decay management)
Building Management	Sensors to monitor mold, smoke/fire, and other indoor threats	Aggregate of controls/sensors for preventive maintenance on assets and real-time environmental adjustments	

* *Speeds are measured per device. Most agricultural producers use many of these devices on a single Internet connection.*

In reference to **Table 3**, above, today's more readily available low-powered IoT networks solve for farm coverage but are unable to support many edge applications, including imagery transfer between devices and autonomous imagery analysis. 5G or other mobile broadband services must be made available to support these use cases. Solving for device density and capacity can result in an impact of over $100 billion (global) by 2030 across precision agriculture technology categories of smart crop monitoring, drone farming, autonomous farming machinery, and smart building management.

Conversely, forestry is another important form of specialty crop agriculture. The traditional cycle for most agricultural practices falls under a 12-month cycle. Forestry cycles typically range from 10 to 50 years—sometimes even longer. Forestry measurements today are typically acquired via drone (to measure the canopy) and a human walkthrough under the canopy. Both data sets are then merged to produce a point-cloud of the forest. This composite data set enables foresters to establish an inventory of trees with key quality measurements. For typical forest production needs, broadband coverage is essential at headquarters where data from above and below the canopy can be uploaded and processed with specialized hardware, typically GPU-based processing systems, to generate aggregate data. This practice requires bandwidth like a farmhouse, where greater download and upload speeds are necessary to transmit significant amounts of data. Therefore, it is critical to raise the bar significantly on both ends with a better balance between download and upload.

However, forest management practices require a different type of connectivity. General forest management practices focus on monitoring extremely broad acres, typically in the thousands of acres per forest. While the forest service leverages satellite imagery for much of their work, they also maintain thousands of sensors across managed forests to monitor basic weather conditions and, more importantly, detect fire. The deployment of these sensors is similar in nature to the need for low-speed but extremely broad coverage areas to enable sensors equipped with antennas above the canopy to transmit data back to monitoring stations, such as the Remote Sensing Applications Center (RSAC). The ability to identify and assess basic characteristics of forest health and a fire early on is key to effectively managing limited firefighting resources. Low speed coverage over the United States' forested lands could enable the deployment of additional sensors to assist the federal government with identification and risk management, potentially leading to millions of dollars of savings to the U.S. economy and residences due to reduced fire damage.

Communications Technology Overview

With the advancement of terrestrial and non-terrestrial wireless technologies, we are beginning to have actual experience with the potential of what precision applications can deliver to the Agriculture Community. However, the lack of connectivity to much of our agricultural lands has a detrimental impact on the Agriculture Community and the surrounding areas. While the technology is available today for connectivity, the United States[17] must focus on how to expand the level of connectivity and its geographic coverage, which is required to support the demands of the Agriculture Community for precision agriculture, no matter how rural or remote the location.

For years, rural America, including the Agriculture Community, has suffered from poor broadband connectivity, resulting in an inability to adopt technology. COVID-19 has amplified these struggles. Many of the latest yield-maximizing farming techniques require broadband connections for data collection and analysis performed both on the farm and in remote data centers. However, 25% of U.S. farms have no access to the Internet, according to a USDA report. Where connectivity allows, farmers and ranchers have embraced technologies that allow their farming businesses to be more efficient, economical, and environmentally friendly.[18]

Data and Bandwidth

The Agriculture Community requires both broadband and narrowband connectivity. Initially, there are two types of broadband coverage that are necessary to increase the adoption of precision agriculture equipment and practices:
1) low-speed, broad coverage and
2) high speed, high throughput and targeted coverage.

These two connectivity profiles work together to enable sensor data aggregation fused with decision-support systems that can issue commands into the field, providing for detailed data-gathering and initial automation capabilities.

Currently, the FCC defines advanced telecommunication capability as 25 Mbps download and 3 Mbps upload speeds, which is an asymmetrical profile. The infrastructure funding legislation, passed by in the U.S. Congress on November 5, 2021, the Infrastructure Investment and Jobs Act of 2021, would fund broadband at 100/20 Mbps speeds for download and upload respectively. At this time, symmetrical download/upload should only be considered for broad application terrestrial wireline networks, as symmetrical standards are currently technically impractical for wireless technologies. Higher-bandwidth activities typically carried out on a farm include

[17] Food Security and Nutrition Assistance 2020 (Sept. 2020, U.S.D.A. Economic Research Service, contact: Morrison, RM).
[18] Farm Computer Usage and Ownership 2019 (Aug. 2019, USDA, National Agricultural Statistics Service).

equipment system updates and troubleshooting, the uploading of large data sets obtained from autonomous vehicles, and the viewing of large data sets. Pushing for a higher standard and continually raising the bar improves the utilization of precision agriculture practices and sustainability of U.S. farm production.

In addition, the Agriculture Community requires narrowband voice and data. This traffic can be carried on a low- or higher-latency basis. This is an important form of connectivity because a fair amount of traffic from field base sensors requires low data speeds per device.

In the future, as increased bandwidth becomes available with lower latency across a wider coverage area, we expect to see equipment that is able to stream vast amounts of data it generates, allowing for faster decision-making than the acquire, return to home, and upload processing methods in use today.

We cannot wait to begin the adoption of precision agriculture equipment and techniques until high-speed connectivity across all agricultural lands can be achieved.

Significant progress can be made with current technologies and those that will be deployed in the near term by leveraging low speed, higher-latency connectivity across agricultural lands, with high-speed connections targeted at agricultural operation centers. Each geographic area has unique challenges to meet, and there is no one-size-fits-all approach to supporting the Agriculture Community's adoption of precision agriculture—but without connectivity, precision agriculture's value is low, and so will be its rate of adoption.

Spectrum

The lifeblood of wireless connectivity is spectrum, which can have different technical characteristics. Lower-band spectrum is ideal for many agricultural applications using terrestrial wireless technologies. At the lower frequencies, transmissions travel much farther and propagate very well through crops and canopies. This leads to two key benefits. First, fewer sites are needed to cover a region. Second, the battery life of devices increases so that they can reach the same distance at a lower transmit power, reducing the labor and expense needed to recharge devices.

The FCC has demonstrated leadership in enabling regulations for dynamic spectrum sharing, in the Citizen Broadband Radio Service (CBRS) and TV White Space (TVWS) spectrums. The TVWS spectrum is especially beneficial for precision agriculture because TV towers are typically in cities, meaning that many TV channels are unused and available for farms in rural areas. Because each TV channel is 6 MHz wide and there are typically 20 or more channels in rural areas, a large amount of bandwidth is typically available for precision agriculture applications. TVWS also exists in the lower frequencies and provides very favorable propagation characteristics.

Dynamic spectrum sharing is a trailblazing step that opens up several new scenarios for precision agriculture. Additional policies can help increase the adoption of broadband spectrum and devices for agricultural applications. Geofencing farms to allow for more flexible use of spectrum in the farm can drive innovative applications. For example, a single tower might be able to provide coverage to the entire farm, the base station would be able to communicate with diverse devices, and satellite-to-terrestrial relays could lead to innovative connectivity solutions. The appropriate spectrum could be used for each application.

Spectrum is essential for non-terrestrial technologies, as well. Today's high-throughput broadband geostationary satellites rely on bands in the millimeter wave frequency, as do the planned mega-non-geostationary orbit constellations. These systems can be used for backhaul for terrestrial systems and direct-to-the-farm communications. For these systems to be able to support the needs of the Agriculture Community, the FCC must ensure that adequate interference free spectrum is available for these uses.

The Possibilities for the Future

Precision agriculture is evolving rapidly and offers many benefits both on and off the farm in rural communities. Growth of precision agriculture ecosystem through innovation and expanded access to connectivity, will allow these benefits to increase exponentially. Many of these technologies rely on fast network speeds with low-latency to process data quickly and return a result. We expect these technologies to begin their adoption in centralized locations where fast network connectivity is available. We are beginning to see some of these technologies deployed on field equipment with the added burden and cost of the computing power necessary to process generated data. This model is similar to early personal computer models, which required significant support and maintenance for basic operations. Compare this model to the smartphone, which has limited processing storage and relies on the power of connectivity to quickly and efficiently deliver constantly evolving and improving service with minimal effort from users. The smartphone model is what we envision for many precision agriculture tools, which relies on an ever-evolving connectivity layer to keep up with agriculture demands.

Computer Vision/Machine Learning (CVML) and Smart Machine Technology

With the advent of high-performance computing, new techniques in development (such as advanced algorithms, robotics technologies that actuate algorithmic outcomes in milliseconds, CVML, and smart machine technology) hold significant promise for improving agricultural productivity and environmental sustainability. However, in order to adequately train a computer to recognize images and drive actuation rapidly, a significant amount of data must be captured, processed, and labeled. It is estimated that hundreds of thousands to millions of images are required in order to create a system robust enough to provide value to producers.[19] In practice today, these images are captured by humans or machines deployed throughout the rural area. The data is stored on hard drives and either transferred via overnight delivery or via the rural broadband environments where connectivity can be found, albeit greatly restricted by the speed at which large volumes of data can be transferred. The lack of connectivity impedes the speed of the machine learning process, which in turn inhibits producers from gaining value from this technology in their operations. However, as systems are deployed in a commercial setting with higher-speed connectivity, these systems will have the ability to capture more images, transfer them wirelessly for analysis, and ultimately make the machine learning model more robust and able to perform better over time.

In a study combining computer vision and deep learning for phenotypic analysis of lettuce, the AirSurf-Lettuce open source platform was found to be capable of scoring and categorizing iceberg lettuce with very high accuracy (>98%). Furthermore, novel analysis functions have been developed to map lettuce size distribution across the field based on which tagged harvest subregions (tagged by GPS) have been identified. This enables farmers to implement precision agriculture practices to improve the actual yield and crop marketability before the harvest.[20] It is important to note that the multispectral images used to feed this model were 1.5–2 GB per

[19] Davis, T. and Murphee, J., It's Time for Solid Rural Broadband Connections, Farm Bureau Viewpoints/Focus on Agriculture, August 5, 2020
[20] (Bauer et all, 2019).

image. At minimum, LTE 5G broadband speeds would be required to transfer these images for processing.

Using this as an example, we can demonstrate the effect of upload speed on the viability of precision agriculture tools and practices. If we take a small area of coverage from the above example—say, 10 pictures that amount to approximately 20 GB of data to transfer—we can chart the time it will take to move this data for processing and action.

Upload Speed	Time to Upload
3 Mbps (current broadband standard)	0 days, 15 hours, 54 minutes, 26 seconds
14 Mbps (current average mobile download speed*)	0 days, 3 hours, 24 minutes, 31 seconds
20 Mbps (proposed wireless standard)	0 days, 2 hours, 23 minutes, 10 seconds
100 Mbps (proposed wireline standard)	0 days, 0 hours, 28 minutes, 38 seconds
1 Gbps (future expected wired standard)	0 days, 0 hours, 2 minutes, 52 seconds

* https://www.speedtest.net/global-index/united-states

Labor is a significant expense in agriculture, and waiting for technology to process something is a waste of resources. Upload speeds are critical to the adoption of precision agriculture tools.

Unmanned Aerial Vehicles (UAVs)

UAVs can enable the Agriculture Community to see in great detail how the land is structured, monitor crop and livestock health, and track how external factors such as weather are impacting outcomes over time. These systems use satellites to guide their flight path and interconnect to the public Internet. They gather a large amount of geo-referenced data that can be used to make day to day decisions on what actions the producer should take to improve productivity. With connectivity, this data can be sent to cloud-based analysis tools for processing and recommendations on actions to take next. If connectivity is non-existent, slow, or unreliable, decisions are delayed, and outcomes related to actions taken are diminished, due primarily to the lag in time between data capture and executing the decision. The lack of ability to act in a timely manner undermines the effectiveness and impedes the adoption of these technologies. The certainty of taking the right action at the right time further declines due to the variable nature of weather and other factors that impact agriculture every day.

Autonomous Systems/Robotics

Similar to the technologies in computer vision, machine learning, and smart machines, this technology relies heavily on the capture, processing, labeling, and training of computer algorithms with large amounts of data. However, this technology is distinctly different, in that the system will have the ability to execute without human oversight nearby. To achieve this, the system must have a high-speed, low-latency, and highly reliable connectivity infrastructure.

Current autonomous systems still require a fair amount of human oversight. Faster connectivity will drive improvements to the point where human monitoring of the machine will be limited to either recognition of an obstacle or specific job execution parameters being out of specification. Agricultural practices and processes require large investments on the part of the producer, and mistakes can lead to total crop failure and large business impacts. The ability of autonomous systems to adequately report back to farm managers is essential and relies on connectivity as a mission-critical enabler of system performance and health.

A typical topology for a robotic fleet requires a master external computer connected to the fleet units through a wireless communication system that runs a mission manager (mission planner and mission supervisor) that sends commands to and receives data from the fleet mobile units.[21]

[21] AirSurf-Lettuce: an aerial image analysis platform for ultra-scale field phenotyping and precision agriculture using computer vision and deep learning, 2019, Bauer et al. (January 2019); available at: https://www.biorxiv.org/content/10.1101/527184v1

Table 4 provides examples of the opportunities that Robotics and Autonomous Systems (RAS) could enable and the benefits associated with their deployment for U.S. producers in various sectors of agriculture.

***Table 4.** Benefits to the Agriculture Community of Highly Automated and Autonomous System Adoption*

Opportunity	Benefits
Weed from plant ID and actuation on only weeds	• Reduces herbicide usage by 50–90%, with associated cost savings • Reduces environmental impact footprint from spraying operations
Nitrogen deficiency or adequacy in crops	• Improves yields/output • Optimizes use of nitrogen within the field where a yield response is most likely • Improves nitrogen management practices (right source, right amount, right place, right time) that favorably impact the environment
Early pest and disease ID and actuation in the area of issue	• Improves yields/output • Reduces use of crop protection products in season and enables more precise application only in areas where needed (versus broadcast application)
Autonomous machines executing agricultural tasks	• Aids in agricultural productivity where limited skilled labor can be allocated to other tasks • Allows for farming around the clock during narrow task execution windows • Creates potential for smaller robots to do more on farms, reducing soil compaction
Self-optimization of equipment systems	• Reduces the need for highly skilled labor in difficult environments and minimizes downtime associated with maintaining equipment and system performance at the highest level possible
Phenotyping of livestock or crops	• Improves resiliency of next-generation breeding processes for adapting to environmental condition changes

Benefits of connectivity to farming and the agriculture ecosystem ensuring connectivity to improve precision agriculture will advance the country's goals for addressing food security and food scarcity. Direct benefits could include greater efficiency in farming operations, greater productivity to meet growing demand, improved economics for the individual farmer, improved supply chain management, and improved health and welfare of livestock.

Agricultural emissions are a measurable contributor to climate change. Using tools such as sensors and drones that can measure emissions and transmit data over broadband, farmers can estimate Greenhouse Gas (GHG) emissions and adopt practices to minimize them.

Agriculture can also be a potential solution to climate change. Farm management practices, such as no-till or reduced till, cover-cropping, and nutrient management, which are also referred to as regenerative agriculture practices, can lead to an increased amount of carbon in soil. Farmers can financially benefit through initiatives such as the Carbon Bank being proposed by the USDA or by selling carbon credits in a climate exchange. However, connectivity is key for a farmer to practice regenerative agriculture and benefit from the carbon exchange. Growers need to understand the impact of choosing a specific regenerative farm management practice and need to be connected to trade carbon credits in the market. The latest advances in carbon markets require cost-effective Measurement, Reporting, and Verification (MRV) schemes, which require affordable broadband Internet access.

There are also significant indirect benefits that we can expect to see as connectivity becomes more accessible for farmers and the rural communities where they are located. These benefits include:

- Decreased population flight from rural communities;
- Improved rural economic opportunities, including through the development of technology that is supporting businesses and services;
- Improved ability to deliver healthcare and education through telehealth and tele education;
- Greater civic engagement through e-government platforms;
- Increased access to goods and services not available in rural communities;
- More equitable access to online resources; and
- Improved environmental monitoring of low-income and disadvantaged communities near agricultural lands.

