Heliostats Improving Vegas Energy (HIVE)

EML 4501 – Summer C 2021
Group 2: Aidan Amstutz, Tyson Calvert, Logan Laird, Pedro Marcano, Alexi Saliba, Kaitlin Smith, James Soto

Abstract

Our team's Hedgehog Concept is to have the best overall efficiency of the heliostat module. This includes having the most efficient heat transfer qualities, as well as durability of the unit over time and under ambient weather conditions. We aim to accomplish this task with a unique hexagonal alvariumesque mirror design and two pulley movement system where control is propagated through a universal joint. The pulley system is a distinctive method of aligning the reflective surface as it reduces the force required by the motors relative to the traditional azimuthal drive, which in turn allows for less torque demand and inexpensive motors. A base plate is also utilized to support a module and ensure that heliostats remain orientated correctly in the rough terrain.

Heliostat positioning is based on a sun positioning algorithm which uses predicted sun patterns to determine the best module orientation for optimum accuracy of reflected rays. This method has been proven through research to have minor losses and can even work in suboptimal weather conditions, which will allow an array to maximize performance. The layout of the field is based upon a Fresnel lens and will arrange modules in a linear orientation to account for light dispersion from the farthest heliostats. This positioning will also allow for mirror surfaces to be cleaned easily which will ensure that reflectivity is maximized. With the synthesis of these distinguished subsystems, the final design boasts the highest performance efficiency over the duration of its operation.

Product Functionality

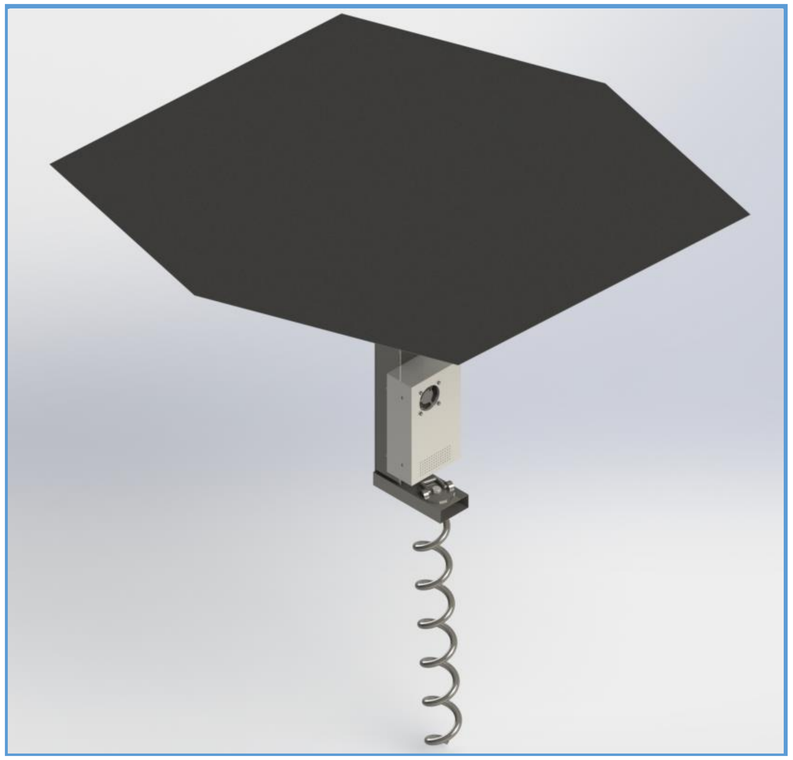
Heliostats are devices used to reflect sunlight in a desired direction, making them commonly used in solar energy applications. By using an array of heliostats, large amounts of solar power can be concentrated, allowing for the usage of solar energy in the desired application of a small-scale methane reforming reactor operating at 1000°C. The heliostats concentrate solar energy into a receiving tower, heating the working fluid and effectively replacing the combustion reaction of fuels which would normally provide heat.

