EL-Modulinspektion im Feld mit KI-gestützter Fehleranalyse

6. Juni 2024

7. Niedersächsisches Forum Solarenergie

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Im Johannistal 31a
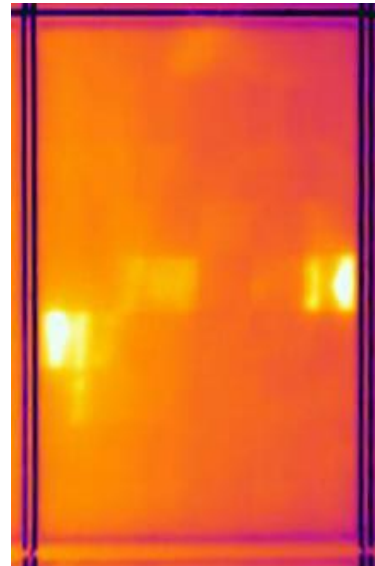52064 Aachen
www.aepvi.com

Methods of Inspection

High-volume image-based measurements

	Visual VI	**Thermography** IR-Mpp	**Inverse Thermography** IR-Inv	**Electroluminescence** EL

Visual
VI

1,000 – 10,000 mod./ day

glass breakage, scratches
soiling, snail trails
discolouring

Thermography
IR-Mpp

25,000 – 60,000 mod./ day

inactive modules
lost or defect substrings
hot-spot patterns

Inverse Thermography
IR-Inv

400 – 2,000 mod./ night

inactive modules and cell parts
lost or defect substrings, PID
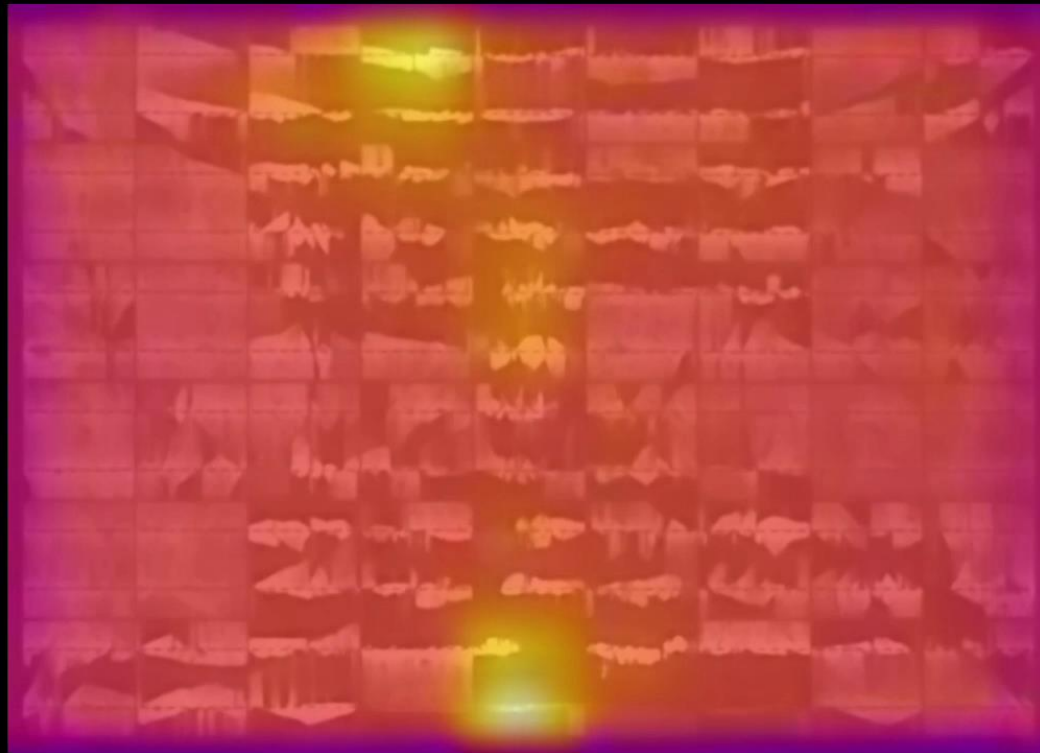high resistance connections
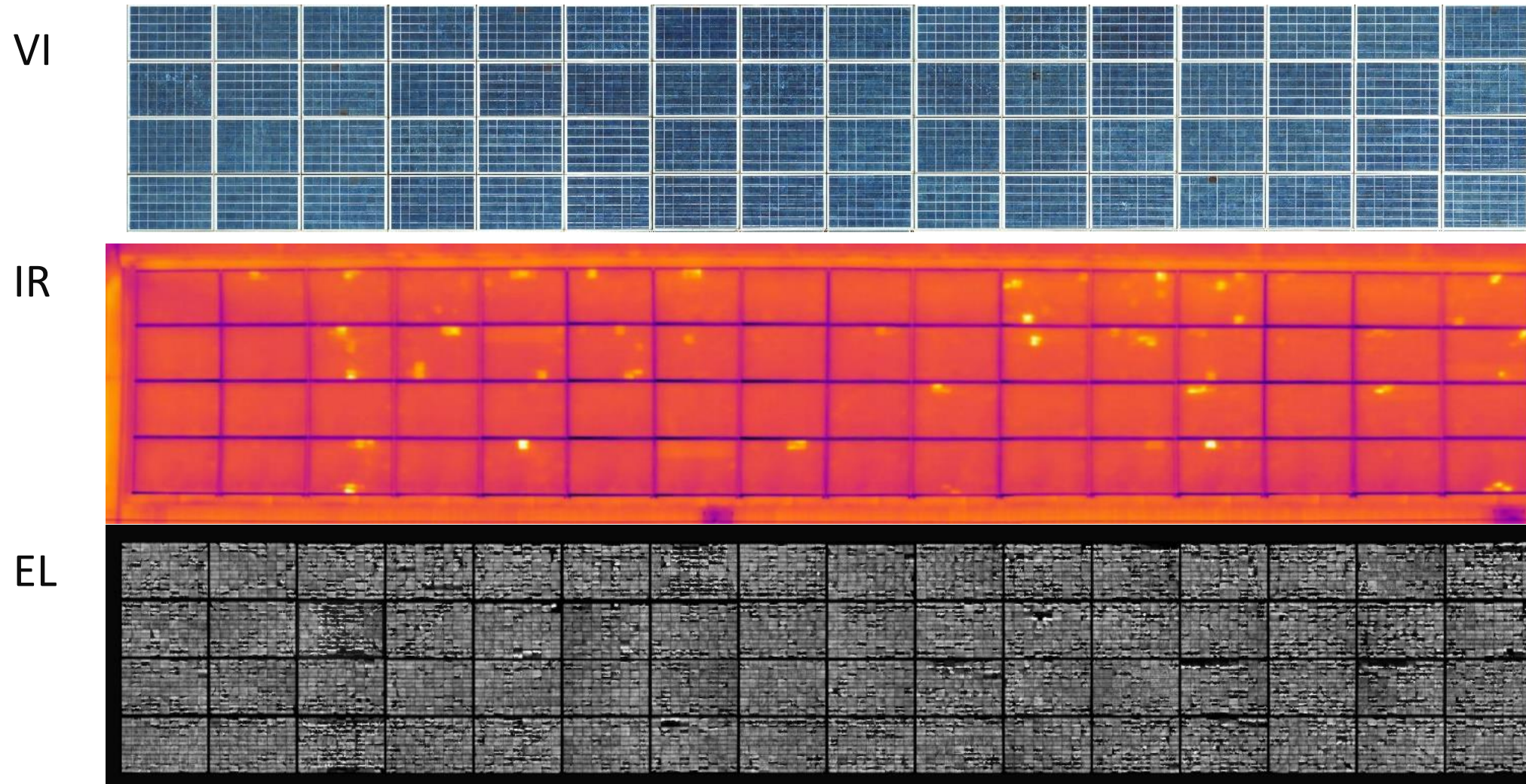
Electroluminescence
EL

