Volateq

A GERMAN AEROSPACE CENTER (DLR) SPIN-OFF

# Conducting autonomous inspections with m3t and volateq’s software solution

INCREASING PROFITABILITY OF SOLAR ASSETS THROUGH ONE-OF-A-KIND ANALYSIS

WWW.VOLATEQ.DE

# Volateq

- DLR (German Aerospace Center) spin-off founded in 2020
- Provider of SaaS (Software as a Service) for inspection of utility scale solar power plants
- Serving >25% of global CSP capacity & successfully entered the PV market
- Focus on innovation, highest level of automation, fast data processing and ease of use

Volateq DLR https://www.dlr.de/sf

# Agenda

- Sun to electricity: CSP and PV technologies
- Analysis of inspection markets
- Failure detection in CSP and PV
- Data acquisition & processing workflow
- Use cases
- Result presentation in Volateq's webapp
- Outlook, R&D
- Q&A session

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# Concentrating solar thermal technology

**Fun fact: fancy images of CSP plants often appear in videos/presentations on sustainability:**

## CSP Characteristics:

- 8 GW global installed capacity
- Different layouts: point and linear concentrators
- Cheap storage option
- Only direct normal irradiance is harvested
- Output options electricity or process heat
- Mainly utility scale projects
- Growing number of hybrid PV-CSP projects

## CSP Prospects:

High growth rates expected:

- Growing need for dispatchability in electricity markets
- Decarbonization of industrial heat

# Photovoltaic technology

Part of a PV solar field. Image source: Volateq drone footage

## PV Characteristics:

- ~1500 GW global installed capacity (as of 2023)
- Instantaneous electricity production according to irradiance
- Diffuse and direct irradiance components are harvested
- About 50% utility scale projects globally

## PV Prospects:

Continuing high growth rates (20% p.a.) expected because of:

- Cheapest renewable energy technology in many regions of the world
- Virtually endless use cases

At Volateq we work with both, PV and CSP plant types

# POSSIBLE PROFIT LOSSES DUE TO INSUFFICIENT CONDITION MONITORING

## Solar plant economics

| | Plant nominal power | 100 | MW |
|---|---|---|---|
| | Full load hours | 2,500 | h |
| | Power generated | 250,000 | MWh |
| | Price/MWh | 100 | €/MWh |
| | Plant revenue | 25,000,000 | € |
| | | | |
| | > 4% efficiency gain | >1,000,000 | € |
| + | O & M cost reduction | >100,000 | € |
| + | Enhanced safety | >100,000 | € |

**550.000 €** loss / year
**100 MW CSP plant**

**220.000 €** loss / year
**100 MW PV plant**

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MARKET POTENTIAL FOR DRONE BASED CONDITION MONITORING

# SIZE & DYNAMICS

## CSP

CONCENTRATED SOLAR POWER

8 GW INSTALLED CAPACITY

**4 M€**

All CSP

**3 M€**

Only Parabolic Trough

## PV

PHOTOVOLTAIC

1.5 TW INSTALLED CAPACITY IN 2023

**>20% YEARLY MARKET GROWTH**

**1.1 B€**

For an installed capacity of 5.6 TW in 2030

**0.7 B€**

Utility-Scale Solar Fields in 2030

## GDI

GLOBAL DRONE-BASED INSPECTION

**30 B€**

Based On Market Research until 2030

# CUSTOMER BENEFITS OF AERIAL INSPECTION SOFTWARE (as a SERVICE)

## GAIN CLARITY

Get a clear and concise image of the status of the site and changes over time in terms of optical performance, damages and soiling.

## SAVE RESOURCES

Achieve quicker measurements, less labor force and less costs with an easy-to-use automated software solution.

## WIN AUTONOMY

Acquire data of your site whenever you want, without being dependent on external experts and service providers.

## IMPROVE PERFORMANCE

Get actionable results to prioritize your maintenance schedule.

## INCREASE PROFITABILITY

Better field conditions and savings in resources lead to higher profits, longer lifetime and increased safety.

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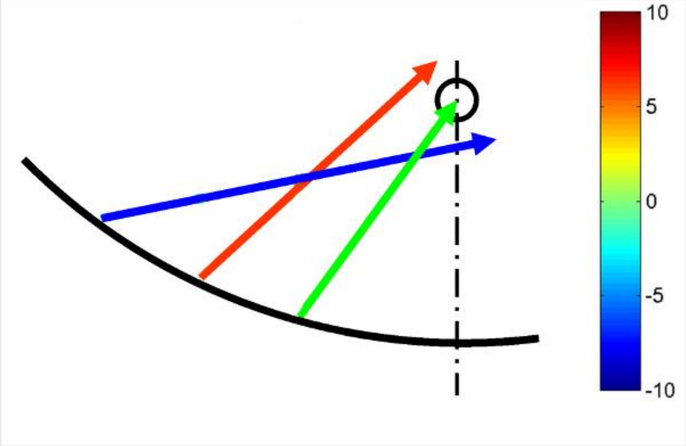
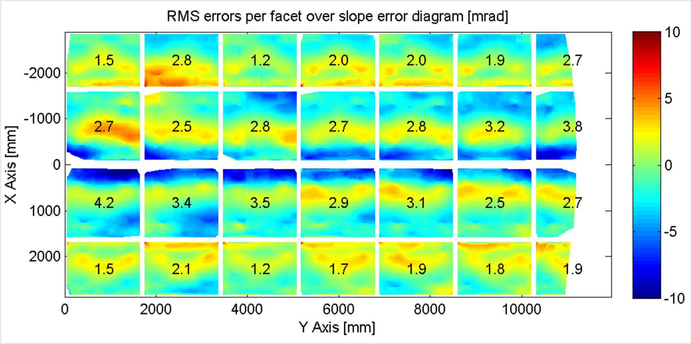
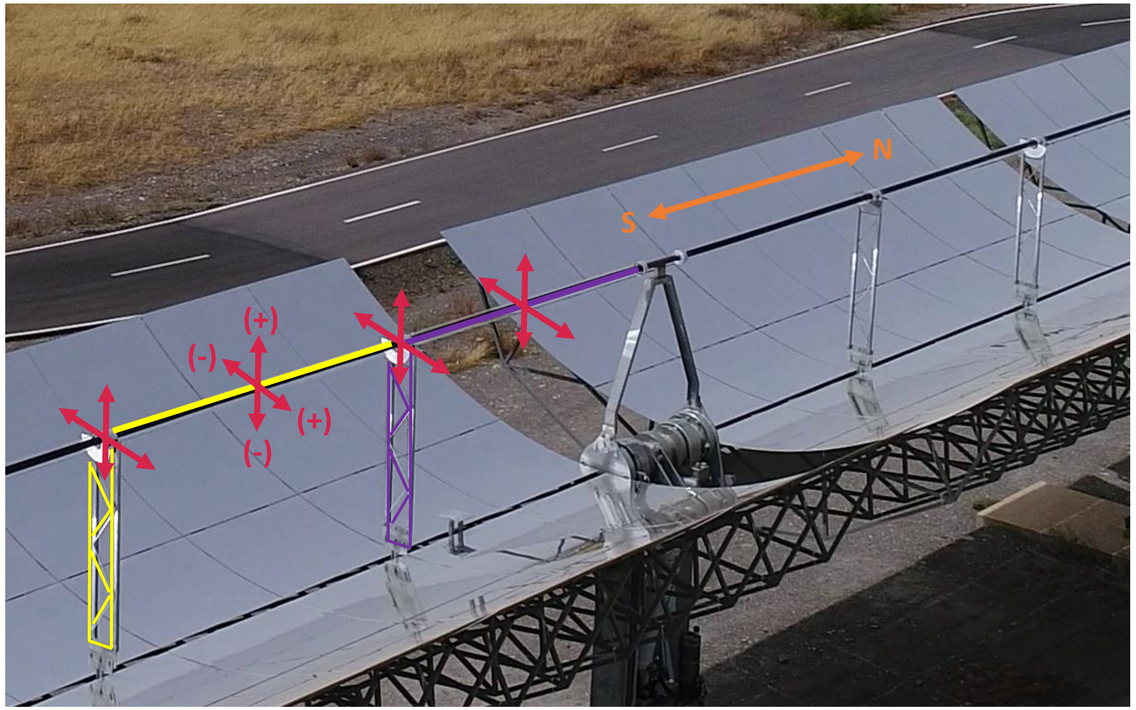
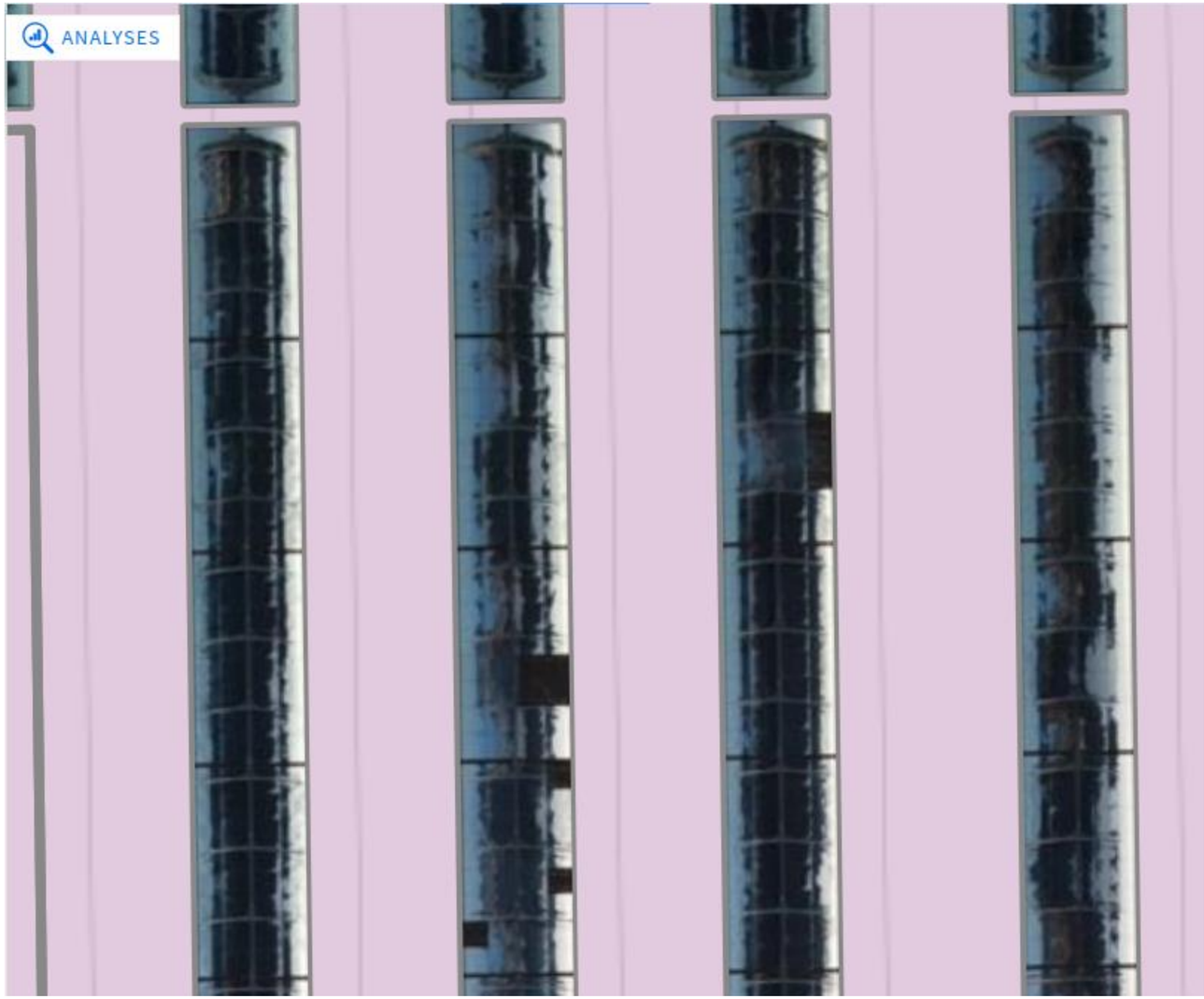
# OPTICAL PERFORMANCE




