Making the Non-Intrusive Optical (NIO) Method Commercial Ready

ASME
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Photo by Dennis Schroeder, NREL 55200

What is Concentrating Solar Power

- Concentrating Solar Power (CSP) is a type of solar technology that uses mirrors to concentrate solar power to a tower

How Does CSP Generate Power

- Focused sunlight from heliostats heats up liquid in the central tower
- The thermal energy generated is then used to turn a turbine to generate electricity

What are Heliostats

- Heliostats are parabolic mirrors
- They track the sun to reflect sunlight to the central tower

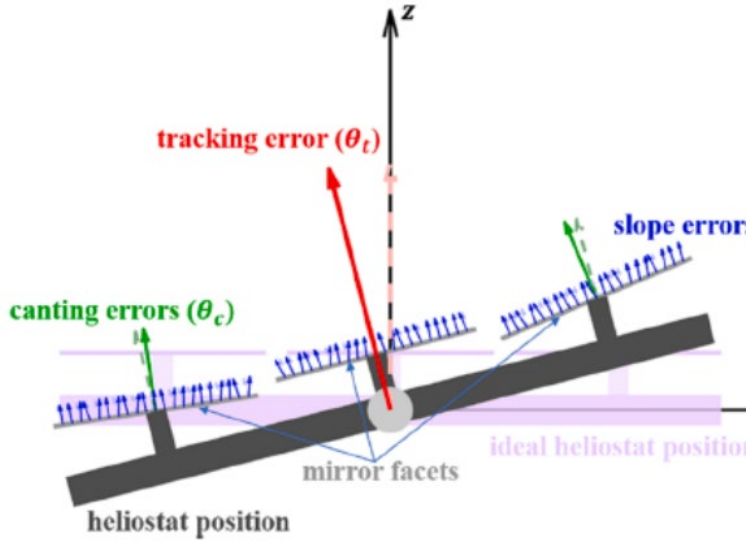
Optical Errors

Why errors matter

- Misalignment with the tower causes significant energy loss
- Loss in energy means loss in money

