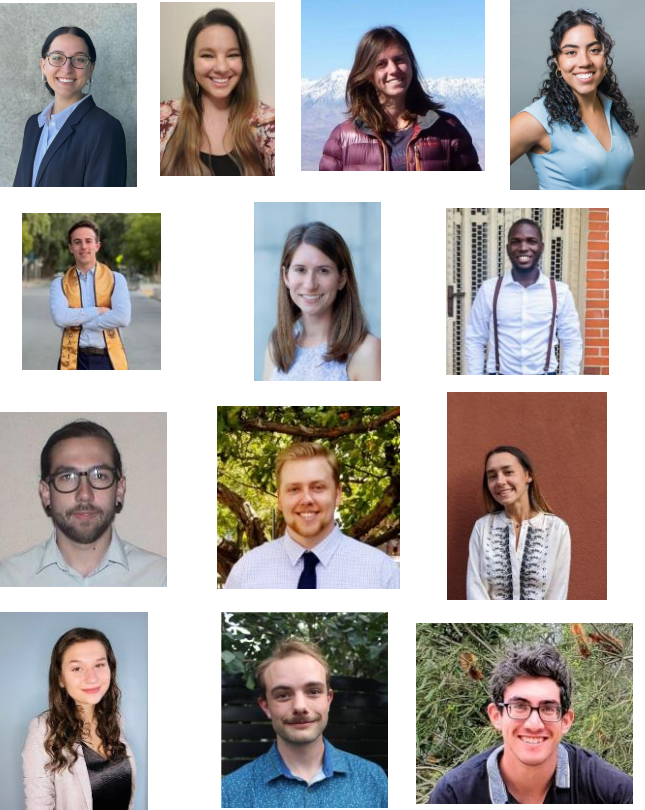




Heliostat Consortium Seminar Series

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



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, SNL, and the DOE have taken on twelve interns over the year of 2022 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:

- NREL
- Raven Barnes
- Mackenzie Dennis
- Kyle Heinzman
- Maggie Kautz
- Mojolaoluwa Keshiro
- Dylan Mayes
- Katelyn Spadavecchia
- Gabriel Shuster
- Daniel Tsvankin

- SNL
- Felicia Brimigion
- Natalie Gayoso
- Dimitri Madden

- DOE
- Nicole Piatko

Title: Intern Projects in Heliostat Technologies at NREL, SNL, and DOE

Host: Dr. Rebecca Mitchell

When: Aug 1st 1-2 PM MDT

Zoom:
<https://nrel.zoomgov.com/j/1602290924?pwd=NWh6eitQVHV0dkFwU2Y5SHIwcG9lZz09>





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Raven Barnes
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National Renewable
Energy Laboratory (NREL)

Mentor: Dr. Alex Zolan

Project Title: Compilation
of Heliostat Standards and
Best Practices

Abstract:

In 2021, the US Department of Energy (DOE) established a Heliostat Consortium (HeliCon) lead by the National Renewable Energy Laboratory (NREL), Sandia National Laboratory (SNL), and several other developers and industry professionals. Concentrated Solar Power plants (CSP) are underutilized due to high capital costs and continuous operations and maintenance (O&M) required. Heliostats are a crucial component of CSP plants as they are mirror assemblies that constantly tilt throughout the day to track the sun's movement and reflect this back on a central receiver, positioned at the top of a power tower. HeliCon aims to improve heliostat performance by supporting research and development of new designs and best practices in the CSP industry. During my Science Undergraduate Laboratory Internship (SULI), I conducted a literature review to understand the current CSP landscape and which areas were lacking the most. From the literature review, I compiled a draft survey to send out to existing CSP plants, manufacturers, and other industry professionals. The responses to this survey will help improve heliostat performance in the CSP industry and push us towards a cleaner energy sector.

Bio:

Raven Barnes is a senior at Georgia Institute of Technology in Atlanta. Here, she is majoring in Mechanical Engineering with a minor in Energy Systems and will be graduating at the end of the summer. Within her Energy Systems minor, she has specifically taken classes in renewable energy as that is her primary passion and what sector she will work in after her education. After graduation she will be working with a company out in San Leandro, CA on lithium metal pouch cells and preventing thermal runaway within them.