# ABSOERBER TUBE ALIGNMENT

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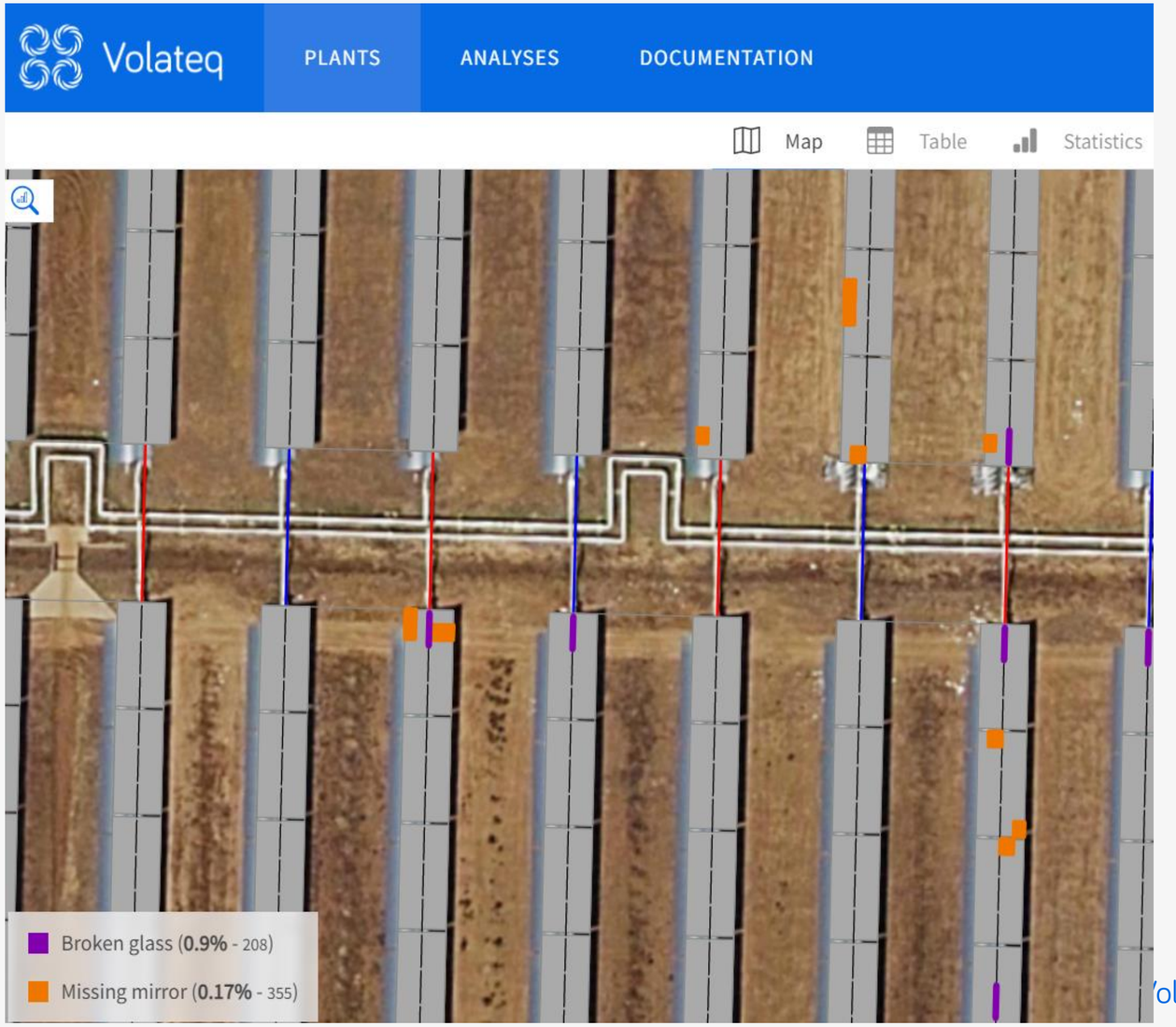
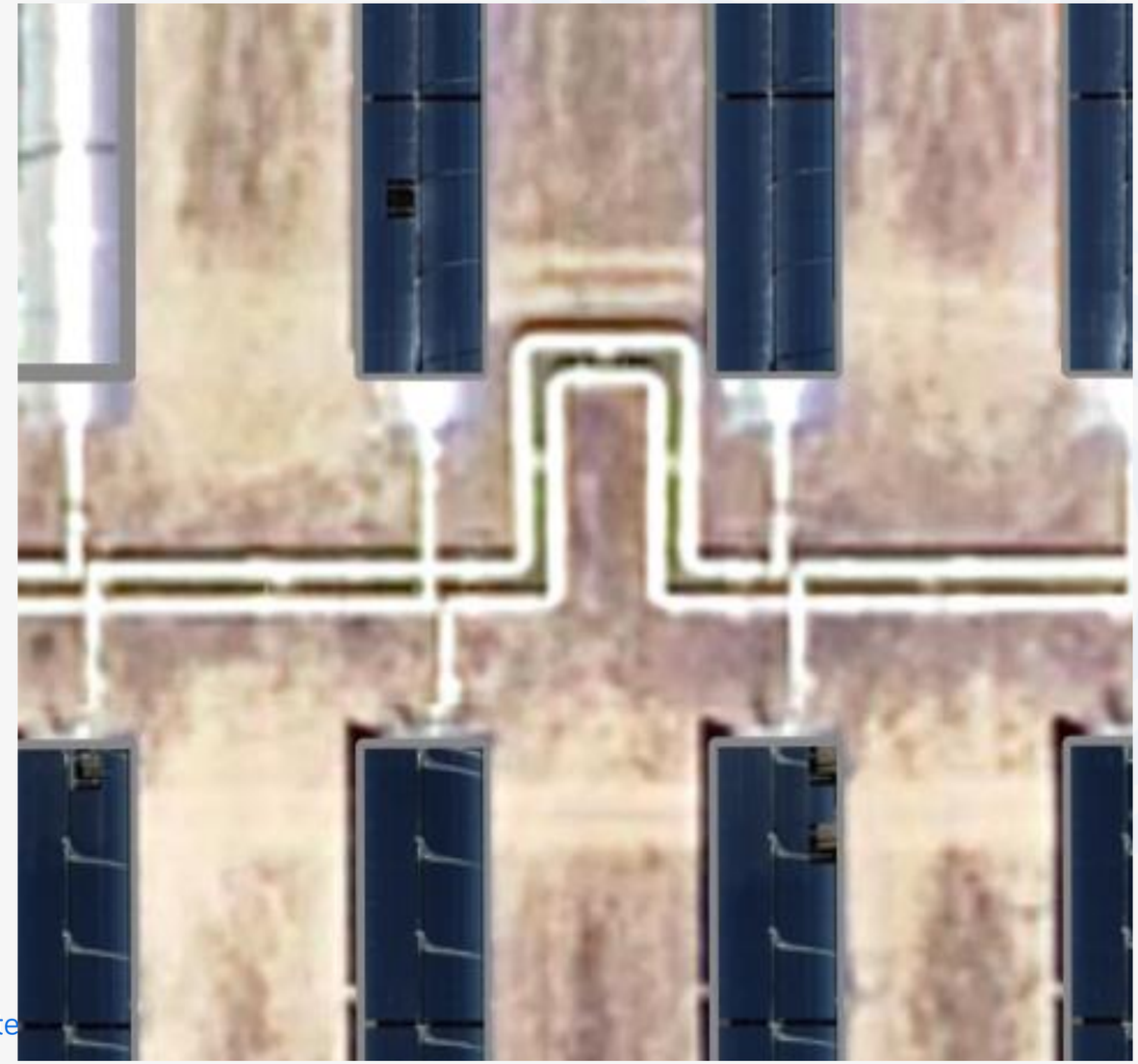
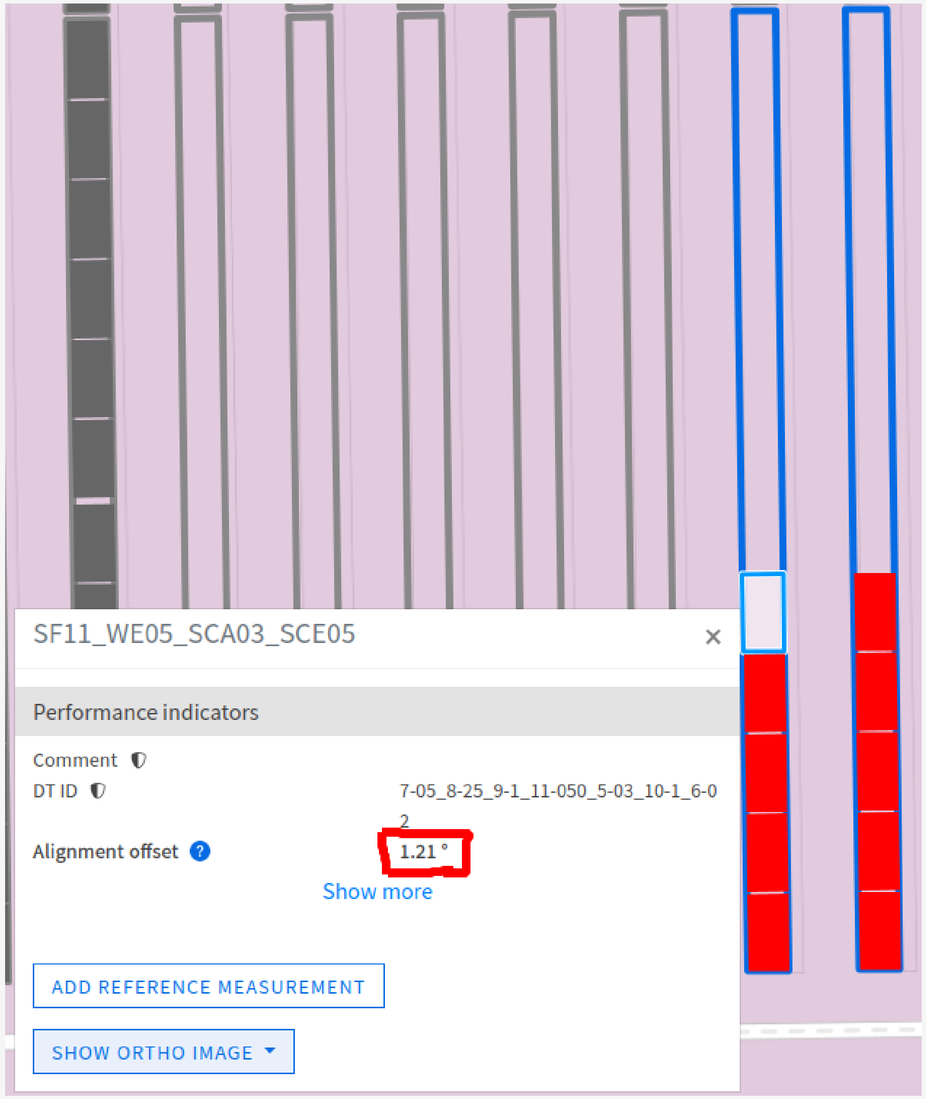
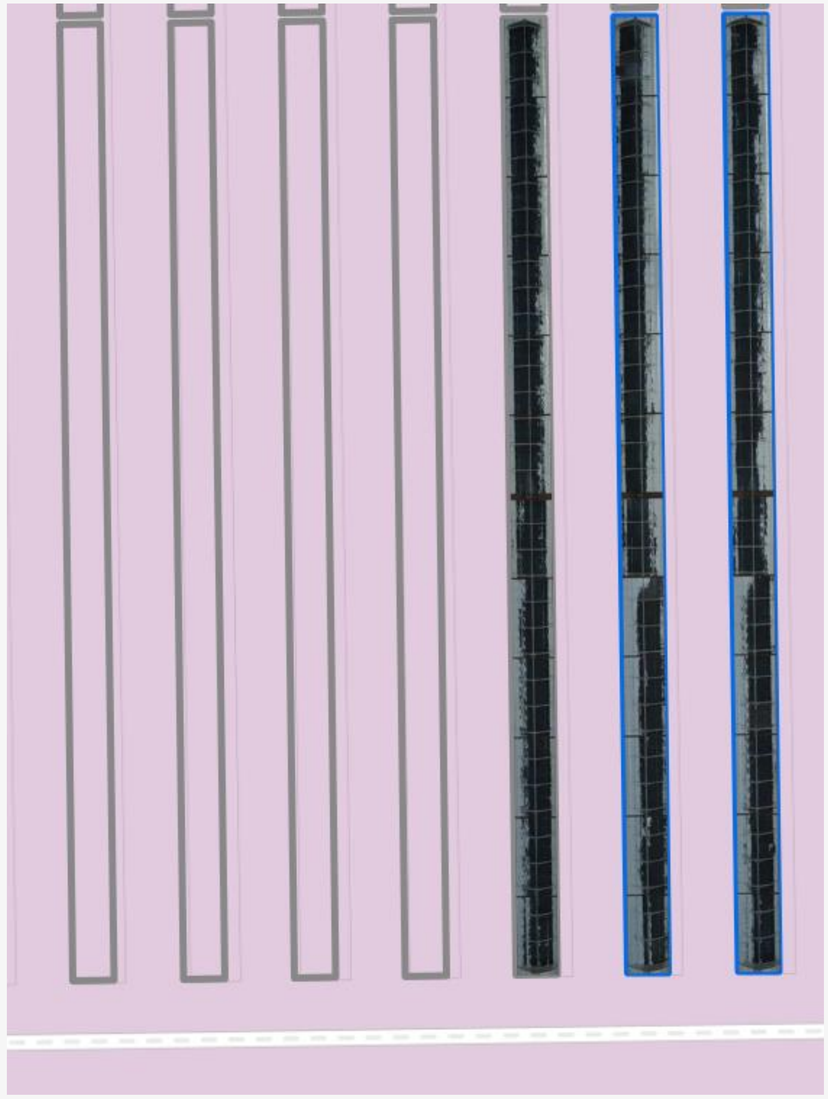
# GLASS BREAKAGE



