Minds in the Vines: Technology of the CENIC-Connected Drones, Cameras, and LoRaWAN Sensors at the Iron Horse Vineyards Testbed

7NRP Thursday May 7, 9:45am -10:10am

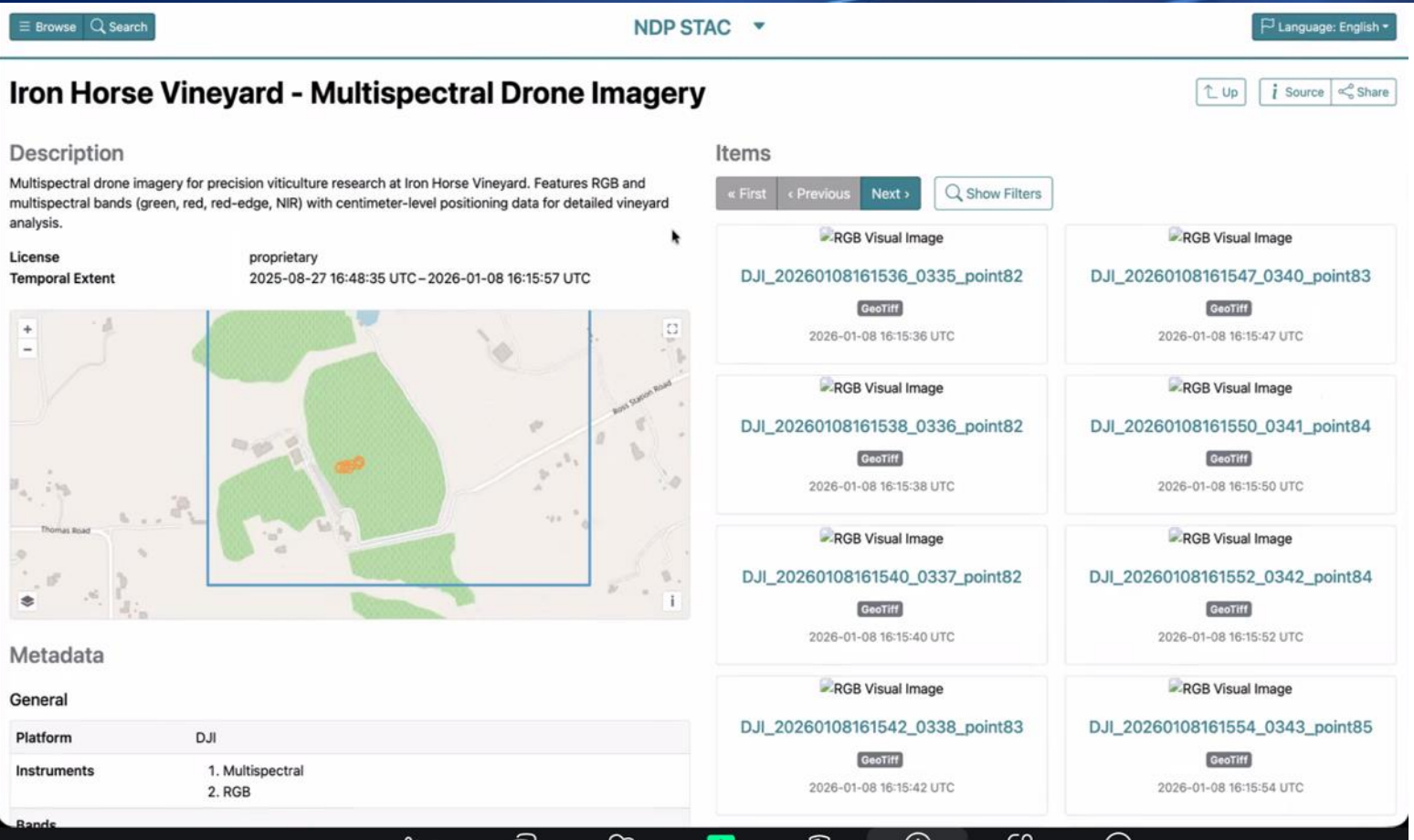
Presenters: John Graham and Tom DeFanti
(Way too many slides!)
Please watch the videos from 7NRP

Tom: CENIC 10G-connected Iron Horse Vineyards Testbed, Sebastopol, CA

Minds in the Vines: Goals

1. Create a digital vineyard twin with open source/non-proprietary tech;
2. Provide visual analytic tools for winemakers and crop managers;
3. Involve community college and university faculty and students;
4. Encourage entrepreneurs by distributing debugged data collection and processing methods, and
5. Contribute to an open shared and growing database for researchers;
6. Inspire other testbeds in precision agriculture;
7. Demonstrate the value of a 10G Science DMZ to ISPs and industry

Sharing is Key: Drone Imagery on the National Data Platform



NATIONAL DATA PLATFORM

NRP NATIONAL RESEARCH PLATFORM

Sensor Data on the National Data Platform

NATIONAL DATA PLATFORM

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IoT Sensor Data

Organization: Iron Horse Vineyards

Creator Name: Kate O'Laughlin

Last Updated: March 26, 2026 at 5:00 PM PDT

IoT environmental sensor data from Iron Horse Vineyards. Includes temperature, humidity, soil moisture, CO2, and other environmental measurements from various sensor devices deployed throughout the vineyard for precision viticulture research.

Data and Resources

- IoT Sensor Data InfluxDB — View More
- STAC Catalog — View More

Tags

environmental-sensors iot precision-viticulture

Decision-Critical Metrics for Fine Wine Growing

Vine Water Status — The Key Lever in Fine Wine
Monitoring soil moisture, vine water potential, and evapotranspiration enables precise deficit irrigation — influencing berry size, skin-to-juice ratio, phenolic concentration, and overall balance.

Frost Risk — Vintage Protection
One frost event can wipe out a year's work.
Real-time alerts from water line pressure sensors and drone surveillance allow targeted sprinkler repair and proactive protection.

