Examining Current and Future Connectivity Demand for Precision Agriculture

Interim Report – December 2, 2022

CONTENTS

Introduction

> *"I'm going to challenge you to offer me everything you can give; and I will challenge friends to build technologies to use it. We've never had enough to know how much we really need. You keep building and I'm going to write a business plan for how I will make money as a farmer by acquiring more data to make better decisions."*
>
> – Jeremy Wilson, Farmer, EVP/COO North American Director of Ag Gateway 8/25/22

Jeremy was one of several guest speakers who informed the Examining Current and Future Connectivity Demand (Connectivity Needs) Working Group since we began meeting in March 2022. His experience cobbling together connections using wireless technology across his farm is representative of farmers and ranchers across the United States who are struggling to innovate because of inadequate to no connectivity and lack of access due to affordability.

Meanwhile, **the urgency to build out more robust and reliable connections to support precision agriculture is greater than ever because of multiple crises** including the invasion of Ukraine and extreme weather events impacting global food supplies. Rapidly rising inflation around the globe and havoc in the supply chain are impacting food and energy prices, setting the stage for widespread famine in developing countries, as well as heightened food insecurity here in the U.S.

Precision Agriculture is proven to increase yields as well as improve natural resource management; those tools require connectivity in the field. Call it "last acre." Last mile goes to the farm house. Last acre goes to the head of lettuce, to the sensor.

Lessons learned and knowledge gathered from our speakers, our working group members, and the foundational work completed in the first round of the Task Force, in 2019-2021, have culminated in these guiding tenets:

- **Data Must Flow To and From the Decision Maker:** All data related to a farm must be accessible to the farm manager at *every location* on the farmed properties to enable the farm manager's ability to analyze and make decisions, and that decision maker must be able to communicate back to every part of the farm so that decisions can be implemented in real time.
- **Connectivity to the Last Acre:** Interoperability of varied transmission technologies as well as interoperability between makes and models of equipment - including tools such as planters and sensors in the ground, on livestock, or in storage facilities, is essential for informed management.
- **Digital Innovation, Data, Drive Increases in Food Supplies:** Precision agriculture, coupled with research and biotechnological advances, has enabled exponential growth in yields in the last 20 years. Continued gains are necessary to achieve the Congressional goal of doubling food output on the same or less acreage by 2050. That's doubling the amount of food produced in all human history in less than 27 growing cycles.

- **The importance of now:** We are at an historic moment of public and private investment in digital infrastructure that is unlikely to be sustained over time. It is critical that funding is directed toward building architecture that allows for scalable, flexible and affordable application of precision agriculture in the future.

Our work has reaffirmed the need to bolster the current infrastructure supporting connectivity to position farmers and ranchers so they can meet the demands for food production in times of so many crises, the ever-growing need to feed the global population, to manage soil and water for long-term productive capacity and health, and to be resilient in erratic and changing climate conditions.

The emerging technologies to enhance productivity and increase management efficiency require an ecosystem of connectivity components in the field, with edge computing capability at the farmhouse/headquarters, so that farmers and ranchers can afford to adopt and effectively deploy the advances.

The Context within the Precision Agriculture Task Force

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 from the Agriculture Improvement Act of 2018 (2018 Farm Bill).

The Task Force is chartered by the Federal Communications Commission (FCC) at the direction of Congress to develop policy proposals and provide advice and recommendations to the 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.

The 2018 Farm Bill sets forth the charge of the Connectivity-Needs Demand Working Group in Section 12511(b)(5)(B) as part of the expectations of the Precision Agriculture Connectivity Task Force:

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 particular 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.

Connectivity-Needs Demand Timeline and Process

Given the urgent need for improvements in connectivity to support precision agriculture's current and future capabilities, our working group supports "future-proofing" the data network architecture to support ongoing advances in precision agriculture, starting with the 2023 Farm Bill.

After receiving assignments and leadership participating in an orientation with the FCC, our first working group meeting was March 17, 2022. All members were given the first-round report and asked what key questions and drivers we should explore to build on the foundation established in round one. Our work is supported by FCC and USDA staff members who have updated our working group on actions taken by the FCC on round one recommendations. The full working group has convened biweekly since April 14th. Members made (and continue to make) suggestions on key topics and speakers.

We have heard from experts on the following topics: the Paperwork Reduction Act; ARA wireless living labs agriculture and rural community network and research; Nelson Farms in eastern Washington state connectivity, software and prescription farming; USDA Agricultural Research Service on trends driving connectivity needs; AIFARMS (Artificial Intelligence for Future Agricultural Resilience, Management and Sustainability) on future applications in varied use cases; and Ag Gateway to discuss data gathering, sharing and analysis needs across the supply chain and mobile network industry standards.

Key takeaways from presenters include:

- Agricultural data needs will continue to outpace broadband buildout.
- Some of the challenges to "last acre" connectivity come from crop canopies and difficult terrain.
- More spectrum in the lower frequency band could help. Ease of licensing is essential.
- We need to recognize that machine vision and analyses (artificial intelligence) are coming sooner rather than far off in the future. Getting and sharing imagery (i.e., from "always on" cameras, monitoring a cow) involves huge files, again pointing to the need for higher bandwidth in the field and for Edge computing.

For many farmers today, employing a drone means downloading the data on a thumb drive, uploading it off site, waiting three to five days for processing of the data, and compiling a report, before action can be taken in the field.

The technology exists to make and implement farming decisions in real time in the field that will save resources, lower costs, increase production, etc. The goal of this interim report is to help determine what it is going to take to start utilizing these tools. Right now, lack of connectivity stands in the way, therefore, getting that keystone in place is essential. Then, affordable applications and timely, actionable data are key to adoption.

In mid-July, we formed three subgroups to dig deeper into defining aspects of our charge:

Current Needs and Opportunities – to consider policy needed to improve current connectivity across all modes of delivery to the last acre, including considerations of interoperability issues due to legacy technology and multiple vendors.

Data Trends – to consider taxonomy and metrics, cross checking round one use cases for increasing data, latency, jitter and other quality indicators and Additional or New use cases including limited supply chain considerations to determine data sharing costs, data ownership and sharing measures.

Future Needs and Opportunities – to explore the infrastructure, including what private or public entities bear costs and what training and tools are required to activate, needed to move into prescription farming which requires improved analytics and application of data for farmers to make decisions and apply or put into action their desired outcomes.

The report of each subgroup follows the glossary of terms.

GLOSSARY OF TERMS

AI = Artificial Intelligence
Cloud = Cloud computing
Edge = Edge compute
eMBB = Enhanced Mobile Broadband
EPC = Evolved Packet Core
FCC = Federal Communications Commission
FDD = Frequency Division Duplexing
IoT = Internet of Things
LEO = Low Earth Orbit
M2M = Machine to Machine
ML = Machine Learning
MSC = Mobile Switching Center
NIST = National Institute of Standards and Technology
NTIA = National Telecommunications and Information Administration
Precision Ag = Precision Agriculture
RAN = Radio Access Network
RF = Radio Frequency
TDD = Time Division Duplexing
UAV = Unmanned Aerial Vehicle
USDA = United States Department of Agriculture

PRECISION AGRICULTURE—means managing, tracking, or reducing crop or livestock production inputs, including seed, feed, fertilizer, chemicals, water, and time, at a heightened level of spatial and temporal granularity to improve efficiencies, reduce waste, and maintain environmental quality.

PRECISION AGRICULTURE EQUIPMENT— means any equipment or technology that directly contributes to a reduction in, or improved efficiency of, inputs used in crop or livestock production, including— (A) Global Positioning System-based or geospatial mapping; (B) satellite or aerial imagery; (C) yield monitors; (D) soil mapping; (E) sensors for gathering data on crop, soil, or livestock conditions; (F) Internet of Things and technologies which are reliant upon edge and cloud computing; (G) data management software and advanced analytics; (H) network connectivity products and solutions including public and private wireless networks; (I) Global Positioning System guidance, auto-steer systems, autonomous fleeting and other machine to machine operations; (J) variable rate technology for applying inputs, such as section control; and (K) any other technology that leads to a reduction in, or improves efficiency of, crop and livestock production inputs, which may include seed, feed, fertilizer, chemicals, water, and time.

Subgroup – Current Needs and Opportunities

Interim Recommendations to Precision Agriculture Task Force

The immediate need for improved connectivity and data delivery cannot be overstated.

Immediate action is needed to ensure seamless connectivity through all modes of data delivery to drive the adoption of Precision Agriculture practices. Data-driven farming requires a Precision Agriculture Connectivity Infrastructure that enables highly secure hyperscale Cloud connectivity, farm-based edge compute platforms, private 5G wireless systems, public wireless field coverage and all other forms of terrestrial and non-terrestrial networks. This infrastructure will enable artificial intelligence, quantum computing, machine vision, numerous forms of automation and more innovations by software developers.