800 – 4,000 mod./ night

as IR-Inv, plus: cell cracks
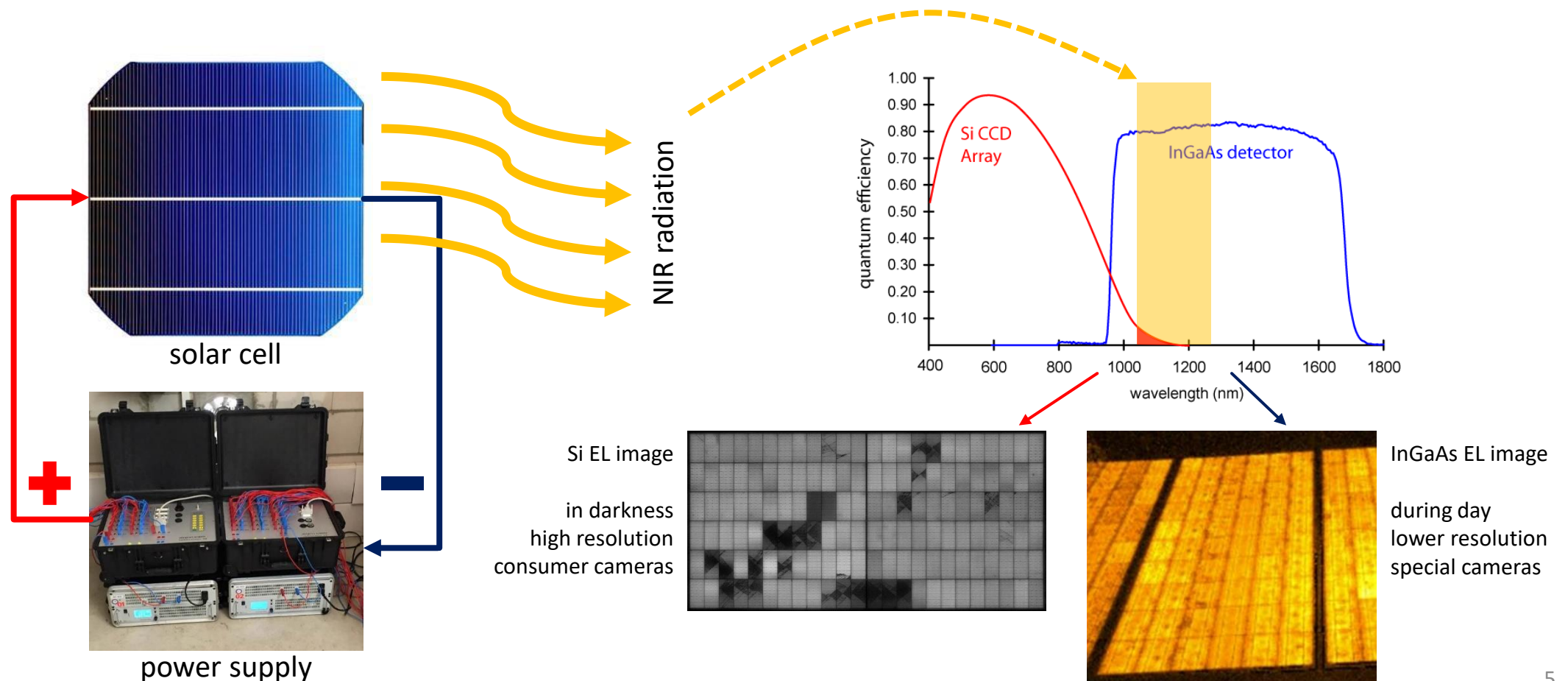busbar and contact problems
early stage PID and LeTID