Canopy Microclimate — Disease and Purity Control
Monitoring cluster-zone temperature, humidity, and leaf wetness helps:

- **Anticipate mildew outbreaks**
- **Reduce unnecessary sprays**
- **Preserve fruit purity and site expression**

More Decision-Critical Metrics for Fine Wine Growing

Berry Ripening Curves — Style-Defining Decisions
Phenolic ripeness versus sugar ripeness defines wine style.
AI models that integrate Brix, pH, acidity, tannin evolution, and weather patterns support precision harvest timing.

Fog and Microclimate Patterns — Climate Adaptation
Tracking shifts in fog behavior and diurnal swings is essential for monitoring climate change impacts and preserving regional identity.

Heat Events and Smoke Exposure — Risk Mitigation
Real-time environmental monitoring helps anticipate heat stress, acid loss, and smoke exposure, enabling earlier or segmented picking decisions.

AI-Driven Analysis for Fine Wine Growing

The Goal: Augmented Judgment with AI

- **The goal is not to replace the farmer, but to strengthen human judgment with data-driven insight — pattern recognition, predictive modeling, and precision response.**
- **In fine wine, where small differences define greatness, technology is not about scale. It is about nuance.**
- **Joy Sterling says: “AI is the new tractor!”**

On-Site 10G-connected Mac Studio M4 and Ubiquiti Dream Wall

Mac Studio M4 (Apple M4 Max Chip)

- 16-core CPU, 40-core
- GPU, 16-core
- 128GB unified memory
- 2TB SSD storage
- Front: Two USB-C ports, SDXC card slot
- Back: Four Thunderbolt 5, ports, two USB-A ports, HDMI port, 10Gb Ethernet port

Ubiquiti Dream Wall

- Wall-mounted 10G cloud gateway
- WiFi 6, high-power PoE switching

John: Connectivity and Sensor Installation: Soil, Air, and Other Sensors

John: Top Decision-Critical Metrics Provided by Sensor Data

METRIC	SENSORS/TOOLS	OUTCOME
Yield Forecasting	Drone canopy mapping, soil and microclimate data	Forecast yields to improve harvest planning, cellar readiness, and sales alignment
Air Quality/Smoke Risk	PurpleAir (PM2.5, gases, humidity, temp) to detect wildfire smoke and particulates that threaten grape quality	Provide early warnings to guide harvest and wine-making decisions
Water System Integrity	Milesite water pipe pressure to monitor irrigation lines for leaks or uneven pressure	Protect against water waste, erosion, and runoff
Seismic Monitoring	Omron Earthquake Sensor to detect seismic events and structural shifts on site	Ensure safety and resilience in vineyard operations
Frost Risk Indicators	ATMOS 41 Weather Station + pole-mounted temp/humidity sensors Drone night flights to locate plugged sprinklers in real time	Track canopy-level temperature, dew point, wind, and soil temperature. Guide frost protection system deployment with precision timing. Monitor frost protection lines for leaks or uneven pressure

More Top Decision-Critical Metrics Provided by Sensor Data

METRIC	SENSORS/TOOLS	OUTCOME
Soil Moisture and Conductivity	TEROS 22 + Dragino soil probes	Measure soil water potential, moisture, and conductivity across hilltops and swales. Prevent overwatering, optimize irrigation, and highlight terroir-driven variability.
Canopy Density and Vine Vigor	DJI Mavic 3 Multispectral Drone + Insta360 ground-level imagery	Map vine vigor, canopy density, shading, and detect disease risk. Improve balance for healthier vines and higher-quality grapes.
Fog and Microclimate Patterns	Milesite & SenseCAP CO2/temp/humidity sensors, ATMOS 41, PurpleAir	Monitor fog incidence, duration, and microclimate shifts. Anticipate ripening delays and mildew risk while preserving freshness.
Berry Ripening Curves	Drone multispectral imaging + vineyard sampling	Track ripening progression and block-by-block uniformity. Optimize harvest timing for sparkling vs. still wine styles.
Data Integration	Streaming of real-time data to national research networks	Enable AI-driven analysis, data sharing, and multi-university collaboration

Winemaker David Munksgard Chose Sites for Monitoring Moisture, Temperature and Conductivity Sensor with LoRaWAN Transceiver & Solar Charger & CO2 Sensors

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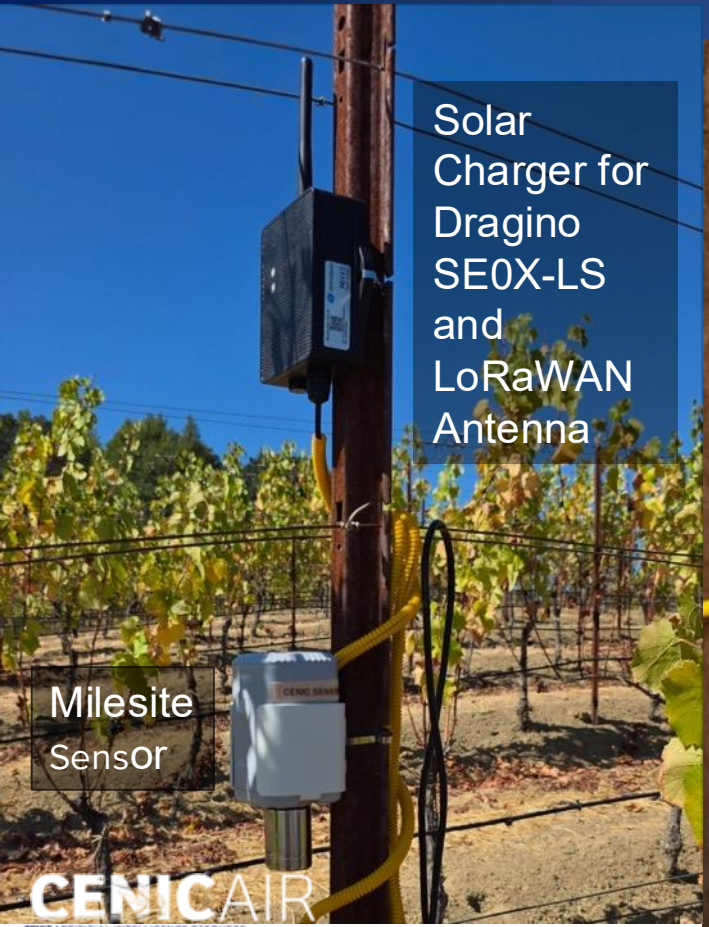
NRP NATIONAL RESEARCH PLATFORM