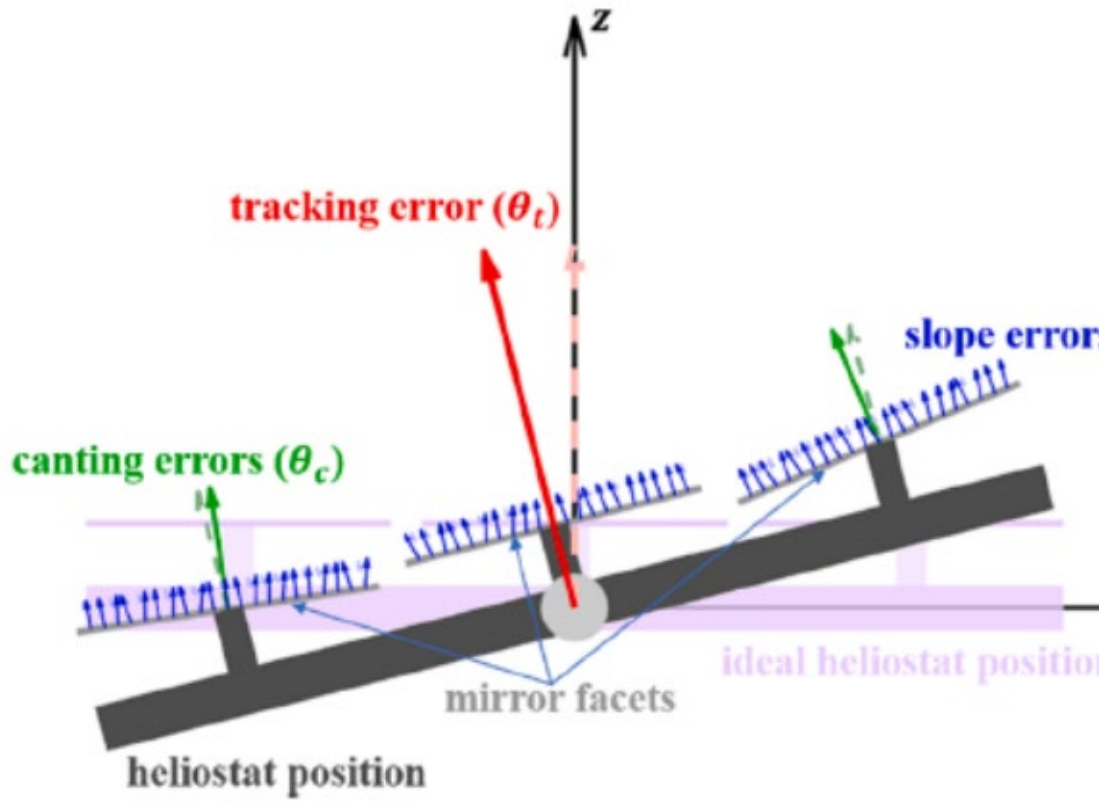
Where they come from

- Manufacturing errors
- Weather
- Wear and tear



3 Types of Optical Error

- **Slope Error:** Microscopic imperfections in the mirror surface
- **Canting Error:** Average slope error across an individual mirror
- **Tracking Error:** Overall orientation error of a heliostat

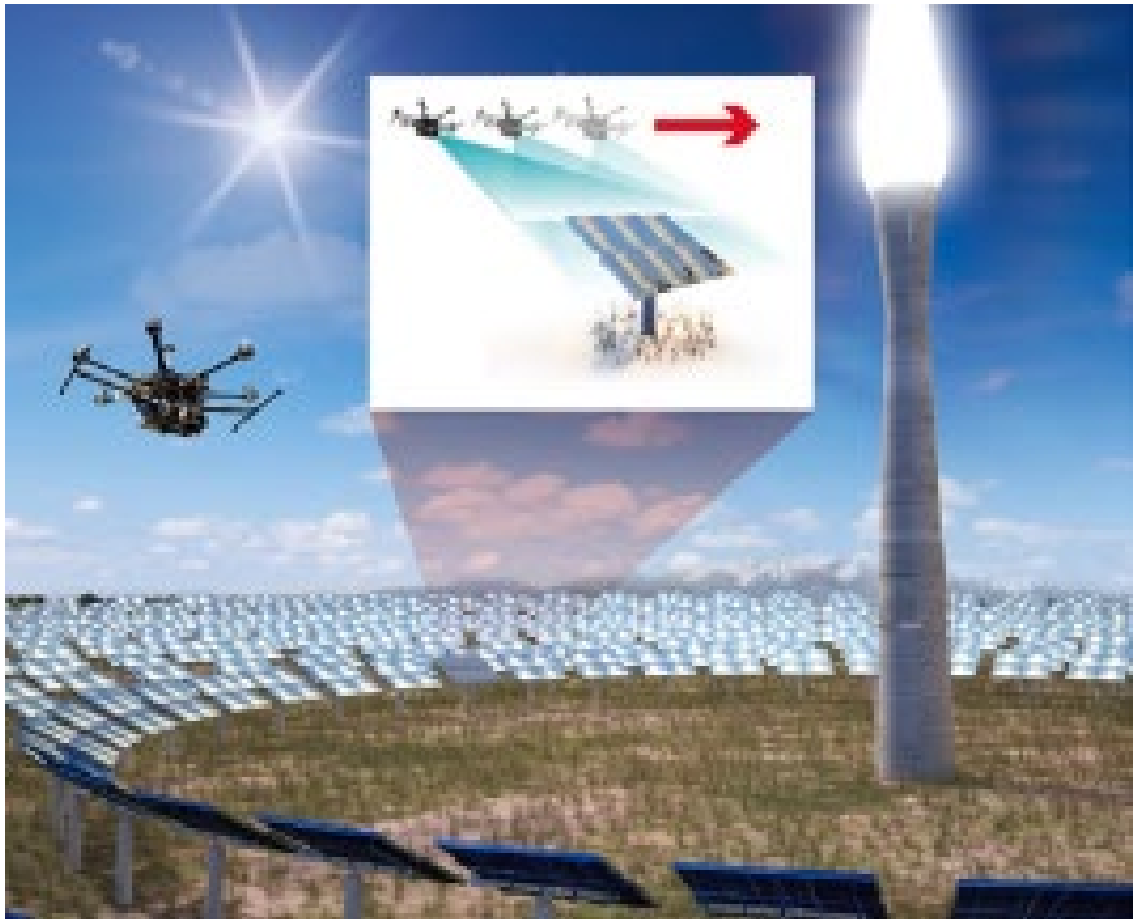


Current Method of Measuring Error

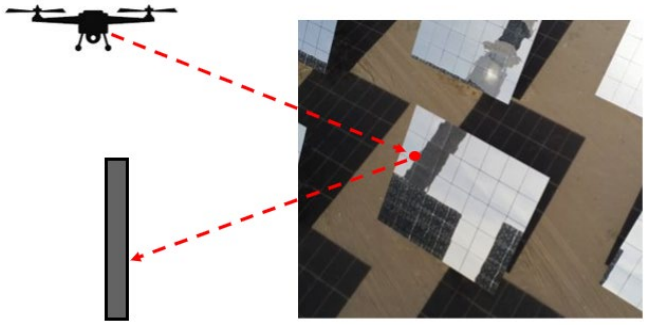
- Current methods are manual
- Risk of increasing heliostat optical errors
- Slow
- Thousands of heliostats