# CONCENTRATOR ALIGNMENT



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# THERMAL LOSSES

# **SAFETY** (fumes, friction, blockage, insulation , ...)

# AVAILABLE PRODUCT PACKAGES & ANALYSIS INTERVALS

## PACKAGES

- HCE Temperature
- HCE Advanced
- Collector Package
- Concentrator Geometry
- Torsion Package
- HCE Alignment
- Glass Breakage Package

## INTERVALS

after initial setup

- **YEARLY 1**
  *Subscription with only one analysis per year*
- **YEARLY 2**
  *Semiannual analysis intervals*
- **YEARLY 4**
  *Quarterly analysis intervals*
- **YEARLY 12**
  *One analysis per month*

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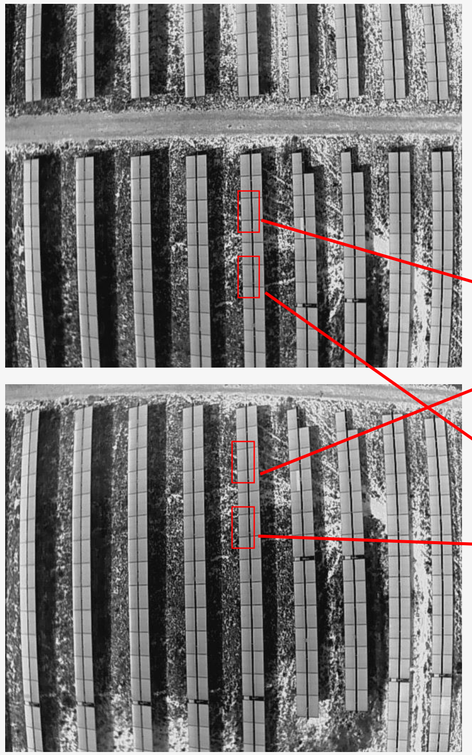
# Principles of our PV workflow

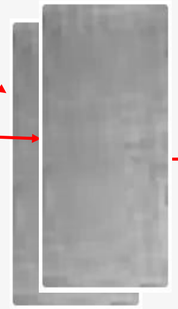
## 1. Original IR images



From each original image modules are identified and geolocated.

## 2. module IR ortho images

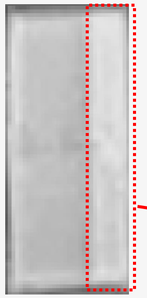
Mod 1001



Mod 1007

IR-ortho images are cropped Stacks of images for each module are created

## 3. PV Thermographic failure analysis



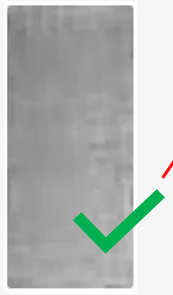


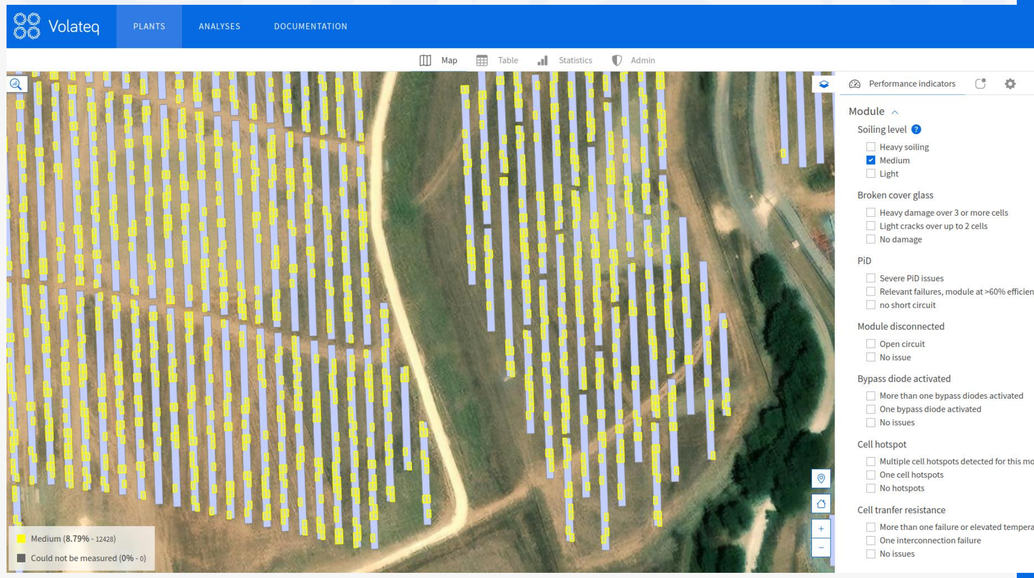
Image stacks are merged, failure types detected and categorized

## 4. Results table for webapp

| Failure category | Affected module Nrs. |
|---|---|
| none | 1007,... |
| Bypass diode | 1001,... |

