

visual
intelligence

Validating Scalable Solar Microcrack Detection with Drone-Based Sub-Millimeter RGB Imaging

In a utility-scale trial, it was demonstrated that sub-millimeter RGB drone imaging can deliver actionable panel-level intelligence by identifying cracked modules at scale.

Summary

Microcracks in photovoltaic (PV) modules are a well-known driver of long-term power loss, thermal hotspots, and asset risk in utility-scale solar farms. While laboratory techniques such as electroluminescence (EL) imaging provide high sensitivity, they are costly, slow, and impractical to deploy across operating sites at scale.

|0.3_{mm}

GSD achieved to consistently identify cracking in RGB imagery

This white paper presents results from a field-based trial conducted at an operating utility-scale solar facility. The study demonstrates that sub-millimeter RGB imagery collected by drones can reliably detect, rank, and spatially map panel-level cracking across thousands of modules under real-world conditions.

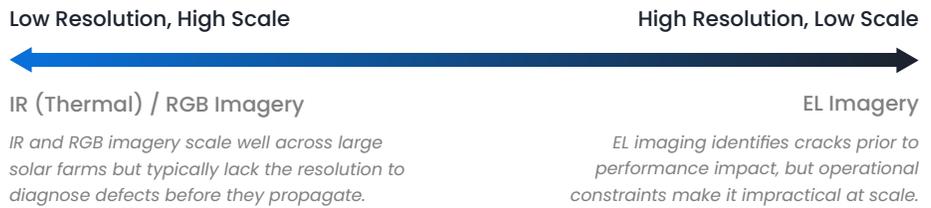
Using high-resolution aerial imagery (~0.3 mm ground sample distance), moderate and severe cracking was consistently identified and classified, even under challenging environmental conditions. Rather than attempting to reconstruct full crack geometry, the approach focuses on relative crack density to support severity ranking and risk triage.

The results confirm that scalable crack detection programs should prioritize repeatability and decision support over exhaustive diagnostics, enabling cost-effective inspection workflows for large solar portfolios.

Microcracks at Scale

As utility-scale solar assets grow in size and complexity, asset owners increasingly rely on data-driven inspections to manage performance risk and control O&M costs. Microcracks—small fractures within crystalline silicon cells—pose a persistent challenge because they are difficult to see during routine inspections yet can materially impact long-term energy production.

Traditional crack detection methods such as Electroluminescence (EL) imaging remain the gold standard for sensitivity, but they require controlled conditions, physical module access, and high per-panel cost. As a result, they are poorly suited for evaluating cracking across tens of thousands of panels at operating sites.



While infrared (IR) and traditional RGB imaging support rapid, low-disruption inspection at scale, they are fundamentally limited for crack detection. Thermal methods reveal damage only after performance degradation has occurred, and traditional RGB imagery lacks the resolution to identify cracking.

Fig. 1
Imaging Approach
Side-by-Side
Comparison

Capability	EL Imaging	IR (Thermal) Imaging	RGB Imaging (Traditional)	RGB Imaging (VI)
Accuracy	High	Low	Medium	High
Direct Crack Visibility	Excellent	None	Poor	Excellent
Scalable to Large Sites	Poor	Excellent	Excellent	Excellent
Geolocation & Panel ID	Limited	Medium	Excellent	Excellent
Cost Per Panel	High	Medium	Low	Medium
RMA Value	High	Low	Low	High

Field Test Hypothesis

The goal of this trial was to evaluate whether our patented drone sensor, combined with proprietary collection and processing software, could reliably and consistently capture RGB imagery at utility scale with sufficient resolution to detect cracking—while maintaining a cost per panel that is economically viable.

Solution / Field Deployment

For this trial, we deployed our dual-sensor payload, purpose-built to capture sub-millimeter accuracy and surface coverage across solar infrastructure. Developed through years of R&D and supported by dozens of international patents and strategic partnerships, the system is engineered to produce high-precision RGB imagery that accurately follows panel surface contours.

Unlike conventional drone technology that forces a tradeoff between resolution and coverage, our solution delivers both. Data acquisition is performed at a safe distance from panels, and follow planned flight geometries to maintain consistent ground sample distance, capture one to two panels per image, and accommodate variations in panel height across terrain.

