Illumigator

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Abstract

Illumigator is a low-cost heliostat designed for efficient solar tracking in concentrated solar power plants. The Hedgehog Concept focuses on ease of manufacturing and assembly, reducing the labor costs and making repairs and maintenance a simple process. *Illumigator* strives to be sustainable in its design, taking advantage of off-the-shelf parts and using sustainable building materials without sacrificing longevity. The heliostat can be disassembled and reassembled easily to make repairs in a timely manner. What makes *Illumigator's* design unique is its wooden design, which was chosen due to its mechanical properties under long term usage and status as a renewable material consisting of a low carbon footprint. Moreover, the design is distinctly reproducible; its ability to track any solar angle, the materials selection, and the lack of a need for advanced manufacturing methods makes this design implementable in a wide variety of locations. Additionally, the lack of advanced manufacturing techniques or required machinery allows for manufacturing of most components via simple woodcutting and hand-drilling, opening the design to be built by non-industry sources. Dual-axis tracking is achieved via a pulley system that directs the module position and a feedback control system that updates the motor position, resulting in an overall uncomplicated mechanical design. The heliostat's anchoring system allows for quick and simple installation in the field, eliminating the need for any costly operations such as concrete filling. *Illumigator* employs mechanically clamped mirrors which supply the necessary power and concentration ratio while avoiding shading and still being low-cost.

Product Functionality

The heliostat is capable of tracking the sun throughout the day, operating via a pulley system to control the module position. Six subsystems are identified to describe aspects of its functionality.

The support structure consists of an entirely wooden design and houses the motors and hardware used to control the movement of the heliostat. Wood screws are used to fasten each panel of wood together to the form the subsystem.

A stake used as the anchoring system is secured below the structure, while a U-joint is secured to the top of the structure where the module is situated.

The module utilizes the same material as the support structure. Structurally, it consists of three wooden beams configured in a cross. Clamps are added at the ends of each beam to hold four mirrors in place. The module is able to rotate via a U-joint and attachment to the pulley system.

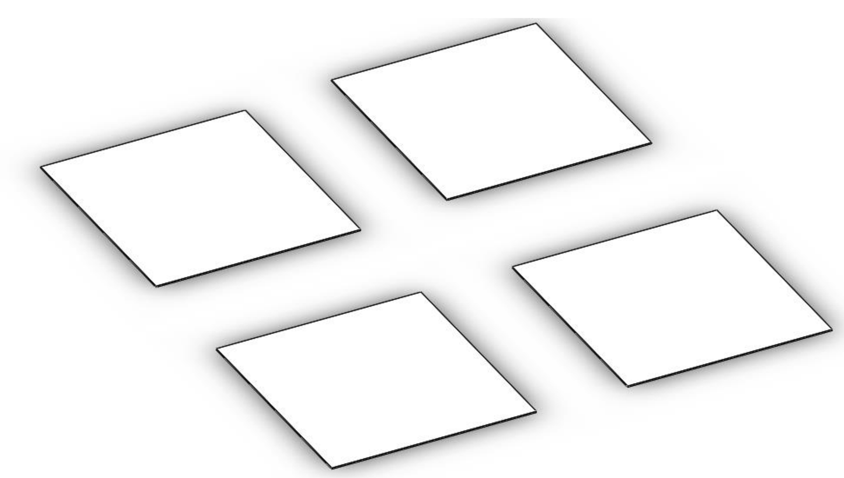
The mirror array consists of four flat rectangular mirrors. The mirrors are secured to the module via four wooden clamps on the outer points.

