Heliostat Technology Advancement
REQUEST FOR PROPOSALS (RFP)

RFP RFX-2022-10161

Submit proposals adhering to the template with page limits to HelioConRFP@nrel.gov by: 4:00 pm MT, Tuesday, November 8, 2022. Additional information about the Heliostat Consortium can be found at: *https://www.heliocon.org*

RFP Issue Date:	09/20/2022
RFP Webinar	10/10/2022 4:00 p.m. MDT
Submission Deadline for Full Proposal:	All Topic Areas: 11/08/2022 4:00 p.m. MT
Expected Date for Selection Notifications:	December 2022
Expected Time Frame for Award Negotiations:	January 2023 – February 2023

READ THIS DOCUMENT CAREFULLY

This solicitation is being conducted under the procedures for competitive subcontracts established by the National Renewable Energy Laboratory (NREL).

NREL will award a subcontract based on the following.

BEST VALUE SELECTION

All Statement of Work (SOW) requirements being met with the best combination of:

* Technical factors (based on qualitative merit criteria), and
* Evaluated price (or cost).

IMPORTANT DATES

Issue Date: September 20, 2022

Solicitation Webinar: October 10, 2022, 4:00 p.m. MDT

Deadline for Questions: October 14, 2022, 4:00 p.m. MDT

Response Due Date: November 8, 2022, 4:00 p.m. MT

Award Selection Anticipated: December 2022

A webinar to address questions regarding the HelioCon RFP solicitation is scheduled for October 10 at 4:00 pm MDT. Interested parties can participate in the webinar by registering at:

HelioCon RFP

After registering, you will receive a confirmation email containing information about joining the webinar.

Please submit questions by October 14, 2022, to HelioCon.RFP@nrel.gov. Questions are permitted during the webinar via the webinar chat box. However, the official response to any and all questions submitted will be provided in a posted RFP Amendment.

1. Solicitation Type - Best Value Selection

Pricing Arrangement - Firm Fixed Price Subcontracts

Submit responses to and request information from the NREL RFP Contact below.

2. NREL RFP Contact:

Bill Peters
Subcontract Administrator
National Renewable Energy Laboratory
15013 Denver West Parkway, MS: RSF030
Golden, CO 80401-3393

Phone: (303) 284-4332

Email: HelioCon.RFP@nrel.gov

Electronic (PDF) copies of forms and appendices can be found at:
https://www.nrel.gov/workingwithus/standard-terms.html and
https://www.nrel.gov/workingwithus/forms.html

Roadmap to Advance Heliostat Technologies for Concentrating Solar-Thermal Power
https://www.nrel.gov/docs/fy22osti/83041.pdf

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1. REQUEST FOR PROPOSALS DESCRIPTION

HELIOSTAT CONSORTIUM BACKGROUND

The Heliostat Consortium (HelioCon) is led by the National Renewable Energy Laboratory (NREL) and includes partners Sandia National Laboratories (Sandia) and the Australian Solar Thermal Research Institute (ASTRI). HelioCon is a U.S. consortium to support research, development, validation, commercialization, and deployment of low-cost heliostats for concentrating solar power (CSP) and concentrating solar thermal (CST) applications. Heliostats are a critical component of CSP power tower technologies. A heliostat field represents 30%–50% of the direct system cost and can be a large component of plant operations and maintenance (O&M) costs. To meet the U.S. Department of Energy Solar Energy Technologies Office's (DOE-SETO) target of 5 cents/kWh for baseload CSP configurations or 0.8 cents/kWh for thermal production, significant techno-economic improvements for heliostats will need to be realized—both a reduction in costs and an improvement in performance and reliability.

HelioCon works closely with DOE and a board of advisors composed of CSP developers, component suppliers, utilities, and international experts to achieve the DOE-SETO 2030 objectives for U.S.-manufactured heliostat cost, performance, and reliability. To further advance U.S. heliostat technologies, HelioCon engages with subject matter experts and general stakeholders for direct, project-level collaboration, external consulting, and mission-specific panels or workshops.

In the next five years, HelioCon aims to:

* Develop strategic core capabilities and infrastructure to support high-performance heliostat manufacturing, validation, and optimization and facilitate industry's ability to design, manufacture, install, and operate central receiver heliostat fields with higher technical and economic performance.
* Ensure that these capabilities are readily available to industry and academia, meeting their needs.
* Fund research on new technologies with significant potential to improve heliostat field economic performance.
* Form U.S. centers of excellence focused on heliostat technology to restore U.S. leadership in heliostat research, development, and validation.
* Promote workforce development through encouraging student internships and postdoctoral positions, as well as the formation of a HelioCon early career scientist group to promote networking and highlighting existing training and educational programs in heliostat design, production, and operation.

SOLICITATION PURPOSE AND OBJECTIVES

Through this solicitation, NREL aims to fund research, development, validation, and deployment of low-cost heliostats for CSP and CST applications.

Projects supported by this Request for Proposals (RFP) will focus on lowering the cost of heliostats and heliostat technologies, improving technical performance and reliability, and creating new market opportunities for the heliostat industry, with the goal of enabling widespread deployment of concentrating solar to decarbonize the electricity grid and energy systems.

One of the goals of publicly funded applied R&D is to mitigate the inherent risk of novel solutions. Key to achieving that goal is a systematic, domain-specific evaluation methodology, such as design of experiments, action research, or verification and validation testing. The testing itself should be preceded by well-designed test plans that examine the expected range of operation and generate statistical confidence in the results. To assist in these aspects, capabilities at the national laboratories will be made available in support of the selected projects. Proposals may take advantage of national laboratory resources and expertise at NREL (Addendum A) or Sandia (Addendum B) to help advance the proposed work as needed. Consultation and assistance from other HelioCon members is also encouraged.

Engaging in R&D activities with the support of public funds comes with the responsibility to disseminate the outcomes to the nation's researchers, its industry stakeholders, and the general public. It is a goal of this RFP to encourage broad, open, and lasting access to research results, including important data sets and software code, that the projects generate. To broaden and amplify the impact of the R&D work, SETO supports commercialization efforts for the diffusion of the technologies, intellectual property, and expertise developed by the funded projects.

Successful proposals to this RFP will address the critical gaps identified by industry members, stakeholders, and suppliers in the HelioCon Roadmap report. NREL will seek to select high-impact projects that are strategic in time, that use or enhance lab capabilities, and that establish a basis for future years. This RFP also aims to broaden the heliostat R&D community. HelioCon is interested in proposals supported by diversity in experience and perspectives. HelioCon also encourages applications from members of groups traditionally underrepresented in engineering and science. Based on the findings in the HelioCon Roadmap, this solicitation seeks to fund ambitious, high-impact proposals in the following topic areas.

Topic Area 1: Advanced Manufacturing

Topic Area 2: Metrology and Standards

Topic Area 3: Components and Controls

Topic Area 4: Field Deployment

Topic Area 5: Techno-Economic Analysis

Topic Area 6: Resource, Training, and Education

AVAILABLE FUNDING: Up to **$3 million in total funding** is available to fund multiple projects solicited in this RFP pending appropriations, program direction, and go/no-go decision points. The total funding of $3 million is expected to fund 4 to 8 projects. Individual awards may vary between $250,000 and $1,500,000 total.

2. TOPIC AREAS

Within each topic area below, specific needs are highlighted that were identified in the HelioCon Roadmap and are of particular interest. Other areas of research that address needs of a topic area may also be proposed. Areas of interest listed for each topic area are not exhaustive, and many ideas may crosscut several topic areas. Please refer to the *HelioCon Roadmap* for further details on each topic area. Proposals must have a focus on near-term impact achievable within the period of performance presented in the Technical Volume.

Topic 1: Advanced Manufacturing

Heliostat manufacturing directly influences both solar field cost and revenue and is a major contributor to overall CSP economic performance. Efficient manufacturing begins with initial product design, identifying a design that achieves high performance while also produced by an inherently efficient manufacturing process. It continues through supply chain, procurement, component manufacture, factory assembly, transportation, and field installation, and ends when a functional heliostat is installed in the field. This comprehensive perspective allows optimization of the entire process and design tradeoffs between component manufacture, subsystem assembly, full heliostat assembly, and field installation. Manufacturing, assembly, and installation processes occur throughout this process, presenting multiple opportunities for reducing cost to achieve DOE's $50/m^2 goal.

As detailed in the HelioCon Roadmap, several obstacles to efficient manufacturing exist. Innovative high-performing and low-cost heliostat mirror facet/array designs[1] are needed. Mirror array designs must satisfy a number of key functional criteria, including high optical accuracy, high stiffness, and durability across 25–30 years in harsh CSP environments. Light weight is a further advantage, reducing the cost of supporting structures. In addition to enabling efficient manufacturing, a cost-effective mirror array design must also consider the principles mentioned above to enable efficient manufacturing. There lacks, within the heliostat industry, sufficient mirror array fabrication process knowledge for high economic performance. Innovative supporting structure designs that reduce cost while achieving functional goals are also needed. Often, heliostat designs are not created for high productivity manufacturing at the outset. Finally, in many cases, there is a lack of experience in designing high-productivity manufacturing lines among heliostat developers.

The Areas of Interest for Topic Area 1 Advanced Manufacturing include but are not limited to:

- The development of a mirror array fabrication process that delivers high optical precision, high reflectivity, high stiffness, low weight, efficient manufacturing, and low cost.
    - One approach could include composite mirror development to reduce mirror costs and support thin glass designs. Such designs might increase reflectivity, optical accuracy, and stiffness, while reducing both cost and weight. Other design concepts accruing similar advantages are also welcome.
    - All designs should address functional requirements including materials reliability concerns, which relate to the Components and Controls topic area.
    - All designs should include prototype demonstrations of at least two example curvatures, corresponding to heliostat-to-target ranges of a smaller value no greater than 100 m

[1] Here we will use the term "mirror array" to refer to the ensemble of mirrors that are rigidly connected and that the heliostat steers to direct and focus sunlight on a desired target. Example arrays include rectangular grid, a single row, a circular pattern, or even a single facet. The term "mirror array" Is meant to include all of these possibilities, so for example, single-facet heliostat designs qualify for consideration.

and a larger value no smaller than 500 m. Other prototype plans may be proposed and will be evaluated on their merits.

- Proposals should consider past research developing advanced mirrors and explain how the proposed work will build upon or exceed previous achievements. Proposals for a new design, or proposals to improve an existing design, are both welcome.
- Proposals should demonstrate knowledge and utilization of advanced manufacturing in other areas, such as automotive manufacturing (for example).
- HelioCon strongly encourages direct collaboration between heliostat developers and manufacturing solution partners, starting early in the design phase.
- Proposed work should include conceptual design of the envisioned high-productivity manufacturing line, with preliminary estimates of cycle time, work in process volume, capital cost, operating cost, and production volume required to yield profitability.
- High resolution measurement of optical slope using a validated system is required. To support this, funded proposals will receive a no-cost license to Sandia's SOFAST optical metrology software including technical support to enable prototype diagnosis and validation on-demand at their facility. Proposals should include budget for the necessary equipment and space at their facility. The Q-Dec system marketed by CSP Services will be considered a suitable alternative; other proposed metrology options will be considered on their merits and should include a method for measuring optical slope with high spatial frequency. Optical performance results should be reported with SOFAST resolution and accuracy or better.

- The development of an improved design and fabrication process for heliostat supporting structures, achieving high rigidity, reduced cost, efficient fabrication and reduced weight.
    - This could include development of alternative designs using composite or other materials optimized for high-performance manufacturing to reduce cost and improve reliability. Other design concepts are also welcome.
    - All designs should address functional requirements including materials reliability concerns, which relate to the Components and Controls topic area.
    - Evaluation of mechanical stiffness, degradation, and performance should be included in successful proposals.
    - Proposals should consider past research developing advanced heliostats and explain how the proposed work will build upon or exceed previous achievements. Proposals for a new design, or proposals to improve an existing design, are both welcome.
    - Proposals should demonstrate knowledge and utilization of advanced manufacturing in other areas, such as automotive manufacturing (for example).
    - HelioCon strongly encourages direct collaboration between heliostat developers and manufacturing solution partners, starting early in the design phase.
    - Proposed work should include conceptual design of the envisioned high-productivity manufacturing line, with preliminary estimates of cycle time, work in process volume, capital cost, operating cost, and production volume required to yield profitability.

- Other topics related to advanced heliostat design and manufacturing. Examples include but are not limited to:
  - Field installation automation.
  - Variable-focus heliostats or facets.
  - Thoroughly documenting a heliostat for a baseline reference. A company may suggest documenting its own heliostat as a baseline reference, but if so, its performance evaluation should be independently validated. The national laboratories can provide assistance with this validation.
  - Detailed documentation of existing or previous heliostat manufacturing processes.
  - Document heliostat mirror/glass manufacturers and their current activity level, including CSP mirror manufacture.
  - The trade-off between face-up and face-down heliostat stow. Proposed work should build upon and update the previous study reported in Blackmon, J. B, "Non-Inverting Heliostat Study", Sandia Technical Report SAND78-8190, July 1979 (*https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/1978/788190.pdf*).

Topic 2: Metrology and Standards

Metrology, in the context of heliostats, is the application of measurement for performance assessment and heliostat quality assurance. It is a fundamental requirement of successful large scale CSP deployment. The nature of CSP, particularly achieving high temperatures via high solar concentration ratios, implicitly requires high optical accuracy. Appropriate measurement techniques and standards are fundamental for product design, prototyping, engineering, and improvement.

Opto-mechanical metrology (mirror slope error, mirror facet canting error and heliostat tracking error) is complex, error-prone, and requires high optical precision, necessitating rigorous validation between different technologies on the same measurement parameter(s). Metrology needs for the same set of measurement parameters will vary to a great extent under various conditions, such as a laboratory, an outdoor test site, and in-situ condition.

(Current gaps related to metrology include the lack of multiple (at least two) comparable viable metrology techniques for a given measurement parameter that are widely available to the CSP industry and the lack of validation for any metrology technique against either a trusted metrology technique or ground-truth article.)

Proposals in this topic area must plan to use an available third-party platform for new tool validation. Proposals must put forward a plan to make new tools available to the industry.

The Areas of Interest for Topic Area 2 Metrology and Standards include but are not limited to:

- The development of new **o**pto-mechanical quality assurance tools for mass production (may be specific to individual specific mass production line). Attributes of such tools should include:
  - Ability to measure shape deviation, slope error and canting error
  - Automatic operation
  - Fast assessment speed

- The development of new opto-mechanical quality calibration after installation that will provide quality assurance of an installed heliostat fields to achieve the target performance at the design point. Attributes should include:
    - Accommodating in-situ conditions during construction
    - Minimal manual operation or automatic operation
    - High-precision calibration
    - Fast calibration process

- The development of a new receiver flux quality real-time assurance tool. Attributes should include:
    - Ability to measure flux distribution on receiver geometry in real time
    - Ability to correlate flux distribution with solar irradiance and solar field operation
    - Automatic operation
    - Ability to be directly integrated into solar field control for hazard mitigation

Topic 3: Components and Controls

Heliostats comprise static and dynamic components (reflective area, a control system, and the mounting and tracking mechanism) operating in a highly controlled manner to provide accurate solar flux pointing. These components and their control represent numerous opportunities for cost control, both in actual cost and in reliability, maintenance costs, and lifetime.