We Placed the First Sensors in the Ground Last August

Jake, Joe, and John Installed the Second set of Sensors for Moisture, Temperature, Soil Conductivity & CO2; Tom's Sienna Minivan AWD Got them out to the Blocks

CO2, Temperature, Barometric Pressure, and Humidity Sensors



TEROS and Dragino Soil Sensors

TEROS 22 Matric Water Potential (Soil Suction) Sensor

- Full-range soil water potential sensor
- Pre-calibrated to save time and effort
- Onboard temperature measurement

Dragino SE01-LS Solar LoRaWAN Soil Moisture & EC Sensor

- Ultra-long range spread-spectrum
- High-interference immunity
- Minimizing power consumption
- Measures Soil Moisture, Temperature and Conductivity
- Uploads the values via LoRaWAN IoT Server

Dragino SE0X-LS Soil Moisture & Electrical Conductivity Sensor

- Monitor Soil Moisture, Temperature, Conductivity
- Support wireless OTA update firmware
- IP66 Waterproof Enclosure
- Solar powered + Li-ion battery

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Home
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Resources
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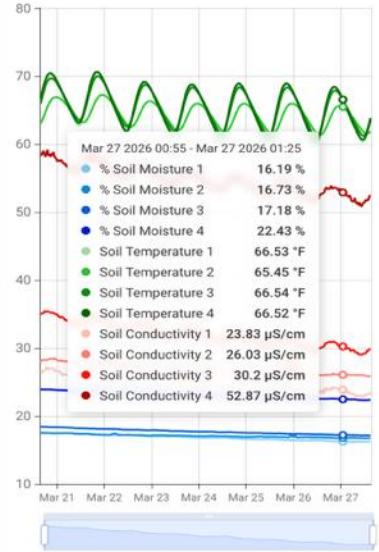
Mobile center
API usage
Settings
Security

Soil Sensors

SE0X Soil Sensors | Realtime - last 7 days | Edit mode

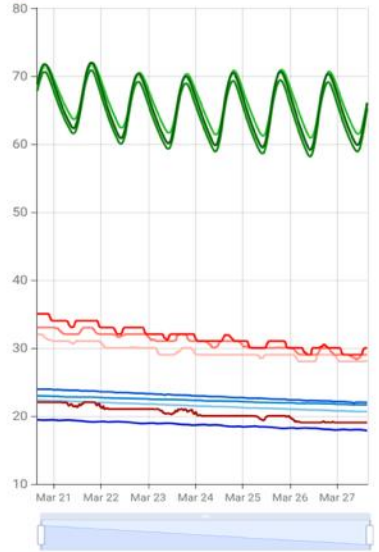
SE0X-LS-1

	Avg	Latest
% Soil Moisture 1	16.81 %	16.19 %
% Soil Moisture 2	17.05 %	16.72 %
% Soil Moisture 3	17.68 %	17.09 %
% Soil Moisture 4	23.04 %	22.33 %
Soil Temperature 1	65.14 °F	63.46 °F
Soil Temperature 2	64.24 °F	61.85 °F
Soil Temperature 3	65.44 °F	63.46 °F
Soil Temperature 4	65.44 °F	63.82 °F
Soil Conductivity 1	24.76 µS/cm	23.54 µS/cm
Soil Conductivity 2	26.85 µS/cm	25.88 µS/cm
Soil Conductivity 3	32 µS/cm	29.88 µS/cm
Soil Conductivity 4	54.72 µS/cm	52.46 µS/cm



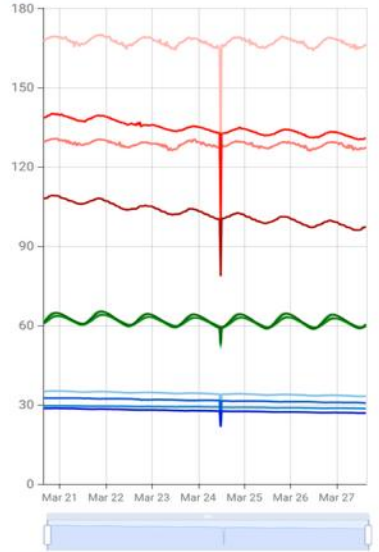
SE0X-LS-2

	Avg	Latest
% Soil Moisture 1	21.45 %	20.61 %
% Soil Moisture 2	22.26 %	21.63 %
% Soil Moisture 3	22.93 %	21.97 %
% Soil Moisture 4	18.66 %	17.82 %
Soil Temperature 1	65.3 °F	66.1 °F
Soil Temperature 2	66.34 °F	66.04 °F
Soil Temperature 3	64.42 °F	65.22 °F
Soil Temperature 4	65.5 °F	66.04 °F
Soil Conductivity 1	29.47 µS/cm	28.13 µS/cm
Soil Conductivity 2	30.87 µS/cm	29 µS/cm
Soil Conductivity 3	31.62 µS/cm	30 µS/cm
Soil Conductivity 4	20.37 µS/cm	19 µS/cm



