FarmBeats: An AI & IoT System for Data-Driven Agriculture

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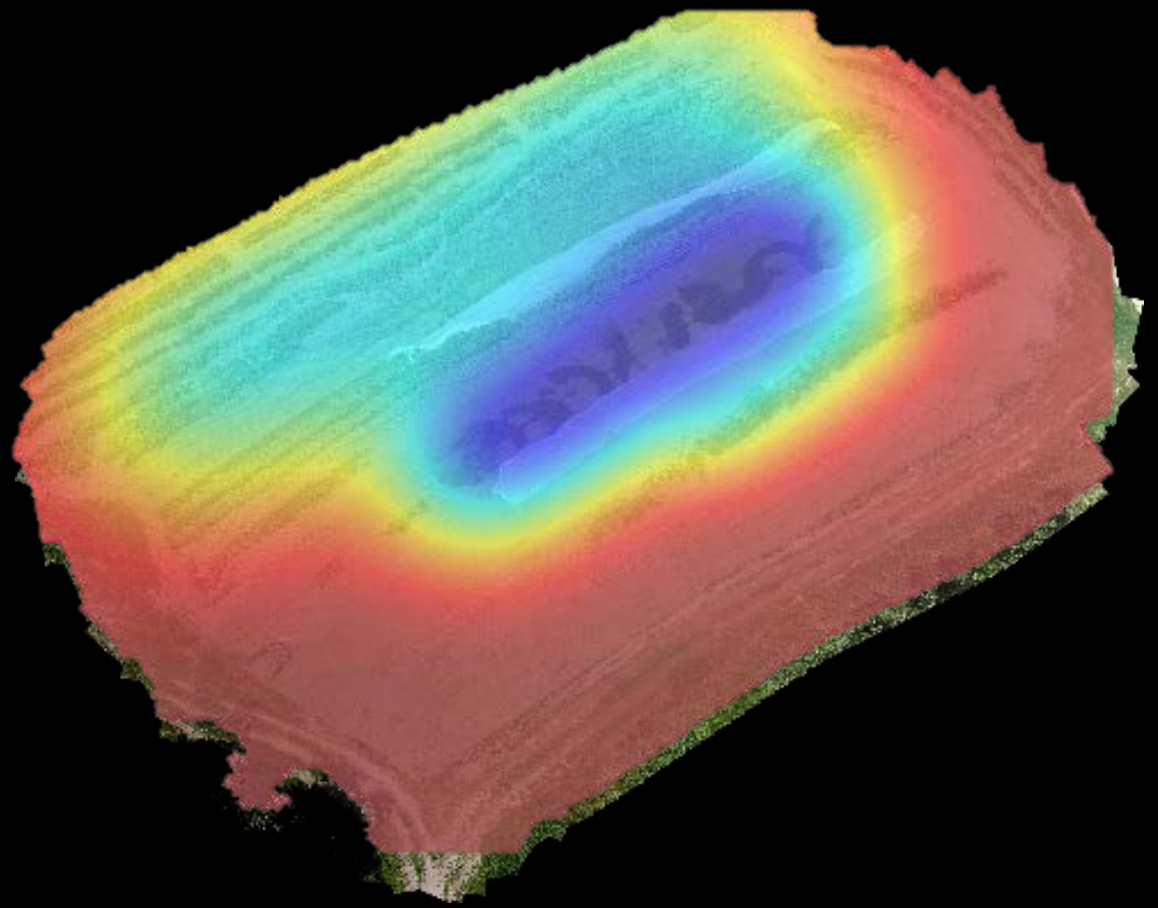
Microsoft

Data-Driven Agriculture



Ag researchers have shown that it:

- Improves yield
- Reduces cost
- Ensures sustainability

But…

According to USDA, high cost of manual data collection prevents farmers from using data-driven agriculture

IoT System for Agriculture

Problem 1: No Internet Connectivity

- Most farms don’t have any Internet coverage

- Even if connectivity exists, weather related outages can disable networks for weeks

Problem 2: No Power on the Farm

- Farms do not have direct power sources

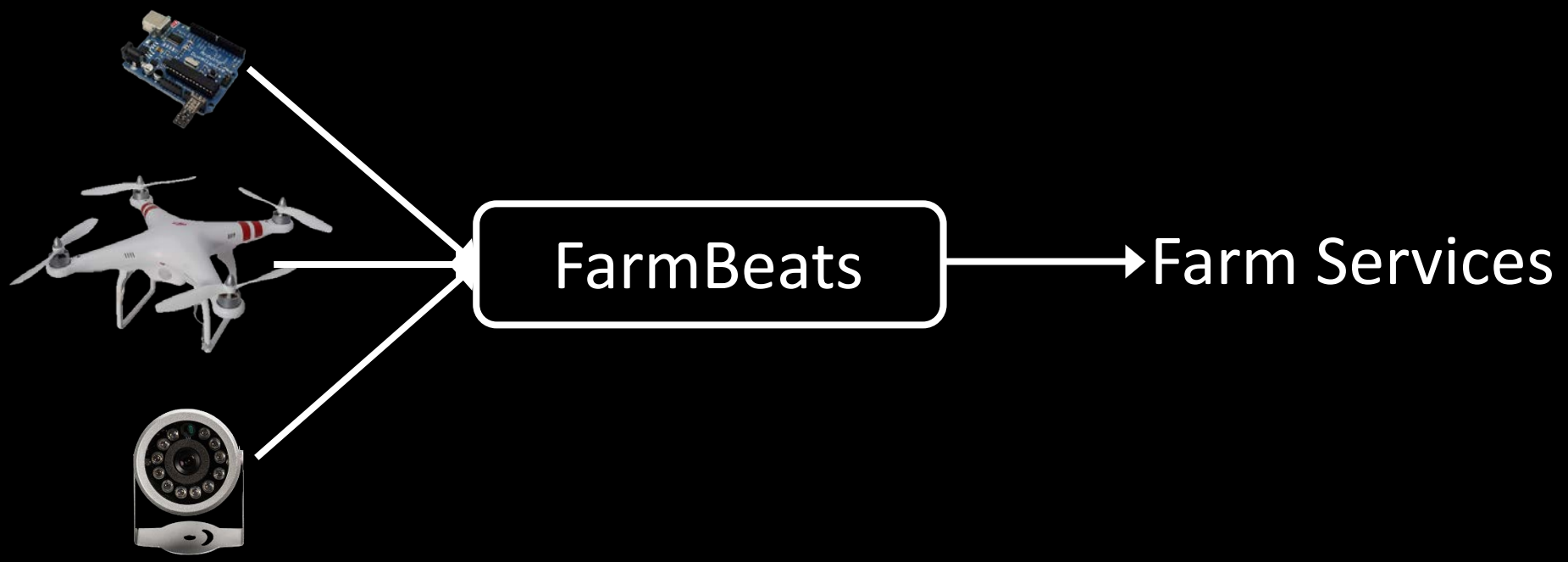
- Solar power is highly prone to weather variability