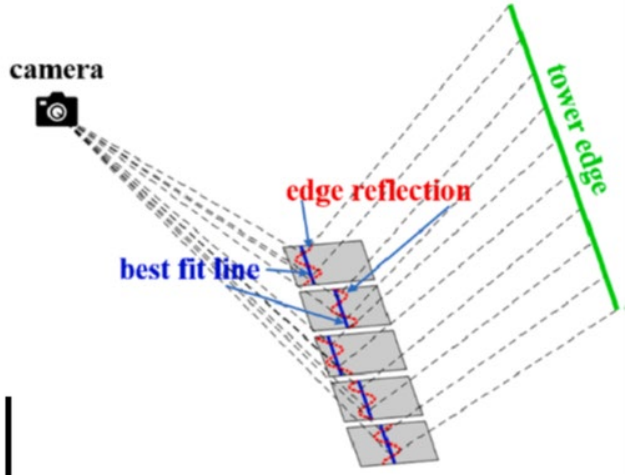
Using Drones to Save the Day

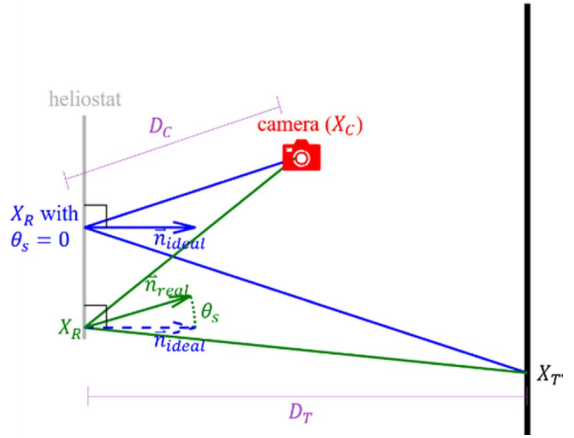
- Using drones, we can take images that capture slope error from the tower reflection in a heliostat
- This allows us to characterize error without altering the heliostat



How Error is Calculated







1. Track the tower in the reflection of the heliostat
2. Identify the location of the edges of the tower
3. Using known field positions and ideal heliostat geometry to predict where the tower should appear in the heliostat reflection
4. Compare the real and ideal position of the tower edge

Why NIO Matters

- Allows CSP field operators to optimize their fields
- Helps create more accurate economic models
- Allows for CSP field to produce more power

Steps to NIO

NIO can be broken down into 3 critical steps:

