Customer Needs Statement

Small-scale Heliostats for Industrial Solar Processing
Last Updated: February 21, 2022

Overview

Heliostats are mirrors that move in two axes to track the sun throughout the day and focus light to a central source, as shown in Figure 1.[1] The resulting generated heat can be used to drive a power block, an industrial process, or even produce solar fuels by reversing combustion reactions. Decreasing the cost and solar concentration ratio of heliostats is a key step towards enabling a host of concentrating solar thermal technologies.

Figure 1. A concentrating solar energy generation field centered around a collection tower holding a central receiver target.

The customer, the UF Renewable Energy Conversation Laboratory, requests innovative engineering designs for low-cost ($< \$100/\text{m}^2$), small scale ($< 1\ \text{m}^2$) modular heliostats. As shown in Figure 2, decreasing individual heliostat size provides several advantages related to 1) to tracking accuracy and optical performance [e.g. decreased wind loads, higher concentration ratio], 2) cost [e.g. flat mirrors, plastic parts], and 3) practicality [e.g. simple drive systems, mounting and off-the-shelf parts] that represent a heliostat design paradigm shift.[2] **Designs failing to capitalize on innovations enabled by small heliostat size will be rejected by the customer!**

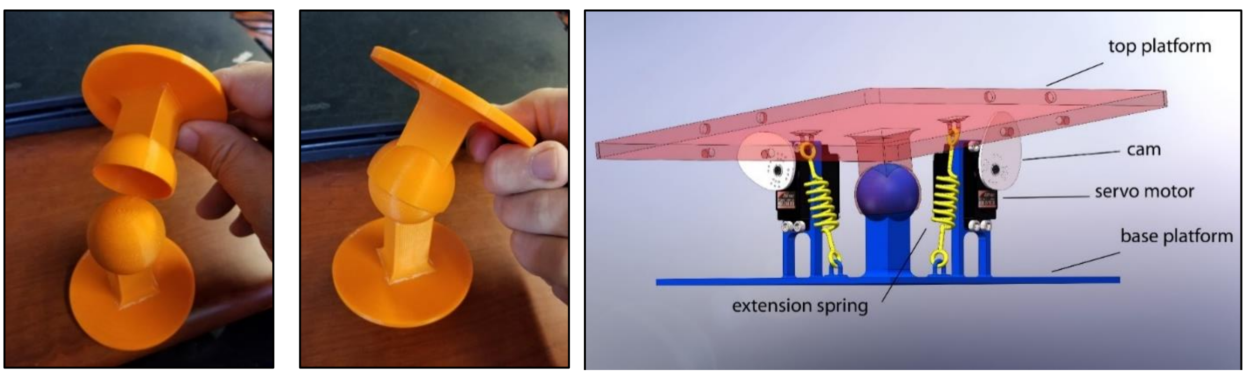
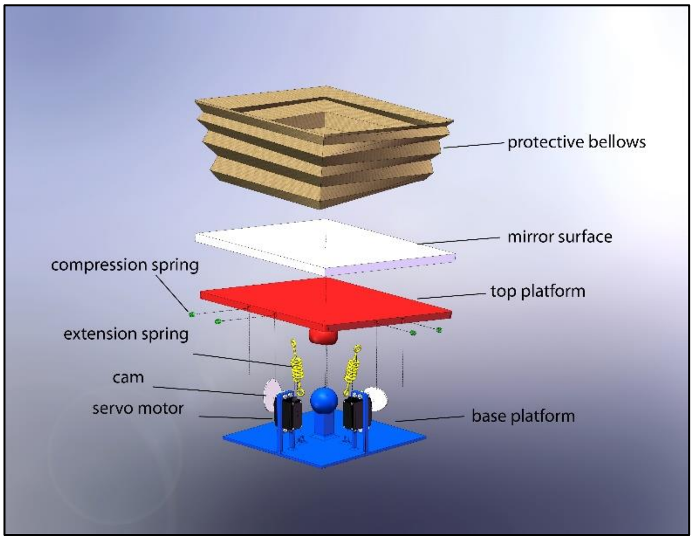


Figure 2. Left and Center: Prototype ball and socket joint. Right: Control of top platform relative to base.