Problem 3: Limited Resources

- Need to work with sparse sensor deployments
  - Physical constraints due to farming practices
  - Too expensive to deploy, and
  - Cumbersome to maintain

In this talk

- FarmBeats: An end-to-end IoT system that enables seamless data collection for agriculture



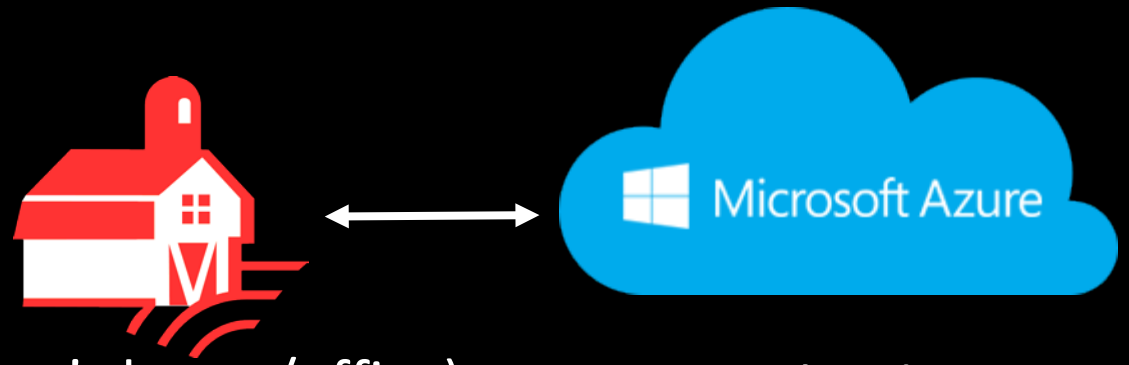
In this talk

- FarmBeats: An end-to-end IoT system that enables seamless data collection for agriculture

- Solves some key challenges:
  - Connectivity in the Farm
  - Limited Sensor Placement
  - Internet to the Farm
  - Power Availability

- Deployed in two farms in NY and WA for over six months

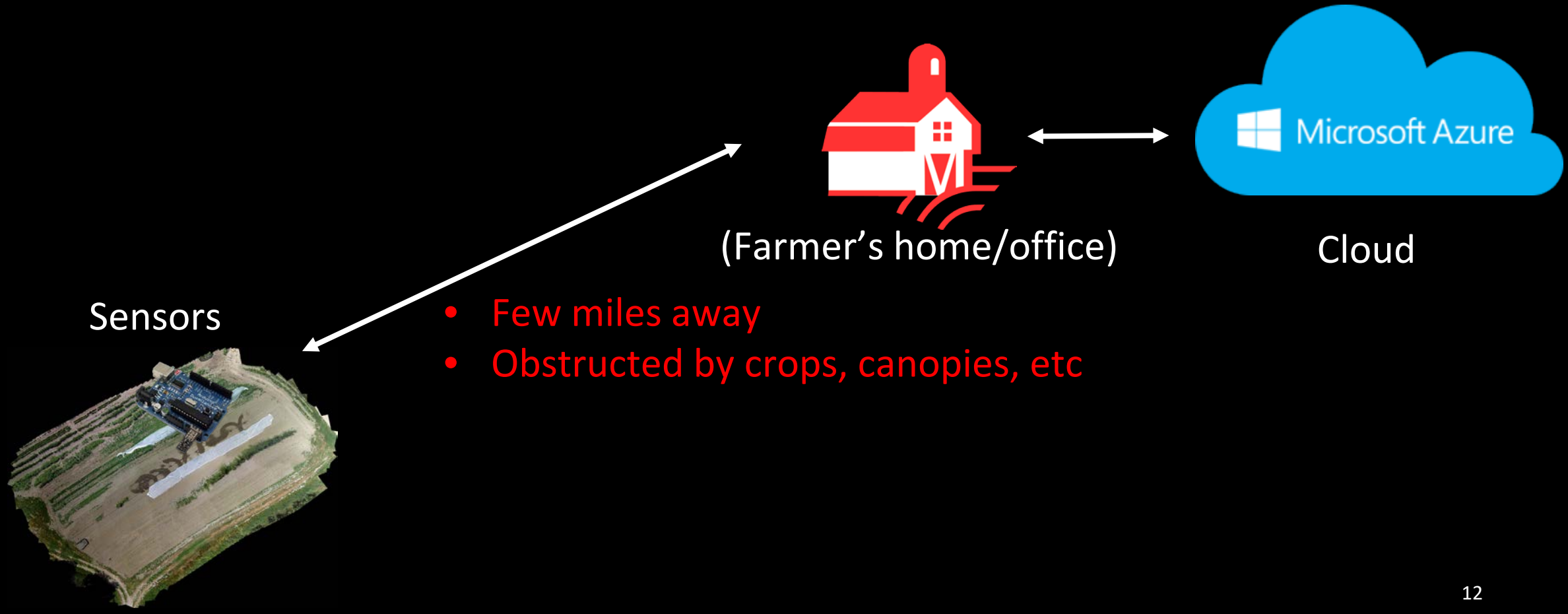
Challenge: Internet Connectivity



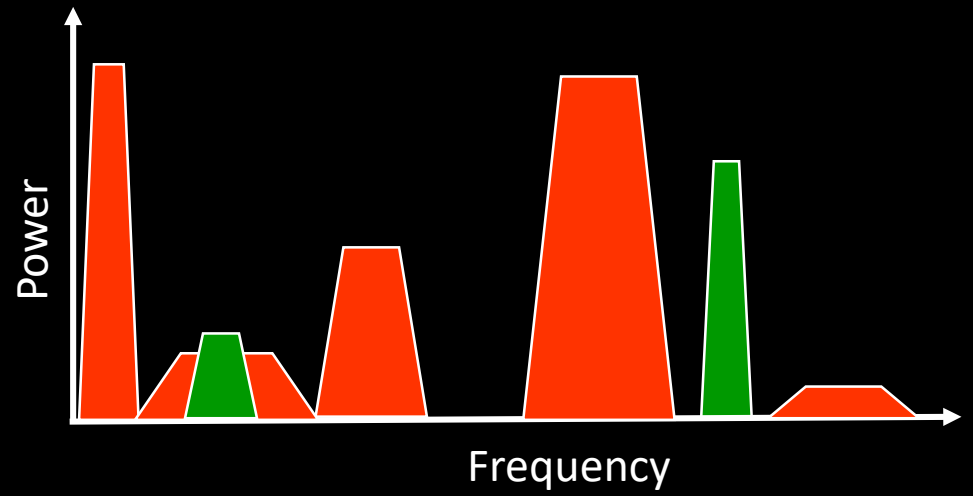
(Farmer's home/office)

