Electroluminescence Inspections by Autonomous Drones

IEA PVPS Task 13 Meeting: Workshop

23 October 2025

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Electroluminescence Inspections

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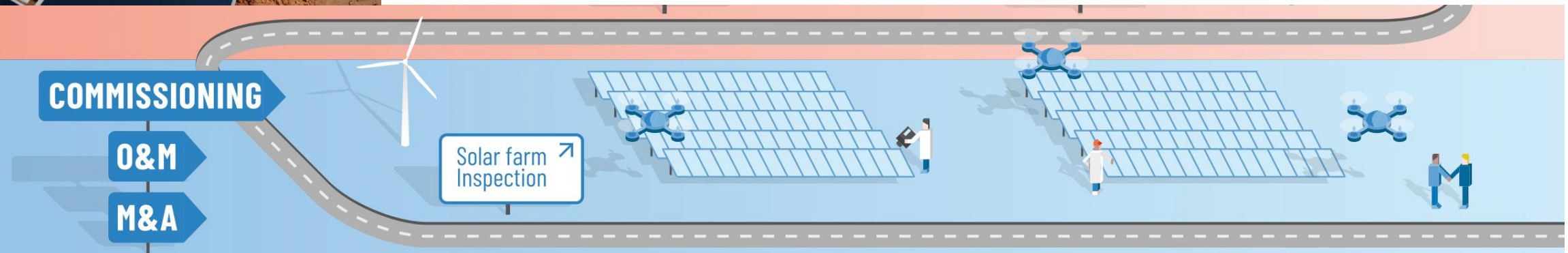
Quality assurance of PV modules by EL:

- Factory audits
- Laboratory analysis
- On-site inspections
  - Incoming goods testing
  - Commissioning: installation quality control
  - Status check after damaging events:
    - Storms
    - Mistreatment of modules
    - Damage caused by maintenance work
  - Technical Due Diligence



Outdoor EL Inspection Platforms: EL Tripods

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- Tripods and bridges for 1 to 8 modules
- Mobile labs: on-site module testing prior to installation
- Highest quality EL images