Recent efforts have improved some component designs to lower the costs of customized components such as the drive system, which can account for up to one-third of the total heliostat cost[2]. Drives remain one of the most expensive components in a heliostat system, accounting for approximately 50% of the SETO's \$50/m^2 cost target for heliostats. Mirror facets also account for a high proportion of heliostat component cost that could be improved to reduce levelized cost of energy and levelized cost of heat. Commercially available heliostat mirrors (including adhesives and supports) represent nearly 50% of SETO's \$50/m^2 cost target[3].

Alternative materials and components are being considered to reduce heliostat weight, while improving rigidity and control and reducing costs. Additionally, resilient control of the heliostat is required for adjustment of heliostat structure so it can accurately track sun position to reflect concentrated sunlight toward a receiver. Wireless and closed-loop controls have become increasingly attractive for new installations as they offer potential cost savings and enhanced performance. Heliostat durability and reliability are not well characterized but are of key importance to ensure high performance and safe operation over the designed lifetime. Component degradation, particularly for drives, mirrors, and electronics are also not well documented in literature but are critical for predicting long-term system performance and planning, as well as financing system O&M.

As detailed in the HelioCon Roadmap, several obstacles to reliable, low cost and high performing components and controls exist. Composite materials and other advanced structures are necessary to reduce weight, increase reliability and lifetime with lower costs associated with fabrication,

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[2] Coventry, J. and Pye, J., 2014. Heliostat cost reduction–where to now?. *Energy Procedia*, 49, pp.60-70.
[3] Gauche, P., Shultz, A., Stapp, D., Sullivan, S., Ho, C.K., Turchi, C., Zhu, G., Yellowhair, J. and Mehos, M., 2019. *US DOE Gen3 and SunShot 2030 Concentrating Solar Power R&D: In search of \$0.05/kWh autonomy and seasonal storage* (No. SAND2019-14225C). Sandia National Lab.(SNL-NM), Albuquerque, NM (United States)

transportation, and deployment. Lower cost mirror designs are needed with comparable performance to existing glass mirrors. Wireless control system approaches could reduce up-front capital expenditure through minimized wire and conduit use and installation as long as new failure or reliability issues are avoided. Additionally, the ability to use closed loop controls for automated calibration, could reduce commissioning time and O&M hours, reduce drive requirements, and reduce overall costs.

The Areas of Interest for Topic Area 3 Components and Controls include but are not limited to:

- User-defined proposals for validating new wireless control systems
  - Development/demonstration of wireless control architecture, signal communication, and methods of hardware integration are needed for industrial scale heliostat applications.
  - Wireless technical and resiliency issues, tracking error, ease of integration, fault tolerance, safety during a potential signal drop, ease of operation, and cyber security issues are all of concern.

- User-defined proposals for developing and validating new closed-loop controls
  - Closed loop controls can enable automated calibration, reduction of commissioning time and O&M hours, reduction of drive requirements, and overall cost reduction.
  - Proposals that target this area of interest must include a plan to publish the fabrication process.
  - Proposals should include validation and testing over a range of environments.
  - Assessment of the cost impacts through lower cost drives and fewer labor hours (commissioning and throughout plant life) as well as any increase in optical performance is of interest. This relates to the TEA topic area.
  - Proposed closed-loop controls must optimize power management to keep power needs low, while also providing a strategy to address on-board electronics reliability.

- Cyber security, fault tolerance, and safety proposals for wireless communications and controls to identify and address potential vulnerabilities

Topic 4: Field Deployment

Field deployment captures all activities required to establish a functioning solar field, from site selection. capitalization and permitting, field layout, on-site assembly and field installation, field commissioning, operations and maintenance and end-of-life disposal/recycling. The non-trivial issue in field deployment optimization is that each deployment is site specific and heliostat specific, and for this reason innovations may not translate from one deployment to another. Still, through the gap analysis completed in the HelioCon Roadmap, field deployment cost reductions can derive from optimal learning rates, heliostat design features that facilitate ease of installation, and improvements in installation and O&M processes.

Primary obstacles to achieving optimized field deployments include the following:

- Investor risk: Deficits between projected and actual power production, reliability issues, and past issues with permitting related to community opposition or wildlife encounters remain prominent in the minds of investors and utilities which demands increased rigor on the part of developers to provide assurance of performance and compliance with federal, state, and local land use requirements.

- Industrial process heat: CST may provide an economic means of producing decarbonized heat for industrial processes without the efficiency losses inherent in electric to thermal conversion. However, heliostat fields and receiver towers may not be familiar to or well-conceptualized by the industries hoping to decarbonize. The opportunities and challenges of heliostats over other types of collectors or photovoltaics are not well understood and new industry-centric tools to quickly provide architypes, performance models, and technoeconomic analysis for new and retrofit industrial field layouts are needed to remove barriers for market adoption.
- Deployment-specific costs: Costs specific to field deployment and O&M are not well understood due to the limited number of deployments over a relatively long period of time and the uniqueness of each deployment. It is therefore difficult to quantitatively identify the most impactful opportunities for cost reductions such as automated washing systems, wireless communications, wireless photovoltaic power, and towerless calibration methods.

The Areas of Interest for Topic Area 4 Field Deployment include but are not limited to:

- Proposals that will mitigate both actual and perceived investor and utility risk by identifying and addressing the causes of power production underperformance, reliability issues, and challenges or delays to permitting and deployment.
    - Refine models with improved accuracy for power production over life of plant
        - Address both power prediction models and economic models
        - Consider past imprecise plant power predictions for existing CSP plants
        - Perform model sensitivity analysis to determine factors that could have significant contribution to error
    - Performance degradation modeling due to evolving heliostat reflectivity and structural mechanics over life of plant. This is also related to Components and Controls, as well as the Metrology topic area.
    - Identify federal, state, and local barriers to permitting and potential solutions. There is particular interest in understanding historic reasons for permitting challenges and case studies that assess the opportunities as well as the social, cultural, and economic impacts to tribal and rural communities
    - Interactions between heliostats and wildlife can result in animal deaths or harm, and are violations of the Endangered Species Act, National Environmental Protection Act, and Migratory Bird Treaty Act. Autonomous avian and terrestrial animal detection, avoidance, and deterrence technologies and economically viable field operational procedures that evade interactions with nature are sought to address these risks.

- Develop feasible system concepts/designs for heliostat field integration for a retrofitted or new plant for an industrial process heat application. Work with partners in one or more thermal energy-intensive industries such as glass, steel, hydrogen, chemical, or cement to assess the appropriateness of heliostat fields in specific sites to facilitate future adoption of CST by industry. Teams proposing to this area should have an industrial partner lead with a CSP subject matter expert co-PI.

    - Exemplar field layout and integration considering plant constraints (operations, existing infrastructure/obstructions, existing utilities, etc.)
    - Field layout tools should accommodate user-centric retrofitting of existing industrial plant features such as real estate and property lines, or other constraints such as parking lots and open fields
    - Develop technoeconomic analysis tools that are intuitive to plant owners/operators and provide the relevant inputs and outputs needed by industry.

- Deployment cost reduction: The cost/schedule of deployment and O&M is data deficient and site specific. Work with industry partners to identify the deployment-specific costs and field-specific O&M costs and to identify the contributing factors with the highest impact such as location, geology, and heliostat design.
    - Develop technologies that directly reduce the cost and schedule of field deployment processes
        - Autonomous deployment and calibration tools
        - Develop standards for foundation requirements as a function of soil type
        - Autonomous and/or waterless mirror washing technologies
    - Perform a multivariate cost analysis of field deployment, field mirror washing and replacement costs, and heliostat repair costs from detailed cost records obtained from deployed plants.
    - Quantify and rank opportunities for cost reduction throughout the field deployment scope.

Topic 5: Techno-Economic Analysis (TEA)

TEA uses models and analysis to quantitatively assess the benefits of heliostat design, manufacturing, and operation concepts for HelioCon. A central objective of this topic is to relate the cost and performance of heliostats and heliostat components to the overall plant performance.

There are no items to address in this round of the HelioCon RFP. However, use of TEA or life cycle assessment (LCA) or other probabilistic modeling in proposals to other topic areas when beneficial is encouraged.

Topic 6: Resource, Training, and Education

Resource, Training, and Education encompasses resources, practices, programs, and opportunities to provide newcomers with an adequate knowledge base and training to conduct R&D efforts; help outsiders join the workforce; and foster a productive, healthy, and fulfilling environment for all workers. Accessibility of institutional knowledge, training/reference material, and industry data among the existing and future workforce is key to supporting the growth of the industry. Supporting university and student involvement in the industry through professional development opportunities and curriculum development is necessary for establishing a stable workforce pipeline. Increasing public awareness of the technology area and future demand will help to expand the community involved in the industry. Major gaps in RTE that have been identified include:

- Lack of programs and guidance for promoting Diversity, Equity, and Inclusion and engaging underserved communities in the industry
- Lack of heliostat technology related research projects in universities
- Little public awareness/visibility of heliostat technologies and CSP
- Available heliostat technology resources are not easily accessible to the public
- Little exposure of students in Science Technology Engineering Mathematics (STEM) fields to heliostat technologies and CSP
- Insufficient curriculum and training materials on heliostat fundamentals for newcomers to the field or new workers in R&D or plant O&M

The Areas of Interest for the Resources Training and Education Topic Area include but are not limited to:

- Proposals which engage students and universities in professional development opportunities. Teams should include a university and industry partner.
    - Create a summer internship program in which university or community college students are paired with industry mentors at operating plants or companies involved in heliostat technologies. Students would travel to the industry location and gain hands-on experience. Programs that target minority/underrepresented student communities are encouraged. Industry sponsorships/cost-share is also encouraged.
    - Create a collegiate competition in which students compete in building and testing heliostat related technologies, for example, original heliostat designs or designing a commercial-scale plant and proposing a business plan. The *Collegiate Wind Competition* can serve as a model for this competition. Successful proposals will include clear project milestones, support student learning and professional development, provide planning for marketing the competition to students and for publishing information gathered from the competition online, and taking steps to ensure the competition is accessible to community colleges/underrepresented student communities.
- Proposals targeted at curriculum development in universities and community colleges. Teams should be university led. Call for assistance/collaboration from HelioCon team is particularly encouraged.
    - Development of curriculum modules that can be integrated into existing renewable energy course work to reach students with a variety of STEM backgrounds.
    - Development of vocational/technician development curricula in energy focused programs at community colleges
- Proposals targeted at supporting plant training and hiring needs. Teams should include a commercial plant partner.
    - Gathering and publishing data on plant hiring/training needs for each phase of plant development
    - Creating solar field training curriculum for new plant workers with hands-on experience

- Proposals to other topic areas are encouraged to address Resource, Training and Education needs in their project plans. Please note inclusion of internships, postdocs, creation of training content, and career development in those proposals.

3. AWARD INFORMATION

AVAILABLE FUNDING: Up to **$3 million in total funding** is available to fund multiple projects solicited in this RFP pending appropriations, program direction, and go/no-go decision points. The total funding of $3 million is expected to fund 4 to 8 projects. Individual awards may vary between $250,000 and $1,500,000 total.

PERIOD OF PERFORMANCE: Proposals are requested for a 1-3 year period of performance. If a multi-year project is proposed, continuation beyond year 1 will be contingent upon several elements, including satisfactory performance and annual Go/No-Go decision review. At the Go/No-Go decision points, NREL will evaluate project performance, project schedule adherence, the extent milestone objectives are met, compliance with reporting requirements, and overall contribution to the program goals and objectives. As a result of this evaluation, NREL may, at its discretion, authorize the following actions: (1) continue to fund the project, contingent upon the availability of funds; (2) place a hold on go-ahead for the project, pending further supporting data or funding; or (3) end the subcontract because of insufficient progress, change in strategic direction, or lack of funding.

4. COST SHARE REQUIREMENTS

COST SHARE: The cost share must be at least 20% of the total allowable costs for research and development projects (i.e., the sum of the Federally funded share, and the recipient share) and must come from non-Federally funded sources. Offerors may propose higher amounts of cost share, which may be in the form of cash or in-kind contributions. Cash contributions include, but are not limited to personnel costs, fringe costs, supply and equipment costs, indirect costs, and other direct costs. Allowable in-kind contributions include but are not limited to the donation of time or the donation of space or use of equipment.

Example – 20% cost share: The following is an example of how to calculate cost sharing amounts for a project with $1,000,000 in federal funds with a minimum 20% non-federal cost sharing requirement:

- Formula: Federally funded share ($) divided by Federally funded share (%) = Total Project Cost
    - Example: $1,000,000 divided by 80% = $1,250,000
- Formula: Total Project Cost ($) minus Federally funded share ($) = non-federally funded share ($)
    - Example: $1,250,000 minus $1,000,000 = $250,000
- Formula: Non-federally funded share ($) divided by Total Project Cost ($) = non-federally funded share (%)
    - Example: $250,000 divided by $1,250,000 = 20%

Upon selection for award negotiations, applicants are required to provide additional information and documentation regarding their cost share contributions.

5. INTELLECTUAL PROPERTY

Successful Offerors to this Request for Proposals (RFP) will gain access to HelioCon activities, including workshops, annual review meetings, and seminars. Each selected awardee will be required to become a HelioCon Consortium Member and sign on to the HelioCon Consortium Agreement and Non-Disclosure Agreement. Current Consortium Members working on the project have all signed the Consortium Agreement and are already Consortium Members. The provisions of the HelioCon Consortium Agreement have been designed to meet the needs of the HelioCon Consortium and are non-negotiable and no-changes will be accepted. Contact heliostat.consortium@nrel.gov for a copy the current HelioCon Consortium Agreement. Members are included in discussions on research needs, have distinct IP rights and obligations, and have regular contact with researchers at the national laboratories.

6. ELIGIBILITY

Offerors may include for-profit business, Educational Institutions, or non-profit businesses. Foreign entities are eligible to propose. Non-eligible entities include NREL, Sandia, U.S. Federally Funded Research and Development Centers, state or local government entities, foreign National Laboratories, and foreign Government organizations.

Multi-investigator teams may be needed to achieve the aggressive goals set forth by the HelioCon Roadmap report. Investigators are strongly encouraged to seek and describe links and intended collaborations with existing HelioCon supported researchers along with their engagement with the Heliostat Consortium. Information about existing HelioCon research can be found at https://www.heliocon.org.

Support from the national labs (NREL and Sandia) should be considered to assist with testing, consultation, and narrow analysis support. Support from the national labs should not constitute a joint research project. Note that NREL and Sandia will not be eligible to receive awards or subawards under this RFP, but the facilities and expertise at NREL and Sandia can be utilized to support projects. Lab scope will be negotiated upon selection to meet available resources. Please refer to Addendums A and B on national lab capabilities and for Lab Points of Contact.

7. COMPETITIVE SOLICITATION USING BEST VALUE SELECTION

This Solicitation shall be conducted using Best Value Selection that results in the selection of submitted proposals for potential subcontract award that is most advantageous to NREL based on the best value combination of (a) evaluated qualitative merit and (b) evaluated price of the proposals submitted.

Best Value Selection is based on the premise that, if all proposals are of approximately equal qualitative merit, the award will be made to those with the lowest evaluated price. However, NREL will consider selecting proposals with a higher evaluated price if the offer demonstrates the difference in price is commensurate with the higher qualitative merit. Conversely, NREL will consider selecting proposals with a lower evaluated qualitative merit if the price differential between it and other proposals warrants doing so.

8. DATA SHARING

All project proposals are required to include a plan to submit findability, accessibility, interoperability, and reusability (FAIR) compliant data.