Cloud

Challenge: Internet Connectivity



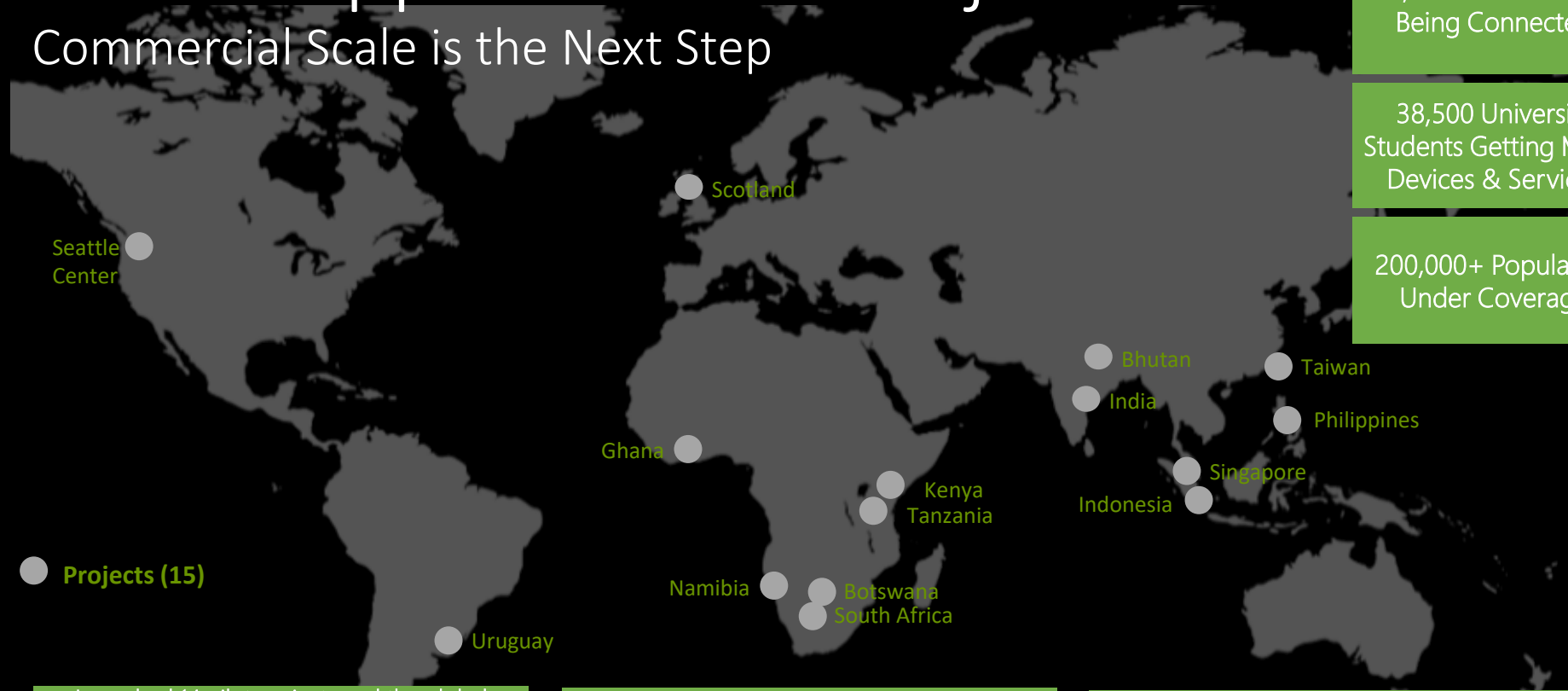
TVWS using Dynamic Spectrum Access (DSA)



- **Determine** available spectrum (**white spaces**)
- **Transmit** in "available frequencies"
- **Detect** if primary user appears
- **Move** to new frequencies
- **Adapt** bandwidth and power levels

MSFT Supported Pilot Projects

Commercial Scale is the Next Step



36,000 K-12 Students Being Connected

38,500 University Students Getting MSFT Devices & Services

200,000+ Population Under Coverage

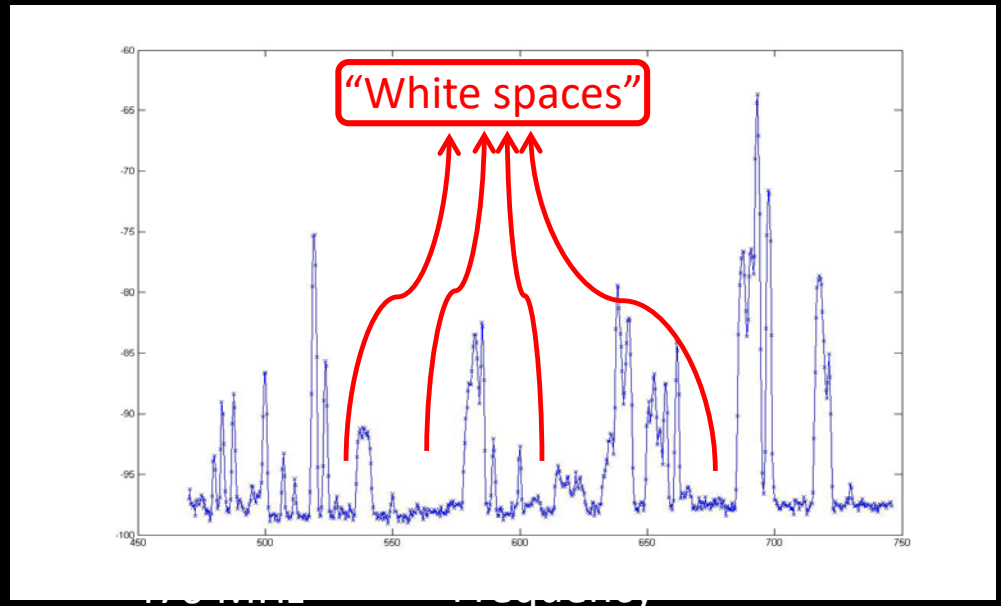
Launched 14 pilot projects and the global Dynamic Spectrum Alliance. Objective: Trigger regulatory changes and develop commercially viable ecosystems for TV White Spaces technology.

Regulatory changes achieved in USA & Singapore with drafts in UK and Canada. Critical progress made in ITU-D and ITU-R.

Built working relationships with USAID, OPIC, World Bank, PEPFAR, DFID,/UKAID, Africa/Asia/Inter-America Dev. Banks, non-profits, ITU, ISP and Telco providers.

TV White Spaces in the Farm

- What are the TV White Spaces?
  - Unused TV channels
- Benefits over Wi-Fi, Zigbee, etc
  - High throughput at long range
- Key insight for farms:
  - “lots” of TV spectrum is available, more than 100 MHz
  - Just like Wi-Fi router covers the home, TVWS base station can cover the farm



In this talk

- FarmBeats: An end-to-end IoT system that enables seamless data collection for agriculture

- Solves some key challenges:
  - ✓Connectivity in the Farm
  - Limited Sensor Placement
  - Internet Connectivity to the Farm
  - Power Availability

- Deployed in two farms in NY and WA for over six months

Challenge: Limited Resources

- Need to work with sparse sensor deployments
  - Physical constraints due to farming practices
  - Too expensive to deploy and maintain
- How do we get coverage with a sparse sensor deployment?

