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Federal Ministry
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by the German Bundestag

FAST CALIBRATION OF HELIOSTATS

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26th Cologne Solar Colloquium

June 22, 2023

cspservices
concentrating solar power services

DLR

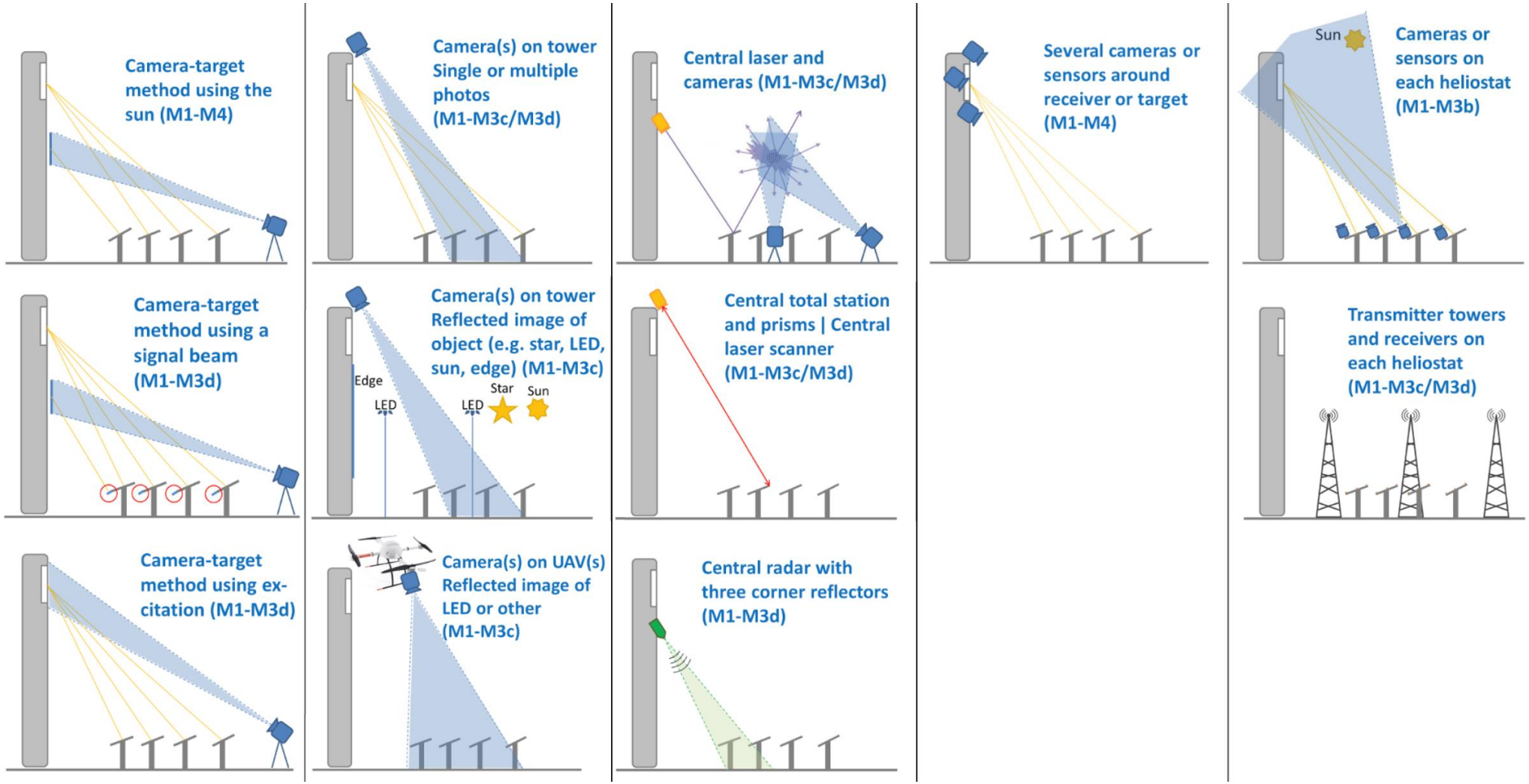
Motivation

Ashalim
121 MW_e
~50.000 heliostats

Ashalim Plot B by Megalim Solar Power

- High number of heliostats
- High pointing accuracy required
- Faster calibration → shorter commissioning time!

Many different methods



Sattler et al. – Solar Energy 207, 110 (2020)

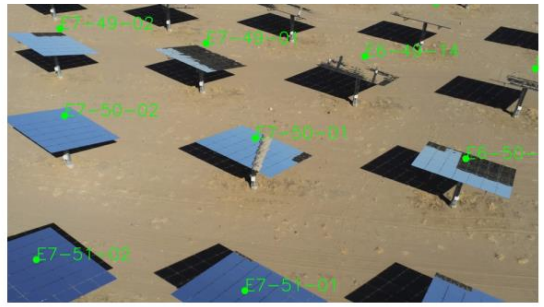
Many different methods

Sattler et al. – Solar Energy 207, 110 (2020)