9. PROPOSAL RESPONSE CONTENT AND FORMAT

Proposals must be submitted using the appropriate Word template attached to this document (Addendum C) and available at https://www.heliocon.org. Full Technical Proposals: Full technical proposals are strictly limited to 14 pages. References, 2-page resumes, letters of support, and current/pending support should be appended to the proposal file and are excluded from the page limit. A template for current/pending support can be found at the end of the template document. No information outside of the page limit will be considered. Anything after the page limit will be cut before the proposals are sent to review.

SECTION	MAXIMUM PAGE COUNT	DESCRIPTION
Technical Volume	**14**	**See below.**
Cover Page	1	See section 9.1 below.
Project Summary (Project Overview and Technical Description, Innovation, Impact)	5	This section should be a summary of the proposed project and its potential to contribute to the SOLICITATION PURPOSE, SCOPE, AND OBJECTIVES section above. See section 10.2 below.
Project Objectives and Work Plan	5	This section should include the following subsections: I. Overview II. Tasks & Deliverables See section 10.3 below.
Team Composition, Capabilities	3	This section should include Team Qualifications and Resources. See section 10.4 below.
Additional Supporting Documentation		**See section 9.5 below.**
References and Bibliography	2	See section 9.5.1 below.

Resumes/CVs	2 pages per person	See section 9.5.2 below.
Letters of Commitment	1 page maximum for each	See section 9.5.3 below.
Proposed Deliverables Milestone Payment Schedule	1 page maximum for each	See section 9.5.4 below.
Price/Cost Proposal	No Limit	See Section 9.5.5 below
Representations & Certifications for Subcontracts/Purchase Orders	N/A	See section 9.5.6 below.
Conflicts of Interest Representations/Disclosure	N/A	See section 9.5.7 below.

9.1 Cover Page – 1 page maximum

The proposal must include a cover page that includes:

- The Request for Proposal title and number
- The Project Title
- The Lead organization's name and principal investigator (with postal address, telephone numbers, and email address)
- A list of the Partners participating in the project and any other collaborating individuals or institutions. Note: NREL and Sandia will not be eligible to receive awards or subawards under this RFP, but the facilities and expertise at NREL and Sandia can be utilized to support projects.
- Any statements regarding confidentiality
- Acceptance or change/exception with reason to the sample subcontract schedule
- anticipated period of performance, and the standard terms and conditions and/or the intellectual property terms and conditions in the appendices. The offeror shall explain any proposed change/exception with respect to the sample subcontract schedule and terms and conditions. Any proposed change/exception must contain sufficient amplification and justification to permit evaluation. Such proposed changes/exceptions will not, of themselves, automatically cause an offer

to be termed unacceptable. However, many proposed changes/exceptions or one or more significant exceptions not providing any obvious benefit to the NREL or the Department of Energy may result in rejection of such offer as unacceptable. In addition, the cover letter shall include a summary statement indicating acceptance of the statement of work or any change with the reason(s).

9.2 Project Summary - 10 pages maximum

- Project Overview – suggest 1 page to include
  - Background: The applicant should discuss the background of their organization, including the history, successes, and current research and development status (i.e., the technical baseline) relevant to the technical topic area being addressed.
  - Project Goal: The applicant should explicitly identify the targeted improvements to the baseline technology and the critical success factors in achieving that goal.
- Technical Description, Innovation, Impact: suggest 4 pages to include
  - Relevance and Outcomes: The applicant should provide a detailed description of the technology, including the scientific and other principles and objectives that will be pursued during the project. This section should describe the relevance of the proposed project to the goals and objectives of the RFP, including the potential to meet specific DOE technical targets or other relevant performance targets. The applicant should clearly specify the expected outcomes of the project.
  - Feasibility: The applicant should demonstrate the technical feasibility of the proposed technology and capability of achieving the anticipated performance targets, including a description of previous work done and prior results.
  - Innovation and Impacts: The applicant should describe the current state of the art in the applicable field, the specific innovation of the proposed technology, the advantages of proposed technology over current and emerging technologies, and the overall impact on advancing the state of the art/technical baseline if the project is successful. Offerors should clearly define the target markets for the technology being developed, and how the proposed technology relates to existing or competing technologies. Offerors should include data or references to support cost and performance claims.

9.3 Statement of Project Objectives and Work Plan - suggest 5 pages

  - Project Objectives: The applicant should provide a clear and concise (high-level) statement of the goals and objectives of the project as well as the expected outcomes.
  - Technical Scope Summary: The applicant should provide a summary description of the overall work scope and approach to achieve the objective(s). The overall work scope is to be divided by performance periods that are separated by discrete, approximately annual decision points. The applicant should describe the specific expected result of each performance period.
  - Work Plan: The Workplan should describe the work to be accomplished and how the applicant will achieve the milestones, will accomplish the final project goal(s), and will produce all deliverables. The Workplan is to be structured with a hierarchy of performance period (approximately annual), task and subtasks, which is typical of a standard WBS for any

project. The Workplan shall contain a concise description of the specific activities to be conducted over the life of the project. Task descriptions should consist of: A distinct title, description of the activities, Potential risks or barriers and approaches for overcoming them, and Key personnel or resources.

- Milestone Summary: The applicant should provide a summary of appropriate milestones throughout the project to demonstrate success. A milestone may be either a progress measure (which can be activity based) or a SMART technical milestone. SMART milestones should be Specific, Measurable, Achievable, Relevant, and Timely, and must demonstrate a technical achievement.
- Go/No-Go Decision Points: The applicant should provide a summary of project-wide Go/No-Go decision points at appropriate points in the Workplan.
- End of Project Goal: The applicant should provide a summary of the end of project goal(s). At a minimum, each project must have one SMART end of project goal.

9.4 Team Composition, Coordination, and Capabilities (3 pages maximum)

Teaming Overview: Strong team composition, available resources and capabilities, and effective leadership and coordination are vital components of a successful proposal. Please address the Project Leader and Key Personnel qualifications, including past experience and subject matter expertise. This section should clearly address the relevant evaluation criteria (see Section 10), highlighting the following:

- How this team is uniquely suited to achieve the project objectives
- Description of Offeror team member capabilities including the performance levels of any relevant materials, cells, modules, and equipment that will be available at the start of the project.
- How the Offeror firm will make decisions (i.e., which research areas are most important to pursue, whether any new capabilities are needed, etc.)
- Identification of any non-federal resources that are expected to be leveraged by the consortium in pursuit of its goals (See Non-Federal Resources and Industry Effort below).
- If applicable, list lab support requested from national lab. List the capabilities within each lab that this proposal seeks to utilize (See Addendums A and B). Provide a brief rationale of the benefit to the project of the use of these capabilities.

9.5 Additional Supporting Documentation

9.5.1 References and Bibliography (2 page maximum)

Relevant references may be cited, but do not include copies of referenced articles in the electronic submission in response to this RFP.

9.5.2 Resumes/CVs (2-page maximum per person)

Abbreviated (2-page maximum per person) resumes should be supplied for at least the primary investigator at each Subcontractor institution and, optionally, the coinvestigator. (Submitted resumes shall not include Social Security Numbers). Resumes are not included in the final page count.

9.5.3 Letter of Commitment (1-page maximum)

Letters of Commitment from other entities listed in the proposal are suggested. Letters of commitment for the price participation are required If the price participation is coming from a 3rd party.

9.5.4 Tasks and Deliverables - Required from each Offeror

This section should specifically delineate what work each Offeror will perform. The price should reflect the scope of work requested in this RFP.

Deliverables:
Should a subcontract be awarded, the Offeror will be reimbursed for deliverables achieved by the project team and received by NREL during the negotiated period of performance (1 to 3 years). The deliverables should be challenging but achievable. They should also be achieved within the proposed period of performance (1-3 years) by the Offeror. It is important that the task structure supports the proposed deliverables and that the proposed deliverables are of high value. Deliverables will be reported directly to NREL.

In addition to project-specific deliverables, HelioCon requires several program-related deliverables to ensure objectives are met.

Note that the following deliverable requirements should be planned and budgeted:

- A deliverable that describes the current state of research, development, and/or product at the Offeror Organization is due within the first 4 months.
- Brief quarterly reports (max 10 pages) and presentations documenting progress, summarizing the current status of Subcontractor's projects, tracking Subcontractor impacts on the industry and research community, and providing a financial update.
- Participation in meetings. These are held at approximately annual intervals with specific time and locations to be determined. Successful participation requires attendance, presentation (oral or poster), and submission of a project summary report. Travel to the two annual workshops is required.
- All projects are required to upload data to HelioCon and work with the data team to ensure full compliance with open data requirements.
- A Final Project Deliverable, due at month 12 or 24 or 36 (depending on Period of Performance, that includes:
    - A final report, suitable for public dissemination, detailing the accomplishments of the project.
    - A final deliverable that demonstrates the achieved level of progress with respect to the defined objectives.

Example Deliverable Table:

Deliverable No. (Year #)	Associated Task(s) No.	Deliverable Description	Due Date (Quarter, Year)	Proposed Deliverable Payment
1.1	1	Initial Report	Q0, Y1	$200,000
1.2	1	Quarterly Report	Q1, Y1	$10,000
1.3	1	Quarterly Report	Q2, Y1	$10,000
1.4	1, 2	Quarterly Report	Q3, Y1	$10,000
1.5	1, 2	Quarterly Report	Q4, Y1	$30,000
…		…		…
2.2	1	Project Specific Deliverable	Q2, Y1	$50,000
2.6	1	Project Specific Deliverable	Q4, Y1	$10,000
…		…		…
3.4	1, 2, 3	Final Project Report	Q4, Y3	$10,000
3.5	1,2,3	Final Project Deliverable	Q4, Y3	$100,000

9.5.5 Price/Cost Proposal (no limit)

A completed "Price/Cost Proposal Form" with a minimum 20% price participation (cost share) in an electronic copy (converted to PDF file) is required. Documentation to support all elements of your proposed price (cost) for the minimum 20% price participation (cost share) but higher cost share is encouraged. What your organization chooses to submit should clearly show the price participation elements/components of your proposal. Letters of commitment for the price participation are required if the price participation is coming from a 3rd party.

An individual offeror's price (cost) proposal standard format can be used if the data included is substantially the same as the NREL form. The offeror's price (cost) and delivery terms must be valid for 120 days from the date of the offer. The price (cost) proposal should include support documentation for all categories of the proposed price (cost). The price (cost) proposal should separate price (cost) for lower-tier subcontract(s) and include support documentation for all categories of the proposed lower-tier subcontract(s) price (cost). In accordance with the instructions on the Price/Cost Proposal Form (Excel form with tabs), please be sure to provide a breakout of your price/cost proposal by task to include labor hours, labor rates, and a list of other direct costs, expendable materials, and basis of estimate/assumptions for proposed travel, etc. Also include documentation to support all elements of your proposed price/cost, such as quotes from vendors (or past invoices or purchase orders for similar items) for material and equipment, screen shots of airfare and other travel related quotes, proposals from lower-tier subcontractors, audit reports, etc. See the "Price/Cost Proposal Form" for specific instructions. This form is found under "Request for Proposal (RFP) Forms (Non-Construction)" at the following link:

https://www.nrel.gov/workingwithus/assets/pdfs/price_cost_form_2.pdf

Please note that Federal funding of equipment will likely result in Federal ownership and delivery of equipment to NREL.
Provide a proposed payment schedule for deliverables, taking into consideration the level of effort, and other costs associated with each deliverable

9.5.6 A completed "Representations & Certifications for Subcontracts/Purchase Orders" form.

Please download from the NREL general access website link below:
http://www.nrel.gov/workingwithus/forms.html

9.5.7 EITHER the "Organizational Conflicts of Interest Representation Statement" OR the "Organizational Conflicts of Interest Disclosure Statement", as applicable per the "Instructions for Completion of Organizational Conflicts of Interest Statement – Disclosure or Representation Statement". The forms and instructions are located at the following link:
http://www.nrel.gov/workingwithus/forms.html

9.5.8 This solicitation requires the submittal of electronic proposals

Each RFP must be submitted in a PDF file sent to the NREL RFP Contact by email at HelioCon.RFP@nrel.gov. The e-mailed submission must include the RFP Number (RFP RFX-2022-10161) and the proposal title "Heliostat Technology Advancement" in the subject line.

9.5.9 Late submissions, modifications, and withdrawals of offers

Offers, or modifications to them, received from qualified organizations after the latest date specified for receipt may be considered if received prior to award, and NREL determines that there is a potential price (cost), technical, or other advantage, as compared to the other offers received. However, depending on the circumstances surrounding the late submission or modification, NREL may consider a late offer to be an indication of the offeror's performance capabilities, resulting in downgrading of the offer in the technical evaluation process. Offers may be withdrawn by written notice received at any time before award.

9.5.10 Restrictions on disclosure and use of proprietary data (Nov 2018)

Offerors who include in their proposals proprietary data that they do not want disclosed to the public for any purpose or used by the government or NREL, except for evaluation purposes shall, in addition to including the "*Notice for Handling Proposals*" and mark the following —

1. Mark the title page with the following legend:
   "This offer includes proprietary data that shall not be disclosed outside the government or NREL and shall not be used or disclosed—in whole or in part—for any purpose other than to evaluate this offer. If, however, a subcontract is awarded to this offeror as a result of—or in connection with—the submission of proprietary data, the government or NREL shall have the right to duplicate, use, or disclose the proprietary data to the extent required in the resulting subcontract. This restriction does not limit the government or NREL's right to use this proprietary data if obtained from another source without restriction. The

proprietary data subject to this restriction are contained on pages [insert page and line numbers or other identification of pages] of this offer"; and

2. Highlight (in yellow) the proprietary data on each page it wishes to restrict and add the following footer:

"Use or disclosure of proprietary data contained on this page is subject to the restriction on the title page of this offer."

9.5.11 Notice of right to receive patent waiver (derived from DEAR 952.227-84) and technical data requirements.

Offerors (and their prospective lower-tier subcontractors) in accordance with applicable statutes and Department of Energy Acquisition Regulations, (derived from DEAR 952.227-84) have the right to request a waiver of all or any part of the rights of the United States in inventions conceived or first actually reduced to practice in performance of the subcontract that may be awarded as a result of this solicitation, in advance of or within thirty (30) days after the effective date of subcontracting. Even where such advance waiver is not requested or the request is denied, the subcontractor will have a continuing right during the subcontract to request a waiver of the rights of the United States in identified, individual inventions.

Domestic small business firms, educational institutions, and domestic nonprofit organizations normally will receive the clause: Patent Rights - Retention by the Subcontractor, which permits the offeror to retain title to subject inventions, except in subcontracts involving exceptional circumstances or intelligence activities. Therefore, domestic small business firms, educational institutions, and domestic nonprofit organizations normally need not request a waiver.

If an offeror's proposal includes a lower-tier subcontract to another organization, that lower-tier organization's business type will determine the applicable intellectual property provisions that will apply to the lower-tier subcontract. Note that a lower-tier subcontractor may apply for a patent waiver under the same conditions as the offeror.

Under a research, development, and demonstration project, the Department of Energy and NREL are unable to ascertain, prior to receipt of offers or performance of the project, their actual needs for technical data. It is believed that the requirements contained herein are the basic needs of the Department of Energy and NREL. However, if the offeror indicates in its proposal that proprietary data will be used or withheld under its proposed effort, the Department of Energy and NREL reserve the right to negotiate appropriate rights to the proprietary data. The appropriate rights may include "Limited Rights in Proprietary Data" and/or "Subcontractor Licensing."