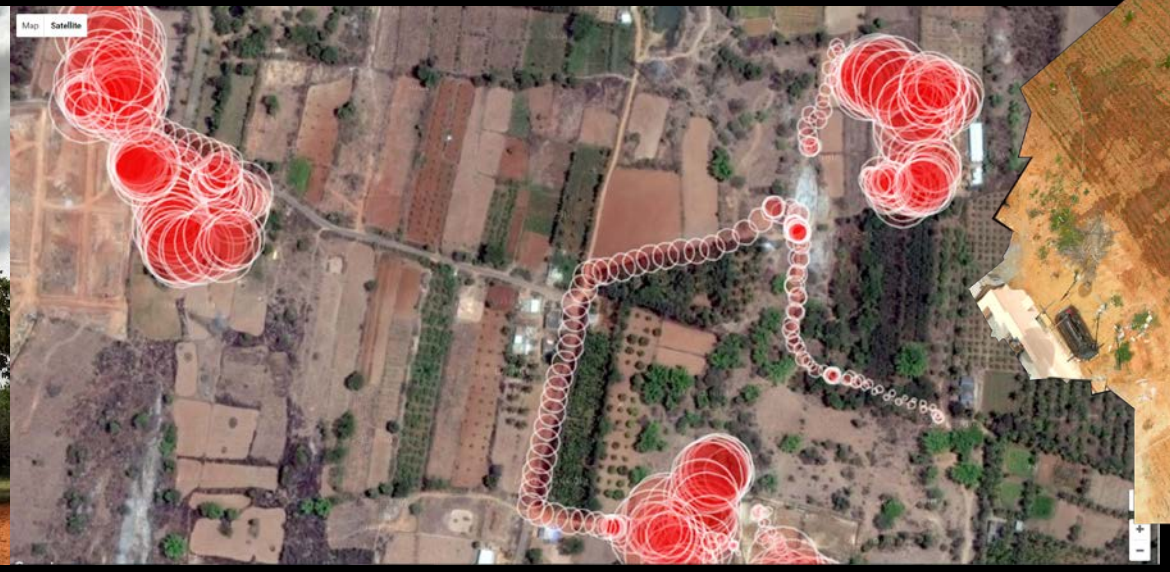
Idea: Use UAVs to Enhance Spatial Coverage

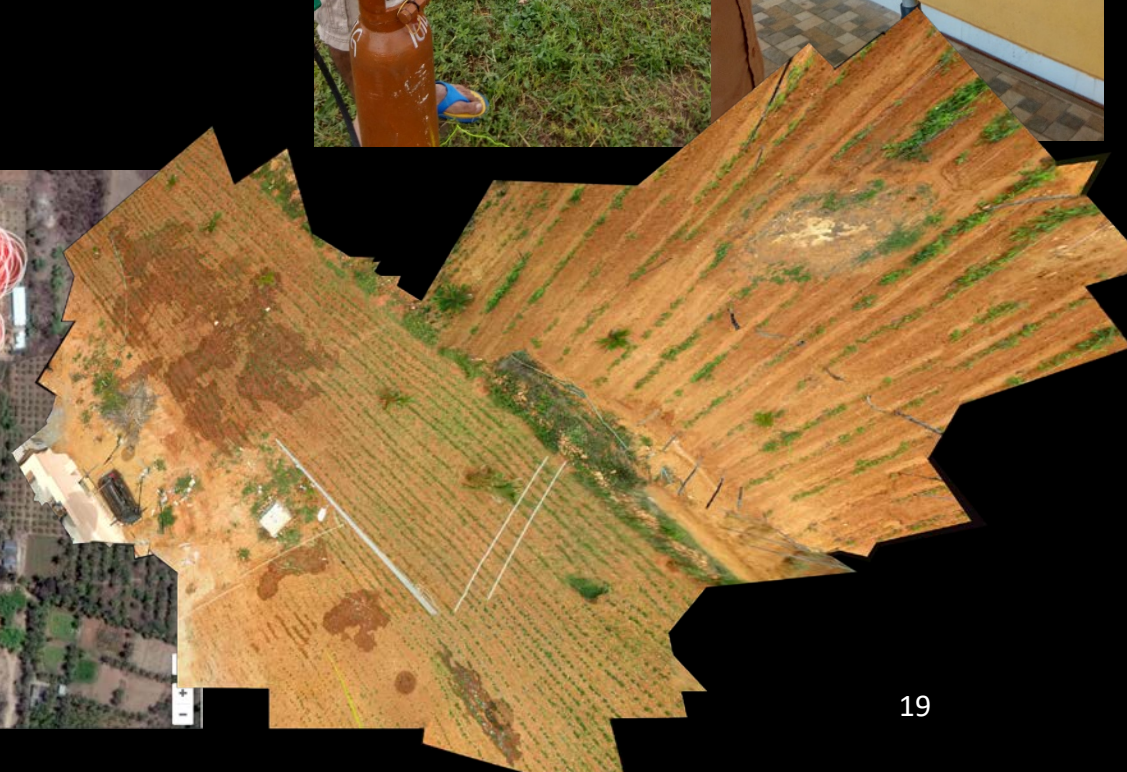
- Drones are ~1000 dollars and automatic
- Can cover large areas quickly
- Can collect visual data

Combine visual data from the UAVs with the sensor data from the farm

Low-cost Aerial Imagery: Tethered Eye (TYE)

- UAVs have a few limitations:
  - limited battery life
  - Regulatory concerns
  - Cost > 1000 dollars

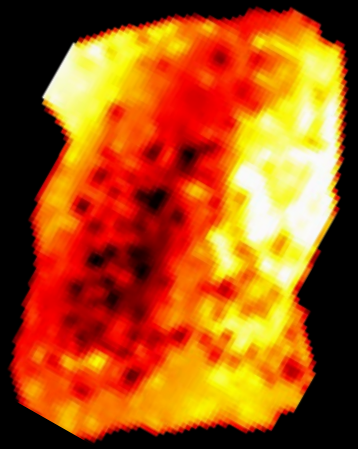




Idea: Use Drones to Enhance Spatial Coverage

Drone Video

Panoramic Overview



Precision Map

Sparse Sensor Data

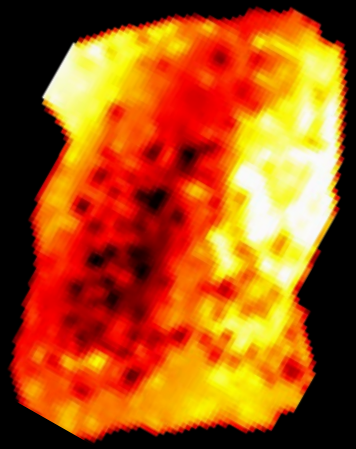
Formulate as a Learning Problem

Panoramic Overview

Using Sparse Sensor Data

Drone Video

Panoramic Overview



Precision Map

FarmBeats can use drones to expand the sparse sensor data and create summaries for the farm

In this talk

- FarmBeats: An end-to-end IoT system that enables seamless data collection for agriculture