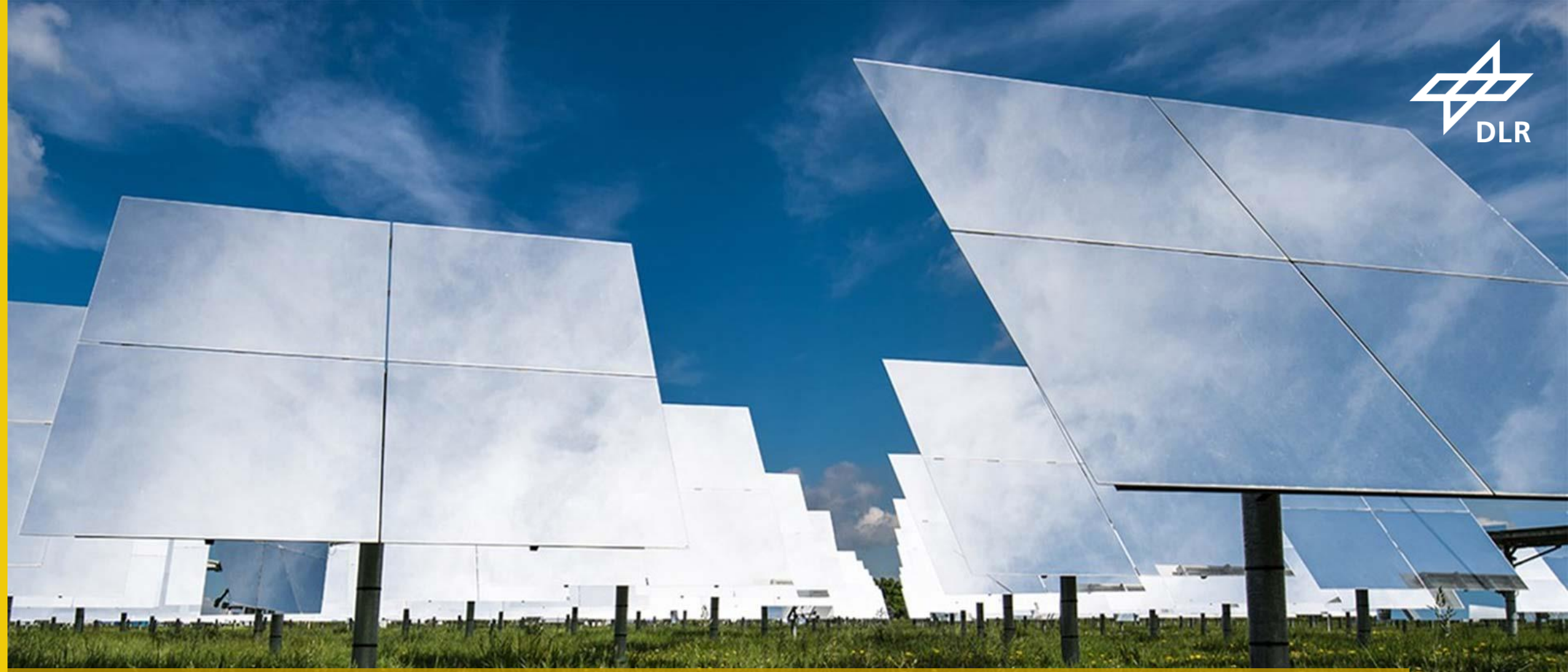
Alternative technique from NREL

Example Technique: Non-Intrusive Optical (NIO) Tool

- **Objectives**
  - In-situ technology suitable for utility-scale heliostat fields
  - Measure slope error, canting error and tracking error
- **Approaches**
  - Drone-driven camera
  - Reflectometry
  - Automated image-processing through computer vision and machine learning
- **Status**
  - Entered into demonstration stage
    - NSTFF (done)
    - Crescent Dunes (done)
    - Cerror Dominador (planned)



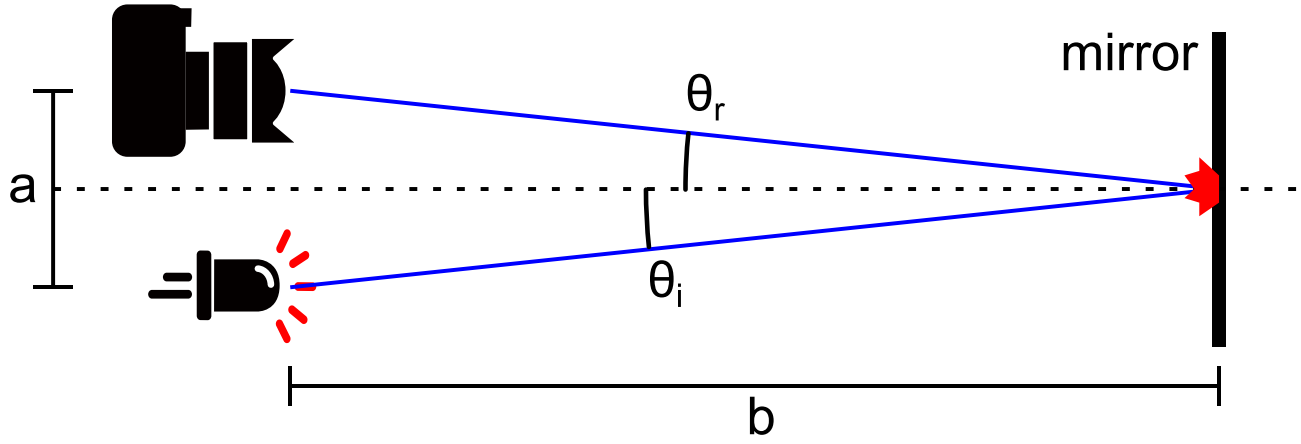
Guangdong Zhu, NREL

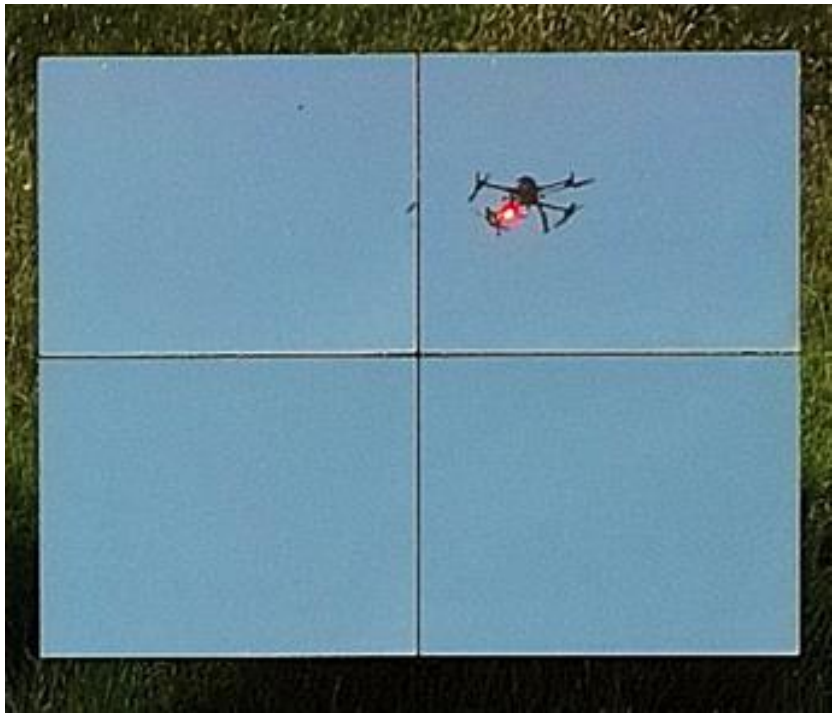


METHOD & DATA ACQUISITION

The measurement principle (*HelioPoint* method)

