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

2023 Heliostat Consortium (HelioCon) Workshop: Project Highlight at NREL

Guangdong Zhu, NREL

On behalf of HelioCon's NREL team

July 12th, 2023 • 2023 HelioCon Workshop: Summary Session • Washington DC

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

HelioCon: Team

- Leadership team:
  - NREL researchers and administrative support
    - Lead: Guangdong Zhu, Ph. D.
  - Sandia researchers
    - Lead: by Margaret Gordon, Ph.D.
- Non-voting members:
  - ASTRI: Australian Solar Thermal Research Institute
- Board of Advisors
  - Utility, developers, plant owners, component suppliers, EPCs, Academia, standards and international advisors
- Members
  - RFP awarded project performers
  - Other Consortium funded project performers and cost-share providers.
- Non-consortium stake-holders
  - Subject-matter experts; U.S. and international institutions.

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
SOLAR ENERGY TECHNOLOGIES OFFICE

NREL Transforming ENERGY

Sandia National Laboratories

ASTRI Australian Solar Thermal Research Institute

CSIRO Australia's National Science Agency

Australian National University

THE UNIVERSITY of ADELAIDE

QUT

SolarDynamics

THE UNIVERSITY OF NEW MEXICO

THE UNIVERSITY OF ARIZONA

Northeastern University

SARCOS

TIETRONIX

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NREL Team


Chad Augustine


Raven Barnes


Miriam Coron


Jack deBloois

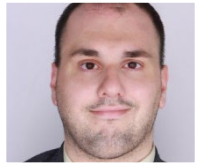

Mackenzie Dennis


Rebekah Durand


Ulrike Egerer

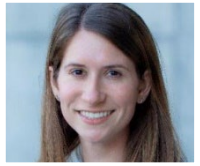

Tucker Farrell


Cindy Gerk


Mike Grabel

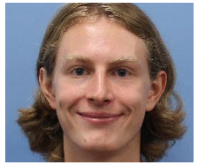

Patrick Hayes


Kyle Heinzman


Maggie Kautz


Mojo Keshiro


Devon Kesseli


Louis King


Parthiv Kurup


Dylan Mayes


Mark Mehos


Rebecca Mitchell

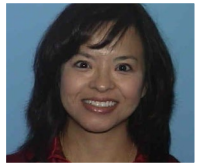

Matt Muller


Jessica Roe

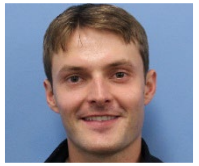

Gabriel Shuster


Katelyn Spadavecchia


Brooke Stanislawski


Linh Truong


Daniel Tsvankin


Evan Westphal


Shashank Yellapantula


Guangdong Zhu


Alex Zolan

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Outline

- HelioCon management
  - HelioCon website
  - HelioCon seminars
- Metrology & standards
  - NIO technology
  - ReTNA technology
  - NREL third-party platform development
- Components & controls
  - Composite heliostat design evaluation
  - Heliostat design qualification standard
- Field deployment
  - Third-party high-fidelity solar field performance prediction model
  - Wind load characterization
  - Analysis of Heliostat O&M at Ivanpah
- Techno-economic analysis
  - Process heat system of heliostats
- Resources, Training and Education
  - HelioCon database
- International collaboration
  - Ray-trace round robin test
  - Laboratory slope error metrology round robin

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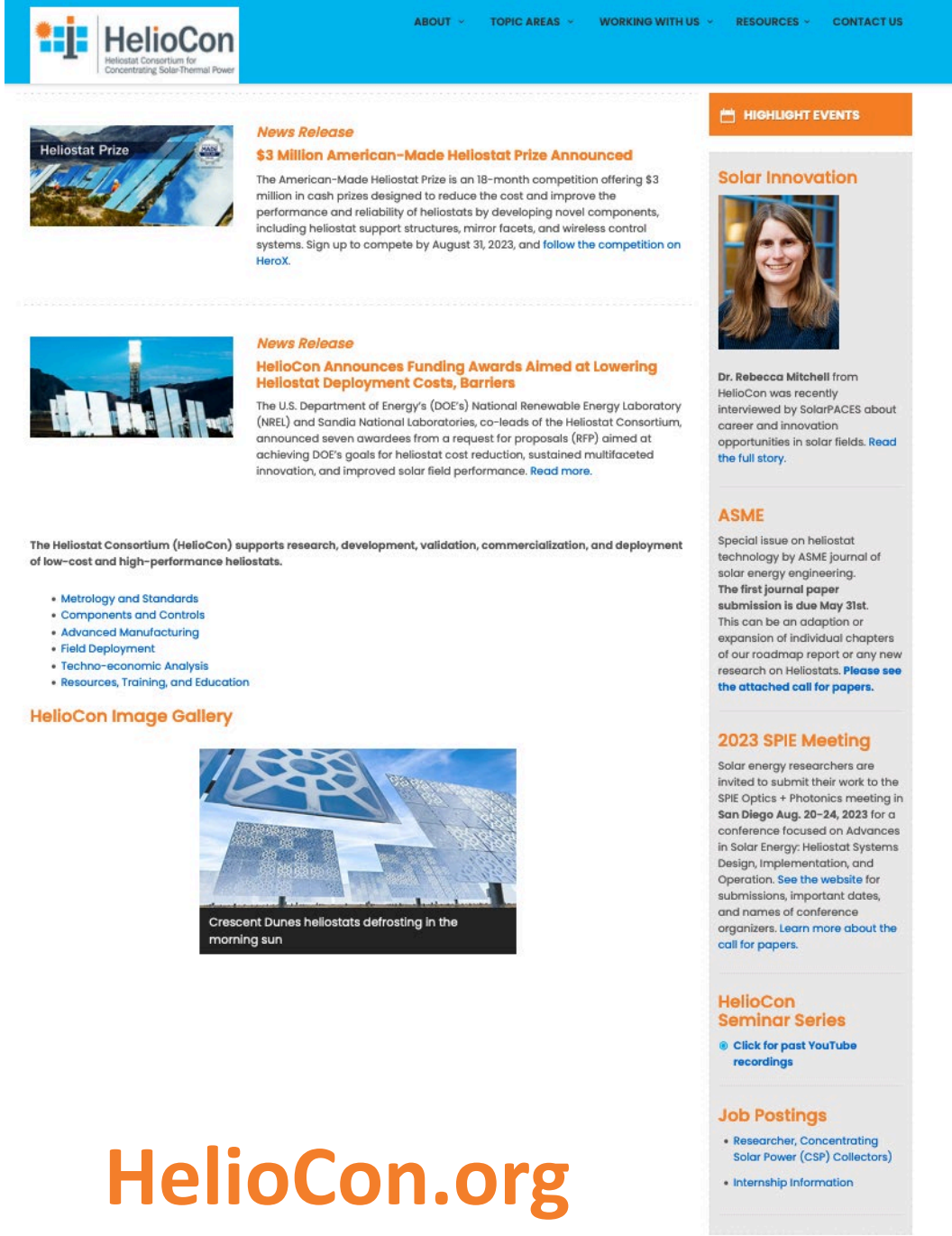
Project: HelioCon Website

