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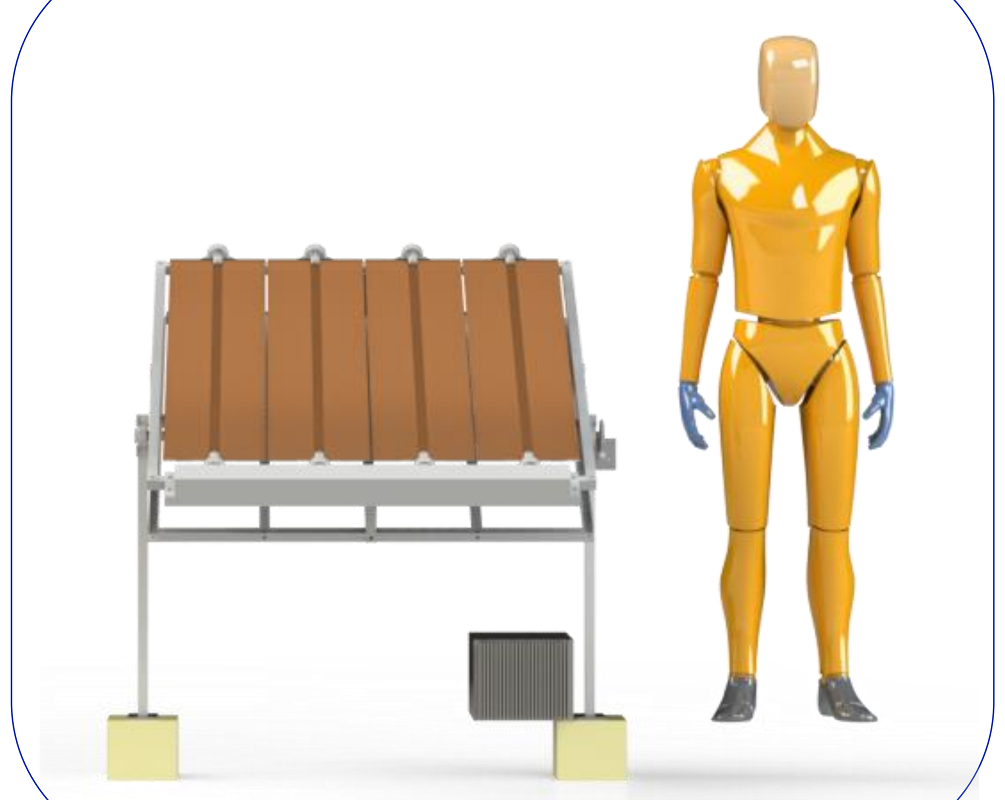
Elijah Crain, Tyler Gernay, Courtney Gill, Steven Jenkins, Lane Ouzts, April Sebok, Jacob Wissinger

HelioWAVE

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

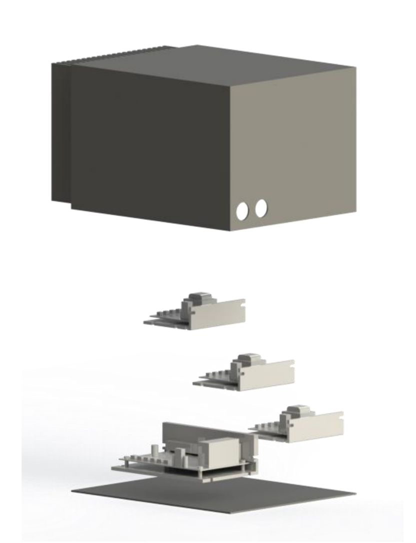
Abstract:

HelioWAVE is a dual-axis tracking heliostat consisting of a steel U-channel chassis that structurally supports the reflecting surfaces. The goal in designing the heliostat is to optimize cost and design parts to improve manufacturability which was decided based on our diverse backgrounds and passions, including strengths in manufacturing, control theory, and computer aided design. We believe this design will not only achieve this concept, but also revolutionize the industry. Our main support structure for the heliostat, the chassis, uses varying steel U-channels, fasteners, and welded joints for easy manufacturing and cost effectiveness. This configuration serves as an aerodynamic frame that can withstand Las Vegas winds due to its simple alignment. Each reflecting surface is provided with its own motor to allow for a dual independent axis tracking system that rotates the connecting shafts of each reflecting surface. This will allow each surface to rotate horizontally about its center at the necessary independent angle towards the receiver tower. The reflecting surface design features a very compact configuration, which allows for optimal concentrated focal thermal output while also minimizing the size of the heliostat to allow for more space in the surrounding solar plant field. In terms of vertical rotation about the azimuth, the heliostat will include a rotating shaft along the steel chassis frame, powered by a motor and gear configuration which will angle all four reflecting surfaces synchronously. The use of only five motors will drive down cost and enhance power consumption, ultimately increasing our heliostat's design life.