- LED and camera fitted to a drone
- Normal vector is bisector of LED and camera



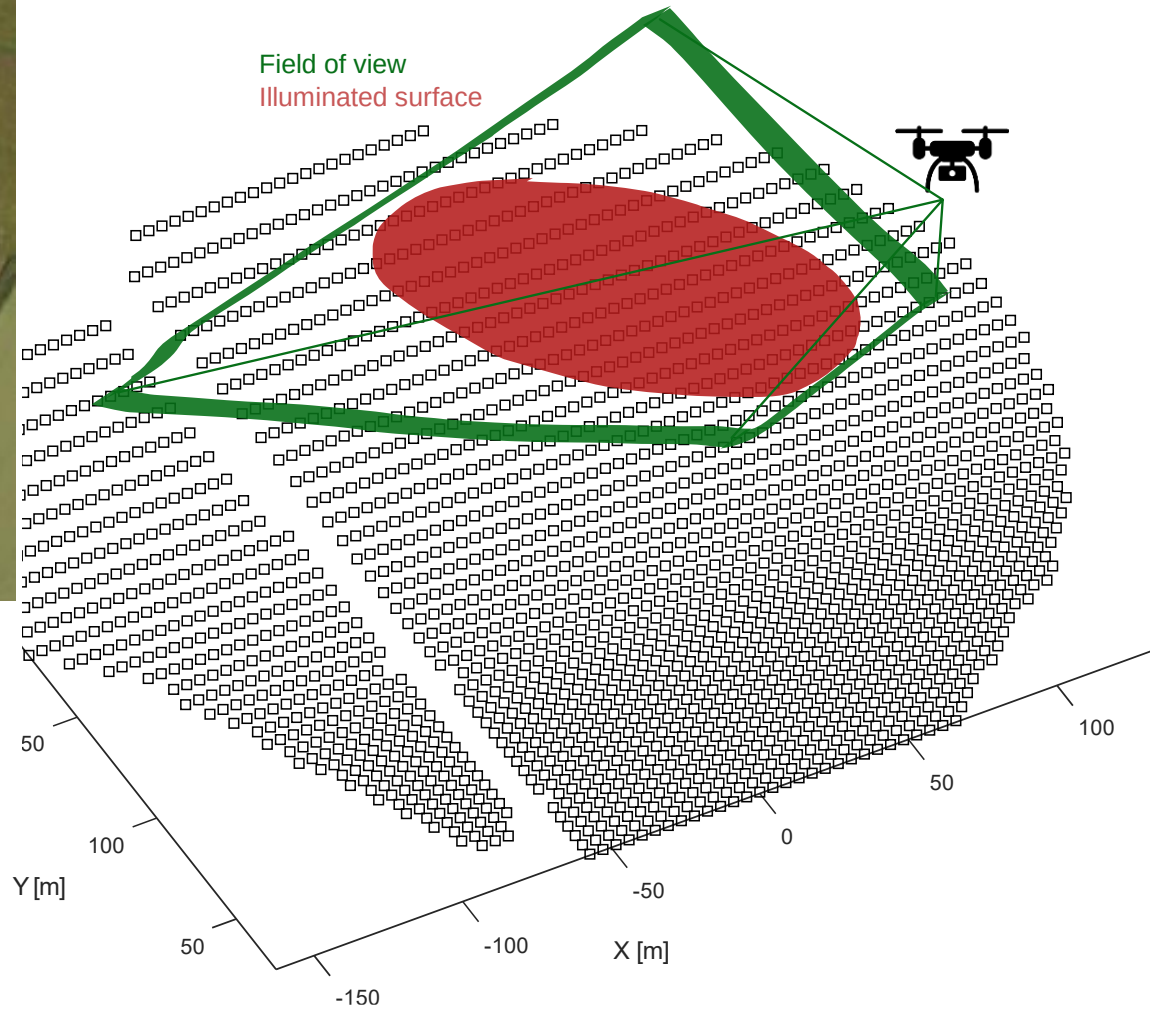


The setup

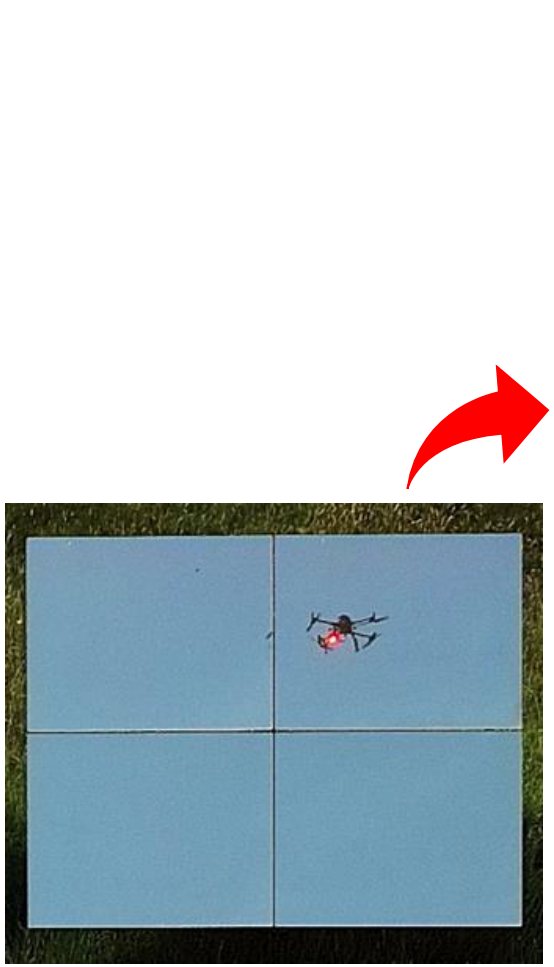
- Commercially available drone equipped with
  - RTK
  - calibrated camera
  - strong LED