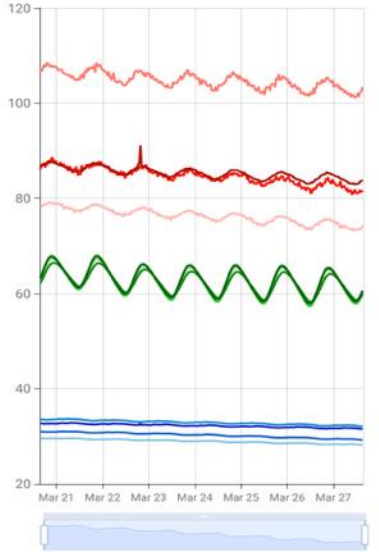
SE0X-LS-3

	Avg	Latest
% Soil Moisture 1	34.1 %	33.15 %
% Soil Moisture 2	29.01 %	28.44 %
% Soil Moisture 3	31.54 %	30.59 %
% Soil Moisture 4	27.62 %	26.75 %
Soil Temperature 1	61.88 °F	60.55 °F
Soil Temperature 2	61.25 °F	59.68 °F
Soil Temperature 3	61.42 °F	59.75 °F
Soil Temperature 4	61.9 °F	60.23 °F
Soil Conductivity 1	167.05 µS/cm	166.39 µS/cm
Soil Conductivity 2	128.34 µS/cm	127.43 µS/cm
Soil Conductivity 3	134.58 µS/cm	130.79 µS/cm
Soil Conductivity 4	102.26 µS/cm	96.96 µS/cm



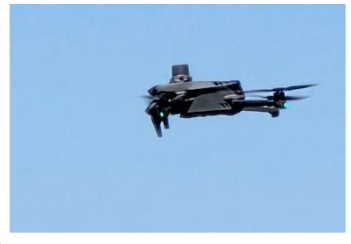
SE0X-LS-4

	Avg	Latest
% Soil Moisture 1	28.93 %	28.13 %
% Soil Moisture 2	32.88 %	32.04 %
% Soil Moisture 3	30.22 %	29.19 %
% Soil Moisture 4	32.2 %	31.53 %
Soil Temperature 1	62.37 °F	60.07 °F
Soil Temperature 2	62.61 °F	60.12 °F
Soil Temperature 3	62.36 °F	59.84 °F
Soil Temperature 4	62.81 °F	60.59 °F
Soil Conductivity 1	76.3 µS/cm	74.24 µS/cm
Soil Conductivity 2	104.75 µS/cm	103.41 µS/cm
Soil Conductivity 3	84.65 µS/cm	81.66 µS/cm
Soil Conductivity 4	85.3 µS/cm	83.9 µS/cm



SCAN ME

ATMOS 41 Weather Station
Latitude: 38.4553240
Longitude: -122.8992430
Precipitation: 0.0 ml/hr
Solar: 754.10 W
Strikes: 0.00 count
StrikesDistance: km
windDirection: 96.50 deg
windSpeed: 1.77 km/hr



1976 2026
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VINEYARDS
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Explore tinyl.co/4SIF

View the Drone Flight

CENIC


SDI-12-LS-US915-3
ATMOS 41 Weather Station
Latitude: 38.4553240
Longitude: -122.8992430
Precipitation: 0.0 ml/hr
Solar: 754.10 W
Strikes: 0.00 count
StrikesDistance: km
windDirection: 96.50 deg
windSpeed: 1.77 km/hr
Ross Station Road
500 ft

2:08 | p-nautilus.io:8080

sensors

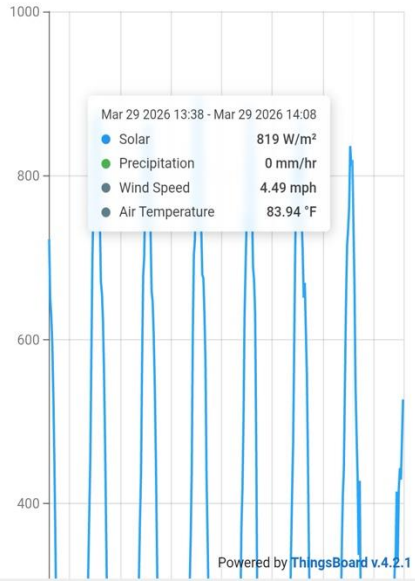
Iron Horse Vineyards - Sensor Map

2:08 | p-nautilus.io:8080

Weather Station

ATMOS 41 Weather Station

	Min	Max	Avg	Lat
Solar	0 W/m²	896 W/m²	238 W/m²	527 W/
Precipitation	0 mm/hr	0 mm/hr	0 mm/hr	0 mm
Wind Speed	0.54 mph	5.82 mph	2.12 mph	2.17 m
Air Temperature	37.96 °F	85.64 °F	59.12 °F	72.44



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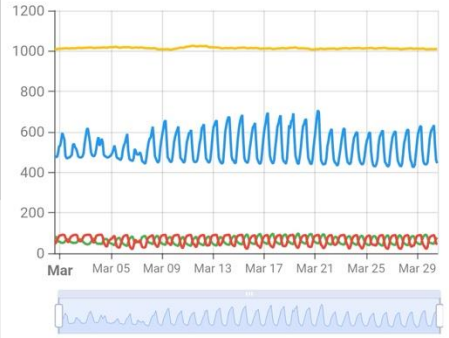
sensors

2:12 | p-nautilus.io:8080

CO2 Sensors

EM500-CO2-915M-1

	Avg	Latest
CO2	523.09 ppm	445.09 ppm
Temperature	61.76 °F	77.43 °F
Humidity	64.33 %	43.09 %
Barimetric Pressure	1014 mb	1009.26 mb



EM500-CO2-915M-2

	Avg	Latest
CO2	479.78 ppm	420.17 ppm
Temperature	62.37 °F	77.42 °F
Humidity	62.58 %	41.79 %
Barimetric Pressure	1013.19 mb	1008.43 mb

Powered by ThingsBoard v.4.2.1

Research-grade Weather, Water Pipe Pressure, Quake Sensors

ATMOS 41 Gen 2 Weather Station

- Measures temp; humidity; vapor/barometric pressure; wind speed, gust, direction; solar radiation, precipitation, lightning strikes
- Designed for harsh climates

EM500-PP-915M Water Pipe Pressure Sensor

- Temperature Compensation for High Accuracy
- IP67 waterproof
- High-capacity battery 10 yrs

Omron D7S Earthquake Sensor (not yet)