aerial pv inspection

Thermography and Electroluminescence

Combination of Measurement Methods

Revealing root causes of hot-spots by electroluminescence

VI

IR

EL

Electroluminescence Principle

- Power is supplied to the PV module (reverse operation)
- Electroluminescence: Cells radiate in a narrow band around 1,150 nm (NIR: near infrared)
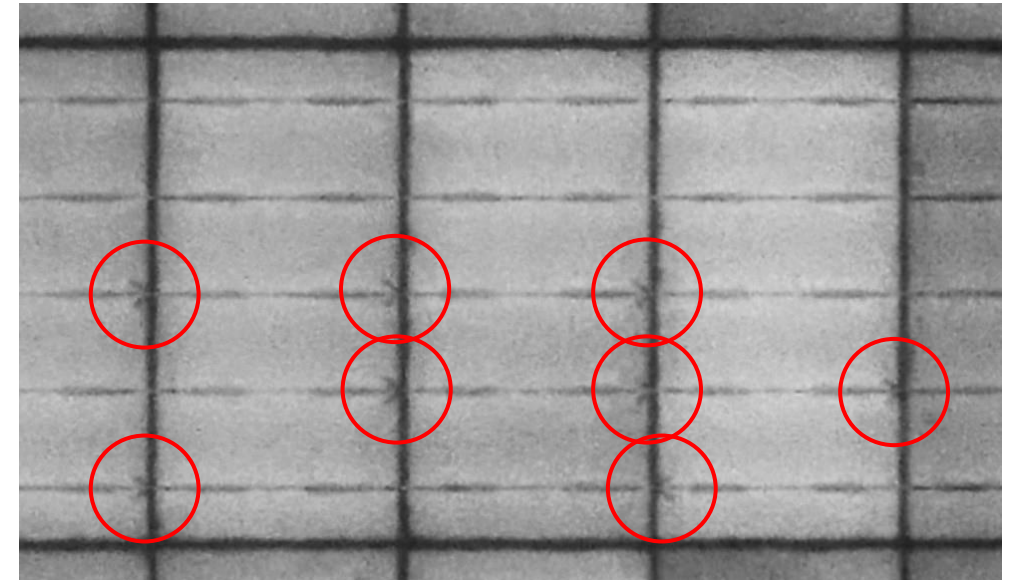- NIR radiation can be recorded by Si-CCD or InGaAs sensors: we use Si-CCD

solar cell

power supply

NIR radiation

Si EL image

in darkness
high resolution
consumer cameras

InGaAs EL image

during day
lower resolution
special cameras

Power for EL and IR-inverse Inspections

- Switches for energizing one module or up to 100+ strings
- 2x 15 kW for multi-string energizing

Inspection Platforms: EL Tripods

- Tripods and Bridges
  for 1 to 8 modules
- Mobile lab: on-site module
  check before installation
- Highest quality EL images

