Powering the **Future of Precision Farming**

Achieving Agricultural Automation with an Autonomously Adaptable Living Network™

RAJANT

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Agriculture Today:
On the Verge of a Revolution

The agriculture industry may be growing, but so is the burden on today's farmers. Agricultural operations around the world face mounting pressure to feed an ever-increasing populace, meet stringent sustainability regulations, and overcome a myriad of other modern challenges, all while conserving both farmland and water due to a diminishing natural resource base.

What the agricultural industry needs most today is to perfect its operational efficiency, creating as much yield as possible while using as few resources as possible.

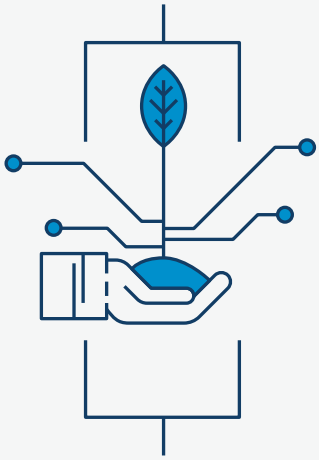
Luckily, by leveraging Industrial Internet of Things (IIoT) and Industry 4.0 technologies, modern farmers can harness the power of automation to establish Precision Farming practices, or practices that use technology to flexibly ensure that every inch of arable farmland is properly utilized for the future of farming.

Now, the questions are: what will the rise of Precision Farming and agricultural automation mean for farming operations in practice? What applications could be leveraged to help them solve the issues that are most pressing for their unique environments? And what will farming operators need to enable these new assets and programs, which will have increasingly autonomous demands, over time?

In this white paper, we'll discuss the vision for the future of Precision Farming and how it can be made a reality with the right network: one that is as equally autonomous as the assets it must support.

In 2016, the **global agriculture industry** was worth close to **USD $3.2 trillion.**[1]

The **global precision farming market** is anticipated to reach **USD $10.23 billion by 2025.**[2]



The **global precision farming market,** specifically, is expected to **grow by a CAGR of 12.64% from 2016 to 2021.**[2]

Precision Farming:
An Answer to Today's Agricultural Pressures

The ultimate question for today's agricultural industry is this: **How can farmers achieve peak productivity while also keeping costs low and using sustainable practices?**

Finding an answer to this question could have major implications for farmers. It could mean feeding the growing population while using less farmland; using fewer natural resources while increasing yields; reducing pests and diseases without stripping the soil of its nutrients. **In short, the right holistic solution could revolutionize the way the world farms.**

Luckily, thanks to the introduction advanced equipment and rugged, dynamic networks, the agricultural industry is taking the first steps toward that answer: **Precision Farming with IIoT and automation.**

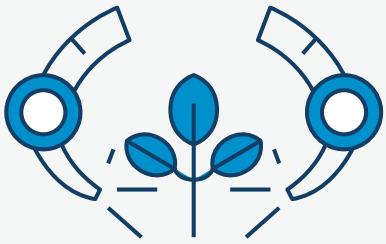
Precision Farming relies upon Industrial Internet of Things (IIoT) devices and other automated equipment to increase efficiency while remaining sustainable, working day and night to produce a higher yield. Leaders in the agricultural industry are now embracing it with open arms—in fact, the Agricultural Robots market is projected to reach $16.3 billion by 2020.[3]

The global agriculture machine-to-machine (M2M) market is also projected to see significant advances in the near future, growing at a CAGR of more than 47% over the next five years.[4]

The ultimate vision for Precision Farming is a solution that uses connected technology to simultaneously address all of a farmer's pain points, from increasing yield to streamlining harvesting to improving irrigation efficiency.

