Megan Davis, Matthew Harper, Stefano Marconi,
Austin Maxwell, Juliana Mishur, Allan Osmar

JAAMMS SOLAR©

EML4501 Spring 2022 - Group 8

Abstract

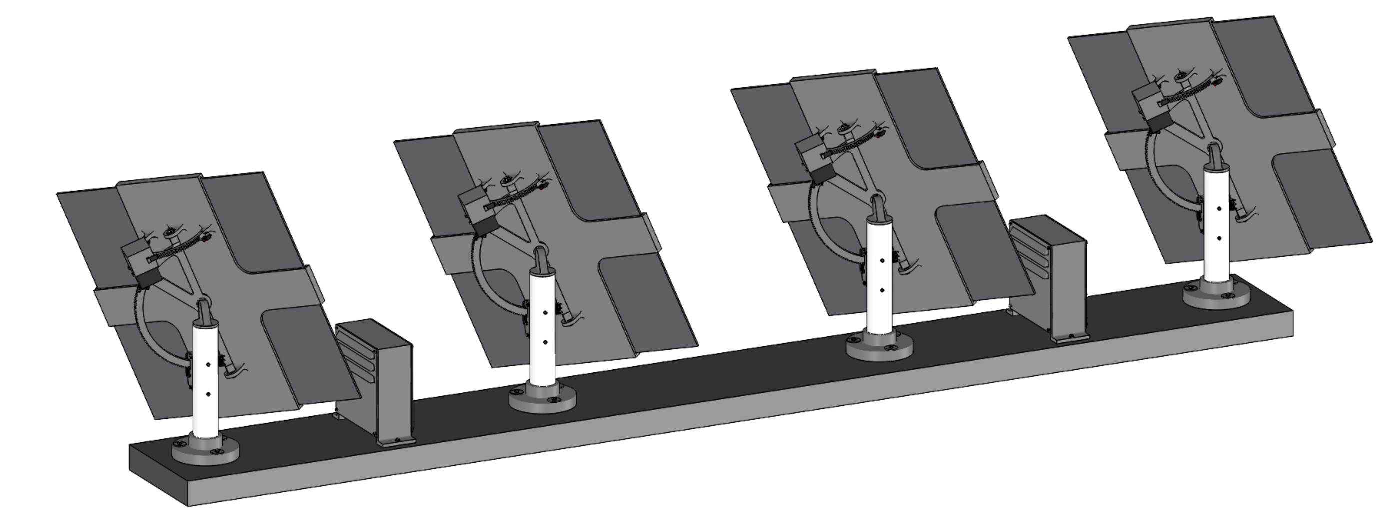
JAAMMS Solar brings a multitude of advancements to solar energy production not previously provided by today's heliostat vendors. Established by the principle that we will maximize product efficiency by minimizing cost, a simplistic design will provide substantial energy at a valuable cost. Limiting the parts necessary to produce the function needed will drive down cost, thus requiring a simpler dynamic for the assembly. The design consists of a rim-drive actuator, which will provide rotation in both x and y-axes. The rim-drive will utilize Espressif controllers to power two modules at once. Each module will use two 12-volt NEMA stepper motors to power the rim-drive. The motor which drives the primary axis is mounted on PVC structure, while the motor that drives the secondary axis is mounted on the primary axis. Since multiple research papers have stated large heliostats are more cost efficient than smaller ones, we decided to maximize the mirror area of individual heliostats while satisfying the customer need of having at least four heliostats per module. Each mirror will be mounted to the PETG platform using manufactured grips to securely hold the mirror in place, with additional foam placed between the spacing between the platform and mirror to prevent further vibration. Each individual module will be supported by a concrete base, due to the material's low cost and durable structure with limited damaging affects due to weathering. Additionally, each heliostat will be positioned along the base to eliminate any shading.

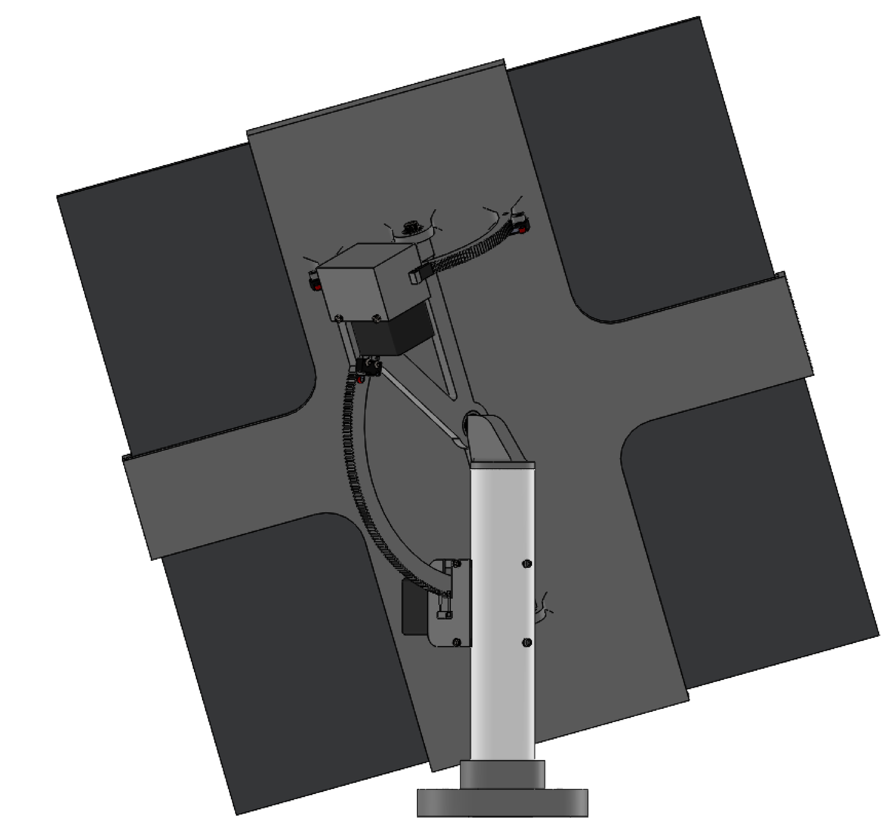
Our logo is a jar of Sun Jam. The logo plays on the onomatopaeia, the name of our company pronounced quickly resembles "jam".