As stated previously, a number of conditions heighten the urgent need for improved connectivity to support precision agriculture applications. Examples in today's food production environment include resource management in the face of drought; employee safety, health and rural emergency response times and diagnostic capabilities; air quality sensors in vineyards as wildfires are more frequent; food safety traceability 'to the head of lettuce;' ecosystem markets and verifying the results of best management practices, online reporting to various agencies.

The enormous increase in crop yields needed to avert global famine will be largely driven by digital transformation of the agri-food industry that will bring additional gains in efficiency, productivity, sustainability and innovation.

With these and many other examples in mind, we submit the following recommendations for consideration by the Precision Agriculture Task Force:

Target Existing Infrastructure Investments to Enable Gains from Precision Ag

- The Connectivity Needs-Demand Working Group supports the recommendations of the Data Mapping Working Group to encourage Congress to expand its 2020 mandate in the Broadband DATA Act to the FCC to include working lands when measuring wireless coverage and quality to the last acre rather than road miles.
- Farmers and ranchers must be at the center of the precision ag ecosystem and at the core of making technology decisions; data gathering, analysis and deployment so advantages accrue first at the field level then to technology providers and agri-food industry.
- As adopted by the Task Force in the 2021 Report, include Precision Ag Connectivity Infrastructure as an eligible expense for reimbursement as part of all federal and state broadband stimulus programs.[1]
- Recommend federal agencies, state and local governments prioritize connectivity on working lands, which we call the "last acre", predicated on geography, not population.

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[1] Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture in the United States, Report adopted as of November 10, 2021 at 72 (2021), https://www.fcc.gov/sites/default/files/precision-ag-report-11102021.pdf.

- Set a symmetrical standard of 100/100 Mbps at the field level and 1/1 Gbps to headquarters, farm office, farmhouse or farmstead.[2]
- Continue to push for more middle mile buildout to support connectivity on working lands
- Recommend that agencies add incentives or requirements that boost scoring when field level connectivity is demonstrated in applications for funding.
- Encourage USDA ReConnect Funds be extended to fund grants for new, open access cellular towers and for retrofitting existing towers or structures (i.e. water towers, grain legs) to encourage multiple operators in rural areas and eliminate "dead zones."

Take Corrective Actions to Allow Current Connectivity and Transition to Near Future Applications

- As adopted by the Task Force in the 2021 Report, develop a closed-loop audit process to ensure that the proposals that were awarded funding are implemented and meet the milestones stated in the proposal with enforcement when these funding requirements are not met.[3]
- Suggest that the Mapping Working Group recommend agencies 'groundtruth' 5G deployments with multiple devices simultaneously downloading and uploading data at the field level and advance the need for further discussion of 5G deployment 'on the farm.'[4]
- Explore ways to ease licensing of lower frequency bands to extend a range of technologies.
- Support Mapping Working Group's recommendation for a 'Negative Map' of areas with no coverage; suggest funding through the Farm Bill, and to emphasize the importance of independently verified information to avoid contradictory maps.

Act Now to "Future Proof" Food Production in the United States

- Future-proof the network to support scalable connectivity at the field level starting with the 2023 Farm Bill.
- Identify the learnings from the roll out of 5G. i.e. agricultural equipment built prior to 2015-2017 runs on 3G, yet often 3G is being shut off to make room for 5G which presents challenges for basic connectivity, resulting in whole swaths of the farm going dark. Make recommendations for how to avoid such shortfalls going forward.
- Make recommendations on security improvements or guards that are needed in the networks, including the equipment, add-on technology, and in operator behavior patterns.
- In order to better deal with future supply chain issues, incentivize domestic production of components such as antennas, power supplies, chipsets, modem, to enable connectivity now and in the near future.

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[2] Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture in the United States, Report adopted as of November 10, 2021 at 72 (2021), https://www.fcc.gov/sites/default/files/precision-ag-report-11102021.pdf (recommendation in the 2021 Report to "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" at a minimum performance of 100 Mbps download and 20 Mbps upload).

[3] Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture in the United States, Report adopted as of November 10, 2021 at 73 (2021), https://www.fcc.gov/sites/default/files/precision-ag-report-11102021.pdf.

[4] The FCC's Broadband Data Collection currently has resources regarding crowdsourcing and other challenges to its broadband data maps. *See* https://www.fcc.gov/BroadbandData/consumers.

- Endorse consistency across federal agencies - FCC, USDA, NTIA and include Congress in setting uniform standards and coordinated timing of programs to promote connectivity.

Recognize the Urgency Driving the Need for Rapid Deployment

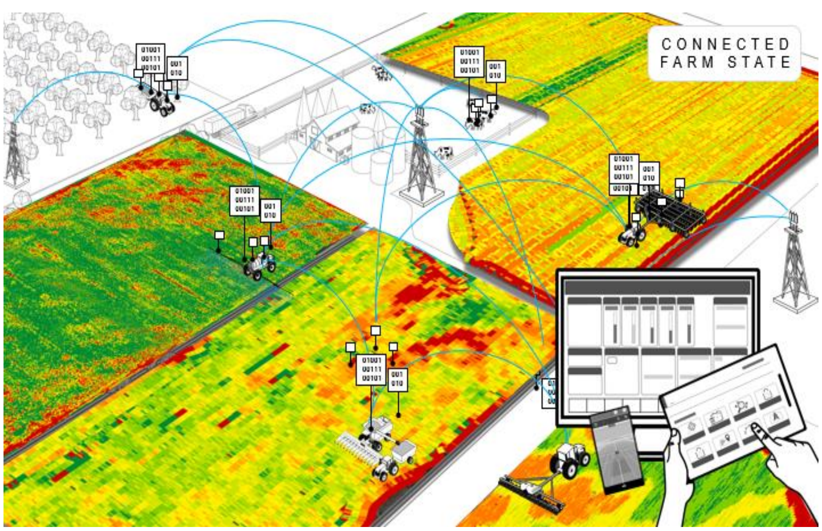
- Elected officials declare food security as a vital component of national security.
- Build the case that the $42 Billion plus in broadband investment from the Infrastructure Investment and Jobs Act of 2021 be focused on food production as a matter of national security, tackling water scarcity and food insecurity.
- Build the case that broadband investment directed toward Precision Ag is a climate smart investment, promoting more efficient land use, better resource management of water, fertilizer, and other inputs.
- Build the case that connectivity to the last acre is essential for water quality, food safety, alleviating labor shortages, and reducing food loss at the farm level.
- Encourage programs that provide competitive options for connectivity to the last acre, also for redundancy, most important in times of disaster.

Subgroup – Data Trends

As the Data Trends subgroup, we leveraged our experience and the knowledge gained from guest speakers to evaluate how the precision agriculture landscape has evolved over the last several years:

- Precision Ag use cases have not dramatically changed over the past two years but the demand of growers to leverage technology and data requirements associated with each use case continues to increase.
- 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.
- The real-time management practices enabled by a Precision Ag connected operation vs a non-connected operation have a direct impact on growers profitability.

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. This manual documentation of farm practices, seeding rates, fertilization rates, etc. are generally calculated at the farm or field level, not accounting for variation across a farm or field. The level of resolution is largely limited based on the farmer's individual capabilities.



As shown in the image to the left, Precision agriculture, with connectivity across an operation, allows growers to generate greater amounts of data on a more granular scale, creating better insights for making decisions. The Exact rate and placement of every seed, gain of fertilizer, application of herbicide, enabled by precision agriculture, enable the grower to apply exactly what is needed, where it is needed to minimize inputs and maximize crop yields. Connectivity enables a grower to build and seamlessly execute a plan which matches the complexity of the environment in which their crop is grown.

The goal of Precision Ag practices is increasing quantity and quality while ensuring cost efficiency in production and supply chains and reducing environmental impacts of agriculture operations. This goal is, rightfully, a moving target because as technology evolves the level of resolution and the available data across fields and a growing season will increase. The drive for increased resolution (more data) to make better decisions for better outcomes will not end. As the image below illustrates, each pass through a field generates data which the grower can use to make decisions in real time. The historic data is also used by the grower to make a more informed plan for the next pass, making each subsequent pass more efficient and productive.

