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Adrien Arias, Jarett Cox, Olivia Dodge, Zariq George, Cristian Hooker, Abraham Sheikh, Noelle Turner

HelioSmart

UF Herbert Wertheim College of Engineering
Department of Mechanical & Aerospace Engineering
UNIVERSITY of FLORIDA

ABSTRACT

The hedgehog concept of HelioSmart is to reduce the number of motors needed for a practical, simple design which eliminates unnecessary waste, maximizes profit, and reduces cost. Competitive cost efficacy is achieved with affordable, easily manufactured materials and only three motors per module. This small heliostat design includes a flange-supported pole structure manufactured from ABS polycarbonate. The 4-heliostat module is controlled remotely with a Raspberry Pi via Wi-Fi with a maximum range of 100 *m*. The central shaft rotation is achieved by a motorized belt and the azimuthal position is adjusted using stepper motor and gear combination. The reflective surface is a thin layer of silver under glass, which prevents oxidation and allows easy maintenance without sacrificing the highly desirable reflectivity of 95%. With only three motors, the design achieves 360° of rotation in increments as small as 0.5°. In addition to high maneuverability, the design boasts an efficiency of 50% afforded by minimal shading, maximum reflection, and limited light dispersion. This optimized heliostat delivers a useful power of greater than 1 *MW* and a solar concentration greater than 1000 suns. Given its continued elemental exposure in Las Vegas, Nevada, the module is designed to withstand wind loads of up to 136 *N* and preserve the computer system, motor, and gears through a protective enclosure. This thoughtfully designed heliostat provides the customer with a lifetime of up to 25 years to contribute towards a cleaner, greener future of energy.

PRODUCT FUNCTIONALITY

The HelioSmart module uses four individual reflective surfaces to redirect sunlight to a central receiver from up to 100 m away. The module consists of two sets of double-mirror heliostats for a total of four reflective surfaces. Each pair of heliostats uses a simple gear and motor configuration to vertically position the beam of sunlight on the receiver. The rotational motion of all individual heliostats used to position the mirrors horizontally with respect to the receiver is linked with a single motor, gear belt system, lazy-susan bearing. The entire module is secured by anchoring the flanges at the pole base in the ground.

KEY FEATURES

- One short pole and platform frame holding two heliostat mirrors
- Two base flanges to secure the structure
- One taller pole and platform frame holding an additional two mirrors
- Thermally resistant rubber belt gear driven belt
- Position-Control DC motor driving the belt system
- Two position-control DC motor-driven gear systems for vertical positioning
- Raspberry Pi Wi-Fi receiver to receive command signals and produce actuation

COST BREAKDOWN

OTS Parts	$143.63
Modified OTS Parts	$24.30
Raw Materials	$142.35
Manufacturing Labor	$15.00/hr
Assembly Labor	$4.20
Energy Consumption	$0.003/hr

REFLECTIVE SUBSYSTEM

- Plane mirrors
- Silver-backed glass
- 95% reflectivity

STRUCTURE SUBSYSTEM

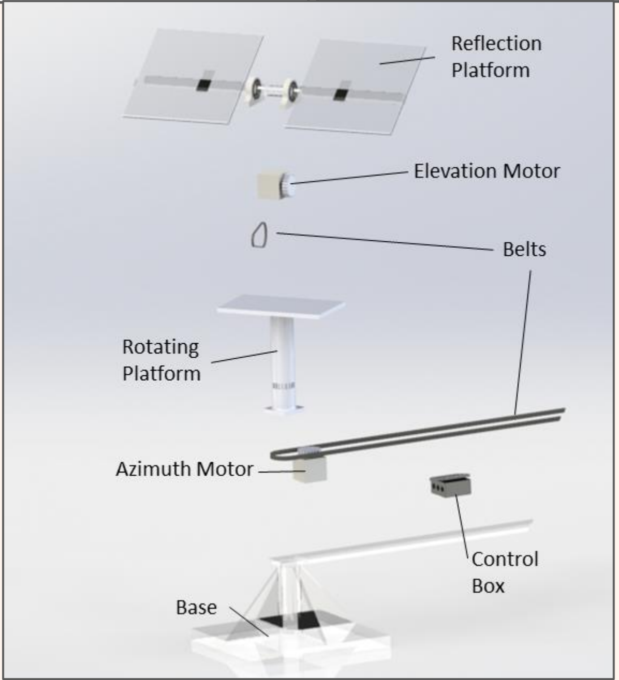
- ABS polycarbonate structure
- Platform for holding actuation components
- Base flanges for holding entire structure in the ground