Tested at the solar tower in Jülich

Solar tower Jülich, DLR



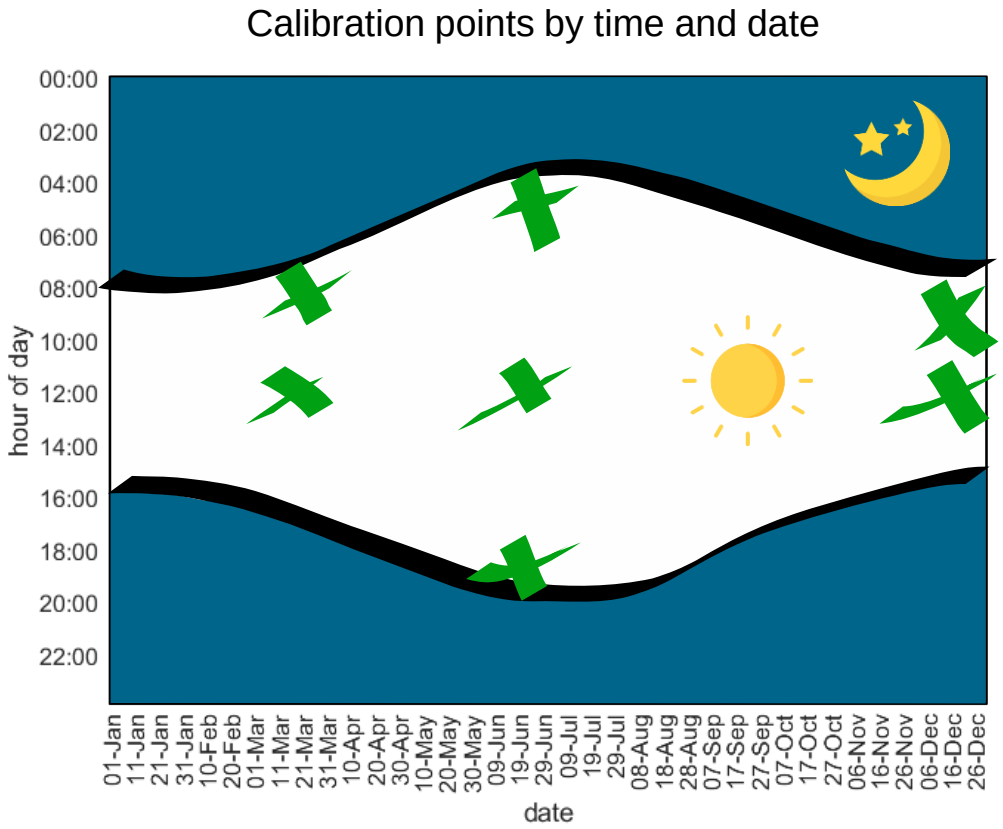
The Image Data

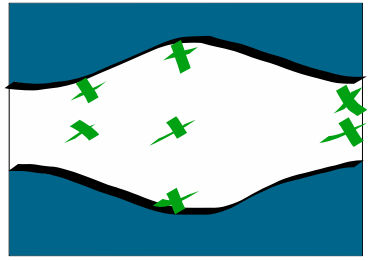


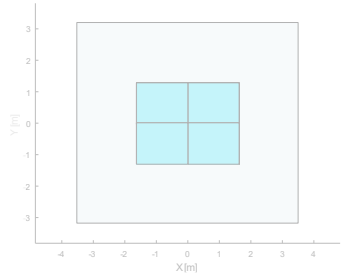
Flight Route Planning

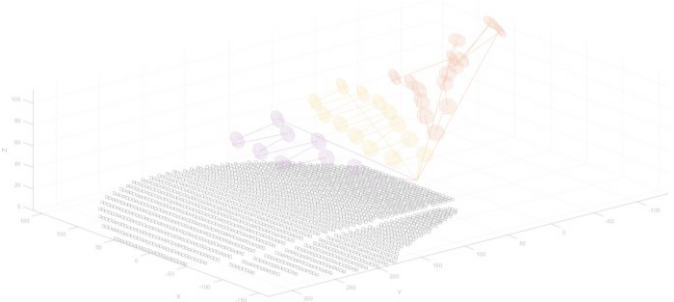
Steps:

1. Definition parameter set







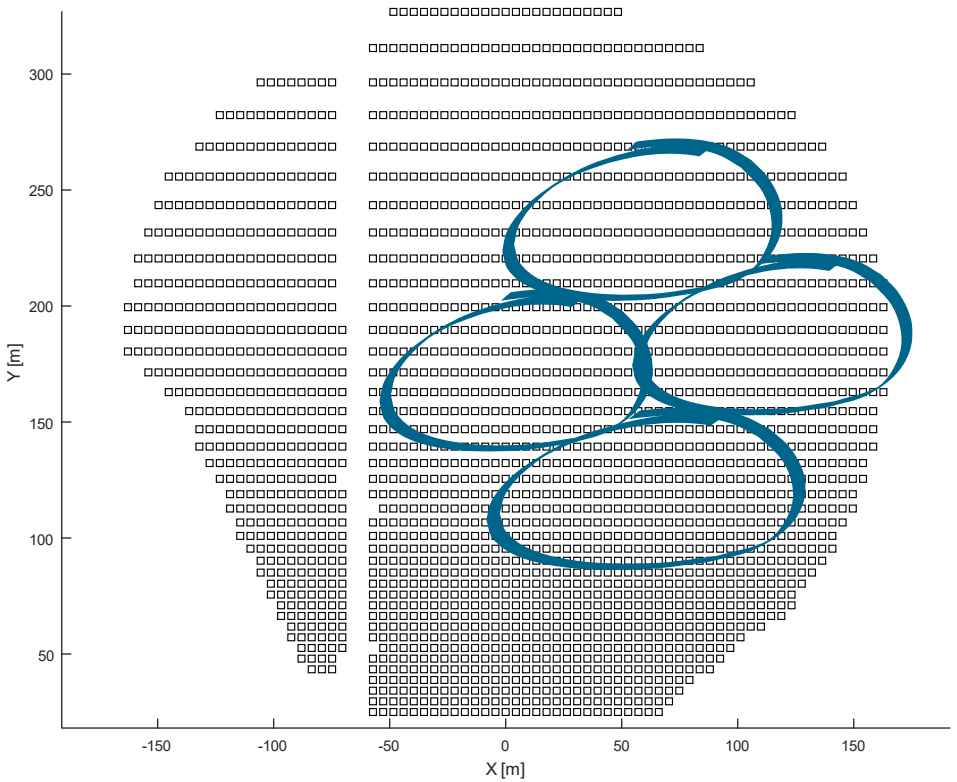


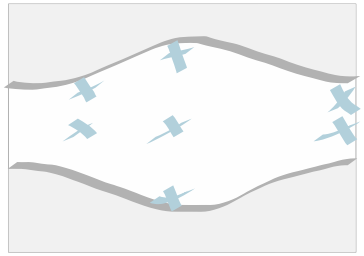
Flight Route Planning

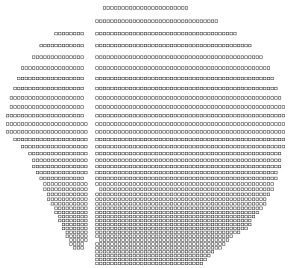
Steps:

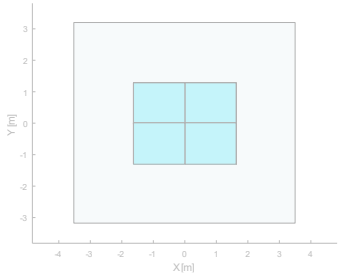
1. Definition parameter set
2. Building clusters of heliostats