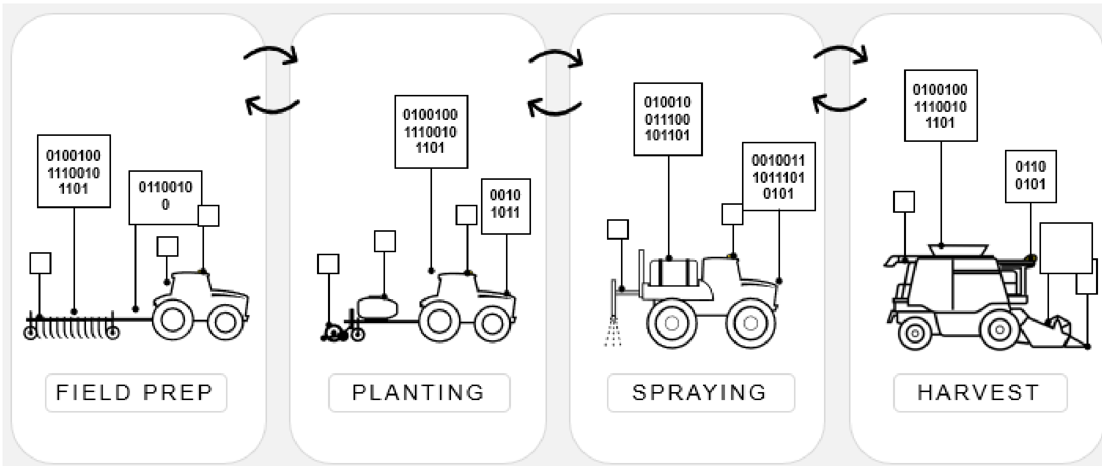


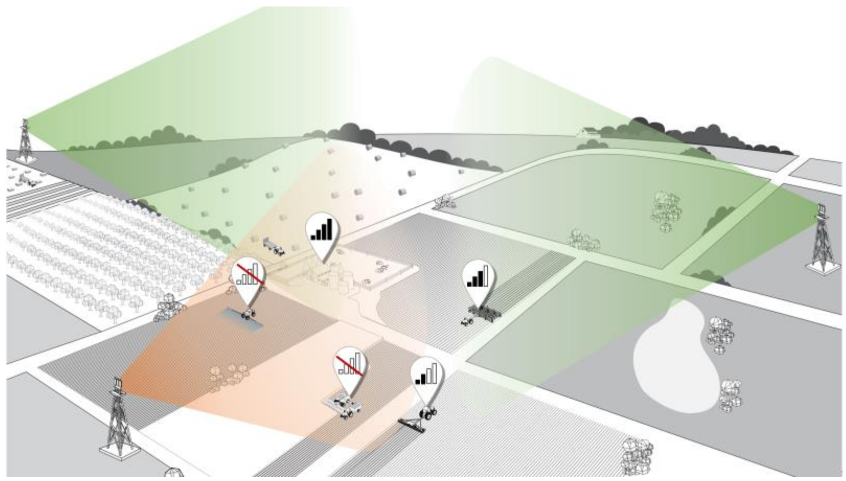
Figure 1: Pass to Pass operational data for a row crop operation

The use of broadband and other advanced technology in agriculture is increasing. These applications enable users to obtain greater input efficiencies and yields while mitigating potential climate impacts and carbon footprints. Agricultural technology (ag tech) can be deployed for crops and animal farming. As technology advances and prices decrease, ag tech adoption is anticipated to increase. Cloud-based and other ag tech systems rely upon secure and robust fixed and mobile broadband connections. Broadband availability in rural agricultural regions will be necessary to maintain domestic and international competitiveness and production capabilities. This paper provides an overview of agricultural markets and technology in the United States and demonstrates the imperative to deploy, develop and maintain broadband connectivity in rural U.S. agricultural regions.

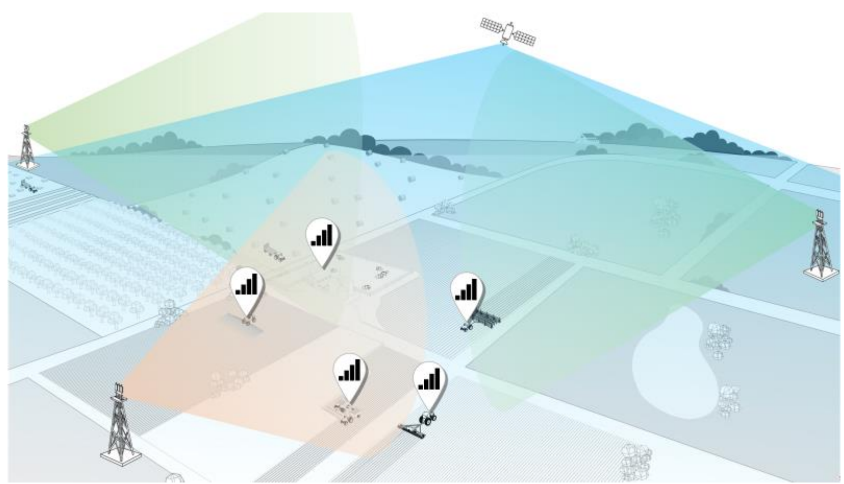
Wired and wireless facilities are necessary to support the full complement of precision agriculture tech solutions. Mobile sensors in the field rely on wireless solutions, while data intensive, high-capacity applications demand low-latency and security provided by fiber networks. Moreover, wireless communication services rely on terrestrial wired fiber optic facilities; **stated differently, "wireless needs wires."** Wireless communications networks include a mobile switching center (MSC) facility at some point in the communications path. The MSC connects wireless antennae facilities to the wired network. By way of example, a mobile signal transmits from the device to a tower antennae or base station, and then to an MSC that accepts the spectrum-based signal and redirects it along terrestrial wired facilities. If the final destination is a wired location, then the signal stays on the wired network; if the final destination is wireless, then the signal will route to the MSC closest to the destination for emergence and reentry to the wireless network.

In order to provide robust connectivity for the transactional and business aspects of agriculture, including, but not limited, commodities and livestock sales, or whether to serve the inherent technological demands of wireless networks that rely on substantial underlying fiber infrastructure, a holistic view of the network is necessary to ensure that these complementary technologies provide a symbiotic beneficial basis for ag tech. Accordingly, the deployment of wireless communications services, whether 3G, 4G or 5G, 6G and beyond requires wired facilities along the general path of communications. To this end, the role of terrestrial wired broadband facilities must be contemplated as comprehensive ag tech solutions are examined

As many growers work to adopt Precision Ag practices, connectivity is voiced as a continual frustration point. A grower has to manage various connectivity technologies and services to take full advantage of the data coming from their operation. Office, equipment buildings, mobile phones, new equipment, old equipment, service vehicles, fuel trucks, tender trucks are just a few examples of the various items a grower must get and keep connected, along with various technologies such as fiber, wi-fi, satellite, and cellular to attempt to get their operation connected. Many times getting an operation connected is a trial and error process with little data available to drive decisions. The image illustrates the challenge a farmer has connecting their equipment on every acre of their fields. Even with the connectivity hardware on all pieces of equipment, the farmer still has to manage the service to those devices to enable connectivity. The different colors from the cell towers in the image below represent different service providers.



Even when coverage is present, the interoperability limitation between service providers inhibits a growers ability to connect their equipment, which limits their ability to drive real time decisions. As growers continue to experience this scenario we see a growing expectation that connectivity technologies and service providers work seamlessly together to enable data flow over any available connection. The image to the right illustrates a scenario where all wireless connectivity technology and service providers work together to connect the growers operation.



Satellite communication technologies play an increasingly active role in Precision Ag, with innovative and nimble use cases in fields and ranches that span the connectivity needs universe including water, soil, irrigation, weather, silo/tank monitoring; livestock health and movement tracking; machinery utilization and health; weather and climate sensing; and endless new innovations. Intensive deployment of NGSO satellite networks, “smallsats,”“cubesats” (and smaller), and new developments in cellular-satellite interoperability technologies promise to provide low bandwidth connectivity in even the most remote places on earth. Agencies making decisions about attaining last acre connectivity must consider satellite’s ability to fill in the most remote spaces, increasing interoperability potential, and rapid development of applications that make use of specialized sensors and data transmission enabled by existing and emerging networks.

Subgroup – Future Needs and Opportunities

The Sub-Group's overarching objective is to define the technologies needed to sustainably double crop yields with less land and less water in less than 28 crop cycles while lowering emissions and reducing the overall carbon footprint. The Task Force's "first term report", published in November 2021, focused on grower/producer types that included row crops, broadacre, specialty, permanent, livestock, poultry, and many of the applications, solutions, speeds, and bandwidth requirements that might be necessary to support them.

In this second interim report, the Connectivity Needs Working Group concentrates on the fundamental architecture and requisite infrastructure necessary to support the digital transformation and automation of the agri-food industry to enable and accelerate the adoption of data-driven farming practices.