9.5.12 Disclaimer

NEITHER THE UNITED STATES; NOR THE DEPARTMENT OF ENERGY; NOR ALLIANCE FOR SUSTAINABLE ENERGY, LLC; NOR ANY OF THEIR CONTRACTORS, SUBCONTRACTORS, OR THEIR EMPLOYEES MAKE ANY WARRANTY, EXPRESS OR IMPLIED, OR ASSUME ANY LEGAL LIABILITY OR RESPONSIBILITY FOR THE ACCURACY, COMPLETENESS, OR USEFULNESS FOR ANY PURPOSE OF ANY OF THE TECHNICAL INFORMATION OR DATA ATTACHED OR OTHERWISE PROVIDED HEREIN AS REFERENCE MATERIAL.

9.5.13 Solicitation disputes

The General Accountability Office and the Department of Energy do not accept or rule on disputes for solicitations for Requests for Proposals issued by Management and Operating Contractors for the Department of Energy (operators of Department of Energy National Laboratories). Should an offeror have any concerns regarding the NREL solicitation process or selection determination, the offeror may contact Paul White, Advocate for Commercial Practices, at (303) 384-7575. NREL will address each concern received from an offeror on an individual basis.

9.5.14 Prohibition on use of certain telecommunications and video surveillance services or equipment per the John S. McCain National Defense Authorization Act Section 889(a)(1)(B)

In accordance with the John S. McCain National Defense Authorization Act Section 889(a)(1)(B), NREL is prohibited from contracting with any offeror that uses, and/or whose lower-tier subcontractor(s) use, covered telecommunication equipment or services as a substantial or essential component of any system, or as a critical technology of any system, on or after 08/13/2020, unless an exception applies, or a waiver is granted. This includes such equipment or services from five Chinese companies: **Huawei, ZTE Corporation, Hytera Communications, Hangzhou Hikvision, and Dahua Technology**.

9.5.15 Compliance with Section 508 of the Rehabilitation Act (found at 29 U.S.C. 794d)

The requirements of Section 508 of the Rehabilitation Act apply to NREL's procurement of all electronic and information technology (EIT) and any development, maintenance, or use of EIT.

9.5.16 RFP Terms and Conditions

1. Appendix A Statement of Objectives dated 9/3/22.
2. Sample Subcontract Schedule - .
3. Appendix B-2, entitled General Terms and Conditions, dated 3/01/2020
4. Appendix C-1 or C-2 (depending upon organization's classification), entitled Intellectual Property Provisions, dated 08/01/2022
5. Appendix D, entitled Standard Terms and Conditions for Subcontracts in Excess of $700,000, dated 3/1/20
6. Appendix F, Small Business Lower-Tier Subcontracting Plan, dated 3/1/20

9.5.17 NAICS Code and Small Business Size Standard

a. The North American Industry Classification System (NAICS) for this solicitation is 541690 and,

b. The small business size standard for is $16,500,000 in annual receipts. (Annual receipts of a concern means the annual average gross revenue for the last three fiscal years.)

9.5.18 Notice Regarding NREL Payments to Subcontractors

It is NREL's standard practice to make all payments to domestic subcontractors via electronic (ACH) payments or to international subcontractors via wire transfers. Any Offeror receiving notification of an award under this solicitation must complete and submit a "Request for ACH/Wire Banking Information" form to the applicable NREL Subcontract Administrator. Payments to subcontractors will be deposited directly into the subcontractor's designated bank account in accordance with the banking account/wire transfer information provided on the form by an authorized company representative. An electronic (PDF) copy of the form will be provided by the NREL Subcontract Administrator upon notification of award. Please do not include an ACH form with your response to this RFP.

10. PROPOSAL EVALUATION

Step One - Initial Evaluation

An initial evaluation will be screened for adherence to the above guidelines and relevance to the targeted topic areas. Proposals that do not meet the guidelines will be excluded from further consideration. Proposals that meet these criteria will be reviewed by technical experts on the HelioCon Selection Team using the following criteria.

Step Two - Discussion and Selection

All acceptable proposals will be evaluated against the merit criteria below. NREL reserves the right to conduct site visits to Responders of this proposal prior to selection. Responders selected through the process will be contacted with the intent to negotiate an acceptable Statement of Work, based on the Responder's proposal.

Technical Merit (70%)

- How effectively does the proposal address the HelioCon goal for the Topic being proposed?
- What is the potential impact of this work on the HelioCon goal identified above if it is successful?
- What is the relevance of the proposal in addressing the gap(s) identified in the HelioCon Roadmap?
- Does the proposal clearly describe the current and future field relevance of the work?
- How will the results be made publicly accessible? Is this sufficient for industry adoption?
- Which public data sets or tools will be made publicly available?
- What is the likelihood that this research would be effectively leveraged by HelioCon collaborators in the solar industry?
- What is the plan for stakeholder engagement to use this research or build on the results from this work?
- What can HelioCon or the heliostat community learn, if either successful or unsuccessful?

Organization and Execution of Work Plan (30%)

- Is the work plan clearly articulated and effective in achieving the goals of the project?
- Are the milestones and deliverables clearly articulated and appropriate?
- Does the proposal demonstrate that they can either accept inputs from or provide outputs to other projects to create model chains and compatible property libraries or create a publicly accessible calculation tool?
- Does the proposal include a data plan that includes providing data meeting FAIR standards (www.go-fair.org/fair-principles/) to provide data sets and/or analysis tools to HelioCon?

- What is the likelihood of the proposed work to succeed based on the budget and work period proposed?
- Does the team have the skills and resources necessary to build this capability?
- Is this proposed effort differentiated from the research in other SETO-funded projects (e.g., SETO lab call, etc.) and how does it compare to the current state of the art? See SETO's active and inactive projects at https://www.energy.gov/eere/solar/solar-energy-research-database

11. PRICE EVALUATION FOR BEST VALUE SELECTION

After evaluation of the qualitative merit criteria, the combined qualitative merit value of the offer will be considered relative to the price (cost).
The combined qualitative merit value will be considered substantially more important than the Firm Fixed Total price proposed.

12. ADDITIONAL FACTOR FOR EVALUATION

DIVERSITY, EQUITY, AND INCLUSION

NREL aspires to be a world-class leader in workforce diversity, equity, and inclusion by creating and maintaining a culture of respect, caring, and belonging. Proposals should address the following applicable components:

1. DEI within the project team (inclusive environment and inclusion of underrepresented staff) 2. DEI in research and implementation partners (e.g., partnering with a minority-serving institution) 3. Projects involving and benefiting underserved communities 4. Smart goals and metrics to quantify success and track goal attainment.

13. EVALUATION PROCESS

NREL will evaluate proposals in two general steps:

Step One - Initial Evaluation

An initial evaluation will be performed to determine if all required information has been provided for an acceptable proposal. Responders may be contacted only for clarification purposes during the initial evaluation. Responders shall be notified if their proposal is determined to be not acceptable and the reasons for rejection will be provided. Unacceptable proposals will be excluded from further consideration.

Step Two - Discussion and Selection

All acceptable proposals will be evaluated against the scope of interest and the qualification requirements; the qualitative merit criteria, additional factors, and price evaluation listed above. NREL reserves the right to conduct site visits to Responders of this proposal prior to selection. Responders selected through the best value selection process will be contacted with the intent to negotiate an acceptable Statement of Work, based on the Responder's proposal.

14. PROPOSAL SELECTION

The HelioCon Selection Team (with additional technical experts approved by NREL If needed) will review proposals according to the merit criteria above. The HelioCon Selection Team anticipates making selections in December 2022 for work starting in March 2023.

Please plan for these requirements in your budget. This Solicitation does not commit NREL to pay costs incurred in the preparation and submission of a response to this request RFP.

FORMATTING INSTRUCTIONS

Formatting instructions are as follows:

* A page is defined as one side of an 8 ½" x 11" sheet of paper.

* Use 12-point font.

* Maintain at least 1-inch margins on all sides.

Each RFP must be submitted in a PDF file sent to the NREL RFP Contact by email at HelioCon.RFP@nrel.gov. The e-mailed submission must include the RFP Number (RFP RFX-2022-10161) and the proposal title "Heliostat Technology Advancement" in the subject line. The RFP must be directed toward meeting the requirements of the Solicitation. You should provide only the minimum amount of information required for proper evaluation. Keep your proposal as brief as possible and concentrate on substantive information.

This Solicitation does not commit NREL to pay costs incurred in the preparation and submission of a response to this RFP.

Addendum A – NREL Capabilities

Point of Contact for NREL Lab Capabilities: Mark Mehos ***mark.mehos@nrel.gov***
(Note: Offeror communication with this contact shall be for the sole purpose of verifying NREL capabilities)

Advanced Optical Materials and Collector Characterization Capabilities

Optical Characterization

NREL's Advanced Optical Materials Characterization Laboratories provide analytical and measurement capabilities for developing and testing optical properties and performance of materials used in CSP systems such as CSP mirrors, glass, glazings, and coatings. In materials characterization, researchers' study and quantify the properties of materials such as permeability, adhesion, reflectivity, transmissivity, and absorption. We can measure a wide range of feature sizes (from nanometers to meters) and sample sizes (from millimeters to tens of meters). Optical measurement equipment at NREL includes the following:

Equipment Name (Manufacturer)	Equipment Type	Equipment Specifications
L1050 (Perkin Elmer)	Spectrophotometer	Measures hemispherical reflectance or transmittance at 8° incidence angle over UV/visible spectrum, nominally 250-2500 nm. Resolution of up to .05 nm. Capable of larger range with additional detectors.
D&S (Device & Services), 2 units – 1 USB, 1 RGB	Specular Reflectometer	Measures specular reflectance at 660nm wavelength within envelops of 7, 15, 25, and 46mrad. RGB model measures at additional wavelengths with light filter.
ET100 (Surface Optics Corporation)	Portable Emissometer	Measures emittance in 6 bands in the IR spectrum 1.5-2.0, 2.0-3.5, 3.0-4.0, 4.0-5.0, 5.0-10.5, 10.5-21 microns Measures directional thermal emittance as function of reflectance at 20° and 60° Measures total hemispherical emittance at 20°
SOC-100 HDR (Surface Optics Corporation) coupled with Nicolet 6700 (Thermo Fisher)	SOC-100 HDR coupled with FTIR	Performs Fourier-transform of IR input data from SOC Hemispherical-Directional Reflectometer to measure emittance as a function of wavelength and temperature Wavelength range from 1.5-25 micron Temperature range in beyond 500 deg. Emittance as function of temperature can be measured via mathematical model or directly with heated sample stage
410 - Solar Reflectometer (Surface Optics Corporation)	Portable Spectrophotometer	Measures specular, diffuse, and total reflectance over 7 wavelength bands at 20° incidence. Outputs reflectance or absorptance as function of reflectance. 335 - 380 nm, 400-540 nm, 480-600 nm, 590-720 nm, 700-1100 nm, 1000-1700 nm, 1700-2500 nm

ramé-hart 590	Contact Angle Goniometer	Measures contact angle, surface energy, surface tension, and interfacial tension

Weatherability and Durability

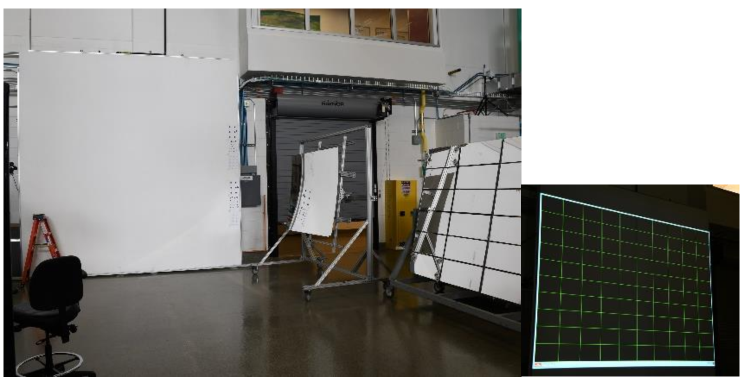
NREL's advanced materials weatherability and durability laboratories use temperature- and humidity-controlled chambers to test for weathering durability, corrosion on mirrors, delamination of polymers under controlled conditions. A *searchable materials database* encompassing the results of the NREL's historical and ongoing efforts in the evaluation of solar mirror materials was developed under NREL'S DOE/SETO-funded project titled "Development and Validation of a Xenon Arc Lamp Accelerated Aging Method for CSP Solar Mirrors Materials". The database allows users to access reflectance and degradation data from thousands of reflectors across numerous reflector types and composition, weathered in a variety of representative environments. Weatherability and durability measurement equipment available at NREL includes the following:

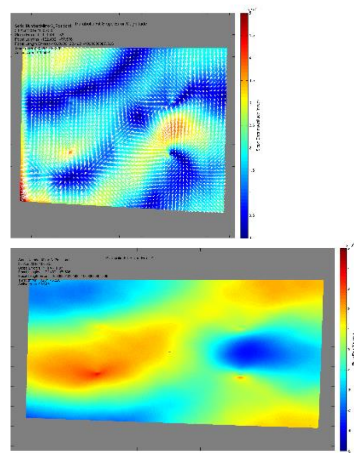
Equipment Name (Manufacturer)	Equipment Type	Equipment Specifications
Ci5000 (Atlas), 5 units	Environmental Chamber	10%-95% Relative Humidity in light cycles Light output up to 2 suns See filter options to choose spectrum options
XR260 (Atlas)	Environmental Chamber	4 Xe Lamps producing 1 sun output 4 ft. x 6 ft. Test Plane 0%-90% Relative Humidity -10°C to 110°C with light exposure -40°C to 110°C Dark
Blue M Small (Thermal Product Solutions)	Environmental Chamber	Dark Chamber 85°C and 85%RH 65°C and 65%RH 65°C and 85%RH
Blue M Large (Thermal Product Solutions)	Environmental Chamber	Dark Chamber 85°C and 85%RH 65°C and 65%RH 65°C and 85%RH
Small Solar Simulator (ORIEL Corporation)	Environmental Chamber	Xe lamp filtered from 300-500nm NREL built chambers can add low and high temperature and low and high relative humidity exposure
Medium Solar Simulator (ABET Technologies)	Environmental Chamber	Xe lamp filtered from 300-500nm NREL built chambers can add low and high temperature and low and high relative humidity exposure
Sun 2000 Large Solar Simulator (ABET Technologies)	Environmental Chamber	Xe lamp filtered from 300-500nm NREL built chambers can add low and high temperature and low and high relative humidity exposure
Salt Spray (Atlas)	Environmental Chamber	
Tenney (Thermal Product Solutions)	Environmental Chamber	20%-98% relative humidity (at sea level and 24°C) -73°C - +200°C, ±0.3°C
Ultra-Accelerated Weather System (NREL)	Accelerated Outdoor Weathering	Cooled samples are exposed to natural sunlight concentrated 100 times below 500 nm

Scrub Abrasion (BYK)	Abrasion Testing	Brush scrub system using brushes of various materials Tests can be run with or without dust
Tabor Abrader (Taber Industries)	Abrasion Testing	Abrasion wheels in multiple materials of varying abrasive qualities available

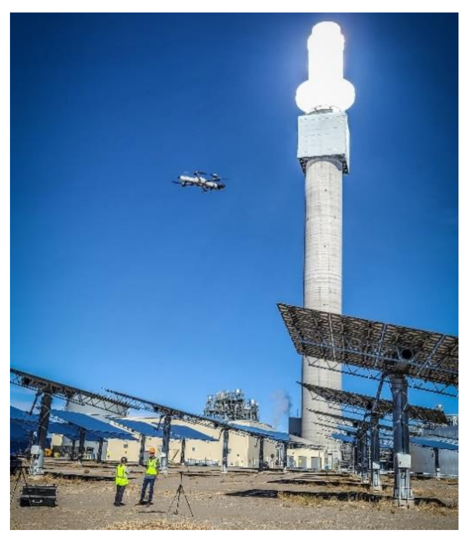
SOFAST Collector Facet Characterization

SOFAST, or Solar Optical Fringe Alignment Slope Technique, is an automated indoor concentrator characterization system that assesses the quality of mirrors for solar applications. A video camera and computer capture and analyze fringe patterns from a reference target pattern in the reflected image of a solar concentrator to identify slope as well as slope errors. Data acquisition is extremely fast, consisting of the time needed to take a few digital photos of the virtual image of the target as seen in the concentrator under test. SOFAST was originally developed by Sandia National Laboratories. Under a Department of Energy-funded partnership agreement, it was licensed to NREL and adapted for trough mirror-facet characterization.