Designs are requested for a small array, or module, of tracking heliostats to provide heat for a 1 MW methane reforming reactor operating at 1000 °C. See Figures 2 and 3 as examples. Known challenges to overcome include: 1) eliminating shading effects while retaining a small footprint; 2) achieving high optical efficiencies while maintaining concentration ratios greater than 1000; and 3) decreasing the overall cost below $\$100/\text{m}^2$. Design engineers may assume heliostat units are powered by ties to a conventional electrical utility distribution grid. Control signals will be passed via conventional WiFi from controllers in each heliostat module to a central hub command computer.

---

1 https://heliogen.com/
2 https://www.osti.gov/servlets/purl/1137299



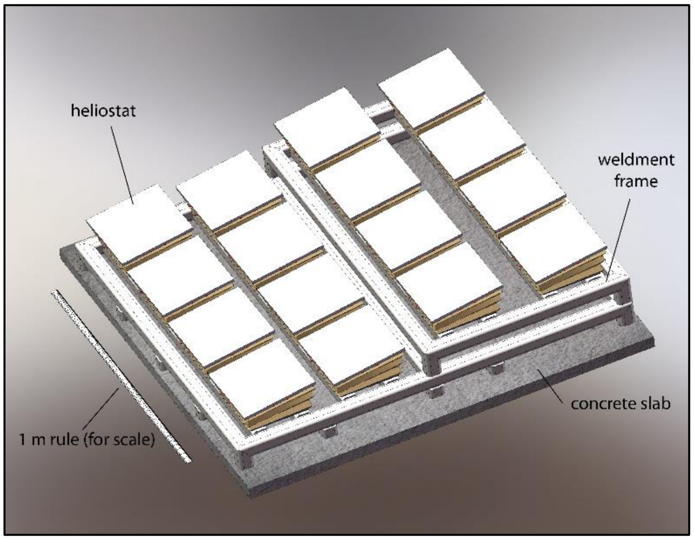


Figure 3. Top: Exploded view of the design concept. Bottom: 1 m^2 module with array of heliostats mounted. Major components are made from lightweight, injection molded plastic parts and off-the- shelf parts.

Features of Individual Heliostat Modules

1. Design capitalizes on innovations enabled by small heliostat size.

2. Total reflector collection area of a single heliostat module is ≤ 1 m^2. *Note: this area is not the heliostat footprint, it is the mirror area.*

3. Each module must be composed of 4-16 heliostats.

4. Each module must mitigate optical losses due to tracking errors not to exceed 40%.
   • Tracking errors of $\theta = \pm 0.25°$ are reasonable to assume.

5. Each module must be capable of tracking the sun throughout the day.

6. Individual heliostat units within modules cannot shade other heliostats in that module. Shading between heliostat units in dusk hours (60 minutes after sunrise and 60 minutes before sunset) is acceptable.

7. Modules must redirect sunlight to receiver target mounted on a central tower up to 100 m tall.
- Design engineers are not responsible for designing the tower or the receiver target.
- If needed, assume the receiver target is 1 m^2
- Structurally the tower can exceed 100 m.
- The receiver target height depends on the solar field layout to avoid shading between modules.
- As part of the collector field design, engineers must specify the receiver mounting height on the tower, but this elevation cannot be below 0 meters (ground level) nor exceed 100 meters.

8. Aggregate cost of an individual heliostat module installed in the solar plant at-scale must be below $\$100/m^2$; cost per reflecting surface area. The cost-per-area to build one heliostat prototype module can exceed this limit. However, at full production volume, the per module heliostat must not exceed $\$100/m^2$.
- It is desirable to achieve, if possible, the U.S. Department of Energy (DOE) heliostat module installed target of $\$60/m^2$.