- Quake detection, peak levels of seismic intensity
- Sends data over LoRaWAN or LoRa P2P to a gateway
- Option to shut down sensitive machines and equipment

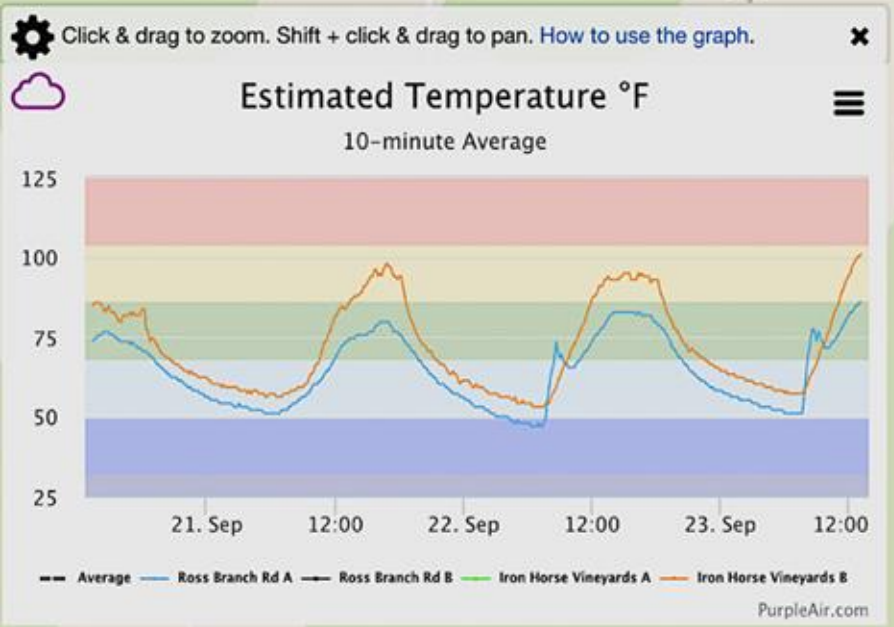
Milesite CO2, Temperature, Humidity, & Barometric Pressure Sensor

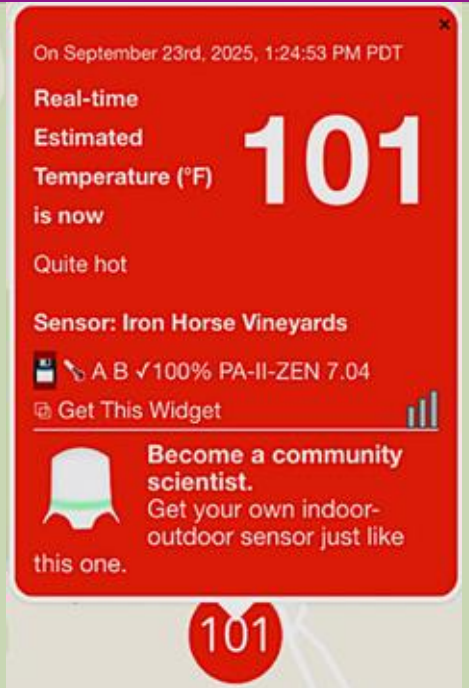
- Measures CO2 Ranges from 400 to 5,000 ppm
- LoRaWAN® Wireless Deployment with Low Power Consumption
- Long-Lasting Battery Life of up to 10 Years
- 8 Vineyard Locations

Purple Air Sensor

PurpleAir

Map Sensors Data About





Office Wall Site (O)

View of Vines & Beyond

Tom: Iron Horse Vineyard Testbed Cameras

DJI Mavic 3 Multispectral Drone: Data and Displays

Vegetation Indices, Particularly NDVI:

Vegetation indices (VIs) are mathematical formulas applied to remote sensing data to provide insights into vegetation health, density, and water content, with the most common being the Normalized Difference Vegetation Index (NDVI).

They work by comparing the reflectance of different light bands, particularly near-infrared (NIR) and red, as healthy vegetation reflects NIR light and absorbs red light.

Normalized Difference Vegetation Index (NDVI): The most popular VI, NDVI assesses vegetation health by calculating the difference between NIR and red reflectance. Use: Monitors plant vigor, biomass, and growth over a season.