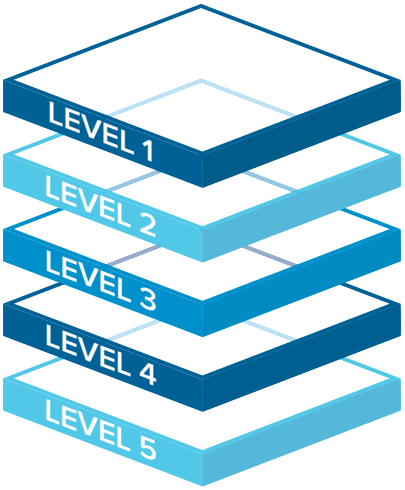
While the realization of a fully automated farm won't happen overnight, farmers can implement a stepwise approach to integrating IIoT into their agricultural operations today, deploying applications that can drive major, immediate productivity gains and then building upon that foundation with more esoteric applications to incrementally increase precision, reduce waste, and maximize yield. **But, they'll need to start with a network that can easily grow to support more and new IIoT-enabled assets, with increasingly autonomous demands, over time.**

The **Agricultural Robots market** is projected to reach **$16.3 billion** by 2020.[3]



Getting There:
The Road to Precision Farming

Automation encompasses a wide spectrum of capabilities, making it an accessible option for farming operations of any size or background. Introducing some level of autonomy to agricultural processes is a crucial first step towards creating a full IIoT environment; it also gives farmers a place from which to continue building to their automation goals in a steady, controlled process.



The following step-by-step levels of automation serve as a roadmap to the applications, functionality, and agricultural benefits of introducing Precision Farming techniques of varying intensities.

LEVEL 1

Stationary Autonomy

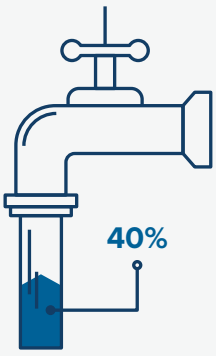
Some of the most basic, yet most effective autonomous farming equipment is static. This stationary equipment is simple to install and records critical agricultural data, alerting farmers to important changes that could impact their operations and productivity.

PERMANENT SOIL SENSORS

Static soil sensors detect a wide variety of soil characteristics, from moisture levels to chemical presence to nutrients. Moisture sensors reduce the risk of human error when it comes to irrigation and can result in a 40% improvement in water efficiency,[5] while electrochemical soil sensors monitor pH and nutrient levels by detecting specific ions and chemicals present in the ground.[6]

Installing these data-collecting sensors allows farmers to monitor soil health and determine when fields are inhospitable to specific crops, always maximizing crop health and yield. In later stages, these sensors can be paired with GPS and other aerial mapping technologies to give farmers a dynamic "soil map" of their land.[7]

Moisture sensors can result in a **40% improvement** in water efficiency.[5]



E-SILO TECHNOLOGY

Large amounts of silage are highly difficult to track and monitor with traditional farming technology. In 2016, Wisconsin farmers alone produced approximately 16.6 million tons of corn for silage.[8]

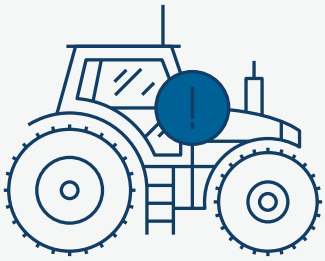
Tracking devices can transform ordinary silos in to E-Silos, capable of reporting a multitude of real-time metrics on the grain or corn being stored. From volume, to temperature, to date added, E-Silo technology gives farmers a 360° view of their silage for maximum efficiency.

STATIONARY SECURITY CAMERAS

Security cameras may be necessary for large farms with many assets. In 2016, tractors made up 14% of all heavy equipment stolen in the U.S.[9] By utilizing autonomously connected cameras, farmers can reduce instances of theft and more easily recover stolen equipment.

When cameras are running on an autonomous, high-bandwidth farm network, they can ensure that each area of the farm is properly surveilled, streaming and storing unique footage in real-time with very little overlap.