Inspection Platforms: Drones

- For inspections by EL, IR, and VI
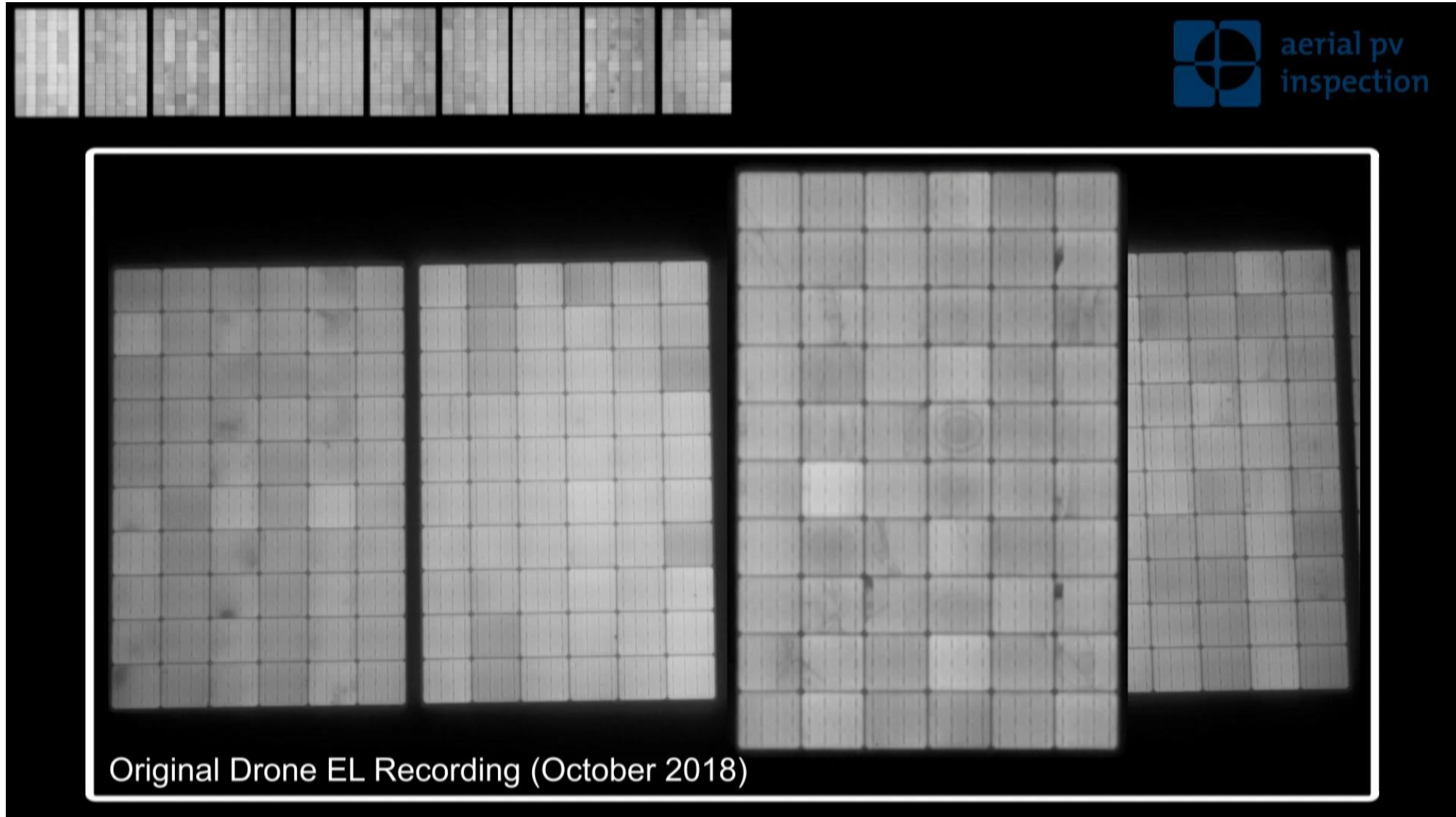- Rooftops, floating
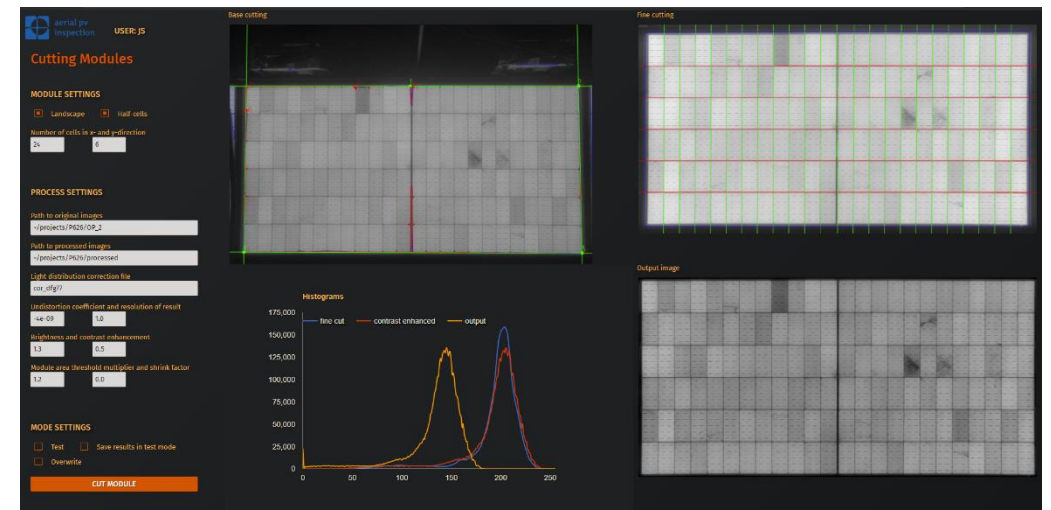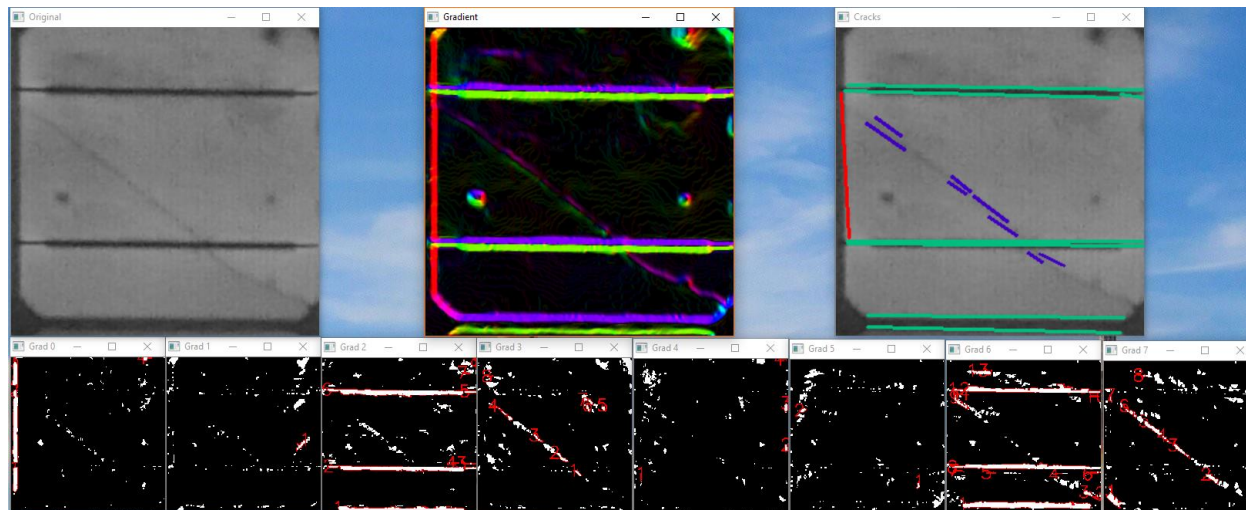- Images and videos
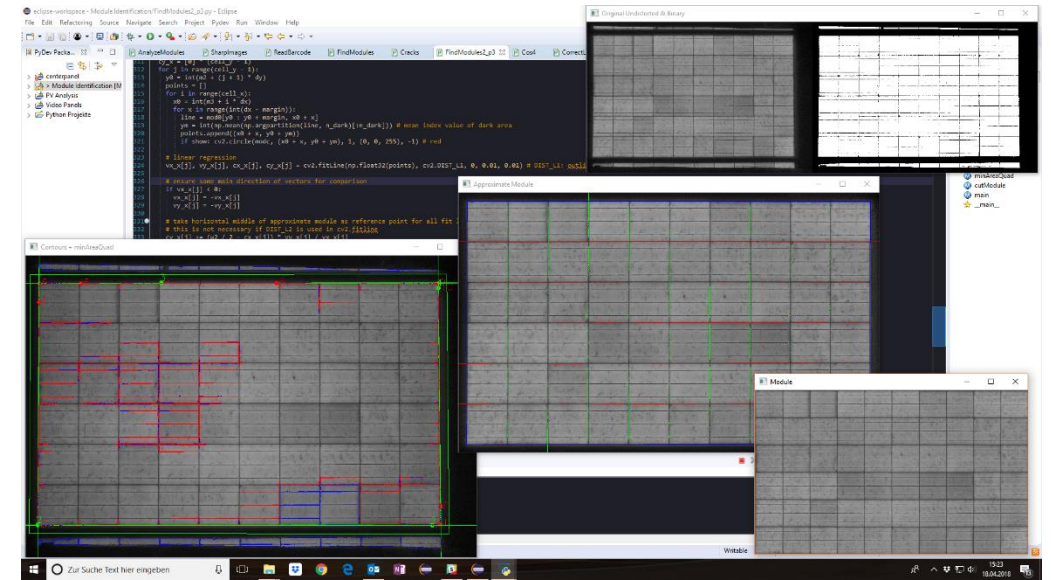
EL drone video