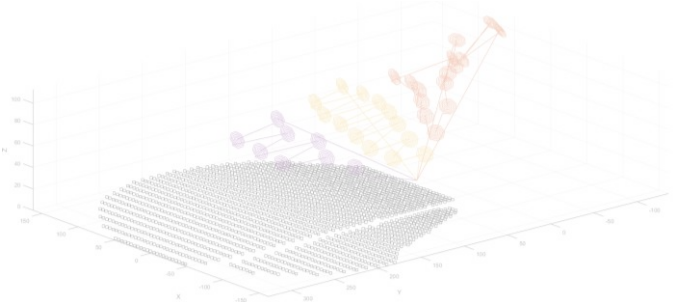
Divide field into subgroups







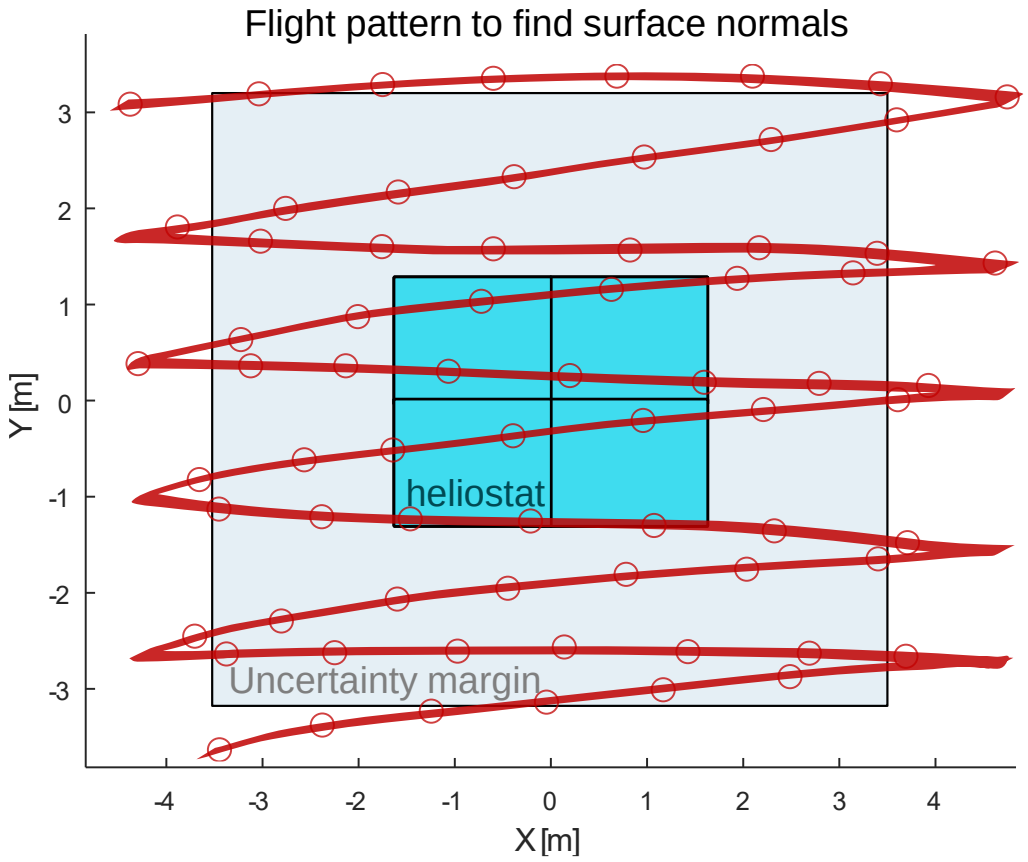


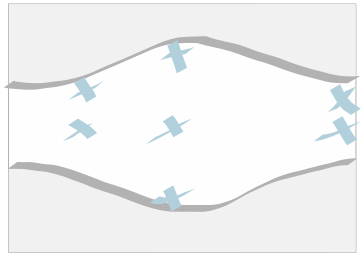


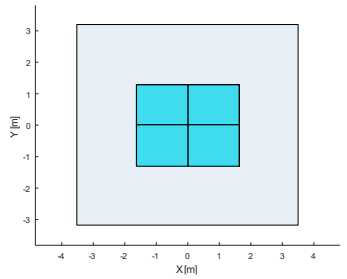
Flight Route Planning

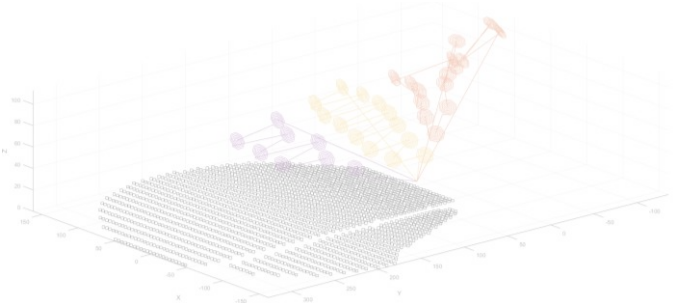
Steps:

1. Definition parameter set
2. Building clusters of heliostats
3. Creating the flight pattern









Flight Route Planning

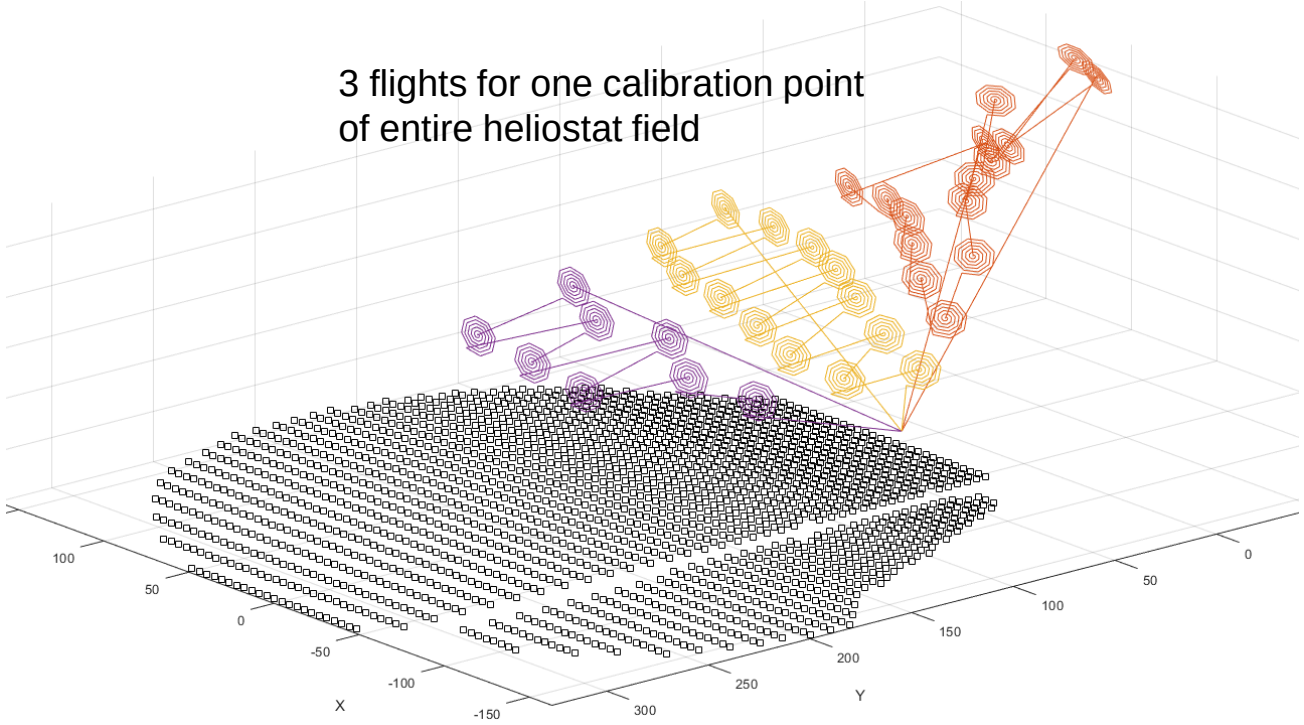
Steps:

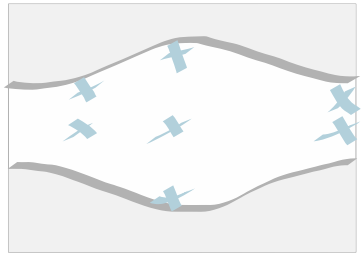
1. Definition parameter set
2. Building clusters of heliostats
3. Creating the flight pattern
4. Deriving flight routes

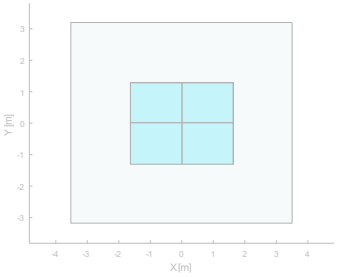
➔ Applicable to industry-sized heliostat fields

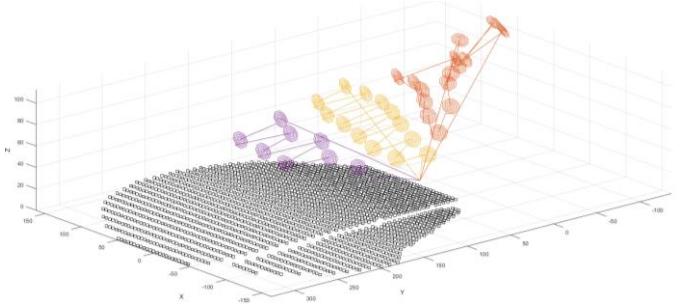
➔ Effort for 50 MW reference-scenario is feasible