Tractors made up
14 percent
of all heavy equipment stolen
in the U.S. in 2016.[9]



LEVEL 2

Semi-Autonomous Machinery

Once stationary Precision Farming equipment is installed, the next step is to introduce semi-autonomous machinery. This moving agricultural equipment is partially autonomous, but must be supervised and/or managed by a human worker, making it an ideal transition phase for those interested in full automation.

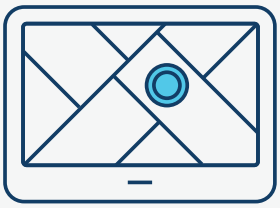
Today, the cost of such self-driving or self-sensing technology is dropping, which also makes it an appealing solution for smaller farmers who want to advance their operations.[10]

SELF-DRIVING TRACTORS

Tractor suppliers are beginning to include GPS, built-in sensors, and variable-rate technology (VRT) in their equipment, which allow tractors to navigate fields autonomously and work together to till, seed, and plant, ensuring that no arable land or resources are wasted.

Many of these guided tractors require operator supervision on a tablet or desktop, and some require a ride-along operator.[12] If an obstacle arises, the tractor's software notifies operators so that they can intercede and manually override the tractor's guided controls.[13]

GPS equipment guidance systems can save farmers up to
7 percent
through the **efficient use of seed, fertilizer, pesticides, and fuel.**[11]

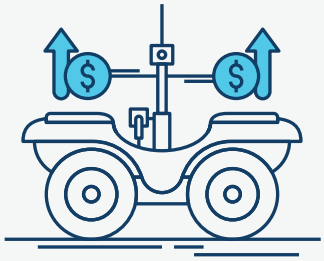


UNMANNED GROUND VEHICLES

Often, compact unmanned ground vehicles (UGV) are used for security purposes. UGV can patrol a farm compound semi-autonomously, relying on an operator to remotely coordinate their efforts and view UGV video in real-time.[14]

As UGVs become more common in agricultural environments, their capabilities may expand to include planting, weeding, and other basic farming tasks with precision, accuracy, and speed.

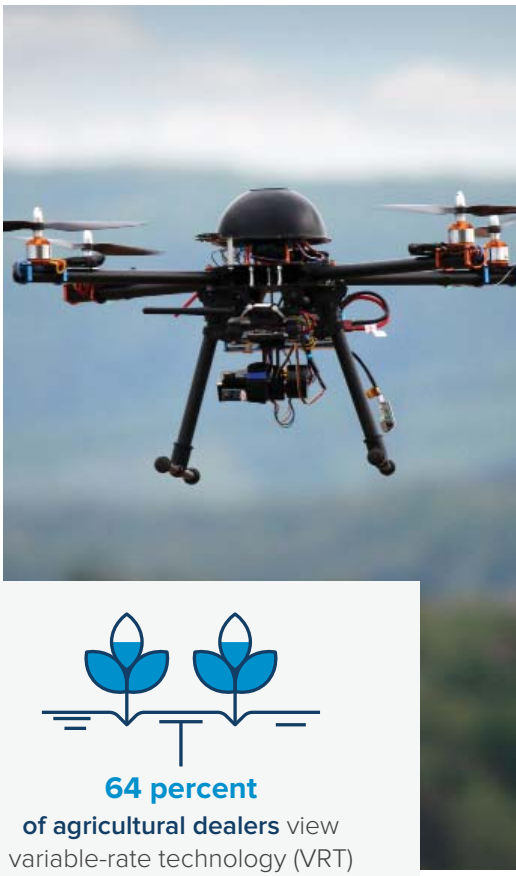
The **UGV Market** is expected to grow to **$2.63 USD billion** by 2021.[15]



LEVEL 3

Single-Task Autonomous Fleets

In the next level of Precision Farming technology, autonomous farming robots and other equipment works together to complete simple tasks. These small, lightweight machines perform manual labor that would otherwise be done by humans or a single piece of large machinery, which reduces ground compression to promote healthy crops.[16]



AG DRONES

Drones and unmanned aerial vehicles (UAV) are now being designed specifically for agricultural purposes, especially crop spraying. A single drone can cover 7-10 acres per hour and distribute over two gallons of liquid.[17]

A swarm of these drones use radar to keep a proper distance from the crop when spraying, and their settings can range from autonomous to semi-autonomous for transitioning farming operations. Drone fleets equipped with cameras can also be used to inspect topography, soil and crop growth—in fact, today in the U.S., 18% of crop acreage is managed by satellite or aerial imagery.[18]

PRECISION PLANTERS

Fleets of precision planters, use GPS technology and sensors to place seeds in the soil with the highest degree of precision and speed.