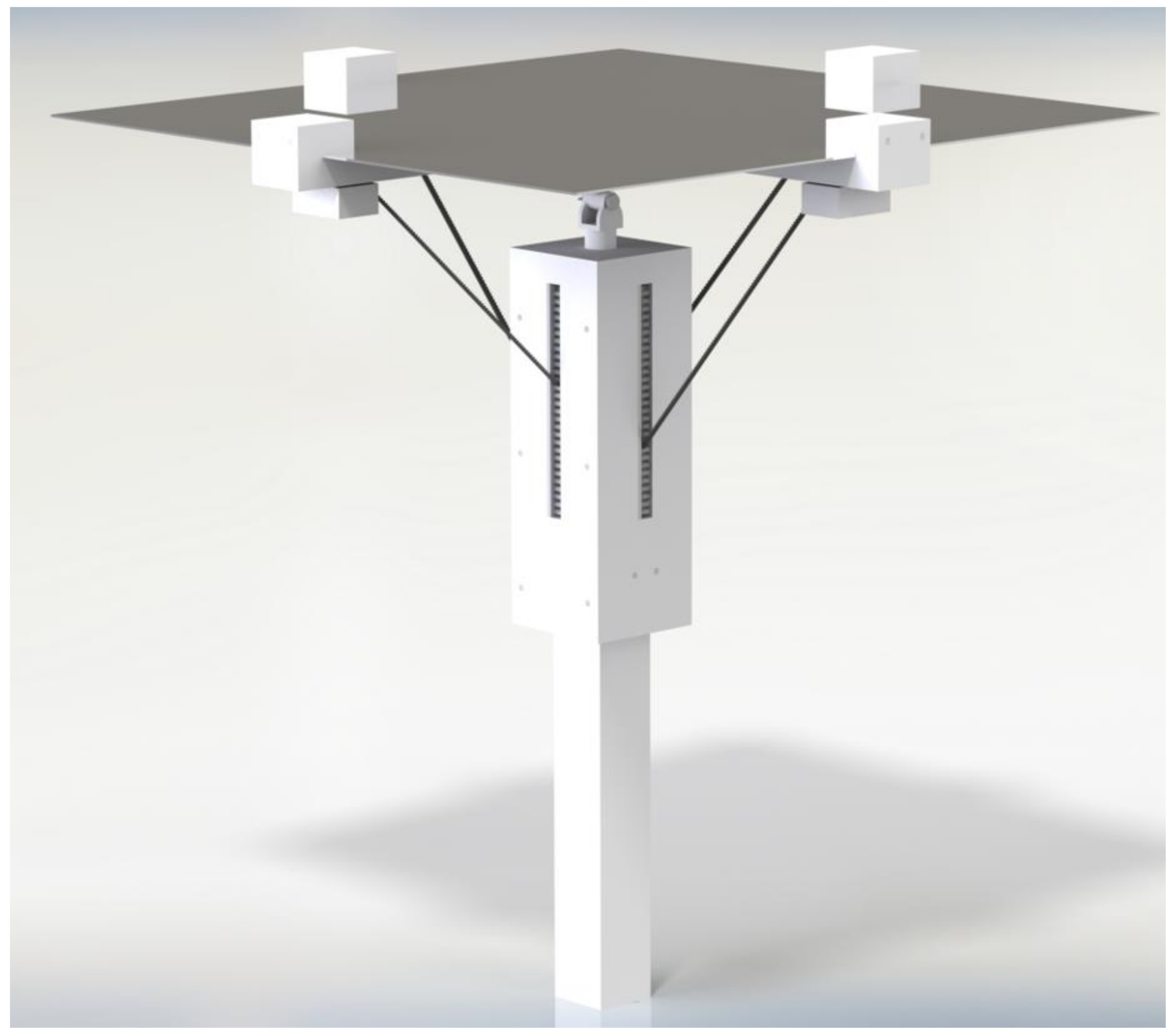
The control system collects data via a Wi-Fi signal from a central computer. The system controls the motors that control pulley position. With encoders, feedback is used to correct the motor position.

The computer mount is a cylindrical capsule situated inside the support structure and houses the controller hardware secured to a mounting plate.