Outdoor EL Inspection Platforms: Drones

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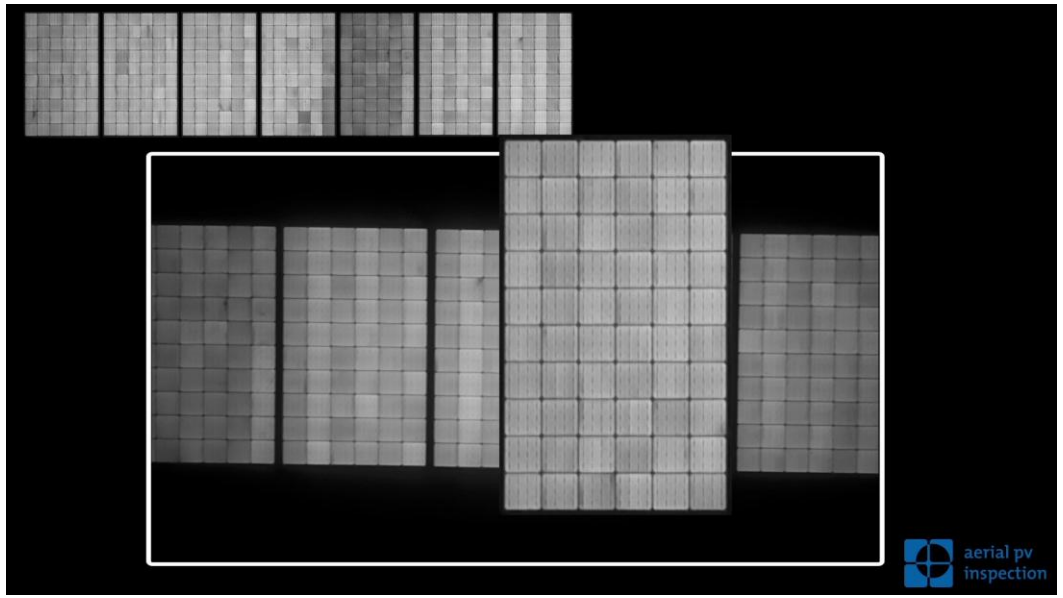
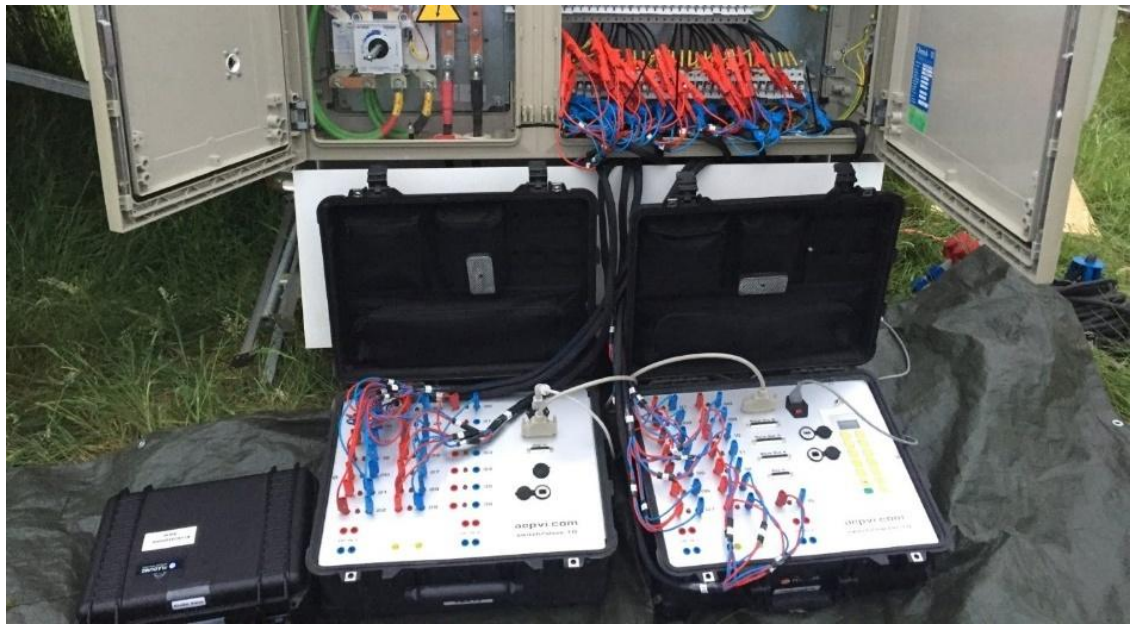
- For inspections by EL, IR, and VI
- Rooftops, floating
- Images and videos



Outdoor EL Inspections: Powering

- Single module power supplies
- Power supplies >20 kW with multiplexers for >100 strings
- In special cases: power to strings by the inverter