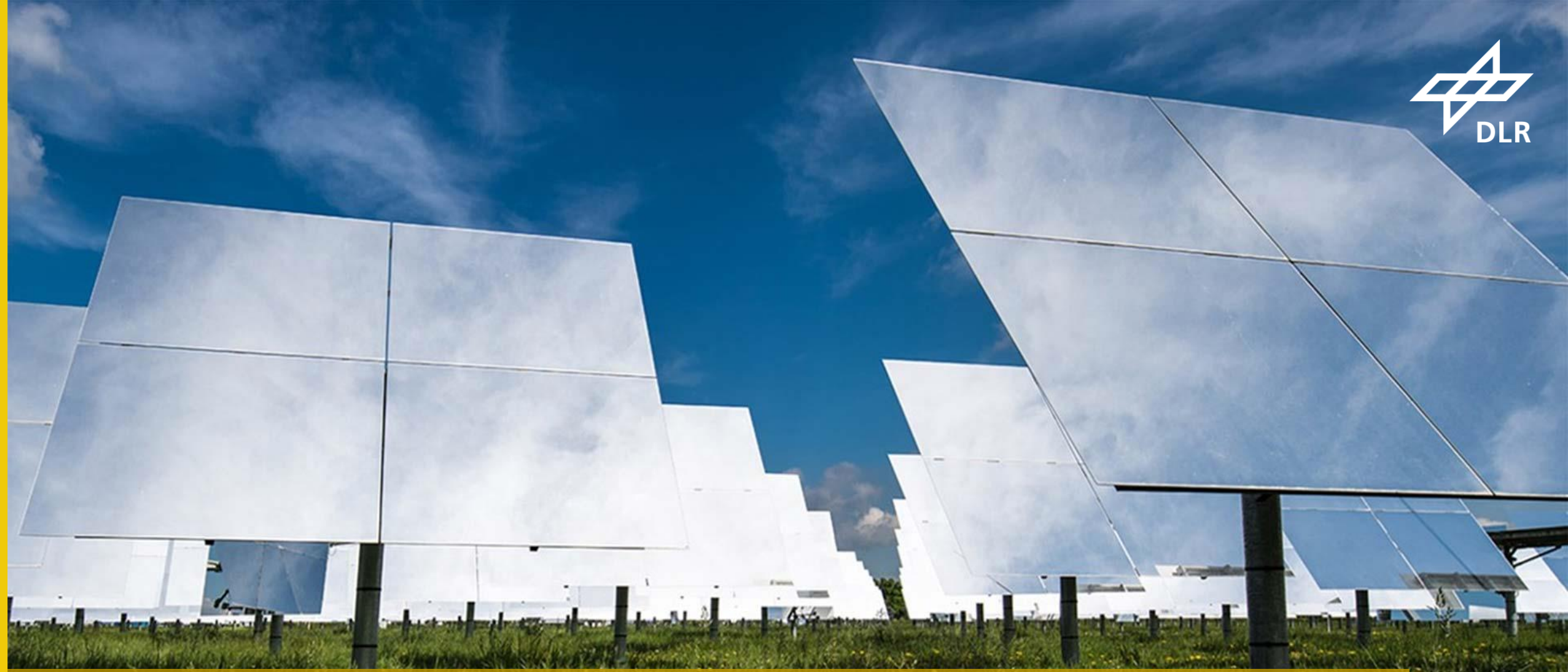
3 flights for one calibration point
of entire heliostat field