By maximizing field space and yields, farmers can ensure that they see a significant ROI from autonomous precision planters.

64 percent **of agricultural dealers** view variable-rate technology (VRT) for planting & fertilizing as a **significant revenue source** in the future.[19]

AG ROBOTS

Agricultural robots work in tandem to perform single tasks. They can take many forms, but one of the most popular is precision milking robots.

Dairy farms can utilize ag robots with sensors, lasers, and archived data about individual cows to milk each cow successfully, applying the right amount of pressure and extracting an appropriate amount of milk.[21]

Robotic milking is becoming increasingly common worldwide, **creating a $1.9B industry** that is expected to grow to **$8 billion by 2023.**[20]

LEVEL 4

Complex Autonomous Equipment

Moving up the levels of Precision Farming automation, next is complex autonomous equipment. This level of autonomy enables machinery to perform tasks that humans cannot—often multiple tasks at once—and does not require the assistance of a human operator.

PRUNING, WEEDING & SOIL-MONITORING AI UGV

An autonomous vine-pruning ground vehicle was recently prototyped in a French vineyard. The vehicle can cut excess greenery precisely every five seconds while also taking measurements of the soil and removing dead shoots.[22]

Powered by location tracking, six cameras, and AI mapping, the autonomous vehicle collects, stores, and memorizes data about each vine. Its multi-tasking autonomy is an advanced example of the future of fully-autonomous UGVs.

MOBILE POWER PLATFORMS

In July 2017, a Canadian engineer unveiled a mobile power platform that connects to compatible agriculture equipment and enhances them with autonomous operations, long-range sensors, data processing, and decision-making capabilities.[23]

Once a farmer programs their field's layout into the system, they can simply watch the equipment till, plant, and harvest. This sort of investment in autonomous farming allows farmers to maintain their current fleets while gaining Precision Farming awareness and functionality.

AUTONOMOUS IRRIGATION

Researchers in Chile have developed an autonomous irrigation system that can save 70% more water than other irrigation systems.[24] The system relies on wireless sensors to take precise moisture measurements and ensure efficiency, greatly reducing water waste.

Not only can these irrigation systems limit water usage, but their enhanced monitoring process can also provide improved documentation for sustainability regulations related to irrigation systems.

Chilean researchers developed an **autonomous irrigation system** that is projected to save **70 percent more water.**[24]

LEVEL 5

Fully Autonomous Operations

Finally, the ultimate level of automation in Precision Farming is a fully autonomous operation. Advanced agricultural operations may invest solely in autonomous equipment that perform all functions to enhance speed, increase productivity and yield, power sustainable practices, gather farm data for insight and visibility, keep costs low, and easily maintain regulatory compliance.

100% AUTOMATED FARMS

In Japan, a vegetable production operation has gone completely automated. Production of lettuce and other greens is stacked to take up less land, and everything from planting to watering to pruning to harvesting is done by autonomous machinery.[25]

By automating every part of their planting, growing, and harvesting, the farming environment saves time, costs, and resources, solving major modern agricultural challenges along the way.

FULLY AUTOMATED CROPS

In the U.K., an experimental research farm harvested its first fully-automated crop, reaping close to 5 tons of spring barley.[26] Experts outfitted standard machinery with robotic technology in order to transform it into fully autonomous equipment that operates without any human intervention.