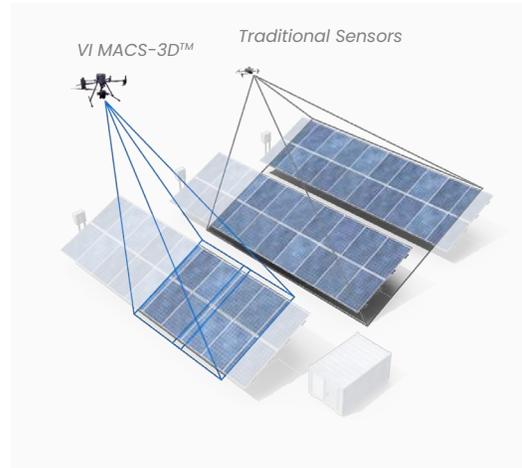
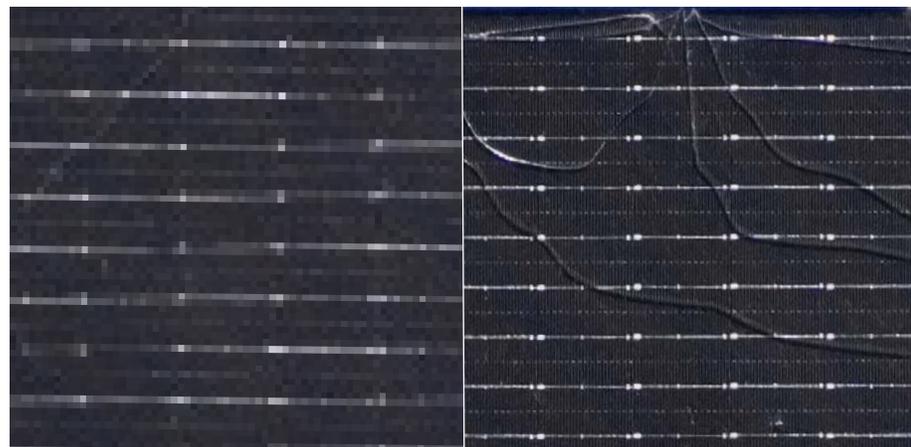


Fig. 2
RGB Imaging Comparison of Traditional Versus Visual Intelligence

RGB Imagery Comparison



Typical Drone Sensor: 1.0 - 3.0cm

VI MACS-3D Sensor: >0.25mm

The trial was conducted at an operating utility-scale solar facility during winter conditions. Data collection was constrained by wind, low sun angles, cloud cover, and intermittent weather interruptions. Despite these challenges, high-resolution imagery was successfully collected across a large contiguous subset of the site, covering approximately ten thousand panels.

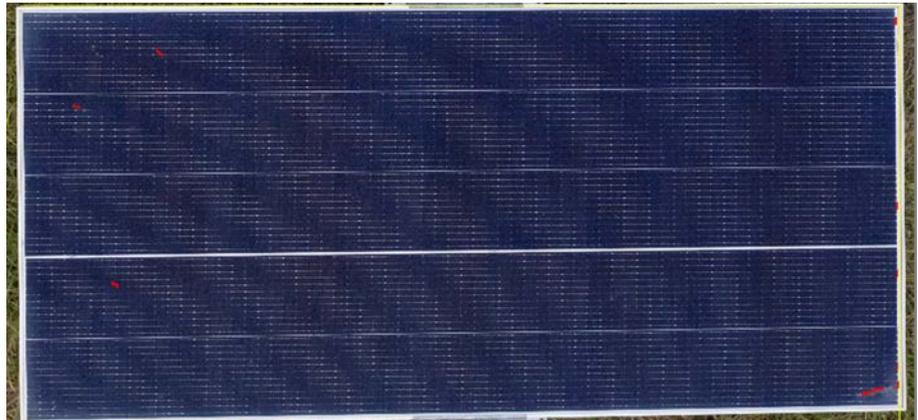
Crack Detection Approach

Each image was processed through an automated workflow that:

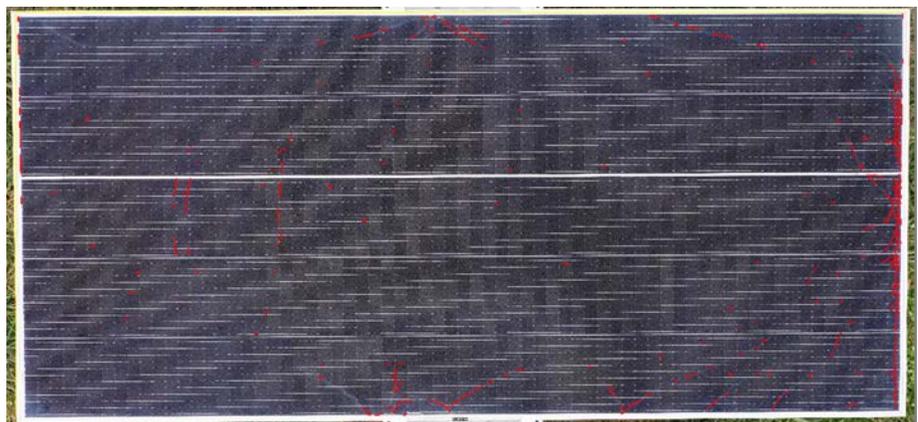
1. Identifies individual panels
2. Isolates the panel frame and cell area
3. Detects spider and radiating crack features within the cells
4. Quantifies detected crack pixels per panel

Rather than attempting to capture every crack segment, the system uses relative crack density as a proxy for severity. Panels are grouped into simple severity categories—none, low, medium, and high—based on calibrated threshold ranges. This approach emphasizes scalability and consistency, enabling reliable ranking of panels by risk rather than precise measurement of crack geometry.

Fig. 3
Crack Severity Examples



Low Crack Severity: <10,000 Crack Pixels



High Crack Severity: <50,000 Crack Pixels

Findings

Analysis of the processed dataset revealed several consistent patterns:

► **Crack Severity is Highly Skewed**

Most panels exhibited no detectable cracking or only low-severity cracking. A relatively small subset of panels accounted for the majority of moderate and severe detections.

► **Moderate and Severe Cracks Are Readily Detectable**

Panels classified as medium or high severity were consistently identified across varying lighting and environmental conditions.

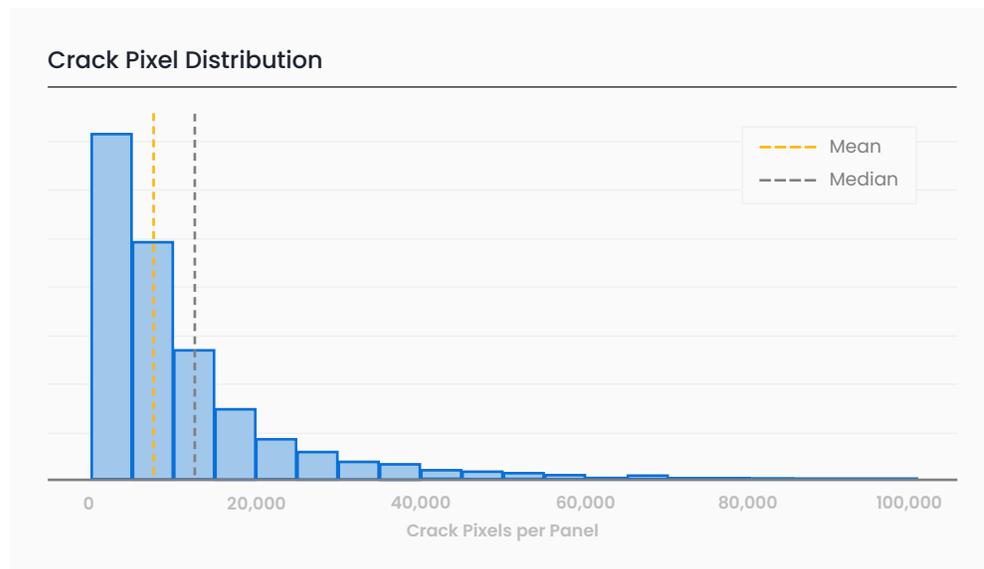
► **Relative Severity is Stable**

Even when image quality was reduced by wind or low sun angles, severity rankings remained consistent.