1. Data Collection

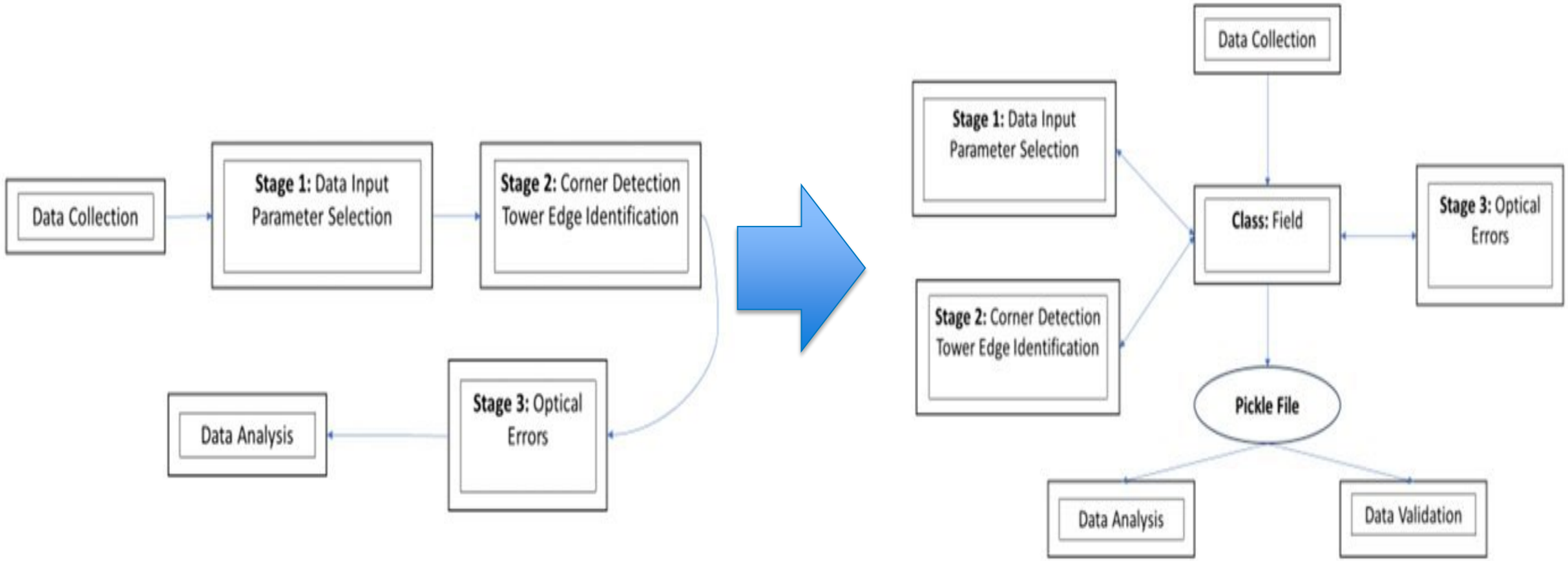
- Creates a flight plan
- Takes images of heliostats on flight path

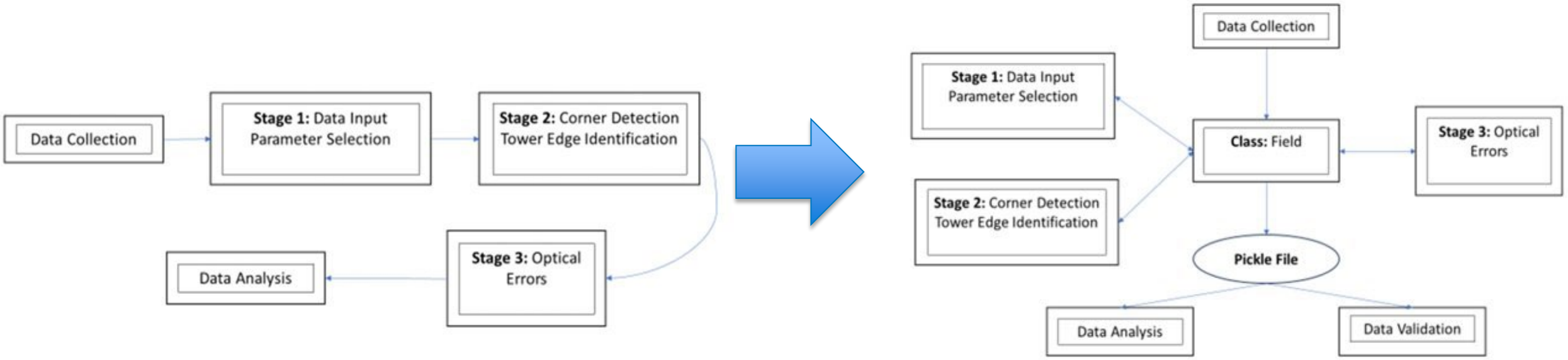
2. Data Processing

- Runs target heliostat corner detection
- Finds tower edges in heliostat reflection
- Calculates error