The created design utilizes a field of heliostat modules designed to track the path of the sun throughout the day, reflecting its rays into a central receiving tower. Each module features a reflective surface, consisting of mylar film attached to a hexagonal frame, a support structure, and a pulley and control system. The control system directs each module in the array for optimal sun-tracking, actuating the motors such that the pulleys can properly position the reflecting surface.

Cost Breakdown

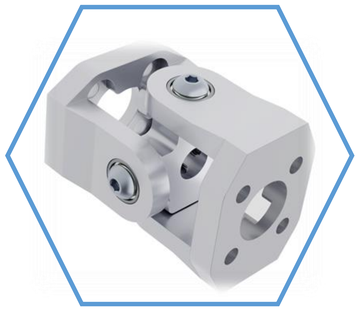
Expense	Cost
OTS Parts	$38.54
Raw Material	$37.03
Manufacturing	$11.15
Assembly	$11.55
Energy Consumption	$0.33
Total	$98.20

Full Assembly



U - Joint

A universal joint, or U-joint, is a cross-shaped part that allows for biaxial rotation. The U-joint features a central cross with ends that fit into endcaps. These endcaps interface with the cross ends with needle bearings, allowing for smooth rotation of the joint in two axes while protecting the bearings from dirt and debris.

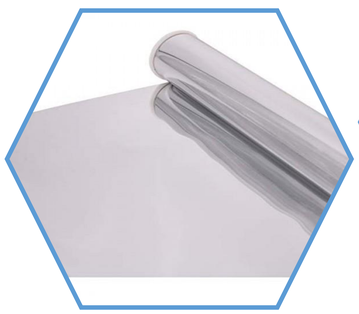


Pulley System

This design features two pulley systems to adjust the angle of the reflective surface. Each system attaches to two opposite sides of the reflective surface, using a stepper motor to adjust the pulley rotation according to the control system. The system utilizes timing belts and a grooved pulley to prevent slipping during rotation.

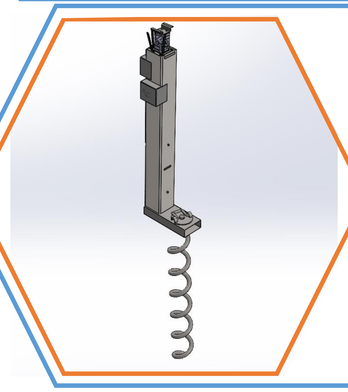
SolaReflex Diffuse Foil

This feature is a solar heating reflector that is provided by ClearDome Solar Thermal. This product is very lightweight, waterproof, and tear resistant. It outperforms other solar heating reflector products by 15-20%. It can reflect up to 95% of visible and invisible light and withstand radiant temperature to 200°C.



Subsystems

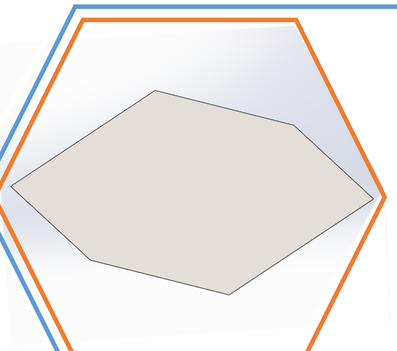
The HIVE concept was divided into four subsystems: the support structure, reflective surface, field layout, and controls system.



Support Structure

The support structure is used to both hold the reflective surface above ground and provide rotational movement to orient the heliostat.

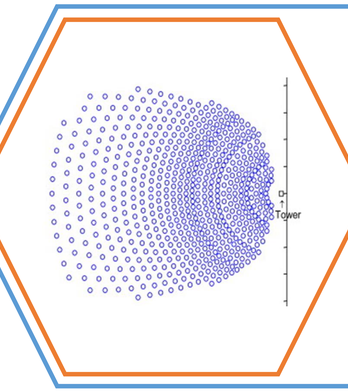
This concept will have two motors which will drive the pulleys rotation. Also, it will be welded to the base plate and connected to the reflective surface with a U – Joint.



Reflective Surface

The reflective surface is used to concentrate and reflect sunlight toward the targeted receiving tower.