Electroluminescence by Drone

Original Drone EL Recording (October 2018)
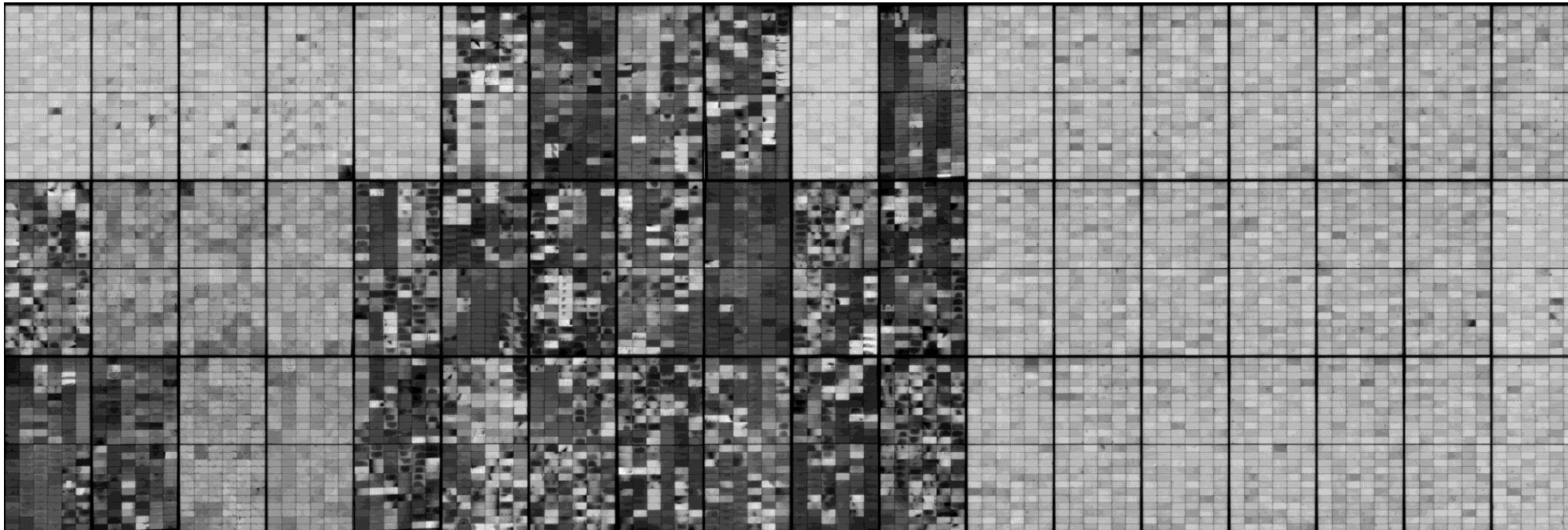
Automated Image Analysis

Module area identification and cutting:
Locate module in EL image, rectify, and cut