Mirror Array

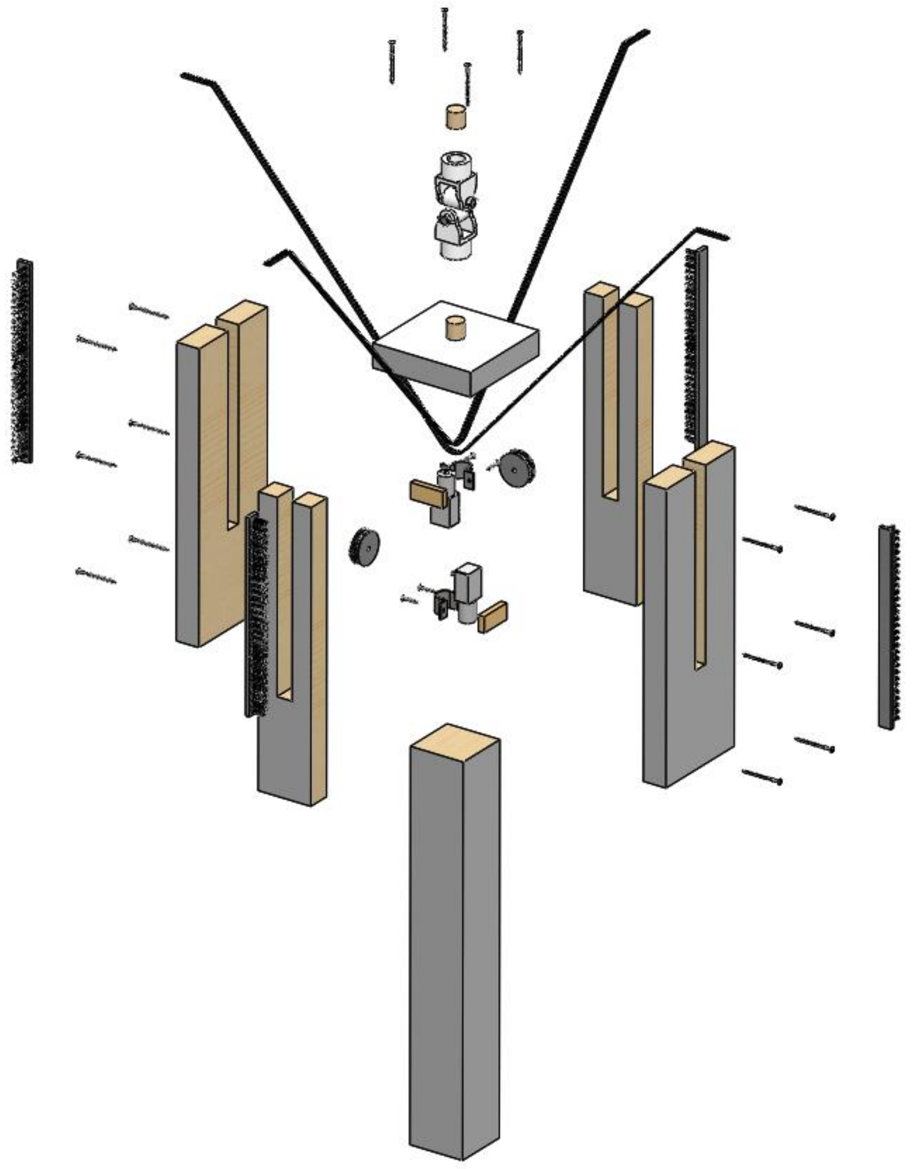
- 1 m^2 reflective area made up of 4 mirrors