Acknowledgements

We would like to extend our gratitude towards our corporate sponsors Cummins and Northrop Grumman. Thank you for supporting the advance of our education and future careers as engineers.



Control/Feedback Sub-System

This image shows the controls subassembly. The components for this subassembly are housed in a steel, sheetmetal box that is mounted to the ground. It contains an Arduino Mega interfaced with an ESP8266 WiFi Module and three L298N motor drivers that connect to the azimuth/elevation motors to control the reflective surface's position via closed-loop positional feedback.

Reflective Surface Sub-System

This image shows the reflective surface sub-assembly. The reflective surfaces for each module are composed of four mirrors made of fused silica glass backed by a layer of silver. These materials were chosen due to their low absorptivity and high Young's Modulus to improve power delivery and reduce loss caused by deflection.

Product functionality

The HelioWAVE operates by rotating on two axes of rotation using DC motors. The motors are controlled by closed loop angle tracking included in each assembly in a box at the base of the module. The controller communicates via WiFi with a central computer hub that will adjust the angles of the HelioWAVE. Each module consists of 4 reflective surfaces that are rotated individually with the DC motors along the azimuth rotation angle. The altitude rotation angle is controlled by one DC motor that rotates a central shaft that is fastened to the chassis of the HelioWAVE. The chassis will be comprised of steel U-channel to support the four reflective surfaces and the four motors. The entire module will be anchored to the ground via concrete blocks, which will provide the assembly with support and stability.

