U.S. Department of Energy
HelioCon
Heliostat Consortium for
Concentrating Solar-Thermal Power

HelioCon Metrology and Standards

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National Laboratory of the Rockies

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conceptual design • components • integration • mass production • heliostat field

Metrology Accomplishments

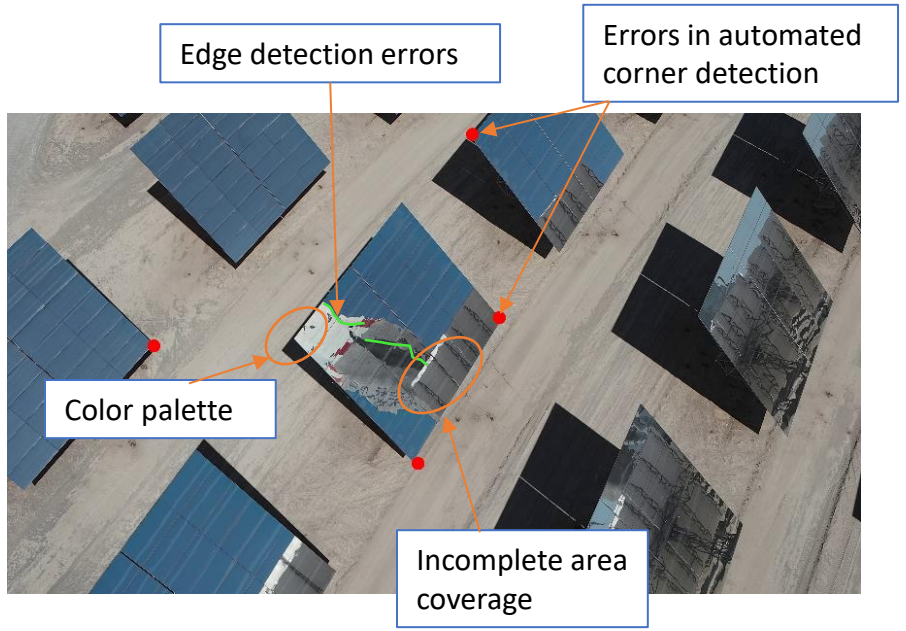
Test Campaign	Date of campaign	Metrology system used	# heliostats measured / processed with NIO	# heliostats measured / processed with ReTNA
Crescent Dunes*	3/30/2022-4/1/2022	NIO	200+ / 5	
Cerro Dominador*	3/28/2024-4/5/2024	NIO	500+ / 8	
Heliogen*	3/4/2024-3/7/2024	ReTNA	-	5 / 5
PSA	9/25/2024-10/1/2024	NIO, BCS	5 / 5	-
Ivanpah*	5/12/2025-5/15/2025	NIO, ReTNA, PG	10 / 3	27 / 14
SolarTAC*	1/10/2025-2/23/2026	ReTNA	-	8 / 8
NLR HFSF	8/28/2025	ReTNA, PG	-	1 / 1

*Contains proprietary commercial data

Next steps:
Internal clarification about existing NDA's and determination in what format reports or modified data could be shared with the public

Conclusions from campaigns:

- ReTNA delivered consistent results in 4 different campaigns and settings
- NIO encountered data processing challenges
  - Lessons learned
  - Rethinking application



Metrology Accomplishments

ReTNA (REflected Target Nonintrusive Assessment)

Advantages:

- Usable outdoors and indoors
- Small, lightweight and low-cost targets
- Highly adaptable and versatile
- No size limit to mirrors by stitching of multi-images
- Measurement uncertainty ± 0.11 mrad (95% confidence)
- Achievable resolution up to 25,000 points per 1 m^2

Limitations:

- System needs to be close to the unit under test
- System struggles with large curvature (< 25 m focal length) or high-frequency errors (surface slope change > 5 mrad per cm).
- Uncertainty depends on quality of initial calibration of marker locations relative to the camera.