3. Data Visualization

- Produces data visualization

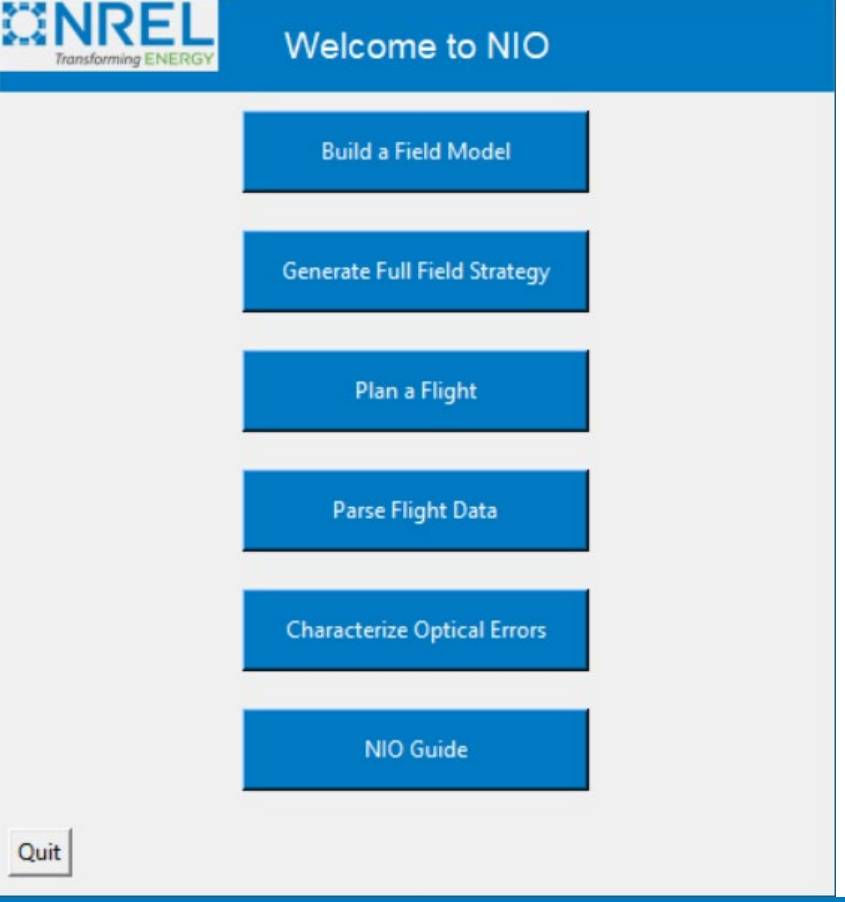

Data Collection
Stage 1: Data Input Parameter Selection
Stage 2: Corner Detection Tower Edge Identification
Stage 3: Optical Errors
Data Analysis
Data Collection
Stage 1: Data Input Parameter Selection
Stage 2: Corner Detection Tower Edge Identification
Class: Field
Stage 3: Optical Errors
Pickle File
Data Analysis
Data Validation