Image enhancement:
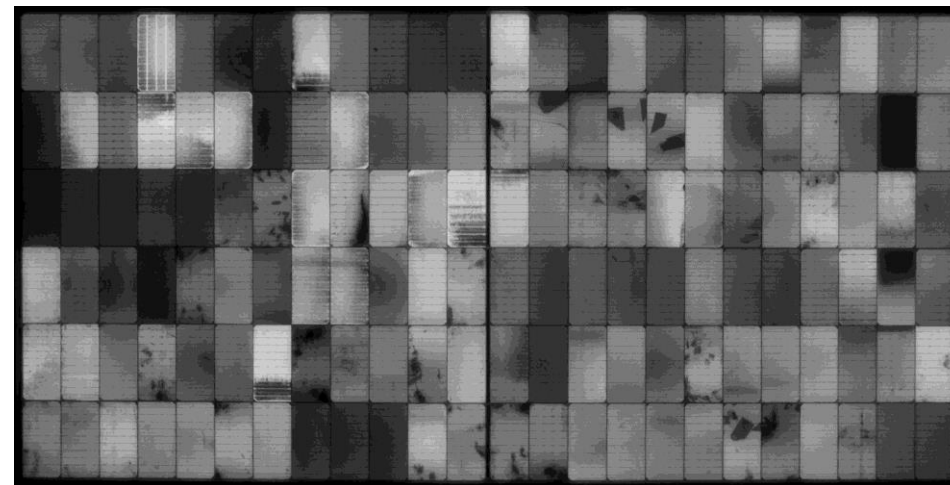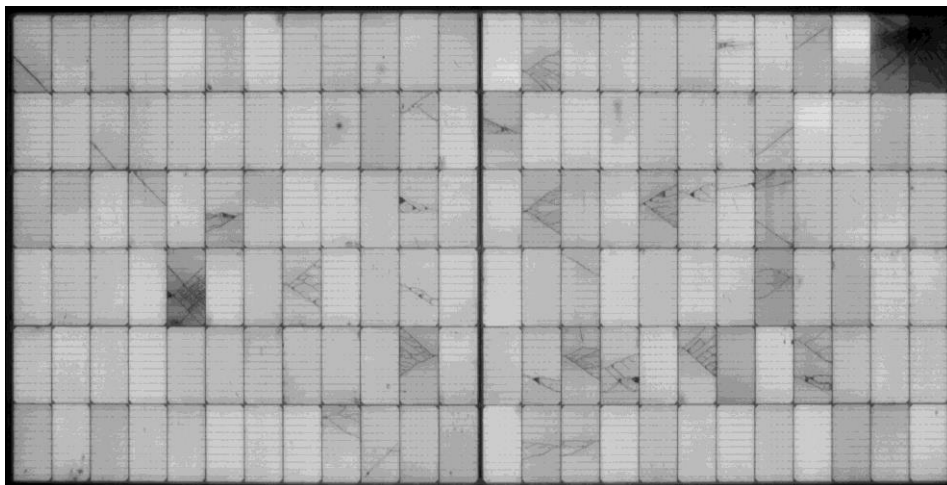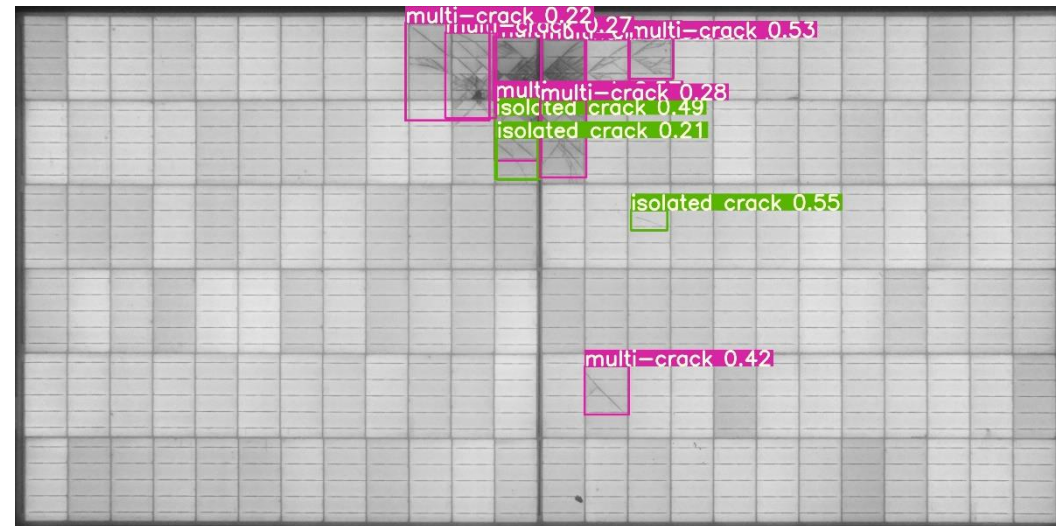Correct light distribution, enhance contrast