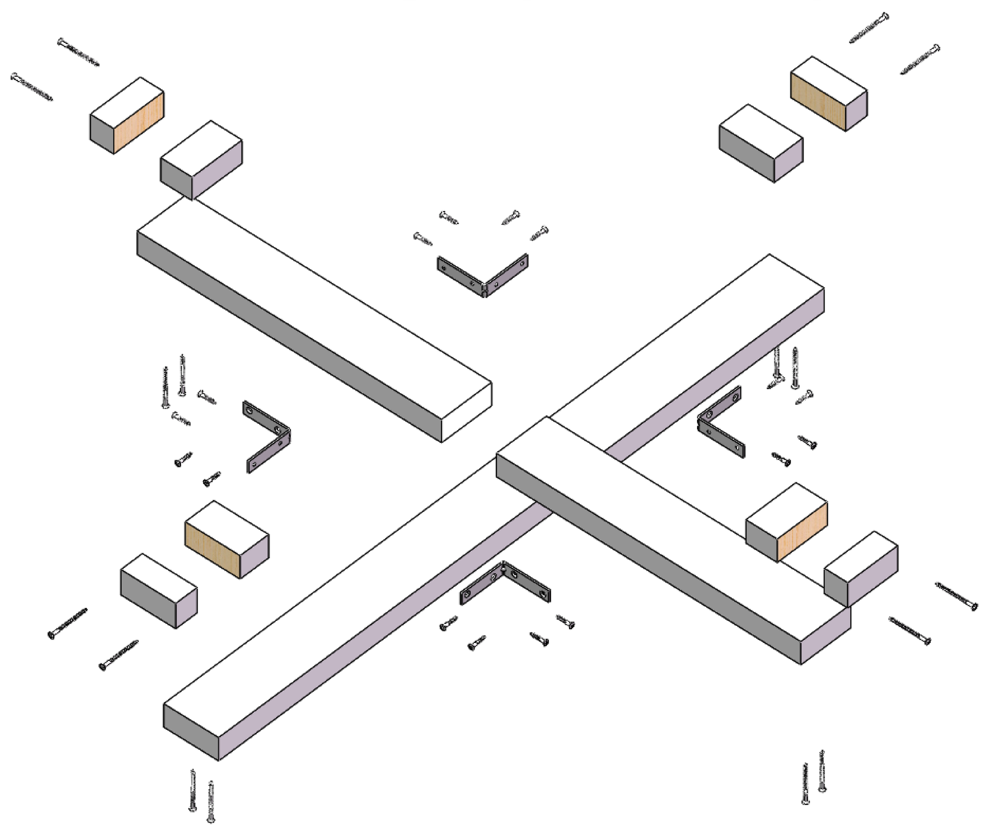
Support Structure and Anchor

- Main material is wood with ABS u-joint
- Houses two motors, a control system, and two pulleys
- Brushes to prevent environmental contamination of motor/pulley
- Planted wooden stake keeps structure intact



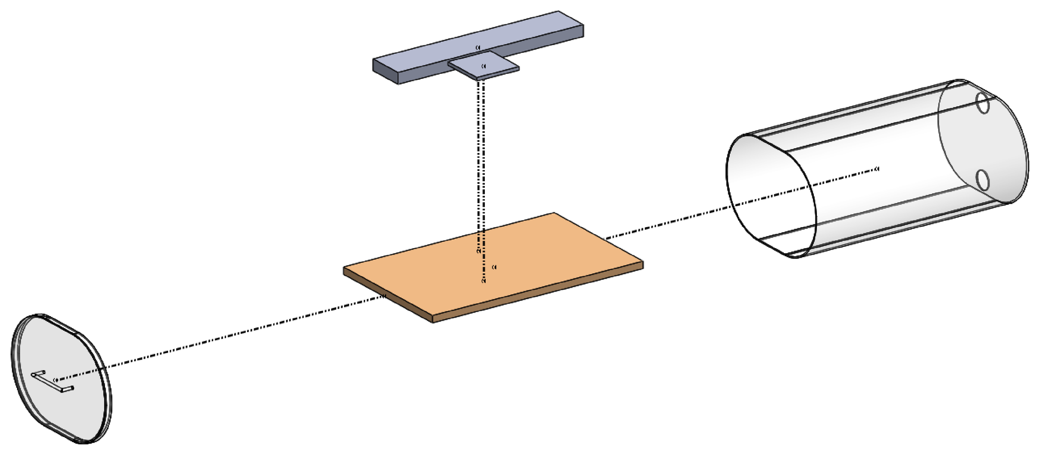
Module

- Main material is wood
- Sets of clamps hold down mirrors
- Actuated via pulley and wire system