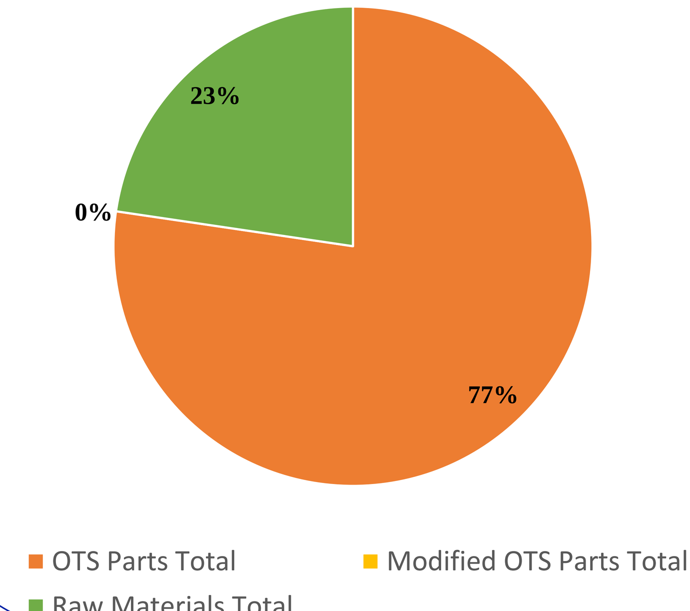
Full Assembly Description

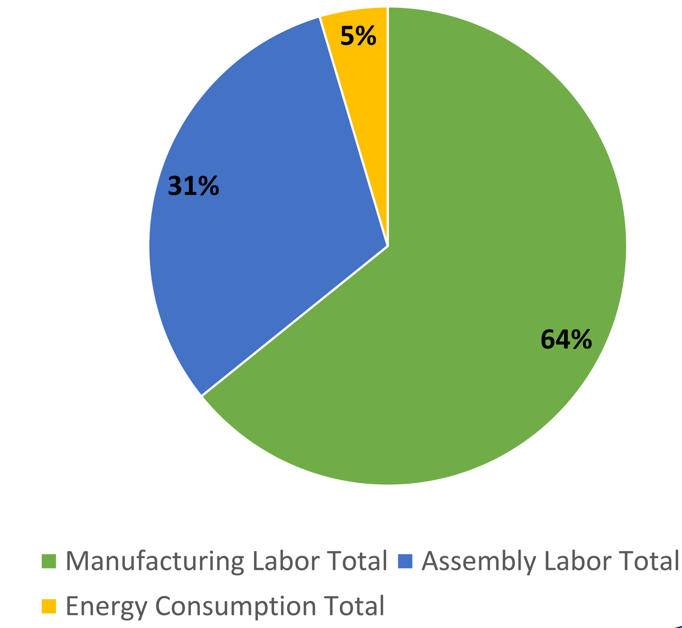
The HelioWAVE is composed of four primary sub-systems: the control/feedback, structure/mount, actuation, and reflective surface. The reflective subsystem contains the four reflective surfaces which track the sun. They are mounted on the structure subsystem, which contains a U-channel chassis connected to concrete blocks which anchor the entire assembly to the ground. The entire module is actuated about the azimuth and elevation axes by the actuation subsystem, which contains five high-torque DC motors: four to actuate the individual reflective surfaces about the azimuth and one to actuate the entire module about the elevation. Finally, these motors are controlled by the control/feedback subsystem, mounted at the base of the assembly, which contains the microcontroller, Wi-Fi module, and motor drivers used to control the reflective surfaces.

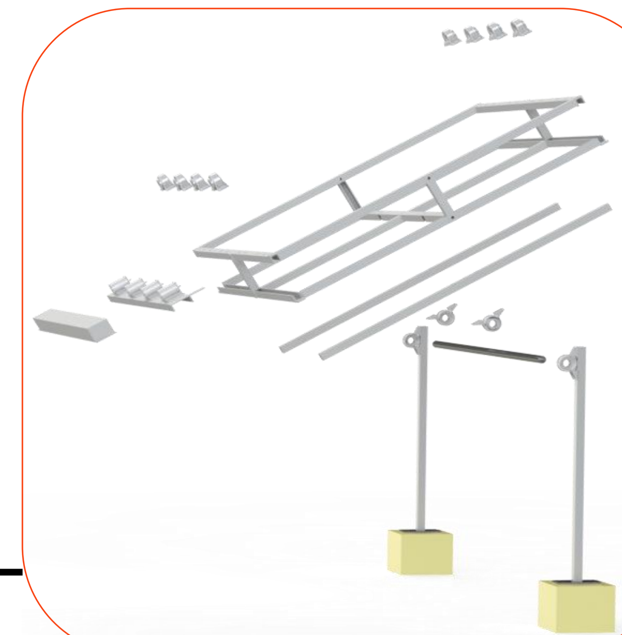
Cost Overview

The final design of the heliostat includes the off-the-shelf parts and manufactured parts. The OTS parts consists of the motors, pillow blocks, fasteners, gears, and the parts in the control box. The raw materials consist of steel, aluminum, reflective glass, and concrete to make the motor casing, the U-channel, and the shafts. The manufacturing labor and the assembly labor were determined by the mean hourly wage of a production worker in Las Vegas, NV multiplied by the number of hours to complete the parts. Manufacturing labor includes cutting, welding, drilling, and bending. The energy consumption cost is the cost of any manufacturing that requires energy.

OTS Parts Total	Modified OTS Parts Total	Raw Materials Total	Manufacturing Labor Total	Assembly Labor Total	Energy Consumption Total	Total
$277.41	$0.00	$81.33	$51.64	$25.08	$3.70	$439.16