In-Situ Heliostat-Field Characterization (NIO)

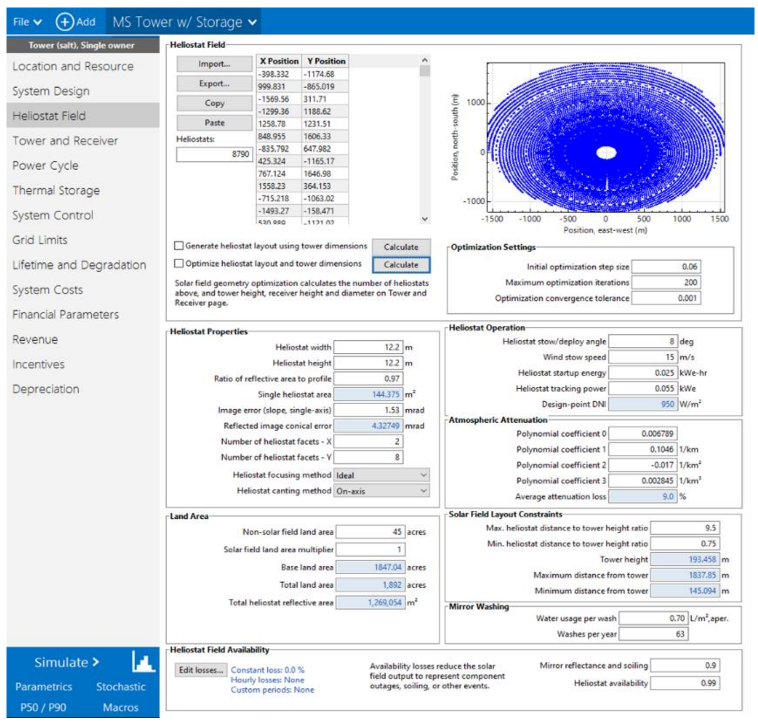


The non-intrusive optical (NIO) technology is designed to measure mirror surface slope error, mirror facet canting error, and heliostat tracking error based on reflection images using the natural target—the tower—in a heliostat field. Automated Unmanned Aircraft System (UAS) waypoint flying is used to position a camera at precise locations to capture images of the reflected tower in the heliostats using a path planning algorithm that considers the solar field parameters and the heliostat orientations at time of measurement. In the post-processing stage, The NIO approach adopts various techniques in photogrammetry, reflectometry, and geometrical optics to first determine the camera position and the actual tower position with respect to the heliostat. Image processing is used to identify the target heliostat features and to detect the position of the reflected tower edge in each image frame. The law of reflections is applied to find the surface normal at the reflection point or line of a reflection image and derive the surface slope error, mirror facet canting error, and heliostat tracking error accordingly. The NIO method allows for an efficient survey of a commercial-sized solar field to provide detailed optical characterization data for each measured heliostat in a utility-scale field of over 10,000 heliostats within a few days or weeks depending on the number of UASs and the size of the field. NIO UAS data collection is being performed at Crescent Dunes Plant in Tonopah, NV. The development of the NIO approach is expected to fill the critical gap for successful solar-field operation and maintenance, which is necessary for the global growth of the solar power-tower technology.

NREL Modeling Capabilities

NREL develops and maintains a suite of modeling tools and capabilities to analyze and overcome technical barriers to accelerate concentrating solar power (CSP) technologies. A list of tools is provided below.

System Advisor Model



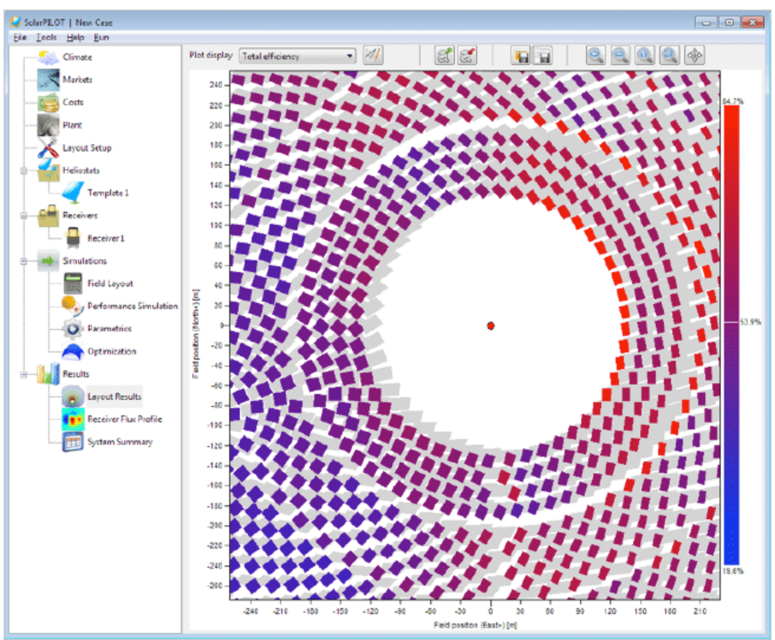
The *System Advisor Model* (SAM) is a free techno-economic software modeling tool for predicting the performance and cost of grid-connected renewable energy projects at specific sites. SAM produces sub-hourly energy output and calculates detailed financial metrics based on installation and operating costs and system design parameters that the user inputs to the model. The SAM tool facilitates decision-making for people in the renewable energy industry including project managers and engineers, policy analysts, technology developers, and researchers.

SAM's CSP models allow for techno-economic analysis of parabolic trough systems using oil or molten salt as the heat transfer fluid, power tower systems using liquid, e.g., molten salt, heat transfer fluids or direct steam systems, linear Fresnel, or dish-Stirling systems. SAM's two industrial process heat (IPH) models are for a solar field that delivers heat directly to a thermal process including IPH parabolic trough with molten salt, oil, or pressurized steam for the field heat transfer fluid, and optional thermal storage with salt or oil as the storage fluid and IPH linear Fresnel direct steam. A generic CSP model uses optical efficiency tables to represent the solar field and can be used to model any kind of CSP system for electric power generation.

Solar Power Tower Integrated Layout and Optimization Tool (SolarPILOT)

NREL's *Solar Power Tower Integrated Layout and Optimization Tool* generates and characterizes power tower systems. The tool is used by researchers, industry technology developers, and academics to evaluate technology performance, quantify the value of research findings, and provide third-party, independent validation for privately developed tools. SolarPILOT provides state-of-the-art functionality with several important features. With SolarPILOT, users can:

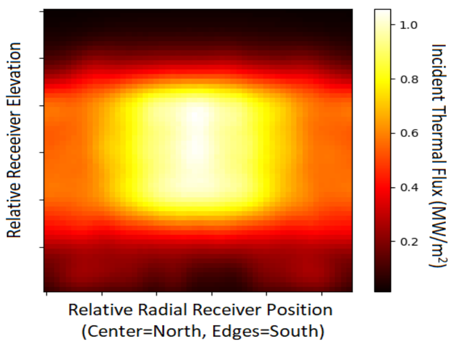
- Create heliostat field layouts that account for local solar and atmospheric conditions, receiver geometry and tower height, market pricing factors, and other considerations
- Constrain heliostat field positions with customizable land shapes and easily define complex land-boundary geometry with software that generates KML files (e.g., Google Earth).
- Model a variety of heliostat optical configurations including multiple facets and aiming/canting schemes
- Create systems with multiple heliostat or receiver geometries
- Simulate receiver flux profiles using smart aiming techniques at any specified time or solar position
- Execute parametric simulations to quickly investigate sensitivity to a design parameter
- View field layouts, flux plots, and aim-point plots with an interactive plotting tool
- Optimize the heliostat field layout and receiver dimensions to minimize expected cost of energy
- Calculate solar field cost
- Execute multi-threaded simulations to reduce simulation time
- Execute scripts that provide in-depth control of heliostat positioning, aiming, land boundaries, and calculation procedures.

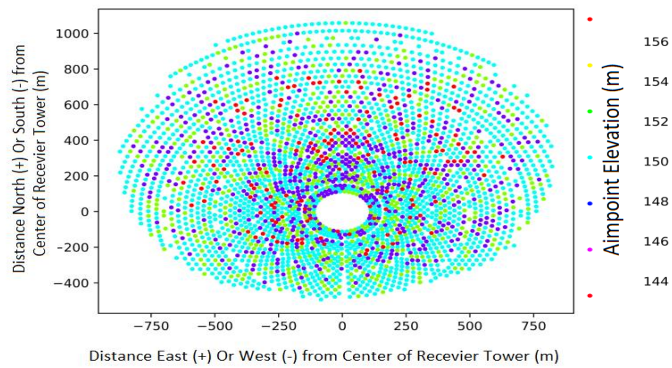


Heliostat Aimpoint and Layout Optimization Software (HALOS)

HALOS is an open-source software decision tool implemented in Python that uses mixed-integer programming models to determine the best aimpoint strategy for the solar collection field of a concentrating solar power (CSP) central receiver plant. Design and operations decisions addressed by this tool include: (i) the location of each heliostat in the solar field, and (ii) the intended aimpoint of each heliostat to the receiver for each hour, across a representative collection of days. Given weather and location data, heliostat specifications, a solar field layout, and a receiver's size, location, and geometry as input, HALOS outputs an aiming strategy that maximizes thermal power delivery to the receiver while ensuring that the thermal flux profile of the receiver falls within design specifications. A key feature of the tool includes a method to subdivide the solar field into subfields, for which the aiming strategy can be optimized separately and in parallel. This allows for aiming strategies to be obtainable using integer programming methods for commercial-scale plants within a matter of minutes.

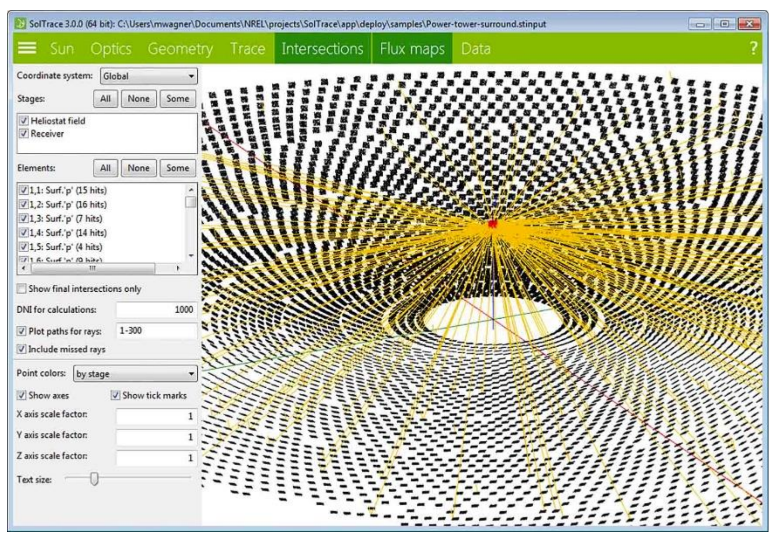
The tool includes a module that directly interfaces with SolarPILOT, an NREL-developed solar field performance characterization tool, to obtain high-fidelity flux maps and solar field layouts. HALOS also accepts flux images in flat-file format.





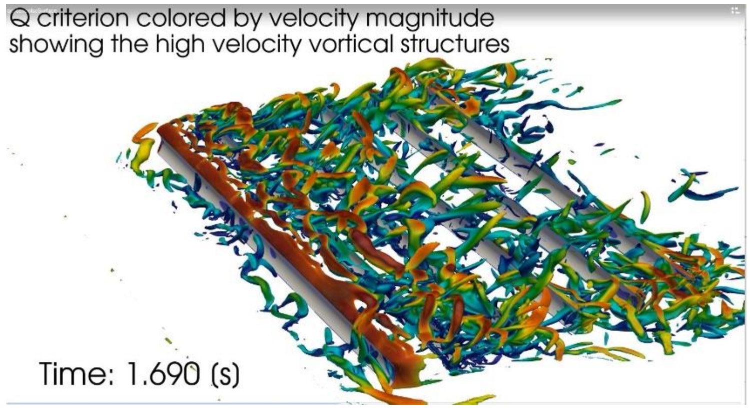
SolTrace

SolTrace is a software tool developed at NREL to model concentrating solar power (CSP) systems and analyze their optical performance. Although ideally suited for solar applications, the code can also be used to model and characterize many general optical systems. The creation of the code evolved out of a need to model more complex solar optical systems than could be modeled with existing tools. The code uses Monte-Carlo ray-tracing methodology in which individual rays are traced through a CSP system while encountering various optical interactions. Some of these interactions are probabilistic in nature (e.g., selection of sun angle from sun angular intensity distribution) while others are deterministic (e.g., calculation of ray intersection with an analytically described surface and resultant redirection). Because it replicates real photon interactions, the code can provide accurate results for complex systems that cannot be modeled otherwise.



Computational Fluid Dynamic Modeling of Wind Loads on CSP Structures

Computational methods have gained maturity to complement wind tunnel testing and empirical design for concentrating solar collectors. Leveraging support from DOE's Wind Energy Technologies Office, NREL has developed a suite of tools capable of incorporating mesoscale weather simulations which can reproduce all the dynamic features in the atmosphere along with large scale terrain features and couple these mesoscale simulations with microscale calculations of atmospheric boundary layers that focus on modeling small-scale and high-frequency turbulent flow behavior close to the ground, while ignoring large scale effects driving weather patterns. DOE's Solar Energy Technologies Office is currently supporting NREL to apply these tools to CFD modeling of flow around CSP collectors.



Previous work has focused on a collector-resolving approach where a collector configuration is fully resolved with a high-resolution computational mesh around single or multiple collector geometries. While such one-off simulations are possible on DOE leadership class supercomputers and useful for scientific inquiry, it is impractical for routine industry use. Typical heliostat field layouts are expected to experience more complex interior wind patterns and wake interactions as a function of wind direction, making the modeling of deep arrays essential for accurately reproducing wind loading at field conditions. An additional complexity with heliostats that computational models should be capable enough to reproduce is dynamic structure behavior. Actuator source like models, successfully implemented for large-scale wind farms, will be essential in modeling collectors in power-tower systems where heliostats are arranged in a complex site layout arrangement and experience transient dynamic loads. NREL is currently developing and validating computationally efficient reduced order actuator-source representation of collectors that can adequately model collectors with modest computational resources while not sacrificing computational accuracy.