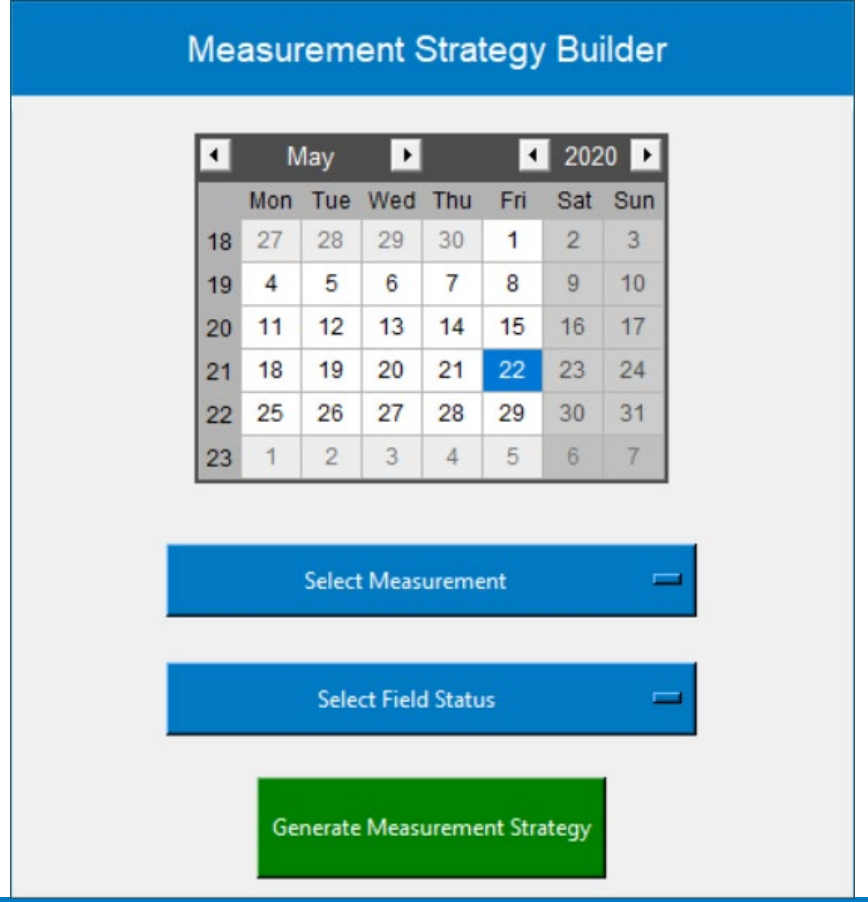


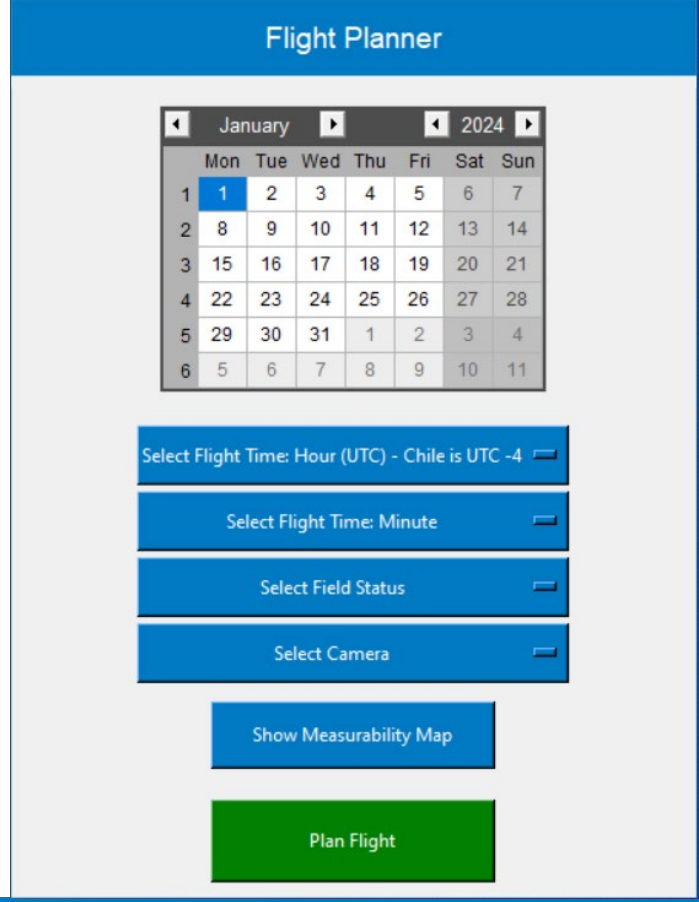
Software Architecture Updates

Prototype to Commercial Software

- Moved to Object Oriented Programming practices
- Modularized the process
- Reduced memory utilization by 20%
- Cut operation time by 33%





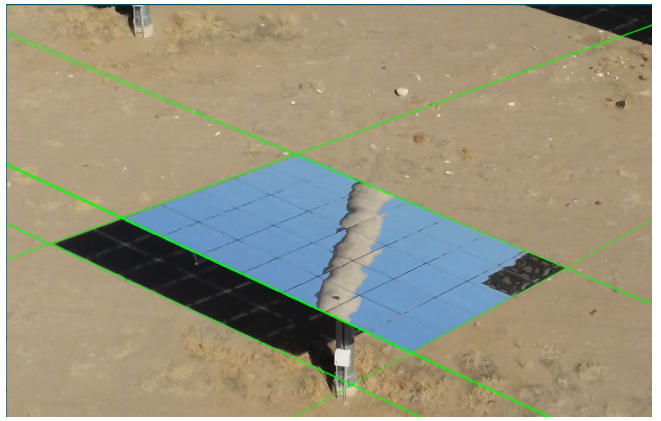


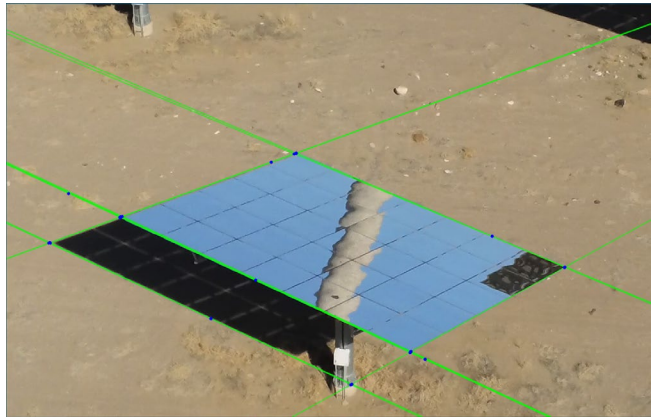
Becoming User Friendly

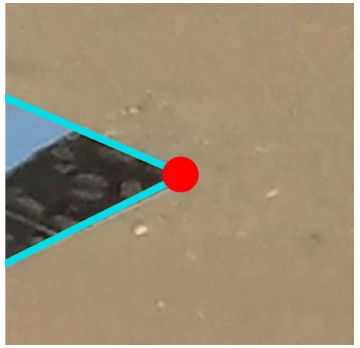
- Flight planner to help users to gain an effective error analysis
- Implemented Graphic User Interface for ease of use