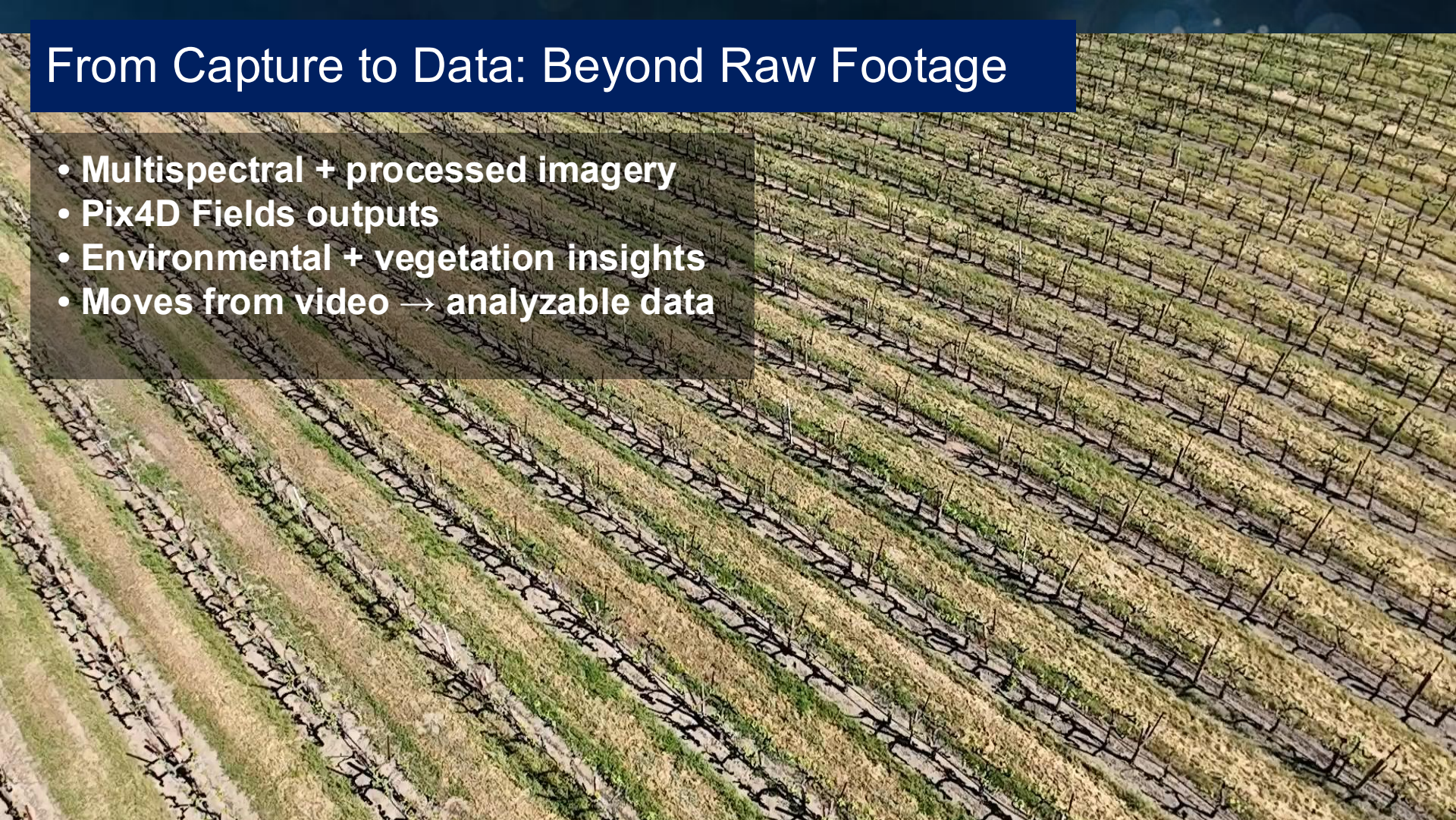
Light Reflection: Different surface types reflect and absorb light differently across the electromagnetic spectrum.

Spectral Bands: Data from specific spectral bands, like red and near-infrared (NIR) highlight characteristics of vegetation.

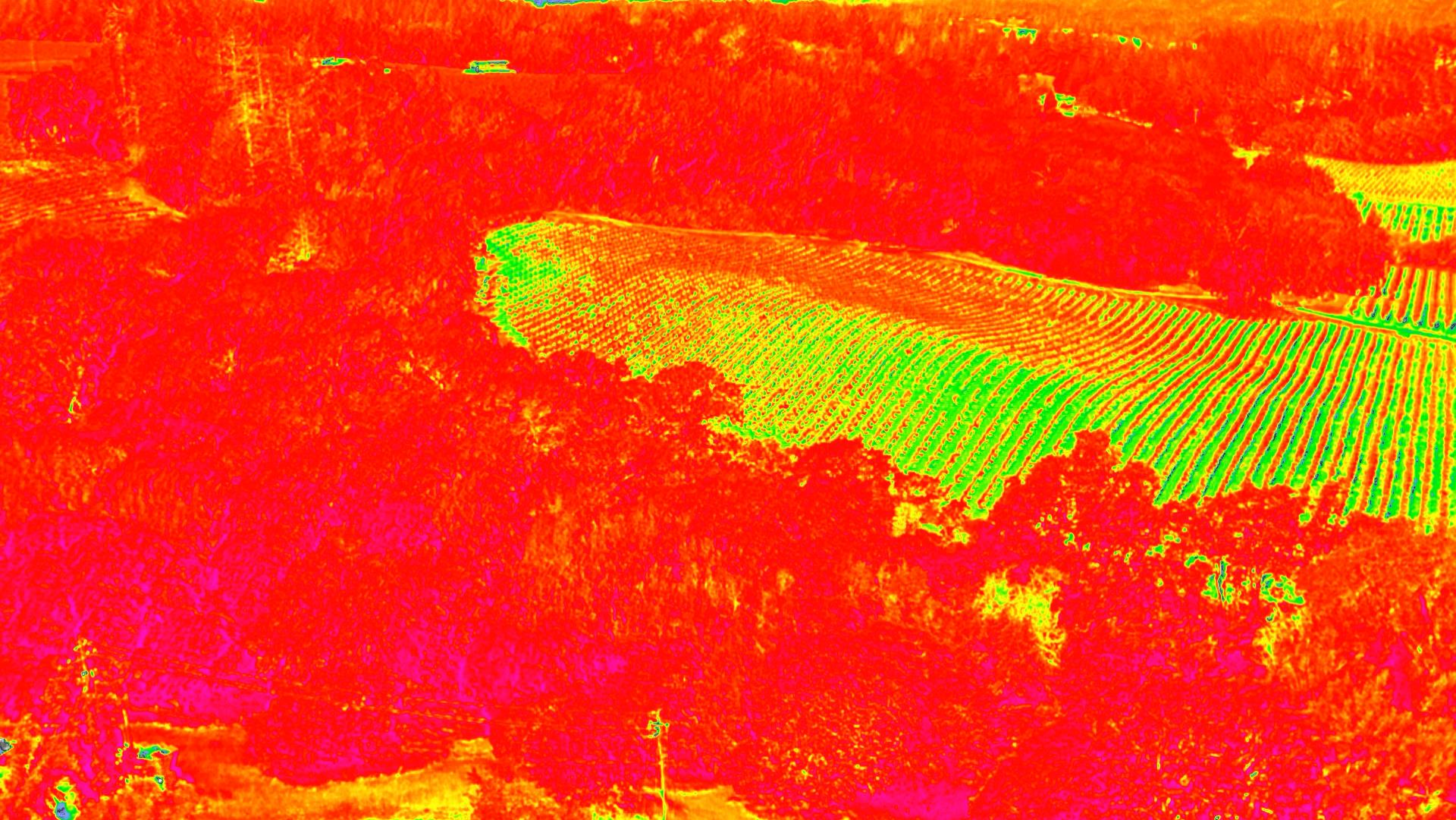
Formula Application: A formula combines the reflectance values from these bands to produce a single index value that indicates a vegetation property.