It is important to note that solving rural connectivity does not solve for agricultural connectivity needs; however, *solving for agricultural connectivity should include and solve for rural connectivity needs.*

Benefits for Food Scarcity and Security

As previously noted, precision agriculture and its enabling connectivity is critical to food security in the United States, including strengthening the nation's food supply chain. It is estimated that 30–40% of food is currently wasted due to poorly operated food supply chains.[22] With more effective inventory tracking and logistics beginning during production, the food supply can be better matched with demand to reduce waste. This will require broadband capabilities at all stages of the food supply chain to access the vast quantity of information necessary to track products. Increased access to better information across the food supply chain can improve decision-making and resource allocation and make up for the labor shortages and succession issues that have plagued the Agriculture Community.

In addition, precision agriculture can trace food contamination problems within seconds using blockchain enabled records.[23] Precision technologies that almost instantaneously pinpoint the source of food tainting will greatly improve the country's ability to respond to such events.

Lessons Learned from the COVID-19 Pandemic

Agricultural supply chains were heavily disrupted during the first few months of the COVID-19 pandemic. The longstanding business of supplying food to institutional customers, such as restaurants and educational facilities, nearly evaporated overnight. At the same time, direct demand from supermarkets, farmers' markets, and farmers rose as consumers prepared more meals at home. Suddenly, institutionally sized food packages had no market—packaging was needed that could go from the supermarket to the home refrigerator. Some food products, typically consumed in greater quantities in restaurants than in the home (e.g., mushrooms) initially saw demand vanish, and many farmers had to seek alternative markets for their livestock and crops.

The situation with farmers' markets and farmers who market directly is an interesting example of the benefit of improved Internet capability on the farm. As supplies tightened in supermarkets during the pandemic, consumers turned toward these alternative food sources.

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[22] https://www.usda.gov/foodwaste/faqs
[23] https://www.usda.gov/sites/default/files/documents/case-for-rural-broadband.pdf

This also occurred because consumers felt comfortable with the safety of these suppliers due to their face-to-face relationships. Farmers' markets saw growth increases, and farmers saw more interest in direct sales. As social distancing began to limit farmers markets, these groups turned toward creating online marketplaces to satisfy this demand.

For some farmers' markets and farmers, COVID-19 forced them into using the Internet to sell their products for the first time. They struggled with poor broadband infrastructure, knowledge gaps, and a lack of a consistent framework for modeling consumer-facing portals. Consequently, for consumers, there was a lack of consistency when shopping farm to farm. Along with improved connectivity to support farm direct sales, education on how to improve consumer/farmer online interaction would be most useful.

Community Benefits

Broadband connectivity directed at precision agriculture will result in many benefits for communities near farms and ranches. One benefit is improved broadband access for the surrounding residents, homes, and small businesses for telehealth, tele-education, and e-government, among other activities. The increased adoption of precision technologies, enabled by improved connectivity, will also spur new tech-based businesses in rural communities (and the associated training and education) to meet the rising demand for agronomic, data analytics, software, and computer support services. Further, by expanding broadband to agricultural communities, rural flight and the educational disparities between rural and suburban/urban areas, which has become so apparent during the COVID-19 pandemic, will likely decrease. Moreover, broadband connectivity is needed on farms to enable the students to learn and practice applying data driven technologies on the farm.

Farmer Quality of Life Improvements

Paul Harvey's famous 1978 speech to the Future Farmers of America (FFA) encapsulates the work ethic of agriculturists: "God said, 'I need somebody willing to get up before dawn, milk cows, work all day in the fields, milk cows again, eat supper, then go to town and stay past midnight at a meeting of the school board.' So God made a farmer." The farmer's workday is long and hard. Compounding these challenges for those that work the land is the fact that over 80% of farm family income now comes from off-farm sources. Farmers are working jobs elsewhere, often full-time jobs, so that they can feed the world as well as their families.[24]

Improvements in precision agriculture and rural connectivity can lessen the load on farmers and ranchers. Looking at Mr. Harvey's example, you will find that robotic technology can feed and milk dairy cows, precision guidance systems for farm equipment can reduce the hours spent in the tractor seat, and that school board meeting can be attended via videoconference, with the farmer not even needing to leave their home!

Farm Worker Safety Improvements

Farming can be a dangerous pursuit. Data from the Centers for Disease Control and Prevention (CDC) shows that every day, some 100 farm workers suffer a lost-time injury. In a recent year, more than 400 individuals died from farming-related injuries.[25] Precision agriculture and improved rural connectivity can help minimize these risks.

Efficiency improvements on the farm through precision agriculture can reduce the hours needed to tend crops and livestock, thus reducing accident risk caused by tiredness and distraction. Crops that require backbreaking labor to pick can now be harvested by intelligent machines. Farmers and ranchers operating in solitary situations can be remotely monitored by coworkers or family members in case an unforeseen accident occurs. Lastly, emergency medical assistance can be summoned by cellphone.

This means that robust and reliable wireless communication are required across our farmlands. With less than 2% of the U.S. population directly involved in agriculture, we need to protect this valuable resource.

Environmental Benefits Through Efficiencies in Agriculture Operations

Significant environmental benefits can be realized through precision agriculture. For example, precision agriculture-based fertilizer, soil, and water management can significantly reduce GHG emissions while often increasing yields and reducing production costs: a typical win-win. Broadband connectivity can help reduce agricultural emissions and fossil fuel use (e.g., from farms by precision application of fertilizer) and methane emissions from dairy. It can also help

[24] https://www.wsj.com/articles/to-stay-on-the-land-american-farmers-add-extra-jobs-1519582071
[25] https://www.cdc.gov/niosh/topics/aginjury/default.html

increase soil organic content by allowing growers to accurately collect and analyze real time data. This analysis can be used to determine appropriate farm management practices that provide the best possible financial and environmental outcomes.

In 2019, the USDA estimated that rural broadband connectivity is the driver of more than one third of the value (or $18 billion to $23 billion per year) that digital technologies could create across the country. Further, the USDA estimated that Variable-Rate Technologies (VRT) could lead to 40% less fuel consumed, 20–25% less water use, and up to an 80% reduction in chemical application. The precise placement of water, fertilizer, and chemicals on the farm will result in significant positive environmental benefits. The greatest scale of benefits can be achieved when technology is used—connected technology can provide even greater benefits.

It is estimated that fertilizer placement has improved 7% with precision agriculture and can improve an additional 14% with further agritech adoption.[26] Irrigation is also aided by precision agriculture, which can map fields and curve rows so that rainwater can be directed for natural irrigation. A study found that current precision agriculture adoption has decreased water usage

Five key environmental benefits were identified to be quantified as a result of P.A. technology adoption

	Productivity	Fertilizer Use	Herbicide Use	Fossil Fuel Use	Water Use
Direct Outcomes *(quantified)*	• Yield benefit from accurate spacing (pass-to-pass, end/point rows) and population rate	• Optimization of fertilizer applications (reduced overlap, avoid skips, best placement and rate of inputs)	• Optimization of herbicide applications (reduced overlap, avoided skips, best placement and rate of inputs)	• Fuel savings from fewer field passes, variable depth of tillage, and/or more efficient harvest	• Application of water avoided due to remote shutoff of center pivots, along with selective application
Indirect Outcomes	• Avoid unproductive/ preserved land from being in production • Reduced soil compaction	• Improved water quality (reduced nutrient runoff) • Improved soil health • Net GHG reduction (including in production of inputs)	• Improved soil health, and reduced erosion through less tillage • Net GHG reduction (including in production of inputs) • Improved water quality • Reduced weed resistance development	• Net GHG reduction	• Improved water quality through reduced runoff • Less energy use by running pumps fewer hours

[26] https://www.usda.gov/sites/default/files/documents/case-for-rural-broadband.pdf

in agriculture by 4% and that an additional 21% reduction could be realized at full adoption of precision agriculture across the country.[27] These examples are from one vertical under broad acre farming. Imagine the gains possible across all agricultural practices.

These sustainability benefits are significant and offer a real public good to rural communities, the country, and the world. These gains can be realized only if policies that promote broadband infrastructure investment necessary to support the adoption of these technologies are recognized and addressed.

Cybersecurity and Data Privacy

As precision agriculture adoption rates increase, so will security threats to the confidentiality, integrity, and availability of precision agriculture technology and information management systems. The Agriculture Community and its vendors must commit to information security standards and implementation to protect this rapidly advancing technology. Technology providers should be working to ensure they meet the National Institute of Standards and Technology (NIST) standards and other relevant industry-driven requirements. We must also recognize that many small farms do not employ IT professionals, so implementation of best practices needs to be straightforward, and security tools must be embedded in technology.

Additionally, privacy concerns continue to be significant, as recognized by the Department of Homeland Security (DHS) in its 2018 Report on Threats to Precision Agriculture.[28] These threats include, but are not limited to, intentional theft of data collected through Decision Support Systems (DSS) or the unintentional leakage of data to third parties; intentional publishing of confidential information from within the industry, such as from a supplier to damage the company or cause chaos; and foreign access to Unmanned Aerial System (UAS) data. The farming community is urged to adopt baseline controls, such as those identified in the above referenced DHS report, and industry best practices to prevent data breaches.

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[27] "The Environmental Benefits of Precision Agriculture in the United States," AEM, ASA, CropLife America, National Corn Growers Association, at 15 (2021) (https://newsroom.aem.org/asset/977839/environmentalbenefitsofprecisionagriculture-2#.YBdQZR2Lc74.link)

[28] Threats to Precision Agriculture (dhs.gov)

Wildland Fire Risk Mitigation

The broadest benefit to the U.S. economy of precision forestry is risk mitigation and early fire detection and assessment. **Table 5**, from the Bureau of Land Management, breaks down the costs incurred by specific wildland fires. The "Other Direct Costs" column includes property losses and all claims submitted to federal agencies following the fire.

The costs of wildland fires are real and significant. If more agricultural lands and wildlands are provided with at least low-speed connectivity, we could support additional fire monitoring stations to promote early detection and enable improved risk assessment and communication

Table 5. Wildland Fires and Associated Costs[29]

	COST CATEGORY							
FIRE	Suppression Costs	Other Direct Costs	Rehabilitation Costs	Indirect Costs	Additional Costs	Total Costs	Total / Suppression	Suppression / Total
Canyon Ferry Complex (MT 2000)	$9,544,627	$400,000	$8,075,921	$55,310	n/a	$18,075,858	1.9	53%
Cerro Grande (NM 2000)	$33,500,000	$864,500,000	$72,388,944	n/a	n/a	$970,388,944	29.0	3%
Hayman (CO 2002)	$42,279,000	$93,269,834	$39,930,000	$2,691,601	$29,529,614	$207,700,049	4.9	20%
Missionary Ridge (CO 2002)	$37,714,992	$52,561,331	$8,623,203	$50,499,849	$3,404,410	$152,803,785	4.1	25%
Rodeo-Chedeski (AZ 2002)	$46,500,000	$122,500,000	$139,000,000	$403,000	n/a	$308,403,000	6.6	15%
Old, Grand Prix, Padua (CA 2003)	$61,335,684	n/a	$534,593,425	$681,004,114	n/a	$1,276,933,224	20.8	5%

to potentially affected communities.

Recommendations

Precision agriculture's value is limited only by our ability to generate and process data. Broadband and wireless technologies are the connective tissue of precision agriculture that will enable the United States and the world to feed ourselves while preserving a healthy world to

[29] Source: The True Cost of Wildfire in the Western U.S., April 2010, available at https://www.blm.gov/or/districts/roseburg/plans/collab_forestry/files/TrueCostOfWilfire.pdf

pass on to future generations.
The Task Force recommends enabling broadband and wireless connectivity over a range of technologies (both terrestrial and non-terrestrial—public and private) to support the connections required for precision agriculture. Broadband and wireless availability is a critical first step toward supporting the adoption of precision agriculture best practices; however, by itself, it falls short of a workable solution.

As discussed below, in order to enable precision agriculture, it is critical that wired and wireless broadband connectivity, edge cloud compute, and private wireless systems be extended to all farms in the United States, including those in the most rural and remote portions of the country. Accordingly, it is important that precision agriculture architecture be made an eligible expense for federal broadband programs, including edge compute infrastructure and private 4G/5G wireless systems to increase adoption. Agriculture, like every other industry, must experience a complete and total "digital transformation" in order to compete on the world stage. While "digital transformation" implies many things, it really means automation. Automation in a digital world brings efficiency, quality, sustainability, and maximum production yields.

Agricultural automation requires cloud computing, connectivity, and precision agriculture software applications. Precision agriculture applications will leverage the analytics of machine learning, computer vision, and robotics. These are the tenets of what is commonly referred to as the next industrial revolution, which is, in effect, an agricultural revolution. The pillars of this agricultural revolution are:

- Industry 4.0
- Cloud computing
- Connected everything
- Artificial intelligence/machine learning

To bring about this agricultural revolution, the cloud must be brought to the farms and ranches—into the fields and pastureland. This requires installing edge servers at farms and ranches and connecting them to existing broadband service. Terrestrial and non-terrestrial wireless coverage of various types must be everywhere. It must, eventually, be lightning fast and of the highest quality. Currently, 5G and its successors are our best path to achieving this vision, including a variety of terrestrial and non-terrestrial technologies. Everything must be connected: sensors, devices, controls, machines, and drones. Precision agriculture software applications must be made available, and these software-based applications and technologies must be adopted by farmers, ranchers, and growers. The infrastructure to generate and transmit the data, along with the applications, must be secured to ensure the integrity of decision-making.

To bring precision agriculture to rural America, the following must occur:

1. The farmhouse, fields and pastureland must have 4G/5G network coverage and connectivity. The network service providers must be interconnected with the private 5G wireless systems at farms and ranches for seamless interoperability and data flow.
2. Edge cloud infrastructure must be created to bring the cloud to farms and ranches to fulfill the promise of automation. The edge infrastructure must be located at farms and ranches and be connected to the broadband present today.
3. Private 5G wireless systems must be implemented at every farm and ranch to connect and collect the massive amounts of data from sensors, machines, and drones. These systems will provide service to the farmhouse, utility yards, barns, stockyards, and outbuildings. These same wireless systems could provide 5G coverage that extends for miles around the center of the farming/ranching operation.
4. Edge computing, private 5G systems, and precision agriculture apps must be included as essential infrastructure in all rural broadband incentive programs from the FCC, USDA, and other federal agencies as well as in state and county programs. By itself, broadband is a bridge halfway. A complete infrastructure and software solution is required for the adoption and realization of precision agriculture.

Based on the analysis of the current and future needs of the Agriculture Community for connectivity of precision agriculture technology, we recommend the following.

Grants and Other Funding Recommendations

Funding for Broadband: Allocate funding from broadband infrastructure to enable broadband connectivity over a range of technologies (both terrestrial and non-terrestrial) to support the connectivity required for precision agriculture. Minimum performance characteristics for funding should be set at 100 Mbps download and 20 Mbps upload while these standards should continue to be pushed to higher levels over time, where practical, to meet the needs of precision agriculture. Network latency should be consistent with the needs of real-time

interactive applications.
We recommend that the states and localities, when making broadband infrastructure funding decisions (whether using federal, state, or local funding), ensure that a reasonable portion of funding is dedicated to facilitating increased connectivity to support precision agriculture.

Because many rural and agricultural communities have been devastated by natural and human caused disasters, additional funding should be considered to ensure resiliency of service delivery via geographically diverse routes. For future funding, we recommend to Congress and funders that the performance criteria be reviewed and updated to reflect the current state of the technology and requirements. We believe that within 5 years, the minimum bandwidth needs for agriculture producers will be 1 Gbps upload and download speeds to core facilities typically served via wireline.

Funding for Edge Compute and 5G Systems: Clarify that precision agriculture architecture, including edge compute infrastructure and private 5G wireless systems, are eligible expenses for federal broadband programs to increase adoption. Clarify that broadband infrastructure funding may be used to support the deployment and adoption of 1) edge compute infrastructure, 2) private 5G wireless systems, and 3) precision agriculture and other relevant artificial intelligence and automation applications so that the critical infrastructure and tools needed to deploy precision agriculture can be developed, deployed, and adopted.

Funding for Internet of Things (IoT)/Machine-to-Machine (M2M): Allocate funding to support wide-area reliable coverage for IoT/M2M. The goal is to maximize agricultural land coverage to support IoT and M2M adoption and deliver real-time information to all stakeholders.