- **Objectives**
  - Create a place to promote the heliostat technology and its application
  - Create a place to share the resources with the public
- **Approaches**
  - An independent website with prompt updates
- **Status**
  - Fully developed website framework
  - Timely update the contents
  - increasing visits
- **Leads:** Cindy Gerk, Patrick Hayes



HelioCon.org

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Project: HelioCon Seminars

- **Objectives**
  - Share the knowledge and insights of top-notch experts to the whole communities
- **Approaches**
  - Host, record and share seminars with the public
- **Status**
  - 16 expert seminars
  - 2 training seminars
- **Lead:** Rebecca Mitchell

HelioCon Seminar Videos

Date	Title	Instructor	Video Link	Training Documents
April 10, 2023	CSP Tower Technology: 10+ Years of Innovation and 35+ Years of Mature Prior Innovation	Yoel Gilon	video	Slides, Flyer
March 1, 2023	Introduction of the 2022 CSP Blue Book of China	Zhifeng Wang	video	Slides, Flyer
February 1, 2023	Solar Field for CSP Tower Technology: Best Practices and Lessons Learned in Operational Commercial Projects	Raul Gonzalez Marcelo	video	Slides, Flyer
November 9, 2022	Mitigating Unconscious Bias in Work Teams	Anelisa Simons SNL	video	Slides, Flyer
October 19, 2022	Transferring Photovoltaic lessons learned to Concentrating Solar Power	Dr. Matthew Muller, NREL	video	Slides, Flyer
August 11, 2022	Advanced Manufacturing for Heliostats – What We Can Learn from Automotive Joining Technologies, Materials, and Automation	Wagon Wills, Gonzalez Group Dr. Randy Brost, Sandia	video	Slides, Flyer
August 1, 2022	13 HelioCon Interns, NREL/SNL/DOE	13 HelioCon Interns, NREL/SNL/DOE	video	Slides, Flyer
July 13, 2022	Heliostat Aerodynamics and Wind Load: Characterization and Prediction in Atmospheric Boundary Layer	Matthew Emes, University of Adelaide	video	Slides, Flyer
June 29, 2022	Soiling Losses for Concentrating Solar Power – Prediction, Assessment, and Mitigation	Dr. Michael Cholette, Queensland University of Technology	video	Slides, Flyer
June 8, 2022	Bottom-up Analyses for Two Heliostat Collectors and an Initial Heliostat Supply Chain	Parthiv Kurup, NREL	video	Slides, Flyer
May 18, 2022	Heliostat Components and Controls	Dr. Ken Armijo, Sandia	video	Slides, Flyer
April 13, 2022	Economies of Scale – Field Deployment Considerations to Accommodate Evolving Energy Markets	Dr. Jeremy Sment, Sandia	video	Slides, Flyer
March 30, 2022	What's Looking Up Down Under? Progress of Australian Solar Thermal Research Institute (ASTRI) Heliostat Activities	Mike Collins, CSIRO Energy	video	Slides, Flyer
March 16, 2022	Resources, Training, and Education for the Heliostat Workforce	Dr. Rebecca Mitchell, NREL	video	Slides, Flyer
February 16, 2022	An Undervalued Foundation for Heliostat Technologies - Optical Characterization, Modeling, and Measurement	Dr. Guangdong Zhu, NREL	video	Slides, Flyer
February 3, 2022	Technoeconomic Analysis of Heliostat Technologies	Dr. Chad Augustine, NREL	video	Slides, Flyer
January 12, 2022	CSP Capabilities at the National Renewable Energy Laboratory	Mark Mehos, NREL	video	Slides, Flyer
December 8, 2021	CSP Capabilities at Sandia National Labs	Dr. Margaret Gordon, Sandia	video	Slides, Flyer

HelioCon Training Videos

Date	Title	Speakers	Video Link	Seminar Documents
May 19, 2022	HelioCon SolTrace Tutorial Session I: A Beginner's Overview	Al Lewandowski	video	Files
August 1, 2022	HelioCon SolTrace Tutorial Session II: Implementing Advanced Geometries	Al Lewandowski	video	Files

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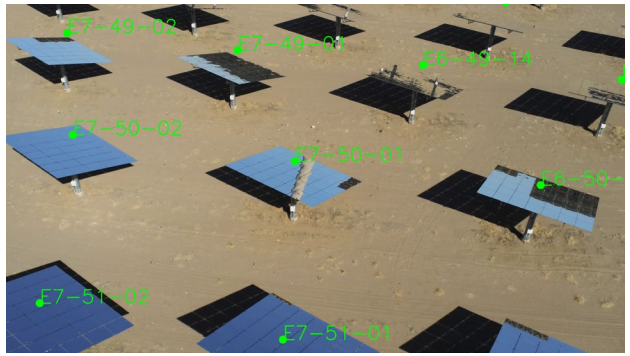
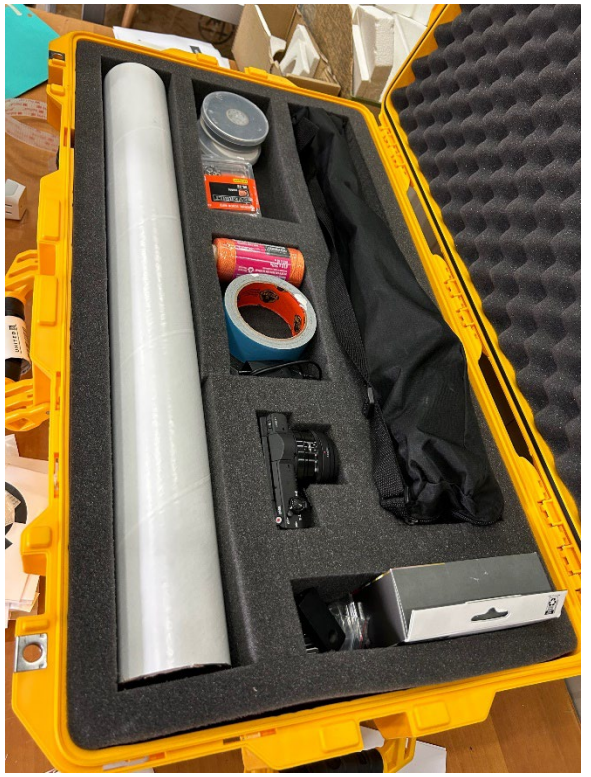
Project: NIO Technology