Interpretation: Higher VI values generally correspond to healthier, more vigorous vegetation, while lower values can indicate stress, drought, or sparse cover.

From Capture to Data: Beyond Raw Footage



- Multispectral + processed imagery
- Pix4D Fields outputs
- Environmental + vegetation insights
- Moves from video → analyzable data



Vegetation Indices Processed from Drones

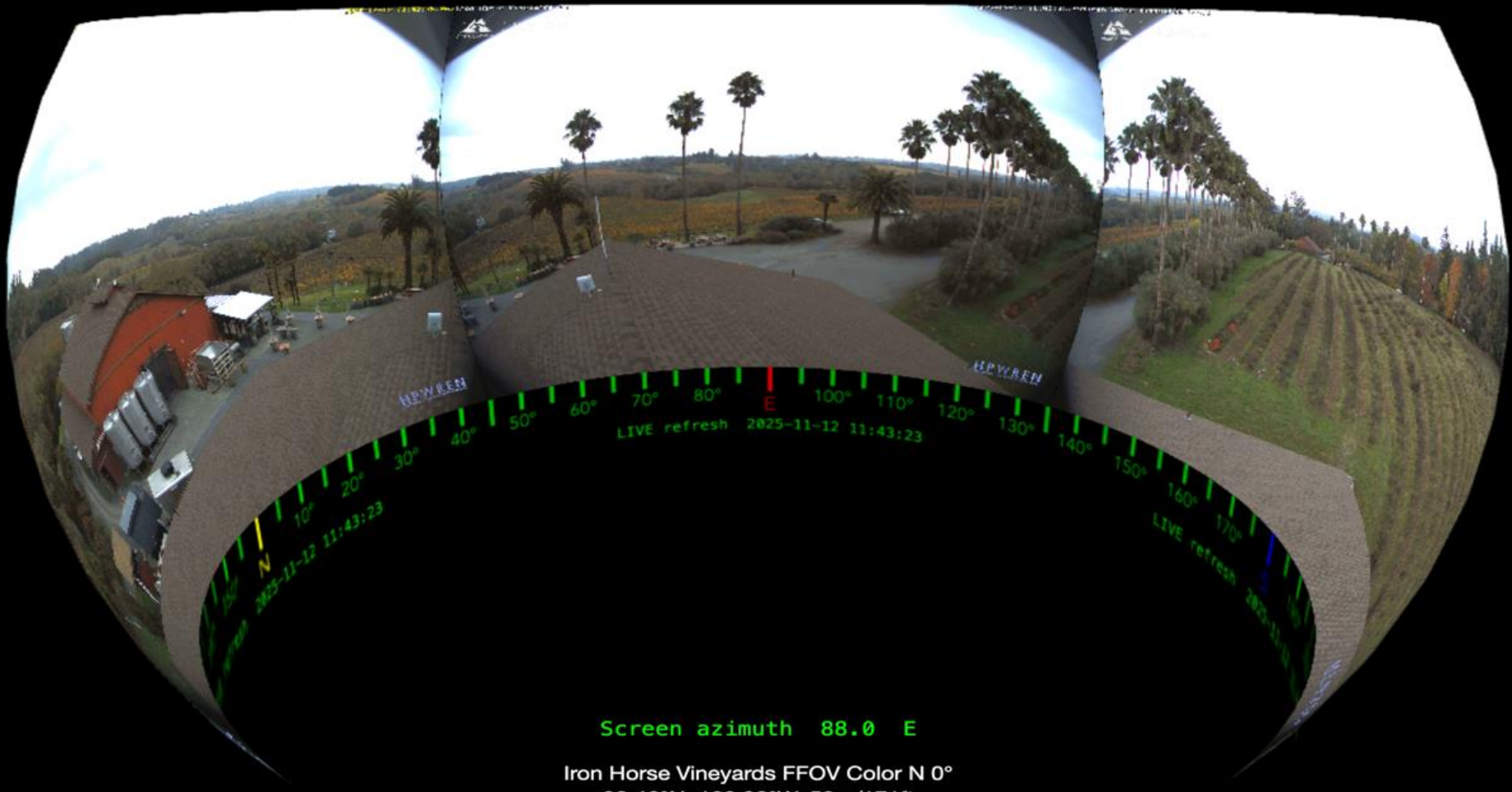
VEGETATION INDEX	CHARACTERISTICS AND USES
Green Normalized Difference Vegetation Index (GNDVI)	Uses visible green light (instead of visible red and near infrared) to measure rates of photosynthesis and monitor plant stress.
Leaf Chlorophyll Index (LCI)	Assesses chlorophyll content in areas of complete leaf coverage.
Modified Chlorophyll Absorption in Reflective Index (MCARI)	Used to measure chlorophyll concentrations and variations in the Leaf Area Index.
Normalized Difference Red Edge (NDRE)	Sensitive to chlorophyll content in leaves against soil background effects (Can only be formulated when the red edge band is available).
Normalized Difference Vegetation Index (NDVI)	Used to measure biomass in precision agriculture (used in forestry to quantify forest supply and leaf area index).
Visible Atmospherically Resistant Index (VARI)	RGB index for leaf coverage. Used to estimate the fraction of vegetation in an image with low sensitivity to atmospheric effects.
Blue Normalized Difference Vegetation Index (BNDVI)	An index without red channel availability that uses the visible blue, for areas sensitive to chlorophyll content.
Triangular Greenness Index (TGI)	RGB index for chlorophyll sensitivity. Relies on reflectance values at visible wavelengths. A good proxy for chlorophyll content in areas of high leaf cover.
Structure Intensive Pigment Index 2 (SIPI2)	Used in areas with high variability in canopy structure (e.g. forestry).