Results table is filled

## 5. Results visualization in webapp

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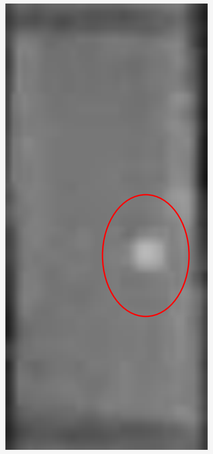
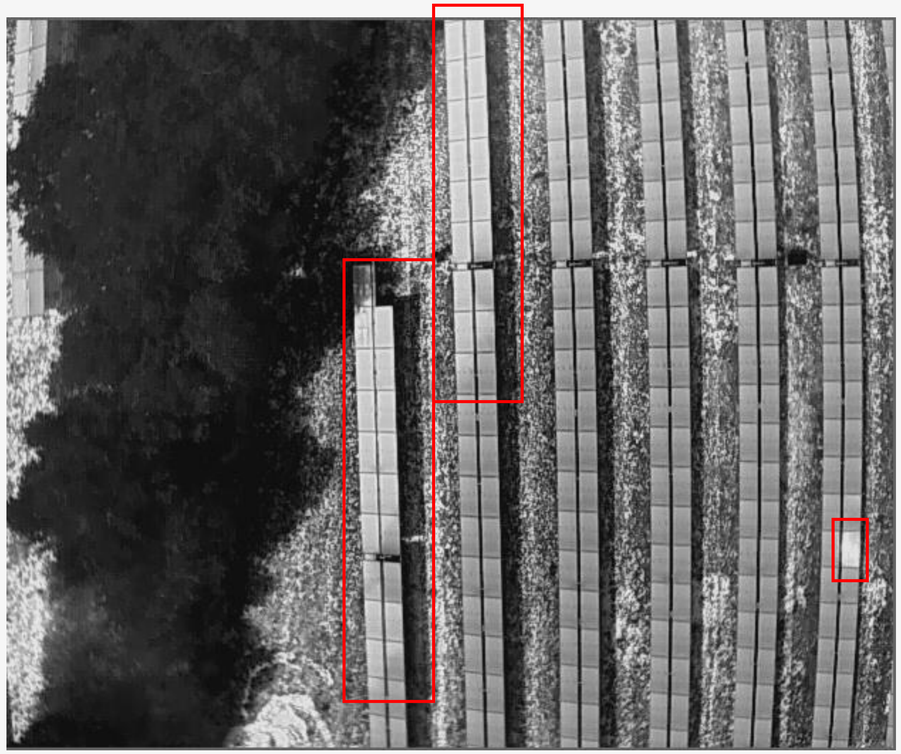
# Other fault types



## Diagnosis: Hot Spot

Single cell failure within a module appears as a hot spot

Cell acts as a resistor, and heats up by more than 5°C.

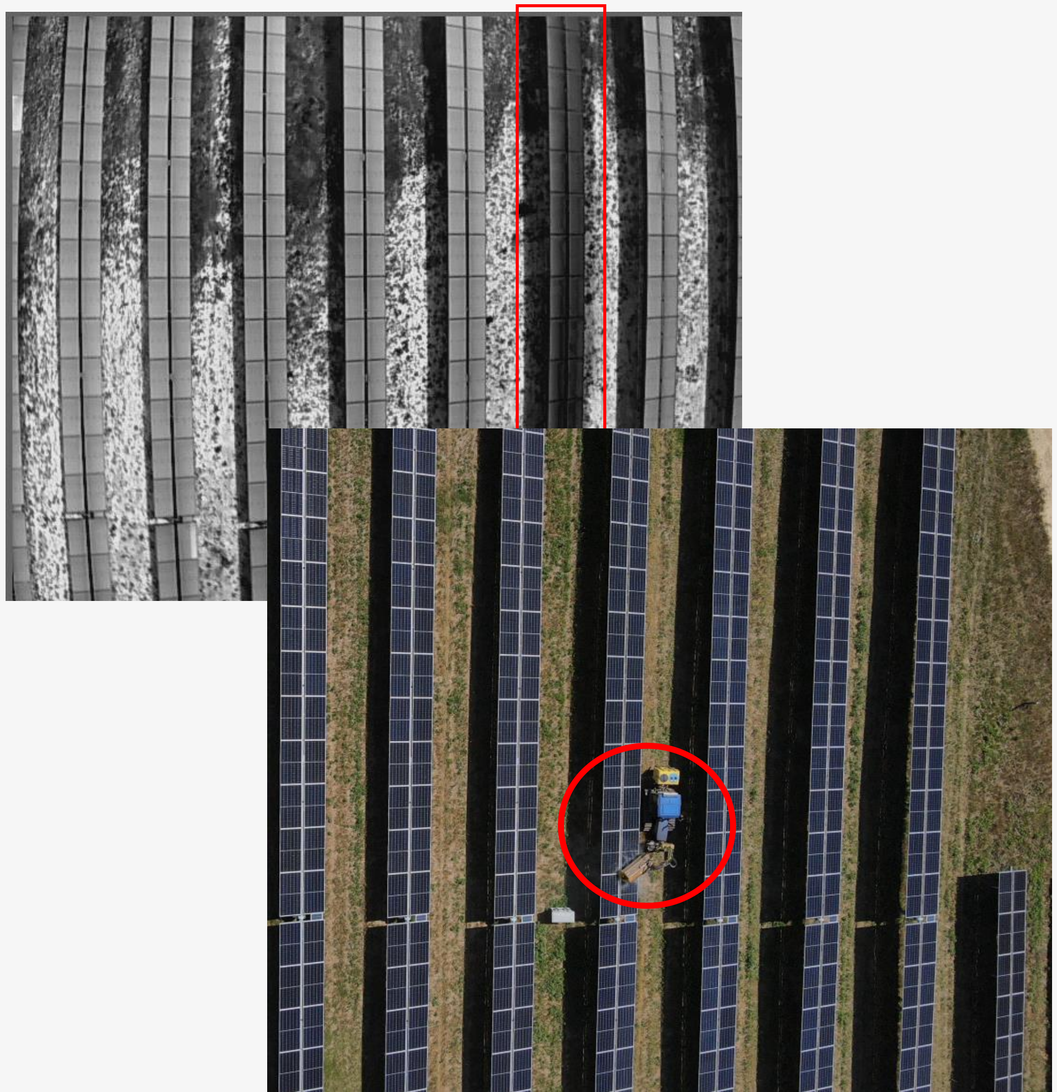


## Diagnosis: offline module and shading

Modules that operate outside their maximum efficiency appear warmer:

- Disconnected module on the bottom right
- Partially shaded strings of modules on the left
  => operation outside MPP leads to inefficient strings

# Double check with RGB



**Diagnosis**

very cold modules are unusual, no typical failure type associated with them:

- What happened?!?
- Double check with RGB images is implemented in our workflow

**Solution:**

**A cleaning truck just passed by these rows**

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RELEVANT FOR OPTICAL PERFORMANCE

# SOILING RATIO

**DATA ACQUISITION TIME** **10 MW = 15 MINUTES FLIGHT**
**Thanks to RGB video data**

## BASICS:

Detection is based on RGB images and scattering theory.

Method licenced exclusively from DLR

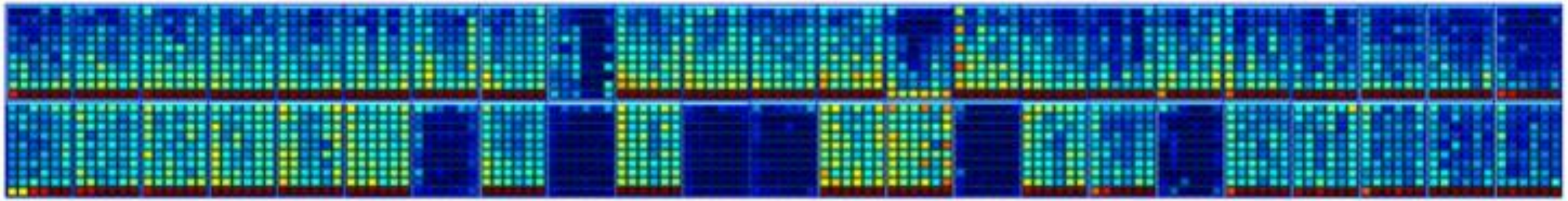
Before first measurement: one-time local dust calibration

## SOILING LOSS QUANTIFICATION:

The **soiling-induced loss over the entire solar** field is reported.

Space-resolution: individual cells – mismatch included in final output

accuracy: **2%** soiling power loss (absolute)



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DLR

https://www.dlr.de/sf

# PRODUCT PACKAGES & ANALYSIS INTERVALS

## PACKAGES

**PV Thermography IEC 62446**

*Detect and classify faults and hotspots according to IEC 62446*

**PV Thermography survey**

*Thermography with a lower spatial resolution and quicker scanning times*

**PV Soiling**

*Soiling DC power loss on cell and module levels from RGB camera. Separate but quick flight routes*

## INTERVALS

after initial setup

**SUBSCRIPTION PILOT**

*You decide on measurement frequency with your own pilots. Access to VolaFly and Webapp for you and your customers*
*Drone in a box solutions to be launched soon.*

**SUBSCRIPTION DRONE IN A BOX**

*Frequent measurements and on-demand inspections with **no lead time***

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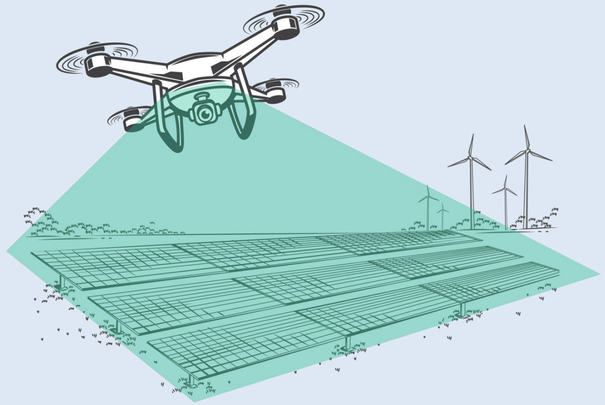
HOW OUR PRODUCT WORKS