Funding for the Extension Service and Agriculture Experiment Stations: Allocate funding to support the Extension Service of the Land Grant University System and Agriculture Experiment Stations to advance the adoption of precision agriculture. This will help facilitate increased research and outreach to farmers to enable the adoption of precision agriculture through a variety of means, including demonstration and providing localized data to support adoption.

Incentive Programs to Encourage Precision Agriculture Equipment and Technology Adoption: Federal, state, and local governments should develop and implement incentive programs (e.g., financial rebates and tax incentives) to encourage the adoption of precision agriculture equipment and technology by farmers.

Note: For all of these programs, there should be a closed-loop audit process to ensure that the proposals that were awarded funding are implemented and meet the objectives stated in the proposal. There must be enforcement when these funding requirements are not met.

Increased Support from Federal Agencies

Additional Support for NRCS: The Department of Agriculture should ensure that the NRCS is sufficiently resourced to provide training and data services to farmers when implementing precision agriculture projects that are environmentally beneficial.

USDA Public Data Set on Performance Characteristics: The USDA should develop a public database containing the performance characteristics of technologies used to support and provide precision agriculture. This dataset should be used by the FCC and other agencies to determine industry need around performance standards (speeds, latency, etc.). This data should also be publicly available to help farmers and others understand the performance requirements of individual technologies.

Standards and Interconnectivity:

Standards Collaboration: The U.S. Government (e.g., NIST, USDA) should work with standards bodies (e.g., 3GPP) to develop 5G-and-beyond data and interconnectivity standards for precision agriculture that will promote economies of scale and ease the burden of adoption for the Agriculture Community. Particular focus should be placed on increasing the upload speeds to meet the evolving demands of precision agriculture data creation and utilization for improved value. Both non-terrestrial and terrestrial technologies are important to include in this work.

Partnering Efforts: All major infrastructure projects at the state and federal levels should be evaluated for the opportunity to partner with connectivity providers, ideally reducing the cost of high-speed infrastructure deployment.

Voluntary Disclosure: Technology providers should be encouraged to disclose performance requirements (e.g., speed, latency, and standards) on their websites and in marketing materials.

PART V: ENCOURAGING ADOPTION OF PRECISION AGRICULTURE AND AVAILABILITY OF HIGH-QUALITY JOBS ON CONNECTED FARMS

Connectivity

American farmers and ranchers work tirelessly to produce wholesome, safe, nutritious and sustainable food, fuel, fauna and fiber across the United States. More than four hundred commercial crops become products including fresh produce, grains, nuts, animal proteins, dairy, and forage crops, which are grown through American agriculture year after year, season after season, in a wide variety of landscapes and climates. The adoption of precision agriculture and the availability of high-quality jobs on the farm are necessary components to maintain American leadership in agriculture.

Like the combustion engine, electrification, and municipal water supply systems before it, access to e-connectivity will shape the future and health of American agriculture. Affordable connectivity to farm structures and in the field is critical for precision agriculture adoption and the continued availability of high-quality jobs on the farm and rural communities.

Data networks, the key facilitator of precision agriculture, are operating to gather, calculate, and report intelligence from within agriculture production. These offer fiscal efficiency, superior environmental practice, and responsible resource allocation, leading to higher yields of safe and wholesome food, fiber, fauna and fuel products.

Connectivity must be deployed to sustain the capacity needs of the industry now, but more importantly into the future. Connectivity goals must be grounded in the need to support evolving precision agriculture applications. Current and future "next generation" precision agriculture technologies, however, require services that allow for greater upload of collected data. As the volumes of data to manage agriculture production increase, higher speeds will likely be necessary, requiring greater data flows, with a better balance of download and upload speeds and reliability.

Networks should be built for peaks, not averages. Just as highways are built to accommodate rush hour traffic rather than 12:00 a.m. traffic, broadband networks must similarly be designed to accommodate the full load of anticipated current and future demand. Building to peak demand is not excessive; rather, it is smart design that enables the network to be leveraged to enable fulfillment of precision ag's complete capabilities. As bandwidth increases so will application development, and many of those applications will be in the agricultural realm. Historically, every major advance in bandwidth has facilitated innovation that has brought new services and applications to digital life.

A variety of technology platforms exist today that can provide **Connectivity to the Acre**. The idea of a single point network to the farm house, shop, or barn is no longer feasible. Today's agriculture producers require multipoint, high capacity networks across their acreage.

- **High Capacity** – Precision agriculture produces large amounts of raw data including shape files, high definition satellite and drone imagery, and rapidly reporting network data points. A high capacity network is able to capture, secure, and transfer these robust data inputs and outputs.

- **Reliability** - Agricultural data inputs and outputs can indicate critical action items for the producer. Network reliability is of utmost importance when considering valuable resources including: time, fuel, feed, water, domestic animals, fertilizers, herbicides, and pesticides. America's farmers and ranchers cannot be asked to use a network that is unreliable.

- **Data Network Download/Upload Capacity** – Agriculture production utilizes both downstream and upstream networking. Implementation of a network that provides greater network capacity with a better balance between download and upload speeds is critical to precision agriculture adoption. The agricultural producer's data outputs are just as decisive as their inputs. As equipment continues to become connected, this becomes increasingly important.

- **Scalability** – Utility infrastructure in general is costly to build, repair, and replace. Consideration to the scalability of any new network should be considered.

The evolution of data networks is far from over. A simple backward view over the last two decades from 56K dial up internet to current 1 gigabit offerings is a telltale window into network requirements to come. Any new network deployed in today's environment must take into account throughput growth rates, and an exponential increase of devices and data streams utilizing the network during its lifespan.

- **Fiscal Investment** – Agriculture production by percentage is conducted primarily in rural environments with low population densities. These low-density environments offer low cost recovery opportunities per network mile. Utility infrastructure must take into account the life of the network, repair and maintenance costs, and funding sources. Network investments must be future ready and upgradeable. Agriculture production takes place in high-cost construction environments.

American agriculture has a tremendous challenge and responsibility to produce enough food to feed the domestic and international population, while conserving natural resources through regenerative practices. Increased precision agriculture utilization will help American producers meet that challenge. The success of this undertaking will call upon the actions of Congress and the USDA with direction from the FCC to help create incentives and programs that will sustain American agriculture, farmers, and ranchers in this century and beyond. Moreover, and as an overarching perspective, rural broadband is critical to the viability of rural America, including the exponential benefits to job growth and availability for all job sectors, including middle skills jobs and opportunities grounded in Career and Technical Education training.[30] As highlighted by this Task Force, lack of connectivity is a key barrier to precision agriculture adoption and the availability of high-quality jobs in rural America.

Incentives for Farmers to Adopt and Use Precision Agriculture

While the focus of the FCC Task Force on Precision Agriculture is centered more on connectivity issues, connectivity is just one of the many aspects of precision agriculture. American agriculture also needs the hardware, software, supporting industries, and government to work collectively and cohesively to achieve success.

The agriculture industry is just over a quarter of a century from the introduction of the yield monitor, with other technologies like guidance, autosteering, and boom control not far behind. While today's equipment comes standard with many technologies, similar to on-road vehicles, with built in capacity to connect later, the nation has not yet achieved a 100% adoption and use rate in American agriculture.

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[30] See, i.e., Seidemann, Joshua, *Rural Broadband and the Next Generation of American Jobs*, Smart Rural Community (2019) (https://www.ntca.org/sites/default/files/documents/2019-04/SRC%20Middle%20Skills%20Web%20Version.pdf) (accessed Sep. 24, 2020).

In the past 25 years, more technologies have come to market, including guidance for crop dusters, unmanned air systems, sensing technology, and greater utilization of imagery and other data to help make decisions. Less than 25% of American farms are using technology to help make direct management decisions.

Several factors create barriers for more rapid and increased adoption.

- **Cost** – While costs have come down considerably, it is still a cost that some farms are not able to overcome.

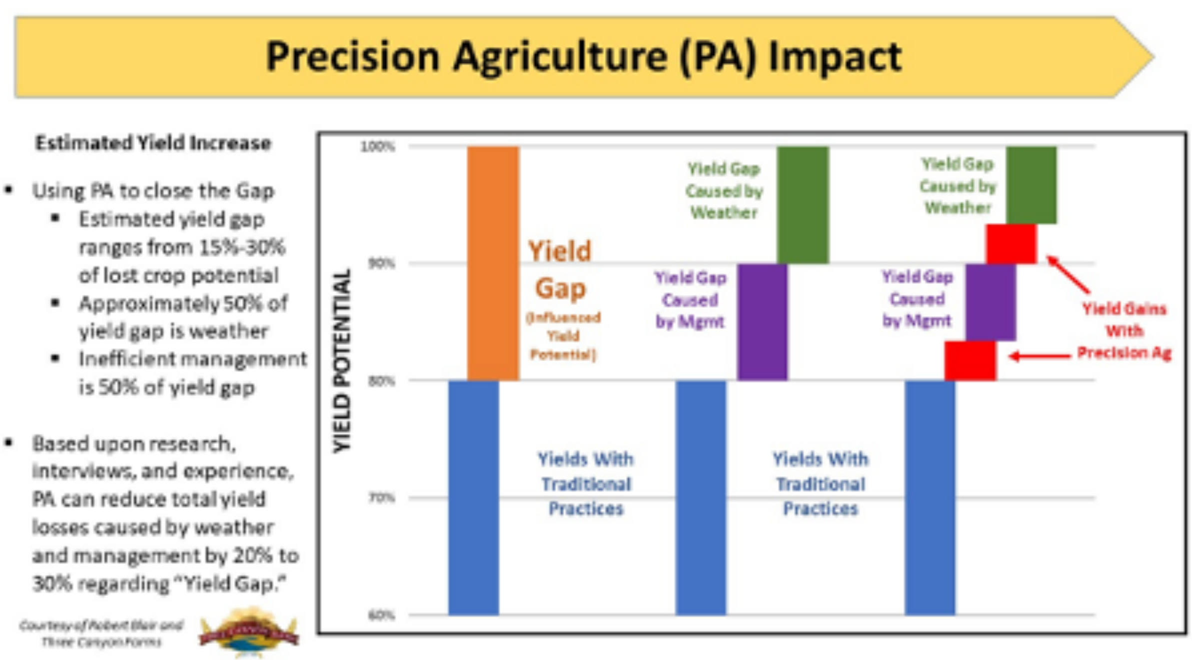
- **Average Age** – The average age of an American Farmer is 57.5 years and that average age is similar to that of the supporting businesses that serve them. This translates to being unfamiliar with the new technologies and management opportunities. The thought process is, "Why should I invest into precision agriculture when I will be retiring in a few years?"

- **Support** – The machinery dealership networks have employees that understand the installation and troubleshooting of the technology; however, there is less application or work flow support to help farmers better understand how to use the data toward resolving operational or management challenges.

- **Lending** – As farms turn to operating loans during economic hardship, the lending system does not incentivize farmers to practice precision agriculture or adopt precision agriculture technologies, despite the fiscal benefits of doing so.
    a. Lending institutions are making it harder for farmers to make capital purchases such as precision agriculture equipment.
    b. Lending institutions are limiting the amount of custom services a farmer can use.
    c. Private industry, Land Grant Universities, and USDA have not done an adequate job of showing lending institutions the financial benefits from data driven management and applications.

- **<u>Government Programs</u>** – While the USDA has programs such as EQIP and CSP that encourage farmers to purchase precision agriculture equipment, they have not progressed traditional farm programs to reward and incentivize the utilization of precision agriculture and data.

- **<u>Government Regulations</u>** – With technology evolving at a rapid pace, regulations that impact agriculture's adoption and utilization of precision ag technology has been an obstacle at the federal and state levels. Examples are:
    a. ***FAA Beyond Visual Line of Sight (BVLOS)*** – The majority of agriculture land is in low population areas and where drones could operate safely. In particular, pesticide application where the drone is only a few feet above the crop canopy.
    b. ***EPA approved methods of application on labels*** – Drones with multiple rotors are not an approved type of aerial applicator and fall into a grey area. Their ability to operate in closer proximity to the ground and above the crop canopy would also make them comparable to an approved ground application method.
    c. ***Applicator Licensing*** – Each state has its own requirement for licensing applicators of crop inputs with some reciprocity between states. With the evolution of drones, the ability for the company/operator to move between states is being hindered by slow to no regulation evolvement.



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Recommendations:

1. **USDA** - As highlighted throughout the 2018 Farm Bill, precision agriculture and precision agriculture technologies are recognized as critical to conservation, productivity and profitability. Therefore, precision agriculture and precision agriculture technologies should be established as "Best Management Practices" throughout the Department.

2. **Crop Insurance** – The USDA RMA "Precision Ag Premium Reduction." When farmers utilize precision agriculture equipment and data management, they lower their operational risk profile through automation in each cropping year and establish crop records that create sustainable long-term value of historical practice. Reductions in premiums to reflect those lower risks would encourage farmers to adopt precision ag.

3. **Ag Lending** – The USDA FSA "Precision Ag Loan Guarantee" by working with traditional farm lenders and with their own lending arm to guarantee loans for producers to purchase direct cost and labor reducing precision agriculture equipment and services. The USDA FSA should recognize this as 'Best Management Practices'.

4. **Conservation Payment** – The USDA FSA should offer a 'Precision Ag Environment Payment', NRCS 'Environmental Quality Incentives Program' (EQIP) and Regional Conservation Partnership Program (RCPP) should recognize precision agriculture technologies and practices as Best Management Practices and establish direct payments for its use. As highlighted throughout the 2018 Farm Bill, precision agriculture and precision agriculture technologies are recognized as critical to conservation, production and profitability.

5. **USDA Modernization** – The USDA should implement department and agency wide interoperability and symmetry of internal program formats to utilize operator driven data for future operator mandatory reporting, farm program creation and cohesive agency interaction

of the data. Continued implementation of the USDA IT Modernization Initiative is critical for encouraging precision agriculture adoption.

6. **Agriculture Regulation Relief** – Congress should expedite beneficial regulation creation for precision agriculture use and implementation in order to keep up with the quickly evolving technologies and practices. Congress should allow a national applicators license to help businesses maximize their ability to operate interstate.

Interoperability of Precision Agriculture Technologies

As the world looks to agriculture for climate solutions and consumer interest in how, when, and where their bio-based product is grown, it is imperative to establish a standard for interoperability. One of the key incentives to adopt precision agricultural technologies is efficiency of resource use (land, seed, livestock, chemical, machinery, labor, management and natural resources) and improved interoperability directly impacts the quality of such decisions. Traceability through a supply chain also requires interoperability, so that verified data moves effortlessly as products change hands, processes occur, and services are performed.

Interoperability refers to the basic ability of computerized systems to connect and communicate with one another readily, even if they were developed by widely different firms or organizations. The connect and communicate functionality is critical for exchanging and making use of information and can be complex. Interoperability requires that the interfaces be fully understood (by each party/program/algorithm) so that these different stakeholders/players can work presently and into the future without restriction. It is recognized that Interoperability can be complex, involving "On Board" capabilities within a vehicle platform or between a tractor implement or leader/follower combination and "off board" capabilities for a vehicle operating within a crop or field level and a cloud based repository. Interoperability can also encompass a "system of systems" where data is being exchanged between cloud based or decision engines before being passed for implementation to individual machines or workers. Interoperability is important in precision agriculture, and digital agriculture approaches more broadly, to improve efficiency of the data pipeline that brings about improved decision making and the associated actions. With current systems, we seem to be far from "single entry" and those managing agricultural systems are busy managing the logistics and strategy of their operations and cannot find time to enter/re-enter data; they cannot find time (or may lack expertise) to wrangle one format of data into another needed by a different piece of software.

There are several reasons that interoperability in agriculture has not yet been achieved. Each of these also point directly to the complexity and difficulty of this issue:

- There are many stakeholders involved such as farmers, original equipment manufacturers, input providers (seed, chemicals), service providers, consultants, government agencies, software/analytics platform companies;

- Multiple cloud platforms are typically required (because of the stakeholders list as well as a combination of private and public data);

- Data in agriculture is an immature market still in infancy with many startup companies and few standards beyond those recognized for equipment; and

- Inherent complexity between individual product solutions or "on board" interoperability and "off board" involving one or more systems interoperating toward a common task.

Other aspects affecting adoption, covered elsewhere in this report include *analytics, incentives, and traceability*. Each of these inherently require interoperability.

1. The highest levels of analytics require strong metadata (contextual information about any data element or array) – this contextual perspective often comes from disparate systems that are not functionally accessible.