Next steps:
Processing code licensing
Public availability of targets and hardware designs

D. Kesseli et al., “Advancements in reflected target nonintrusive assessment (ReTNA) for large optical surface measurement”, https://doi.org/10.1016/j.solener.2026.114417

Metrology Accomplishments

NIO (Nonintrusive Optical Approach)

NIO Lessons Learned Documentation complete

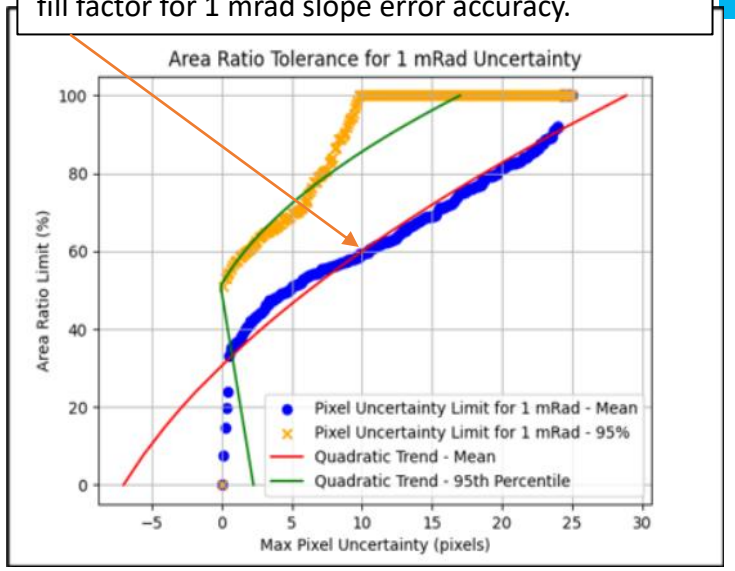
1) No “one-size fits all” data processing solution.
2) Uncertainty of camera has large influence on the measurement accuracy for slope and tracking deviation (up to 10 mrad).
3) Use of the tower reflection as a target creates challenges for obtaining high-quality data.

Two Pathways to move forward with NIO

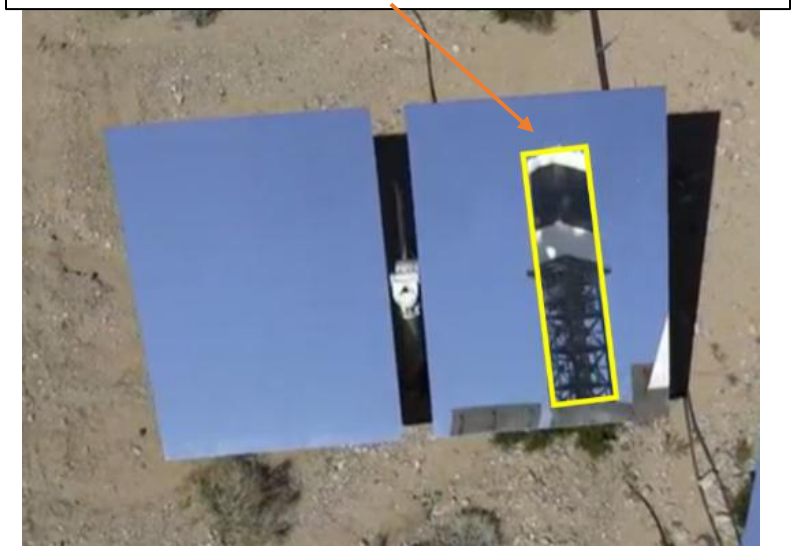
- Use NIO system only for tracking deviation measurements
  - Improved camera accuracy using real-time kinematic (RTK) system
  - Use only tower location in image
- Adapting NIO to leverage other advanced UAS-based measurement techniques
  - Target on drone
  - Soiling & damage assessment
  - UAS-mounted look-back technique (with Sandia)

Next steps:
Implement pathways

For 10-pixel corner uncertainty need 60% image fill factor for 1 mrad slope error accuracy.