# PROCESS BREAK DOWN

**STEP 0:**
INITIAL ONE-TIME SETUP
BEFORE PROCESS CYCLES

## STEP 1:
**SIMPLE & FULLY AUTOMATED DATA ACQUISITION BY CLIENT**

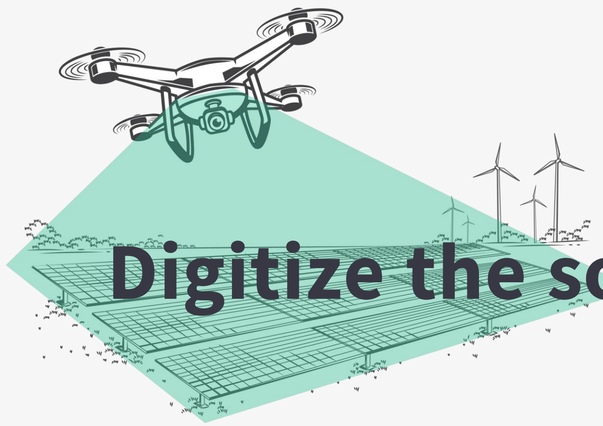


## STEP 2:

**DATA ANALYSIS IN VOLATEQ CLOUD(< 6h)**

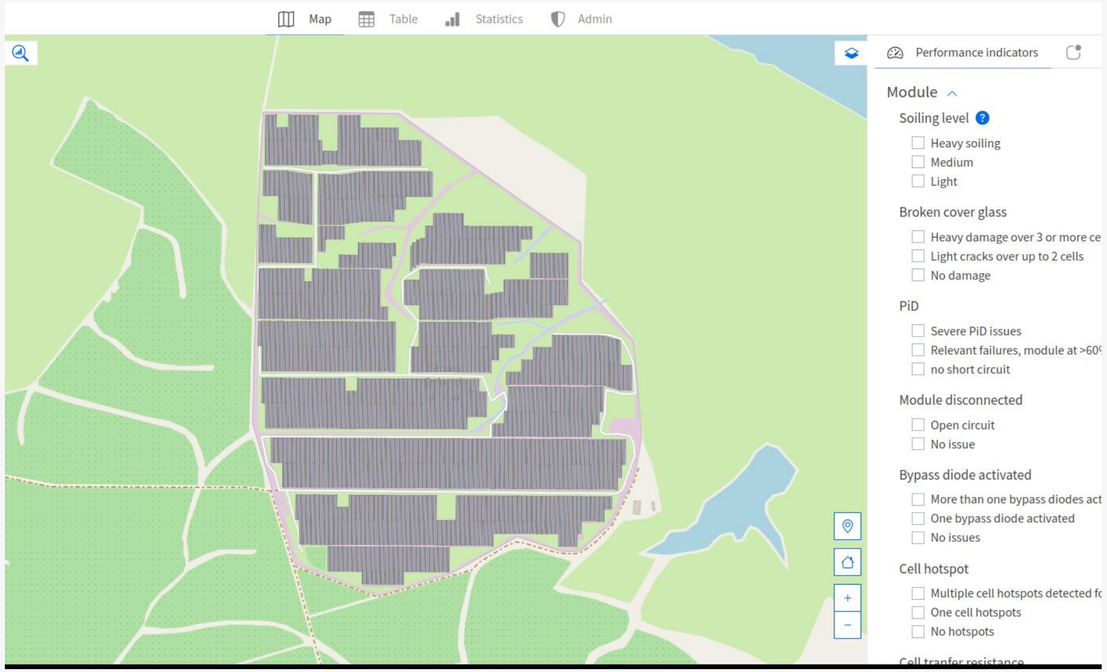

## STEP 3:

**HEALTH REPORT WITH CLEAR ACTIONABLE STEPS FOR OPTIMIZATION**



# Digitize the solar assets

- Google Earth
- 3D scan
- Drawings
- ...

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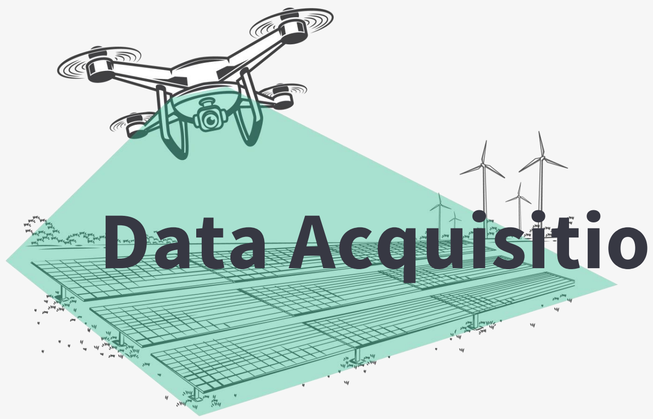

# Data Acquisition

| Parameter | PV | CSP |
|---|---|---|
| Flight height | 15- 40m | 5-120 m |
| Flight speed | 5m/s | 10 m/s |
| Image overlap | ~70% | Not required (videos) |
| Obstacle detection | DJI anti-collision system integrated | |
| Flight restriction | DJI | |


## Apps for settings and waypoint execution

- DJI Pilot / flight-hub
  - Full access to all settings
  - Waypoints via cloud server
- Litchi
  - Perfect for cloud-based interchange of waypoints (API interface)
  - No support for enterprise done settings
- VolaFly (https://app.volateq.de/download-volafly)
  - Clean and simple interface based on **DJI SDK 4/5**

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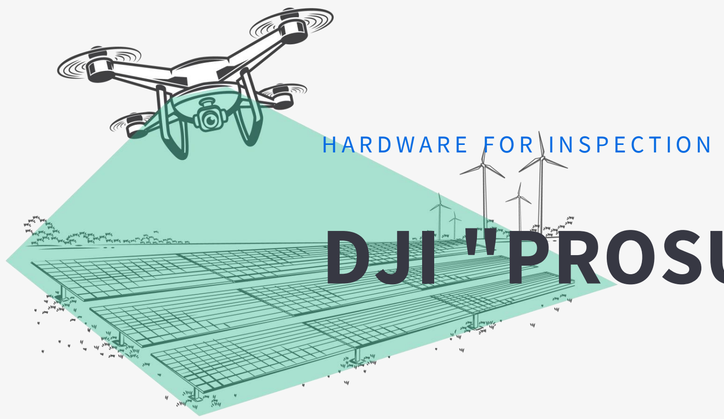