Summary of Functionality

The JAAMMS Solar heliostat model consists of the following primary subsystems: a glass mirror, a two-axis rim drive actuator system, a Espressif controller, and a flat, concrete base for structure purposes. The selection of glass for the material of the mirror allows the design to capitalize on time and resource spent by minimizing maintenance and polishing. The mirror is mounted and connected to the rim drive actuator system through a polyethylene terephthalate glycol (PETG) platform that includes grips. These PETG grips not only allow for easy insertion of the mirror, but they also account for inevitable thermal expansion which could potentially cause for brittle failure in the mirror. Attached to the PETG platform are the two rim drive actuator systems that allow for full tracking of the sun throughout the day. The actuator system consists of two OTS, 12V DC close loop stepper motors, each attached to a 2-gear configuration. The motors provide the necessary rotation to track the on the x and y-axes with respect to the base of the module. The specs and dimensions of the gears directly attached to the shaft of the motors were used design and configure the diameter and number of teeth of the half gears. To prevent from infiltration hazards of water and sand onto the gears, a brush was installed to wipe away contamination before the gears make contact. A polyvinyl chloride (PVC) pipe was utilized as the support connection between the motors and the concrete base of the structure, where one of the motors is fastens along the side of the pipe. To limit interference between subsystem, the motor rotating the primary axis is mounted on the PVC pipe while the other motor is mounted directly on the primary axis. A four-bolt configuration is used to fasten the PVC pipe onto the flat concrete base. To protect the Espressif controller, as well as the amplifiers and microprocessor, from external damages due to expected weather in Las Vegas, NV, a high-density polyethylene encloser was designed to fit the controller while providing the necessary ventilation. Since the power supply is not considered intense enough to require force ventilation, louver vents were implemented along the side of the PE encloser parallel to the surface as a passive, convective ventilation solution. Wiring from the encloser to the motors was protected via weather resistant insulation, as they run along the inside of the PVC pipe. A flat, concrete base of the heliostat allows for the design to minimize potential shading between the modules and neighboring heliostats in the CSP field.

