

Customer Needs Statement

Small-scale Heliostats for Industrial Solar Processing

Last Updated: June 23, 2021

Overview

Heliostats are mirrors that move in two axes to track the sun throughout the day and focus light to a central source.¹ The resulting generated heat can be used to drive a power block, industrial processes, 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.

The customer requests engineering designers to develop small scale ($< 1 \text{ m}^2$) modular heliostats units at low cost and then propose a geographic distribution scheme for these heliostats to generate 1 MW of concentrated solar power by concentrating sunlight to a single spot. Decreasing individual heliostat size induces several advantages related to tracking accuracy and optical performance (e.g. decreased wind loads, higher concentration ratio), cost (e.g. flat mirrors, plastic parts), and practicality (e.g. simple drive systems, mounting and off-the-shelf parts) that represent a paradigm shift in heliostat design; the heliostats should have a cost below $\$100/\text{m}^2$ ².

Designs are requested for a small array, or module, of tracking heliostats to provide heat for a small-scale methane reforming reactor operating at $1000 \text{ }^\circ\text{C}$ (reference). See Figures 1 and 2 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 100; and (3) decreasing the overall cost below $\$100/\text{m}^2$.

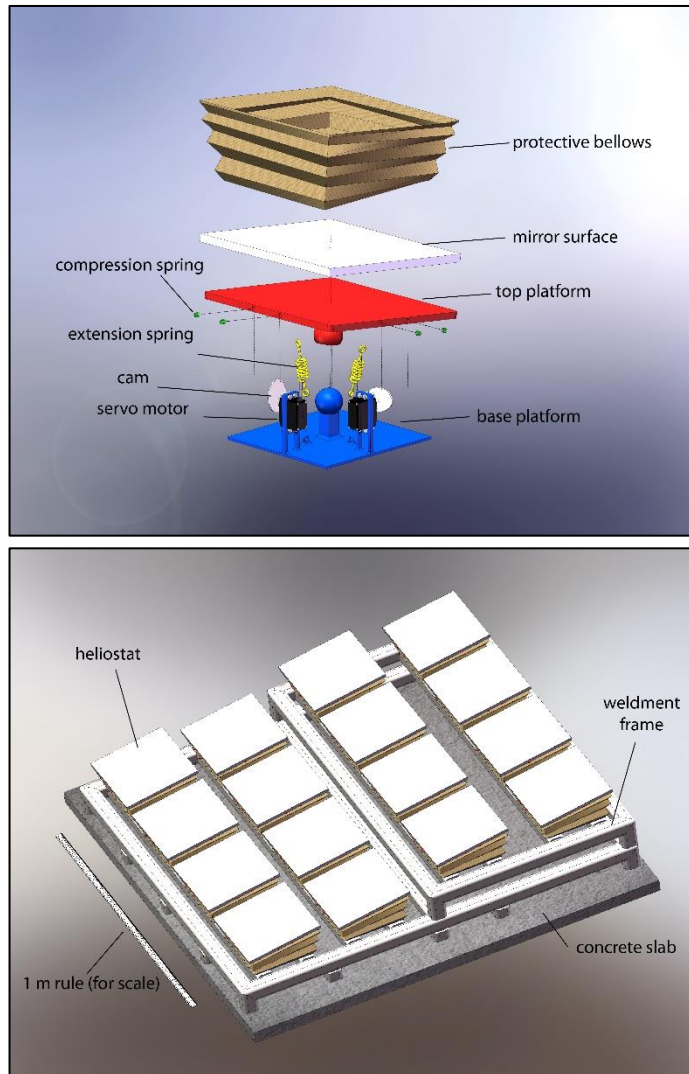


Figure 1. Top: Exploded view of the design concept. Bottom: 1 m^2 module with array of heliostats mounted. Major components are made from lightweight, injection molded plastic parts and off-the-shelf parts.

