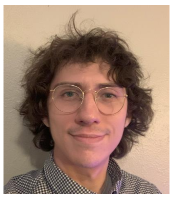
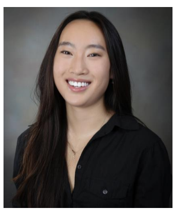
U.S. Department of Energy
HelioCon
Heliostat Consortium for Concentrating Solar-Thermal Power

Heliostat Consortium Seminar Series

Brought to you by the Resource, Training, and Education (RTE) topic area






Title: Intern Projects in Heliostat Technologies at NREL, SNL

Host: Dr. Rebecca Mitchell

When: Aug 28th 1-2:30 PM MDT

Zoom:
https://nrel.zoomgov.com/j/1617922497?pwd=wzQ8wbcT0WI6aU9QGoLjpB5XkVapBr.1

Abstract:

The Heliostat Consortium (HelioCon) is a 5-year research effort led by the National Renewable Energy Laboratory (NREL) partnering with Sandia National Laboratories (SNL), the Australian Solar Thermal Research Institute (ASTRI), and DOE's Solar Energy Technologies Office, to develop and manage a national laboratory-led U.S. consortium to support research, development, validation, commercialization, and deployment of low-cost heliostats for concentrating solar power (CSP) and solar thermal (CST) applications. Project team members at NREL and SNL have taken on eleven interns over the second year of the project to work on a wide range of projects within HelioCon. Each intern will provide a description of their project and highlight key outcomes and findings.

Interns Presenting:

<u>NREL</u>

Milo Davis
Kyle Sperber
Justin Kilb
Yu Zhao

<u>SNL</u>

Javier Martell
Madeline Hwang
Taylor Johnson
Nicholas Phelps
Kristina Ji

NREL Transforming ENERGY

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Milo Davis
Milo.Davis@nrel.gov

National Renewable Energy Laboratory (NREL)

Mentor: Devon Kesseli

Project I Title: NIO Software Refactoring

Project II Title: Template Flow

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Abstract:

Project I
In order to account for the error in the alignment of mirrors to a Concentrating Solar Power (CSP) tower, the Non-Intrusive Optical Metrology (NIO) software has been being developed by NREL for several years. NIO has been adapted from MATLAB into Python in pursuit of an automated version of the software that can be commercialized, but has needed significant refactoring to follow software best practices and be iterated upon. While this is a work in-progress, significant progress has been made in generalizing the software and improving the user's ability to use it.

Project II
NIO was finely-tuned to the Crescent Dunes field of heliostats, and it was discovered that the software encountered new hurdles with data from a different plant. In this case, the Cerro Dominador field in Antofagasta, Chile. It was found that the software had difficulty using color to distinguish between the ground, the heliostat, and the tower in order to identify the four corners of the heliostat. This is due, in part, to the severe weathering on some of the Cerro Dominador plants. Our solution to this is a new method utilizing the computer vision techniques of template matching and optical flow, where template matching is a way to match smaller images onto a larger image and optical flow is an algorithm which tracks the movement of an object in the image.

Bio**:**

Milo is a post-graduate intern who received his Masters in Computer Science with a concentration in Big Data from Arizona State University last July. Prior to NREL, he worked on an experimental Natural Language Processing (NLP) application. Since joining NREL he has been working on NIO code development, processing data, and prototyping corner-finding algorithms. He has also been working on a template for automatically generating lab reports for mirror reflectance measurements. In his free time Milo likes weightlifting, video games, and doing voiceover.

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Kyle Sperber
Kyle.Sperber@nrel.gov

National Renewable Energy Laboratory (NREL)

Mentor: Dr. Rebecca Mitchell

Project I Title: Sophisticated Tower Geometries and Tower Edge Detection

Project II Title: Accuracy Analysis of the Camera Position Detection Algorithm

Project III Title: Camera Sensitivity Analysis

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Abstract:

Project I
NREL's Non-Intrusive Optical Metrology (NIO) is a method of using drones to conduct error analysis of a heliostat to verify its alignment with a tower. The accuracy of NIO relies on the detection of tower edges in the reflection of a heliostat to compute its optical errors. However, towers vary in color, and geometry making it difficult to reliably use computer vision to identify the tower edges in the reflection of the heliostat. To combat this image processing techniques are used to aid in edge detection of a heliostat. In addition, an edge detection algorithm based on the geometry of the tower has been employed to reliably find the corners viewed by a heliostat of any tower geometry or color.