The goal of this operation is to learn more about how automation can improve yields for the future of farming with precision fertilization and soil quality improvements. Scientists believe that the use of smaller, more compact machinery enhances speed, efficiency, and precision.[26]

A research farm in the U.K. harvested **5 tons of spring barley** with completely **automated robotic operations.**[26]

Mitigating Agricultural Challenges Every Step of the Way

No matter the level of automation at which a farm begins, Precision Farming techniques and IIoT connectivity power solutions to agriculture's biggest challenges, allowing operations to be more accurate, efficient, and scalable.

These improvements include:

- **Tilling, seeding, and harvesting fields faster than ever before** in order to meet growing food demands
- **Coordinating crop rotation with ease** in order to promote healthier soil and help restore a natural balance to the land
- **Planting precisely** to utilize every available inch of existing farmland, avoiding further deforestation
- **Monitoring the ground as well as auto-spraying safe bio-pesticides** to decrease instances of transboundary pests and diseases
- **Removing the risk of human error** in irrigation calculations, design, and build, which lessens water waste
- **Allowing farmers to meet regulatory standards** with less effort while documenting their compliance
- **Remaining fully secure and monitored** at all times to protect valuable livestock and equipment

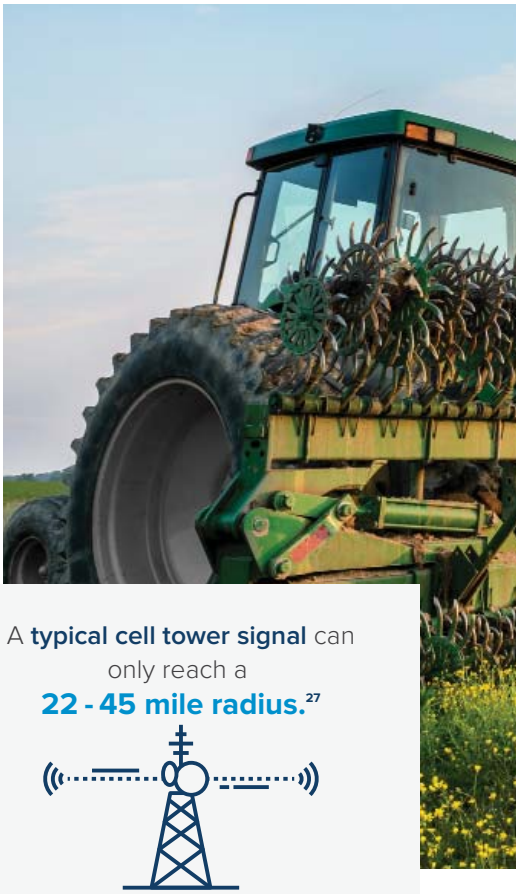
Agricultural Network Requirements and Obstacles

It is clear that automated Precision Farming techniques offer a holistic answer to many of the agriculture industry's challenges. Networking obstacles, however, can often keep traditional farms from adopting automation, or relegate them to a low level of automation without the ability to scale their operations.

Some of the most common agricultural networking and equipment issues are:

1 LACK OF CONNECTIVITY

The majority of America's farms are located in remote, rural areas that lack a strong signal. These farming operations rely on cell towers, spread few and far between, to power their network. Unfortunately, these networks often fall short. With an average signal reach of only 22 – 45 miles, distant cell towers cannot provide the coverage to power agricultural automation over sprawling hectares or land.[27]



A **typical cell tower signal** can only reach a **22 - 45 mile radius.**[27]

2 RUGGED TERRAIN

In an agricultural environment, networking and automation equipment must withstand extreme temperatures, countless weather events, and damaging chemical sprays. In fact, for those reasons, many farmers view autonomous equipment as a liability rather than an investment.[28] For some technologies, simply existing outdoors can be a challenge.