Insta360 Camera 360 Video Took Only 2 Minutes to Transfer 10GB Video File over 10 Gbps Connections to CENIC's CalREN

Insta360 Camera

- **Full 360° video (2x4K)**
- **Excellent resolution and jitter suppression**
- **Captures grape- and canopy-level context**

John: Four PoE HPWREN Fire Cameras Connected to UCSD's WiFIRE Servers Here at QI


Screen azimuth 88.0 E
Iron Horse Vineyards FFOV Color N 0°
38.46°N, 122.90°W, 52m/171ft

Aurora on 11-11-2025 captured by the WiFire/HPWREN Cameras

AXIS Q63 Networked Pan Tilt Zoom Camera Planned to be an Addition to the >1,000 Alert California Feeds

Audio Support	Yes
Camera Mechanical Design	Pan / tilt / zoom
Digital Video Capture Resolution	3840 x 2160
Digital Zoom	12
Max Frame Rate	60 frames per second
Max Panning Speed (degree/sec)	550
Max Tilting Speed (degree/sec)	500
Max Video Resolution	3840 x 2160
Motion Detection	Yes
Panning Range (degree)	360
Shutter Speed (Max)	1/2 second (time unit)
Shutter Speed (Min)	1/111000 second (time unit)
Video Modes	4K UHD (3840 x 2160)

CENICAIR
CENIC ARTIFICIAL INTELLIGENCE RESOURCE

ALERTCalifornia | UC San Diego

G6 PTZ UVC-G6-PTZ-W With AI Webhook—Train to See Bugs?

All-weather, 4K dual-lens camera with 10x hybrid zoom, 1/1.8" 8MP image sensor, Multi-TOPS AI Engine, and ultra-low latency pan-tilt-zoom control for motion tracking.

- IR Night Vision
- 30 m (98 ft)
- Zoom Mode
- 10x Hybrid
- Resolution: 4K
- Field of View:
- Wide: H: 109.9°, V: 56.7°, D: 134.1°
- Tele: H: 26.6°, V: 15.1° , D: 30.4°
- Pan-Tilt Range:
- Pan: 350° Tilt: 100°
- Two-way audio

Want to detect Lantern Flies! None seen yet west of the Rockies.

Deer detection might be appreciated Could yell at the deer day or night

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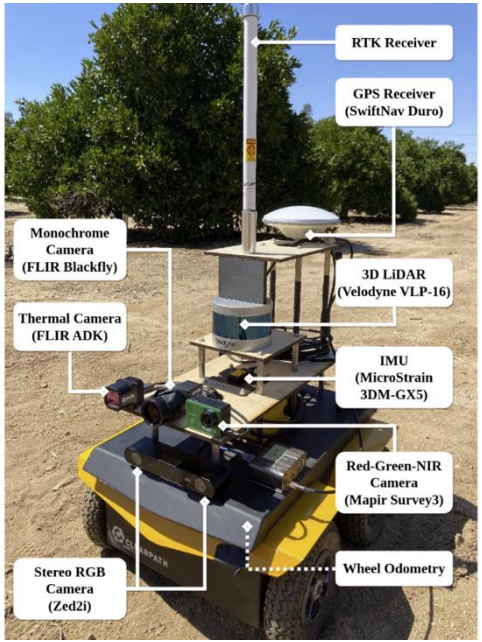
Links to Software and Data-driven Agriculture Websites

PIX4Dfields Classroom educational – 5-year license
https://www.pix4d.com/pricing/pix4dfields/
DJI Terra Flagship + DJI Modify Flagship Subscription
https://store.dji.com/product/dji-terra?vid=106944
UgCS Educational Program
https://www.sphengineering.com/partners/educational-program?country=united-states
Pix4D Agriculture - Precision agriculture masterclass
https://www.youtube.com/watch?v=PXjktKz9n3k&t=4697s&ab_channel=Pix4DAgriculture
DSLRPros Webinar | DJI Mavic 3M Multispectral - Everything You Need to Know
https://www.youtube.com/watch?v=4YGenwy-e-0&ab_channel=DSLRPros
From Sky to Glass | Using Mavic 3 Multispectral To Manage Vineyards
https://www.youtube.com/watch?v=pAuq479TIJw&ab_channel=DJIEnterprise
Drones, Satellites & Other Futuristic Vineyard Technology Presentation
https://www.youtube.com/watch?v=wlgmUtx7yno&t=1277s&ab_channel=VintalityTechInc.

Tom: What's Next?

- Continue all year to gather data from sensors, drones, cameras, microphones
- Widely share data and processing via CENIC AIR/NRP and NDP Jupyter Labs
- Train & test AI models
- We dream of:
  - Installing the Sage Grande Thor Blade with edge inference
  - Using ground penetrating radar on autonomous tractors
  - Ultraviolet drone night runs to detect molds, mildews, insects
  - Bug detection by AI with close-focusing cameras
  - Microbiome analysis of soil and vines with UCSD/SIO
  - Collaboration with other CENIC researchers and testbeds
    - CPP, CSU Fresno, CPH, CSU Fullerton,
    - UCD, UCANR, UCM, UCR----------> UC RIVERSIDE | ARCS Laboratory
    - And national ones too (e.g., OSU ICICLE pipeline, NMSU)



CENIC AIR
CENIC ARTIFICIAL INTELLIGENCE RESOURCE

NRP NATIONAL RESEARCH PLATFORM

Iron Horse Vineyards' Testbed Goals

- Attracting young people into viticulture through real-world experiences
- Providing hands-on training in sensors, drones, data science, viticulture
- Building a pipeline of farm steward talent for sustainability in the future
- Compiling open access databases for precision agriculture researchers
- Distributing methods and software for collecting LoRaWAN sensor data and processing drone/Insta360 data to researchers on campuses with farms
- Providing Alert California and WIFIRE camera real-time imagery
- Ultimately, using a year of all this data and lots of CENIC AIR computing, data scientists will train AI models that are tuned with expert viticulture guidance

Questions, Suggestions
Interest in Participation?

Contact:

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jjgraham@ucsd.edu