Project II
NIO's data collection step sends drones to collect images over a filed of heliostats to be later processed to compute optical errors. To accurately compute the optical error of the heliostat the drones position relative to the heliostat is critical. To do this a photogrammetry algorithm is employed that uses control points on the heliostat to determine where the drone is relative to the heliostat. This study aims to understand the ideal points to select on a heliostat, the number of points required to get reliable drone position calculations, and the effects that heliostat imperfections can have on this methodology.

Bio:

Kyle is a graduate student at the Colorado School of Mines studying Applied Mathematics and Wave Phenomena, and Physics. Kyle's focus is using Machine Learning to model sophisticated physical and mathematical systems. As part of his Master's degree program he focuses on using Machine Learning and Thermodynamic models to construct the intermediary dynamics of complex protein networks. In his free time, he enjoys lifting, hiking, trail running, and climbing.

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Justin Kilb
Justin.Kilb@nrel.gov

National Renewable Energy Laboratory (NREL)

Mentor: Dr. Alex Zolan

Project Title: Monte Carlo Simulation to Assess Quality of Heliostat Washing Policies Obtained via Optimization Methods for Concentrating Solar Power Plants

Abstract:

This project aims to develop a stochastic simulation framework for optimizing heliostat washing strategies in Concentrating Solar Power plants. Heliostat reflectance, critical to maintaining plant efficiency, degrades over time due to soiling, which is influenced by stochastic environmental factors such as dust storms and precipitation. Traditional deterministic approaches to scheduling heliostat washing fail to account for this variability, potentially resulting in either inefficient use of resources or excessive operational costs. This research seeks to evaluate and compare various policy-driven washing strategies, with a particular focus on threshold-based approaches, against conventional fixed-schedule methods, to enhance the overall effectiveness and efficiency of heliostat maintenance.

Bio:

Justin Kilb is a PhD student in Operations Research at the Colorado School of Mines. He received his bachelor's in Petroleum Engineering from the Colorado School of Mines and his master's in Data Science from the University of California, Berkeley. Before returning to school for his PhD, Justin was the Chief Drilling Engineer at Ovintiv. This summer, he is working on optimizing mirror-washing and cost forecasting for concentrating solar thermal plants in support of the Heliostat Consortium.

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Yu Zhou
Yu.Zhou@nrel.gov

National Renewable Energy Laboratory (NREL)

Mentors: Rebecca Mitchell, Paul Ndione, and Guangdong Zhu

Project Title: Building a Resource Database for the Heliostat Consortium

Abstract:

Information relevant to concentrating solar power plant, heliostats, heliostat metrology tools and heliostat component suppliers were gathered for the HelioCon Database on the Heliostat Consortium (HelioCon) website. More plants pages have been added to the online power tower CSP plant database and a heliostats database has also been created to share more plant information and heliostats model to the public. Currently, plant database includes 42 tower CSP plants information and 15 heliostats model information. Furthermore, a scoping study of heliostat metrology under HelioCon project was conducted to identify the existing available tools at first, which provide current heliostat relevant metrology capabilities and could promote further development in heliostats' metrology. General technical specifications, cost, and accuracy information of those tools were collected. This HelioCon database provides a centralized, accessible repository of information regarding relevant details related to CSP and heliostats worldwide, which should be able to facilitate research, analysis, and decision-making for stakeholders and help newcomers who are interested in CSP industry to find related information.

Bio:

Yu completed her Ms. in mechanical engineering at Northeastern University and joined NREL as a post-graduate intern in September 2023. During her graduate study, she worked on investigating the requirements for energy generation and storage. At NREL, she has continued her research on evaluating the needs of seasonal storage towards 100% decarbonization. She has also worked on gathering resources for the Heliostat Consortium website and conducting scoping study for heliostat metrology tools. In her free time, she likes hiking, baking and sunbathing by the beach.

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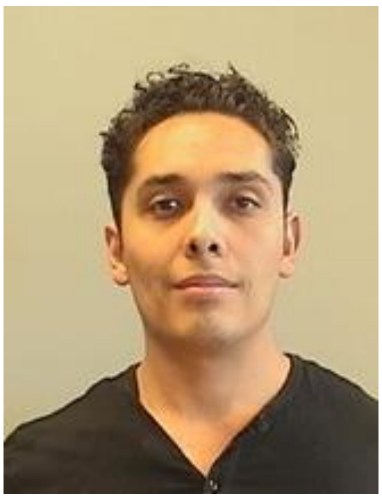

Javier Martell
jamarte@sandia.gov

Sandia National Laboratories (SNL)

Mentor: Dr. Ken Armijo

Project Title: Development of a digital wind tunnel for heliostat wind loads analysis.