These results show that operational crack detection does not require full crack reconstruction to deliver actionable insights. Identifying higher-risk panels captures the majority of operational value.

Fig. 4

Crack Pixel
Distribution



The trial highlighted two important characteristics of automated RGB crack detection:

- High confidence in crack presence
- Panels with moderate or severe cracking were reliably flagged.
- Partial crack capture is sufficient
- While automated detection does not capture the full crack network, severity ranking—not total crack length—is the primary driver for O&M decisions.

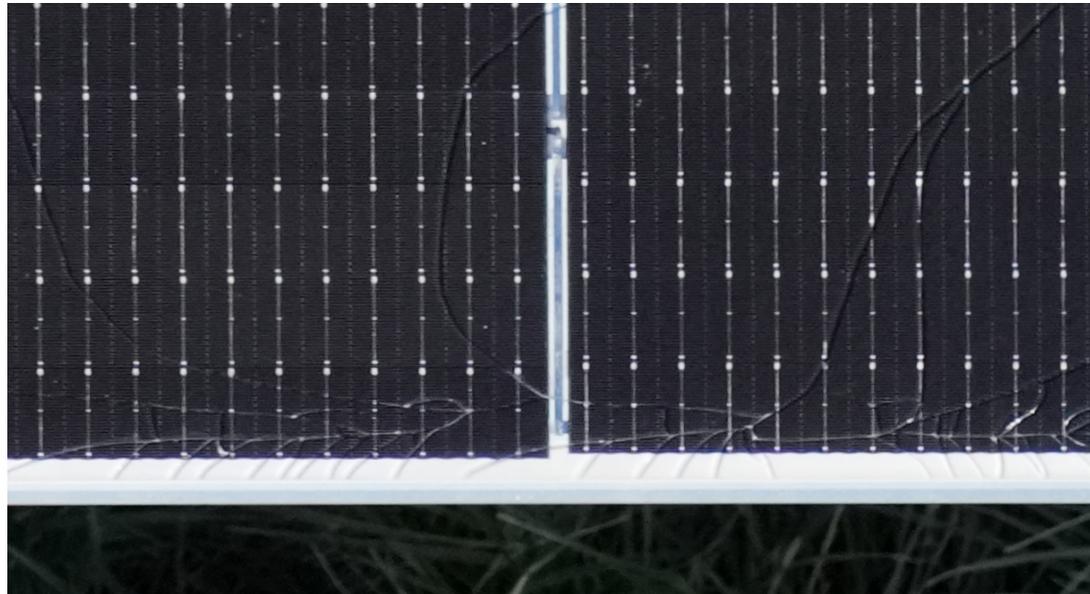
For utility-scale inspection programs, knowing which panels need attention is more valuable than measuring every crack segment.

Scalability and Portfolio Use

The validated workflow is well suited for portfolio-level deployment due to:

- Efficient drone-based data collection
- Automated processing pipelines
- Standardized severity classification
- Compatibility with GIS, CSV, and KML outputs

As module sizes increase and wafer thickness decreases, susceptibility to microcracking is expected to rise, increasing the value of scalable crack detection programs.



Implications for Asset Managers

Sub-millimeter RGB imaging enables a risk-based inspection model that allows asset owners to:

- Identify specific panels with elevated cracking risk and performance issues
- Prioritize targeted follow-up inspections or remediation
- Reduce uncertainty in performance and power-loss forecasting
- Avoid unnecessary intervention on low-risk panels

This approach supports scalable crack monitoring across large portfolios while keeping inspection costs under control.



Conclusion

This trial demonstrates that sub-millimeter RGB drone imagery provides a practical, scalable method for detecting and prioritizing solar panel microcracks at utility scale. While not a replacement for laboratory diagnostics, high-resolution aerial imagery reliably identifies panels with meaningful cracking under real-world operating conditions.

By focusing on repeatability, severity ranking, and spatial context, asset owners can integrate crack detection into routine inspections, reduce operational risk, and better protect long-term asset value.