The fundamental architecture to enable data-driven farming at the highest level involves the collection of massive data from millions of sensors that is transformed with artificial intelligence into actionable information for growers and producers to augment their farming decisions.

Each farm will ultimately have thousands & eventually millions of connected devices, sensors and controls that will build the complex architecture of digital infrastructure. This digital infrastructure will be comprised of edge Cloud computing platforms; public and private 4G, 5G & 6G systems; satellite; last-mile, middle-mile and long-haul fiber cables; with local, regional, and national data centers.

Artificial intelligence (AI), edge, 5G, Cloud connectivity, data centers, and devices, form the fundamental building blocks for Precision Ag and data-driven farming practices.

Real-time AI and intelligent feedback requires an industrial Internet of Things (IoT) world of connected everything, autonomous everything, digitally-transformed processes and business models. True data-driven farming practices need machine vision with 5G, 6G and beyond. This world of connected everything, supported by AI, machine vision, machine learning, and advanced imagery will ultimately require bandwidth, speeds, and latency above 10Gbps symmetrical with sub-millisecond latency.

This interim report addresses the four major architectural areas that comprise the digital infrastructure needed to deliver the technological solutions that the United States Congress requested in the Agriculture Improvement Act of 2018 (2018 Farm Bill):

1. Artificial Intelligence and HyperScale Cloud Innovation;

2. Edge Cloud Compute, and 5G Private Wireless Infrastructure;

3. Advanced Device Connectivity Over Public Cellular Networks; and

4. Highly Secure Cloud Connectivity, Micro-Local, Regional, and National.

We submit the following recommendations for consideration by the Precision Agriculture Task Force:

Increase Spectrum Available for Precision Ag

- FCC develop a strategy to provide a range of licensed and unlicensed spectrum to agriculture for fixed wireless access and mobile broadband, rather than the spectrum be auctioned.
- Evaluate additional spectrum needed for 5G and 6G access to the farm decision headquarters and IoT device connectivity to the last sensor. This includes FCC and NTIA as well as international coordination developing a comprehensive spectrum policy for wireless network use, and input from industry stakeholders on adoption of new spectrum into agriculture equipment/device ecosystem. This policy should focus on achieving scale through unit economics to allow for affordable, mass adoption.
- FCC should consider opening up spectrum for space-to-earth communication for satellites via auction.
- Adopt policy in 3-5 years to accelerate 5G, 6G and like spectrum access, including shared spectrum, and deployment to farmlands in 2030 and beyond.
- Create incentives for service providers to mitigate coverage gaps created during decommissioning of older "G" technologies.

Make Targeted and Informed Funding Decisions

- 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 100 Mbps up, in 2022-2023.[5] These standards should continue to be pushed to higher levels over time, where practical, to meet the quickly evolving needs of precision agriculture. Network latency should be consistent with the needs of real-time interactive applications. Assess funding tiers based on geographical complexity to deploy based on mid-to-high-band 5G through low-band coverage extension network architectures.

- Conduct cost-benefit analysis of emerging use cases in precision agriculture and consider higher funding priorities for future "G" public wireless networks capable of supporting use cases with highest returns.

- We recommend that the state and local entities, 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 Ag. 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. This may include subsidies to develop low cost 5G/6G rural

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[5] Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture in the United States, Report adopted as of November 10, 2021 at 72 (2021), https://www.fcc.gov/sites/default/files/precision-ag-report-11102021.pdf (recommendation in the 2021 Report to "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" at a minimum performance of 100 Mbps download and 20 Mbps upload).

infrastructure, for example leveraging software-defined Radio Access Network (RAN) and Evolved Packet Core (EPC).

- We recommend to Congress and funders that the performance criteria be reviewed and updated to reflect evolving technology and requirements. We believe that by 2023, the minimum bandwidth needs for agriculture producers will be 1 Gbps upload and download speeds to farm headquarters typically served via wireline.

- Clarify that Precision Ag-Infrastructure which provides Cloud economics, global innovation, and IoT connectivity, are eligible expenses for all federal grant, loan, and incentive programs like existing Broadband programs. Precision Ag-Infrastructure is typically considered to be comprised of highly secure Cloud connectivity, distributed cloud architecture, (Edge Compute), and future-proofed wireless technologies, (typically referred to as 5G or 5G and beyond) deployed as public and private systems

- As adopted by the Task Force in the 2021 Report, 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.[6]

- Identify opportunities and create a blueprint for interdepartmental ways of working across more than 100 federal broadband programs administered by various agencies.

Increase Support from Federal Agencies

- As adopted by the Task Force in the 2021 Report, the FCC and other agencies should use this dataset to determine industry needs 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.[7]

- With UAVs experiencing significant growth over the next decade in both farming and supply chain operations, the USDA should invest in testing new use cases and engage the Federal Aviation Administration (FAA) in promoting safe practices.

Standards and Interconnectivity:

- Suggest that the Adoption and Jobs Working Group recommend that 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 Ag 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 Ag data creation and

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[6] Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture in the United States, Report adopted as of November 10, 2021 at 72 (2021), https://www.fcc.gov/sites/default/files/precision-ag-report-11102021.pdf.
[7] Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture in the United States, Report adopted as of November 10, 2021 at 73 (2021), https://www.fcc.gov/sites/default/files/precision-ag-report-11102021.pdf.

utilization for improved value. Both non-terrestrial and terrestrial technologies are important to include in this work.

- USDA Agricultural Research Service (ARS) and FCC should dimension 6G's impact on Precision Ag use cases and align funding with industry needs with immediate focus on collaboration with ongoing regional applied research initiatives. This may include orchestration of new public-private partnership models to accelerate test beds for agriculture using 6G and Cloud ecosystems.

- Engage the third-party operator and investor community on viable funding models to simulate neutral-host infrastructure availability and leasing to Tier 1 mobile operators in unserved/underserved agriculture lands. Models should include capital and ongoing operational expenditures required for supporting infrastructure with low subscriber quantities.

- Studying and factoring in satellite service, devices, and enabled applications in government broadband and agricultural funding and R&D programs, especially with the pressures of global food and climate crises, is fundamentally important.

ARTIFICIAL INTELLIGENCE & HYPERSCALE CLOUD INNOVATION

Sustainable Precision Ag relies on the ability to collect data and leverage the data to drive insights – a concept often referred to as data-driven agriculture, in which a farmer's knowledge about the farm is augmented with data and AI-driven insights. However, to get to this vision we need to (i) capture large amounts of data, and (ii) merge this large amount of data from different sources, to turn data into intelligence and actionable insights.

The data about a farm comes from a variety of sources, either directly from the farm, e.g., from sensors, drones, cameras, or tractors, or from remote sensing data in the Cloud, e.g., from satellites with optical or multi- or hyper-spectral cameras, or radars or weather stations. Cloud services, such as WinField's R7 leverage Cloud hosted platforms, such as FarmBeats, to aggregate all of this data in one place, so that for any farm we have data from satellites, tractors, weather services, etc.

This data, with the predictive capabilities of AI, can then be merged to predict values across space and time. For example, combining satellite imagery with soil samples or sensor data, can be used to build an entire map for a farm, such as the soil moisture, or soil nutrient map of a farm. This can then be merged with weather predictions, to not only estimate the current soil or crop map, but the soil or crop health as well as scheduling operational tasks up to a few days in advance.

These predictive capabilities of AI in the Cloud can then be combined with the power of edge compute. The predicted maps can then advise actions to tractors and irrigation systems on the farm. For example; if portions of a farm are likely to be in stress, they need chemical intervention, or if a portion of the farm will be too dry, it needs irrigation, etc.

A question we try to answer in this document is whether the Cloud capabilities of today are enough to meet the data-driven agriculture needs of tomorrow.

1. Cloud needs ways to bring in substantial amounts of data from space to the data centers. Precision Ag needs large amounts of data – not just from the farm, but also from space. Several companies are investing in higher resolution satellite imagery, which will require additional bandwidth from satellite to ground. Space companies, such as Planet Labs, are launching new satellites with hyperspectral imaging capabilities. These require more data bandwidth to send the data to the ground and new ways to feed that data into the data centers – from ground stations close to data centers, e.g., Azure Orbital, AWS Ground Stations, or Edge computing in space.
2. Second, we need secure data-sharing techniques in the Cloud, protecting individual farmer data, so it can be safely shared with multiple stakeholders. One of the biggest obstacles to the widespread use of AI in agriculture is the lack of good farm level data, at scale, largely because farmers are skeptical about sharing data with other stakeholders. As a result, there is no good collection of labeled data to train the AI models.