ACTUATION SUBSYSTEM

- Polyurethane rubber belt
- Grooves manufactured into pole structure
- Position-Control DC motor for driving the belt
- Ball bearings to allow the pole to rotate
- Position-Control DC motor used for vertical positioning

CONTROLLER SUBSYSTEM

- Raspberry Pi 3b+
- Wi-Fi receiver for receiving signals from command station
- ABS polycarbonate box for limiting exposure to the elements and decreasing likelihood of overheating



HELIOSMART: NEEDS MAPPINGS

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

The metric by which each design concept will be chosen will be determined based increased concentration ratio, low cost, and decreased wind load.

2. Total collection area of a single heliostat module is $\leq 1\ m^2$.

This need has already been quantified.

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

The curvature of a parabolic mirror can be simulated by using a higher number of smaller mirrors. The best arrangement would be a 4x4 square orientation to provide max radius of curvature.

4. Each module must mitigate optical losses, and error must not exceed 40%.

This need has already been quantified.

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

Existing data for tracking the sun throughout the day can be used to quantify this need. The NREL has published a solar positioning algorithm that gives the solar zenith and azimuth angles.

6. Individual heliostats within module units cannot shade other heliostats.

Heliostats must maintain a spacing distance of 1.07 meters at a maximum and a minimum of 0.05 meters to prevent shading.

7. Modules must redirect sunlight to receiver on central tower up to 100 m tall.

Design Engineers must specify the receiver mounting height on tower. Tower must not exceed 100 m or go below 0 m. Receiver height will be dependent on solar field layout to avoid shading.

8. Overall cost of individual heliostat module must be below $\$100/m^2$.

This need has already been quantified.

9. Sun tracking by individual heliostats must be automated and computer controlled.

Receiver/controller must be able to communicate with a central computer up to 100 meters away. Therefore, the receiver range must be at least 100 meters.

10. The total module area relative to the reflecting area should be small.

The size of non-reflecting heliostat module surface area should be minimized. The ratio of total module area relative to the reflecting should be as close to 1 as possible.

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

The cost of each part subtracted from price of closest available OTS part must be $\geq \$0$.

12. Reflective surface of each heliostat must be washable using basic methods.

The reflective surface of each heliostat must be able to withstand pressure washing with tap water of at least 500 psi without scratching or damaging reflective surface.

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

This need has already been quantified.

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

This need has already been quantified.

15. The system operates under ambient and solar conditions in Las Vegas, NV.

The system operates with an average daily direct normal radiation of 8 kWh/m^2 with 3817 hours of sunshine annually, and withstand temperatures as 35 °F and as high as 110 °F.

16. The solar energy collection must deliver to receiver an input power of 1 MW.

The useful power after losses must be at least 1 MW.

17. Solar energy collection must provide concentration ratio > 1000 suns.

This collection field must provide concentration > 1000 kW/m^2. This is 1000 times greater than what the surface of Earth experiences at sea level.

18. Heliostats furthest from receiver tower must account of dispersion of reflected light.

Ideally none of the reflected light from any heliostat module should miss the receiver. While engineering calculations cand determine max heliostat distance. A max distance of 100 m is assumed.

REFLECTIVE SURFACE

1, 2, 8, 12, 14, 15, 16, 17, 18

ACTUATION

4, 7, 8, 11, 14

STRUCTURE

3, 6, 8, 10, 13, 14, 18

CONTROL

5, 8, 9, 14