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



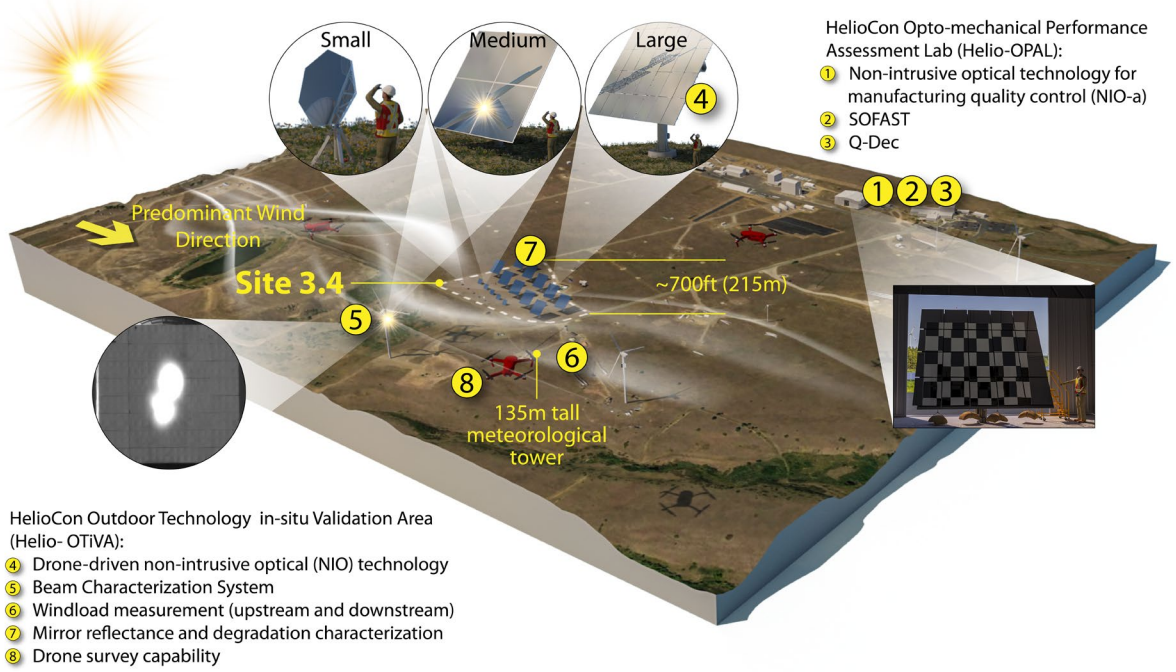
Project: ReTNA Technology

- **Objectives**
  - Laboratory technology suitable for single heliostat prototype
  - Portable, efficient and automatic
  - Measure slope error, canting error
    - Varying orientation
    - Varying load
- **Approach**
  - Deflectometry & photogrammetry
  - Automated image-processing through computer vision and machine learning
- **Status**
  - Completed concept-proof stage
  - Building a prototype at NREL
- **Lead**: Devon Kesseli



Project: Third-Party Evaluation Platform at NREL's Flatirons Campus

- **Objectives**
  - Make available third-party heliostat performance assessment capabilities to serve CSP industry.
    - evaluation of heliostat designs under indoor and outdoor conditions
    - validation of newly developed metrology technologies by others
- **Approach**
  - Develop/acquire, install and calibrate most-advanced metrology technologies within HelioCon
  - Demonstrate the test capability with a case study
  - Call for test services on commercial heliostat designs
- **Status**
  - Developing new techniques
- **Lead**: Rebecca Mitchell



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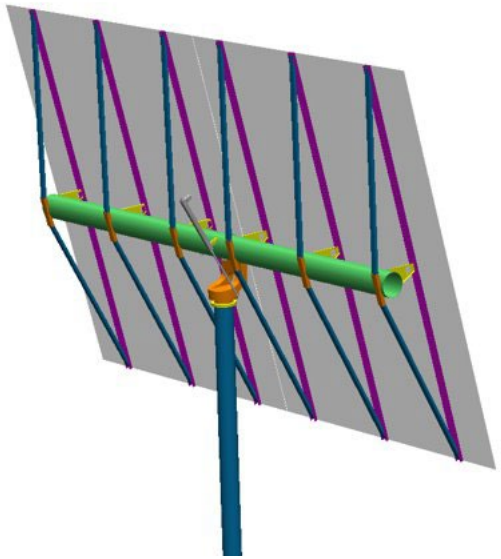
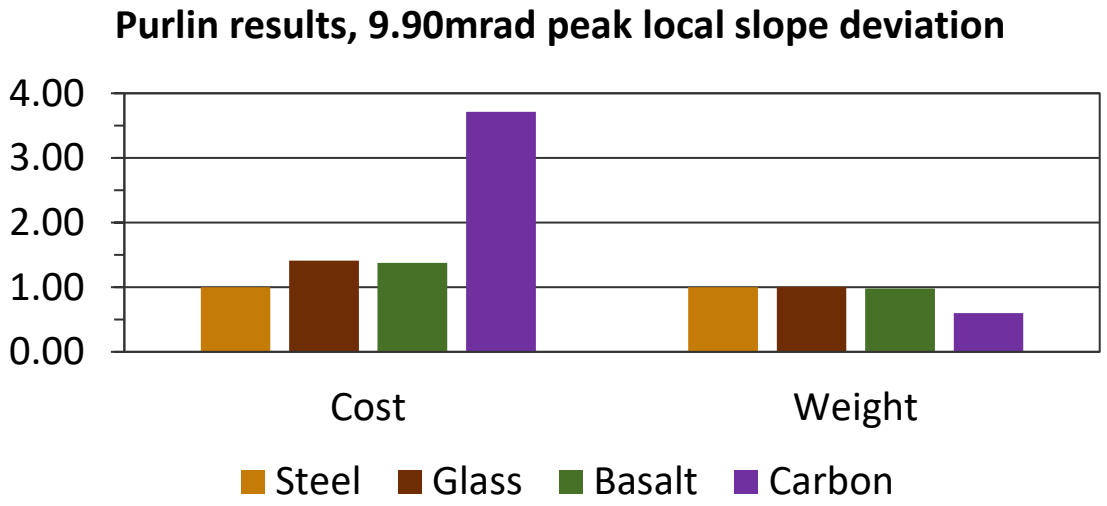
Project: Composite Heliostat Design Evaluation