Field Measurement of Wind Loads on CSP Structures

Traditionally most of the studies investigating impact of wind loading on concentrated solar power (CSP) collector structures have been in highly controlled wind tunnels. However, these wind tunnel-based studies are incapable in reproducing wind conditions, turbulence characteristics and flow length scales often observed in the field. These differences in flow characteristics artificially influence the loading seen on collector structures.

To avoid such differences, NREL has been performing field measurements of wind conditions and loading on parabolic troughs at the Nevada Solar One (NSO) parabolic trough power plant in Boulder City, Nevada. These first-of-its-kind experiments are yielding a high-resolution dataset that is being used to characterize the complex flow field observed in power plants with parabolic-trough collectors. To fully understand the role of atmospheric turbulence along with unsteady wakes generated by the upstream rows, the team installed 4 meteorological towers each equipped with multiple sonic and cup anemometers. The met towers are also paired with scanning lidars to measure wind conditions across a large area. Lidar is deployed to measure the flow conditions within the collector array to gain insights into the wake structures emanating from upstream collectors and their impact on the wind loading on downstream structures. Such measurements are providing valuable insight into wind loading in deep-array conditions, as well as wind-loading conditions at the "edges".

In addition to wind data, the experiments are also including sensors to measure the loads on collectors and support structures that are time-synchronized with the wind sensors to provide a detailed picture of the unsteady loading experienced by the collectors. This enhanced understanding of interior wind loads will lead to reduction in both overdesign with excessive cost and under-design resulting in catastrophic failure.

High Flux Solar Furnace (HFSF

NREL's *HFSF* is available for testing by universities, businesses, the Department of Energy, Department of Defense, national laboratories, and other partners. It is suited for small-scale feasibility studies and testing of a wide range of technologies with a diverse set of experimental requirements. On-sun functional component performance and materials testing relevant to components used in concentrating solar power systems such as receivers, collectors, and reflector materials. The facility has been used for evaluation and development of state-of-the-art measurement systems for extreme solar environments.

Addendum B – Sandia Capabilities

Point of Contact for Sandia Lab Capabilities: Margaret Gordon ***megord@sandia.gov***
(Note: Offeror communication with this contact shall be for the sole purpose of verifying Sandia capabilities)

Since the late 1970's, the Concentrating Solar Technologies Department at Sandia National Laboratories has been at the forefront of research, development, testing and validation of heliostat technologies as well as related technologies in power towers, heat exchangers, and thermal energy storage. Sandia continues to pursue innovative CST research in order to increase performance and reduce the LCOE and LCOH of concentrating solar energy. In the course of this history, Sandia has developed many tools and capabilities for analysis and improvement of heliostats, including design, construction, measurement, validation and utilization of large-scale testing facilities for the full characterization of heliostats. Sandia has extensive experience in using these tools that are listed below.

Concentrating Solar Optics Laboratory

The mission of the Concentrating Solar Optics Laboratory (CSOL) is to provide excellent optical metrology to support NSTTF and solar fields world-wide. We work to develop accurate, robust solutions to hard problems:

- Indoor mirror optical characterization.
- Outdoor heliostat pointing and beam quality analysis.
- Outdoor heliostat optical characterization.
- Dynamic effects.

We aim to make all of our capabilities easily available to industry, supporting all development phases including prototype development, high-volume manufacturing, and outdoor operation.

<u>Capabilities:</u>

In addition to a broad array of instruments such as specular reflectometers, emissometers, light intensity meters, flux gages, laser alignment devices, and both manual and automated camera systems with associated lenses, we utilize several systems to perform heliostat optical metrology:

- Heliostat field testing of metrology systems.
- Beam characterization system (BCS).
- Deflectometry for both individual mirror facets and multi-facet heliostats (SOFAST).
- LIDAR scanning to assess facet canting angles.
- Unmanned Aircraft Systems (UAS) flight operations.

In addition, we are developing new capabilities that are expected soon:

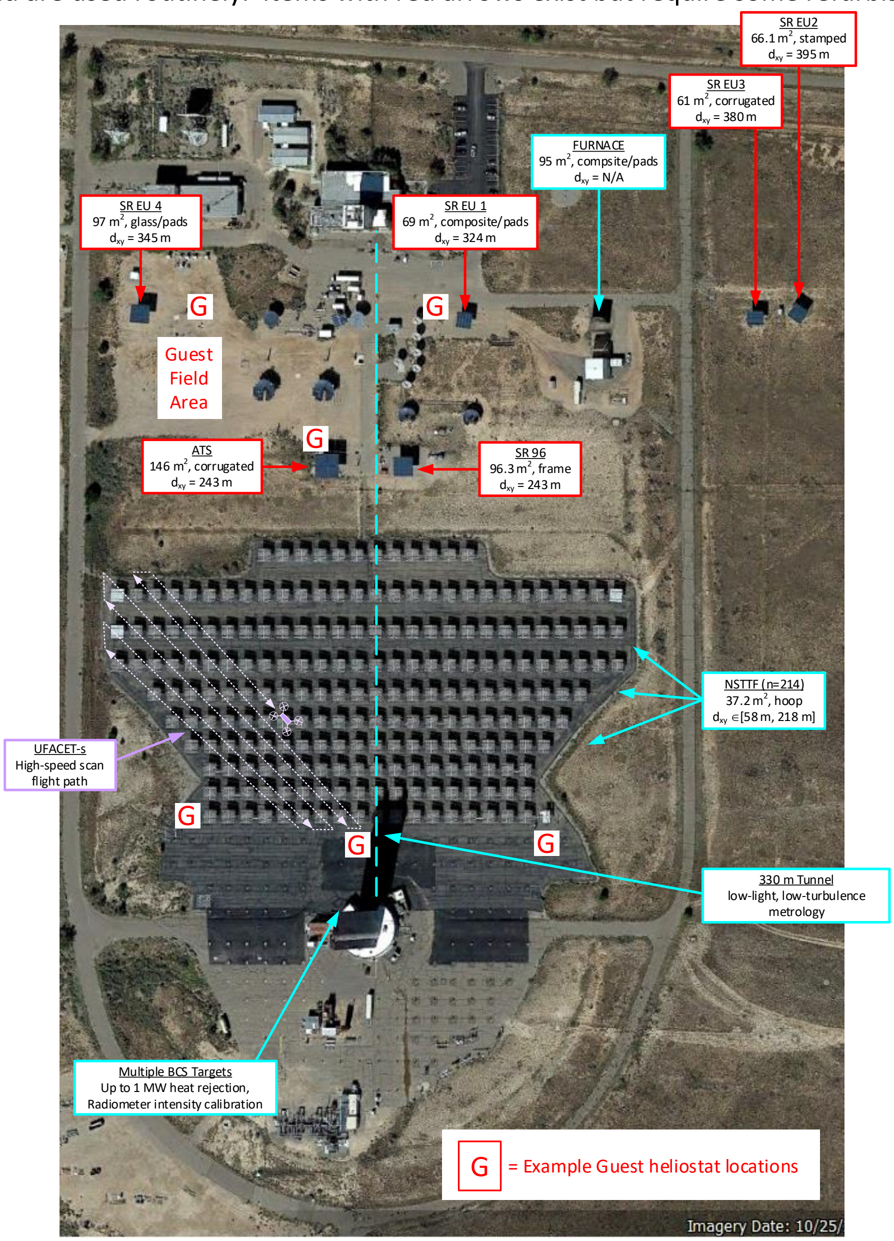
- Ground truth methods of verifying metrology accuracy (anticipated mid FY23).
- High-speed measurement of heliostat optical parameters outdoors (anticipated mid FY24).

All of these are further explained detail below.

Heliostat Field

The Sandia NSTTF heliostat field contains 214 heliostats which are used on a routine basis for a variety of test purposes. These include supporting the development and evaluation of outdoor in-situ metrology techniques. Teams seeking to test their metrology systems are welcome to use the NSTTF as a testing location. The ground truth methods and outdoor deflectometry methods under development described below are intended to provide known optical parameters to serve as a reference for metrology system evaluation.

The Sandia NSTTF heliostat field also routinely supports evaluation and testing of guest heliostats that are brought to the site for testing and evaluation. In the illustration below, the red "G" marks indicate some of the guest heliostat locations that are available. Ranges to the tower are up to 450 m for permanent installations, and up to 1 km for temporary installations. In this illustration, items with cyan arrows exist and are used routinely. Items with red arrows exist but require some refurbishment.

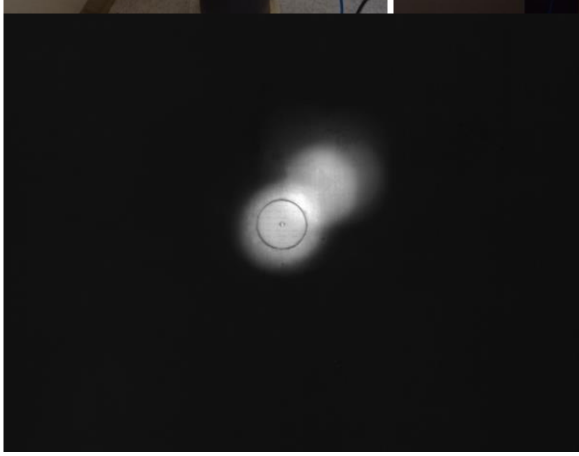
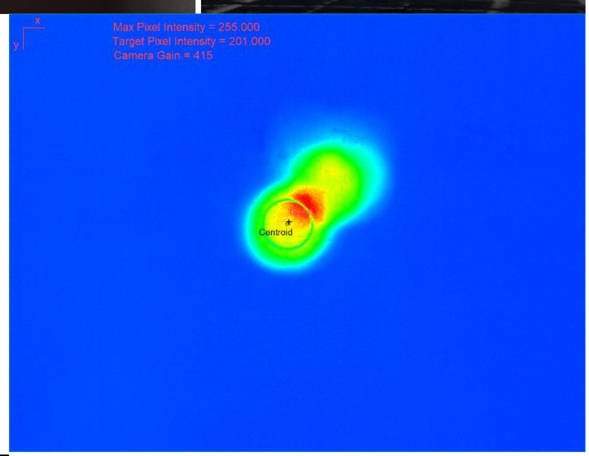


Beam Characterization System (BCS)

The beam characterization system (BCS) has been in routine use at Sandia since the late 1970's. It is designed to assess heliostat reflected beam quality and pointing accuracy. The system is comprised of a flux target with cooling, flux radiometer, digital camera system, and associated image capture analysis software. It is capable of measuring both detailed solar flux distributions and total flux power, and can also measure dynamic beam motion effects.

The Sandia BCS system includes multiple targets. The largest target is 9.75 m x 11 m, with active chilling at its center; additional smaller BCS targets exist at other levels, two with heat rejection up to 1 MW. By employing a series of neutral density filters, the optical system can take measurements of beams with a wide range of flux intensities, varying from 0.15 W/cm^2 to 300 W/cm^2. Using our standard camera, beam images are 1626 x 1236 pixels; beam fill factor can be adjusted with a zoom lens. Depending on setup details, image processing software can resolve beam centroid locations to within a few millimeters, which corresponds to a tracking angle resolution much finer than 0.1 mrad.



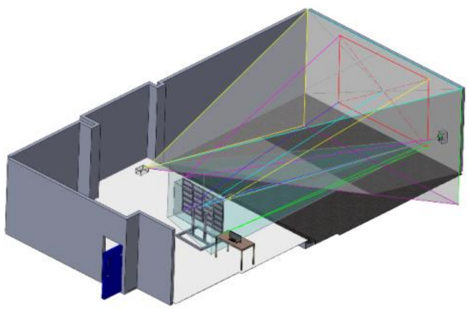




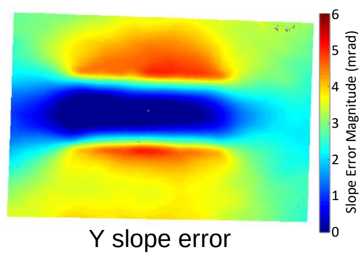
Deflectometry (SOFAST)

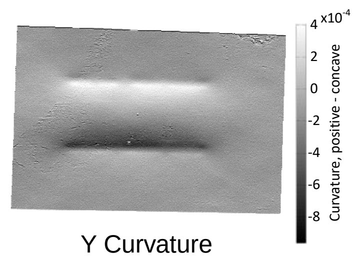
Deflectometry is a measurement technique which can rapidly capture a high-resolution map of mirror surface normals, which determine the mirror's reflective properties. The resulting map can then be used to generate a variety of analytic results describing mirror performance.

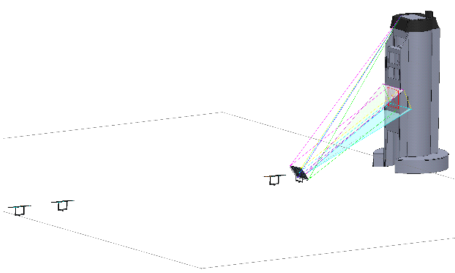
SOFAST is a deflectometry system developed at Sandia which has been in routine use since circa 2010. It provides excellent support for (a) prototype development, by providing rapid feedback on mirror shape details, and (b) high-volume manufacturing, by providing rapid measurements (< 10 sec) and support for data logging and statistical process control. SOFAST is capable of measuring both single mirror facets and multi-facet heliostats, and outputs a suite of analytic products describing mirror shape and solar optical performance. The SOFAST documentation package includes an interactive SolidWorks CAD tool to aid layout design.

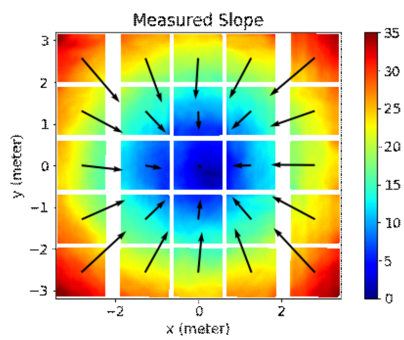
We are currently in the process of further improving SOFAST and expect to release SOFAST version 2.0 in FY23. Emerging capabilities we anticipate soon include outdoor measurement of full heliostats *in situ*, optical evaluation of mirror shape deviation under extreme temperatures (-40 °C to +85 °C), and an inexpensive desktop implementation for small optics and educational purposes.

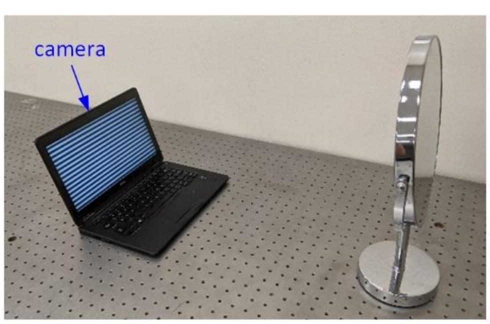


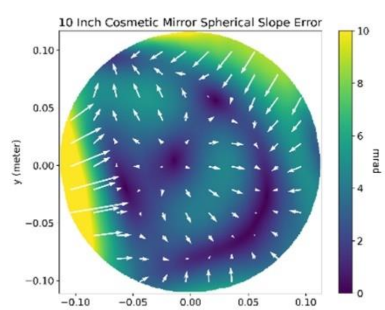






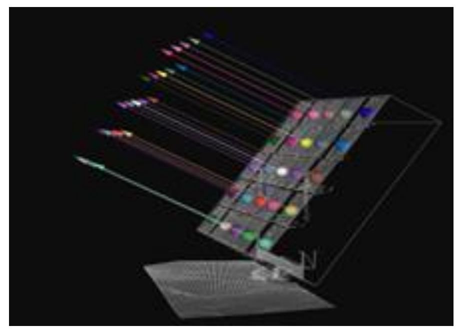






LIDAR Scanning

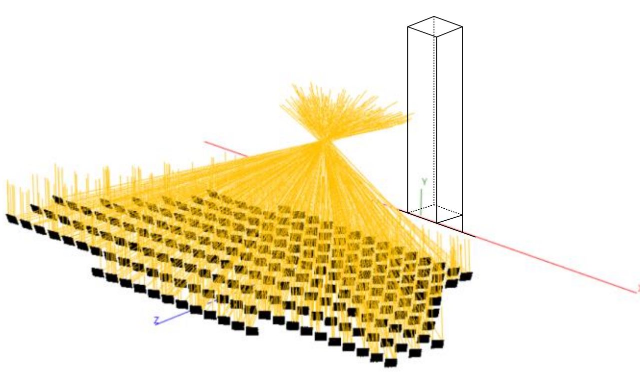
Sandia has developed technology to use three-dimensional LiDAR scanning as a means of measuring heliostat facet canting angles. When mirror surfaces are soiled, their front sides can be measured with a LIDAR scanner. Mirror back sides can be measured regardless of soiling state. Sandia software can then analyze the resulting 3-d scan data to identify heliostat facets and analyze their canting angles. This system can measure facet canting at multiple tilt angles to assess the effects of gravity deformation. The LiDAR scanner is a general-purpose measurement device that can also be used for other measurement purposes.