HARDWARE FOR INSPECTION

# DJI "PROSUMER" DRONES

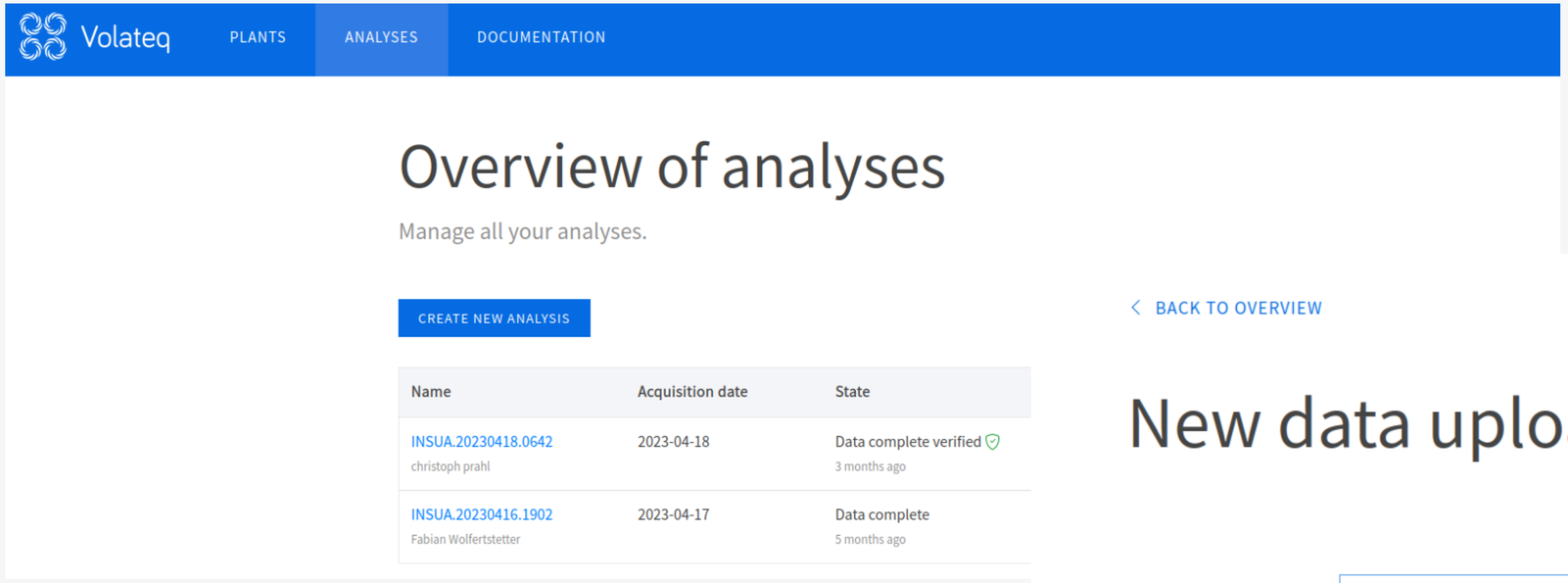
## Experience with DJI Mavic drones

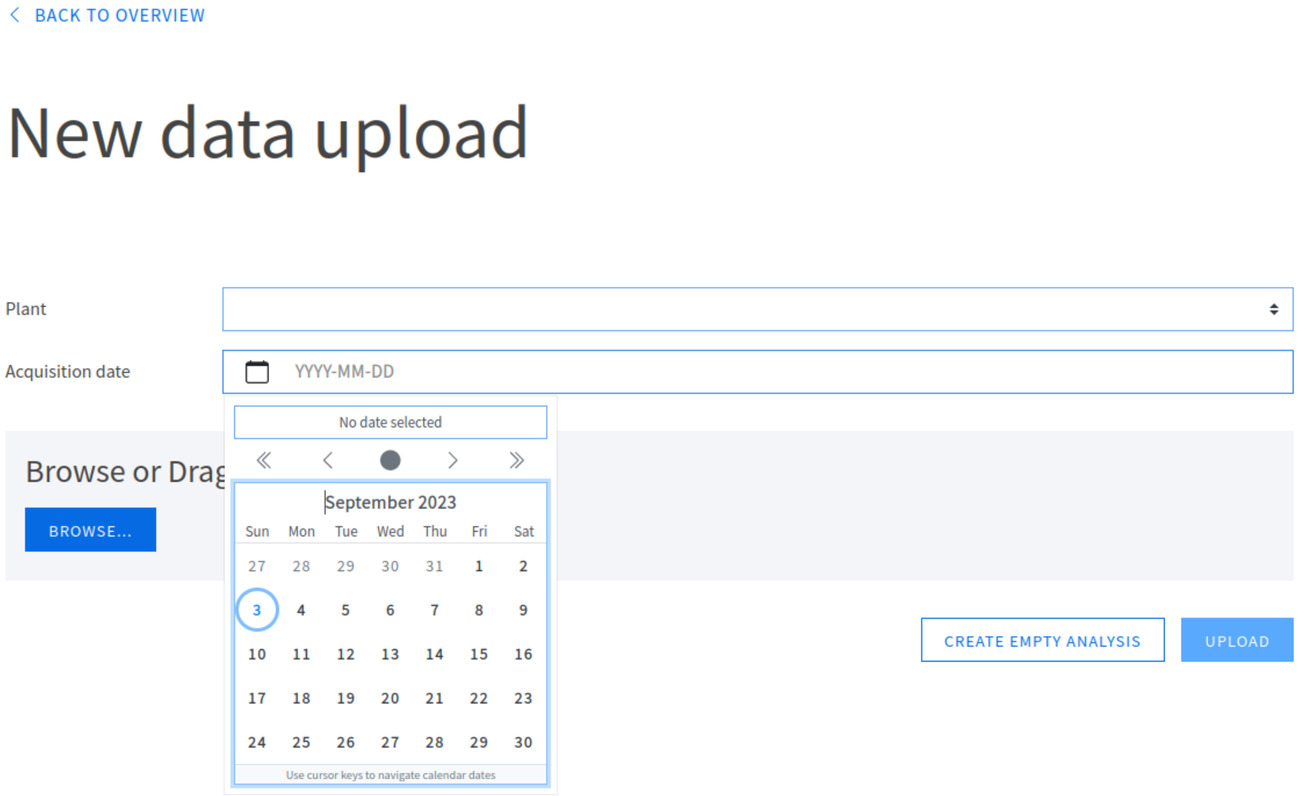
- Intuitive & easy handling
- Cost-effective
- Worldwide availability
- Good pay-load specs
- Global technical service

| Specifications | M2EA | M3T |
|---|---|---|
| Weight | 909 g | 920 g |
| Dimensions (L×W×H) | Folded: 214×91×84 mm, Unfolded: 322×242×84 mm | Folded: 221×96.3×90.3 mm, Unfolded: 347.5×283×107.7 mm |
| Max Speed | 20 m/s | 21 m/s (S-mode) |
| Max Flight Time | 31 min | 45 min |
| Max Wind Speed Resistance | 10 m/s (scale 5) | 12 m/s (scale 6) |
| Operating Temperature | -10° to 40° C | |
| GNSS | GPS+GLONASS | BeiDou+Galileo+GPS |
| Obstacle Sensing | Forward/Rear/Downward binocular vision<br>Left/Right single vison<br>Up/Down infrared sensor | Omnidirectional binocular vision system, supplemented with an infrared sensor at the bottom of the aircraft |
| Camera | RGB Wide + Thermal | Wide + Thermal |
| IR Sensor Resolution | 640*512@30 Hz | 640x512@30 Hz |

AFTER FLIGHTS ARE FINISHED

# Upload data to VolaFly App / Webapp



# Drone Legislation – work in progress
## Some 1st hand experiences from our projects

| Country / region | :-) | :-( |
|---|---|---|
| EU | Common rules for a large territory | • Restricted airspace: You must deal with national authorities to obtain a NOTAM.<br>• Slow legislation authorization for autonomous flights / DIB systems (at least in Spain) |
| Morocco | Straightforward working with local pilots | Original quote: "Guns are easier to legalise than drones." |
| Israel | Straightforward working with local pilots | 120 m flight altitude is already an exception (as of 2022) |
| South Africa | Straightforward working with local pilots / our customers | Time-consuming process to become a drone pilot |
| USA | Straightforward working with local pilots | |
| UAE | 1 out of 2 clients managed to get permissions | Different rules apply within the UAE<br>High hurdles/costs for daily flights |

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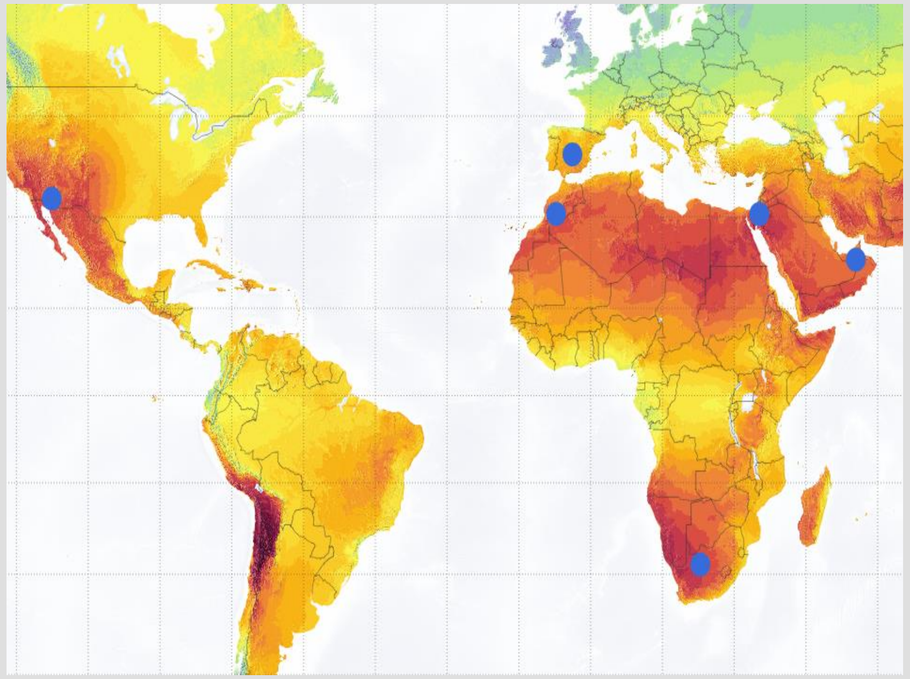
# Examples of successful use cases

**6 countries | 4 continents | 2 GW installed CSP**



| Client / Country | Atlantica Sustainable Infrastructure (USA) | Seratype (South Africa) |
|---|---|---|
| Plant Name / Location | Solana / Arizona | Ilanga / Upington |
| Power / Storage | 280 $MW_{el}$/ 6 hours (full load) | 100 $MW_{el}$/ 5 hours (full load) |
| Scope / Objective | Overall solar field heath check | Monitoring of degradation processes, verification of the effectiveness of countermeasures |
| Frequency | One time | Bi-weekly |
| Timeline | 2022/07 - 2022/09 | 2021/11 - present |
| Who flies the drone | External provider | Client's own staff |

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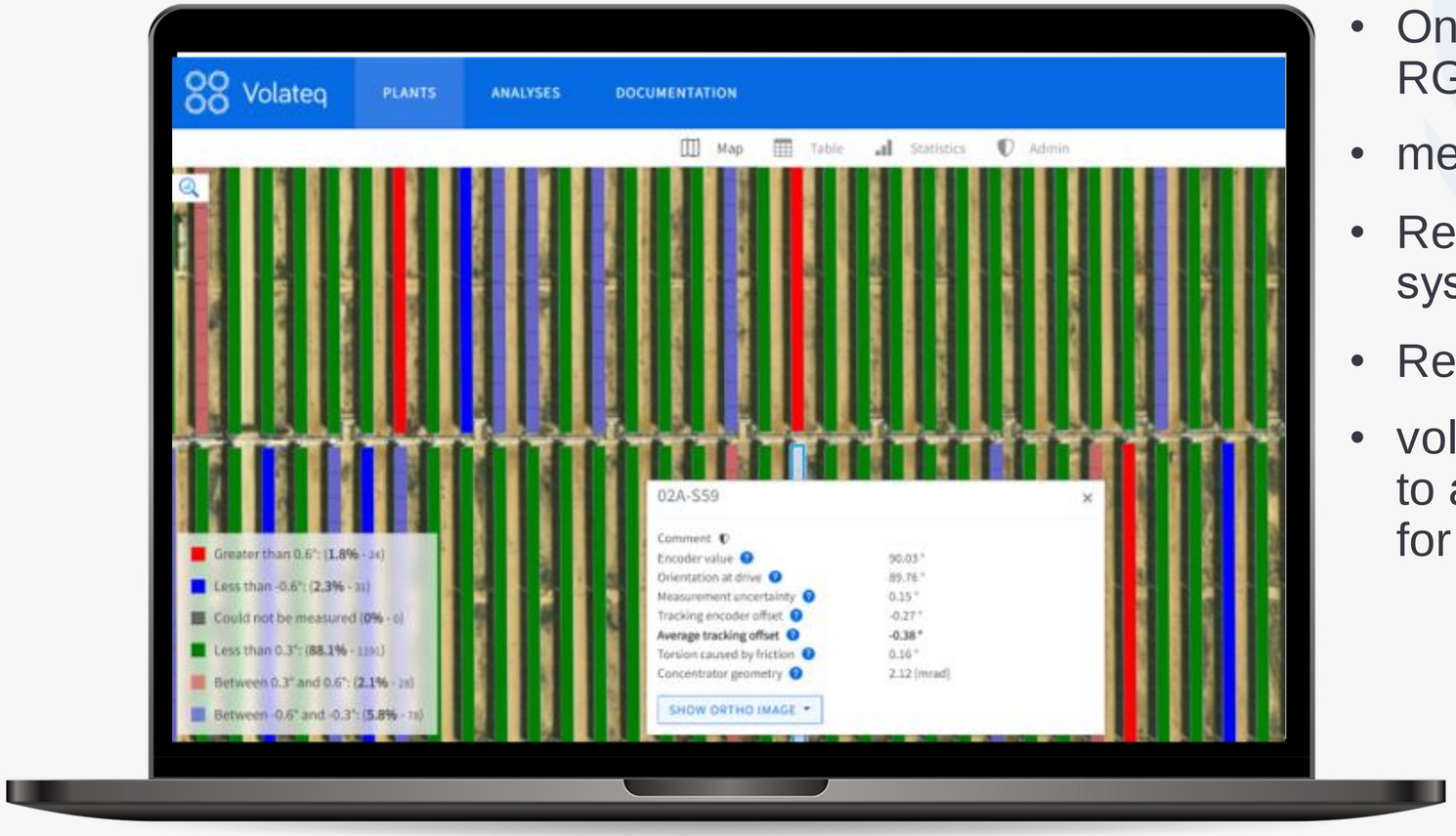
TAKING A LOOK AT THE