Crack detection:
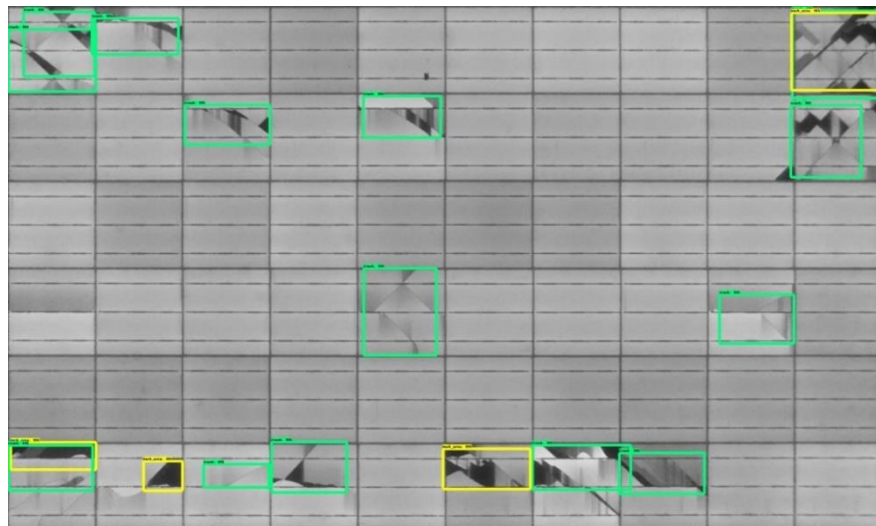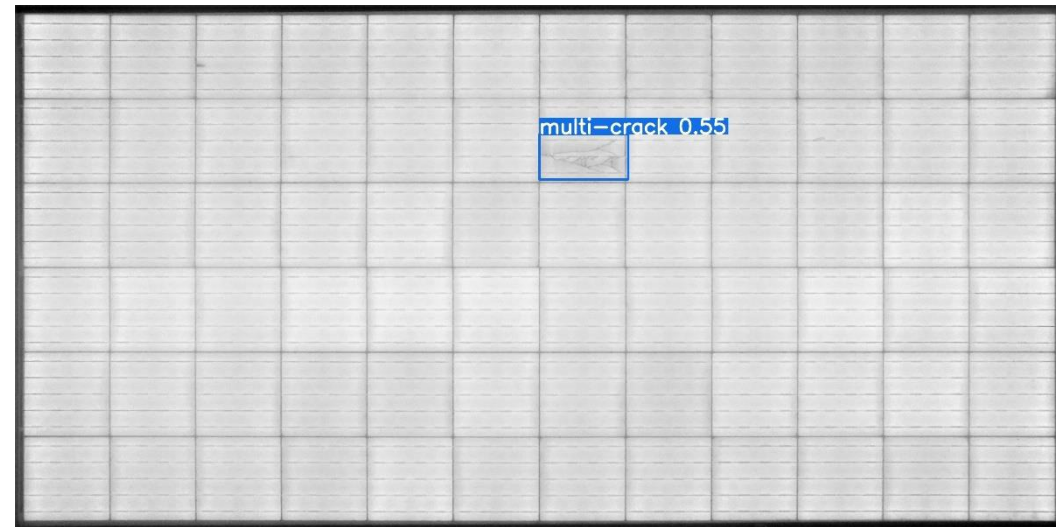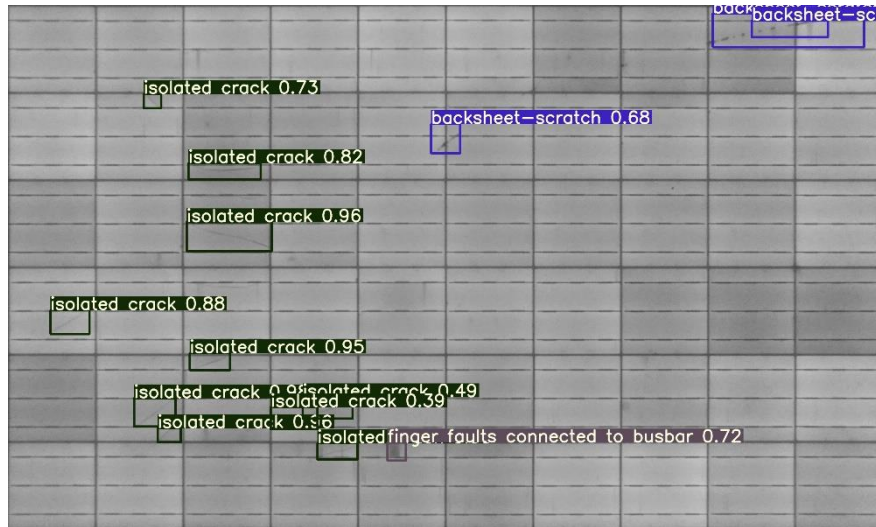Identify cracks by shape (experimental)
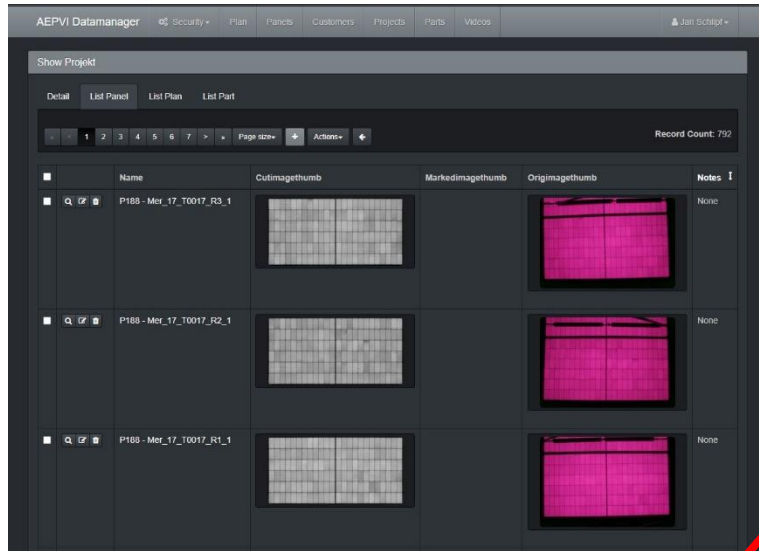
Production and Installation Faults

- Cracks and scratches: typical faults induced by bad module handling during transport or installation

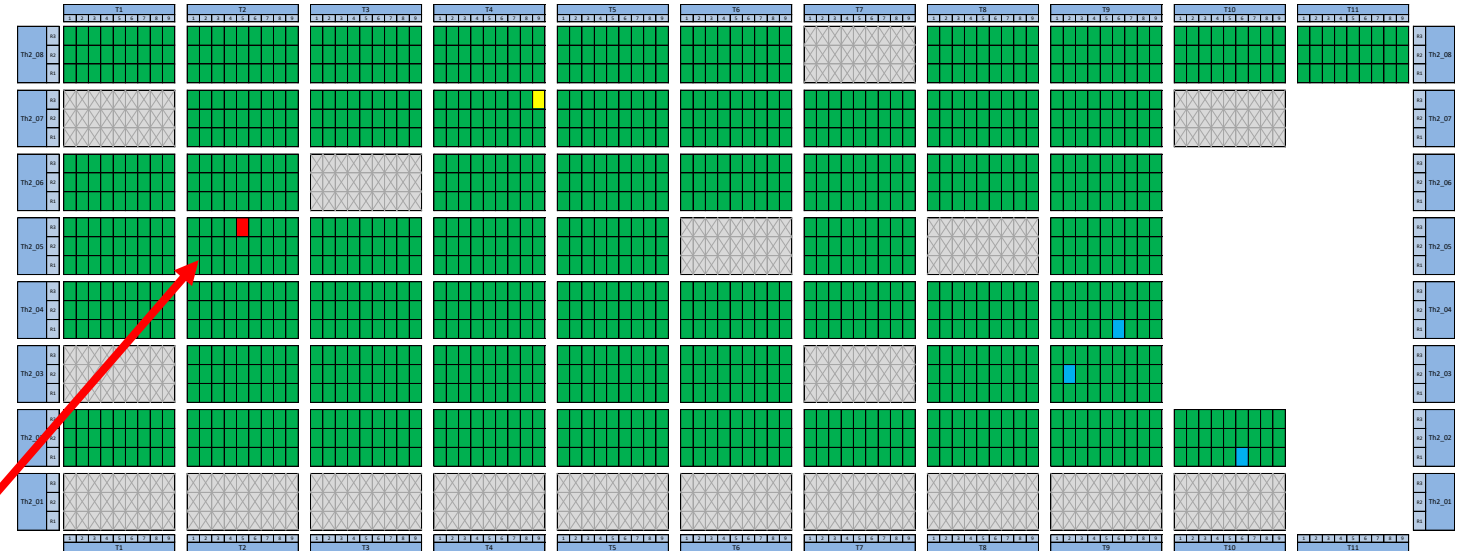- Cell inhomogeneities: typically from module production, not all are faults