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Mackenzie Dennis
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National Renewable Energy
Laboratory (NREL)

Mentor: Dr. Rebecca Mitchell

Project I Title: Developing
Resources, Training, and
Education Materials for the
Heliostat Consortium

Project II Title: Management
of Beam Characterization
System at NREL

Abstracts:

Project I

Project goals were to gather all relevant literatures, including available educational and training resources, on CSP and heliostat development into a centralized database. An introductory report on heliostats and central receiver CSP plant design was developed to help shorten the learning curve for those unfamiliar with the technology.

Project II

Beam characterization systems (BCS) are a method of accurately measuring and correcting for tracking errors in active heliostats. For further research and development of the technique, NREL is developing a scaled down prototype of the physical system, as well as an image processing algorithm to calculate the relevant errors from the collected data. Primary contributions from two SULI interns (Kyle Heinzman and Katelyn Spadavecchia) will be further expanded and refined to improve NREL's BCS capabilities and future development of a full-scale BCS research facility.

Bio:

Mackenzie has been a graduate intern at NREL for eight months, with a background in mechanical engineering and earth sciences. She has been working primarily on compiling Resource, Training and Education materials for CSP research. She has contributed to an extensive literature review on heliostats and collaborated on beam characterization system research and development at NREL.



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Abstract:

Concentrating Solar Power (CSP) is a renewable energy technology used to directly reflect the sun's rays into a concentrated beam of light. One form of CSP technologies incorporates this strategy using a power tower, where a field of heliostat mirrors can concentrate high amounts of sunlight onto a central receiving tower for energy conversion. The purpose of this project is to collect and characterize the beam reflected from a single mirror onto a target for training an image processing algorithm. The imaging data collected in this project includes design considerations for the construction of the target frame, the target's size and surface, as well as the compatibility of the camera's images to be processed. This Beam Characterization System (BCS) will help to standardize and determine associated errors with measuring the power output of each heliostat. The impact of this project will help lead to design improvements for implementing a large-scale Power Tower plant in Colorado for the future.

Bio:

Kyle is a recent graduate from the University of California, Davis with a BS in Mechanical Engineering. This upcoming fall he will start working at a startup company in Northern California, specializing in manufacturing cobalt-free lithium-ion batteries. Kyle will look to attend graduate school in the future and wants to pursue a career researching renewable energy technologies relating to decarbonization. In his free time, he enjoys catching up with old friends and exploring new cities.



Kyle Heinzman

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National Renewable
Energy Laboratory (NREL)

Mentor: Tucker Farrell

Project Title: Beam
Characterization System
Hardware Data Collection



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Maggie Kautz

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National Renewable
Energy Laboratory (NREL)

Mentor: Dr. Guangdong
Zhu

Project Title: Fixed Shape
Optimization of Heliostat
Mirror

Abstract:

Concentrating solar power (CSP) uses mirrors or lenses to concentrate, or focus, sunlight onto some sort of receiver. There are four types of CSP technology: parabolic troughs, power towers, linear Fresnel collectors, and dish/engines. This project will focus on a power tower plant, a type of CSP technology in which a field of mirrors, heliostats, reflect sunlight onto a central tower that has water or sand running through it as the medium for driving a heat engine. Current state-of-the-art heliostats have a symmetric geometry, fixed in the full field or in bands of the field. For CSP to become a mainstream electrical generation method, its efficiency needs to be increased. Power output of these power tower plants could be increased with different mirror geometries. The goal of this project is to determine the optimal fixed shape of a heliostat mirror that will yield the highest intercept factor on the power tower throughout a given day and ultimately throughout a year.

Bio:

Maggie is entering her 4th year in the Optical Sciences PhD program in the James C. Wyant College of Optical Sciences at the University of Arizona. Her research focuses on opto-mechanical design for astronomical instrumentation and solar energy projects. She received her BS in Optical Engineering at the University of Arizona as well.



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Mojolaoluwa Keshiro
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National Renewable
Energy Laboratory (NREL)

Mentor: Devon Kesseli

Project I Title: Laboratory
Non-Intrusive Optical
Technology Development

Project II Title: HelioCon
Social Media CSP
Education

Abstract:

Project I

Following the development of NREL's Non-Intrusive Optic (NIO) tool that can accurately measure the different optical errors of heliostats in a power plant, it became apparent that we could modify this tool into a warehouse/lab scale metrology tool that could be used by heliostat researchers and manufacturers. This project focused on testing the newly developed tool, comparing measurements with results collected using other metrology methods such as SOFAST and photogrammetry, and conducting a sensitivity analysis to test the allowable uncertainty of our input parameters. The aim of the project is to develop a validated prototype lab-scale heliostat optical error characterization tool. In the future, this will be automated so that it can be licensed to heliostat developers and manufacturers.