3 INDUSTRIAL INTERFERENCE

Between silos, buildings, and heavy machinery, signal reflection and refraction is common in agricultural environments. Any large pieces of metal, glass, or bodies of water can interrupt a signal.[29]

4 LEGACY INFRASTRUCTURE

Farmers with traditional or outdated wired infrastructures often struggle with new network elements that require a higher level of flexibility in order to scale. To effectively support new mobile-driven IIoT applications, farms with wired infrastructure must integrate some type of wireless mobile connectivity.

Finding a Solution to Power Every Level of Agricultural Automation

Agricultural networks must overcome these common obstacles in order to successfully utilize autonomous Precision Farming applications and enable the IIoT at varying levels.

That makes installing a network that addresses these challenges a top priority for farming operations that wish to move up the levels of autonomy and Precision Farming best practices.

Moving up the Levels with Rajant's Kinetic Mesh®

Rajant's Living Network™ solution, powered by a fully mobile and ruggedized private wireless network known as Kinetic Mesh®, integrates with legacy infrastructure to drive Precision Farming automation at every level.

Rajant's Kinetic Mesh network becomes more valuable as automation becomes more complex, delivering long-term ROI through its ability to seamlessly scale to support increasingly automated operations. No matter where a farming operation begins or which level of automation it wishes to achieve, Rajant powers better, more dynamic connectivity than traditional network alternatives.

LEVEL 1

Stationary Autonomy

KEY NETWORK REQUIREMENT:

High bandwidth to support the streaming of massive amounts of data and video collected from diverse sensors and monitoring applications.

- **Wired Network**
- **Cellular Network**
- **Traditional Mesh Network**
- **Rajant Kinetic Mesh®**

The majority of traditional network infrastructures can sufficiently support applications that operate autonomously but in largely fixed locations, although operators must be mindful that the amount of data they need to collect will only continue to grow, and as it does so must their network's capacity.

The Rajant Advantage:

‘MAKE-MAKE-MAKE-NEVER BREAK’ CONNECTIVITY

Unlike traditional Make-Before-Break networks, where only one connection can exist between a node and an access point at any time, **Rajant’s BreadCrumb**® nodes equipped with **InstaMesh**® networking software can direct traffic via multiple peer connections simultaneously, without the need for a controller node. Instead of continually breaking and re-establishing connectivity as nodes move between access points – as traditional wireless infrastructures require – BreadCrumbs are able to dynamically establish a multitude of connections with their neighboring nodes, creating hundreds of potential paths to direct traffic.

In a Rajant Kinetic Mesh® network, no connections need to be broken for new ones to be made, eliminating any single point of failure, bottlenecks, and timeouts due to dropped connectivity. This provides the high bandwidth, low latency performance Precision Farming devices demand. Each BreadCrumb node can also support up to 4 frequencies, further increasing the usable spectrum for bandwidth-intensive autonomous applications.

LEVEL 2

Semi-Autonomous Machinery

KEY NETWORK REQUIREMENT:

Signal resilience keep operators in constant control over the systems they’re guiding, even as equipment moves around silos and large machinery that can block or interfere with signals.

- ✗ **Wired Network**
- ! **Cellular Network**
- ✓ **Traditional Mesh Network**
- ✓ **Rajant Kinetic Mesh®**

Networks that dedicate frequencies to a single purpose, like LTE, have increased potential for slowed traffic and congestion because data can only travel one way to reach the application server. There is no way for it to route around node outages or interference. This may be sufficient for delay-tolerant farming applications like smart eSilo monitoring, but creates a lack of resiliency to support real-time autonomy platforms.

The Rajant Advantage:

FULL REDUNDANCY FOR FAIL-PROOF CONNECTIVITY

Networks that handle mission-critical applications, like the semi- and fully-autonomous systems used in farming today, must be designed with an awareness of the high stakes affiliated with downtime. The built-in redundancy of multiple connections enables a Kinetic Mesh® network to uphold the level of reliability and resilience Precision Farming applications require by increasing the capacity of every transceiver, with multiple transceivers providing multiple paths around interference, congestion, and node outages.