   The Cloud needs to incorporate data-sharing mechanisms, such as multi-party compute, at low cost. For example; technologies such as confidential compute, homomorphic encryption, or other data-sharing techniques. This would enable large scale, privacy preserving, data repositories to drive the training of AI models, and the adoption of AI techniques.

3. The Cloud can play a key role in making the next generation of farm communication infrastructure more affordable. One of the key challenges of data-driven agriculture is affordability, beginning with affordable connectivity in the farmer's house, and to "Things" in the middle of the farm. To make the communication infrastructure affordable, flexible, and easily upgradeable, carriers are increasingly adopting the Cloud. While carriers are moving their 5G EPC operations to the Cloud, the future 6G networks might have portions of the RAN split across the Cloud, as well as edge. This could make the networks more affordable and nimble, thereby driving an increased adoption of data-driven agriculture.

In conclusion, to truly drive the vision of Precision Ag, where every inch of the farm is mapped, both below and above the surface, and predictions are made up to a few weeks in advance, we need an enormous investment in Cloud infrastructure. To put it in perspective, the cost of the compute infrastructure needed for OpenAI, that parsed through all-natural language text, was over $1 billion. To map soil and plants at a fine scale, and generate AI models, will require a significantly bigger infrastructure such that the large number of processing units, and the AI infrastructure, combine different streams of data, train models at very high resolutions, and generate predictions about what is likely to happen in any part of every farm, at a scale that can help us realize our goal of sustainably feeding the world.

EDGE CLOUD COMPUTE & PRIVATE 5G WIRELESS INFRASTRUCTURE

AI requires a highly secure hyper-scale Cloud presence directly at the farm. Moving the Cloud to the farm requires edge Cloud computing technology and infrastructure. Edge technology will allow all 2.1 million farmers in America to have their own Cloud that would give them control over their own data while enjoying the innovation supplied by the world's nearly 25 million software developers. Edge technology will also minimize the unnecessary transport of massive amounts of data generated by machine vision functions, drone imagery, tens of thousands of wireless devices, sensors, and controls as well as many other automation tools made available by the digital transformation of the agri-food industry.

Edge technology nearly eliminates latency, further accelerating the digital transformation process toward complete automation. This will dramatically accelerate the adoption of data-driven farming practices that support data-driven agriculture. Edge technology will drive the return on investment to justify the deployment of private wireless systems at scale to all farms ensuring wireless connectivity down to the last acre.

Precision Ag'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 pass on to future generations.

Enabling broadband and wireless connectivity over a range of technologies (both terrestrial and non-terrestrial—public and private) is required to support the functions of Precision Ag. Broadband and wireless availability is a critical first step toward supporting the adoption of best practices; however, by itself, it falls short of a workable solution.

It is critical that wired and wireless broadband connectivity and Precision Ag-Infrastructure be extended onto or near all farms in the United States, including those in the most rural and remote portions of the country. Accordingly, it is important that Precision Ag-Infrastructure be made an eligible expense for federal broadband programs to enable to use of Precision Agriculture Practices. Agriculture, like every other industry, must experience a complete and total "digital transformation" to compete on the world stage. While "digital transformation" implies many things, it translates to automation. Automation in a digital world brings efficiency, quality, and sustainability, and will maximize yields.

Agricultural automation requires Cloud computing, connectivity, and Precision Ag software applications. Precision Ag 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: 1) Industry 4.0, 2) Cloud computing, 3) connected everything and 4) 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 and capable of providing quality, symmetrical service at high speeds. Currently, 5G and its successors are our best path to achieving this *Connectivity Demand* vision, including a variety of terrestrial and non-terrestrial technologies. Everything must be connected: sensors, devices, controls, machines, and drones. Precision Ag software applications must be developed then 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 Ag to rural America, the following must occur, using both satellite and terrestrial solutions:

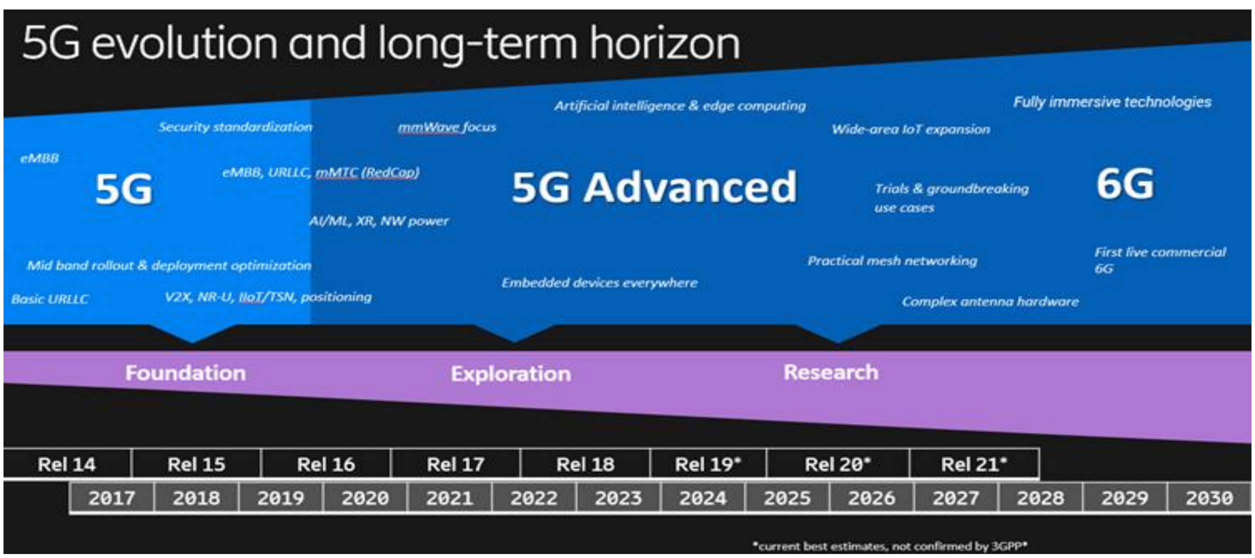
1. The farmhouse, fields and pastureland must have 4G/5G and beyond network coverage and connectivity. The network service providers must be interconnected with the wireless systems at farms and ranches for seamless interoperability and data flow.

2. Edge Cloud infrastructure, located at farms and ranches and connected to broadband, must be created to bring the Cloud to farms and ranches to fulfill the promise of automation.

3. 5G wireless and beyond systems, both private and public, must be implemented at every farm and ranch to connect and collect massive amounts of data from sensors, machines, and drones. These systems will provide service to the farmhouse, utility yards, barns, stockyards, and outbuildings.

ADVANCED DEVICE CONNECTIVITY OVER PUBLIC WIRELESS NETWORKS

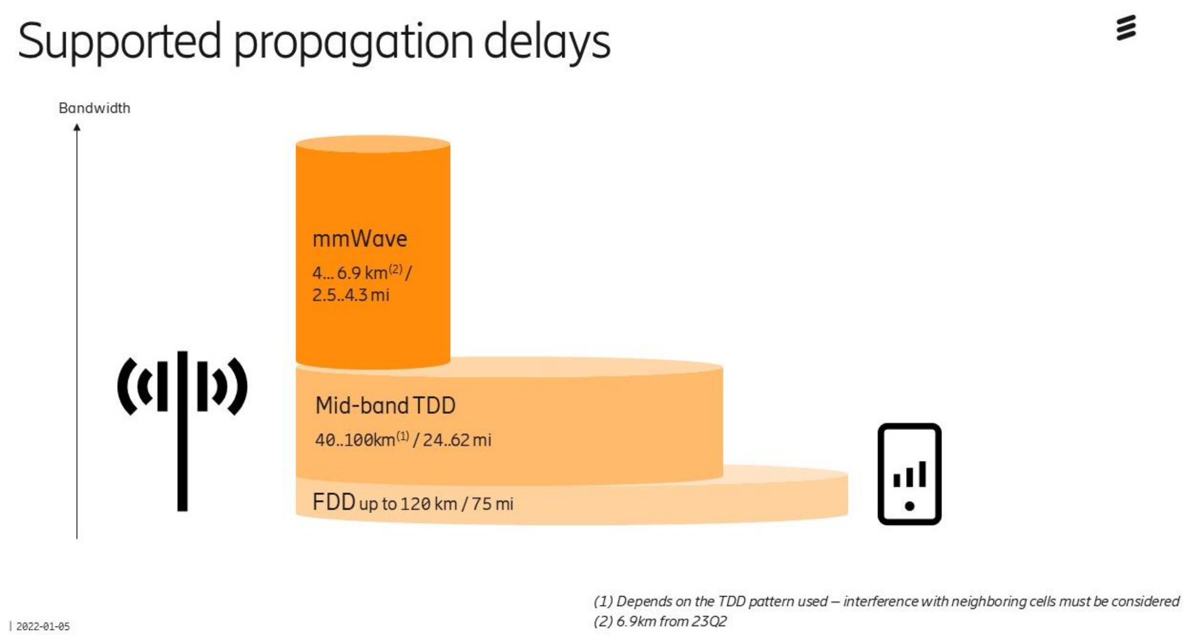
A future state in farming with 5G (from low-band covering 95%+ to commonly available mid-to-high band) capable of connecting embedded devices everywhere with enhanced mobile broadband (eMBB) and ultra-reliable and consistent low latency with good reliability is key to Precision Ag and Cloud adoption.