2. One of the best incentives to adopt precision agricultural technologies is efficiency of resource use (land, seed, chemical, machinery, labor, management) and improved interoperability directly betters the quality of such decisions as well as the time needs to make/enact those decisions.
3. Traceability through a supply chain requires a degree of interoperability so data moves effortlessly as products change hands, processes occur, and services are performed.

The six levels of precision agriculture adoption (**Figure 1)** require increasing levels of interoperability. Levels 2 and above require disparate systems to communicate ("communicate" means "autonomously" with minimal human intervention). It is ironic that data itself, which is already digital, is becoming autonomous much later than the complicated machinery with embedded sensors which is generating the data. When data was solely used for strategic (infrequent, but important) decisions, there might have been time for offline wrangling to work around a lack of interoperability. However, we assert that data will be better when its use is near-term (because this will encourage data pipeline functionality, solicit better attention to calibration, etc.). Given this, the use of data toward improving logistics and tactical decision making also puts pressure toward improved interoperability because the data pipeline must function in near real time.

Figure 1. Six levels of precision ag adoption proposed by the PrecisionAg Institute (https://www.precisionag.com/institute/six-levels-of-precision-agriculture-adoption-identified-by-the-precisionag-institute/).

Interoperability is often discussed solely regarding the technical/functional aspect. This is can be disaggregated into foundational, structural, and semantic levels. "Foundational" establishes secure inter-connectivity to send/receive. "Structural" adds format, syntax, and organization at the data field level which is required for interpretation. "Semantic" adds common underlying codification for a shared understanding (standards, publicly available vocabularies, published exemplars). Due to the interconnectedness and multiple stakeholders, interoperability also requires more than technical/functional aspects. Organizational interoperability, the social dimension, includes governance, policy, social, legal and organizational considerations. These components must be in place to enable shared consent, trust and integrated end-user processes and workflows.

Interoperability requires cooperation amidst competition. The many players must be incentivized to use open source middle layers of data architecture and tools for storage, transfer, and access. The proprietary benefits in data acquisition and analytics will be propelled

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by improved data pipelines that use secure, fully published application program interfaces (APIs). Data may eventually become a commodity, but the insights from that data leave lots of room for many companies, producers, processors, and consumers to prosper.

Recommendation:

- The USDA and FCC should collaborate with industry stakeholders and academia to establish a standard of interoperability for both "on board" and "off board".

Data Collection, Management, & Analytics

There are several considerations around data collection, security, management, and analytics that must be addressed in order to accelerate adoption of precision agriculture.

Data collection and speed will allow producers to make better decisions in real time. Today, advanced telecommunications capability is being defined by the FCC as the capability to achieve 25Mb/ download and 3Mb/ upload. Implementation of a network that provides greater capacity with a better balance between download and upload service is vital to long term sustainability of the industry of Agriculture.

The standard of 25/3Mb has been developed as a benchmark for users to access or download data from a central repository, server or streaming service, enabling faster download and minimizing the upload requirements. The world of Digital and Precision Agriculture and the "Internet of Things" or the "Internet of Food" is a world of two-way communication, requiring both volume and frequency with low latency achievable only through greater network capacity with a better balance between upload and download service levels. On October 11, 2017, Ohio State University research agronomist Trey Colley in the "Terra" project documented that a single 100-acre corn field can generate up to 60.2 terabytes of data with 2475 files using 39 different file types through the normal course of growing their crop in an approximate 110-day cycle. Trey stated, "We collected 18.4 total gigabytes of data for Terra, that's 28 megabytes per kernel. If we collected this amount of data for the whole 100-acre field, there would be 60 petabytes of data."[31]

[31] "World Record for Data Collection Set by OSU Precision Ag Team," Ohio's Country Journal (Oct. 11, 2017) (https://ocj.com/2017/10/world-record-for-data-collection-set-by-osu-precision-ag-team/) (accessed Sep. 24, 2020).

A 2019 study by the United Soybean Board found that 60% of U.S. Farmers and Ranchers do not believe they have adequate connectivity, which infers the stifling of production of up to $133 billion dollars in U.S. Gross Domestic Product. 78% of the 2000 growers and ranchers surveyed do not have another viable option to change service providers, so they may also lack choice for alternative service providers. Even when farms are located within proximity to urban centers, they can experience significant challenges in achieving ample connectivity. This was evident from testimony by Jose Guevara, a pecan farmer near Austin, Texas, and Dale Artho, a farmer from Deaf Smith County, Texas, both members of the Adoption Jobs/Working Group.

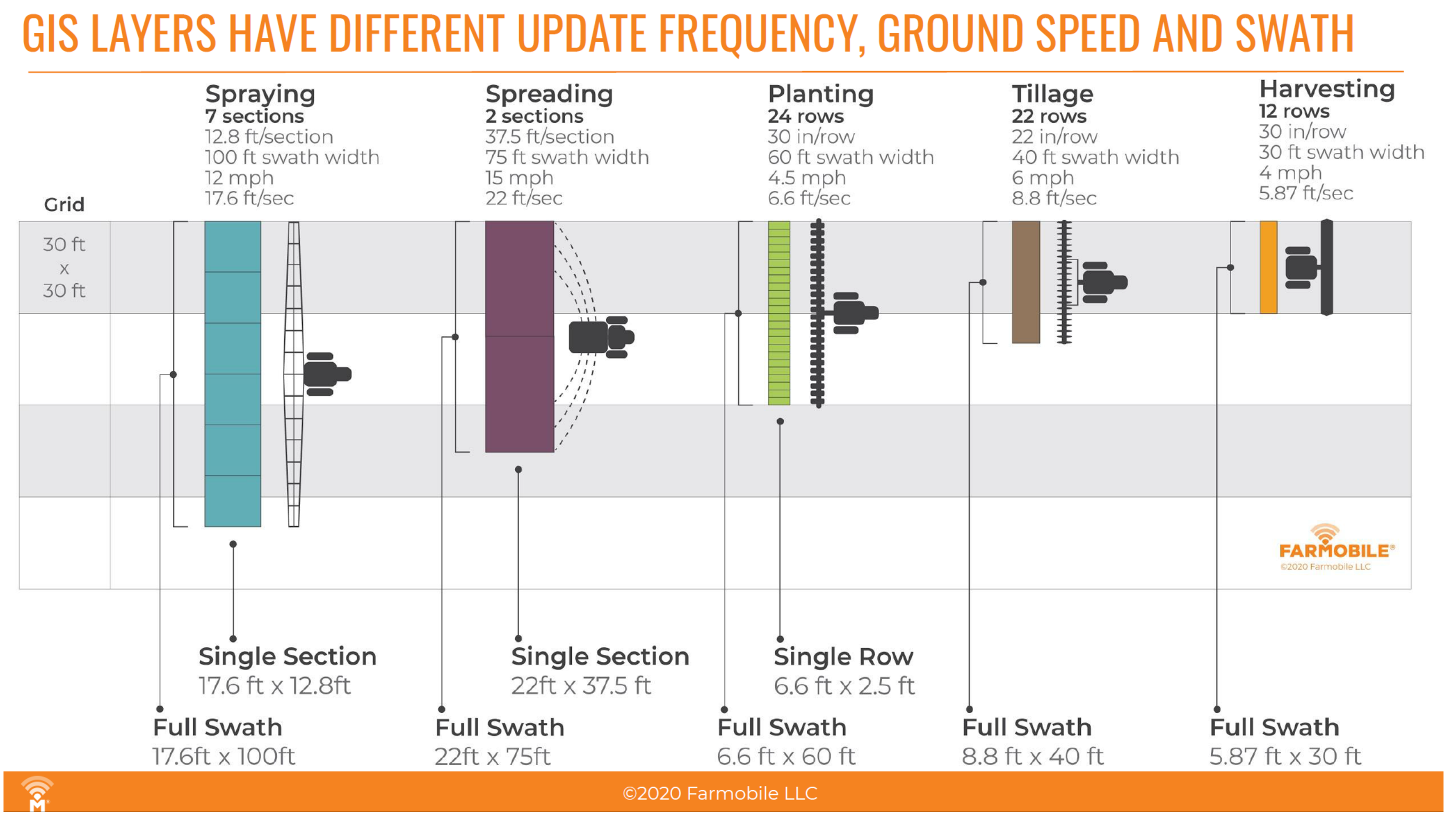
The issue of ample connectivity with respect to adoption may be best represented in the phrase "perception becomes reality." Users adopt a technology only when they trust it is robust, consistently available and proven dependable.

This adoption curve was experienced throughout the United States both with rural electrification in the 1930's and with rural telecommunications in the 1940's. In 2021 and beyond, businesses are becoming increasingly dependent, not only on connectivity, but on internet service at speeds with low latency enabled by greater network capacity and better balance between upload and download service to support full cloud-based access, storage and business decision making. Software solutions to run small businesses are migrating from desktop and server-based solutions to cloud-based solutions improving both reliability through centralized security of a server farm, as well as cost effective access to cutting- edge back office systems.

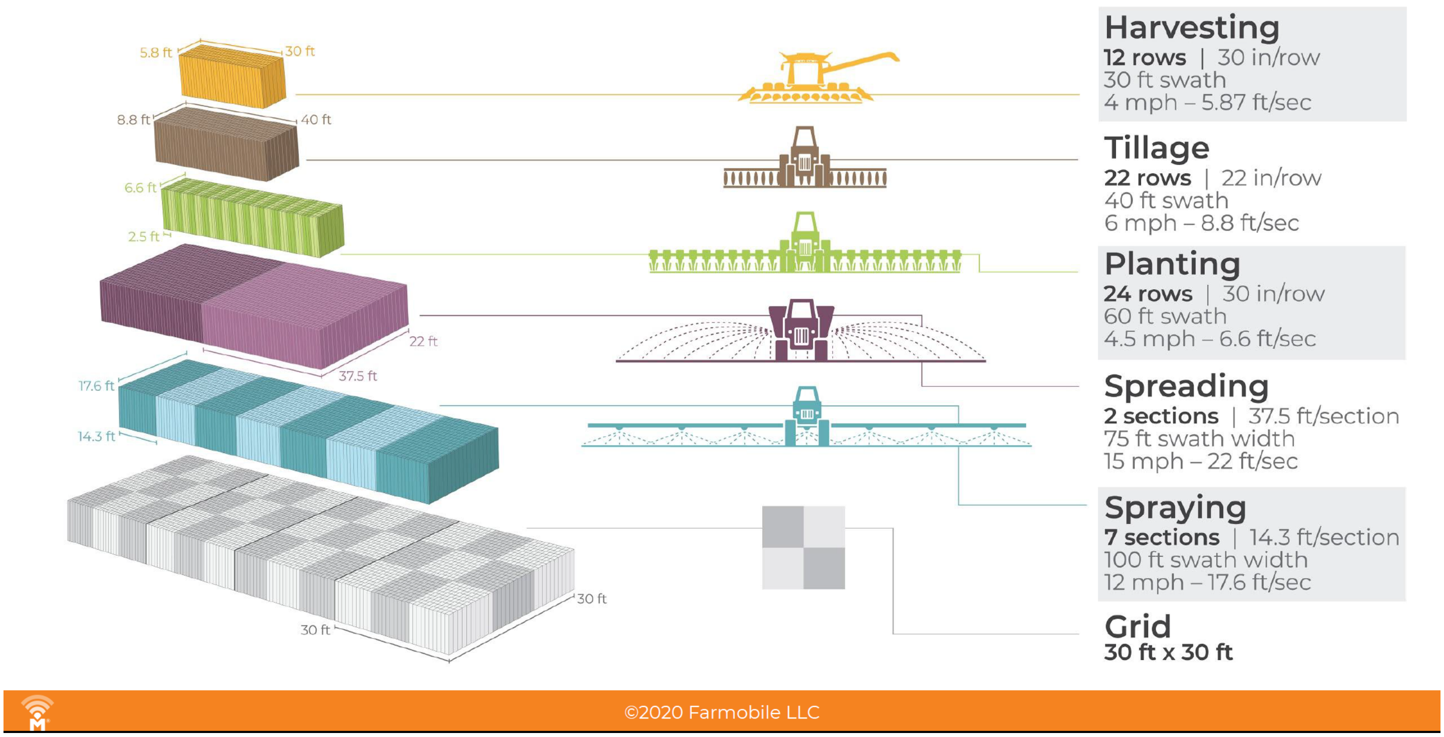
Farms and farm service contractors are small businesses located across rural America. Access to such infrastructure is both vital to their operations and critical to their long-term economic sustainability. Today, they stand on the edge of the digital divide.

When faced with ambiguity about availability, dependability, lack of choice amongst local service providers and other considerations at their office (as well as for remote equipment and infrastructure in fields), farmers are faced with few options. Oftentimes, the most risk averse choice is to sell the farm or business to someone with a larger scale of operations over which to spread such infrastructure intensive and capital costs and IT support responsibilities.

Below are some examples from Farmobile LLC, a provider of telematics to the industry, that illustrates aspects of both the complexity as well the challenges of bringing together differing data layers.



GIS LAYERS HAVE DIFFERENT UPDATE FREQUENCY, GROUND SPEED AND SWATH



Graphics provided courtesy of Farmobile LLC, an agricultural technology company located in Leawood, KS.

Recommendation:

Improvement of use and encouragement toward Federal reporting and agencies to align their existing and individual file management systems to have the capability to receive electronic data layers that are often created through the normal course of farm operations as cited throughout this document.

Specific examples are "As Tilled or As Planted" records to be used as Acreage reporting for FSA compliance and allowance of electronic records or files from combines and grain carts to facilitate crop insurance compliance reporting in a way that streamlines both reporting and remittance to growers and facilitated by electronic exchange of data layers or electronic files. The phrase often used is "report once, use many times" regarding data interoperability within all agencies of the USDA requiring interaction with producers as part of their reason for being. It is not enough for an individual agency of the USDA to have "the capability" of interacting with electronically-reported information from producers, they have "the duty" to accept electronically-submitted information, as verified and accepted by other USDA agencies, as

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being accurate and true. The entire system breaks down if individual agencies refuse to accept information as reported electronically.

Data Privacy and Security

Agriculture, like many other newly connected industries, can be expected to go through a cyber security learning curve. Many public and private industries have been the victims of cyber-attacks where rogue interests utilized ransomware to disrupt operations and stakeholder services. Agriculture is an essential industry and will be subject to many of these same vulnerabilities. Improved access and conventional service providers employing similar protection for power and utility systems, public telecommunications, and business-to-business connectivity services would help the industry improve its self-reliance and mitigate potential security threats.

On 03 October 2018, the Department of Justice (DOJ), Federal Bureau of Investigation (FBI) Cyber Division published Private Industry Notification (PIN) 20181003–001 titled "Advances in Precision Agriculture Increasing Vulnerabilities to Cyber Threats as Smart Farming Gains Wider Acceptance". The following are excerpts from that document.

> The project found most of the threats facing precision agriculture's embedded and digital tools were consistent with threat vectors in all other newly-connected industries. Malicious actors could target precision agriculture to generate similar outcomes: data theft, stealing resources, reputation loss, destruction of equipment, or gaining an improper financial advantage over a competitor through theft of intellectual property or proprietary data. Common threat vectors such as improper use of removable media, spear phishing, and malicious cyber attacks, can easily target precision agriculture. Generally accepted mitigation techniques in other industries were found to be largely sufficient for creating a successful defense-in-depth strategy.
>
> *Confidentiality, Integrity, and Availability (CIA) model to Identify Potential Threat Vectors*
>
> The project uncovered potential threats to the crop and livestock sectors using the CIA model of information security. These threats could impact the agriculture sector's resiliency to withstand new types of disruptions which did not previously exist or dramatically scale up the impact of pre-existing threat vectors.

Based on the diverse nature of the crop and livestock sectors, different aspects of the CIA model were identified as assuming greater importance at different points in the agriculture production chain.

Confidentiality Standard Threats

- Intentional theft of data collected through decision support systems or the unintentional leakage of data to third parties;
- Intentional publishing of confidential information from within the industry such as from a supplier to damage the company or cause chaos;
- Foreign access to unmanned aerial system data;
- Sale of confidential data for financial or other gain.

Integrity Standard Threats

- Intentional falsification of data to disrupt crop or livestock sectors;
- Introduction of rogue data into a sensor network which damages a crop or herd;
- Insufficiently vetted machine learning modeling.