- Solves three key challenges:
  - ✓Connectivity in the Farm
  - ✓Limited Sensor Placement
  - Internet to the Farm
  - Power Availability

- Deployed in two farms in NY and WA for over six months

The Real World

Base Station

Wi-Fi, BLE

Sensors

TV White Spaces

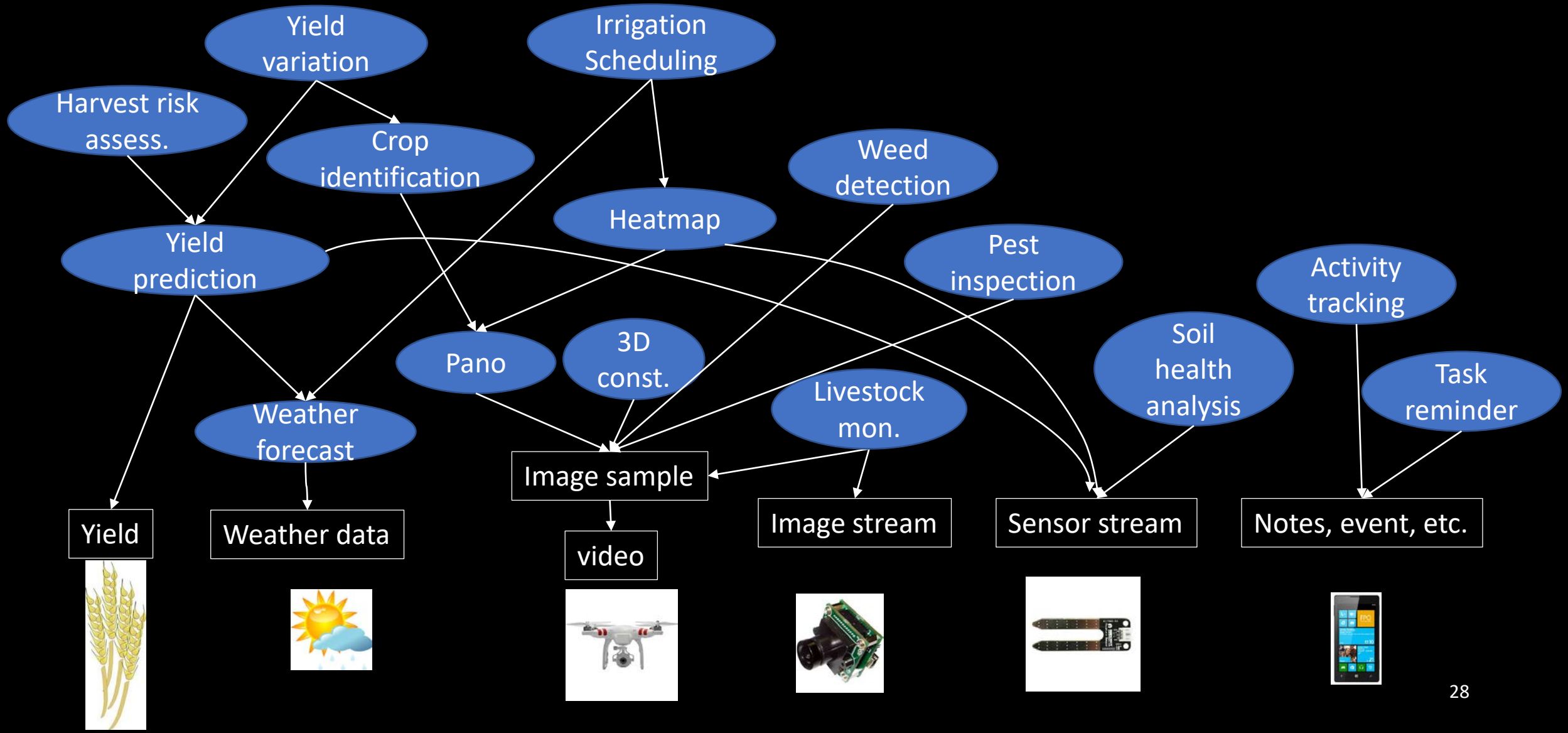
Few miles

(Farmer's home/office)

- Weak Connectivity
- Prone to outages

Cloud

What Services We Can Provide



Service Characteristics

- Large inputs

Data Source	Daily size
Sensor	70K
Drone video	10G
Drone image	4G
Camera	28M

- Latency constraints

Service	Latency
Query sensor data	seconds
Livestock mon.	seconds
Irrigation sched.	hours
Pest inspection	hours
Variability analysis	Days

The Ideal World

The Real World

Base Station

Wi-Fi, BLE

Sensors

TV White Spaces

Few miles

(Farmer's home/office)

- Weak Connectivity
- Prone to outages

Cloud

FarmBeats Design

Base Station

Wi-Fi, BLE

Sensors

TV White Spaces

Few miles

(Farmer's home/office)

FarmBeats Gateway
(IOT Edge)

Weather Data
(Rain, Wind, Pollen)