Fault Analysis and Visualisation

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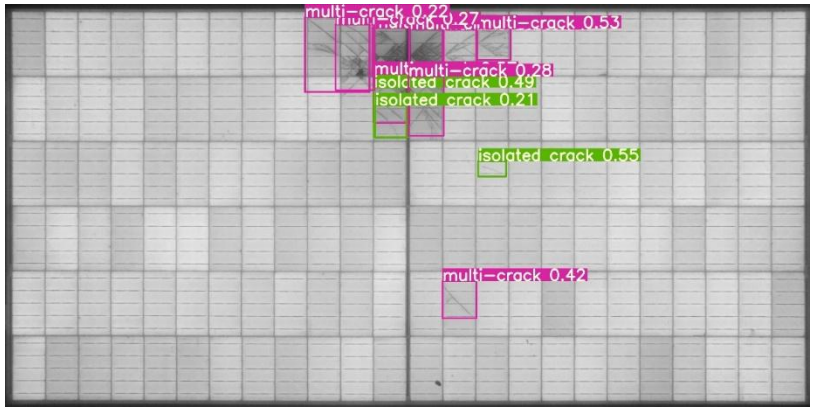
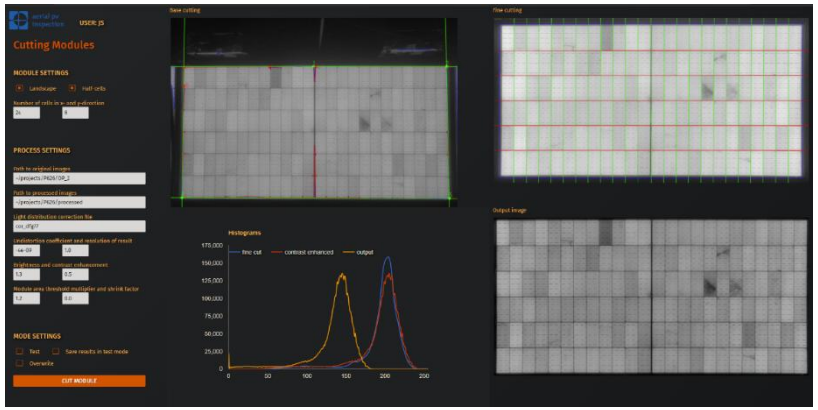
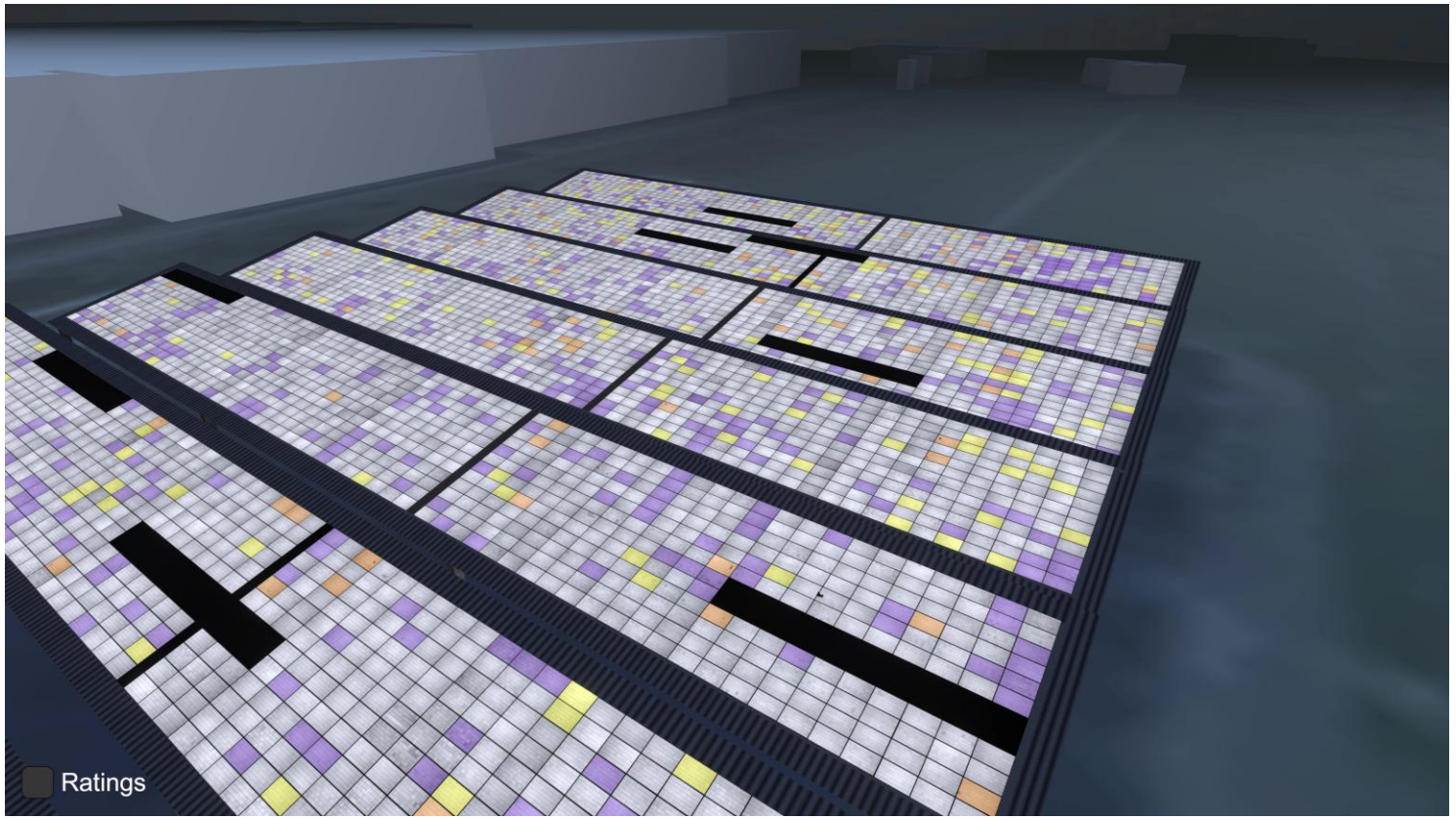
- Automated EL image and video processing
- AI based evaluation and fault classification
- Interactive 3D visualisation