InstaMesh conducts continuous path switching of wireless and wired connections over the best available link, calculating the path that enables the fastest time to delivery in that moment. If one path is not available or interference is identified, the information is dynamically redirected over a redundant available path or paths to ensure it rapidly reaches its final destination.

RAJANT IN ACTION

Eucalyptus Farming

Rajant's Kinetic Mesh network is being deployed to power forest-wide remote monitoring and operational optimization applications for a large eucalyptus farm, including:

- Sensor-based **monitoring of tree growth pace**
- **Identification of disease** via computer vision + AI
- **Fire and disaster management**
- **Real-Time Kinematic (RTK) satellite navigation to enhance precision of position data** from satellite-based positioning systems
- **Fuel management** for anti-fraud, etc.
- **ERP data collection** and upload

LEVEL 3

Single-Task Autonomous Fleets

KEY NETWORK REQUIREMENT:

M2M connectivity via autonomous adaptability that enables equipment to remain in constant communication to autonomously coordinate tasks amongst each other.

- ✗ Wired Network
- ✗ Cellular Network
- ! Traditional Mesh Network
- ✓ Rajant Kinetic Mesh®

Traditional wireless networks assign peers based on the best paths found at the moment of evaluation, and those paths cannot be re-evaluated until the network is reset or an update command is sent. This means that there is no proactive syncing, which causes connectivity challenges in highly mobile and wide-ranging farming environments where nodes are continually moving between access points.

The Rajant Advantage:

AUTONOMOUS ADAPTABILITY

The network demands within today's farming environments are constantly changing as equipment, vehicles, and autonomous assets move over large stretches of rugged and remote acreage. Robust connectivity must be maintained within a network topology that is shifting from second to second, but in traditional wireless infrastructures, a great deal of manual configuration and intervention is needed to make this possible. Conversely, Rajant's patented InstaMesh® networking protocol gives Rajant Kinetic Mesh® autonomous adaptability, enabling the network to react in real-time to changes in network topology, load, and environmental conditions.

Kinetic Mesh is the only wireless network that can truly rise to the challenges of autonomous equipment networking, because the network itself can autonomously load balance traffic, mitigate interference by routing around detected congestion, and dynamically react to topology changes to provide continuous connectivity without fail.