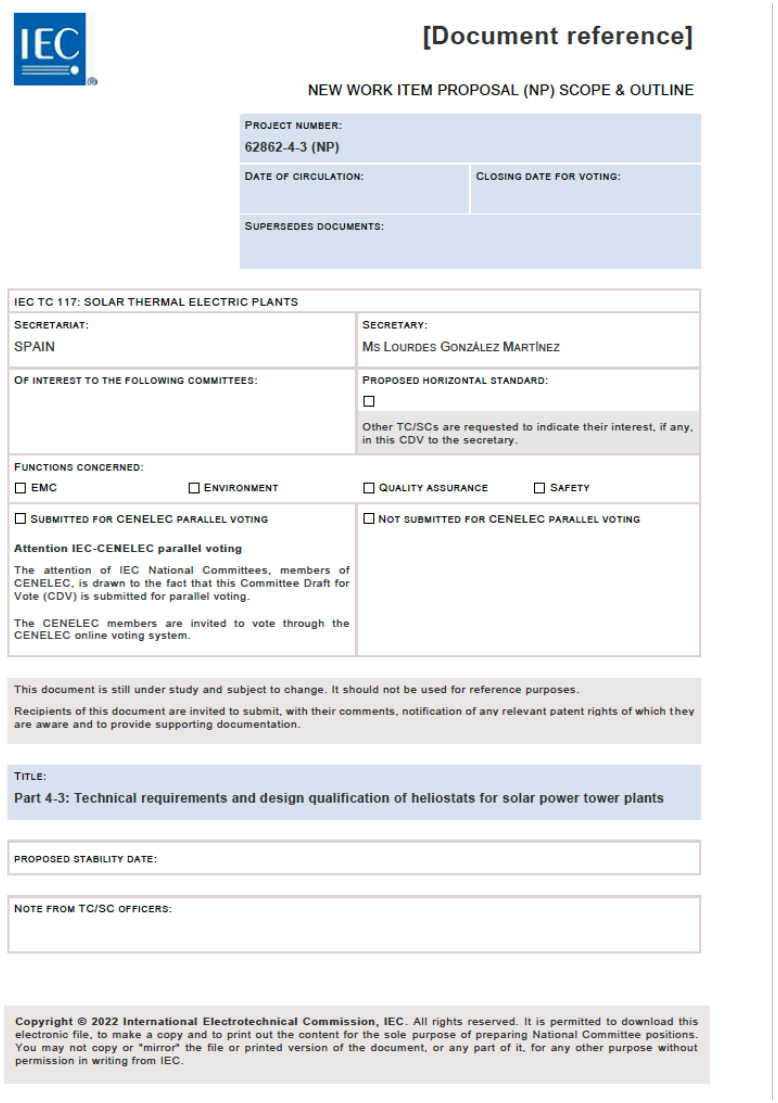
- **Objectives**
  - Evaluate potential of composite materials for heliostat mirror facets and structure for meeting the DOE cost target goal: $50/m2
- **Approach**
  - Perform initial design optimization for reducing heliostat cost
  - Carry out cost comparison between composites and the state of art materials/design
- **Status**
  - Initial results discourage use of unidirectional composites; structural facets (sandwiched composites) or alternatively-designed heliostats optimized for composite beams suggested
- **Leads:** Matt Muller, Daniel Tsvankin





Project: Heliostat Design Qualification Standard

- **Objectives**
  - Develop a standard on: Technical requirements and design qualification of heliostats for solar power tower plants
- **Approach**
  - NREL is co-leading the development with Cosin Solar from China
- **Status**
  - Working group has been formed
  - New standard proposal was just submitted to IEC for the NP approval.
- **Lead**: Daniel Tsvankin



IEC

[Document reference]

NEW WORK ITEM PROPOSAL (NP) SCOPE & OUTLINE

PROJECT NUMBER:
62862-4-3 (NP)

DATE OF CIRCULATION: | CLOSING DATE FOR VOTING:

SUPERSEDES DOCUMENTS:

IEC TC 117: SOLAR THERMAL ELECTRIC PLANTS

SECRETARIAT:
SPAIN

SECRETARY:
MS LOURDES GONZÁLEZ MARTÍNEZ

OF INTEREST TO THE FOLLOWING COMMITTEES:

PROPOSED HORIZONTAL STANDARD:
☐
Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.

FUNCTIONS CONCERNED:
☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY

☐ SUBMITTED FOR CENELEC PARALLEL VOTING

Attention IEC-CENELEC parallel voting

The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Committee Draft for Vote (CDV) is submitted for parallel voting.

The CENELEC members are invited to vote through the CENELEC online voting system.