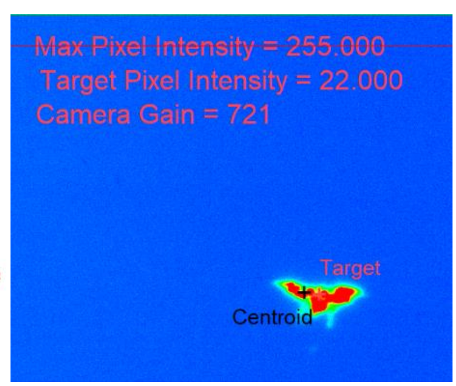


UAS Flight Safety

Active heliostats fields direct an enormous amount of solar flux onto a receiver. In the air space above an active heliostat field, flux intensity grows until reaching a maximum at the solar focus, which may exceed 300 W/cm^2. This creates a region of increasing flux above the field.

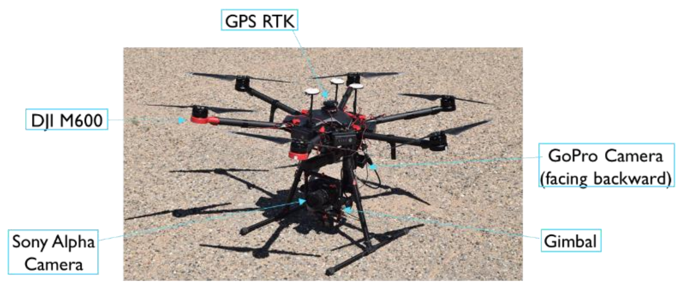
Unmanned aircraft systems (UAS), also known as drones, may be used for a variety of useful purposes to support heliostat field inspection and optical measurement. However, regions of high flux over the solar field cause an invisible hazard to safe flight. At Sandia we have characterized the flux intensity over the solar field, and conducted experiments both verifying safe flight regions, and also demonstrating hazardous regions where solar flux caused permanent UAS damage and loss of flight control. This knowledge can be used to plan safe UAS operations over an active solar field.

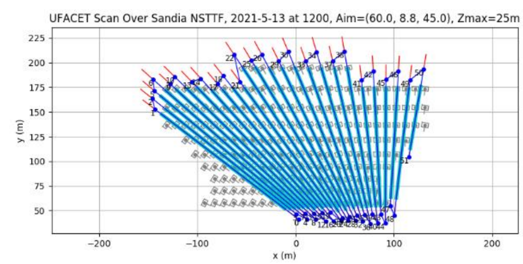


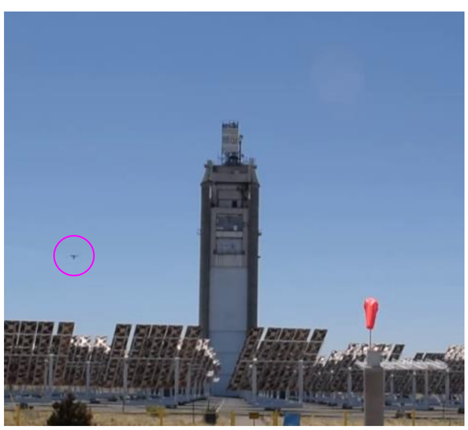


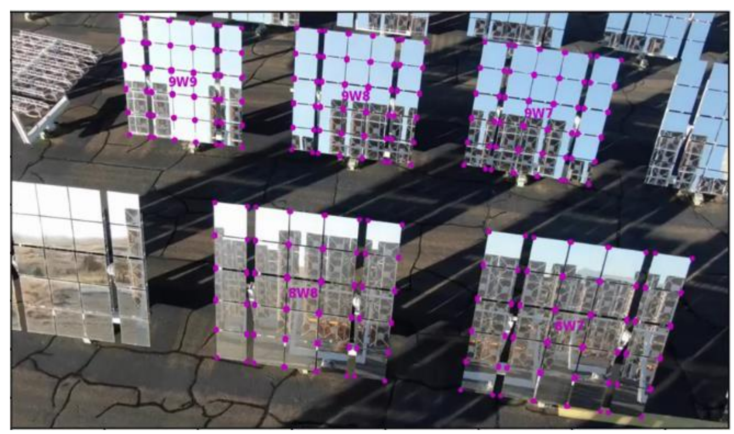
UFACET-1, UFACET-s

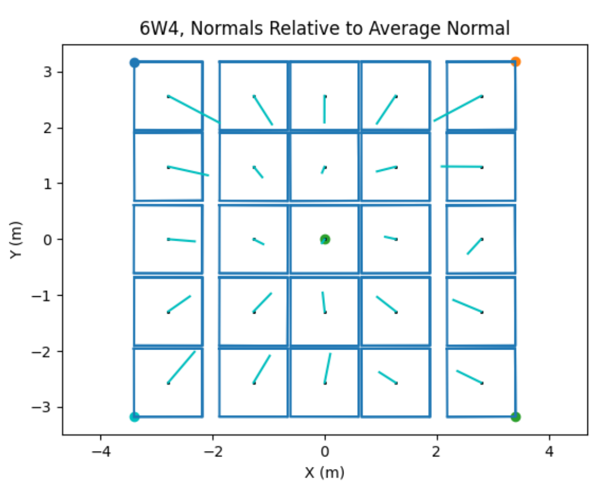
A commercial solar field may have over 10,000 heliostats, and use all or nearly all of them in operation every sunny day of the year. In such an environment, how can a solar field operator assess the state of the solar field, to determine whether each heliostat is maintaining its optical accuracy? Similarly, during solar field construction, how can an operator rapidly calibrate each heliostat, without waiting for BCS? The Sandia UFACET system is designed to address these questions. An unmanned aircraft system (UAS) is equipped with a high-resolution camera and other sensors and is flown in a carefully planned high-speed flight path over the heliostat field. The captured video is then post-processed to recognize heliostats and measure their optical performance. This system is still under development. It is closely related to the NREL NIO system described in Appendix A.

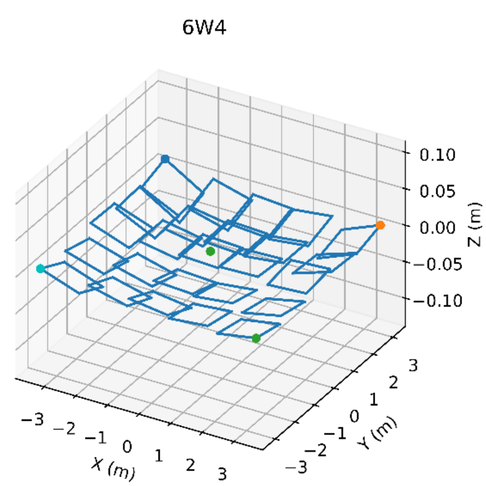












Ground Truth

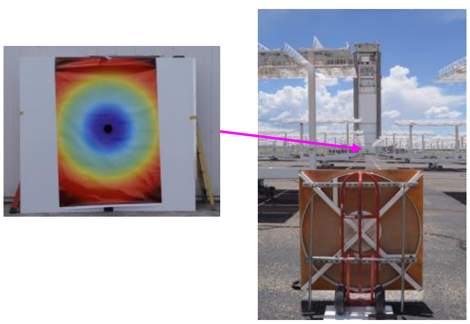
Sandia's SOFAST, LiDAR system, and UFACET are all examples of high-performance systems which return measurements of optical parameters. This raises the question: How accurate are these systems? How can we independently verify their correctness?

Sandia has been pursuing ground truth methods aimed at answering these questions. Our goal is to identify measurement techniques which can be trusted as accurate, and use them to check the accuracy of more complex high-performance systems. An ideal ground truth technique is inexpensive and easy to replicate anywhere. However, it is acceptable if it not as fast, convenient, or general as primary metrology methods. A key requirement of a ground truth method is that it is clearly accurate.

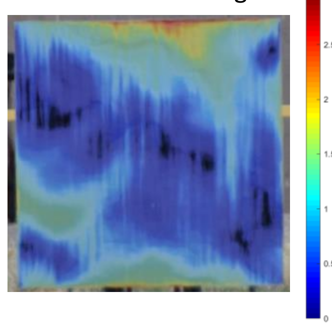
We have been pursuing simple, direct measurement methods or precision physical standards that can be used to calibrate and validate other metrology methods. We have focused on two approaches:

- Simple ground truth measurement methods. Inexpensive and easy to use, their accuracy is inherent in the design of the measurement technique. As of this writing, we have demonstrated two methods for both single facets and full heliostats. Detailed release expected mid FY23.
- A high-quality physical calibration standard mirror. Constructed using astronomical telescope fabrication methods, we anticipate accuracy of 0.1 mrad or better. Expected mid FY23.

We plan to use these to measure heliostats in the NSTTF field, so that the measured heliostat can serve as secondary standards for evaluating heliostat metrology systems tested at NSTTF.



Ground Truth Image



SOFAST Error Plot

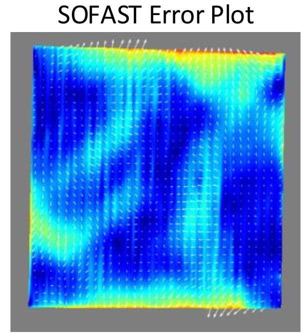


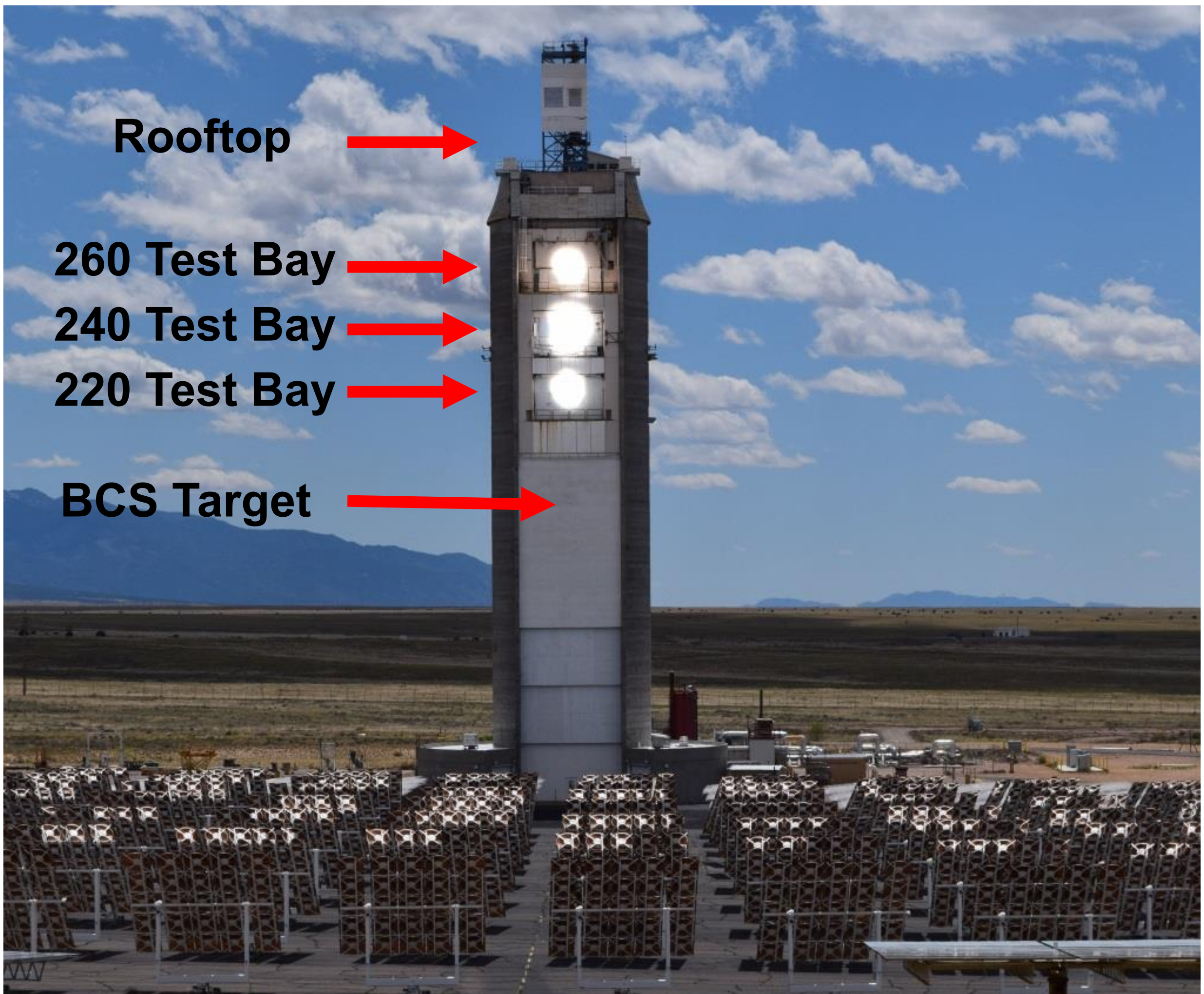
Image credit: Anthony Evans

National Solar Thermal Test Facility Capabilities

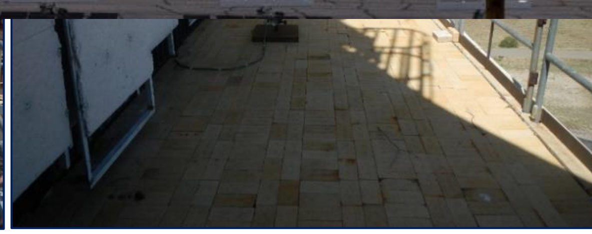
The large-scale capabilities at the NSTTF listed below are also available for use, testing, and validation purposes.

Solar Tower and Heliostat Field

The NSTTF Solar Tower and Heliostat field are the centerpieces of the testing infrastructure for concentrating solar research and development at Sandia. The Solar Tower stands at 200 ft tall, with the rooftop and three test bays at 160, 140, and 120 ft above ground level that can be configured to support any variety of component, material, or system testing. Targets, cameras and other devices can also be mounted at the various levels depending on desired application.



A view across the rooftop looking NNE.



External test deck at the 260 level

Materials test level with high speed (<0.5 s) shutter system and 0.3 Mach wind tunnel. Water-Glycol cooled calibration panel located at the same level.