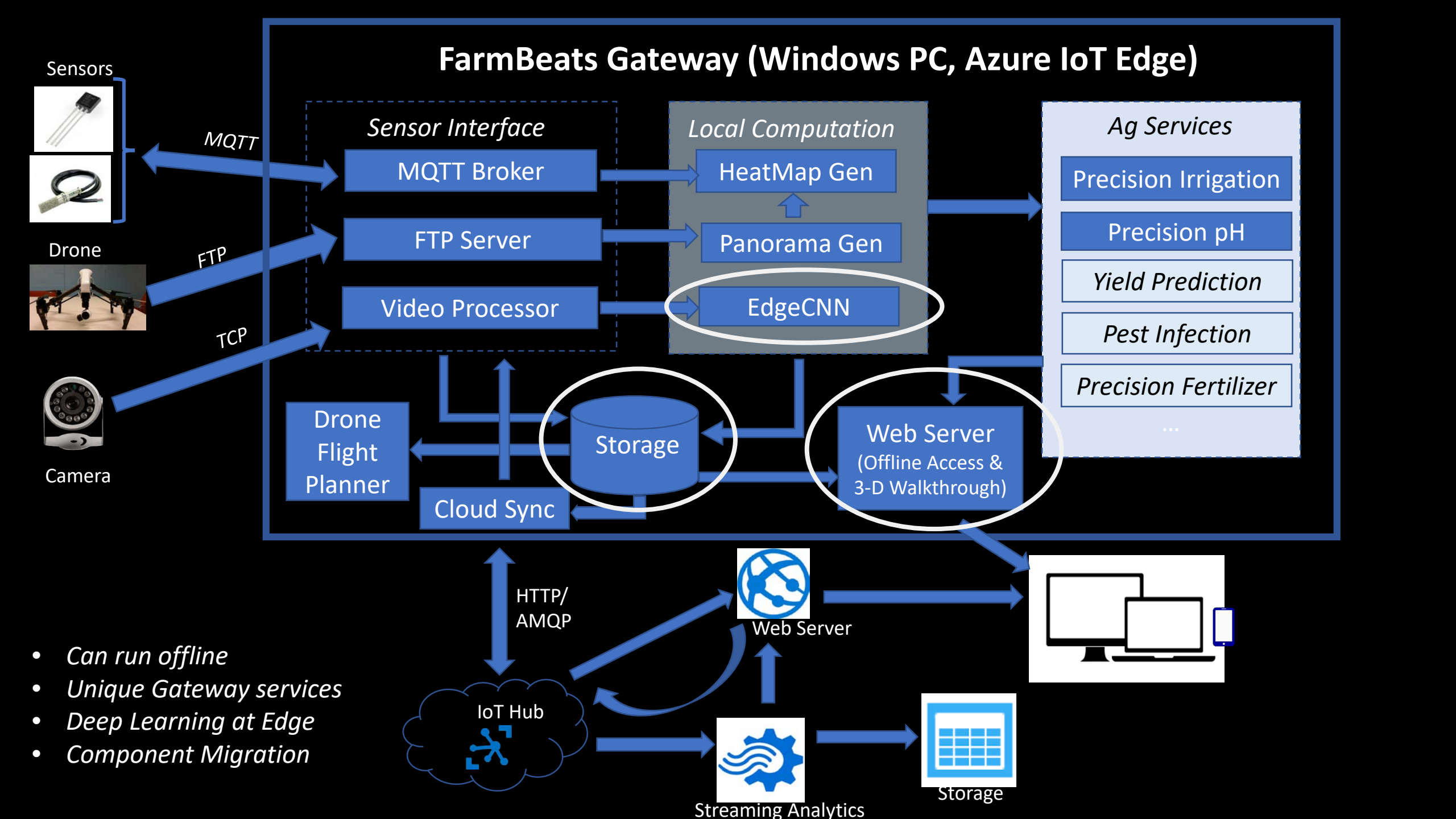
Microsoft Azure

Cloud

Analytics

Seed vendors
Agronomists
Farmers
…

Recommendations
(daily best practices)


FarmBeats Gateway (Windows PC, Azure IoT Edge)
Sensors
MQTT
Drone
FTP
TCP
Camera
Sensor Interface
MQTT Broker
FTP Server
Video Processor
Local Computation
HeatMap Gen
Panorama Gen
EdgeCNN
Ag Services
Precision Irrigation
Precision pH
Yield Prediction
Pest Infection
Precision Fertilizer
...
Drone Flight Planner
Storage
Cloud Sync
Web Server
(Offline Access & 3-D Walkthrough)
HTTP/ AMQP
Web Server
IoT Hub
Streaming Analytics
Storage
Can run offline
Unique Gateway services
Deep Learning at Edge
Component Migration

In this talk

- FarmBeats: An end-to-end IoT system that enables seamless data collection for agriculture

- Solves key challenges:
  - ✓Connectivity in the farm
  - ✓Limited Sensor Placement
  - ✓Weak Connectivity to the Farmer's house
  - Power Availability
    - Solar power, RF power, UAV battery life

- Deployed in two farms in NY and WA for over six months

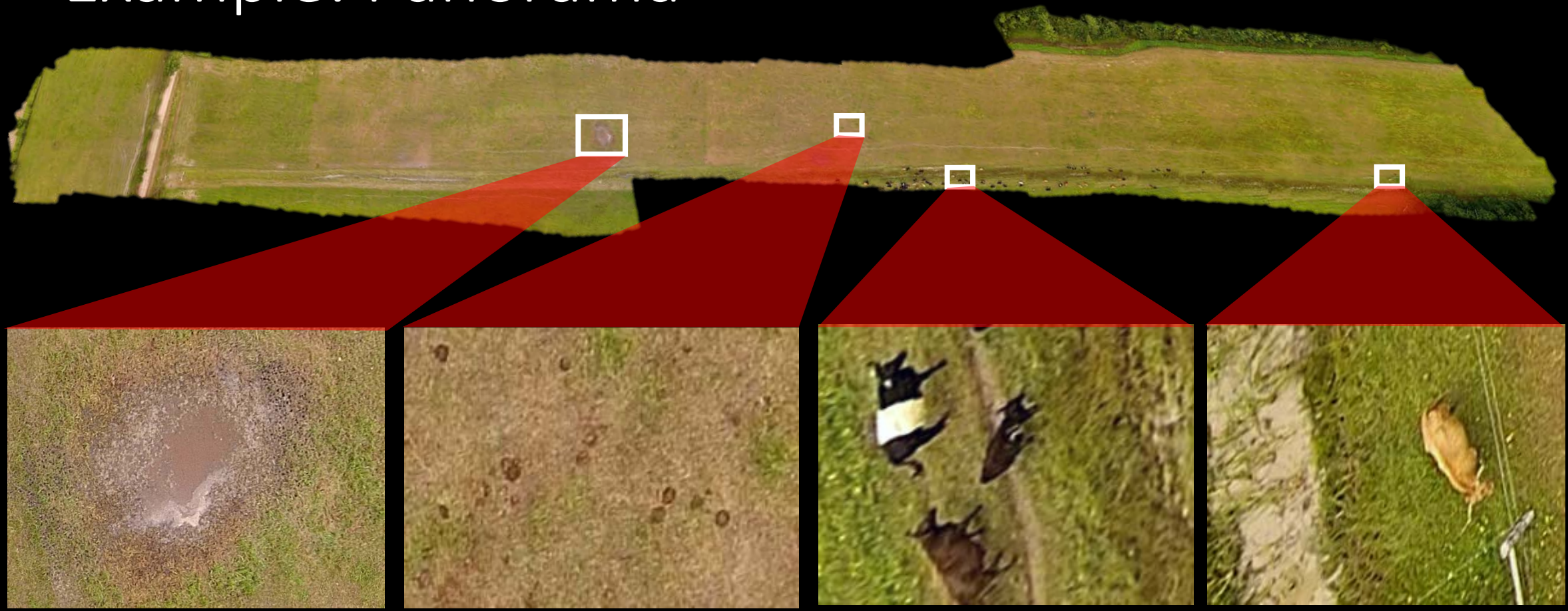
Deployment

- Six months deployment in two farms: Upstate NY (Essex), WA (Carnation)
- The farm sizes were 2000 acres and 5 acres respectively
- Sensors:
  - DJI Drones
  - Particle Photons with Moisture, Temperature, pH Sensors
  - IP Cameras to capture IR imagery as well as monitoring
- Cloud Components: Azure Storage and IoT Suite

Deployment Statistics

- Used 10 sensor types, 3 camera types and 3 drone versions
- Deployed >100 sensors and ~10 cameras
- Collected >10 million sensor measurements, >0.5 million images, 100 drone surveys
- Resilient to week long outage from a thunderstorm