☐ NOT SUBMITTED FOR CENELEC PARALLEL VOTING

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

TITLE:
Part 4-3: Technical requirements and design qualification of heliostats for solar power tower plants

PROPOSED STABILITY DATE:

NOTE FROM TC/SC OFFICERS:

Organizer
Tsvankin, Daniel
Required

3 Accepted
George Kelly (solarexpert13@gmail.com)
Required
Haobin Zhang (zhanghaobin@cosinsolar.com)
Required
Kenneth Armijo (kmarmij@sandia.gov)
Required

4 Tentative
Carl Chin
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Giovanni Picotti (g.picotti@qut.edu.au)
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Yoel Gilon (yoel_gilon@bezeqint.net)
Required

46 Not Responded
Acutt, Calum (Energy, Newcastle)
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Andreas Kämpgen | CSPS
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Andreas Pfahl (Andreas@heliogen.com)
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Prescod, Andru (CONTR) (HQ)
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Required

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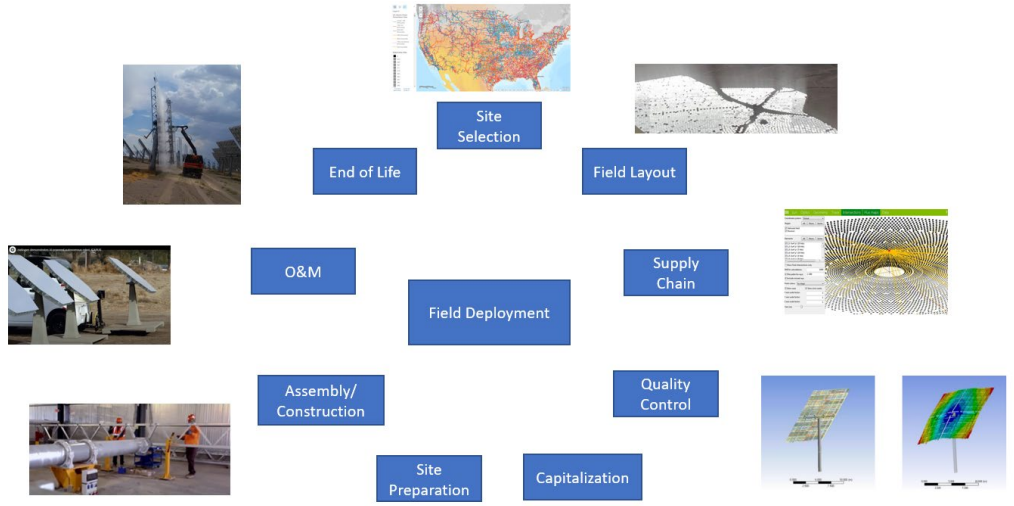
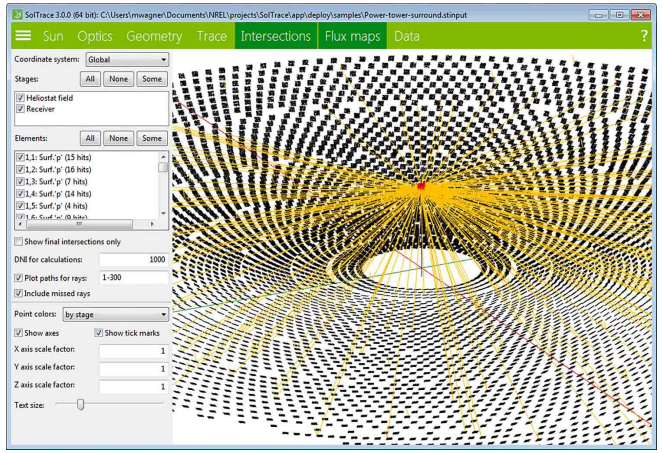
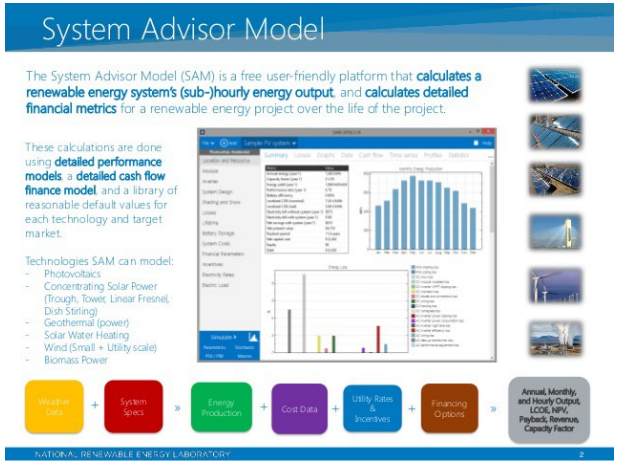
Project: High-Fidelity Performance Model

- **Objectives**
  - High-fidelity performance model to fill the gap between project developers and investors
- **Approach**
  - Define required site-specific data
  - Define required heliostat and heliostat field data
  - Define performance output metrics with associated uncertainties
  - Integrate a suite of modeling tools with necessary improvement
- **Status**
  - Identifying key sources of uncertainty in performance models
- **Lead**: Alex Zolan