# VOLATEQ WEBAPP - features




**Interactive web-application that can be launched on mobile devices. No stable internet in the field is necessary**

- Results and fault categories in tables or maps
- See your live GPS location on mobile devices
- One-click view of result details, ortho images in RGB and IR
- measurement history & comparisons
- Results can be passed to your own management system using API, CSV, XLS, PDF…
- Reports, access to raw data (incl. white label)
- volateq without drones: **Plant management tool** to add observations, images and measurements for any component directly in the field

TAKING A LOOK AT THE

# VOLATEQ WEBAPP – walk through

- General introduction to webapp
  - Plants
  - Users
  - Analysis -> overview
  - Analysis  -> Flight campaign
- Results
- Comparison View
- Ortho - images
- Reference measurement

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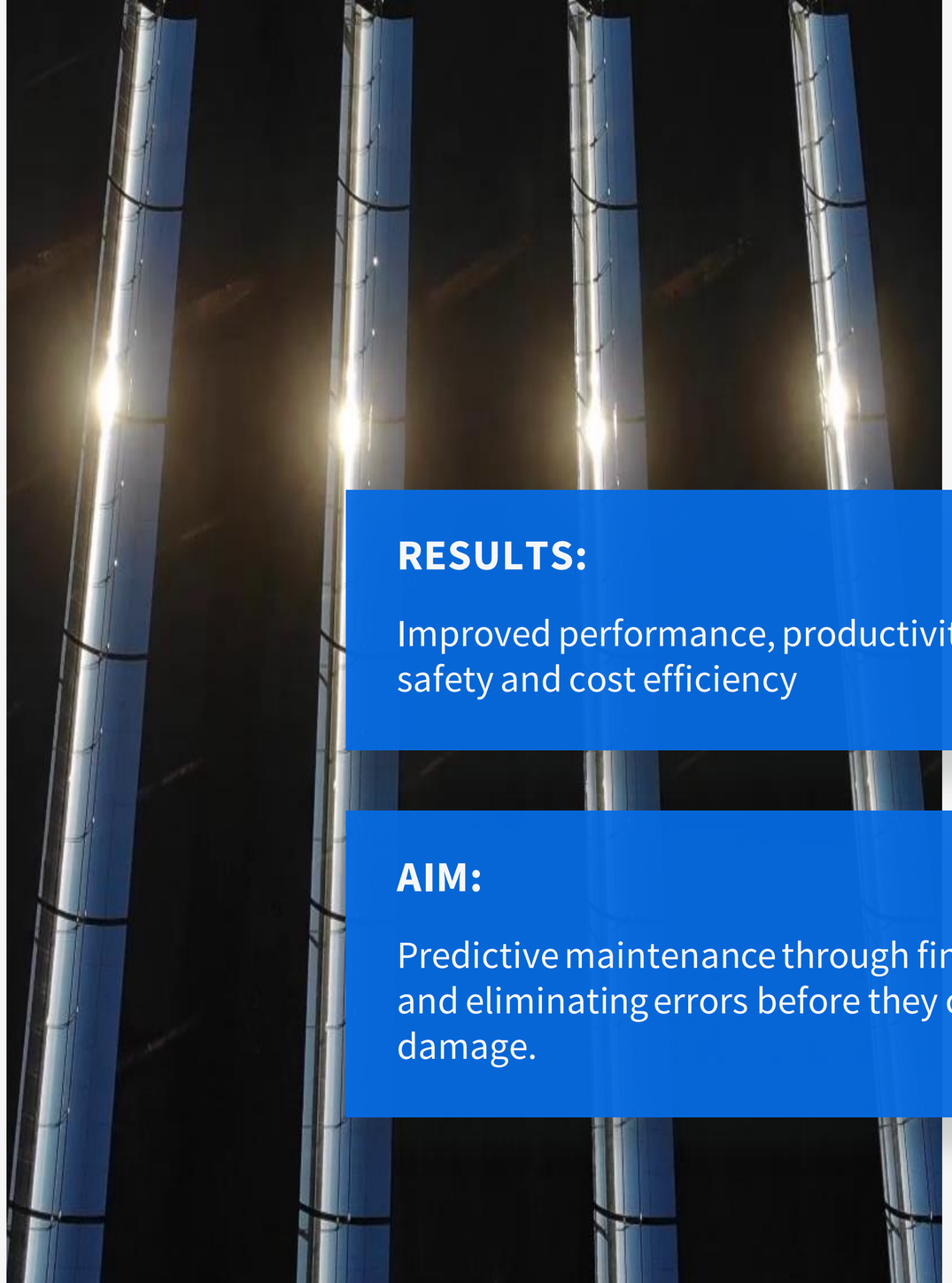
OUR SOLUTION

# VOLATEQ's SaaS TO FULLY AUTOMATE HEALTH MONITORING OF SOLAR FIELDS

- Provides highest level of **automation**
- Enables power plant operators to be **independent** from ext. specialist pilots and analysts → autonomy , flexibility
- Provides **comprehensive** and **actionable reports**
- Software solution can be **applied by anyone** with basic drone flight license
- An **all-in-one solution** to unbox the black box ‚solar field'
- Is **globally** available



**RESULTS:**

Improved performance, productivity, safety and cost efficiency

**AIM:**

Predictive maintenance through finding and eliminating errors before they cause damage.

# Our Vision for the future of aerial inspection

DJI's drone dock with Matrice 30

## Currently working on drone in a box:

- Drone docks will facilitate fully autonomous flights via BVLOS:
  - VolaFly App is BVLOS-ready
  - Strongly requested by CSP customers because of high measurement frequency
  - PV: application in large plants with increased degradation and soiling rates
  - Security and on-demand inspections
- Vision "Drone as a colleague": carried on a vehicle for autonomous support of field staff

## Further developments at Volateq:

- Combined crop health and thermography for Agri-PV
- Biodiversity monitoring in PV
- We are used to complex geometries and desert climates!
- We are open to partnerships and cooperations in the energy sector - contact us!

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# OUR TEAM

**ANNE SCHLIERBACH**
***Marketing & Sales***

Solar Power Projects since 2008: construction, commissioning and research

**DR.-ING. CHRISTOPH PRAHL**
***Technology & Software (Back-End)***

Optimizing Solar Power since 2008

**WOLFGANG REINALTER**
***Finance & Software (Front-End)***

International Solar Power Expert and Project Manager since 1997

**Anna Khadisova**
***Working student***
***Fullstack Developer***

**JEREMY GAUCHEL**
***Technology & Software (Front-End)***

Optimizing Interfaces since 2008

**JOHANNES HIRTH**
***Technology & Software***

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**Dr.-Ing. FABIAN WOLFERTSTETTER**
***Technology & Business Development***

Product owner PV and soiling

**Since recently:**

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***Technology & Software Front-End***

**Francisca Haro**
***Finance & Legal***

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# THANK YOU & CONTACT US

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ADDITIONAL SLIDES

**Please note:** All collectors that are not in the foreseen position at the agreed time for the data acquisition flights, cannot fall into the analysis.

# HOW DATA IS ACQUIRED

Basic data acquisition for HCE temperatures takes place during operation (solar noon). Additional flights take place shortly before civil twilight using the following setup and processes to measure all other key performance indicators.

## FLIGHT
Relevant for the HCE Advanced & Collector Package

### STEP 1
Positioning of all collectors to ~80° (then STOP).

### STEP 2
Turning from ~80° to 90° (then STOP). Necessary to simulate the same direction of movement / sequence as the course of the sun.

### STEP 3
Flight for data acquisition

## FLIGHT
Relevant for torsion by comparing two operating states

### STEP 1
Positioning of all collectors to ~100° (then STOP).

### STEP 2
Returning back from ~100° to 90° (then STOP)

### STEP 3
Flight for data aquisition

WORKFLOW OF OUR

# SUBSCRIPTION-BASED SOLUTION

START **INITIAL ONE-TIME SETUP BEFORE PROCESS CYCLES**

**Monitoring Cycle:** the user is free to use the product autonomously and get an analysis of the health state of the plant whenever they need it and compare changes over time. Usually 4-12 times/year

REPEAT

**DRONE INSPECTION:**
Upon creation of digital twin, user captures data autonomously and gets necessary information to determine plant‘s performance.

DONE BY USER

DRONE INSPECTION REPEATABLE ACCORDING TO **NUMBER OF SUBSCRIPTION INTERVALS**

**ACTIONS OF OPTIMIZATION:**
Based on the actionable recommendations and visualisations to improve productivity and cost efficiency.

DONE BY USER

**DATA UPLOAD:**
User uploads acquired image data to Volateq‘s cloud-based web app (also mobile friendly).

DONE BY SOFTWARE

**SOFTWARE REPORTS:**
App delivers accurate and comprehensible reports with actionable results and visualisations to act on performance and safety issues.

DONE BY SOFTWARE

**DATA PROCESSING:**
Highly skilled software automatically analyzes image data and indicates the location and severity of low performing areas.