EL Inspections by Drone

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Compared to EL inspections by tripod/ bridge:

Pro:

- Single module recordings or fast scan possible
- Also for roofs, façades and floating systems
- Faster for many PV system layouts
- Less manual labour
- Automation possible

Con:

- Flight permissions needed, no-fly zones
- High-tech: prone to errors, less robust
- Susceptible to wind and rain
- Longer preparation time
- Videos instead of photos: lower quality

EL Image Quality

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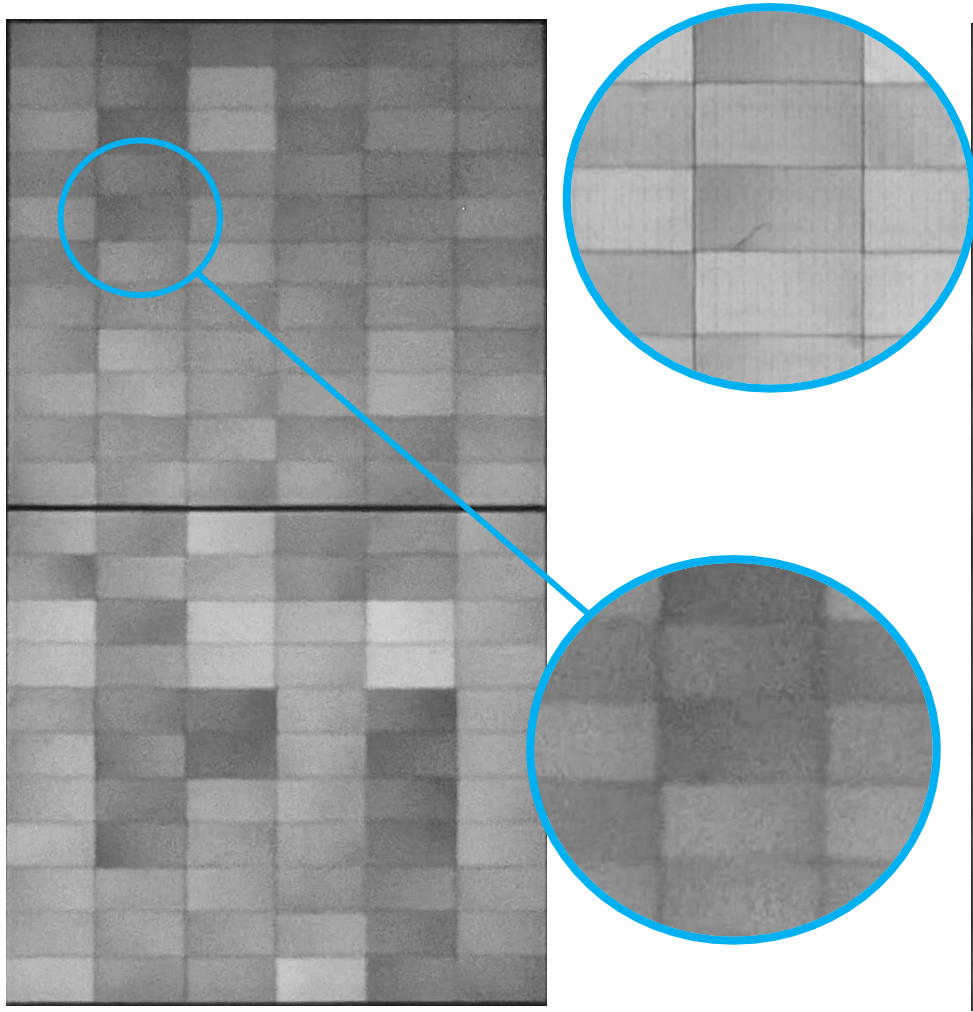
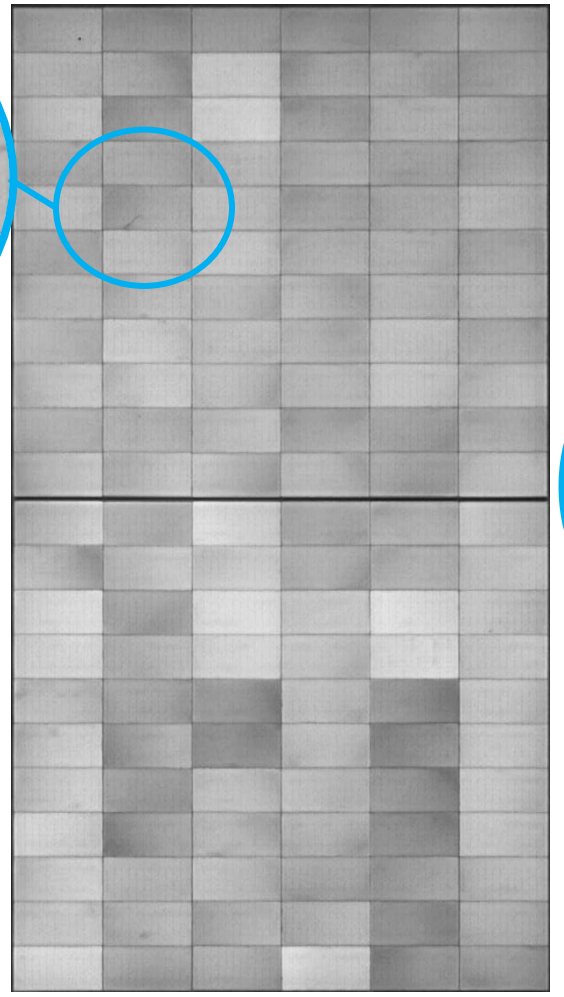
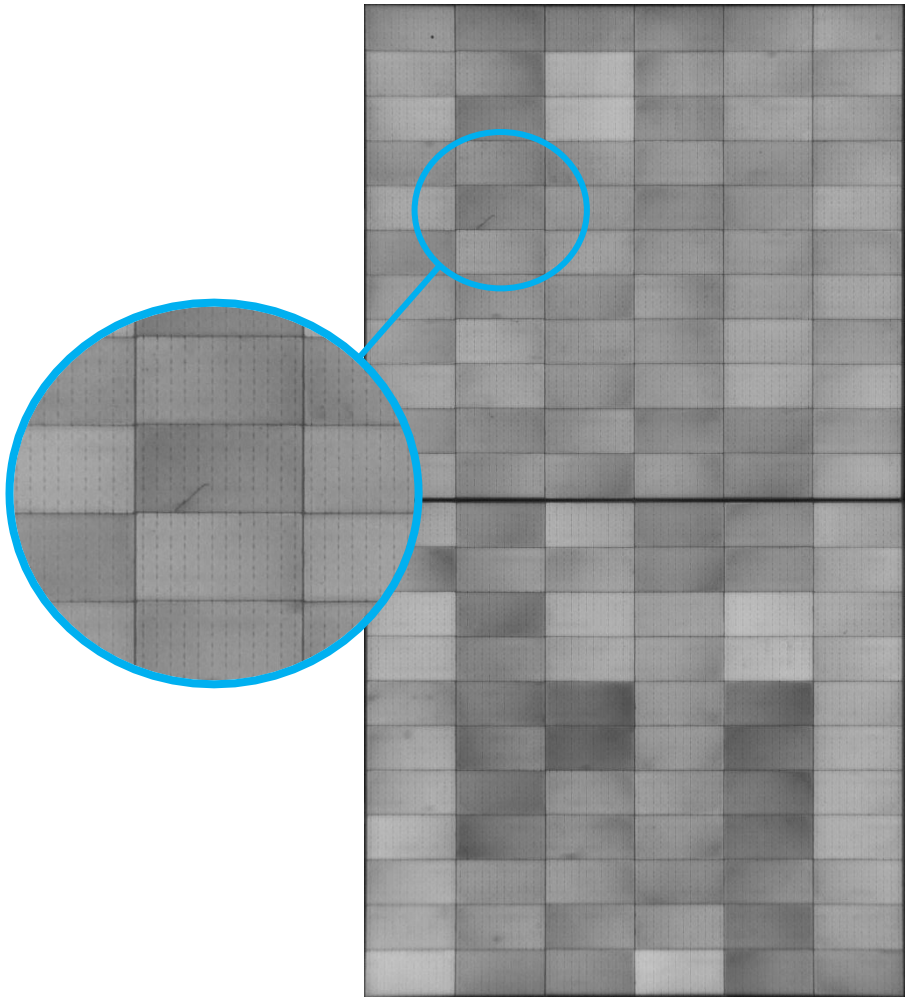