Fault Detection by Neural Networks
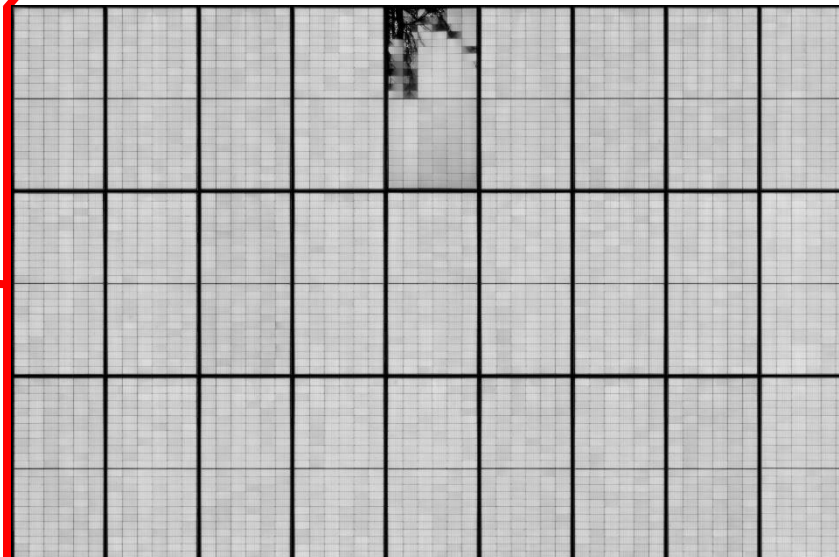
Data Management and Reporting

EL image database

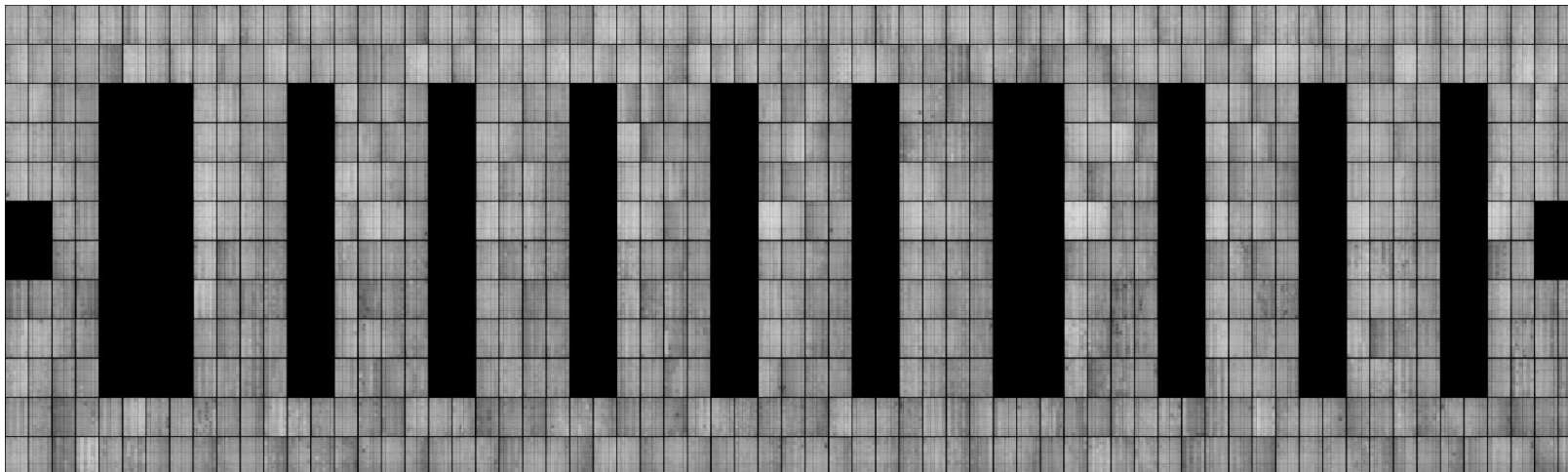Inspection result overview

3D map

EL map of table 05_T02

GPS plant map with EL overlay

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3D Visualisation

Summary

- PV inspections:
  visually (VI), by thermography (IR), by electroluminescence (EL)

- Measurement hardware:
  cameras, power multiplexer, tripods, drones

- Analysis software:
  image processing, AI (neural networks) for fault detection

- Visualization of results:
  images, videos, Excel, 2D, 3D, interactive

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