Position of whole tower reveals pointing normal vector



Metrology Accomplishments

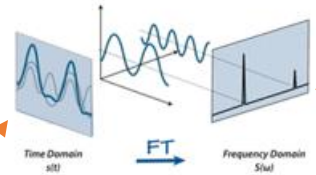
BCS (Beam Characterization System)

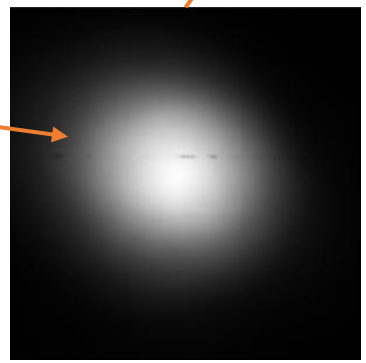
- Collaboration of NLR, IMDEA CENER, ANU, and CYI
- Round robin analysis of over 16,000 artificial BCS images was completed.

Next steps:
Publication of Best Practices Guideline on hardware, image processing and measurement procedures.

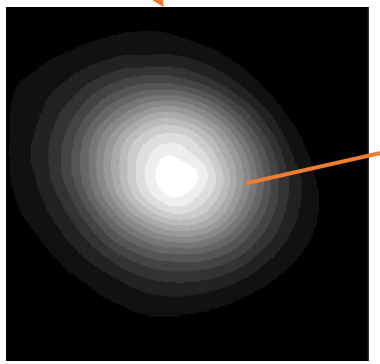
Data acquisition

Denoising



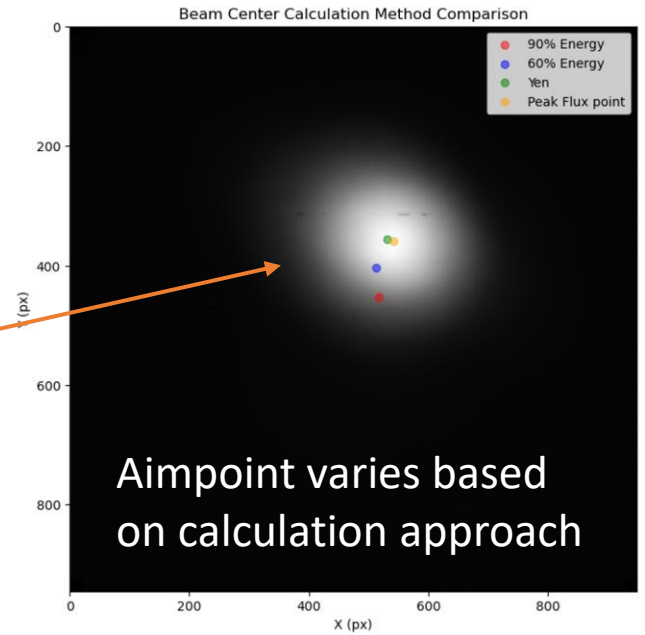


Raw data



Denoised data

Computer vision
Aim calculation

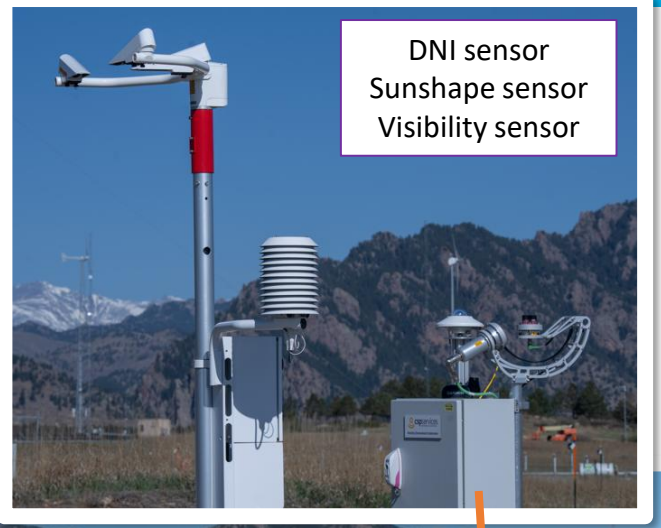


Metrology Accomplishments

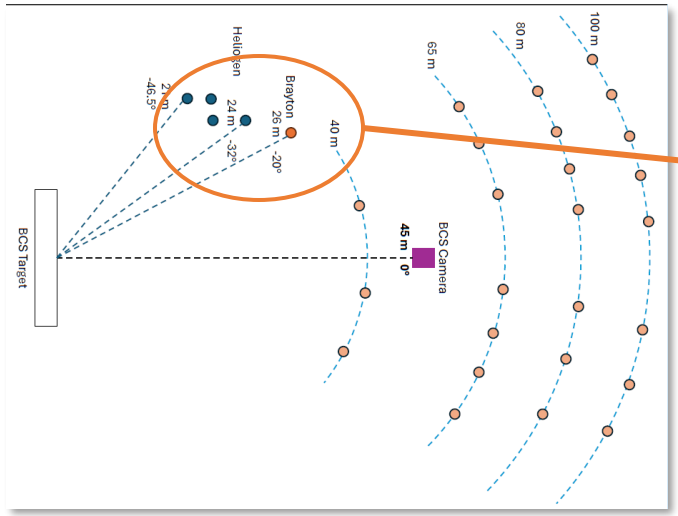
5 installed heliostats with customizable control system

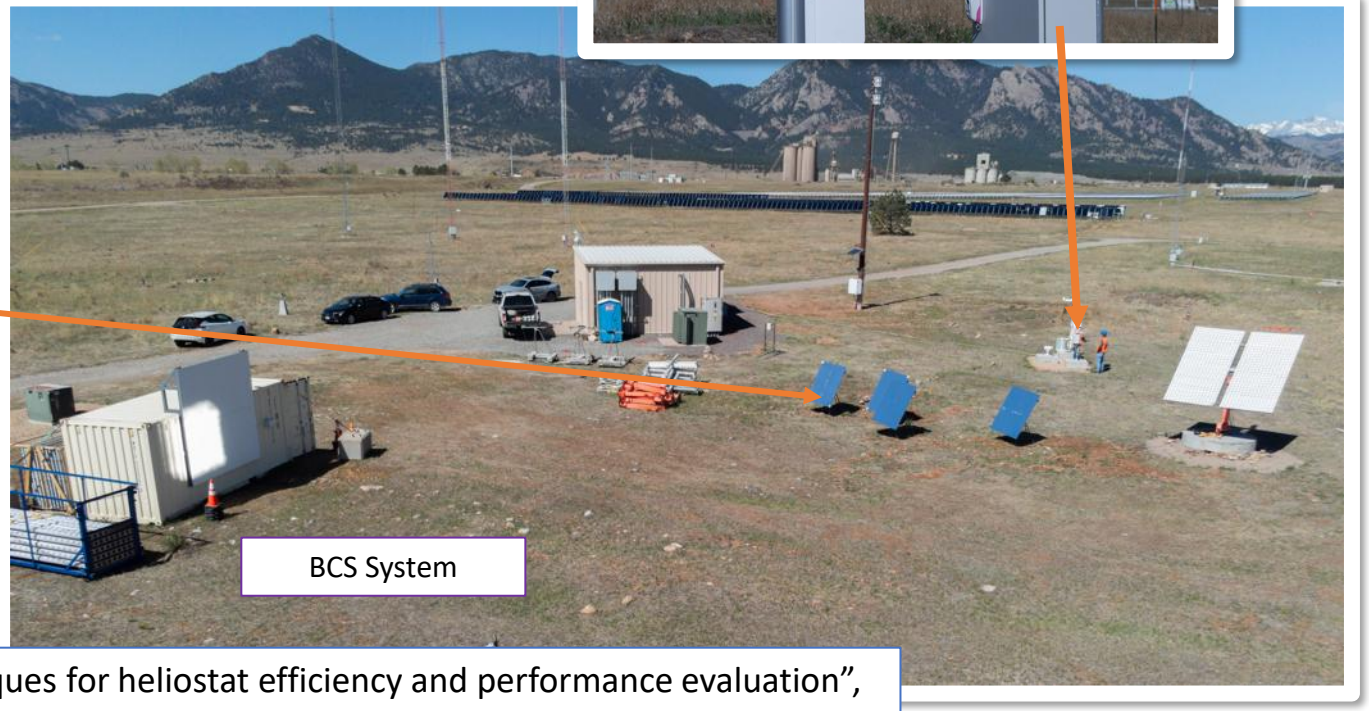
Groundwork for creation of
3rd party metrology platform:

- Standardized heliostat performance characterization
- Characterization of changes over time
- Performance under wind loads



DNI sensor
Sunshape sensor
Visibility sensor



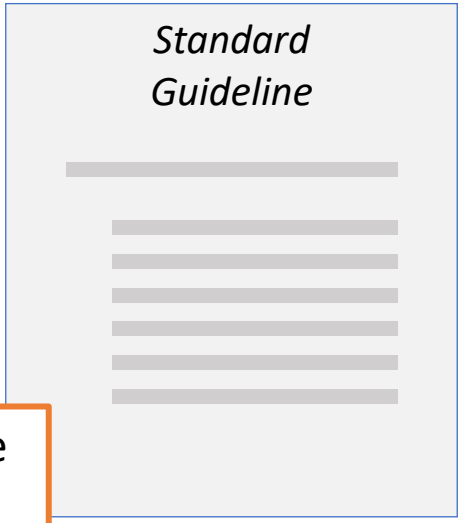


BCS System

S. Meyen et al., "Comprehensive assessment of metrology techniques for heliostat efficiency and performance evaluation", https://doi.org/10.1016/j.solener.2026.114572

Standardization Accomplishments

1) BCS best practices guideline drafted (Round Robin NLR, IMDEA CENER, ANU, and CYI) .
   - ➢ hardware recommendations and compare software and image processing algorithms.
2) "Guideline for Characterizing and Evaluating Candidate Project Sites for Solar Thermal Application" published https://www.nlr.gov/docs/fy26osti/100173.pdf.
3) Report on "Statistical correlation of heliostat pointing deviation with wind" published soon.
4) Steady progress on IEC heliostat design and test standard PT 62862-4-3: 90% complete.



Issues grouped in topic	Status
Wind speed specifications (sections 4.2, 6.5.3–6.5.8, 8.2.11)	**Complete,** a new set of wind speed definitions was formulated.
Angle and deviation definitions (sections 3.14, 6.3)	**Almost complete.** Revisions were received from DLR and Cosin Solar and need to be approved by the group.
Mechanical performance and load testing (section 8.4) ***EXPERT INPUT NEEDED***	**In progress.** It was determined that this section needs a re-write. Cosin Solar provided text based on their best practices and experience. Review in progress
Data processing, tracking accuracy and communication/defocusing (sections 7.2.1.3, 7.2.2.2, 7.3, 8.2.4, 8.2.8)	**In progress.** New edits from Cosin Solar is under review

Challenging because state of the art is inconclusive. More research is needed!

Next steps:

Developing guidelines on:

- Complete IEC standard
- CSP modeling tools and workflows
- Wind speed definitions and measurement relevant for CSP
- Wind speed correlation with static and dynamic loads

Standardization Accomplishments

Remaining Gaps

Central tower specific

- Solar field design and layout guidelines
- Design, selection and testing for absorber materials

Applicable to all collector types including SHIP

- Reliable Soiling assessment
- Wind characterization techniques and guidelines relevant for solar collectors
- Techniques for wind and gravity load characterization on support structures and on optical performance using artificial correlation with actual wind speeds
- Research and model development on implementing real measurement slope and tracking data into raytracing models and extrapolate to high fidelity full field performance prediction that can be validated with actual performance

Plans for FY27:
Address remaining gaps in guidelines.
Produce accessible data and upgrade models

Questions?

To participate in Guidelines and IEC Standards
or have a heliostat tested at Flatirons:

Contact Stephanie.meyen@nlr.gov
Matthew.neber@nlr.gov

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