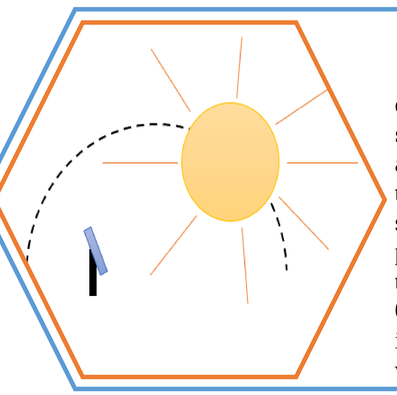
This concept consists of a highly reflective SolaReflex diffuse foil that is applied to the thin piece of steel sheet metal of every heliostat using 3M contact cement as an adhesive.



Field Layout

The purpose of the field layout is to arrange the modules such that the orientation creates optimal reflection of the heliostats to the receiving tower.

This field concept consists of a circular pattern on only one side of the receiving tower. Also, the modules are more separated from each other as the distance to the tower is larger to avoid shading.



Control System

The control system will use daily sun patterns to predict the sun's position throughout the day and determine the orientation of the reflective surface based on this simulated trajectory. Similar programs have shown to offer a tracking accuracy within 0.0003° and maintain operation in suboptimal weather conditions while remaining low cost.

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N1) 1 m^2 Module	M1) Area =1 m^2	**Support Structure**	F1) Module Area = 1 m^2
N2) Between 1 and 16 Heliostats per Module	M2) 1≤ Heliostats per Module≤ 16		F2) 1 Heliostat per Module
N3) Optical Tracking Losses Below 40%	M3) Optical losses < 40%		F3) Optical losses < 40%
N4) Module Must Track Sun Throughout Day	M4) Tracking Error < 0.5°		F4) 0.48° Tracking Error
N5) Heliostats Cannot Shaded Other Heliostats Within Module	M5) Shaded Area is about 0%		F5) Shaded Area is about 0%
N6) Must Accurately Target a 100 m Tower	M6) 180° of Rotation in Both Axes		F6) 180° Horizontal and Vertical Axis Rotation
N7) Cost is less than $100 per Module	M7) Cost < $100/$m^2$	**Reflecting Surface**	F7) Overall Cost of $98.20/$m^2$
N8) Must Be Computer Controlled and Automated	M8) At Least 1 Microprocessor per Module		F8) 1 Microprocessor per Module
N9) Module Area Compared to Reflecting Area Must Be Small	M9) Reflecting Area is At Least 2/3 of Module Area		F9) Reflecting Area Comprises 71.5% of Module Area
N10) Parts Must Be OTS or Similar in Price	10) If Custom, Price < OTS Price, Else Use OTS		F10) All Parts are OTS or Modified OTS
N11) Reflector Must Not Corrode From Standard Cleaning Chemicals	M11) Must Withstand a pH Range of 5-7	**Field Layout**	F11) Resistant to a pH Range of 5-7
N12) Must Sustain a 1MW Power Input	M12) Rate of Heat Input > 1MW		F12) With 1016 Modules Heat Input is 1MW
N13) Must Provide a Solar Concentration Ratio of More Than 1000 Suns	M13) Concertation Ratio > 1000		F13) With Aperture Area of 3 m^2 CR is 1000
N14) Module Distance Must Account for Light Dispersion	M14) Module Distance From Receiver < 100 m		F14) Module Distance From Receiver < 100 m
N15) System Must Last for 20 Years	M15) Life > 20 Years	**Control System**	F15) System Life > 20 Years
N16) Must Be Able to Operate in Las Vegas Desert Environment	M16) Must Be Durable Against Desert Conditions and Temperature Highs of 42° C		F16) Materials Are Durable Against Environment Conditions
N17) Must Allow For Sufficient Space For Washing Vehicle Maneuverability	Module Spacing > 3 m		F17) Spacing of 3m Between Module Rows
N18) Must be Designed For Use on Flat Ground	Angle of Ground Elevation = 0°		F18) Ground Elevation of 0°