Heliostat Detection

1. User selects the corners of a heliostat in the first image
2. Automation of finding remaining corners
   - Optical Flow
   - Template Matching and edge detection
   - Last resort use previous corners

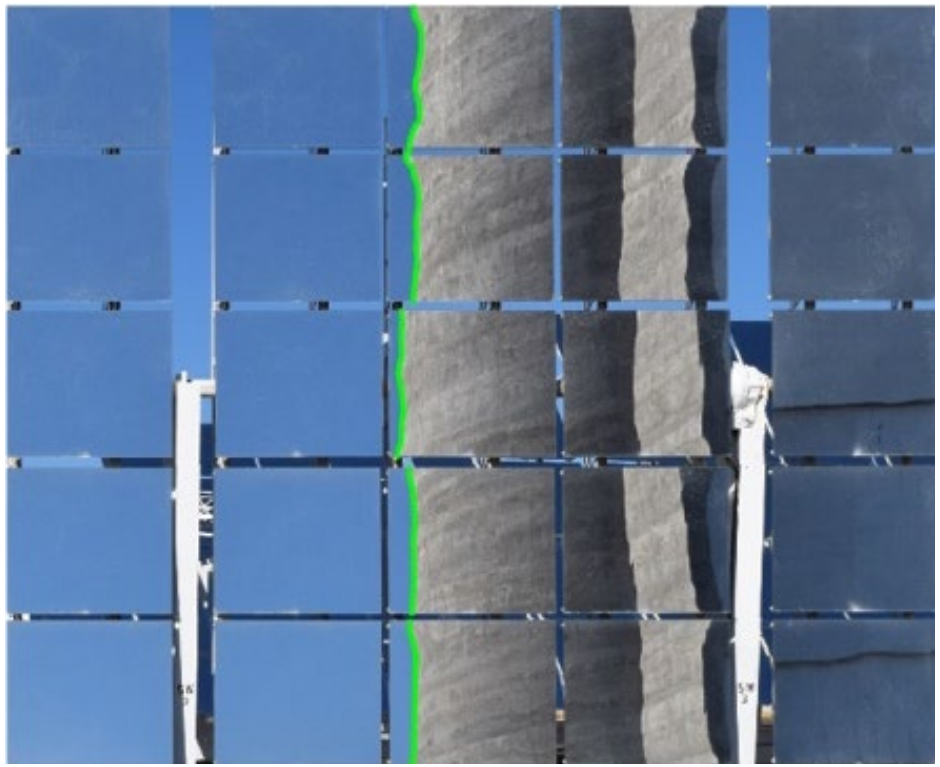




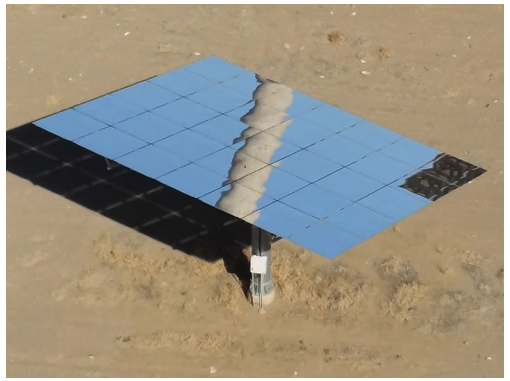


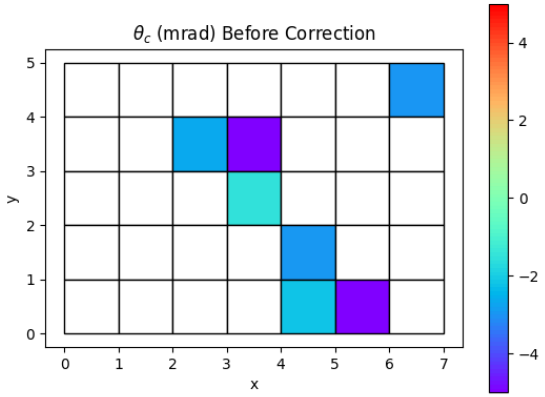
Tower Edge Detection

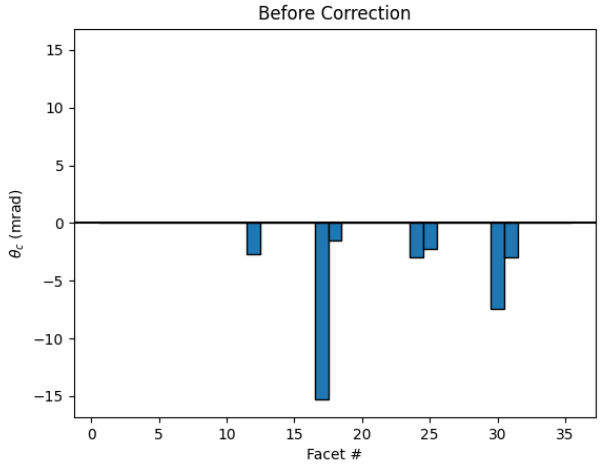
1. Generate a square image of the heliostat
2. Use an 2D search algorithm to identify tower edges