Availability Standard Threats

- Timing of equipment availability;
- Disruption to PNT systems – space-based;
- Disruption to PNT systems – ground based;
- Disruption to communication networks;
- Foreign supply chain access to equipment used in precision agriculture.

Addressing cyber-security and data privacy concerns will decrease reluctance of precision agriculture adoption, mitigate disruption to the food supply chain and ensure fair marketplace competition.

Recommendations:

- Federal cyber security and cyber protection policy should recognize farm and farm record data as critical and essential infrastructure and therefore; a matter of national security. Such data should be considered highly sensitive and malicious acts should be treated accordingly.

- The USDA, Department of Homeland Security, Department of Defense (DoD) and

American Jobs Plan should prioritize the development of precision agriculture cyber security specialists.

- The USDA should work with private industry to establish privacy standards consistent with guidelines established by Federal privacy laws that have the effect of protecting producer-owned data and subsequent aggregate data; USDA may look toward HIPPA to derive the appropriate industry-specific approach.

Priority should be placed by the DoD, National Strategic Research Institute and similar initiatives to reduce the systemic vulnerabilities inherent in an inter-dependent food supply chain.

Existing Funding Mechanisms Should Pivot to Precision Agriculture

An important consideration as policymakers encourage the continued expansion of connectivity to support precision agriculture is the need to ensure that funding mechanisms enable comprehensive support for deployment that enables connectivity throughout cropland and within and among farm structures, facilities, and equipment.

- The average connected household in the United States now has approximately 14 connected devices. Farms, as small businesses employing substantial mobile assets, carry the potential to host a significantly larger number of necessary connections. In today's Digital Farm, we can find a number of Smart Connected vehicles and implements that may be moving or stationary, performing a task with the need to feed data about work or progress back to both a central repository, as well as offices and people. An example presented to our committee can be found at www.grandfarm.com.

These stationary and non-stationary assets perform work functions and rely increasingly on high-capacity fixed and mobile broadband connectivity for data traffic communication with better balance between upload and download levels. These high-capacity, high-speed data streams are necessary to enable the use of cloud-supported, AI-powered solutions that enable on-the-go responses.

Examples include:

- Tractors, performing tasks of tillage, planting, cultivation, or other aspects of crop care.
- Sprayers, dispersing and reporting fertilizers or restricted use plant protection products.
- Combines and Harvesters of crops, capturing records of yield and traceability.
- Seed tenders, providing accountability and traceability of seeds as they are planted.
- Grain Carts that receive harvested crop and transfer it into trucks to begin processing.
- Feed mixers, that receive ingredients, mix, and transfer rations to beef and dairy cattle.
- Spreaders of fertilizer or manure, that are dispersing crop inputs and creating records
- Irrigation systems, that are dispersing water often with nutrition to growing crops.
- Elevators receiving and distributing grains, enabling food traceability.
- Grain Handling and drying facilities, for optimization of energy with product traceability soil moisture or other stationary probes to monitor crops.
- Wearable electronics on cows and large animals to track their health and activity.
- Feeding barns and watering troughs for beef cattle.
- Milking parlors for Dairy cattle that track cattle through the milking process.
- Milking systems, often working semi or autonomous, recording volumes and cycle time.
- Closed and contained feeding barns for pigs, poultry, and other small animals.

The labor efficiencies and economic gains promised by precision ag are documented in a growing number of reports.[32] Moreover, adoption can be expected to increase as the cost of components decreases.[33] And, inasmuch as adoption rates are higher on large farms than small farms, one can expect standard economic principles to drive prices lower as initial users are high-volume users.[34] Accordingly, multiple indicators point toward the benefits and trends

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[32] See, e.g, "4R and Precision Agriculture – Where's the Payback?", Nutrient Stewardship (2014) (available athttps://nutrientstewardship.org/implementation/4r-and-precision-agriculture-wheres-the-payback/) (accessed Sep. 1, 2020), and "Big Savings from Variable Rate Fertilizer," Ohio Farmer (2008) (available athttps://www.farmprogress.com/story-big-savings-from-variable-rate-fertilizer-9–20801) (accessed Sep. 1, 2020). The USDA Economic Research Service takes a more conservative view but finds savings proportional to farm size. See, generally, Schimmelpfennig, David, "Farm Profits and Adoption of Precision Agriculture," Economic Research Service, USDA (Oct. 2016).

[33] See, "Threats to Precision Agriculture," 2018 Public-Private Analytic Exchange Program, U.S. Department of Homeland Security. "Threats to Precision Agriculture" at 9 (2018) (available at https://www.dhs.gov/sites/default/files/publications/2018%20AEP_Threats_to_Precision_Agriculture.pdf) (accessed Sep. 1, 2020).

[34] Although it may be considered that increased demand will spur price increases, unit fixed costs in the production of precision agriculture equipment would be inversely proportional to sales volume, thereby decreasing cost per unit pricing.

toward increased adoption of precision agriculture. Ag, food and related industries contributed more than $1 trillion to the U.S. GDP in 2017, or about 5.4% of GDP.[35] Therefore, the increased adoption of technologies that increase efficiencies and performance in those industries should be pursued. Therefore, Federal broadband policies should address the need for bi-directional communication, reliability and greater speed with a better balance between download and upload levels.

Federal broadband policy is rooted in the Communications Act of 1934, as amended (Act). The universal service directives in the Act mandate that residents of rural and insular areas of the Nation enjoy access to communications services that are reasonably comparable to those available in urban areas, and at reasonably comparable rates.[36] Even as precision ag adoption grows on large farms, it is useful to remind the discussion that even the largest of the Nation's farms are in rural areas. Therefore, adherence to the principles of "reasonable comparability" among rural and urban spaces is necessary to support precision ag deployment on the largest farmlands. Accordingly, existing mechanisms may be augmented to promote the adoption of precision agriculture by including the following in Federal policy making:

Inclusion of Farms and Farmlands in Broadband Mapping as "Potential User"

Broadband mapping is currently focused on identifying residential and business locations. The inclusion of cropland as a location subject to buildout requirements could be difficult inasmuch as different farm and croplands, whether for beef, dairy, row crops or specialty crops, may have different bandwidth requirements and rely on technology ranging from stationary and mobile sensors to sophisticated AI-reliant, cloud-supported devices that require high-capacity wireless support to enable real-time applications. Accordingly, how farmland is to be accounted will require an examination of the current and anticipated precision agriculture needs for each livestock and crop set. Those sets, in turn, will assist in defining the type of networks and support that are required to support precision agriculture in those regions. For example, a service territory whose predominant farming operations consist of row crops may be calibrated differently for support than a region whose predominant farming operations are dairy production. Regions that support both types of farms would be evaluated through calculations

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[35] "Ag and Food Sectors and the Economy," Economic Research Service, U.S. Department of Agriculture (available at https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy/#:~:text=Agriculture%2C%20food%2C%20and%20related%20industries,about%201%20percent%20of%20GDP) (accessed Sep. 1, 2020).

[36] 47 U.S.C. § 254.

that estimate the relative anticipated farming needs and then extend support accordingly.

Weighting of Farms Served when Contemplating High-Cost Support Allocations

The USDA ReConnect program includes "weights" that favor areas with farms. While no rural or high-cost universal service support area should be subject to diminished or deprivation of support for lack of farmland, the USDA program indicates that the Federal policymakers have already recognized the role of broadband in farms, and the role of farms in building local communities. Accordingly, the USDA ReConnect program paves the way for the FCC to offer specific consideration in the USF and CAF high-cost programs for farmland. As described above, this may be accomplished by including the cost of connecting farm fields and facilities to broadband.

Recognition that Precision Ag Relies Upon both Fixed and Mobile Connections

FCC policy must recognize, consistent with its recent Section 706 reports, that fixed and mobile services are not substitutes but are rather complementary services. In the microsystem of a farm this may be seen in the following example: a rancher may rely on remote sensors that track the health, food consumption and activity of its cattle in the field. These will rely on mobile wireless capabilities. At the same time, the rancher may participate in online cattle auctions that rely on high-capacity, low-latency wired broadband services. In this example, the complementary systems of both fixed and mobile services are necessary to support the farm. Moreover, and as expressed in numerous papers and studies, wireless services require wires. At some point, and particularly as 5G is investigated for increasing industrial and other uses, fiber deep into the network will be necessary to provide sufficient backhaul capability.

Sustainability and Traceability

Sustainability: Today's consumer and global marketplace demand products that are rooted in sustainable practices. These buying decisions directly impact American agriculture and the ability to market products backed by verified data while proving to the world the sustainable practices, carbon sequestration and carbon footprint generated through the lifecycle of the bio-based product.

Precision agriculture plays a major role in sustainability in today's market. It has been made possible by the rapid development of sensing technologies, management information systems, advances in farm machinery and appropriate agronomic and economic models. The benefits of using precision agriculture practices include increasing crop yields and animal performance, cost reduction and optimization of process inputs. Thus, precision agriculture aims to reduce the environmental impacts of agriculture and farming practices, contributing to the sustainability of agricultural production. These production technologies vary by farm operation. They include:

- For crop operations: weather modeling, pest and disease modeling, frost detection, precision seeding, variable rate applications, machine learning & visioning, irrigation management, environmental sensors, soil moisture technologies, machinery & labor coordination, and commodity storage monitoring.

- For livestock operations: animal tracking (RFID tags), fertility planning, feed management, health & stress detection, environmental control, environmental sensors, robotic operations, unmanned herding, waste management, and automated sorting.

While digital technologies are already creating value within the agriculture industry today, realizing the full potential of these technologies, according to the USDA, could create approximately $47–$65 billion annually in additional gross benefit for the U.S. economy. In other words, if broadband Internet infrastructure, digital technologies at scale, and on-farm capabilities were available at a level that met estimated producer demand, the U.S. could realize economic benefits equivalent to nearly 18 percent of total production, based on 2017 levels. Additionally, according to USDA, further adoption of these technologies can reduce fuel consumption by 40%, reduce water consumption 20–50%, and reduce chemical applications up to 80%.[37]

Traceability: From a policy perspective, the accurate and timely traceability of products and activities in the supply chain has become a new factor in food and agribusiness. Increasingly, consumers demand for verifiable evidence of traceability is an important criterion of food product quality and safety. Food safety and traceability are currently at the forefront of both government and industry discussions around the world from a food safety and supply chain vulnerability perspective.

[37] A Case for Rural Broadband," Economic Research Service, United States Department of Agriculture, at 23 and 32 (2019) https://www.usda.gov/sites/default/files/documents/case-for-rural-broadband.pdf

Traceability plays a significant role in helping businesses be competitive in the domestic and global marketplace. The ability to trace a product through all stages of production on farm, processing, distribution, transport and retail to the end point, or consumer, is becoming a standard business practice for all involved in today's food supply chain. Adopting traceability is not a choice, it is a requirement for continued American leadership in agriculture.

- **Produce Industry:** Traceability has been important to the produce industry for many reasons, including improving food safety by being able to quickly and accurately remove potentially harmful products from the supply chain. The produce industry launched an effort to address the topic of traceability. The Produce Traceability Initiative was formed in 2008 by representatives from over 40 companies including growers, packer/shippers, marketers, distributors and wholesalers, food service and retail and eight trade associations to begin working on an action plan to ensure the industry has a process that will work for the entire supply chain.

- **Beef Industry:** A comprehensive animal disease traceability system has been a priority for USDA for the beef industry for quite some time, from a disease outbreak standpoint. USDA is committed to implementing a modern system that tracks animals from birth to slaughter using affordable technology that allows for quick tracing of sick and exposed animals to stop disease spread. In September 2018, USDA established four overarching goals to increase traceability. These goals are: (1) Advance the electronic sharing of data among federal and state animal health officials, veterinarians, and industry, including sharing basic animal disease traceability data with the federal animal health events repository (AHER), (2) Use electronic identification tags for animals requiring individual identification in order to make the transmission of data more efficient; (3) Enhance the ability to track animals from birth to slaughter through a system that allows tracking data points to be connected; and (4) Elevate the discussion with States and industry to work toward a system where animal health certificates are electronically transmitted from private veterinarians to state animal health officials. In an article in Beef Daily, author Amanda Radke discussed how several Wyoming ranchers are working with a company to implement a traceability program using block chain technology.[38] One of the struggles their operation is facing with the systems is a lack of connectivity. According to the

[38] Radke, Amanda, "Blockchain to bring transparency to beef business", August 2018, Beef Daily, https://www.beefmagazine.com/beef-quality/blockchain-bring-transparency-beef-business

National Cattlemen's Beef Association, it is estimated that approximately 61 percent of global beef exports come from countries with nationally significant traceability systems in place. If connectivity lags, traceability lags, so the U.S. will fall behind its international competitors. According to a 2019 study by the United Soybean Board, 60% of U.S. farmers and ranchers do not believe that they have adequate internet connectivity to run their business. Connectivity still remains one of the largest obstacles for precision agriculture adoption.

Recommendations:

1. With the special focus on sustainability, there should be additional federal resources devoted to precision agriculture applications that promote sustainable farming practices through the USDA.

2. Due to the food safety components of traceability, there should be federal resources devoted to agricultural traceability technology and connectivity issues by the FDA and USDA.

3. The USDA should recognize precision agriculture technologies and digitization as the means to promote and verify sustainable farming practices while reducing the carbon footprint and increasing sequestration through more efficient processes and operational management.

Automation and Telemetry

Initial findings show automation and remote telemetry technologies utilized in precision agriculture will help alleviate labor shortages, enhance sustainability and traceability, and increase efficiencies while driving the demand for skilled jobs such as IT techs, field techs, network engineers, administrators, and agronomists. These technologies are also recognized for their positive impact on natural resource conservation and energy management in the 2018 Farm Bill.

However, challenges of the small and medium sized growers and their razor thin margins make them hesitant to invest in new technology without a very clear return on investment and understanding of how the technology will reduce operation risk and streamline operations. Those that are interested may face resistance from their banks or difficulty understanding and adopting the recurring revenue business models (e.g. SAAS) favored by younger companies. Larger cooperatives are making technology investments, but their tolerance level for interacting with young, unproven technology companies is low. This is an excellent focus area for targeted, appropriate subsidies – one of our interviewed companies had definitive proof of greater adoption in Nebraska when their product was subsidized for the first year.

Recommendations:

1. Expand federal programs such as the USDA, CSP and EQIP to be more proactive rather than reactive to areas considered "high stress" only.

2. Reduce red tape for subsidies: A prohibitive amount of red tape and administrative requirements are a disincentive to using them. Other countries' programs such as Israel and New Zealand appear to have low barriers to adoption and reduced red tape.

3. Focus subsidies on outcomes, not solution types. Currently, the USDA NRCS subsidies require the use of certain technologies (such as soil moisture sensors) instead of focusing on desired outcomes. For example, alternate technology may achieve the same end (more efficient water use) through measuring the plants instead of the soil. Ensuring that subsidies are objective focused instead of solution focused will broaden the available solution types and encourage competition among solution providers.

4. Designated Test Farms: National test farm sights were highlighted as a particularly effective method of increasing producer awareness and trialing new agriculture technologies. While the U.S. Government does not typically participate in markets, this could easily be overcome through the USDA/NRCS designation of 'technology leading' producers – individual small / medium farms who receive subsidies to try new technologies of interest and/or through partnership with Land Grant Universities. An example of this type of program is reflected at University of Nebraska's 'Testing Ag Performance Solutions (TAPS)' program.

The Role of Land Grant Universities, Extension Programs and Community Colleges

Another major topic identified was the success of STEM and precision agriculture technology tracts offered by land grant universities, extension and community colleges. Currently there are dozens of institutions involved in research and real-time development of precision agriculture strategies. However, higher education's efforts to prepare an adequate diversified workforce to support the skilled job demand caused by precision agriculture adoption requires concerted focus.

That said, some excellent work has begun at the Community and Junior College level, as exemplified by Northeast Junior College in Colorado. Another great example shines through in a public-private partnership with the IoT4Ag Project funded by the National Science Foundation. "Collectively, the IoT4Ag Center will educate students, engineers, agriculture professionals and other members of farming communities through audience-specific lessons and hands-on classroom, laboratory and field activities. Bringing together academic, government and industry partners with the farming community, the center will create an innovation ecosystem that ensures the rapid translation of IoT4Ag practices and technologies into commercial products and economic impact."[8] Workforce development is one of the main pillars of this project.