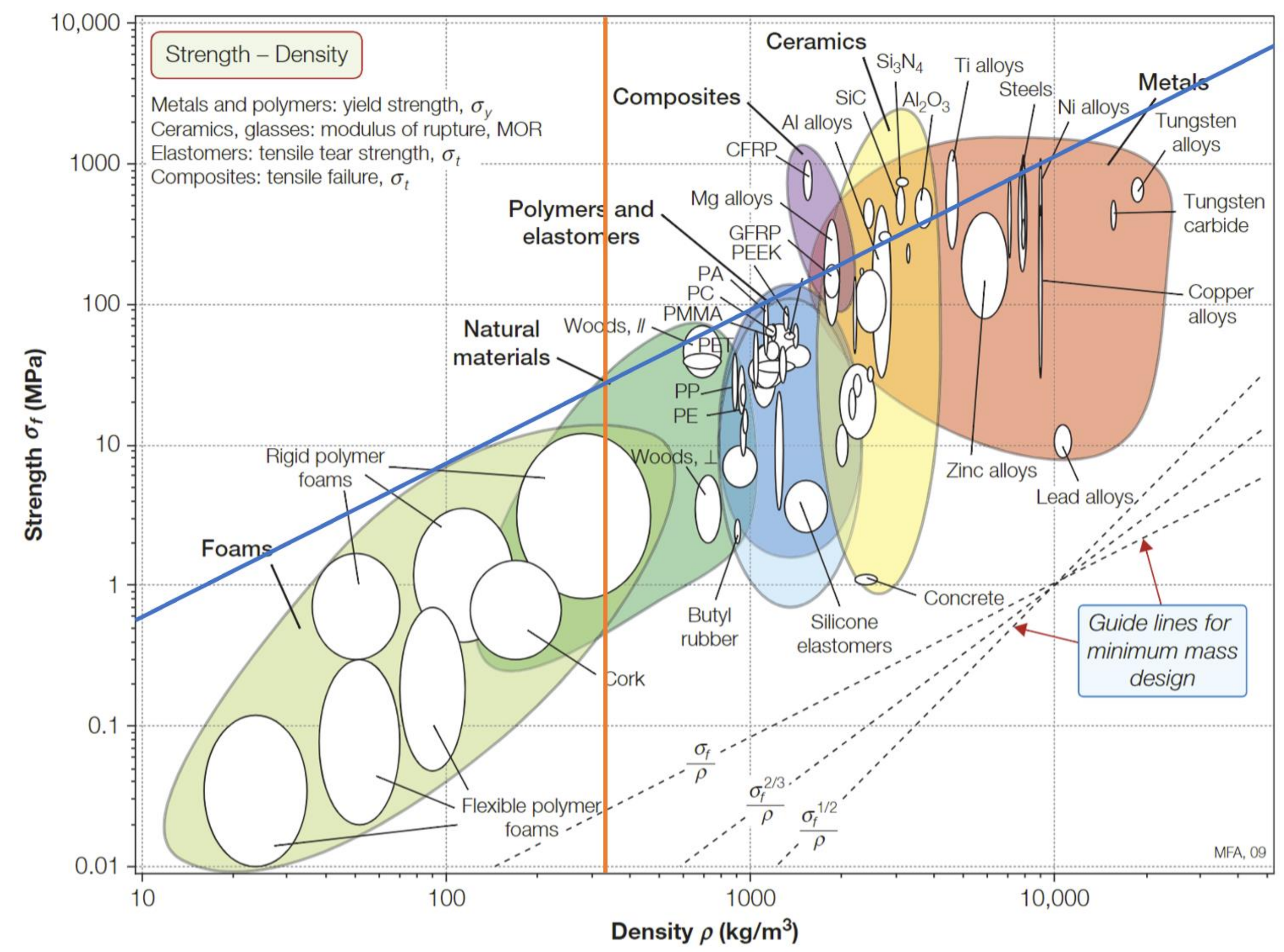


Computer Mount

- OTS container with a balsa wood mounting platform



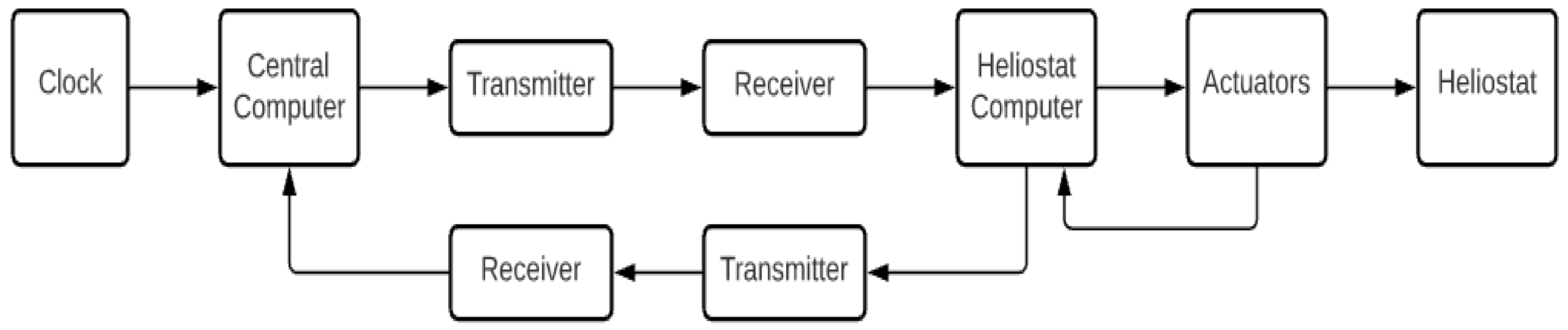
Material Selection



The material for the heliostat was determined through Ashby plot analysis with material strength to density as the selection index.. Wood was selected for most subsystems, giving a cost advantage over competition.