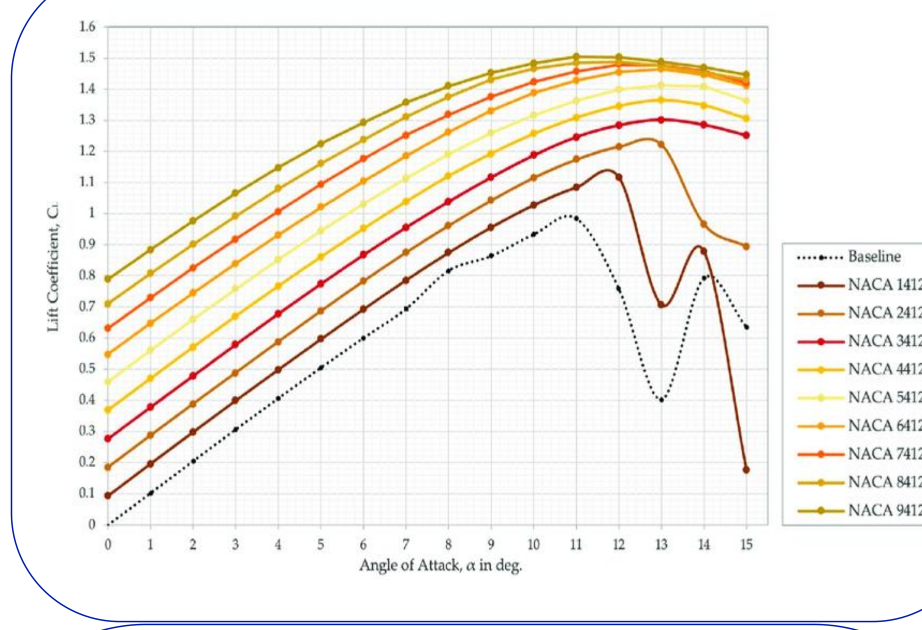


Structure/Mounting Sub-System

This image shows the structure and mounting mechanism for our design. The main structural component for our heliostat is a chassis featuring the mounting for the four reflective surfaces and accompanying motors via motor mounts and pillow blocks. The chassis is mounted via pillow blocks to a driven shaft which is in turn mounted to two supporting legs bolted to concrete footings.

Actuation Sub-System

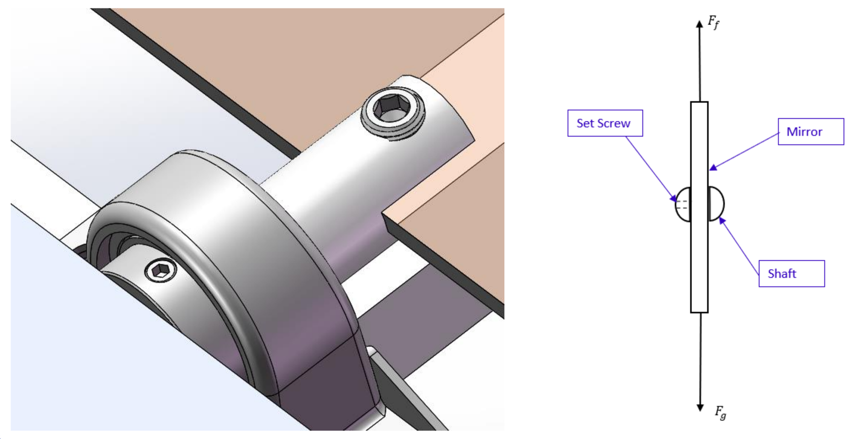
This image shows the actuation sub-assembly for our design. The actuation for this design is accomplished entirely by DC motors. Four DC motors are attached to the reflecting surfaces to drive them about the azimuth angle. One DC motor is attached to the shaft under the chassis to drive the whole module about the alpha angle.



Wind Resistance

$$n = \frac{F}{F_L} = 94.4$$

One of HelioWAVE's key design features is its structural stability in high wind-speed situations. In instances where the wind speed exceeds 50 mph, the design will go into "safety mode," where the mirrors rotate until they are completely flat and facing towards the sky. In this configuration, the most likely mode of failure is shear failure in the pillow-block fastener joints caused by the lift generated by the reflective surface. If the reflective surface is approximated as a high-camber airfoil (NACA 9412) with a relatively high lift coefficient, we can clearly see after conducting a fastener analysis that the force required to cause the fastener joints to fail in shear is 94.4 times greater than the lift force generated on the reflective surface, meaning this design is extremely safe in the high-speed wind conditions frequently encountered in Las Vegas.



Slip Resistance

One important feature of the HelioWAVE is its slotted shafts that the reflective surfaces slide into. The shafts have a flat, milled cutout coated with rubber that the reflective surfaces will rest against as they rotate about the azimuth. The rubber-backed shafts also provide a high force of friction that prevents the reflective surfaces from falling out of the shafts at angles of rotation up to and approaching 90 degrees. Finally, to further ensure the mirrors stay safely secured to the shafts, a set screw will be used to tighten down each mirror onto the shaft backing. After calculating the required tightening torque for the set screw, a joint separation factor of safety of 6196 was found, ensuring the reflective surfaces will stay safely secured to the shafts, even at extreme angles of rotation.