The Irrigation Innovation Consortium (IIC) is another example of public-private engagement to advance research, development and training in the precision agriculture space. The goal of the IIC is to accelerate the development and adoption of water and energy-efficient irrigation technologies and practices through public-private engagement involving five leading agricultural research institutions plus 15 of the leading private sector irrigation technology providers. The IIC has a 5-yr, $5M grant from the Foundation for Food and Agricultural Research (FFAR) to advance pre-competitive irrigation research in the areas of water & energy efficiency, remote sensing & big data applications for improving irrigation water management, systems integration & management, and accelerating technology development and/or adoption.

This FFAR grant requires a 1:1 match from any nonfederal funds to be utilized for a total investment of $10M over 5 years. These types of multi-region, multi-crop and multi-disciplined projects are examples that should be replicated.

Increased enrollments in STEM and agriculture tracts as well as student- led Ag Tech start-ups demonstrate that many institutions are succeeding in promoting precision agriculture as a viable and exciting career path. Cooperative program outreach by community colleges, extension locations, and in particular, through distance learning collaborations between institutions presents a major opportunity. These programs would support rural citizen retention, diversify the skilled workforce and support the adoption of precision agriculture and demand for rural e-connectivity.

Recommendations:

1. Streamline the ability for school districts, local extension agencies, and land grant universities to further partner with public companies to increase educational opportunities and entrepreneurial programs.

2. Encourage state legislatures to increase their funding for STEM programs, K-12 and community colleges.

3. Increase access to distance learning, allowing rural citizens to satisfy post-secondary education and college level degrees, more specifically allowing individuals engaged in farming to stay active in operations while achieving their educational goals.

4. Develop a robust program tract for AgTech/ IT Security Specialist.

The Need for Career and Technical Education and Apprenticeships

With the demand for skilled jobs expected to increase with the adoption of Precision Agriculture, Career Technical Education and Apprenticeship programs provide an avenue to rapidly fill this demand while providing hands on training for a skilled workforce.

On dairy farms, for example, automated devices that milk and feed animals can also track each cow's activity and alert producers to potential problems. Because these tasks are traditionally done by the producer and farm personnel, e-connectivity can substantially reduce the amount of time and effort necessary to run farms. This leads to dramatic increases in flexibility, enabling time and talent to be directed to more advanced tasks.

These programs provide the specialized training to upskill on farm personnel and expand high-quality training programs across precision agriculture verticals. The American Jobs Plan as well as multiple state initiatives have been identified as beneficial tools to attract and develop a technologically skilled workforce to support the deployment of rural broadband networks and precision agriculture technologies.

Over the course of our research, public-private partnerships were identified as a key driver to establishing successful and sustainable initiatives:

- **Pennsylvania Ag Education**

a. In 2017, the General Assembly amended the Public-School Code of 1949 to establish a state Commission for Agricultural Education Excellence to assist in developing a statewide plan for agricultural education and coordinating implementation of related agricultural education programming within the Pennsylvania Departments of Agriculture and Education.[39]

b. The program supports FFA participants, including contracting with the Center for Professional Personnel Development at Penn State University to design and provide teacher training courses in electronics and hydraulics.

c. The Pennsylvania Department of Education furthered vocational certifications for teachers from industry in six curricular areas within agriculture education

d. Established Apprenticeship for Ag Equipment Service Technicians, one example of the highly focused training for careers in agriculture.

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[39] "Commission for Agricultural Education Excellence," Pennsylvania Department of Agriculture, Pennsylvania Department of Education (May 2020) (https://www.agriculture.pa.gov/Business_Industry/workforce-development/Documents/Agricultural%20Education%20in%20PA%202020.pdf).

- **4-H**

    a. 4-H Spin Clubs are special interest clubs that allow four or five individuals to learn together about a various topic including coding, STEM, and other related topics. These clubs have increased in popularity in recent years highlighting interest in technology fields within agriculture career tracts.
    b. 4-H Game Changers introduces children ages 8–14 to problem- solving skills leveraging computer science concepts, creating the connection between physical activity, real-world application and agriculture.

- **Agriculture Future of America**

    a. A non-profit organization that connects college students and young professionals with careers in agriculture and food, through premiere training and professional development.

Recommendations:

a. Expand the model exemplified by Pennsylvania to further expand AgTech careers at the state and local level.

b. Further fund programs such as Ag Futures of America, FFA and 4-H through partnerships with the USDA and other public agencies.

c. Promote The American Jobs Plan across associations and organizations within the agriculture space in order to expedite the commencement of such programs.
d. Federal, state and local funding should establish an AgTech/IT Security Specialist program tract.

COVID-19 Broadband Availability & Connectivity

COVID-19 has changed the world as the home has become the office, the school room, the medical exam room, the store and the entertainment hub. Precision Agriculture adds yet another level of demand on networks that are already running at capacity in much of our rural regions here in the US. As a result, homes will require greater capacity, more reliability and continue to maintain a level of affordability; however, precision agriculture connectivity will suffer as the home takes network precedent. We need to focus on scalable, future proof networks that will scale to the applications that are yet to be developed as well as continue to meet our daily increased demand. COVID-19 has expedited this issue and it is not likely we will be going backwards to pre-COVID-19 practices. There will be more telework, remote learning, telemedicine, commerce and precision agriculture data that will need to share the same connection. Demand for upload speeds will match those of download speeds as data is collected and more widely shared.

COVID-19 aimed a spotlight on the usefulness of, and need, for broadband to support education, healthcare, telework and other critical industries such as agriculture. The focus on our nation's food supply has never been so magnified as during the COVID-19 pandemic. The demand placed on our producers to provide safe, healthy and abundant food must be met with on-farm connectivity and policy needed to support the call. Without on-farm connectivity, it is impossible to track goods through the supply chain during time of high demand as experienced through the pandemic. These imperatives have been championed consistently by rural advocates in prior years, as economies of scale might not support economic, educational, or healthcare opportunities that are available in more densely populated urban regions.

In this section we describe sector-specific needs and provide examples of rural broadband deployments that met the challenge of COVID-19. These accomplishments offer experiential validation of prior expositions while defining a road map for future rural needs that will encourage precision agriculture adoption and support high-quality jobs.

Economic Development

Broadband plays a critical role in supporting both on-site and telework opportunities in rural regions. For firms with an on-site presence, a robust broadband connection expands marketplace opportunities by broadening the range of interactions that can be enjoyed with clients and customers. For telework-based firms and their employees, broadband enables firms to not only balance various needs of their employees but to also recruit from a deeper pool of qualified candidates. COVID-19 and office closures illuminated the crucial need for telework capabilities.

According to the U.S. Bureau of Labor Statistics (BLS), non-farm unemployment reached 10.2% in August 2020. While this was a decline from 14.7% in April 2020, it still rivaled peak unemployment during the Great Recession, which reached 10%.[40]

Against this backdrop, telework emerged in 2Q20 and 3Q20 as a lifeline for many jobs. This is especially important in rural areas as the economic benefits of telework include stimulating economic activity beyond the home of the worker and into the general community through follow-on impacts generated by consumer spending. Of course, not all jobs can be teleworked: according to data cited by Pew Research Center, about 60% of U.S. jobs must be done on-site, including those that rely upon machines and equipment.[41] The remaining 40% of U.S. jobs, however, offer important telework opportunities. Although the ability to telework does not necessarily translate to zero job loss, data indicate a lower likelihood of job loss. Pew notes that from February to March, employment in jobs that could not be performed via telework were down 2.7%, while telework-capable jobs decreased 0.5%.[42]

These indicia lead to several conclusions: First, the rapid, necessary transition to telework demonstrates that even if full telework is not ideal for all sectors, some measure of telework greater than that formerly entertained will likely be the norm in the future. Second, regions where telework cannot be engaged will be foreclosed in some measure from relief when conditions close usual venues of employment. Third, current so-called "forced telework" may shift perspectives of both employers and employees. As some anecdotes of people considering leaving "the city" emerge (even if long-term demographic impacts cannot be predicted), it is

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[40] "Employment Situation Summary," U.S. Bureau of Labor Statistics, USDL-20-1503 (Aug. 7, 2020) (https://www.bls.gov/news.release/empsit.nr0.htm) (accessed Aug. 26, 2020). Overall, improvements from 2Q20 to 3Q20 were tempered by residual impacts in many sectors. Retail trades added about a quarter-million jobs, but employment was still down nearly one million from February 2020. Employment in hospitals, dental offices and home care services increased, but job losses in nursing and residential care facilities continued to decline. Manufacturing and financial services enjoyed modest gains. Overall, the largest job losses since April 2020 were in leisure and hospitality; employment in professional and business services increased slightly, but mostly due to temporary help services.

[41] "Telework May Save U.S. Jobs in COVID-19 Downturn, Especially Among College Graduates," Rakesh Kochhar and Jeffrey Passel, Pew Research Center (May 6, 2020) ((https://www.pewresearch.org/fact-tank/2020/05/06/telework-may-save-u-s-jobs-in-covid-19-downturn-especially-among-college-graduates/) (accessed Aug. 26, 2020) citing, Dingel, Jonathan I. and Neiman, Brent, "How Many Jobs Can be Done at Home," National Bureau of Economic Research (Apr. 2020) https://www.nber.org/papers/w26948.pdf) (accessed Aug. 26, 2020).

[42] "Coronavirus is Making Some People Rethink Where They Want to Live," Catherine E. Shoichet, Athena Jones, CNN (May 2, 2020) (https://www.cnn.com/2020/05/02/us/cities-population-coronavirus/index.html) (accessed Aug. 26, 2020).

safe to say that the topic is enjoying fresh consideration from new-found perspectives.[43]

Wabash Communications of Louisville, Illinois, noted the steep increase in telework during the COVID-19 emergency and provided free upgrades to all Fiber to the Home (FTTH) customers, increasing 100Mbps and 250Mbps packages to the 500Mpbs package for free through the end of the school year when at-home demand might be strained by remote learning students and teleworking parents. Rainbow Communications in Everest, Kansas, installed thirty (30) community Wi-Fi hot spots throughout its service area in Northeast Kansas that provides free internet access. It also increased the internet plans at local libraries to accommodate the higher usage demand. Yard signs have been posted at the locations to make the community aware of the free service in addition to social media posts. These steps assisted residents with job searches at this time.

To be sure, COVID-19 data sets are yet developing. But one element is axiomatic: where jobs can be retained through telework, the "tele" aspect must be available. Without broadband, those opportunities and the follow-on economic benefits would be lost.

Education

By the end of the 2019/20 school year, about 55 million American students had been affected by COVID-19 related school closures.[44] There are indications that some blend of staggered schedules and remote learning will be implemented for at least the short/medium term. Sufficient broadband capability in each household will be necessary. Of the 32 million U.S. households with children 18 and under, 91.3 percent have at least one working parent.[45] Accordingly, given telework statistics gathered during COVID-19, it can be expected that 11.7 million U.S. households with children will need to serve multiple broadband users during the

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[43] "Map: Coronavirus and School Closure," Education Week (Sep. 14, 2020) (https://www.edweek.org/ew/section/multimedia/map-coronavirus-and-school-closures.html) (accessed Sep. 14, 2020).

[44] Duffin, Erin, "Number of Families in the US by Number of Children 2000–2019, Statista (Nov. 12, 2019) (https://www.statista.com/statistics/183790/number-of-families-in-the-us-by-number-of-children/) (accessed Sep. 14, 2020).

[45] See, "Telework May Save U.S. Jobs in COVID-19 Downturn, Especially Among College Graduates," Pew Research Center (May 6, 2020) (https://www.pewresearch.org/fact-tank/2020/05/06/telework-may-save-u-s-jobs-in-covid-19-downturn-especially-among-college-graduates/#:~:text=In%20a%20Pew%20Research%20Center,result%20of%20the%20coronavirus%20outbreak.&text=The%20potential%20for%20the%20labor,already%20be%20stretched%20to%20capacity) (accessed Sep. 14, 2020). This calculation relies upon 32.17 million U.S. households with children ages 6–18, with an employment rate among those households of 91.3%, and a 40% telework rate.

school/workday.[46] The promise of rural broadband in meeting current and future educational needs can be seen in the actual performance of small, community-based broadband providers in the past months of COVID-19.

BBT (Alpine, Tex.) increased speeds for all customers, suspended data overage charges, and provided Wi-Fi to first responders and utility technicians; Ben Lomand Connect (McMinnville, Tenn.) established free community Wi-Fi spots; Skyline Membership Cooperative (West Jefferson, N.C.) offered two months free internet to students in need; and, West Carolina Tel (Abbeville, S.C.) offered free internet to new student or teleworking customers, and upgraded existing student or teleworking customers for two months. Another rural broadband provider is planning a "no student left unconnected" approach for the coming year. These steps are important: even at medium quality, Zoom consumes about 1.35GB/hr. at 720p. And with the prospect of blended learning and staggered days, connectivity will be critical. These data and anecdotes inform policies to promote robust rural deployments that will enable not only remote learning in times of crisis but also access to learning where economies of scale do not support certain opportunities in rural areas.

Health Care

Rural residents, on average, are older and face higher rates of chronic and acute conditions than their urban counterparts. When combined with distance from specialists and other socioeconomic factors, access to adequate and affordable health care in rural areas can be difficult. Broadband, however, can help shatter these barriers and result in improved health outcomes at lower costs.

By way of example, COPD (chronic obstructive pulmonary disease) is more common in rural areas than urban.[47] But, for better or for worse, those rates are not related to unsolvable conditions. Rather, the CDC (citing a University of Wisconsin study) explains that rural COPD rates are due, in part, to "less access to smoking cessation programs" and the fact that "[r]

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[46] Rural Health, COPD, Centers for Disease Control and Prevention (https://www.cdc.gov/ruralhealth/copd/index.html) (accessed Aug. 26, 2020).

[47] "Urban-Rural Differences in COPD Burden," Chronic Obstructive Pulmonary Disease (COPD), Centers for Disease Control and Prevention (https://www.cdc.gov/copd/features/copd-urban-rural-differences.html#:~:text=Rural%20populations%20may%20have%20more,living%20in%20more%20urban%20areas) (accessed Sep. 14, 2020) citing 2016 County Health Rankings: Key Findings Report, Population Health Institute, University of Wisconsin (2016) (https://www.countyhealthrankings.org/sites/default/files/media/document/key_measures_report/2016CHR_KeyFindingsReport_0.pdf) (accessed Sep. 14, 2020).

ural residents are also likely to be uninsured and have higher poverty levels, which may lead to less access to early diagnosis and treatment."[48] While these are not insignificant obstacles, neither are they impossible. In similar vein, sparse populations, challenging terrain, and capital-intensive networks would seem to stand in the way of broadband deployment in those same rural regions, but the right public policies combined with community commitment have proven successful in building rural broadband. Actions intended to meet the COVID-19 challenge demonstrate how telehealth demand grew and was met.

In March 2020, the U.S. Department of Health and Human Services (HHS) amended Medicare Fee-For-Service (FFS) rules to ease Medicare beneficiaries' access to healthcare. More than 100 additional services were added to the "telehealth eligible" list. This action was especially important at a time when many health care systems curtailed elective procedures and limited in-person visits. Physicians and patients responded impressively: according to HHS data, in April 2020, 43.5% of Medicare primary care visits were conducted via telehealth, a remarkable increase from the previous February in which only 0.1% of primary care visits were via telehealth. Iowa, South Dakota, and Oklahoma saw 33% increases in telehealth usage; even Nebraska, which logged the lowest telehealth increase, saw a stunning 22% increase.[48] Fortunately, data point not only to acceptance of telemedicine among younger Americans, but among older populations, as well. While studies have shown that relative interest in telemedicine tends to decline disproportionally to age, it must be remembered that those surveys are snapshots in time. Take, for example, broadband adoption, generally.

Although trends indicate that older users are less likely to adopt, the total number of older users is actually increasing over time.[49] Perceived relevance is increasing as more aspects of daily life go "online," and users who were in the 50–60 demographic a decade ago now populate the 60–70.[50]

In rural areas, small, facilities-based, locally operated broadband met the COVID-19 challenge with broadband. In Hazen, North Dakota, West River Telecom worked with area hospitals

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[48] "HHS Issues New Report Highlighting Dramatic Trends in Medicare Beneficiary Telehealth Utilization Amid COVID-19," US Department of Health and Human Services (Jul. 28, 2020) (https://www.hhs.gov/about/news/2020/07/28/hhs-issues-new-report-highlighting-dramatic-trends-in-medicare-beneficiary-telehealth-utilization-amid-covid-19.html) (accessed Aug. 26, 2020).