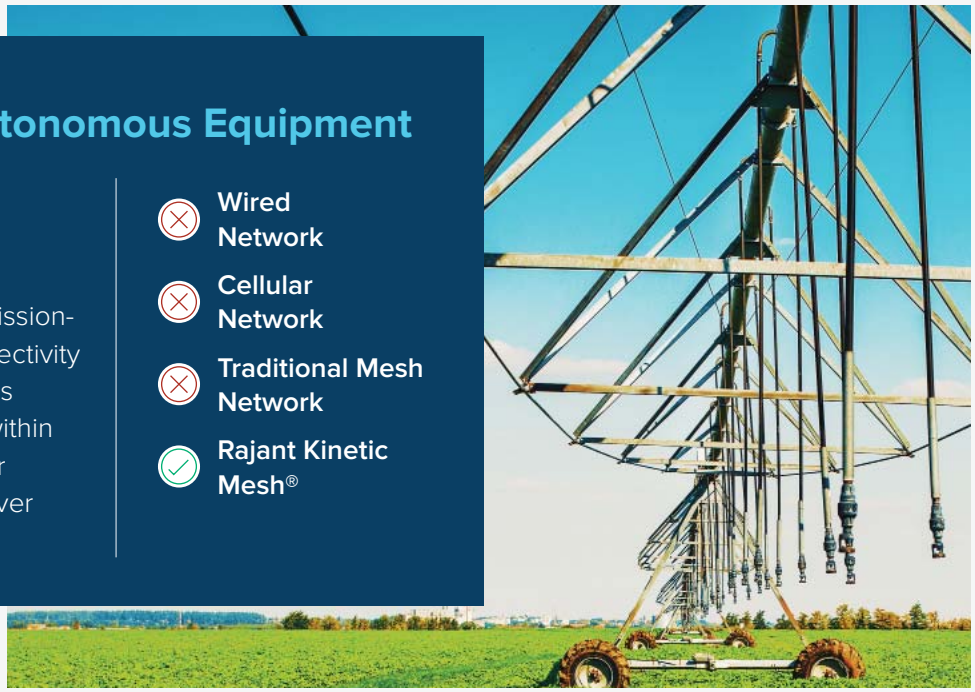
LEVEL 4

Complex Autonomous Equipment

KEY NETWORK REQUIREMENT:

Total mobility that supports support mission-critical mobile connectivity to keep autonomous assets continually within coverage, no matter where they travel over vast farmland.

- ✗ Wired Network
- ✗ Cellular Network
- ✗ Traditional Mesh Network
- ✓ Rajant Kinetic Mesh®



Only Rajant's Kinetic Mesh brings farming assets to life, moving *with* farm operations to drive IIoT capabilities and enable highly-mobile, highly-secure Precision Farming practices for any level of automation, including effective support for fully autonomous operations.

The Rajant Advantage:

UNPARALLELED NETWORK MOBILITY

The shortcomings of traditional network infrastructures, from their Make-Before-Break approach to the level of manual intervention required to optimize performance, means that they lack the agility to support the mission-critical mobility that fully autonomous farming applications demand.

In a Kinetic Mesh® network, all BreadCrumbs are equipped with the intelligence of InstaMesh® and can therefore autonomously self-optimize as the network moves and changes. This enables a fully mobile network that upholds unwavering mobile connectivity in dynamically changing farm environments. In fact, BreadCrumbs® can be deployed directly onto virtually any farming asset, transforming it into network infrastructure to seamlessly connect hot zones and provide ubiquitous coverage over vast acreage.

Ruggedized Equipment for the Harshest Farming Environments

From harsh weather and pesticide sprays to rough conditions and field debris, farmers must be confident in the ruggedness of their equipment. Rajant's BreadCrumb® nodes are built to withstand even the harshest conditions and extreme environments while still remaining lightweight and easy to deploy.

BreadCrumb nodes are:

- Built to MIL STD 810G
- Designed for IP67 (6-dust tight, waterproof)
- Protected from shock and vibration
- Enabled for 170,000 hours Mean Time Between Failure (MTBF)
- High-performance in severe temperature (-22° to 176° F, -30° to 80° C)

RAJANT IN ACTION

Palm Oil Plantation

Rajant's Kinetic Mesh® network is bringing connectivity to a 480,000+ hectare palm oil plantation spread across remote islands and locations with minimal cellular coverage, supporting applications for:

- Monitoring and management of **soil moisture, water use, fertilizer use and levels,** etc.
- Measuring and management of **seed and crop density**
- **Monitoring via tethered drone,** which relays stored data collected from IoT monitoring devices to a mobile vehicle equipped with an ME4 BreadCrumb driving around the plantation perimeter.

Rajant Kinetic Mesh®:
Powering Farms of the Future

Rajant's Living Network™, powered by Kinetic Mesh, is an easily-configurable, autonomously adaptable wireless network solution for next-gen agricultural environments.

Different from all other offerings, Rajant's Kinetic Mesh is fully mobile, providing wireless broadband connectivity that is simple, yet fail-proof in any application, instantly creating a truly "living" mesh solution for evolving agricultural demands—regardless of an operation's current automation level. Rajant's solution integrates with legacy infrastructure to deliver the IIoT connectivity farmers need, seamlessly scaling with evolving agricultural operations.

With a track record of success across industry sectors, Rajant's Living Network™ is **easy to deploy, easy to maintain, and has proven ROI,** providing the automation and scalability that agriculture needs today for Precision Farming of tomorrow.

Discover how you can transform your agricultural environment into a Precision Farming operation with one simple, autonomous solution.

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