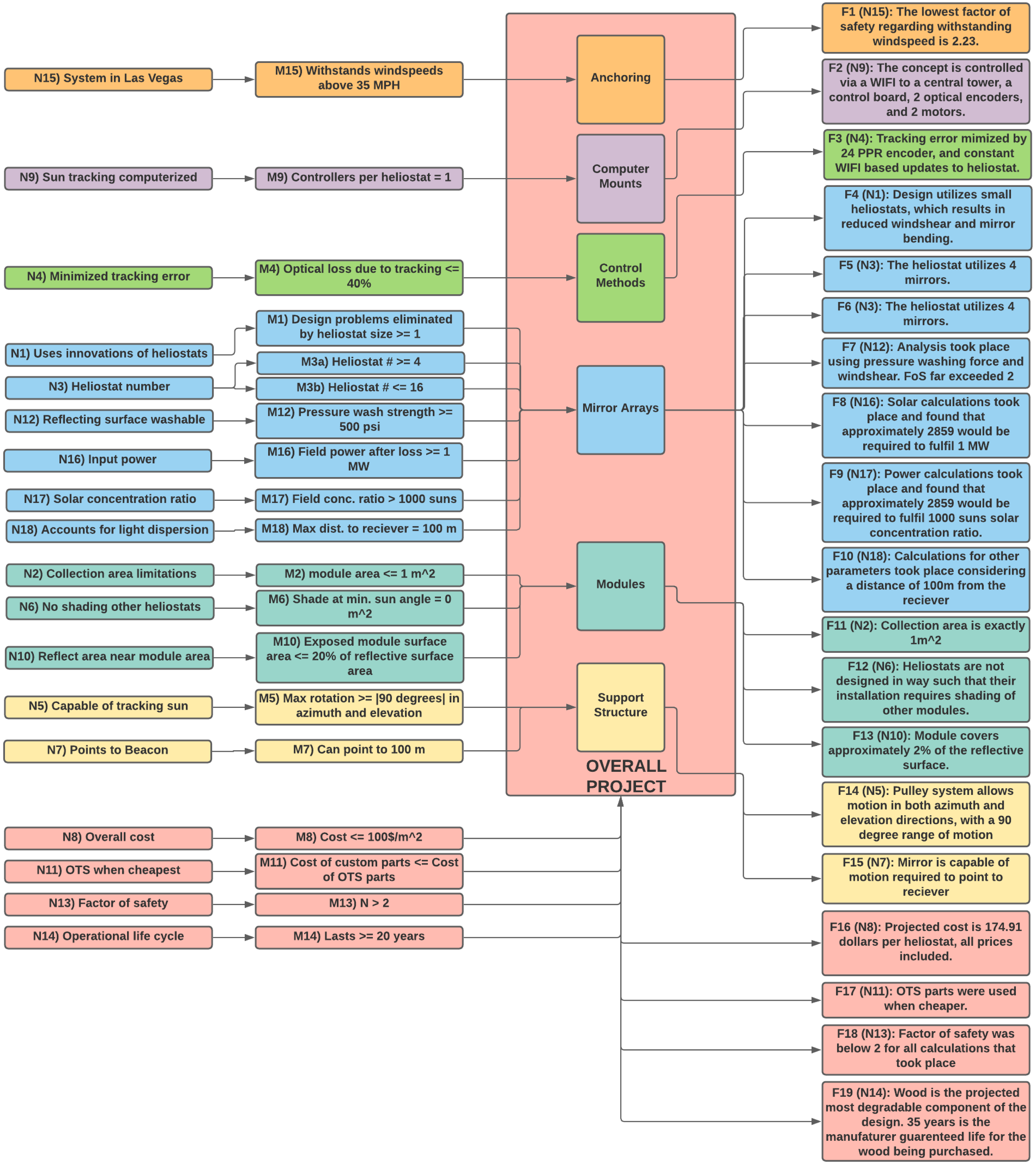
Control System

- Feedback control to adjust motor position in real time



Cost estimates and statistics:

- *Total per heliostat*: $149.64
- *OTS parts*: $53.60
- *Modified OTS parts*: $13.28
- *Raw materials*: $44.11
- *Manufacturing*: $30.40
- *Assembly labor*: $8.25
- *Energy consumption*: $1322.12/month (based on single family home)


N15) System in Las Vegas
M15) Withstands windspeeds above 35 MPH
Anchoring
F1 (N15): The lowest factor of safety regarding withstanding windspeed is 2.23.
N9) Sun tracking computerized
M9) Controllers per heliostat = 1
Computer Mounts
F2 (N9): The concept is controlled via a WIFI to a central tower, a control board, 2 optical encoders, and 2 motors.
N4) Minimized tracking error
M4) Optical loss due to tracking <= 40%
Control Methods
F3 (N4): Tracking error mimized by 24 PPR encoder, and constant WIFI based updates to heliostat.
N1) Uses innovations of heliostats
N3) Heliostat number
N12) Reflecting surface washable
N16) Input power
N17) Solar concentration ratio
N18) Accounts for light dispersion
M1) Design problems eliminated by heliostat size >= 1
M3a) Heliostat # >= 4
M3b) Heliostat # <= 16
M12) Pressure wash strength >= 500 psi
M16) Field power after loss >= 1 MW
M17) Field conc. ratio > 1000 suns
M18) Max dist. to reciever = 100 m
Mirror Arrays
F4 (N1): Design utilizes small heliostats, which results in reduced windshear and mirror bending.
F5 (N3): The heliostat utilizes 4 mirrors.
F6 (N3): The heliostat utilizes 4 mirrors.
F7 (N12): Analysis took place using pressure washing force and windshear. FoS far exceeded 2