A minimum of 100 Mbps symmetrical with less than 50 millisecond latency to the last acre substantially will improve near-term outcomes from field preparation to harvesting. For agriculture to receive 5G service with sustained downlink speeds of 1Gbps and higher at the farmhouse, it is imperative to adopt a strategic plan for deep fiber distribution in rural areas to connect 5G small cell sites capable of mid-high band spectrum including CBRS. However, a layered approach to 5G with low, mid, and high bands covering agricultural lands should be the target for 2030 due to the realities of costly mobile network equipment placement and fiber construction (including aerial plant). As fiber penetration grows less than 1.5% per year (source: OECD and Vertical systems 2021), funding should be strategic in support of backhaul to 5G small cell sites.

To highlight the importance of a layered approach to 5G, the table below reflects RF propagation from a radio node in low band FDD (frequency division duplexing) reaching 75 miles, mid band TDD (time division duplexing) reaching 24.62 miles and high band mmWave (millimeter wave at 24-40 GHz) reaching up to 4.3 miles.

Although low bands deliver lower bandwidth and may not reach 1 Gbps to the farmhouse, considering deployment economics these bands are imperative to reach our 2030 goal for 100 Mbps symmetrical last acre coverage.



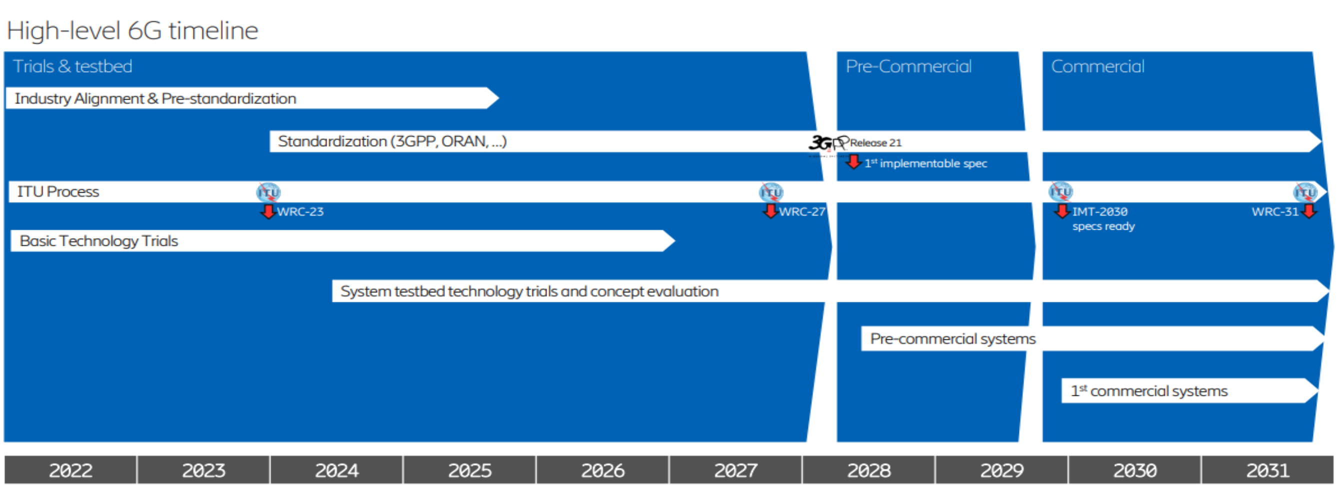
For a future perspective on small cell propagation and fiber access needed in agricultural areas, reference a [2021 commercial deployment of 5G mmWave] by Ericsson, US Cellular, Qualcomm and Inseego accomplishing 1Gbps downlink speeds at a range of 7 km (4.3 miles).

Examples of use cases that could be enabled through 5G connectivity:

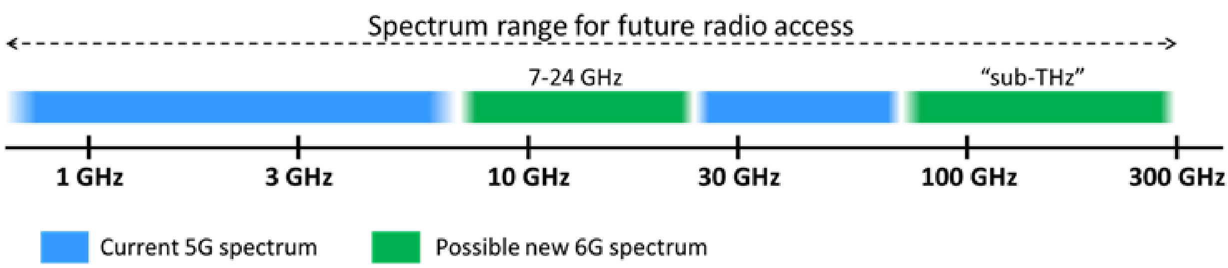
Specific to high-quality video streaming for drone imagery and autonomous operations, a recent NSF AERPAW collaboration delivered video streaming during drone operations at 100 Mbps uplink and 450 Mbps downlink. This would not have been possible without 5G network connectivity delivered on mid-band spectrum.

As the US transitions to 6G in the 2030s and leverages a decade of 5G market maturity, expect an increasing number of interactions blending human, physical, and digital worlds. Versatile platforms, delivered over 6G, will be available in precision agriculture to enable high-performance communication, local to non-local coverage, privacy, security, resilience, compute offloading, AI functions and spatial data.

6G timeline perspective:



As stated in a recent blog by Ericsson on Hexa-X, "Development will be intense around the interactions between these worlds; through connected intelligence, enabling machines to communicate without limits; immersive communication, removing distance as a limit for human experience; twinning of the physical sensing/actuators and programmable digital representations; and finally the fundamental ambition of a sustainable world, enabled by network technology." To realize 6G use cases in US agriculture, technology spectrum and channel allocation must be aligned and deployed within a reasonable timeframe. This may include 6G EPC and RAN technology sharing existing spectrum bands with previous Generations, use of new spectrum between 7-24 GHz and emergence of sub-THz frequencies.



To highlight prospective 6G use cases which can also be applied to US farming:

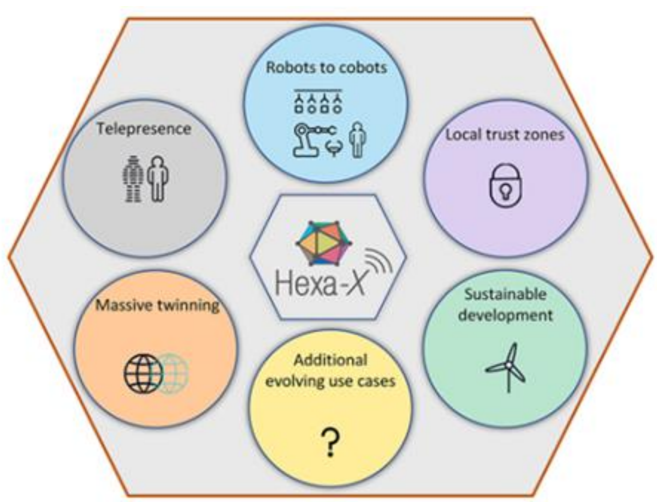
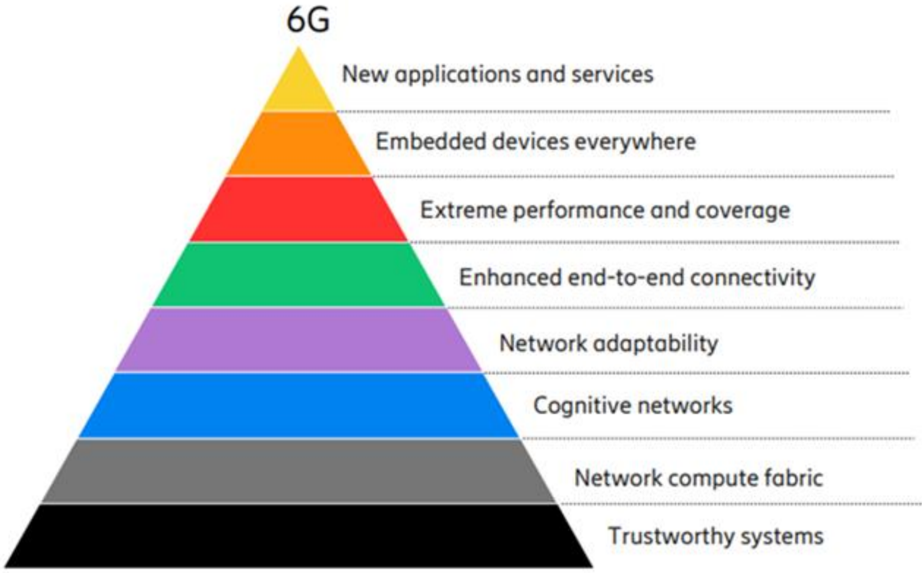


Figure. 1. 6G use case families identified by the Hexa-X project. Source: Hexa-X, D1.2.