¹ <https://heliogen.com/>

² <https://www.osti.gov/servlets/purl/1137299>

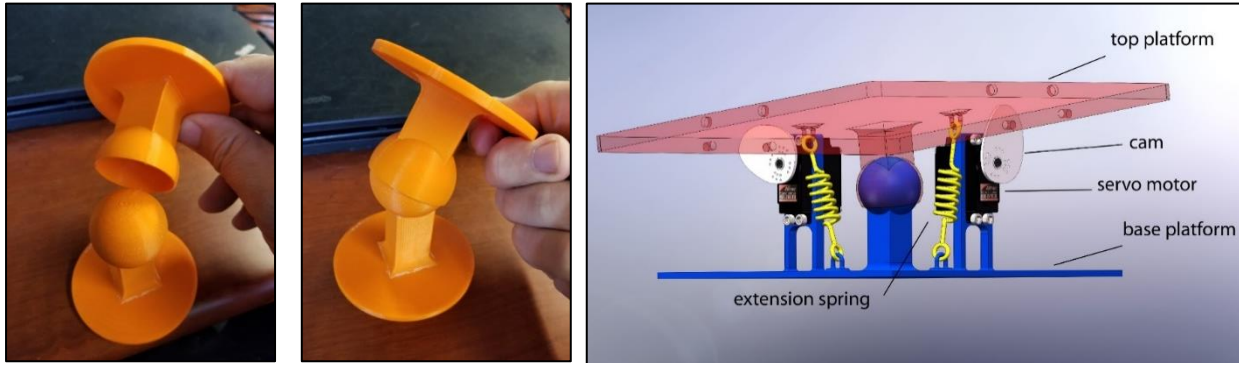


Figure 2. Left and Center: Prototype ball and socket joint. Right: Control of top platform relative to base.

The parallel with development of a low-cost modular heliostat unit, the customer also requests that design engineers develop a viable geographical layout where multiple heliostats units are arranged into a concentrating solar energy generation field like the one shown in Figure 3.

Design engineers may assume heliostat units in the energy generation field are powered by ties to a conventional electrical utility distribution grid. Control signals will be passed back and forth via conventional WiFi from small computers in each heliostat module to a central hub command computer.



Figure 3. A concentrating solar energy generation field centered around a collection tower holding a central receiver target.

Features of Individual Heliostat Modules

1. Total collection area of a single heliostat module is $\leq 1 \text{ m}^2$.
2. Each module must be composed of 2-16 heliostats.
3. Each module must mitigate optical losses due to tracking errors not to exceed 40%.
 - Tracking errors of $\theta = 0.5^\circ$ are reasonable to assume.
4. Each module must be capable of tracking the sun throughout the day.
5. Individual heliostats within module units cannot shade other heliostats in that unit.
6. 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.*
 - *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) or exceed 100 meters.*

7. Overall cost of an individual heliostat module must be below \$100/m².
 - It is desirable to achieve, if possible, the U.S. Department of Energy (DOE) heliostat module target of \$60/m².
8. Sun tracking by individual heliostats should be automated and computer controlled using an onboard computer within each individual module.
 - Control signals will pass back and forth via conventional WiFi from computers in each heliostat module to a central hub command computer.
9. The total module area relative to the reflecting area should be small
 - Do not, for example, include 1 m² 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.
10. Individual parts must be equal in price or less expensive than the closest available OTS part.
11. The reflecting surface of each heliostat must be washable using conventional cleaning techniques to remove dust and residue.

Features of the Concentrating Solar Energy Collection Field

12. 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.
13. The concentrating solar energy collection field must provide a solar concentration ratio greater than 1000 suns
14. 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

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).
17. Adequate spacing must be provided for a conventional cleaning vehicle to pass through the arrangement of heliostat modules and access all units for cleaning.

18. The topography of the overall installation may be assumed to be completely flat.

- Non-flat topology created by conventional earthmover equipment can be considered if it confers an advantage.

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: Yes

Q2: 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?

A2: Assume heliostat units in the energy generation field are powered by ties to a conventional electrical utility distribution grid.

Q3: 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?

A3: Engineers on this project are just responsible for the mechanical and physical layout aspects of the design. Code will not be required and is not expected as part of the deliverable.

Q4: 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?

A4: Each heliostat module will be equipped with a small computer to control individual heliostat motion. Command inputs will arrive from a central computer hub, and WiFi will be used to send and receive these signals.

Q5: 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.

A5: 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 of the modules will be located at the north-south axis so greater rotation past vertical is required.