Abstract:

Heliostats experience wind loads that influence the efficiency and material selection that they are built with. Traditionally, Heliostats are built with steel to ensure structural safety when operating at high wind velocities. By creating a digital wind tunnel model, the heliostat structure can be studied under different wind speeds and configurations. By extracting these pressure loads on the heliostat, and performing a FEA harmonic analysis response, different materials can be studied to assess better vibration response and structural integrity.

Bio:

Javier obtained his Bachelor and Master of Science in Mechanical engineering from the University of Texas at El Paso (UTEP). At UTEP, he performed research in digital engineering and modular CubeSat structures. He developed a modular mechanical interface for CubeSats, and digital twin models for CubeSats environmental testing qualifications. He also interned at Sandia National Laboratories for the concentrated solar technologies group. At Sandia, he performed research related to thermal energy storage systems, heliostat vibration analysis, and decarbonization of industrial processes. He developed Ansys models to asses system performance, and parametric studies of systems.

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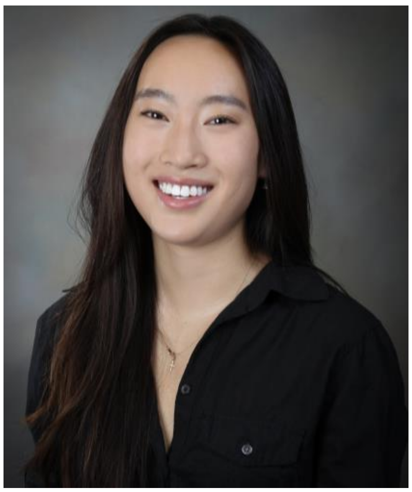

Madeline Hwang
mhhwang@sandia.gov

Sandia National Laboratories (SNL)

Mentor: Dr. Randy Brost

Project Title: Calculating Off-Axis Canting Angles

Abstract:

The use of heliostats for Concentrating Solar Power is a method that utilizes parabolically shaped mirrors (facets) which are canted to best reflect and concentrate the power of the sun onto a central receiver. A reliable method to measure these facet canting angles is necessary, since small errors in heliostat pointing result in significant power losses. A source of such small errors includes imperfections in facet canting angles. My project goal is to compute off-axis canting angles for each facet for an ideal case of our heliostats at NSTTF with Python. We will then conduct error analysis by comparing the ideal facet canting angles to present measurements of our heliostats' facet canting angles. By optimizing the canting angles, we can improve reliability and increase efficiency during operation, thus producing higher power generation. The Python code developed will become a part of the code base of OpenCSP, an open-source platform which can be utilized by the CSP community to improve their canting angles and measurement techniques.

Bio:

Madeline is a senior at the University of New Mexico studying electrical engineering and psychology. She is a year-round intern at Sandia National Laboratories National Solar Thermal Test Facility (NSTTF). Her work at Sandia focuses on writing Python code for OpenCSP and developing heliostat management and maintenance procedures. She also works in a neuroscience research lab conducting experiments with transcranial direct stimulation for patients with Alzheimer's Disease and developing analytical tools for her lab. You can often find her in the Sandia Mountains trail running, making dinner with friends, swimming, volunteering around Albuquerque, or painting.

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Taylor Johnson
tljohn@sandia.gov

Sandia National Laboratories (SNL)

Mentor: Dr. Randy Brost

Project Title: Technoeconomic analysis of a hybridized PV-CSP plant integrated with particle thermal energy storage

Sandia National Laboratories

Abstract:

Integrating solar thermal technologies with thermal energy storage for consistent power delivery is emerging as a critical strategy for decarbonizing industrial processes. This study investigates the methods and economics of combining photovoltaics (PV) and concentrated solar power (CSP) with particle thermal energy storage (TES) to provide the industrial sector with a reliable and cost-effective energy source while reducing greenhouse gas emissions. Various configurations of PV, CSP, and TES are evaluated and benchmarked against grid power to meet demand, generating a Levelized Cost of Electricity (LCOE) estimate that highlights the economic and environmental advantages of renewable energy solutions. A machine learning model is employed to predict the LCOE based on location-specific data, enabling the identification of optimal sites for deploying these hybrid systems.