9. Sun tracking by individual heliostats must be automated and computer controlled using an onboard controller within each individual module.
- Control signals will pass back and forth via conventional WiFi from controllers in each heliostat module to a central hub command computer.
- Teams must specify at minimum the power supply, controller, driver, prime mover, and software to facilitate heliostat actuation.
- Teams are not responsible to develop a specific code or program to actuate the heliostat.

10. The total module area relative to the reflecting area should be small
- Do not, for example, include 1 m^2 of reflecting surface on a module with area ~10 times larger.
- The size of non-reflecting heliostat module surface area should be minimized
- Consider shading effects at high solar incidence angles (in the morning and evening) and ensure individual heliostats within modules are spaced accordingly.

11. Individual parts must be equal in price or less expensive than the closest available OTS part.

12. The reflecting surface of each heliostat must be washable using conventional cleaning techniques to remove dust and residue.

13. Factor of Safety for any mechanical feature or function must exceed N = 2.

14. Each mirror (heliostat unit) in a heliostat module must move independently of all other mirrors in its module in at least one axis. Multiple mirrors actuated together in both axes count as one mirror.

Features of the Overall Installation

15. Operational lifetime of the installation must exceed 20 years.

16. The system operates under ambient and solar conditions in Las Vegas, NV (36 °N in the American Southwest). *Note: ambient conditions of concern include but are not limited to 1) high wind speed, 2) extreme temperatures [both hot and cold], 3) rain & flooding, 4) sand & dust, and 5) infiltration by pests [e.g., insects and rodents]*

Features of the Concentrating Solar Energy Collection Field
(Teams are not required to provide a detailed design of the field)

17. The solar energy collection field made of individual heliostat units must deliver to a central receiving tower target a concentrated focal thermal input power of 1 MW (after losses) for at least 1 hour each day (baring days/times when the sun is obscured by cloud cover).

18. The concentrating solar energy collection field must provide a solar concentration ratio greater than 1000 suns at all times 60 minutes after sunrise and 60 minutes before sunset (baring times when the sun is obscured by cloud cover).

19. The distance of heliostat units furthest from the collector target tower must account for dispersion of reflected light from the heliostats relative to the size of the absorbing aperture of the solar receiver target.

- Ideally none of the reflected light from any heliostat module should miss the receiver aperture.
- While engineering calculations to determine maximum heliostat distance are preferred, a max distance of 100 meters may be assumed absent more precise calculations.

Design Engineer Questions Answered By Customers

Q1. Are we responsible for the placement of multiple heliostat units relative to each other in the field?

A1: Teams are not required to provide a detailed design of the field.

Q2. Is the topography of the overall installation completely flat, or can we build up the ground around the receiver tower if it provides advantage?

A2. You may assume flat topology. However, non-flat topology created by conventional earthmover equipment can be considered if it confers an advantage.

Q3: What is the available onsite power source and infrastructure in the field both to actuate the tracking system and enable computation of how/where to track?

A3: Assume heliostat units in the energy generation field are powered by ties to a conventional 120/220 VAC electrical utility distribution grid.

Q4: Is the sun tracking software considered a sub-system of the design; are we responsible to write the code, or are we just responsible for mechanical and layout aspects of the overall system?

A4: Engineers on this project are just responsible for the mechanical and physical aspects of the heliostat module design. Code will not be required and is not expected as part of the deliverable.

Q5: Does each module need its own computer to run calculations, or are the calculations done at a central hub computer and communicated out to modules? If the control scheme is communicated from central hub, what infrastructure exists for computer-to-computer communication?

A5: Each heliostat module will be equipped with a small computer to control individual heliostat unit motion. Command inputs will arrive from a central computer hub, and WiFi will be used to send and receive these signals.

Q6: For range of motion, why does the reflecting heliostat need to rotate azimuthally more than 90 degrees? It seems like beyond 90 degrees there is no possibility of direct sunlight reflection onto the receiver target.

A6: The azimuth angle of the sun can change more than 180 deg depending on the latitude and season. The heliostat angle bisects the solar and target angle and yes if the target aperture is directly in front of the heliostat 90 deg would work. However, not all the modules will be located at the north-south axis so greater rotation past vertical is required.