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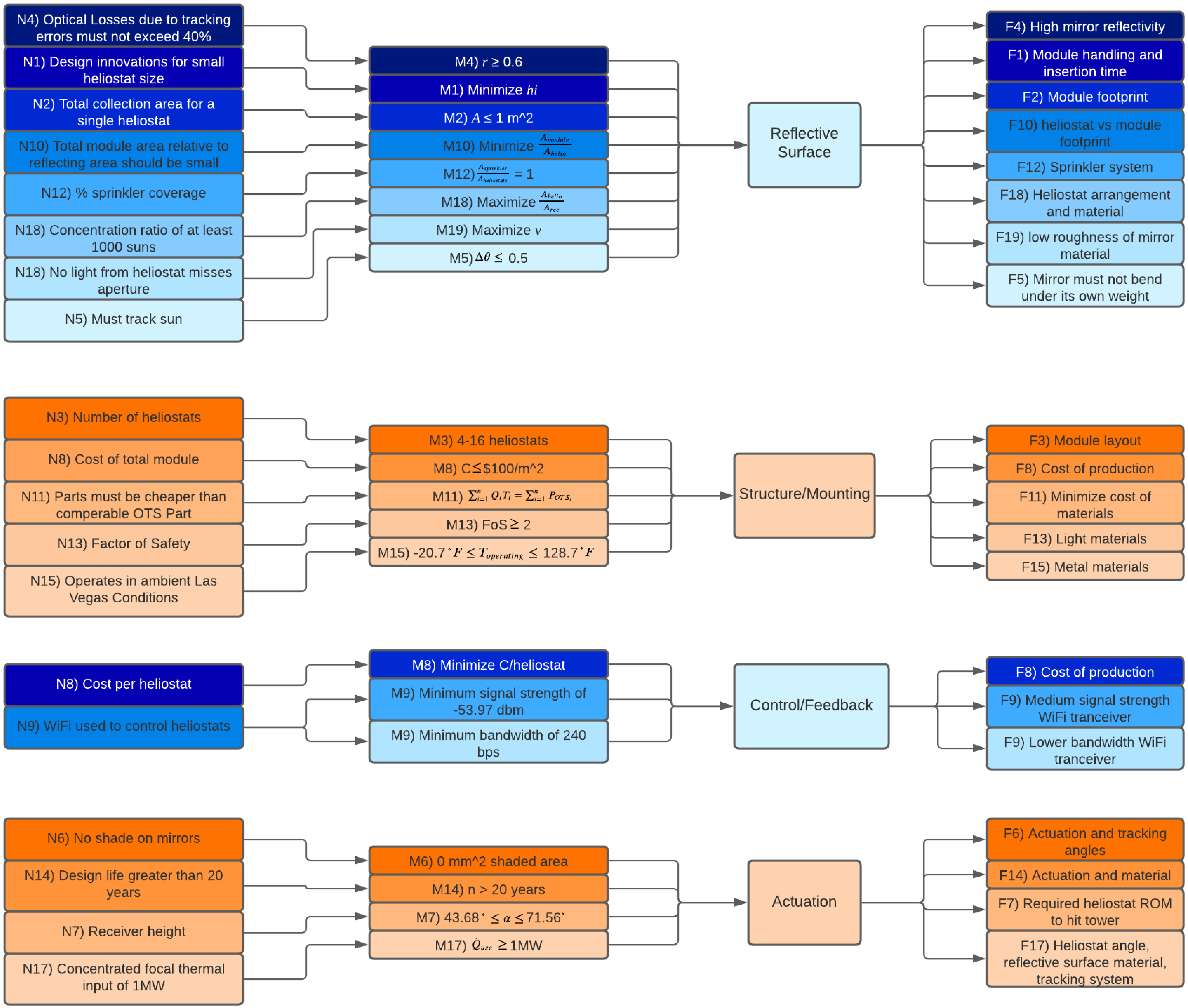
Customer Needs Flow Chart



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