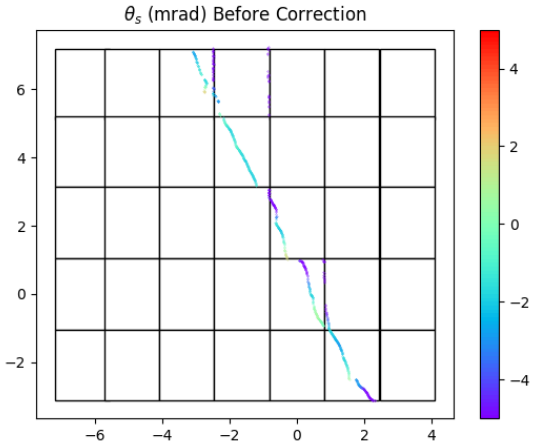


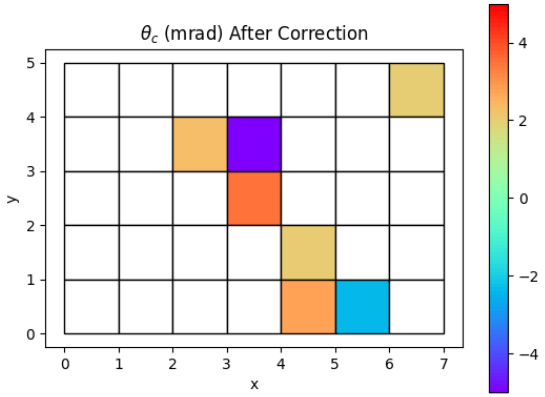
NIO Results

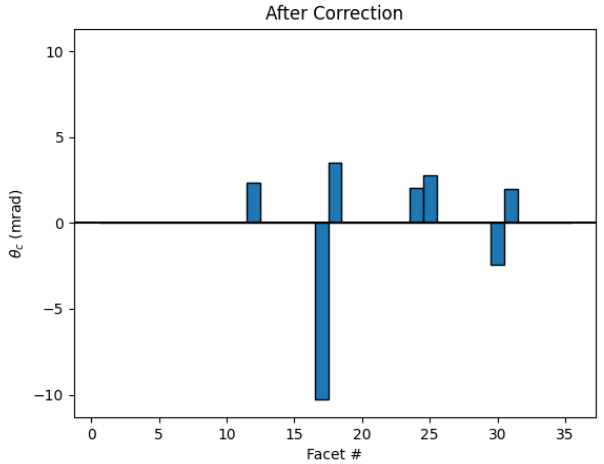



θ_c (mrad) Before Correction
x
y


Before Correction
θ_c (mrad)
Facet #


θ_s (mrad) Before Correction


θ_c (mrad) After Correction
x
y


After Correction
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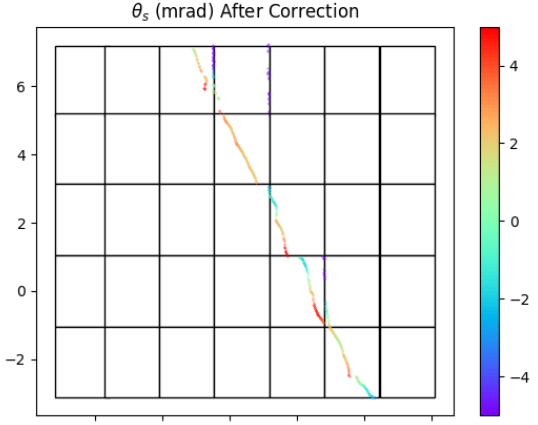
θ_s (mrad) After Correction


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Transforming ENERGY
Thank you
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