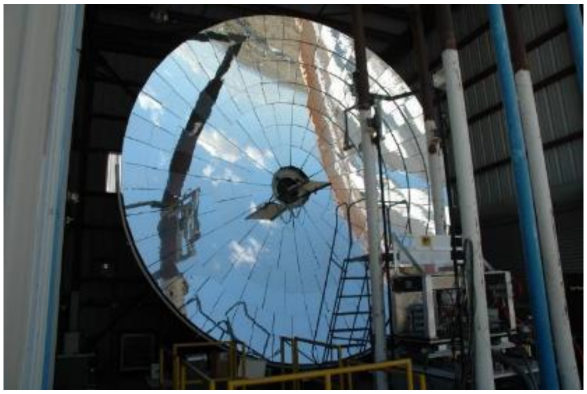
A central 3-story elevating module, capable of raising 400 tons, lifts components and systems to the test bays and rooftop. At ground level, a 60' roll up door and crane are available for access and placement of large components and test articles. The site also has available man lifts, forklifts, and telehandlers with experienced operators.

The Heliostat Field at the NSTTF has 214 operating heliostats each with 25 facets and a total respective reflective area of 37 m^2. The heliostats are computer controlled using open loop controls via the control room located at the north end of the field. The NSTTF field can facilitate a total input thermal capacity of 6 MW_{th}, and peak flux of 350 W/cm^2. Calibration panels, equipped with radiometers are located on each level for temperature-compensated accurate flux measurements, as well as beam characterization targets for flux profile modulation. The incident flux from the heliostat field can be configured for an approximate 1 m beam diameter. The field is also capable of multiple aim point strategies to spread the Gaussian flux profile.

Optics at different levels of the solar tower:

Test Location	Summer Solstice Heat Flux (kW/m^2)	Winter Solstice Heat Flux (kW/m^2)
220 level Test bay	643	603
240 level Test bay	712	646
260 Level Test bay	762	682
Tower Top	773	742

High Flux Solar Furnace:




The high flux solar furnace at the NSTTF is comprised of a concentrator, located in a highbay with roll up door access on two sides and a Heliostat which reflects the sun through an attenuator to control the level of solar flux incident on a respective target. This facility is capable of up to 630 W/cm^2 and 16 kW$_{th}$. The flux profile is Gaussian with an approximate 5 cm diameter. The test system also features an attenuator system that can modulate the flux within 2 W/cm^2 resolution. The facility also features 50k frame rate high-speed UHF cameras as well as an FTIR photometric device. Several solar reactors are used in this facility with a highly-configurable gas distribution system for up to 300 psig and 1 torr pressure and vacuum systems respectively. A FLIR camera, capable of measuring temperatures that range from -20 C to 2000 C over a spectral band of 7.5 – 1.4 um is available for use.

High Flux Solar Simulator

The High-Flux Solar Simulator with Automated Sample Handling & Exposure System (ASHES) is a one-of-a-kind tool which can be used 24/7 with metal-halide lamps. ASHES provides accelerated lifetime aging tests for materials under high-temperature/high-flux conditions. A robotic sample-handling system can be used to move multiple coupons automatically into and out of the concentrated flux sequentially to expose the samples to predetermined temperatures, fluxes, and/or durations. The peak irradiance is ~1.1 MW/m2 with an average irradiance of ~0.9 MW/m^2 over a spot size of ~1 inch (2.5 cm).

Concentrating Solar Power Historical Documents

Sandia National Laboratories (SNL) National Solar Thermal Test Facility (NSTTF) and Sandia Tech Library have developed the world's first and only digital collection of Concentrating Solar Power (CSP) related historical documents, dating back to the CSP program inception at Sandia in the 1970's to the present.
https://www.librarycat.org/lib/SandiaCSP

This archive includes a more than 20,000 paper-based documents spanning reports, engineering drawings and other media recently converted to digital format. Work produced in the United States, Australia, and South Africa among others are archived digitally in this collection. It will provide CSP researchers a unique library of files to help make a larger historical body of CSP documents accessible to the Sandia and global CSP R&D communities.

NSTTF Capability	Specifications
Solar Tower	200 ft tall, roof top + 3 test bays 4-350 sq. ft. test bays, one external deck 1 – 750 sq. ft. test bay BCS target and Lambertian surface Elevating module capable of lifting 400 tons lifts test apparatus from ground floor to testbays Heat rejection at each test bay Analog and digital data acquisition chassis available with variable frequency control. Water-glycol-cooled calibration panel 0.3 Mach wind tunnel and 0.5 s shutter system at one test bay 60 ft rollup door at ground level, and Jib cranes (specs)
Heliostat Field + open pedestals with power & comms	214 Heliostats, 25 facets, 37 m^2 reflective surface area, total thermal capacity of 6 MW_{th}, and peak flux of 350 W/cm^2 on asphalted field
Control tower	with local LAN access, DAQ system, and flux gauges
Long range Heliostat Flux target	For distances up to 1700 m, vertical array of collimated pyranometers.
Long range Heliostat deployment area	Locations for heliostats at distances of up to 0.5 miles from the tower.
Solar Simulator	Four 1.8 KW lamps Metal Halide, 7.2 kW electric, 6.2 kW radiative. 1100 kW/m^2 peak flux over 1 inch spot size, automatic sample changer for 12 samples
Solar Furnace	16 kW with customizable sample platform, controlled atmosphere available, reach black body temperatures upto 5000 K. Peak Flux of 600W/cm^2, 5 cm spot size.
FLIR Camera, A700	Temp measurement range [-20,2000] C with +-2 % accuracy 7.5-14 um spectral band 30 hz frame rate 640x480 pixel resolution 2x Macro lens
Meteorological station	3 site stations for measuring humidity, ambient temperature, barometric pressure, wind speed/direction anemometers, 3 pyrheliometers for measuring DNI. 1 spectrometer.
Data and historical records from the NSTTF	Meteorological data has been collected and stored for over 10 years at the NSTTF. Data includes humidity, ambient temperature, barometric pressure, speed/direction and DNI.
Hi-Bay and Fabrication building	2500 sq ft warehouse w/ 34’ ceiling, 5 ton mobile crane with 24’ lift, welding, lathe, shearer, other machining tools, Optics fabrication space with marble surface.

Addendum C - Technical Volume Template Instructions

This template has been formatted to fit the requirements of the HelioCon RFP and is meant to serve as a guide to writing your proposal:

The Technical Volume to the Full Application may not be more than 14 pages, including the cover page, project summary (including all citations, charts, graphs, maps, photos, or other graphics), and the Team Composition, Capabilities, and Work Plan. All the information is presented in the table below. The applicant should consider the weighting of each of the evaluation criteria (see Section 10 of the HelioCon RFP) when preparing the Technical Volume.

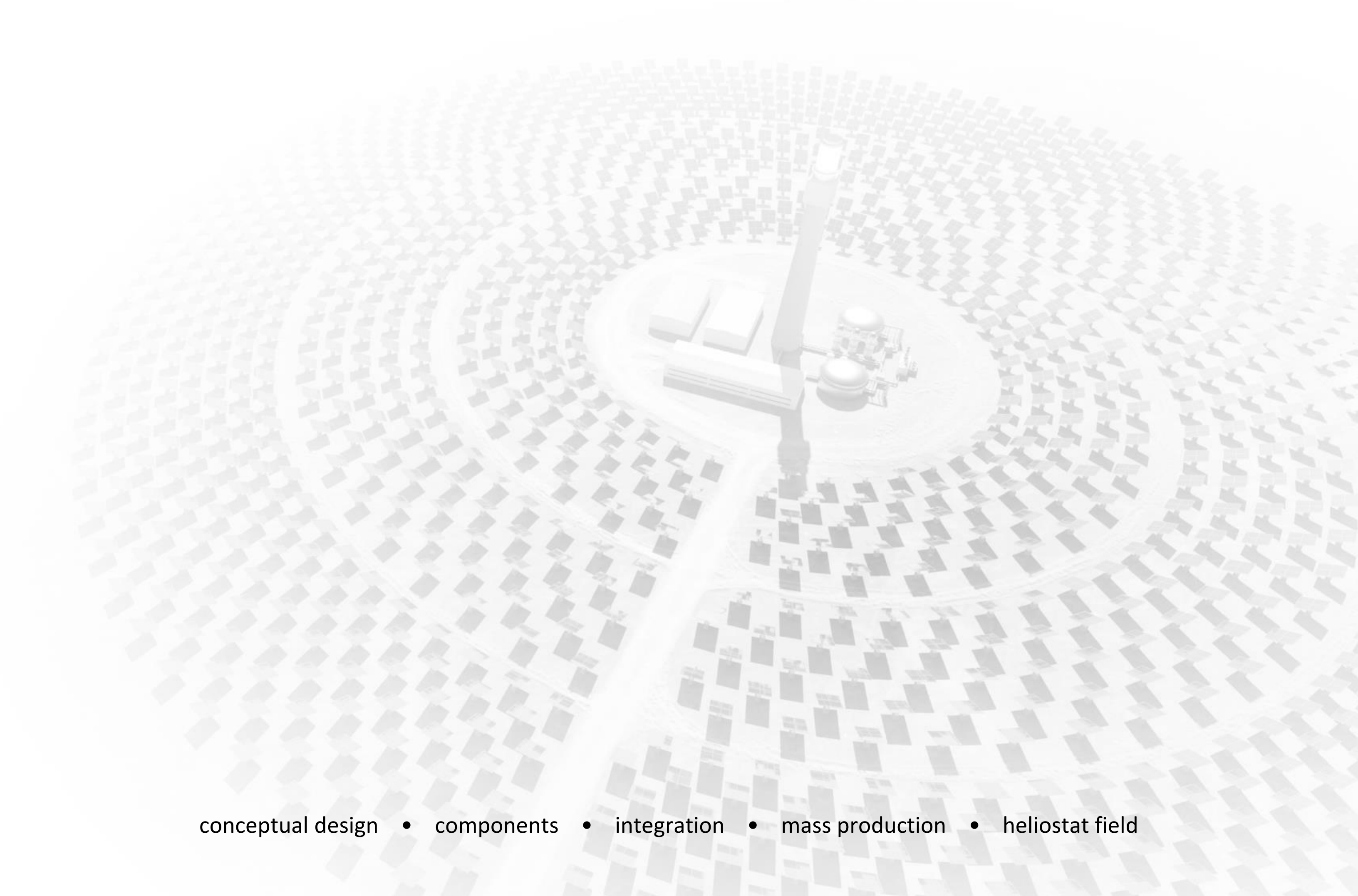
DELETE ALL INSTRUCTIONS/NOTES IN RED ITALIC FONT

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

Heliostat Technology Advancement
REQUEST FOR PROPOSALS (RFP)
RFP RFX-2022-10161

Technical Volume

Project Title:	
Topic Area:	
Lead Organization Name and Address:	
Technical Contact:	Principal Investigator: *Name, Organization* *phone number, email address*
Team Members: **(list partners participating in the project)**	*<name, Institution, email>*
Key Participants: **(list any other collaborating individuals or institutions)**	*<name, Institution, email>*
Statement of Confidentiality:	The topics presented in this technical volume are proprietary and business sensitive. Hence, they should not be shared outside of the HelioCon review team.



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

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

Technical Volume *(10 pages max)*

(Technical Merit 70%, Organization and Execution 30%)

Project Summary:

This section should describe the proposed project and its potential to contribute to the RFP goals. Offerors should clearly define the proposed technology/concept, the current state of that technology/concept, the target markets for the technology being developed, and how the proposed technology relates to existing or competing technologies. Offerors should include data or references to support cost and performance claims.

- *Background: The applicant should discuss the background of their organization, including the history, successes, and current research and development status (i.e., the technical baseline) relevant to the technical topic area being addressed.*
- *Project Goal: The applicant should explicitly identify the targeted improvements to the baseline technology and the critical success factors in achieving that goal.*

Technical Description, Innovation, Impact:

- *Relevance and Outcomes: The applicant should provide a detailed description of the technology, including the scientific and other principles and objectives that will be pursued during the project. This section should describe the relevance of the proposed project to the goals and objectives of the RFP, including the potential to meet specific DOE technical targets or other relevant performance targets. The applicant should clearly specify the expected outcomes of the project.*
- *Feasibility: The applicant should demonstrate the technical feasibility of the proposed technology and capability of achieving the anticipated performance targets, including a description of previous work done and prior results.*
- *Innovation and Impacts: The applicant should describe the current state of the art in the applicable field, the specific innovation of the proposed technology, the advantages of proposed technology over current and emerging technologies, and the overall impact on advancing the state of the art/technical baseline if the project is successful. Offerors should clearly define the target markets for the technology being developed, and how the proposed technology relates to existing or competing technologies. Offerors should include data or references to support cost and performance claims.*

Project Objectives and Work Plan:

- *Project Objectives: The applicant should provide a clear and concise (high-level) statement of the goals and objectives of the project as well as the expected outcomes.*

- *Technical Scope Summary: The applicant should provide a summary description of the overall work scope and approach to achieve the objective(s). The overall work scope is to be divided by performance periods that are separated by discrete, approximately annual decision points. The applicant should describe the specific expected result of each performance period.*
- *Work Plan: The Workplan should describe the work to be accomplished and how the applicant will achieve the milestones, will accomplish the final project goal(s), and will produce all deliverables. The Workplan is to be structured with a hierarchy of performance period (approximately annual), task and subtasks, which is typical of a standard WBS for any project. The Workplan shall contain a concise description of the specific activities to be conducted over the life of the project. Task descriptions should consist of: A distinct title, description of the activities, Potential risks or barriers and approaches for overcoming them, and Key personnel or resources.*
- *Milestone Summary: The applicant should provide a summary of appropriate milestones throughout the project to demonstrate success. A milestone may be either a progress measure (which can be activity based) or a SMART technical milestone. SMART milestones should be Specific, Measurable, Achievable, Relevant, and Timely, and must demonstrate a technical achievement.*
- *Go/No-Go Decision Points: The applicant should provide a summary of project-wide Go/No-Go decision points at appropriate points in the Workplan.*
- *End of Project Goal: The applicant should provide a summary of the end of project goal(s). At a minimum, each project must have one SMART end of project goal.*

Team Composition, Coordination, and Capabilities:

Teaming Overview: Strong team composition, available resources and capabilities, and effective leadership and coordination are vital components of a successful proposal. Please address the Project Leader and Key Personnel qualifications, including past experience and subject matter expertise. This section should clearly address the relevant evaluation criteria (see Section 10), highlighting the following:

- *How this team is uniquely suited to achieve the project objectives*
- *Description of Offeror team member capabilities including the performance levels of any relevant materials, cells, modules, and equipment that will be available at the start of the project.*
- *How the Offeror firm will make decisions (i.e., which research areas are most important to pursue, whether any new capabilities are needed, etc.)*
- *Identification of any non-federal resources that are expected to be leveraged by the consortium in pursuit of its goals (See Non-Federal Resources and Industry Effort below).*
- *If applicable, list lab support requested from X lab. List the capabilities within each lab that this proposal seeks to utilize. Provide a brief rationale of the benefit to the project of the use of these capabilities*

Tasks and Deliverables

This section should specifically delineate what work each Offeror will perform. The price should reflect the scope of work requested in this RFP.

Appendix A: References and Bibliography *(2 page maximum)*

Appendix B: Resumes *(2 page maximum per person)*

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Appendix C: Letters of Commitment *(1 page maximum)*