Project II

The primary objective is to creatively spread a wider range of knowledge on how solar power can be/is being used to generate electricity (apart from photovoltaics) and just generally shine a light on the CSP industry (not just PV) for the public especially the younger population (ages 0-45). Due to our target audience, we would be using the short video content style for Social Media.

Bio:

Mojo is in his second year of getting his master's degree in mechanical engineering at the University of Colorado, Denver. His track focuses on thermal systems and simulation calculations. He loves to work on renewable energy projects, challenging himself across the different technologies. He had his undergraduate degree in Mechanical Engineering also. He has experience and affinity for project management and marketing.



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Abstract:

A non-intrusive optical (NIO) approach has been developed to assist the concentrating solar-thermal (CST) power industry to improve and optimize their component operation, maintenance, and performance. Heliostats, large mirrors that reflect sunlight toward a receiver, are placed in a field surrounding the receiver to concentrate sunlight and transfers it to thermal energy. The NIO approach measures mirror surface slope error, canting error, and heliostat tracking error with optical techniques like photogrammetry. An algorithm was developed to execute and demonstrate the effectiveness of the NIO approach and validate data constraints and robustness. Unmanned aerial systems (UAS) collect images over thousands of heliostats to serve as input to the NIO algorithm. Automation of the NIO algorithm is crucial to speed up processing of thousands of images and remove the number of human hours needed to run the algorithm. Automation assists further feasibility and validation of the NIO approach across different power tower plants and ensures growth of CST technology.

Bio:

Dylan Mayes is one of the NREL interns working on the NIO project. This is his second internship with NREL and he's grateful to have another opportunity to work on such an impactful project and collaborate with teammates to produce something that will further invest in a clean energy future. he completed his undergraduate program at Colorado School of Mines in Geophysics in May of 2020 and was lucky enough to work at the Flatirons Campus with the Water Power Group to develop and optimize code for the Marine and Hydrokinetic Toolkit (MHKit). He moved back to his hometown to study for a master's degree in Geophysics from the University of Houston. In his free time, he likes to spend time with his wife and enjoys boating, hiking, and taking his two dogs to dog parks.



Dylan Mayes

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National Renewable
Energy Laboratory (NREL)

Mentor: Tucker Farrell

Project Title: Non-Intrusive
Optical Algorithm
Automation



Heliostat Consortium Seminar Series

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

Abstract:

The U.S. Department of Energy Solar Energy Technologies Office (SETO) is working to transition to a decarbonized electricity system and energy sector by 2050. Researchers at the National Renewable Energy Laboratory (NREL) provide expertise to help meet the goals of SETO with innovations in concentrating solar power (CSP). CSP plants use heliostats to reflect and concentrate sunlight onto receivers where thermal energy is stored. This energy is used to drive conventional thermoelectric generation systems, industrial systems, or future generation systems. CSP is unique for its thermal energy storage system that can be tapped when the sun isn't available to meet electricity demands. Using image-processing algorithms, software for NREL's Beam Characterization System was developed to measure the power output of each heliostat. Images from a mirror, camera, and target system at NREL as well as images from a commercial CSP plant at Sandia National Laboratory were processed and key features of both the target edges and beam center were identified. With this software, heliostat alignment errors can be controlled and power output can be improved, bringing us one step closer to reaching SETO's goal, which will ensure the transition to a clean energy economy.

Bio:

Katelyn Spadavecchia is a rising senior at Duquesne University in Pittsburgh, PA. she studies physics with minors in environmental studies and math. she has been participating in the Science Undergraduate Laboratory Internship (SULI) program this summer working at the National Renewable Energy Laboratory (NREL). SULI has challenged her to search for a deeper understanding of the numerous renewable energy technologies that are being developed at NREL. she has grown more passionate about environmental issues and has gained insight from and connected with professionals who research ways to combat climate change. Her short exposure at NREL solidifies her goals towards a PhD in environmental physics where she will navigate my place in the climate crisis.