[49] "Internet/Broadband Fact Sheet," Pew Research Center (Jun. 12, 2019) (https://www.pewresearch.org/internet/fact-sheet/internet-broadband/) (accessed Aug. 26, 2020).

[50] See, e.g., Greenwald, P., Stern, ME, Clark, S., Sharma, R., "Older Adults and Technology: In Telehealth, They May Not Be Who You Think They Are," International Journal of Emergency Medicine (2018) (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5752645/) (accessed Sep. 14, 2020).

and clinics to plan for overflow locations and ensure connectivity. Ben Lomand Connect in McMinnville, Tennessee, provided resources for customers via social media including livestreaming experts on mental health. These and other rural broadband-enabled rural telehealth efforts offer not only qualitative benefits, but quantitative benefits, as well.

Telehealth enables users to avoid lost wages and travel expenses while increasing local medical facility revenues. A 2017 report projected substantial economic benefits from rural telehealth deployment, including: travel expense savings of $5,718 per medical facility, annually; lost wages savings of $3,431 per medical facility, annually; hospital cost savings of $20,841 per medical facility, annually; increased local revenues for lab work ranging from $9,204 to $39,882 per type of procedure, per medical facility, annually; and increased local pharmacy revenues ranging from $2,319 to $6,239 per medical facility annually, depending on the specific drug prescribed.[51]

These are but a few examples of how rural broadband helped blunt the impacts of COVID-19 in rural spaces and offer examples of best practices and policy visions for even ordinary times. Indeed, the formation of the American Connection Project Broadband Coalition, a large, multi-party coalition evidences growing recognition of the need for better broadband connectivity throughout the United States.[52] This coalition builds upon prior efforts that have demonstrated empirically the value of rural broadband.[53] These financial and quantifiable gains are complemented by qualitative, "quality of life" gains.[54]
The full range of broadband impacts on daily life – from economic development, education, health care and other vital services – has been revealed and illuminated in the COVID-19 crisis

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[51] See, Schadelbauer, Rick, Anticipating Economic Returns of Rural Telehealth, Smart Rural Community (2017) (https://www.ntca.org/sites/default/files/documents/2017-12/SRC_whitepaper_anticipatingeconomicreturns.pdf) (accessed Aug. 26, 2020).

[52] "Land O'Lakes and Partners Form a Coalition to Close America's Digital Divide," Broadband Communities (Jul. 13, 2020) (https://www.bbcmag.com/breaking-news/land-o-lakes-and-partners-form-a-coalition-to-close-america-rsquo-s-digital-divide) (accessed Sep. 26, 2020).

[53] See, i.e., Gallardo, Roberto, Strover, Sharon, and Whitacre, Brian, "Broadband's Contribution to Economic Health in Rural Areas," Research and Policy Brief, Community & Regional Development Institute, Cornell University (Feb. 2015) (https://cardi.cals.cornell.edu/publications/research-policy-briefs/broadband%e2%80%99s-contribution-economic-health-rural-areas/) (accessed Sep. 26, 2020) (finding median income, number of firms and education levels in non-metro counties were all positively correlated to broadband adoption. See, also, "A Cyber Economy: The Transactional Value of Internet in Rural America," iGR/Foundation for Rural Service (2018) (https://www.frs.org/sites/default/files/documents/2018-03/A-Cyber-Economy_The-Transactional-Value-of-the-Internet-in-Rural-America.pdf) (accessed Sep. 26, 2020) (finding, inter alia, that internet usage among rural and urban consumers is largely similar; that rural consumers account for approximately 15% of all consumer, internet-driven transactions annually; that the estimated value of rural online transactions is nearly $1.4 trillion).

[54] See, Manlove, Jacob and Whitacre, Brian, "Use of Broadband Linked to Greater Levels of Civic Engagement," Daily Yonder (Sep. 22, 2016) (https://dailyyonder.com/use-of-broadband-linked-to-greater-levels-of-civic-engagement/2016/09/22/) (accessed Sep. 26, 2020).

and recognized by numerous Congressional initiatives to move broadband policy forward. In these, the interconnected and interdependent relationships among rural and urban spaces must be considered.

> ". . . if you think about it, for this big country – and it was big by European standards – a major challenge for our founding leaders was how to bring it all together. So, communications of various kinds was very much a part of the agenda [and] the Constitution. Congress was given the right to build postal roads. You have the Erie Canal. You had the land-grant colleges. Even the Agriculture Extension Service, which was a great organization for the diffusion of innovations. And, we have forgotten all that for some reason. A lot of that actually helped develop the rural areas. It helped make us the world's great agricultural power, and we sort of say, "OK, let's move on." You cannot just move on. As new technology comes along, we must continue to play that role of using communications to bring the country together."[55]

The inextricable links between rural and urban spaces demands that precision agriculture and associated broadband policies are not a discrete *rural* broadband policy, but part of *national* broadband policy.

Recommendation:

- The FCC and USDA should consider precision agriculture connectivity as an imperative driver of our nation's food security.

The FCC and USDA should consider on-farm broadband as critical rural infrastructure for surrounding rural communities and the ecosystems they support. These benefits positively impact education, health care, and rural vitality, leading to the expansion of precision agriculture adoption and the availability of high-quality jobs.

[55] Beyond Rural Walls: A Scholars' Conversation About Rural and Urban Spaces," Foundation for Rural Service, Smart Rural Community, at 7 (2016) (https://www.ntca.org/sites/default/files/documents/2017-12/SRC_whitepaper_beyond_rural_wall(FRS).pdf (accessed Sep. 26, 2020).

Measuring On-Farm Broadband Deployment and the Adoption of Precision Agriculture

The lack of measurable broadband availability and service level metrics at the field level are barriers to meaningful on-farm deployment of connectivity that supports the adoption of precision agriculture technologies. To deliver adequate connectivity to the farm structures detailed in this report, it is essential that an interactive tool be utilized across agencies responsible for funding broadband deployment to measure progress, build in accountability, and prevent funding overlap.

Recommendations:

- The FCC and USDA should utilize a suite of mapping tools, including crowd source data, capable of collecting real- time speed tests and service levels consistent with or relying on the FCC Performance Measurement requirements, as may be applicable to the provider of internet service at the section or field level.
- Due to continued technological advances, the FCC and USDA should collaborate with the Agriculture Community determine adequate connectivity needs and service levels in perpetuity.
- The USDA should adjust Farm Census to explicitly request broadband service levels available at on- farm structures highlighted in this report.
- The USDA should leverage Farm Census to identify on- farm connected devices such as but not limited to: soil moisture probes, animal RFID tags, proximity sensors, environmental quality sensors, irrigation sensors, weather stations.

APPENDIX A – Task Force Members

Chair:
Teddy Bekele, Senior Vice President and Chief Technology Officer; *Land O'Lakes*

Vice Chair:
Catherine Moyer, Chief Executive Officer and General Manager; *Pioneer Communications*

Members:
Michael Adelaine, Ph.D.,Vice President for Technology and Security; *South Dakota State University*

Seth Arndorfer, Chief Executive Officer; *Dakota Carrier Network*

The Honorable Dale Artho, Commissioner; *Deaf Smith County, TX*

Andy Bater, Farmer; *Fifth Estate Growers LLC*

Peter Brent, Operations Manager and IT Director; *New Vision Farms*

Chris Chinn, Director, Missouri Department of Agriculture; *Missouri Department of Agriculture*

Anthony Dillard, Tribal Councilman; *Choctaw Nation of Oklahoma*

David Goldman, Director of Satellite Policy; *SpaceX*

Michael Gomes, Vice President, Business Development – IoT; *Topcon Agriculture*

Daniel T. Leibfried, Director, Advanced Technology, Intelligent Solutions Group; *John Deere*

Mike McCormick, President; *Mississippi Farm Bureau Federation*

Jeff Pettit, President and CEO of Noash Construction, Inc.; *National Association of Tower Erectors*

Steve Vail, Vice-Chairman, Board of Directors; *NineStar Connect*

Christopher McLean, Acting Administrator, Rural Utilities Service, *United States Department of Agriculture, Ex-officio Task Force Member*[56]

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[56] Prior to January 20, 2021, Chad Rupe, Administrator, Rural Utilities Service, United States Department of Agriculture served as the ex-officio Task Force Member.

APPENDIX B – Working Groups

(*Denotes a full Task Force member)

Mapping and Analyzing Connectivity on Agricultural Lands Working Group:

Chair:

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Vice Chair:

Dr. Sreekala Bajwa

Vice President, Dean & Director, *College of Agriculture & Montana Agricultural Experiment Station*

Seth Arndorfer*

Chief Executive Officer, *Dakota Carrier Network*

Dan Barcus

Farmer & Rancher, *Blackfeet Nation*

Teddy Bekele*

Senior Vice President and Chief Technology Officer, *Land O'Lakes*

Brent Birth

President and Sole Member, Stone Corner Resources, LLC, *National Society of Professional Surveyors*

Joseph Carey

Director, Wireless Strategy, Natural Resources Sector, *Trimble, Inc.*

Lynn Follansbee

Vice President, Law & Policy, *USTelecom – The Broadband Association*

Todd Harpest

External Affairs & Regulatory Director, *MetaLINK Technologies*

Tom Kealey

Director, *Idaho Department of Commerce*

Miles Kuschel

Owner & Operator, Rocking K Ranch, *Minnesota Farm Bureau*

David Larson

Precision Solutions and Telematics Advisor, *CNH Industrial*

Todd Myers

President, Kenneth G. Myers Construction, *Power & Communication Contractors Association*

Matt Splitter

Farmer & Member of Kansas Corn Growers Association, *National Corn Growers Association*

Joy Sterling

Chief Executive Officer, *Iron Horse Vineyards*

Mark Suggs

Executive Vice President & General Manager of Pitt & Greene Electric Membership Corporation, *National Rural Electric Cooperative Association*

Jessica Zufolo

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Examining Current and Future Connectivity Demand for Precision Agriculture Working Group:

Chair:

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Director, Advanced Technology, Intelligent Solutions Group, *John Deere*

Vice Chair:

Blake Hurst

President, Missouri Farm Bureau

Members:

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Farmer, *Fifth Estate Growers LLC*

Peter Brent*

Operations Manager and IT Director, *New Vision Farms*

Dr. Ranveer Chandra

Chief Scientist, Azure Global, *Microsoft*

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Valerie Connelly

Vice President of Government Affairs & Public Relations, *Choptank Electric Cooperative*

James Kitner

Director of Public Affairs, *Yocha Dehe Wintun Nation*

Jennifer Manner

Executive Vice President, General Counsel & Secretary, *Hughes Network Systems LLC*

Catherine Moyer*

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Aeric Reilly

Volunteer Policy & Strategic Management Director, *U.S. Cattlemen's Association*

Haran Rashes

Assistant General Counsel – Regulatory Affairs, *ExteNet Systems, Inc.*

Brian Scarpelli
Senior Global Policy Counsel, *The App Association (ACT)*

Steven Strickland
Director for Partnerships and Channels, *Ericsson*

Lucas Turpin
IT Director for the College of Agricultural Sciences, *Oregon State University*

George Woodward
President and CEO of Trilogy Networks, Inc., *Rural Wireless Association*

Encouraging Adoption of Precision Agriculture and Availability of High-Quality Jobs on Connected Farms Working Group:

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Vice Chair:
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President, Paige Wireless, *Irrigation Association*

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Commissioner, *Deaf Smith County, TX*

Robert Blair
Farmer, *Three Canyon Farms*

Lennie Blakeslee
Managing Director, *CoBank*

Dr. Dennis Buckmaster

Professor of Agriculture and Biological Engineering and Director of Digital Agriculture, *Purdue University*

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Keith Kaczmarek[58]

Skylo Technologies

Rob McDonald

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Josh Seidemann

Vice President of Policy, *NTCA–The Rural Broadband Association*

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[57] Working group member until September 2021

[58] Prior to Keith Kaczmarek, Aaron Kline represented Skylo Technologies.

Dan Spray

President, *Precision Technology, Inc.*

Accelerating Broadband Deployment on Unserved Agricultural Lands Working Group:

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President and CEO of Noash Construction, Inc., *National Association of Tower Erectors*

Vice Chair:

Heather Hampton+Knodle

Vice President, Knodle Ltd. Farms, *American Agri-Women*

Members:

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Luke Deryckx

Chief Technology Officer, *Ookla*

Anthony Dillard*

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Betsy Huber

President, *The National Grange*

Zach Hunnicutt

Farmer, *Nebraska Farm Bureau Federation*

Nick Moody

Board of Directors, *American Soybean Association*

Jarrett Taubman

VP & Deputy Chief Government Affairs and Regulatory Office, *Viasat*

Dr. Alex Thomasson

Professor, Department Head, and William B. and Sherry Berry Endowed Chair *Mississippi State University*

Jimmy Todd

Chief Executive Officer, *Nex-Tech*

Steve Vail*

Vice-Chairman, Board of Directors, *NineStar Connect*

The Honorable Dan Watermeier

Commissioner, *Nebraska Public Service Commission*

APPENDIX C – Working Group Charges

Accelerating Broadband Deployment on Unserved Agricultural Lands

The Accelerating Broadband Deployment on Unserved Agricultural Lands Working Group (Accelerating Deployment Working Group) shall develop recommendations that will allow the Task Force to fulfill its obligations under the following sections of the 2018 Farm Bill and that will allow the Task Force to weigh policies and rules to accelerate deployment on unserved agricultural lands:

- **12511(b)(3)(A)(ii):** Develop policy recommendations to promote the rapid, expanded deployment of broadband Internet access service on unserved agricultural land, with a goal of achieving reliable capabilities on 95 percent of agricultural land in the United States by 2025;

- **12511(b)(3)(A)(iv):** Recommend specific new rules or amendments to existing rules of the Commission that the Commission should issue to achieve the goals and purposes of the policy recommendations described in clause (ii) (i.e., the bullet above).

- **12511(b)(3)(A)(vi):** Recommend specific steps that the Commission should consider to ensuret that the expertise of the Secretary and available farm data are reflected in future programs of the Commission dedicated to the infrastructure deployment of broadband Internet access service and to direct available funding to unserved agricultural land where needed.

To carry out this charge, the Accelerating Deployment Working Group shall evaluate:

- Policy recommendations for the Commission, the Department, and federal, state, and local governments intended to promote the acceleration of broadband internet access on unserved agricultural lands.

- How the Commission can reduce and/or remove regulatory barriers to broadband infrastructure investment on agricultural lands.
- How the Commission should allocate and license spectrum for the purpose of accelerating deployment to unserved agricultural lands; and

- In conjunction with the Mapping and Analyzing Connectivity on Agricultural Lands Working Group, specific steps the Commission should consider to ensure that the expertise of the Secretary and available farm data are taken into account in Commission policymaking affecting broadband deployment on agricultural lands.

- **2511(b)(3)(A)(vi):** Recommend specific steps that the Commission should consider to ensure that the expertise of the Secretary and available farm data are reflected in future programs of the Commission dedicated to the infrastructure deployment of broadband Internet access service and to direct available funding to unserved agricultural land where needed.

To carry out this charge, the Accelerating Deployment Working Group shall evaluate:

- Policy recommendations for the Commission, the Department, and federal, state, and local governments intended to promote the acceleration of broadband internet access on unserved agricultural lands;

- How the Commission can reduce and/or remove regulatory barriers to broadband infrastructure investment on agricultural lands;

- How the Commission should allocate and license spectrum for the purpose of accelerating deployment to unserved agricultural lands; and

- In conjunction with the Mapping and Analyzing Connectivity on Agricultural Lands Working Group, specific steps the Commissions should consider to ensure that the expertise of the Secretary and available farm data are taken into account in Commission policymaking affecting broadband deployment on agricultural lands.

The Accelerating Deployment Working Group shall produce draft reports for the Task Force's consideration addressing the topics above at least every 12 months and shall submit each such report to the Task Force and Commission staff at least 30 days prior to the date of the Task Force meeting at which the Task Force will consider the report.