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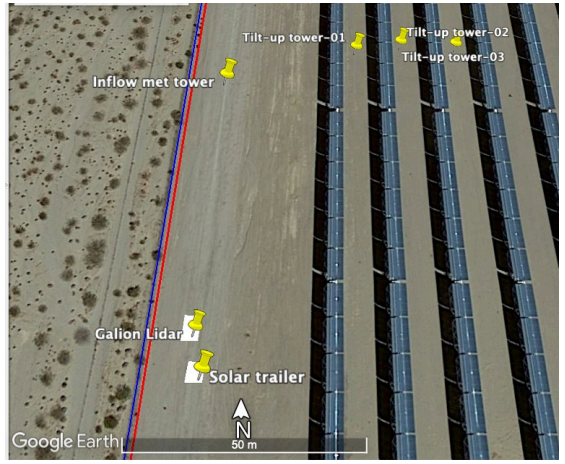
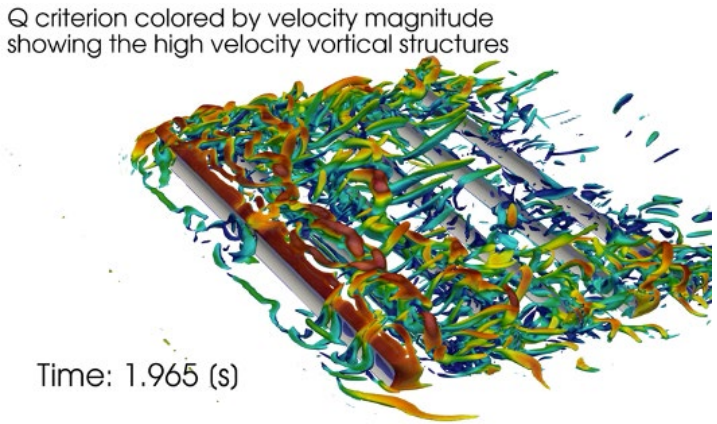
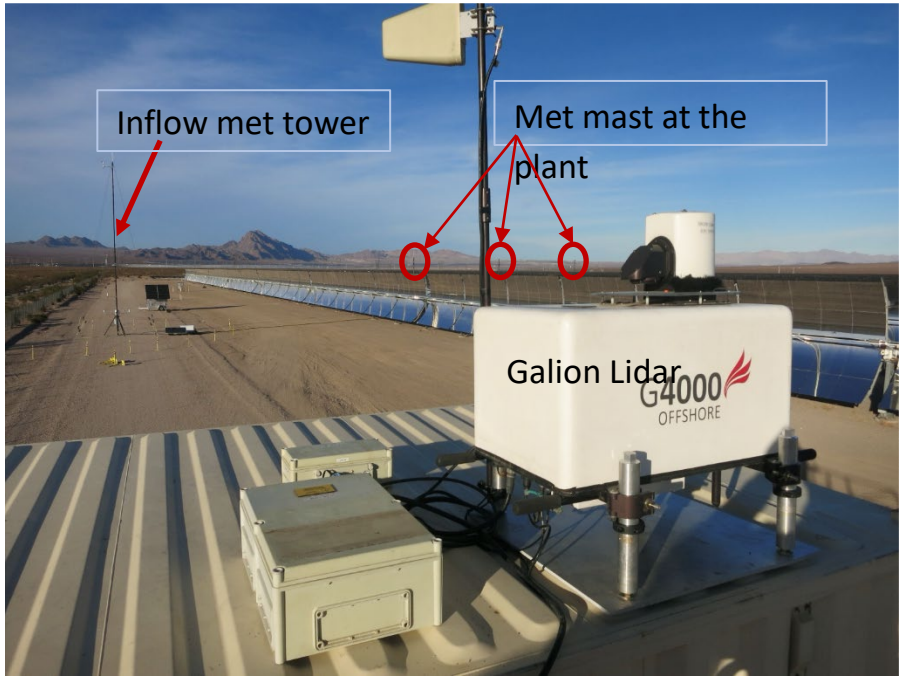
Project: Wind load Characterization

- **Objectives**
  - Develop detailed measurement procedure to characterize the prevailing wind conditions and resulting operational loads
  - Develop and validate a computationally efficient, high-fidelity modeling tool capable of predicting wind-loading in deep-array installations.
- **Approach**
  - Carry out measurement campaign at parabolic trough power plant – Nevada Solar One
  - Carry out measurement campaign at Crescent Dunes power tower plant
  - Validate CFD model with experimental data
- **Status**
  - Near to completion of parabolic trough collector field measurement and model validation
  - To plan the measurement campaign at Crescent Dunes power plant
- **Lead**: Shashank Yellapantula



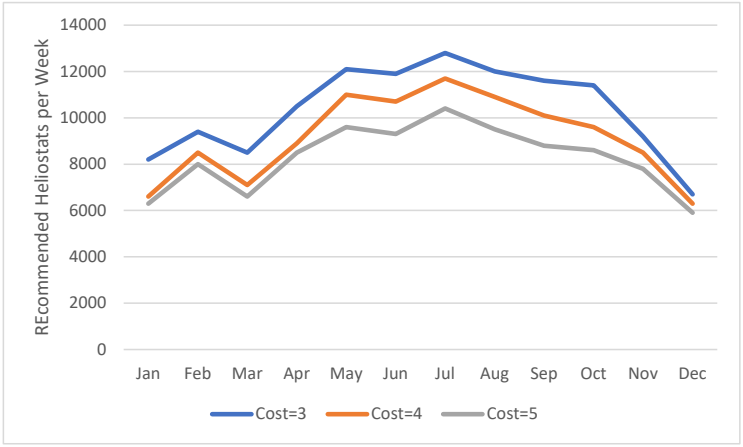




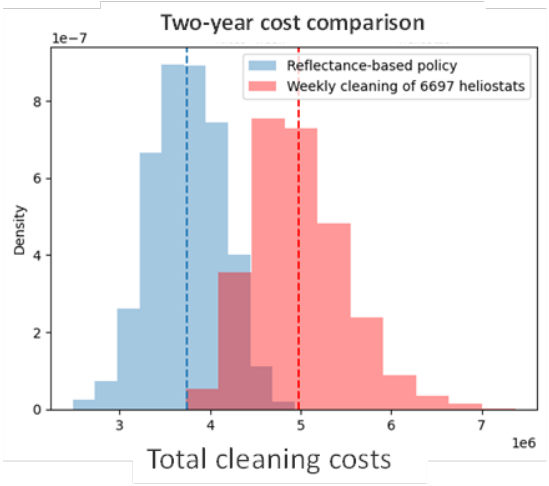
Project: Analysis of Heliostat O&M at Ivanpah

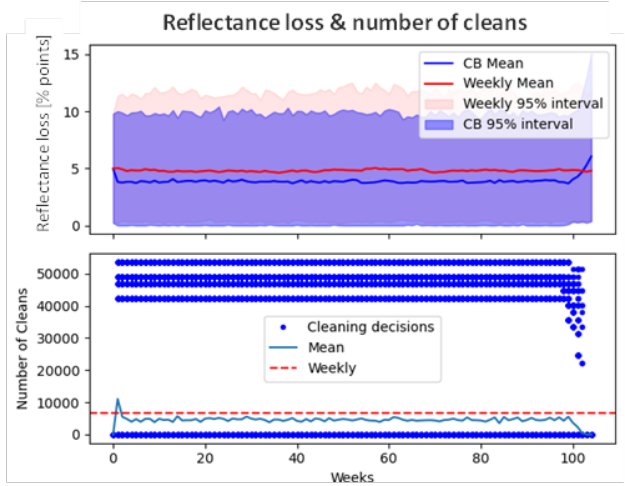
- **Objectives**
  - Obtain field measurements at an operating facility to observe soiling conditions
  - Compare performance of measurement devices and analyze mirror cleaning activities
- **Approach**
  - Obtained >500 measurements across ~120 heliostats in solar field of Unit 1
  - Developed separate models of soiling and cleaning optimization using (a) field-collected data, and (b) historical measurements shared by Ivanpah
- **Status**
  - Results confirmed that Ivanpah's cleaning frequency is appropriate, but it may be worth considering adjusting the cleaning schedule seasonally
  - Final report including analysis completed
  - Report on lessons learned for planning field measurement campaigns under development
- **Lead**: Alex Zolan