DATA ANALYSIS & RESULTS

Image analysis

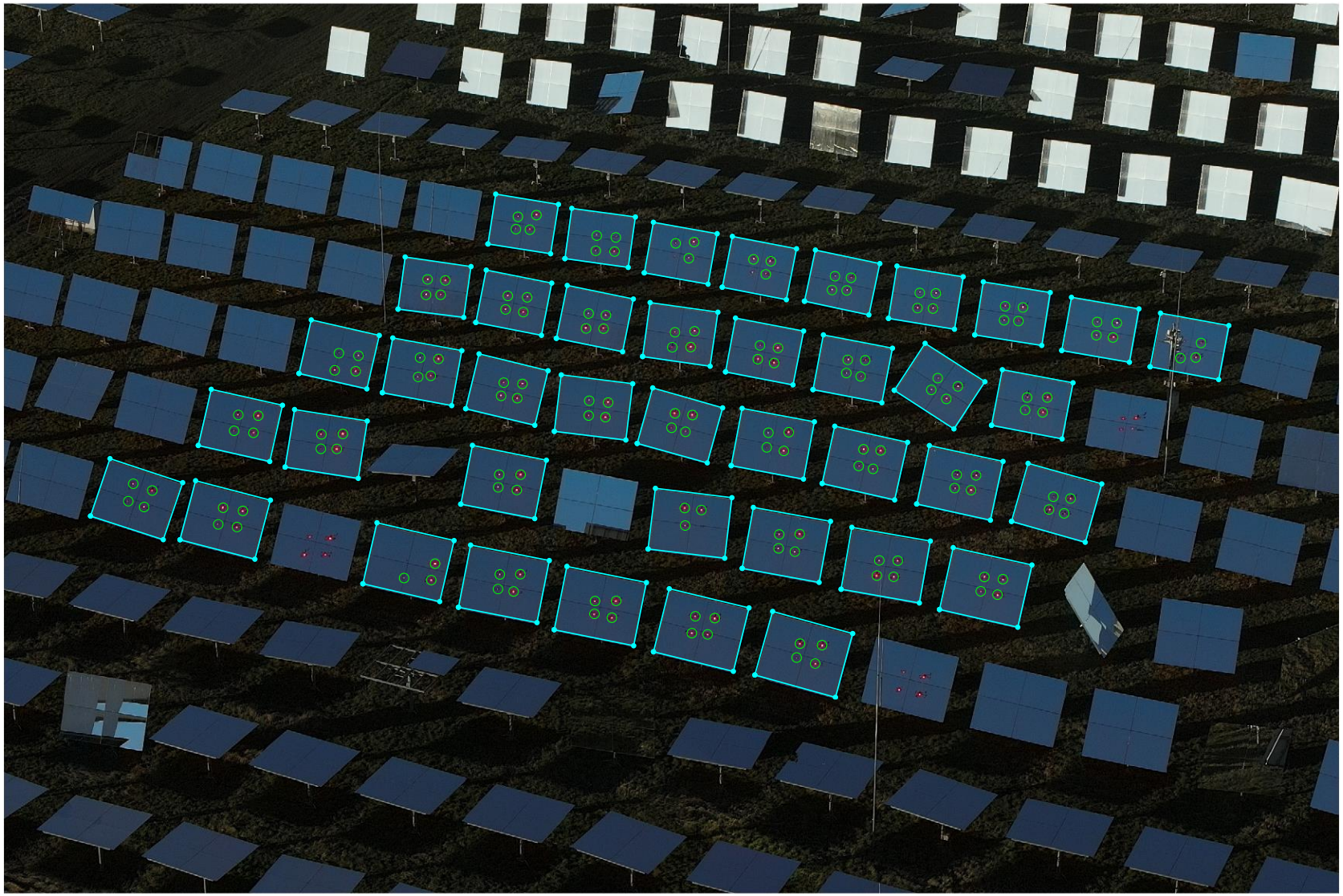
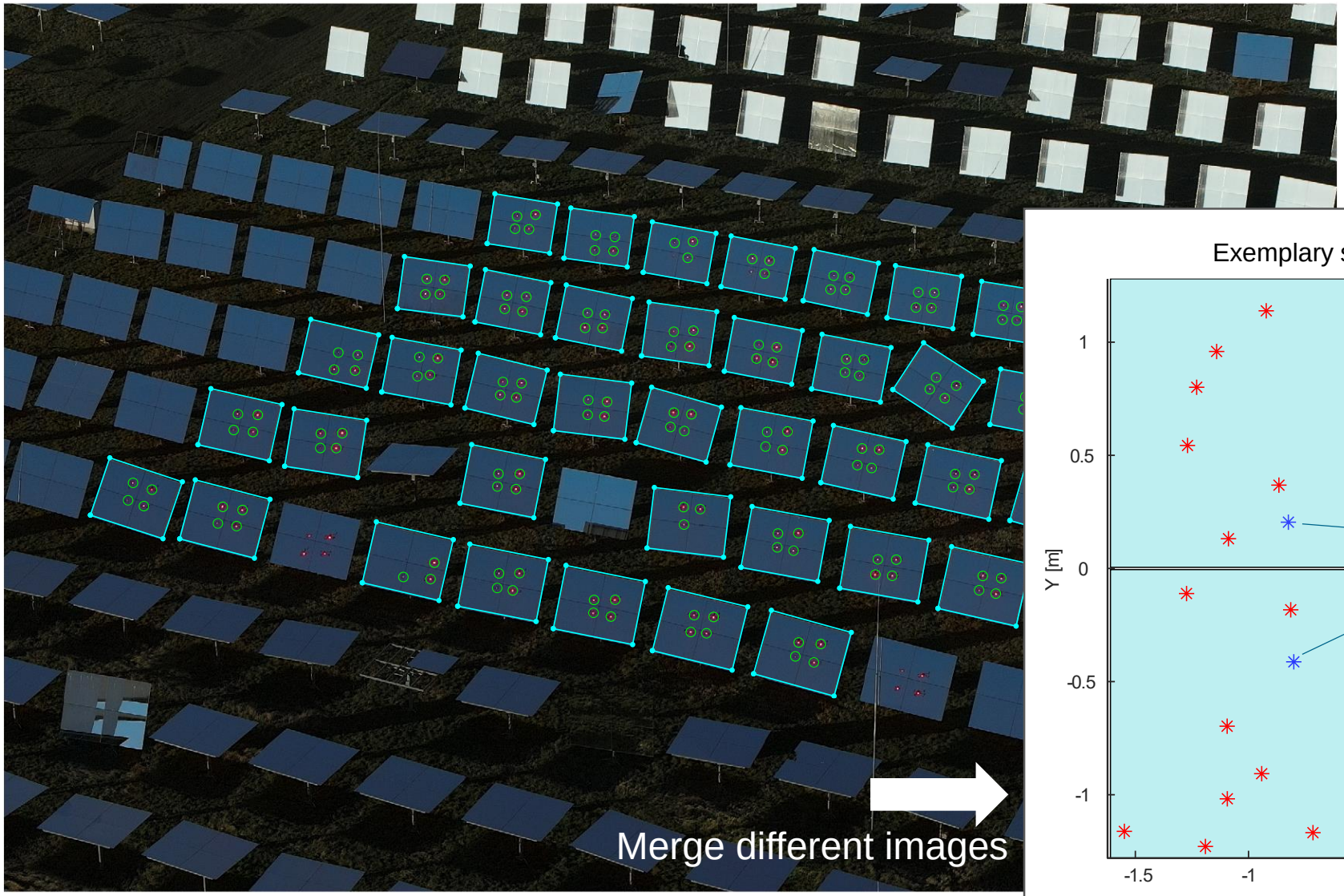
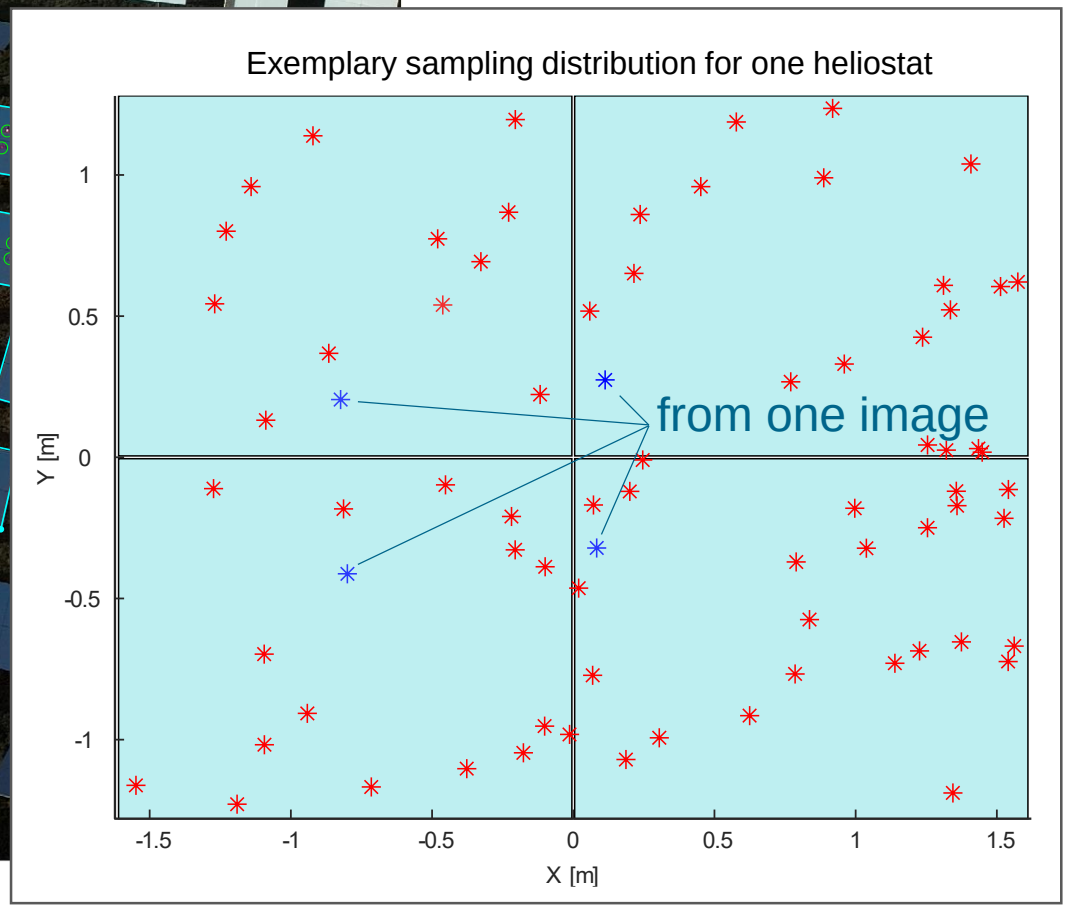