Examining Current and Future Connectivity Demand for Precision Agriculture

The Examining Current and Future Connectivity Demand for Precision Agriculture Working Group (Connectivity-Needs Demand Working Group) shall develop recommendations that will allow the Task Force to fulfill its obligations under the following section of the 2018 Farm Bill and that will allow the Task Force to weigh and prioritize connectivity needs throughout its work:

- **12511(b)(5)(B):** Not later than 1 year after the date on which the Commission establishes the Task Force [December 4, 2019], and annually thereafter, the Task Force shall submit to the Chairman of the Commission a report, which shall be made public not later than 30 days after the date on which the Chairman receives the report, that details the projected future connectivity needs of agricultural operations, farmers, and ranchers.

To carry out this charge, the Connectivity-Needs Demand Working Group shall evaluate:

- Current and future connectivity needs for precision agriculture in terms of coverage, speed, monthly usage, latency, and other factors; the technologies available to meet those needs; and the advantages and limitations of those technologies.

- Whether and how connectivity needs vary by agricultural product, geography, and other factors.

- How and why demand for precision agriculture needs may change over time due to, for example, population increases and shifts, environmental challenges, changes in diets, and increased demand for knowing where food is sourced; and

- Whether the amount or type of connectivity available is or will shift the choices of agricultural producers, for instance from growing one crop or crop type to another.

As part of its charge, the Connectivity-Needs Demand Working Group should consider how far in the future to evaluate connectivity needs. It should also contemplate whether different connectivity technologies create a need for or hurdles to interoperability and compatibility between precision agriculture technologies.

The Connectivity-Needs Demand Working Group shall annually prepare a report for the Task Force's consideration that, if adopted, would fulfill the Task Force's obligations pursuant to sections 12511(b)(5)(B) of the 2018 Farm Bill. The Connectivity-Needs Demand Working Group shall submit its report to the Task Force and Commission staff at least 30 days prior to the date of the last Task Force meeting before the annual statutory deadline.

Mapping and Analyzing Connectivity on Agricultural Lands

The Mapping and Analyzing Connectivity on Agricultural Lands Working Group (Data and Mapping Working Group) shall develop recommendations that will allow the Task Force to fulfill its obligations under the following sections of the 2018 Farm Bill and that will allow the Task Force to measure and analyze connectivity on agricultural lands:

- **12511(b)(3)(A)(i):** Identify and measure current gaps in the availability of broadband Internet access service on agricultural land.

- **12511(b)(3)(A)(v):** Recommend specific steps that the Commission should take to obtain reliable and standardized data measurements of the availability of broadband Internet access service as may be necessary to target funding support, from future programs of the Commission dedicated to the deployment of broadband Internet access service, to unserved agricultural land in need of broadband Internet access service.

- **12511(b)(3)(A)(vi):** Recommend specific steps that the Commission should consider ensuring that the expertise of the Secretary and available farm data are reflected in future programs of the Commission dedicated to the infrastructure deployment of broadband Internet access service and to direct available funding to unserved agricultural land where needed.

- Not later than 1 year after the date on which the Commission establishes the Task Force, [December 4, 2019], and annually thereafter, the Task Force shall submit to the Chairman of the Commission a report, which shall be made public not later than 30 days after the date on which the Chairman receives the report, that details 12511(b)(5)(A) the status of fixed and mobile broadband Internet access service coverage of agricultural land, and 12511(b)(5)(C) the steps being taken to accurately measure the availability of broadband Internet access service on agricultural land and the limitations of current, as of the date of the report, measurement processes.

To carry out this charge, the Data and Mapping Working Group shall evaluate:

- Commission broadband deployment data—fixed and mobile—and Department data to identify broadband coverage on agricultural lands.

- In conjunction with the Accelerating Broadband Deployment Working Group, specific steps the Commission should consider ensuring that the expertise of the Secretary and available agricultural land and precision ag technologies data are taken into account in policymaking;

- The suitability of the Commission's and Department's data to appropriately identify and measure current gaps in the availability of broadband Internet access service on agricultural lands for precision agriculture purposes, and any limitations of the data; and

- Specific steps the Commission and Department should take to improve and/or merge their data to better evaluate and facilitate broadband deployment for precision agriculture, including but not limited to specific steps that the Commission should take to obtain reliable and standardized data measurements of the availability of broadband Internet access service in order to facilitate the targeting of support from future programs of the Commission dedicated to the deployment of broadband Internet access service to agricultural lands in need of broadband Internet access service.

The Data and Mapping Working Group shall annually prepare a report for the Task Force's consideration that, if adopted, would fulfill the Task Force's obligations pursuant to sections 12511(b)(5)(A) and (b)(5)(C) of the 2018 Farm Bill. The Data and Mapping Working Group shall submit its report to the Task Force and Commission staff at least 30 days prior to the date of the last Task Force meeting before the annual statutory deadline.

The Data and Mapping Working Group shall also produce draft reports for the Task Force's consideration addressing the other topics it has been charged with considering, i.e., topics arising under section 12511(b)(3) of the 2018 Farm Bill, at least every 18 months and shall submit each such report to the Task Force and Commission staff at least 30 days prior to the date of the Task Force meeting at which the Task Force will consider the report.

Encouraging Adoption of Precision Agriculture and Availability of High-Quality Jobs on Connected Farms

The Encouraging Adoption of Precision Agriculture and Availability of High-Quality Jobs on Connected Farms Working Group (Encouraging Adoption and Jobs Working Group) shall develop recommendations that will allow the Task Force to fulfill its obligations under the following section of the 2018 Farm Bill and that will allow the Task Force to encourage adoption of broadband and precision agriculture on farms and ranches and thereby address labor supply challenges and promote the availability of high-quality job opportunities:

- **12511(b)(3)(A)(iii):** Promote effective policy and regulatory solutions that encourage the adoption of broadband Internet access service on farms and ranches and promote precision agriculture.

To carry out this charge, the Encouraging Adoption and Jobs Working Group shall evaluate:

- Whether and how the adoption of precision agriculture, including automated farming, can alleviate problems farmers are facing related to labor shortages and how to further increase demand for technologically skilled workforce in agricultural areas via the adoption of precision agriculture;

- Ways that government, including the Commission, the Department, and state and local governments, can promote adoption of precision agriculture through policies, regulations, and outreach;

- Ways that government, including the Commission, the Department, and state and local governments, can promote community colleges and universities so that they can continue to grow programs in precision agriculture technology;

- Means for government to partner with industry and stakeholders to promote adoption of broadband Internet access services on farms and ranches and promote precision agriculture and its uses to address labor shortages and make available high-quality jobs;

- Obstacles farmers and ranchers face to adopting precision agriculture;

- Whether any work has been done in this area to date and whether there are lessons from adoption-related efforts in other contexts to apply in the precision agriculture and connected farms context; and

- Metrics that the Commission could apply to measure and track progress towards broadband deployment and precision agriculture adoption on farms and ranches.

The Encouraging Adoption and Jobs Working Group shall produce draft reports for the Task Force's consideration addressing the topics above at least every 18 months and shall submit each such report to the Task Force and Commission staff at least 30 days prior to the date of the Task Force meeting at which the Task Force will consider the report.

APPENDIX D – Working Group Notes

Accelerating Broadband Deployment on Unserved Agricultural Lands

Guiding Principles and Peer Working Group Collaboration

The Accelerating Broadband Deployment Working Group members agreed on core principles within the first few meetings that would guide the research and deliberation that led to recommendations in this report:

- While the working group's charge is defined as accelerating deployment of broadband to unserved agricultural lands within the context of precision agriculture, group members recognized the effectiveness of precision agriculture on agricultural lands is inextricably tied to the ability to analyze and communicate data from decision making headquarters of individual farms and ranches.

- Determining which agricultural lands are unserved and those that are underserved is predicated on the ongoing efforts by the Federal Communications Commission (FCC), other state and federal agencies and recommendations of the Data and Mapping subgroup to improve the granularity and accuracy of existing data.

While individual working group members may have personal preferences for technology to deliver broadband, the group agreed to focus on outcomes rather specific technology solutions.

- When assessing use cases and connectivity needs, policies need to focus on building for future, not just current, needs while recognizing the in-field/pasture/rangeland needs may require different quality specifications than headquarters.

- Scalable technology is a pre-requisite for any broadband buildout effort.

- Encourage policies that allow the end-user to afford it and the company to maintain it over time.

The Accelerating Broadband Deployment Working Group collaborated with peer working groups of Adoption and Jobs, Connectivity Needs and Demand, and Data and Mapping in a variety of ways:

- Joint conference calls of working group chairs and vice chairs were convened by the Task Force Chairman to provide status reports and identify areas of overlap and cooperation.

- Three separate joint calls with presentations from each of the other working groups was held with the entire Accelerating Deployment team.

- Team members from Connectivity and Needs met with team members from Accelerating Deployment to discuss issues in common.

- The Deployment Working Group Vice Chairman and Chairman participated in additional fact finding calls with other working groups on issues that were relevant to deployment.

Given the interdependent nature of the working groups' charges, the Accelerating Deployment team decided to review the other working groups' reports before making its first round of recommendations.

The Accelerating Deployment Working Group also allocated subgroup time to assessing recommendations of the previously convened Broadband Deployment Advisory Committee. That body of work informed some of the recommendations. Additional background materials ranging from presentations by the FCC to articles in agricultural and technology publications were also reviewed by working group members.

Timeline

The first Accelerating Deployment of Broadband Working Group meeting was held March 23, 2020 via conference call. The entire working group met on a biweekly basis, except August 11 and December 22, until the interim report was approved for submission to the Precision Agriculture Task Force in February 2021. Meetings transitioned to a Microsoft Teams platform starting in June 2020. Additional subgroup meetings took place as needed to dive more deeply into issues and work through topics of interest.

Process

The Chair represented the Working Group in full task force discussions and identified key issues. The Vice Chair drafted agendas, notified members, provided background information and minutes, and scheduled joint meetings with other working groups, agencies, or presenters. Members facilitated subgroups to hone topics. Consensus was used to submit recommendations to the full Task Force.

Going Forward

The Charter for the Precision Agriculture Task Force and resulting charges for the working groups require a report on an annual basis. Pending input from the Task Force, the Accelerating Deployment Working Group could explore additional issues related to its charge that include, but are not limited to, the items discussed on pages 35–36 of the report adopted on November 10, 2021 (5G Buildout, Accountability, Formalizing Existing Relationships, Enacting Previous Recommendations, and Funding for Broadband Deployment to Rural Areas to Support Precision Agriculture).

Examining Current and Future Connectivity Demand for Precision Agriculture

The Connectivity Working Group has met multiple times per month in full committee and at the sub-Working Group level to develop our analysis. This summer, we started to meet with the other Working Groups to share and learn from each other's work and discuss the very important issues associated with precision agriculture. The Examining Current and Future Connectivity Demand for Precision Agriculture section of the Report reflects the work of our analysis and these discussions. The next phase of our work will focus on expanding our analysis to fully address the questions our Working Group has been asked to analyze. Our analysis will continue to involve coordinating with the other Working Groups.

Encouraging Adoption of Precision Agriculture and Availability of High-Quality Jobs on Connected Farms

Beginning in April 2020, the "Adoption & Jobs" Working Group launched meetings to undertake their respective portion of the Precision Ag Connectivity Task Force report to be submitted to the Federal Communications Commission. The information in the section of the Report titled Encouraging Adoption of Precision Agriculture and Availability of High-Quality Jobs on Connected Farms are the issues the Working Group has identified as major priorities for discussion for Precision Agriculture across rural America.

Recommendations for Alternate Working Groups from the Adoption & Jobs Working Group

- Agriculture production utilizes both downstream and upstream networking. Implementation of a network that provides greater capacity with better balance between download and upload speeds is critical to precision agriculture adoption. The agricultural producer's data outputs are just as decisive as their inputs. As equipment continues to become connected, this becomes increasingly important. (Examining Current and Future Connectivity Demand for Precision Agriculture Work Group should further explore this recommendation upon Task Force approval).

- The FCC should accelerate the subsidized investment in agricultural lands through existing and new mechanisms to advance technology adoption in agriculture and ensure that these programs are fully funded. (Mapping and Analyzing Connectivity on Agricultural Lands, Examining Current and Future Connectivity Demand for Precision Agriculture, and Accelerating Broadband Deployment on Unserved Agricultural Lands should further research this topic upon full Task Force approval.)

- Work in collaboration with Examining Current and Future Connectivity Demand Working Group to further policy initiatives for recommendations on pages 80–109 of the Report.

APPENDIX E – Selected Sources Researched by Accelerating Deployment Working Group

- A Case for Rural Broadband: Insights on Rural Broadband Infrastructure and Next Generation Precision Agriculture Technologies – USDA 4/19
- "Agriculture Equipment Manufacturers Mobility 2050 Vision" – 4/21/20
- BDAC State Model Code for Accelerating Broadband Infrastructure Deployment and Investment – Draft 12/06/18
- BDAC: Report of the Removal of State and Local Regulatory Barriers Working Group – 1/10/18
- BDAC: Streamlining Federal Siting Working Group – 1/18
- "Big Ideas Born in the Field" – AgWeb 11/5/20
- Coalition to Advance Precision Agriculture – Industry Summary 3/25/20
- "Data-Drive Advances in Agriculture" – K. Sudduth, USDA ARS 4/20
- "Disconnected: Seven Lessons on Fixing the Digital Divide" – Federal Reserve Bank of Kansas City
- "The Economic Impact of Rural Broadband" Revised Edition – Hudson Institute 4/16
- Establishing the Digital Opportunity Data Collection: Second Report and Order and Third Further
- Notice of Proposed Rulemaking – WC Docket No. 19–195; Modernizing the FCC Form 477 Data Program – WC Docket No. 11–10 – 6/25/20
- FCC 20–50
- FCC 20–89, T-Band NPRM and Public Safety T-Band Fact Sheet – 9/18
- FCC 20–89, Commissioner Rosenworcel Statement
- FCC 21–20, Rules to Improve Broadband Data Mapping
- "History: The Story Behind America's Electric Cooperatives and NRECA" – 4/15/20
- "Improving and Increasing Broadband Deployment on Tribal Lands Report to the FCC" – Native
- Nations Communications Task Force 11/19
- "Impact of Broadband Penetration on U.S. Farm Productivity" – K. LoPiccalo, FCC 12/15/20
- Interview with Chickasaw Nation Fiber Buildout Manager – 7/24/20
- Interview with FCC Office of Native Affairs and Programs – 9/4/20
- "Income and Internet Access" – Pew Research 5/7/19
- "Lessons from Open-Access, Middle-Mile Networks" – Benton Institute for Broadband and Society

- "NTCA-USF Study" – Williams, Michael A. and Zhao, Wei with Berkley Research Group 5/20
- "Overview of Internet Service Provider Technology Considerations for Rural Broadband Deployments" – Microsoft 11/19
- "Precision Agriculture Boosts Land Values for Users" – Morning Ag Clips 7/20
- Quiet Zones – Electronic Code of Federal Regulations (eCFR Title 47, Chapter 1, A, Part 1, F 1.924)
- Report of the Competitive Access to Broadband Infrastructure Working Group to the FCC BDAC – 1/18
- Risk Management Framework Online Training – guidance NIST Special Publication 800–37, Revision 2
- Rural Utility Service "Your Partner in Prosperity" Presentation – Chad Rupe, RUS Administrator 4/20
- "Setting the Record Straight on Precision Agriculture Adoption" – Lownberg-DeBoer, Erickson;
- Agronomy Journal Volume 3, Issue 4, 2019
- Small Business in Agriculture presentation – Farmwave, C. Ganssle 4/14/20
- "Special Broadband Insert" – Rural Electric Magazine 12/19
- Statement of Chairman Ajit Pai, FCC "Oversight of the Federal Communications Commission" before the U.S. Senate Committee on Commerce, Science and Transportation – 6/24/20
- "Threats to Precision Agriculture" – 2018 Public-Private Analytic Exchange Program, Department of Homeland Security
- United Soybean Board and NTCA (National Telecommunications Cooperative Association) Webinar – 8/13/20
- Use Case Scenarios from Maine, Illinois and Alabama – 4/20
- Use Case Study with M. Splitter – 5/20
- Utility Lease Model – Brookings Institute 2/20
- "Wireless Needs Wires" – NTCA Article 8/20