Heliostats in Ivanpah Solar Field, Unit 1



Summary of recommended heliostats to wash per week, assuming 0.1% loss per day, using field data





Similar results obtained through a stochastic soiling model using historical measurements

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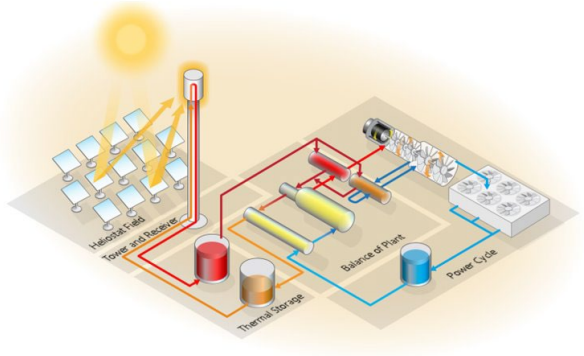
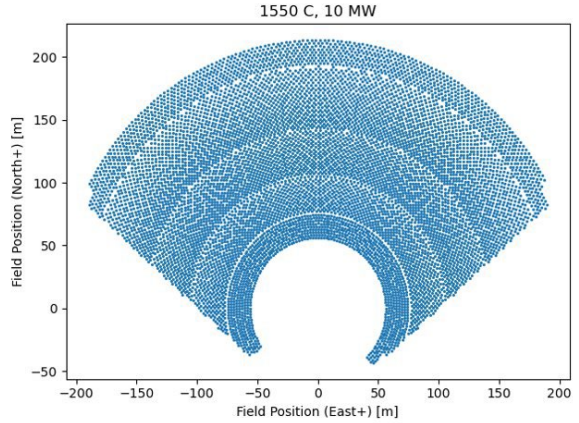
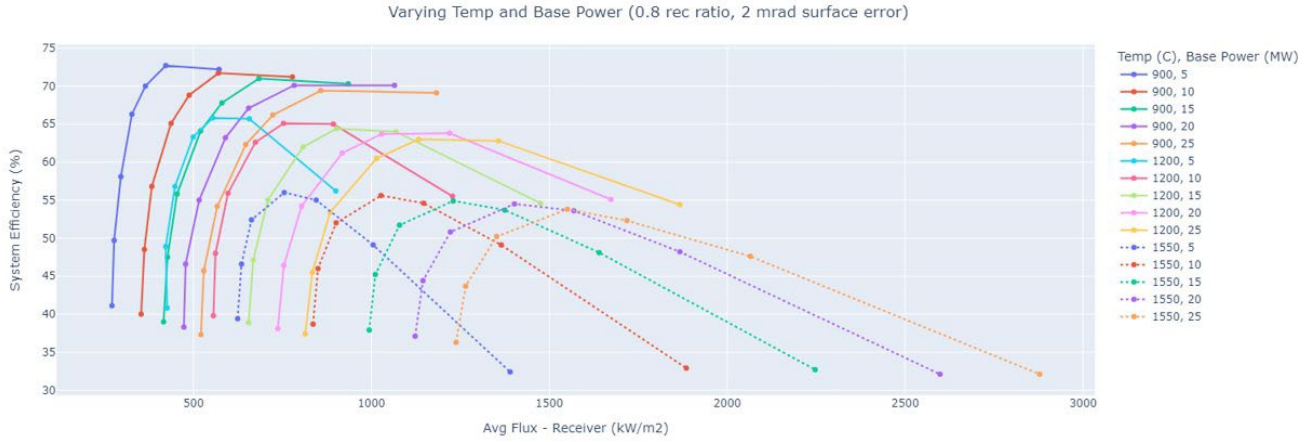
Project: Heliostat Field Optimization for Power Tower Solar Industrial Process Heat Applications

- **Objectives**
  - Develop heliostat field, tower, and receiver model for industrial process heat (IPH) applications.
  - Determine practical and commercial operating limits for IPH applications (temperature, project size, impact of receiver media, etc.)
  - Develop field layout “best practices” for IPH applications
- **Approach**
  - Develop cost correlations for tower and receiver for IPH
  - Optimize base case field layouts based on cost correlations
- **Status**
  - Improving models required for TEA analysis
  - Carrying out initial sensitivity analysis
- **Lead**: Chad Augustine







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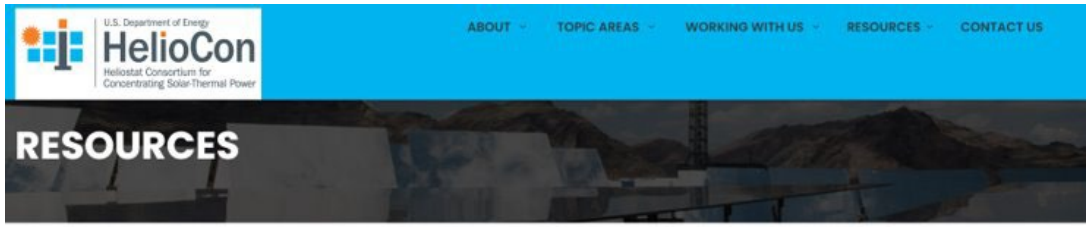
  - Composite heliostat design evaluation
  - Heliostat design qualification standard
- Field deployment
  - Third-party high-fidelity solar field performance prediction model
  - Wind load characterization
  - Analysis of Heliostat O&M at Ivanpah
- Techno-economic analysis
  - Process heat system of heliostats
- **Resources, Training and Education**
  - **HelioCon database**
- International collaboration
  - Ray-trace round robin test
  - Laboratory slope error metrology round robin

Project: HelioCon Database

- **Objectives**
  - Establish a publicly accessible web-based resource database containing fundamental and expert knowledge
- **Approach**
  - HelioCon will gather available resources and knowledge into web database:
    - Industry knowledge: stakeholder contacts, O&M/manufacturing/design practices)
    - Resource library: references, trainings, software tools
    - Resources/guidance for promoting diversity, equity, and inclusion
- **Status**
  - Has completed 1)reference library; 2) Education and training resources; 3) Lists of heliostat component suppliers and developers, metrology tools, and software tools; 4)Existing power tower plant database
- **Lead**: Rebecca Mitchell



Resources

The resources in this section include background on concentrating solar power (CSP), available scientific publications, videos, and additional information on heliostats.