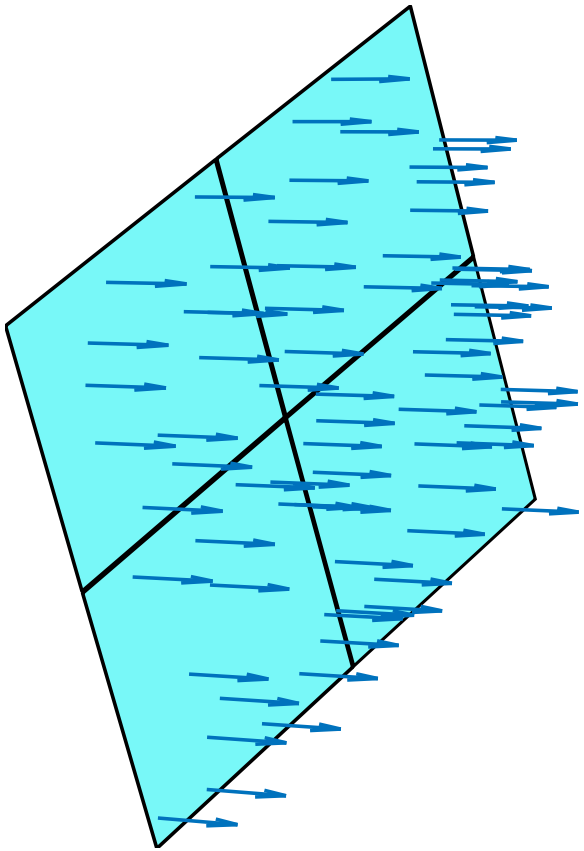
Image analysis





Extract heliostat normal vectors

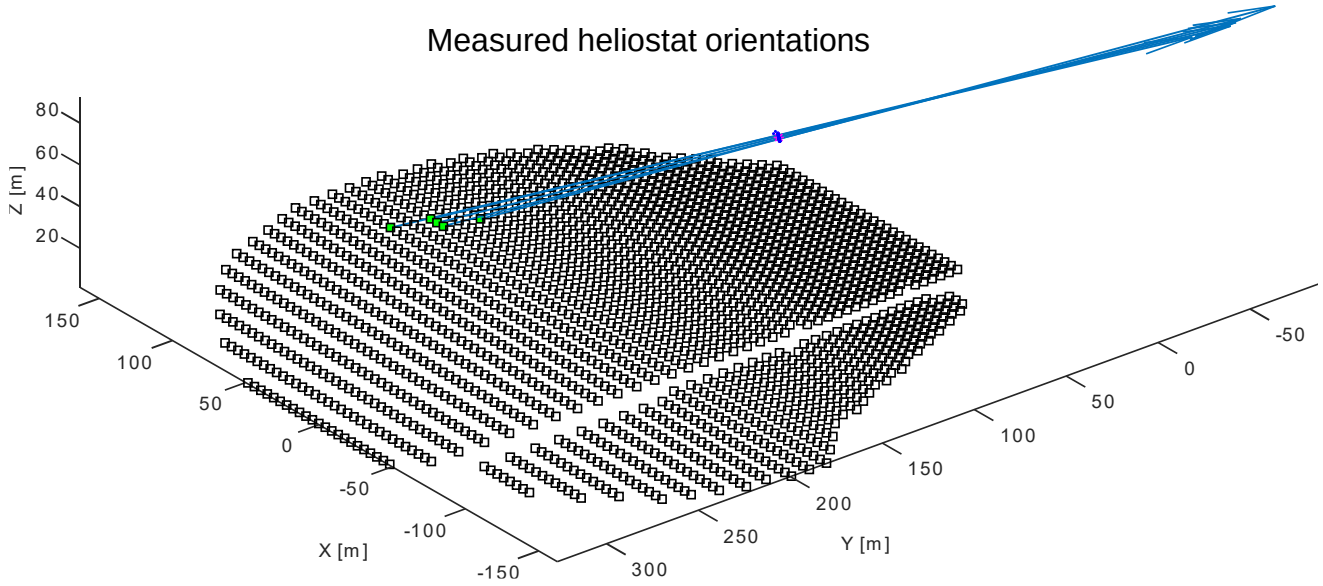
- Calculate normal vectors using drone position and heliostat position



Heliostat surface with local normal vectors

Average

for each heliostat



Results and Conclusion

DLR and CSP Services have developed a fast method for heliostat calibration

- **Projected calibration time of a few weeks** for a common 50 MW plant
- **No further infrastructure required** (but the heliostats)
- **Arbitrary calibration points** can be measured at any time
- Validation tests conducted in early 2023:
  - 5 heliostats were measured with HelioPoint method and compared against precise data obtained with local QDec-H system
  - Average deviation was <0.5 mrad (with 0.2 mrad STD).
- Industrial application readiness within common research project *HelioPoint-II* until end of 2023

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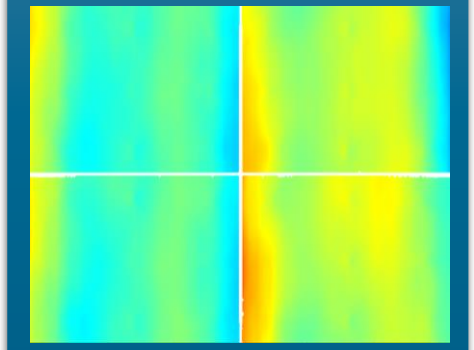
Outlook

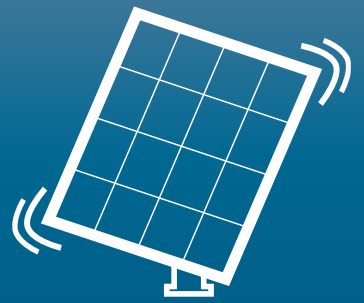
- Development and optimization is ongoing

Calculate slope deviation maps

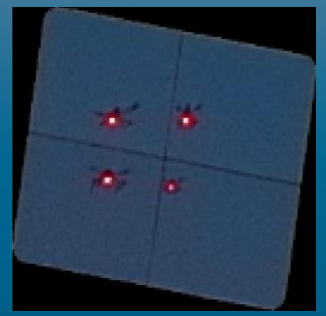


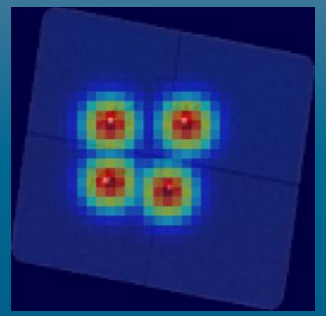
Treatment of overlapping LED reflections

Fully automated flight system (push a button)



Measure heliostats during tracking





Detect reflections using Deep Learning

Imprint

Topic:	**Fast calibration of Heliostats** Development of a fast airborne method for efficient and accurate calibration of entire fields of heliostats.
Date:	2023-06-22
Author:	Julian J. Krauth, Christoph Happich, Niels Algner, Rafal Broda, Andreas Kämpgen, Alexander Schnerring, Steffen Ulmer, and Marc Röger
Institute:	Institute of Solar Research, DLR, in collab. with CSP Services
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