F8 (N16): Solar calculations took place and found that approximately 2859 would be required to fulfil 1 MW
F9 (N17): Power calculations took place and found that approximately 2859 would be required to fulfil 1000 suns solar concentration ratio.
F10 (N18): Calculations for other parameters took place considering a distance of 100m from the reciever
N2) Collection area limitations
N6) No shading other heliostats
N10) Reflect area near module area
M2) module area <= 1 m^2
M6) Shade at min. sun angle = 0 m^2
M10) Exposed module surface area <= 20% of reflective surface area
Modules
F11 (N2): Collection area is exactly 1m^2
F12 (N6): Heliostats are not designed in way such that their installation requires shading of other modules.
F13 (N10): Module covers approximately 2% of the reflective surface.
N5) Capable of tracking sun
N7) Points to Beacon
M5) Max rotation >= |90 degrees| in azimuth and elevation
M7) Can point to 100 m
Support Structure
F14 (N5): Pulley system allows motion in both azimuth and elevation directions, with a 90 degree range of motion
F15 (N7): Mirror is capable of motion required to point to reciever
OVERALL PROJECT
N8) Overall cost
N11) OTS when cheapest
N13) Factor of safety
N14) Operational life cycle
M8) Cost <= 100$/m^2
M11) Cost of custom parts <= Cost of OTS parts
M13) N > 2
M14) Lasts >= 20 years
F16 (N8): Projected cost is 174.91 dollars per heliostat, all prices included.
F17 (N11): OTS parts were used when cheaper.
F18 (N13): Factor of safety was below 2 for all calculations that took place
F19 (N14): Wood is the projected most degradable component of the design. 35 years is the manufaturer guarenteed life for the wood being purchased.