DONE BY SOFTWARE

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VOLATEQS PATH

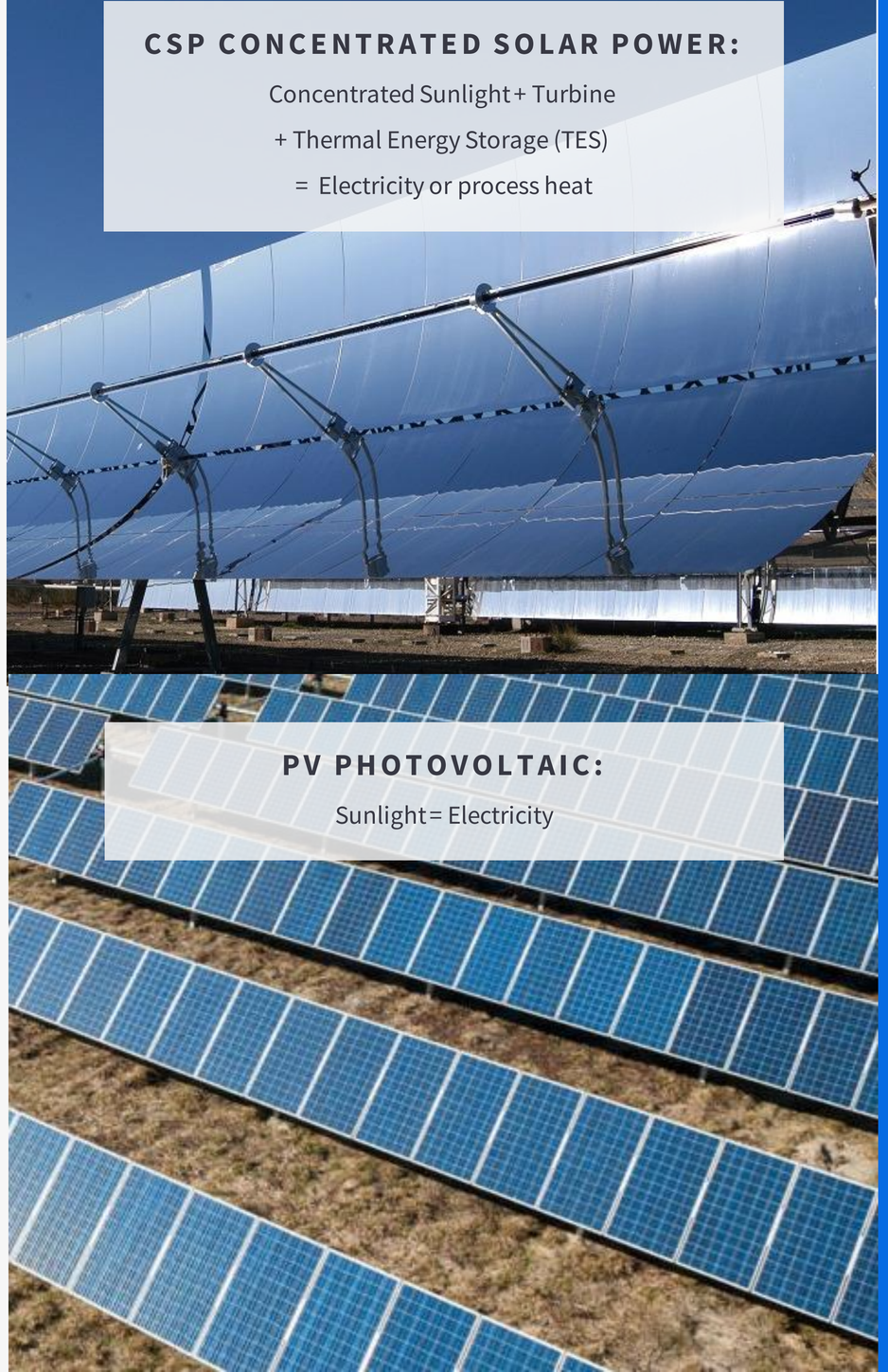
# Our success story

**>2 GW** CSP capacity measured regularily

**300 MW** of PV plants measured in a few months

**Concentrated Solar Power (CSP):**
- Market leader
- Pioneer in CSP aerial inspection
- Introduced more than 1 novel Performance Indicators
- Supplied more than 25% of global installed capacity
- Much higher measurement frequencies than in PV

**Photovoltaic (PV):**
- Recent market entry
- Quick and lean developments thanks to CSP experience
- Innovative product quantitative soiling measurement
- Low flight duration and high automation
- Optimized user experience due to integrated flight control app



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# PV THERMOGRAPHY SURVEY

**GOOD TO NOTE:** No additional flights are required for RGB analysis such as heavy soiling, tracking and shading. Our software can understand and accommodate data from dual camera equipped drones in parallel.

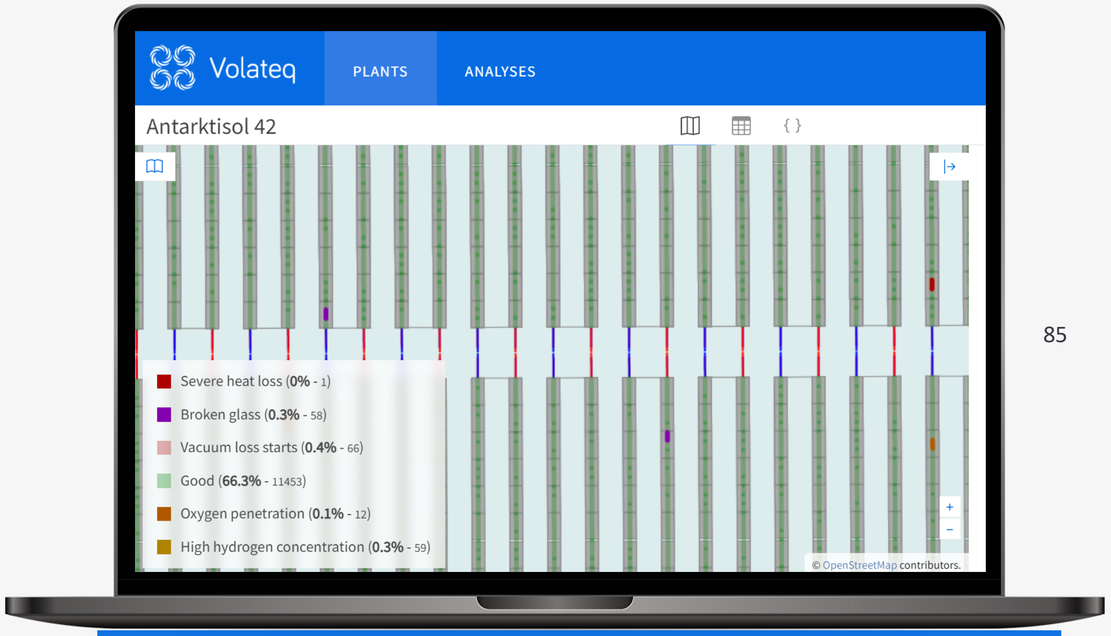



**IMAGE DATA ACQUISITION TIMES**

- **For Thermography Survey: 50 MW in < 1 hour flight**
  failures down to module level with a very high throughput





## PV Thermography

Detection of defects using thermography taken at higher flight height and speed for rapid detection and highest flexibility. Failure categories according to the classification below. IR and RGB-images for every faulty module accessible in webapp.

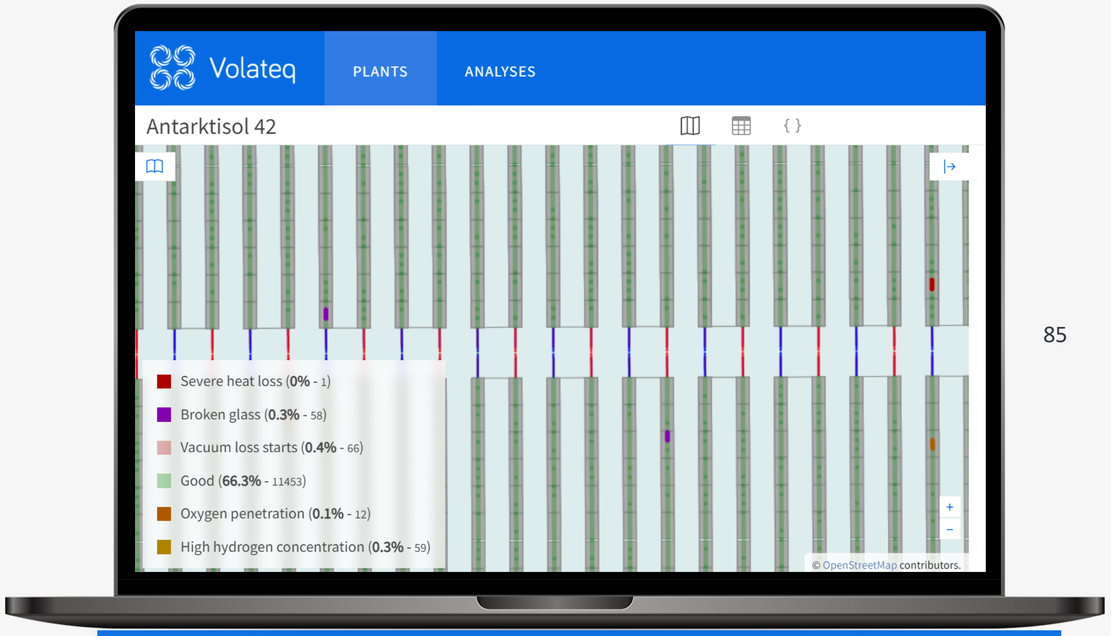
Flight plans are provided automatically for requested time and plant sections. All thermography results are automatically corrected for the influence of heavy soiling, module damage and shading.

**Module surface temperature:**

- Cell-level hot spots with ΔT > 4 K
- Junction box anomalies with ΔT > 4 K
- Anomalous string, combiner or inverter (open circuit)
- bypass diode activation
- PiD affected modules
- Shading, module damage and heavy soiling
- Tracker alignment with 5° accuracy

# PV THERMOGRAPHY IEC 62446

**GOOD TO NOTE:** No additional flights are required for tracking and shading detection. Our software can understand and accommodate data from dual camera equipped drones in parallel.




85

**IMAGE DATA ACQUISITION TIMES**

- **For Thermography HQ: 10 MW in < 1 hour flight with 640*512 IR camera**
  IR thermographic failure detection according to IEC 62446

THERMOGRAPHY HQ

## PV HQ Thermography

Detection of defects according to IEC 62446 at low flight height. Detected failures are reported according to the categories below. IR-image for every categorized module accessible in the webapp. PDF-reports in custom format are charged separately.

All thermography results are automatically corrected for the influence of heavy soiling (e.g. bird droppings), module damage and shading.

**Module surface temperature:**

Sub-module defects according to according to IEC 62446

- Cell-level hot spots with $\Delta T > 10$ K and $2$ K $< \Delta T < 10$ K
- Junction box anomalies with $\Delta T > 4$ K
- PiD affected modules
- Bypass Diode activated
- Cell-Cell interconnection failures
- Transfer resistance failures
- Offline modules
- Shading by vegetation, structures and heavy soiling
- Tracker alignment with 5° accuracy



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