Katelyn Spadavecchia
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National Renewable
Energy Laboratory (NREL)

Mentor: Mackenzie Dennis
and Devon Kesseli

Project Title: Beam
Characterization System
Software



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Gabriel Shuster

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National Renewable
Energy Laboratory (NREL)

Mentor: Dr. Rebecca
Mitchell

Project I Title: Resource,
Training, and Education
Web Development

Project II Title: Non-
Intrusive Optical Slope
Error Sensitivity Analysis

Abstract:

Project I:

This project consists of gathering and organizing publicly available resources and information regarding CSP and heliostats for on the Heliostat Consortium (HelioCon) website. The goal is to create a place where people entering the field can learn about heliostats and the issues that go along with making CSP economically competitive. This will result in a more knowledgeable workforce and ultimately reduce the training costs associated with building a large scale CSP plant.

Project II:

The NIO method requires two measurements be taken of the heliostats surface at different positions. This allows for an accurate calculation of the slope error of the heliostat. The issue is that if the two positions are too similar than the error in the calculation will be too great. Using a simulation of a heliostat in a field I found the allowable range of measurements for the NIO method to be taken.

Bio:

Gabe Shuster is going into his senior year at the University of Utah, studying mechanical engineering with an emphasis in sustainable energy. He has experience with computer run simulations regarding boundary layer turbulence in solar arrays. This summer he worked on some of the Resource, Training, and Education materials and a slope error sensitivity analysis for the NIO project. In his free time he loves to keep bees, make pottery, and rock climb.



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Daniel Tsvankin
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National Renewable
Energy Laboratory (NREL)

Mentor: Dr. Matt Muller

Project Title: Heliostat
Technical Specifications -
Roadmapping,
Development, and
Validation

Abstract:

The ad-hoc nature of heliostat field qualification increases development costs and the potential for operation & maintenance (O&M) cost overruns. This project aims to survey the existing landscape of standards relevant to heliostat fields, identify their gaps, and propose a path forward to a comprehensive global heliostat technical specification under the framework of IEC TC 117. Test regimens are described and proposed. Validation of heliostat-specific performance tests and development of open-source software tools for accomplishing them is conducted.

Bio:

Daniel is future master's student in the Advanced Energy Systems program at the Colorado School of Mines, a current year-round intern developing heliostat standards (and the tools and procedures to execute them), and a former project engineer on custom containment systems for the nuclear and radiopharmaceutical industries. In addition to supporting a future career in the energy transition, his undergraduate mechanical engineering degree assists my endeavors as a hobby automotive mechanic.



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Abstract:

To reduce carbon emissions, electricity SOFAST is a Sandia tool for precise CSP mirror measurements. We have created a SOLIDWORKS interactive tool to visualize the required SOFAST test set up, which historically has been a strong challenge. The tool not only allows the users to interact with the SOFAST set up, but also to accurately assess the correct equipment and their necessary positions, to properly execute SOFAST within a desired space and environment. The tool allows for the users to adjust the positioning and angles of the mirrors of interest, cameras, and projectors, to see and obtain a correct setup. As the mirrors and cameras are adjusted, the mirror's reflection automatically updates accurately according to Snell's law. It allows for users to not only determine if their equipment and mirror size is feasible, but also if their desired testing environment is adequate to support their test needs. The tool solves for three distinct cases, (1) where the mirror and its size is known, the environment and space required is solved for, (2) where the environment is known, mirror is known, and the mirror position is solved for, and (3) a generic case such as determining the layout which will support the largest mirror possible in a given testing environment. For example, a temperature chamber to study the varying effects of temperature on the mirror. The interactive SOFAST tool has been utilized to solve for 8 test setups to date.

Bio:

I am a mechanical engineering graduate student working on my third degree. I obtained my first degree in Geology with a minor in physics from Keene State College in 2015. I have always been passionate about being kind to the planet and wanting to assist wherever I can in renewable energies. After taking some time off to figure out how I would achieve that, I decided to return to academics and graduated with a Bachelor of Science in Mechanical Engineering from UNM in 2021. I am currently pursuing my master's at UNM and am projected to graduate in Spring of 2023. I have worked as a student intern at Sandia National Laboratories since the summer of 2019, originally in MEMs, and transferred to the Solar Tower working with CSP the summer of 2021. I work with Ken Armijo and Randy Brost studying thermodynamic cycles of solar fuels and hydrogen, and SOFAST mirror optimization, respectively. I have enjoyed working on UNM's Solar Splash program, where the team designed and manufactured a solar powered boat to race against other schools. Outside of engineering, I thoroughly enjoy hiking, reading, movies, crafting, and gaming.