EL – Drone Fast Scan



EL – Drone High Quality



EL – Tripod

Expectations for Autonomous Drones

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Definition:

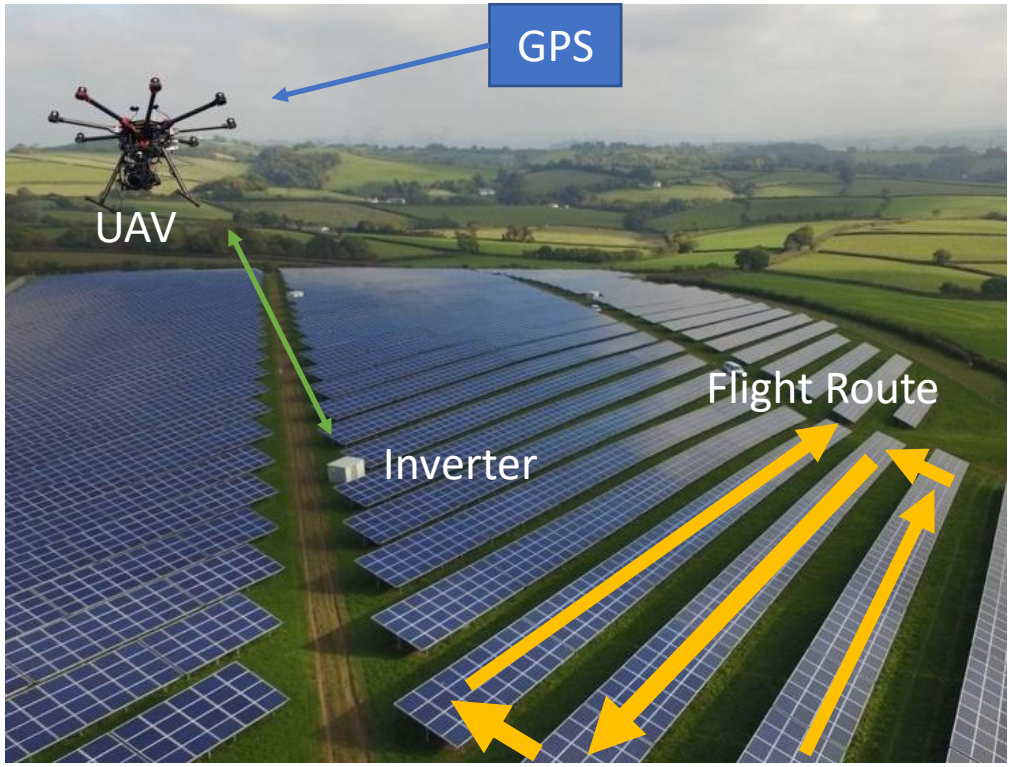
- Automated: Execute scripted instructions
- Autonomous: Adapt, react flexible to environment

Expectations:

- Higher quality, higher throughput, higher frequency
- Lower costs
- 24/7 without people
- Assistance systems as by-products during development

Requirements for maximum effect:

- Certified drones with automatic battery replacement
- Appropriate legal provisions (BLOS, around airports, etc.)
- Inverters with automatic power supply to the modules
- High market demand



Hardware and Software for Autonomous Drones

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Drone (DJI M350 RTK)

Interface board

Gimbal with EL camera

On-board computer

- Basic procedure:
  - Detect module in camera feed
  - Take best picture
  - Move to the next module
  - (Switch power supply to next string)
- Autonomous actions:
  - Compare position and size of detected module to planning, adjust drone position
  - Repeat steps if image quality is insufficient