- Background on Concentrating Solar Power
- HelioCon Seminar and Educational Videos
- Zotero References
- HelioCon Publications

An Overview of Heliostats and Concentrating Solar Power Tower Plants

This downloadable report, '*An Overview of Heliostats and Concentrating Solar Power Tower Plants,*' includes a summary of design types and concerns, components, field implementation and performance assessment of heliostats, along with the standard solar power tower plant design as a reference to those interested in heliostats and CSP tower technology.

Downloads:

- An Overview of Heliostats and Concentrating Solar Power Tower Plants (PDF)
- Metrology Tools List (.xlsx)
- Software(.xlsx)
- Component supplier (.xlsx)

Outline

- HelioCon management
  - HelioCon website
  - HelioCon seminars
- Metrology & standards
  - NIO technology
  - ReTNA technology
  - NREL third-party platform development
- Components & controls
  - Composite heliostat design evaluation
  - Heliostat design qualification standard
- Field deployment
  - Third-party high-fidelity solar field performance prediction model
  - Wind load characterization
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- Techno-economic analysis
  - Process heat system of heliostats
- Resources, Training and Education
  - HelioCon database
- **International collaboration**
  - **Ray-trace round robin test**
  - **Laboratory slope error metrology round robin**

Project: Raytrace Model Round Robin Test

- **Objectives**
  - Examine/improve (if necessary) accuracy of raytrace models available in the market
- **Approach**
  - Perform case studies to validate three raytrace models through round robin test
  - Validate other soltrace models per request
- **Status**
  - Near completion of round robin test of three raytrace models
- **Leads**: Rebecca Mitchell, Ye Wang (ANU), Michel Izygon (TieTronix), John Pye (ANU)

NREL Transforming ENERGY

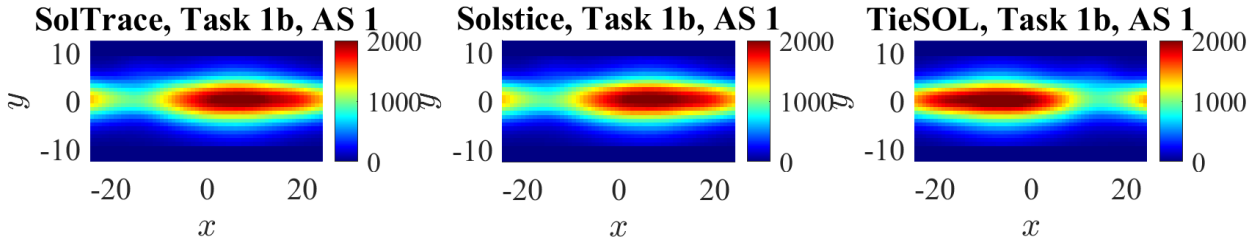
Australian National University

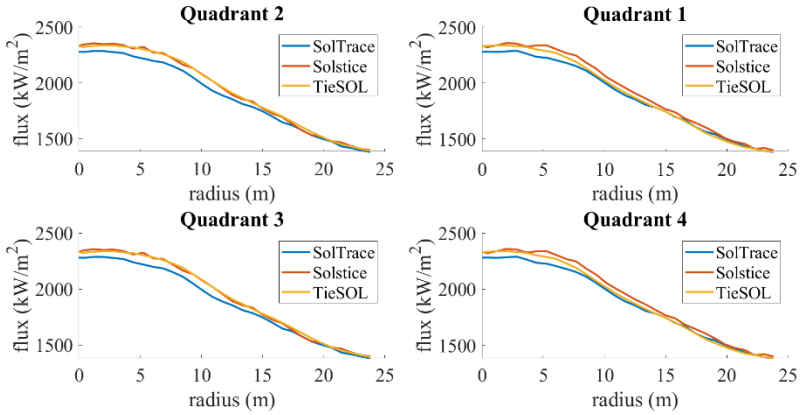
TIETRONIX

SolTrace

Solstice

TieSOL





Project: Laboratory Slope Error Metrology Round Robin Test

- **Objectives**
  - Examine/improve (if necessary) accuracy of laboratory slope error metrology available in the market
- **Approach**
  - Perform round robin test within 5 institutes: ENEA, DLR, Fraunhofer, Sandia, NREL
  - Collaborate with international community with support from EU program
- **Status**
  - Collecting and measuring mirror facets shipped from Europe partners
- **Leads**: Devon Kesseli, Randy Brost (Sandia), Braden Smith (Sandia)

Solar Facilities for the European Research Area

SFERA-III WP10 Task3 round-robin on 3D shape measurements: recommended procedure and ENEA results

Marco Montecchi, Giuseppe Cara, Arcangelo Benedetti

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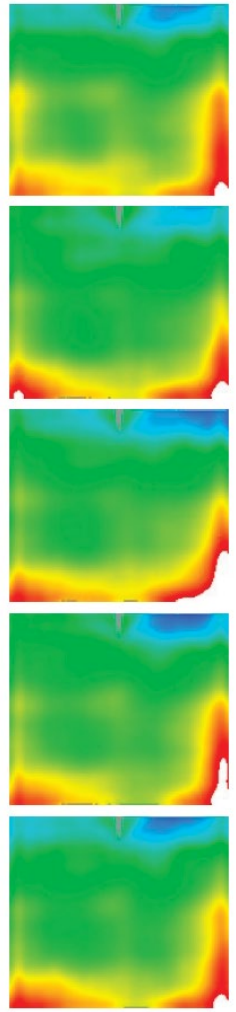

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conceptual design • components • integration • mass production • heliostat field