Example: Panorama



Water puddle

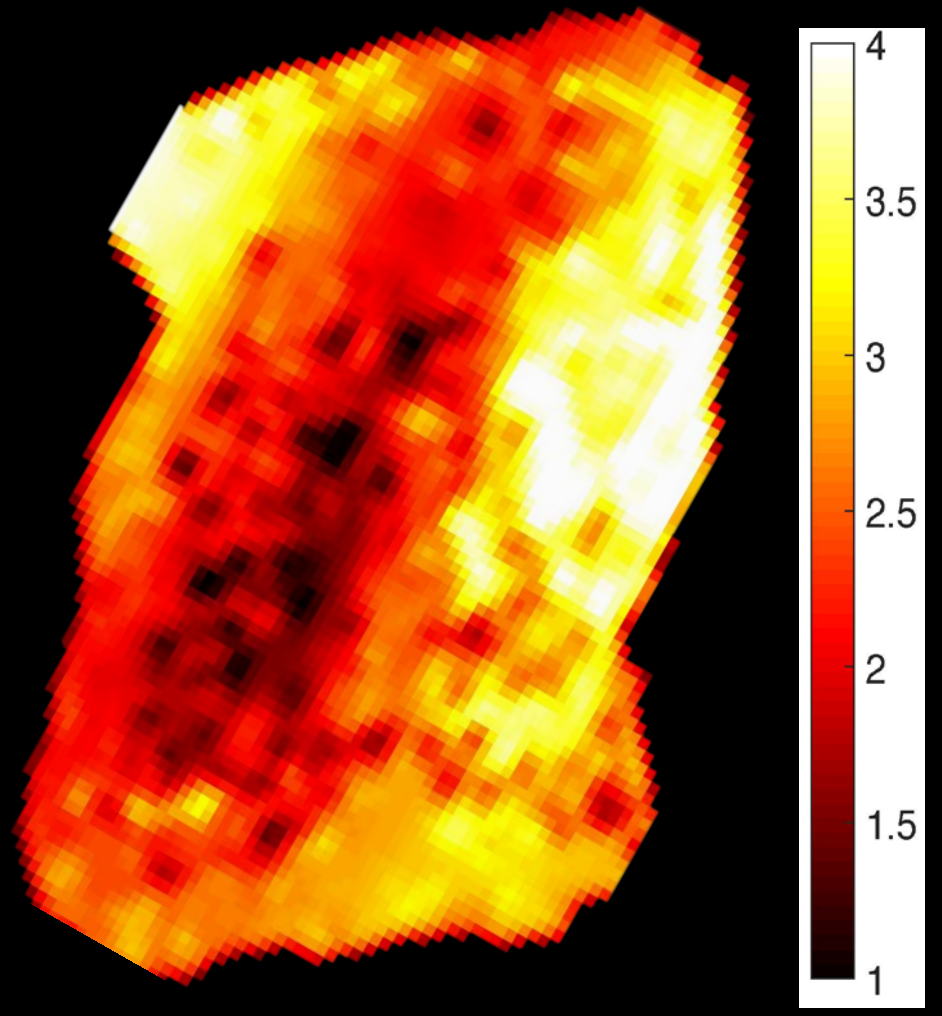
Cow excreta

Cow Herd

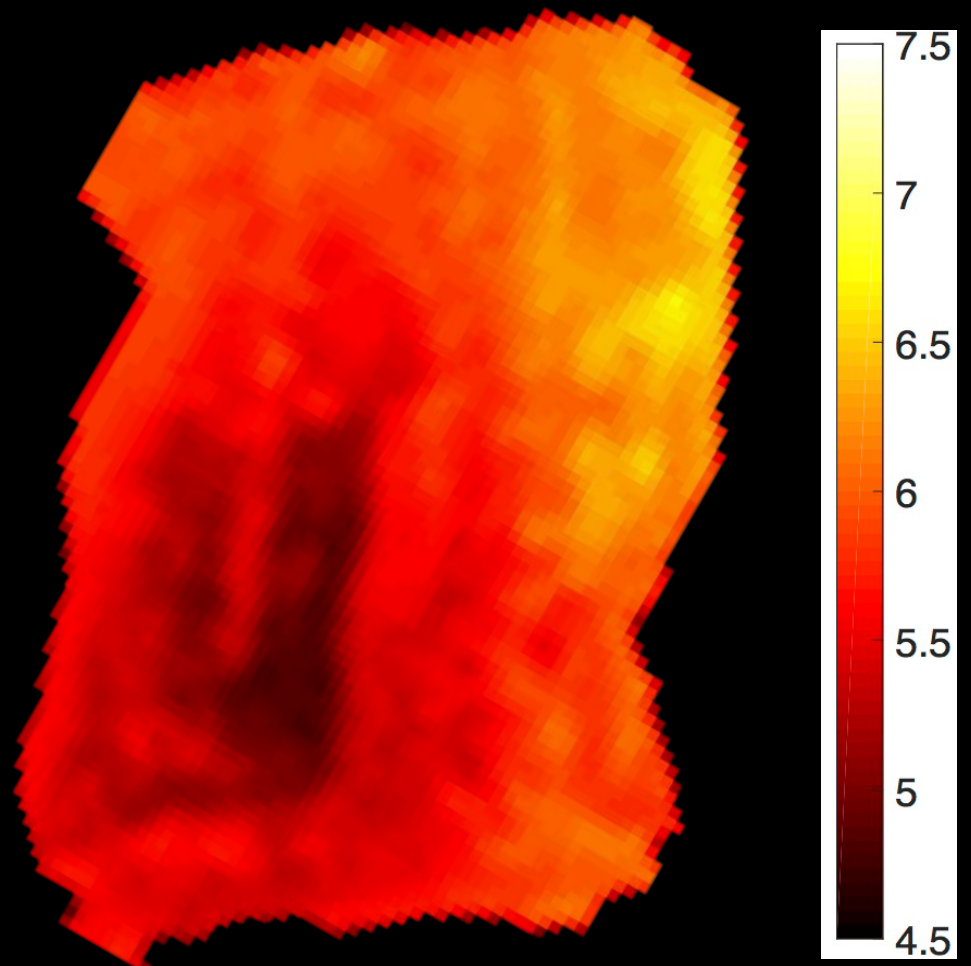
Stray cow

Precision Map: Panorama Generation

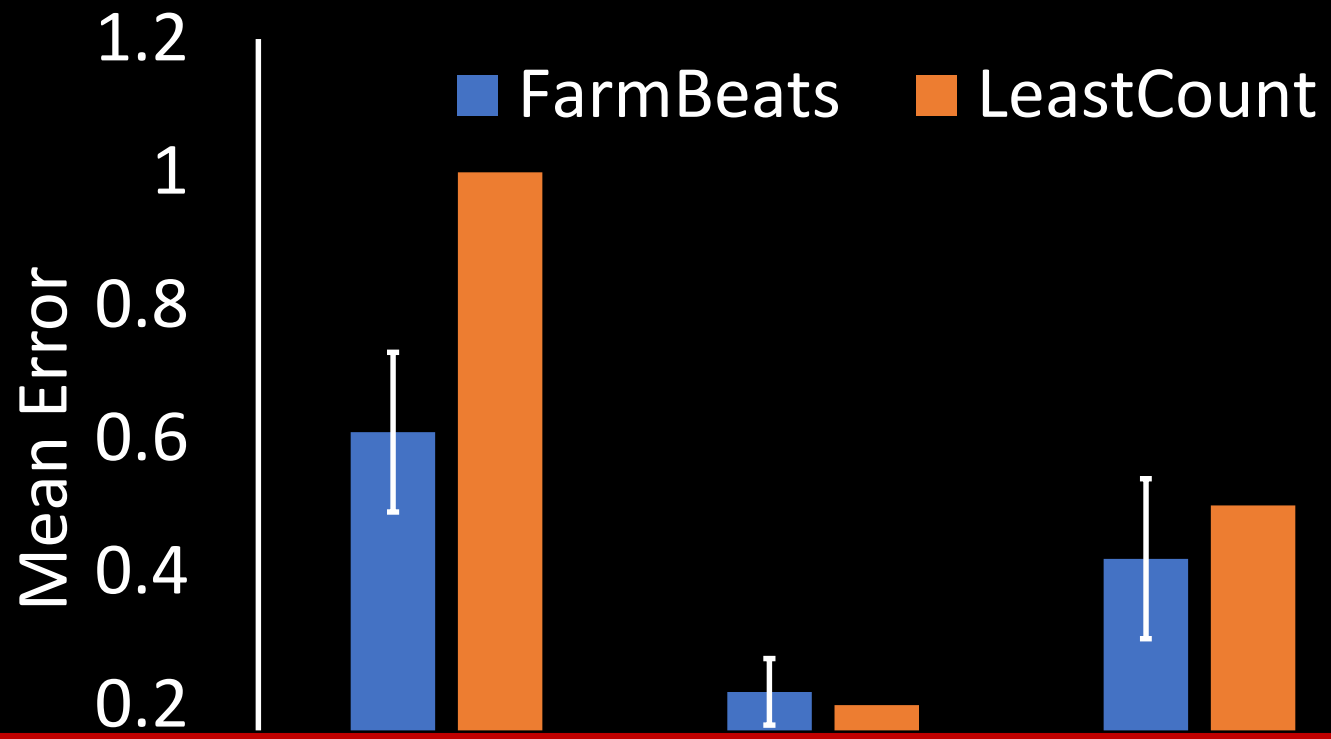
Precision Map : Moisture



Precision Map : pH

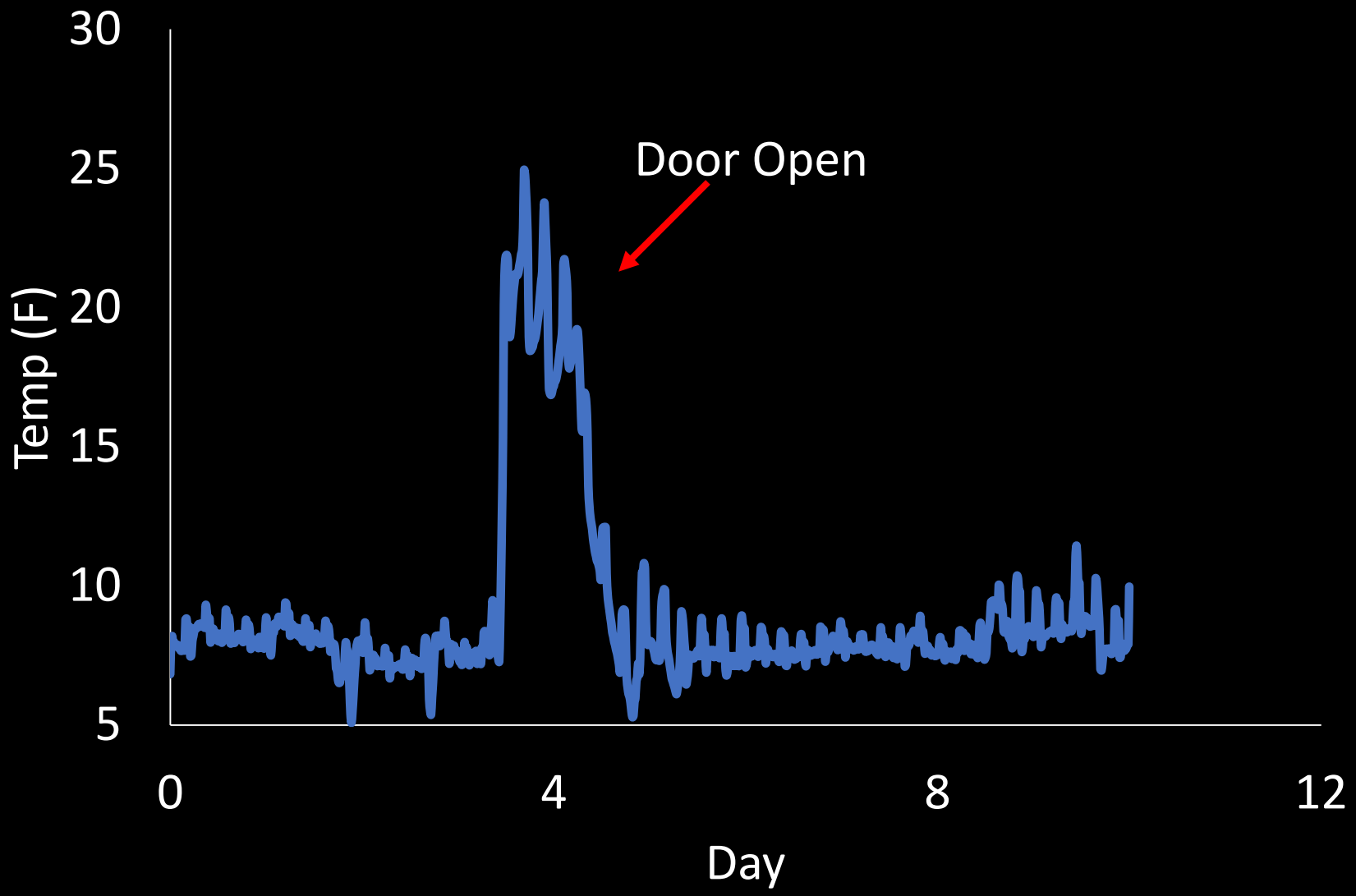


Precision Map: Accuracy



FarmBeats can accurately expand coverage by orders of magnitude using a sparse sensor deployment

Application: Storage Monitoring



Application: Cow-Shed Monitor

Conclusion

- FarmBeats: End to end IoT system for environments constrained by:
  - Limited internet connectivity
  - Power Variability
  - Sparse Sensor Deployment
- Acts as a tool to enhance farm and farmer productivity
- Microsoft’s entire stack for Ag:
  - Data Capture (Azure IoT), providing Insights (Power BI), secure storage (Azure Data Lake), Traceability (BlockChain), AI & ML (Azure ML & Cognitive Services)

Thank you!

Sean Stratman, Dancing Crow Farm, WA

Mark & Kirstin Kimball, Essex Farm, NY

Questions

http://www.microsoft.com/en-us/research/project/farmbeats-iot-agriculture/
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