Development Challenges

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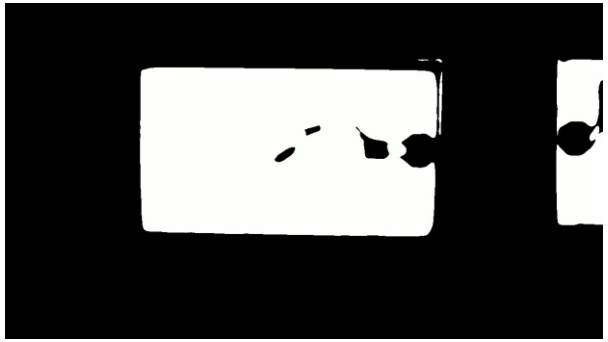
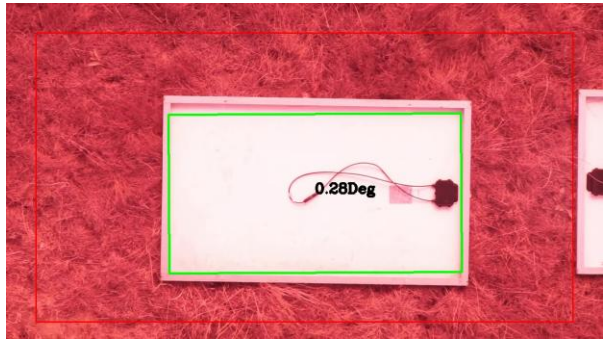
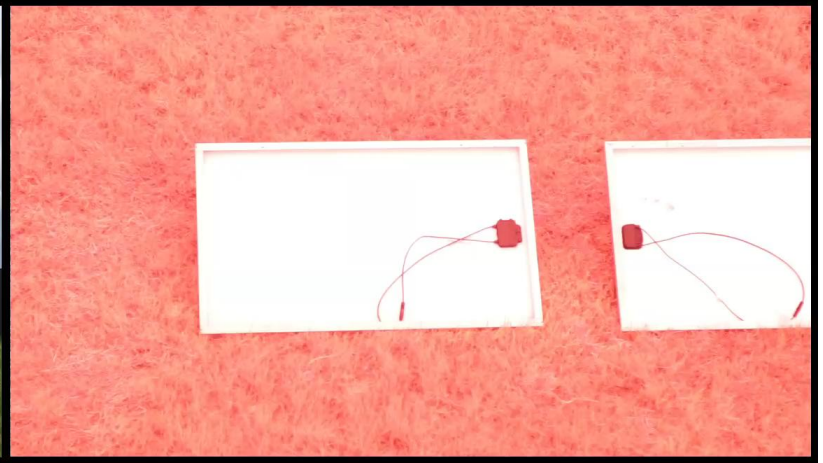




Autonomous Drone Flight (25.05.23)



Autonomous drone flight with inclined panels

First steps with M600:

- Daytime tests with panel backsides to simulate nighttime EL
- Stability issues due to insufficient drone control accuracy

Development Status of Autonomous Drones

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At AePVI:

- Single module recordings
- Nighttime EL with CMOS cameras
- Daytime EL with InGaAs cameras in development
- Next steps: Increase robustness (e.g. handle missing modules), extensive testing

Present and Future of Outdoor EL Inspections

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- Current market demand for EL inspections:
  - At commissioning: sample testing to verify installation quality, typically 500 to 5,000 single module EL images
  - After damage events (mistreatment, storms, etc.): spot check or full inspection (up to 40,000 single module EL images)
  - Sometimes, full inspections of larger systems are requested
- Cost efficiency is crucial:
  - Comprehensive EL inspections are only carried out in the event of serious problems, not yet preventively or for digital twins
- Nighttime EL inspection is preferrable:
  - Best image quality without disruptive light sources
  - No impairment of PV system performance
  - No dependence on irradiation or system voltages
- The future of EL Inspections by autonomous drones:
  - Important technological development for automated maintenance
  - Full potential only with inverters that support power supply

Acknowledgments

- This work was funded in parts by the German Federal Ministry for Economic Affairs and Energy (BMWE)
- We would like to thank ISFH for the many years of successful cooperation.
- We would like to thank Enerparc AG for granting us access to their PV park.

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Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

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