Felicia Brimigion
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Sandia National
Laboratories (SNL)

Mentor: Dr. Randy Brost

Project Title: SOFAST
Interactive CAD Tool



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Natalie Gayoso
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Sandia National
Laboratories (SNL)

Mentor: Dr. Ken Armijo

Project Title: Heliostat
Techno-Economic Analysis

Abstract:

To reduce carbon emissions, electricity generation from clean renewable sources is rapidly rising where the ability to reduce concentrating solar power (CSP) costs will be critical for increased CSP adoption. The U.S. Department of Energy (DOE) has a leveled cost of energy (LCOE) target of 5¢/kWh by 2030 for CSP, however, the current LCOE is 9-10¢/kWh. Thus, cost reductions for generation systems (i.e., CSP) are necessary to achieve DOE's cost reduction goal. Rather than look at the entire CSP system, the heliostat technology alone has been shown to impact the overall cost by more than any other component of CSP applications. Heliostats currently make up roughly 50% of the total cost of the balance of plant (BOP) which indicates possibilities for price reductions to significantly impact LCOE. The U.S. DOE Heliostat Consortium (HelioCon) facilitates technical investigation, techno-economic analysis (TEA), economic feasibility and sustainability for CSP applications. For this heliostat TEA, economic significance will be assessed for each component and metrology of heliostats.

Bio:

Natalie Gayoso is a first-generation master's student at the University of New Mexico studying Environmental Engineering. Her Master's thesis focuses on Techno-Economic Analysis (TEA) of emerging water and energy technologies. Her experience in this field has helped her with the HelioCon TEA Project and other Concentrating Solar Power tasks at Sandia National Laboratories. She started interning at Sandia in 2017 and thoroughly enjoys the research she does. Aside from her scientific interests, she likes reading, CrossFit, videography, and traveling.





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Dimitri Madden
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Sandia National
Laboratories (SNL)

Mentor: Dr. Ken Armijo

Project Title: Heliostat
Components and Controls

Abstract:

The project focuses on Concentrating Solar Power Heliostat Components and Controls. The goal of this work for HelioCon was to evaluate historical heliostat components and control systems used in full scale concentrating solar power facilities, as well as the current industry standards, advancements, and directions. Having worked in concentrating solar power for over 4 years, this was an excellent opportunity to apply my knowledge and experience and to evaluate opportunities for improvement. For furthering CSP systems, this work is valuable. Evaluating the state of heliostat technology, looking at historical technology, improved technology, and research/prototypes for potential next generation tech, is key for CSP goals such as development of industry standards or reduction of cost per square foot.

Bio:

Dimitri Madden is a Mechanical Engineering PhD Student at the University of New Mexico. He earned his B.S in Mechanical Engineering in 2020. He started as an undergraduate intern at the Concentrating Solar Department of Sandia National Laboratories in early 2018 and has been there ever since. He is now a PhD student at Sandia and works there full time between department level work and work for his dissertation. Having worked in concentrating solar power for over 4 years, this was an excellent opportunity to apply his knowledge and experience and to evaluate opportunities for improvement.



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Nicole Piatko

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Department of Energy

Mentor: Andru Prescod

Project Title: Heliostat
Drives and Opportunities
for Cost Reduction

Abstract:

Heliostat drives can account for approximately 30-50% of the total cost of a heliostat, which in itself can be approximately 40% of the cost of a concentrating solar thermal (CST) power tower plant. These drives are important in maintaining high accuracy when reflecting sunlight onto the receiver tower. In addition to being required to be highly accurate (i.e. tracking accuracy of around 1mrad), heliostat drives must also be designed to last up to 30 years in the field, withstand high wind loads and gust events, and minimize backlash while not being very expensive. So, not surprisingly, the high cost of drives come from the rigorous process of designing, manufacturing, and testing them so that they can meet the above requirements. We will briefly review heliostat drive designs and discuss opportunities to reduce their costs while maintaining or improving their technical performance.

Bio:

Nicole Piatko is a rising senior studying mechanical engineering at the University of Virginia. This summer she has been working in the SETO office studying heliostats. She is interested in mechatronics and mechanical systems, as well as efforts in creating sustainable communities. At school she is an applied mathematics teaching assistant and grader, involved in grass material research, and makes cartoons for the school newspaper. In her free time she likes to be outside and play sports with friends.