Prospective performance characteristics of 6G may include 10-100 Gbps data rates, sub millisecond latency, sub centimeter positioning, significantly reduced network energy performance and 100x increase in traffic capacity.

A recent Ericsson whitepaper titled "6G – Connecting a Cyber-Physical World" captures the dependance between 6G networks and enhanced services such as immersive communications, compute-AI, spatiotemporal and omnipresent IoT. As stated in the Ericsson whitepaper, "a foundation of trustworthy systems and a highly efficient compute fabric with built-in cognition capacities, the networks of the future will deliver limitless connectivity for upcoming applications and services."



6G will have an immediate impact on food production outputs and our environment. To list several examples:

- Advanced earth monitoring and real-time decisions based from data collected on pollution, wildfires, and extreme weather.
- Transition billions of farm sensors to "zero energy" and biodegradable to drive sustainability.
- Equip the farm workforce with immersive interaction devices such as smart gloves, skin sensors and massive multisensory merged reality.
- Cognitive networks to enhance farm equipment automation with near real-time algorithms to adjust to work environments, constantly observe and learn from previous actions.
- Interacting navigating robots and 4D mapping sharing sensor data and trajectories, autonomous vehicle use with external sensor network for safe transport.
- Intelligence support systems for preventive measures, energy production, biodiversity measures, wildlife preservation, agriculture, forestry.

In closing, Precision Ag coupled with Cloud infrastructure and 5G into 6G will be key to building a foundation of sustainability and production efficiencies on existing land that is needed to feed the 2050 estimated population. As reported in "Ericsson Mobility and Breaking the Energy Curve Report," data is increasing at an exponential rate and while agriculture accounts for only 3% of emissions, more efficient devices running on 5G and 6G can break the energy curve. When combined with other industries, public wireless networks can contribute to 15% fewer emissions by 2025 alone.

HIGHLY SECURE CLOUD CONNECTIVITY ACROSS LAST MILE, MIDDLE MILE & LONG-HAUL INFRASTRUCTURE

Industries across nearly all sectors are implicated by cyber security concerns. As ag tech comprises more applications for crops, livestock, and poultry, the potential threat to the ag industry increases. Threats to trade secrets, consumer privacy, and financial data are but several aspects that can be compromised by malicious actors. These threats arise at several points as data from sensors and equipment are uploaded to the Cloud. Gateways for attacks include sensors; IoT gateways; Cloud systems; and remote-control systems. Malicious acts may include intentional theft from applications or devices that do not meet sufficient security standards; disruptions damage an individual farmer; or improper access by foreign actors. Moreover, tactics such as ransomware or other intrusions can have debilitating impacts on affected entities. Cyber threats to ag tech are proportionally consistent with those that affect other industries. In June 2021, a ransomware attack resulted in disruptions at the world's largest meatpacking firm. The company paid an $11 million ransom.78 The increasing use of ag tech also implicates greater attention to cyber security in this sector. Intentional or unintentional interference can cause wide-reaching impacts; vast data sets create proportionate risk. Any systems that rely on data, sensors, or other monitoring equipment are subject to adversarial intrusion. For example, automated feed bins can be compromised; livestock data can be manipulated to portray false incidence of disease, prompting farmers to take unnecessary and potentially harmful action; irrigation systems can be hacked to either over or under-water crops. The threat to national food supplies that in turn can create significant national security consequences has been referred to as "agroterrorism." Pricing information or other confidential data is subject to intrusion, and widespread attacks could skew land sale prices and crop insurance rates. Broadband service provider's networks connecting to agricultural lands across the US play a critical role in supporting the deployment of precision agriculture applications in the US. However, virtually no mandatory cybersecurity rules govern the millions of food and agriculture businesses that account for about a fifth of the U.S. economy. Cybersecurity must be top of mind, as technology is being used to make real-time and near-real-time business decisions in our food production environment. Local broadband providers can assist in providing an additional layer of protection between the producer and the Cloud applications storing and analyzing critical agricultural data.

A growing body of work is examining the need for rigorous attention to cybersecurity for ag tech. From the perspective of an individual farmer, interference with systems designed to maximize planting could reduce efficiencies at the outset, ultimately leading to smaller yields and reduced revenues. Compromises to systems designed to monitor and maintain livestock environments could generate adverse impacts on an entire herd; by way of example, disruptions to climate control systems designed to maintain optimal environments could make facilities too cold or too hot. Moreover, disruptions in systems intended to enable monitoring of herd health could lead either to false reports of herd disease or failures to report actual adverse conditions. These, too, could affect value and pricing. The Federal Bureau of Investigation has recognized these threats, citing 18 U.S.C. § 1831 (Economic Espionage) and § 1832 (Theft of Trade Secrets) as laws that could be violated through either the targeting or theft of trade secrets. In 2019, the U.S. District Court for Eastern Missouri indicted a foreign national who worked for a U.S. company that estimates soil quality based on satellite imaging. Other instances of agricultural espionage include theft of modified seed samples and corn growing strategies. Cybersecurity accordingly warrants consideration among costs of ag tech implementation.

SUMMARY

CURRENT RECOMMENDATIONS REQUIRING IMMEDIATE ACTION

RECOMMENDATIONS REQUIRING ACTION BY 2025

It's estimated that farmers will need to produce 70% more food over the next 30 years to keep pace with the world's growing population and high-performing public wireless networks will be required to connect sensor data (soil, crop, livestock and environmental), autonomous machines, drones and more. Therefore, to support a future state of farming with billions of connected devices processing mass amounts of data at the edge, we must carefully weigh the investment required and time to deploy with generational impacts to rural livelihood, greater crop cycle outputs and sustainable use of limited resources.

According to PEW Research 2021, 28% of rural adults are not connected to fixed broadband and 20% are not connected to a mobile network. Today, broadband access on agricultural lands is achieved through a very limited number of farmhouses served by fiber, increasing availability of LTE and low-band 5G service supporting mobile and fixed-access, and the emergence of LEO Satellite service providers capable of offering universal coverage at limited capacity to fill in unserved gaps. As we think less than 10 years into the future, advanced 5G and emerging 6G network connectivity capable of dynamic and autonomous functions in concert with a Cloud infrastructure and AI ecosystem will be needed at the farm (as discussed in above sections). Furthermore, the short-term beneficiaries of high-performing public wireless networks should not be limited to densely populated urban centers, but also extend to rural America and those responsible for feeding our growing population. As discussed in the sections above, future use cases enabled and/or enhanced by AI/ML, highly secure and reliable networks, cognitive works and IoT automation will require resilient network infrastructure deployed across farmlands with sufficient data rates, consistent latency, agility, security and insight tools capable of supporting the farm of the very near future.

The Connectivity Needs Working Group has identified several actions that need to be taken now and within the next two years to lay groundwork for rapid realization of the advantages of Precision Ag. This table summarizes the immediate recommendations that are elaborated on in the body of the report.