Bio:

Taylor Johnson is a senior mechanical engineering student at the University of Florida with an interest in renewable energy conversion and storage. Taylor's interest in concentrated solar power began during her time as a research assistant in UF's Renewable Energy Conversion Lab studying redox materials for solar thermochemical watersplitting, and extended to thermal energy storage systems during an eight-month internship with the Thermal Sciences Group at the National Renewable Energy Laboratory. Her primary project at NREL focused on a techno-economic analysis of a hybrid photovoltaic-concentrated solar power system coupled with particle thermal energy storage, earning the Outstanding Paper Award at the 18th International Conference on Energy Sustainability. Taylor developed an interest in machine learning through a year-long internship with the Electrochemical Energy Lab at MIT, where she explored the use of ML algorithms in discovering novel lithium-ion conductors, and applied this knowledge to her work at UF, implementing a machine-learning model to predict the efficiency of a solar collector used to inform a techno-economic solar industrial process heat model. Taylor is continuing her research into CSP and TES systems at Sandia National Labs, where she is collaborating with Photon Vault on a techno-economic model for their system. In her free time, Taylor serves as the design lead for UF's Engineers Without Borders team, where she works on water quality and distribution projects for a community partner in Peru.

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Nicholas Phelps
ncphelp@sandia.gov

Sandia National Laboratories (SNL)

Mentor: Dr. Randy Brost

Project Title:
Characterizing a Precise Ground Truth Mirror for CSP Optical Metrology

Abstract:

To determine whether a concentrating solar system is performing as intended, operators must be able to understand the optical characteristics of the mirrors in their field. Performance may suffer if mirrors are not shaped correctly or are pointed at the wrong location. This necessitates ways of assessing those parameters across a heliostat field quickly and easily. To achieve this, a variety of metrology methods and systems have been developed at Sandia, NREL, and elsewhere that are designed to measure the optical quality of concentrating solar mirrors to help draw conclusions about resulting solar power performance. These instruments generally involve complex calculations, raising question regarding their accuracy. Due to how removed from real-world performance these calculations can be, physical feedback from ground truth methods and standards are needed to compare to the output from the complex instruments. To that end, the Concentrating Solar Optics Lab (CSOL) at Sandia has obtained a highly precise mirror made using high accuracy manufacturing techniques, to serve as a ground truth reference for cross-checking complex CSP metrology systems. This mirror required assessment to determine if it met optical quality specifications, and performing this measurement was challenging. We will describe the mirror, our assessment methods, and the results of our assessment.

Bio:

Nicholas Phelps recently graduated from the University of New Mexico with a master’s degree in mechanical engineering. He has been utilizing his background in engineering design, project management, and sustainability to contribute to the efforts of the Concentrating Solar Optics Lab at the National Solar Thermal Test Facility at Sandia National Labs as a summer intern. This internship marks the latest chapter in his book which holds other sections called Eating Pasta on an Erupting Volcano, Running with Bulls, and Row, Row, Row Your Boat!

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Kristina Ji
sonji@sandia.gov

Sandia National Laboratories (SNL)

Mentor: Dr. Jeremy Sment

Project Title: Analysis of Ground Screws for Low-Cost Heliostat Installations

Abstract:

This project explores the optimization of anchoring methods and foundation costs for small-mirror heliostat installations. Current methods of heliostat anchoring and mounting are expensive and complex processes which can end up harming the environment. The objective of this project, then, is to address these issues through testing ground screws as a heliostat foundation method. Ground screws are relatively low-cost and easy to install. They also have a very minimal environmental impact compared to concrete foundation pours. This project hopes to lower the cost of the foundation per heliostat mirror area, simplify the process of installation, and reduce the overall impact on the surrounding environment. In order to further analyze this approach, we test different ground screw lengths in different soil types to determine the maximum axial and lateral loading of the heliostat foundation as a function of the soil composition and ground screw length. This then produces a function with inputs of heliostat area, maximum wind speed, and soil composition (as measured by standard penetration test blow count), and outputs an optimal configuration of ground screws as well as the cost per area of the foundation and mounting solution. So far, we have found that there is currently a price floor of about $5 per m2 of heliostat mirror area for using ground screws to mount large heliostats; however, the price peaks for small heliostats. This project aims to reduce the cost for mounting small heliostats to around the same price floor.

Bio:

My name is Kristina Ji and my background is in mechatronics engineering. For my education, I have a bachelors in mechanical engineering and a bachelors in computer engineering, both from the University of New Mexico. Currently, I am working on obtaining my master's degrees in mechanical engineering focused on space systems with an emphasis in robotics and in computer engineering focused on control systems with an emphasis in computer vision. I have worked for Sandia for approximately 3 years, with over two years in building and facilities energy use management and optimization. I am now working with the NSTTF team as an R&D graduate student intern and am involved with an assortment of different projects, ranging from the project detailed here, to the G3P3 ductwork, to flow control and systems design.

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