ITEM	RESPONSIBLE PARTY(IES)	TIMELINE
Target Existing Infrastructure Investments to Enable Gains from Precision Ag		
Prioritize connectivity on working lands, which we call the "last acre", predicated on geography, not population.	USDA	2023 Farm Bill

Set a symmetrical standard of 100/100 Mbps at the field level and 1/1 Gbps at headquarters.[8]	FCC	Winter 2022-2023
Include grants for open access tower construction or retrofitting in ReConnect funds.	USDA-RUS	Winter 2022-2023
Farmers and ranchers must be at the center of the precision ag ecosystem and at the core of making technology decisions; data gathering, analysis and deployment, so advantages accrue first at the field level then to technology providers and the agri-food industry.	Congress	Winter 2022-2023
Direct a reasonable portion of funding to increased connectivity to support Precision Ag at the last acre that also increases resiliency of service delivery and emergency response in the event of disasters. This may include subsidies to develop low cost 5G/6G rural infrastructure, for example leveraging software-defined RAN and EPC.	FCC NTIA Congress, State and Local funding entities	2023
Take Corrective Actions to Allow Current Connectivity and Transition to Near Future Applications		
Explore ways to ease licensing of lower bands for Precision Ag.	FCC	Spring 2023
Act Now to "Future Proof" Food Production in the United States		
Future-proof the network to support scalable connectivity at the field level starting with the 2023 Farm Bill.	Congress	Spring 2023
Identify lessons learned from transition from 3G to 5G to develop plan to avoid pitfalls in the future; make recommendations on security improvements or guards that are needed in the networks, including the equipment, add-on technology, and in operator behavior patterns; endorse consistency across federal agencies - FCC, USDA, NTIA and include Congress in setting uniform standards and coordinated timing of programs	NIST lead	2023
In order to better deal with future supply chain issues, incentivize domestic production of components such as antennas, power supplies, chipsets, modem, to enable connectivity now and in the near future.	Congress Funding Agencies	Winter 2022-2023

[8] Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture in the United States, Report adopted as of November 10, 2021 at 72 (2021), https://www.fcc.gov/sites/default/files/precision-ag-report-11102021.pdf (recommendation in the 2021 Report to "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" at a minimum performance of 100 Mbps download and 20 Mbps upload).

Develop cybersecurity rules and protocols to protect the U.S. Agri-Food system.	NIST Congress	2023
Recognize the Urgency Driving the Need for Rapid Deployment		
Declare food security as a vital component of national security and build a case that Precision Ag helps meet those security needs as well as long-term, sound management of natural resources.	Congress Administrati on	Winter 2022-2023
Encourage programs that provide redundancy to support Precision Ag architecture to pre-empt disasters leading to disruptions in food production, processing and distribution.	Congress Administrati on	Winter 2022-2023
Build the case that the $42 Billion plus in broadband investment in the Infrastructure Investment and Jobs Act of 2021 be focused on food production as a matter of national security, tackling water scarcity and food insecurity.	Congress Administrati on USDA - subagencies	Winter 2022-2023

RECOMMENDATIONS REQUIRING ACTION BY 2025

The Connectivity Needs Working Group recommends additional actions be taken by 2025 to seize anticipated opportunities with 6G rollout in 2030 and to meet the projected need for food by 2050.

ITEM	RESPONSIBLE PARTY(IES)	TIMELINE
Make Targeted and Informed Funding Decisions		
Conduct cost-benefit analysis of emerging use cases in precision agriculture and consider higher funding priorities for future “G” public wireless networks capable of supporting use cases with highest returns.	FCC USDA-RUS, ERS	2024
Increase Spectrum Available for Precision Ag		

Evaluate additional spectrum needed for 5G and 6G access to the farm decision headquarters and IoT device connectivity to the last sensor. To realize 6G use cases in US agriculture, technology spectrum and channel allocation must be aligned and deployed within a reasonable timeframe. This may include 6G EPC and RAN technology sharing existing spectrum bands with previous Generations, use of new spectrum between 7-24 GHz and emergence of sub-THz frequencies.	FCC NTIA	Nov-Dec 2023 into 2024
Develop comprehensive spectrum policy for wireless network use and input from industry stakeholders on adoption of new spectrum into agriculture equipment/device ecosystem that focuses on achieving scale through unit economics to allow for affordability at the field level.	FCC NTIA	Nov-Dec 2023 into 2024
Auction spectrum for space-to-earth communication for satellites.	FCC	2024
Adopt policy to accelerate rapid 5G, 6G and like spectrum access, including shared spectrum, and deployment to farmlands in 2030 and beyond.	FCC	2025
Create incentives for service providers to mitigate coverage gaps created during decommissioning of older "G" technologies.	FCC	Late 2023
Increase Support from Federal Agencies		
Identify opportunities and create a blueprint for interdepartmental ways of working across more	NTIA	Spring 2023

than 100 federal broadband programs administered by various agencies.		
Invest in testing new use cases for UAVs and engage the Federal Aviation Administration (FAA) in promoting safe practices.	USDA-ARS FAA	2023
Standards and Interconnectivity		
Develop ramp of increasingly higher levels of symmetrical service 5G-and-beyond data and interconnectivity standards, between non-terrestrial and terrestrial technologies, for Precision Ag with focus on increasing the upload speeds. Studying and factoring in satellite service, devices, and enabled-applications in government broadband and agricultural funding and R&D programs is needed.	NIST USDA 3GPP	2023 to 2030 era of 6G
Dimension 6G's impact on Precision Ag use cases and align funding with industry needs by collaborating in the short-term with ongoing regional applied research initiatives. Orchestrate new public-private partnership models to accelerate test beds for agriculture using 6G and Cloud ecosystems.	USDA-ARS FCC	2025
Suggested Recommendations for Other Working Groups to Consider		
Engage the third party operator and investor community on viable funding models that include capital and ongoing operational expenditures to simulate neutral-host infrastructure availability and leasing to Tier 1 mobile operators in unserved/underserved agriculture lands.	*this falls under Accelerating Deployment Working Group purview* FCC USDA	

Assess funding tiers based on geographical complexity to deploy based on mid-to-high-band 5G through low-band coverage extension network architectures.	*this falls under Accelerating Deployment Working Group purview*	
FCC develop a strategy to provide a range of licensed and unlicensed spectrum to agriculture for fixed wireless access and mobile broadband.	*This falls under Accelerating Deployment Working Group purview* FCC NTIA International consultation	Nov-Dec 2023 into 2024
Adopt a strategic plan for deep fiber distribution in rural areas to connect 5G small cell sites capable of mid-high band spectrum including CBRS. A layered approach to 5G with low, mid, and high bands covering agricultural lands should be the target for 2030 due to the realities of costly mobile network equipment placement and fiber construction (including aerial plant).	*This falls under Accelerating Deployment Working Group purview* FCC	2024
Groundtruth 5G service levels in the field.[9]	*This falls under Data Mapping Working Group purview* FCC	Winter 2022-2023

CONNECTIVITY NEEDS NEXT STEPS IN 2023

The Connectivity Needs Working Group has identified several topics that warrant more research and discussion in 2023. The group will drill down into federal agencies' existing efforts to enact previous recommendations, to learn from invited specialists on key topics, and to further explore policy implications of concepts discussed briefly in 2022. Among the list of items to be researched are:

[9] The FCC's Broadband Data Collection currently has resources regarding crowdsourcing and other challenges to its broadband data maps. *See* https://www.fcc.gov/BroadbandData/consumers.

- Models of Interoperability between technologies (i.e. varied spectrum of wireless, satellite, fiber)
- Impacts of private wireless networks on last acre and high bandwidth use cases; whether there is offload for public wireless compute
- Economics of edge compute
- Policy and economic dynamics of subsidizing infrastructure or architecture related to Cloud compute through advisory companies and retailers
- Implementation of regular surveys among farmers or technology providers to determine adoption and access rates and how farmers can be part of closed-loop feedback
- Layered, simultaneous use cases implication on interoperability and overall connectivity

The group plans to reconvene on a biweekly basis in January 2023.

CONNECTIVITY NEEDS WORKING GROUP MEMBERS

Private Sector and State Government Appointees

Heather Hampton+Knodle, **WG Chairman**, Vice President and Secretary of *Knodle, Ltd. Farms*
Joy Sterling, **WG Vice Chairman**, Chief Executive Officer of *Iron Horse Vineyards*

Members

Seth Arndorfer, Chief Executive Officer of *Dakota Carrier Network*
Andy Bater, Farmer with *Fifth Estate Growers, LLC*
Dr. Ranveer Chandra, CTO Agri-Food, Managing Director, Research for Industry of Microsoft
Chris Chinn, Director of the Missouri Department of Agriculture, *National Association of State Departments of Agriculture*
Cassandra Heyne, Regulatory Compliance Analyst of *SpaceX*
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Dan Maycock, Principal, Data Engineering of *Loftus Labs*
Jason Miller, Safety Manager of Tillman Infrastructure, *NATE: The Communications Infrastructure Contractors Association*
Aeric Reilly, Volunteer Policy and Strategic Management Director of the *US Cattleman's Association*
Brian Scarpelli, Senior Global Policy Counsel of *The App Association (ACT)*
Steven Strickland, Director, Partnerships and Channels of *Ericsson*
Mark Suggs, Executive Vice President & General Manager of Pitt and Greene Electric Membership Corporation, *National Rural Electric Cooperative Association*
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