Full Assembly

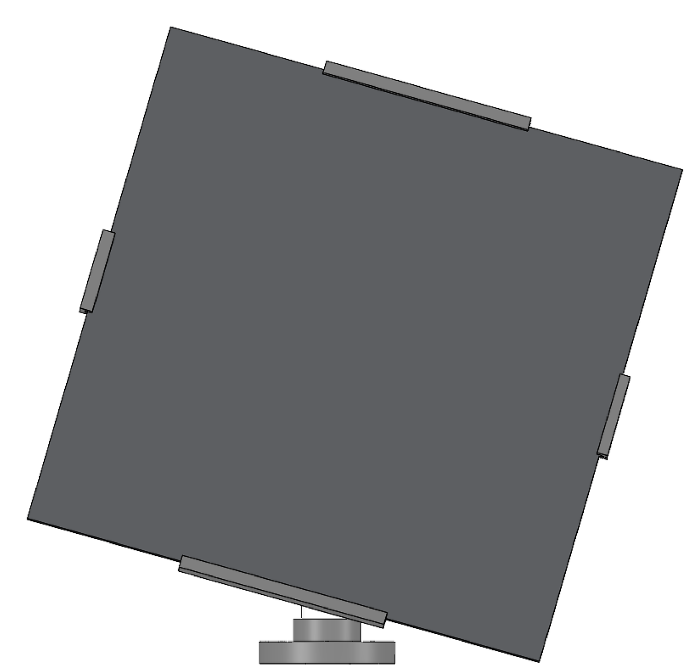




Key Features

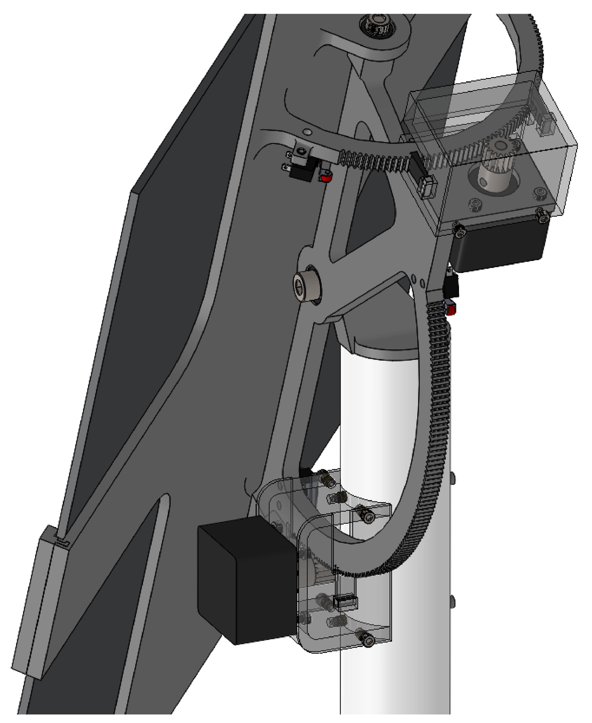
- 0.25 reflective glass mirror per module in a singular heliostat
- PETG grips to hold mirror in place while also accounting for thermal expansion
- 2 rim drive actuator system about primary and secondary axis to consistently track the sun
- Gears enclosures with brush to eliminate contamination at contact points
- High density PE enclosure box for electrical components (Espressif, amplifiers, and microprocessor) installed with passive ventilation via louver vents
- PVC pipe that serves as support structure for rim drive actuators, motors, and protection for wiring
- Cost effective, flat concrete base as support structure for all modules and electrical enclosure boxes
- Narrow concrete support bases that minimizeshading between modules and surrounding heliostats

Mirror Subsystem

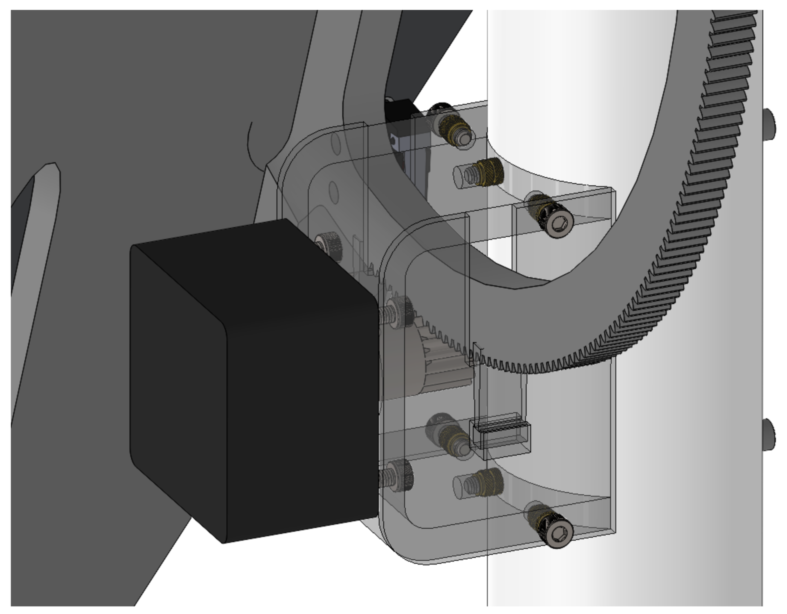


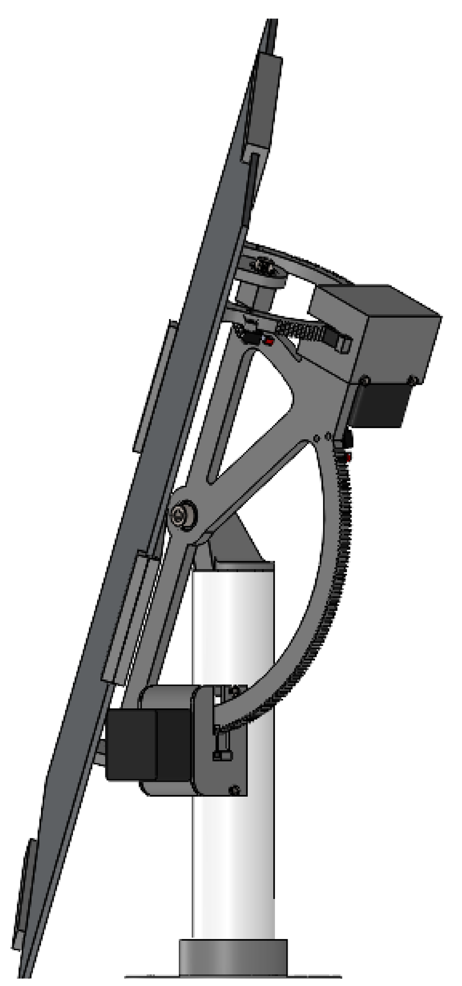
The mirror subsystem is comprised of 4 silver coated reflective solar mirrors, each with an area of 0.25 sq. m. These mirrors are adjusted accordingly as the sun moves throughout the sky via the actuator subsystem.

Actuator and Structure Subsystems

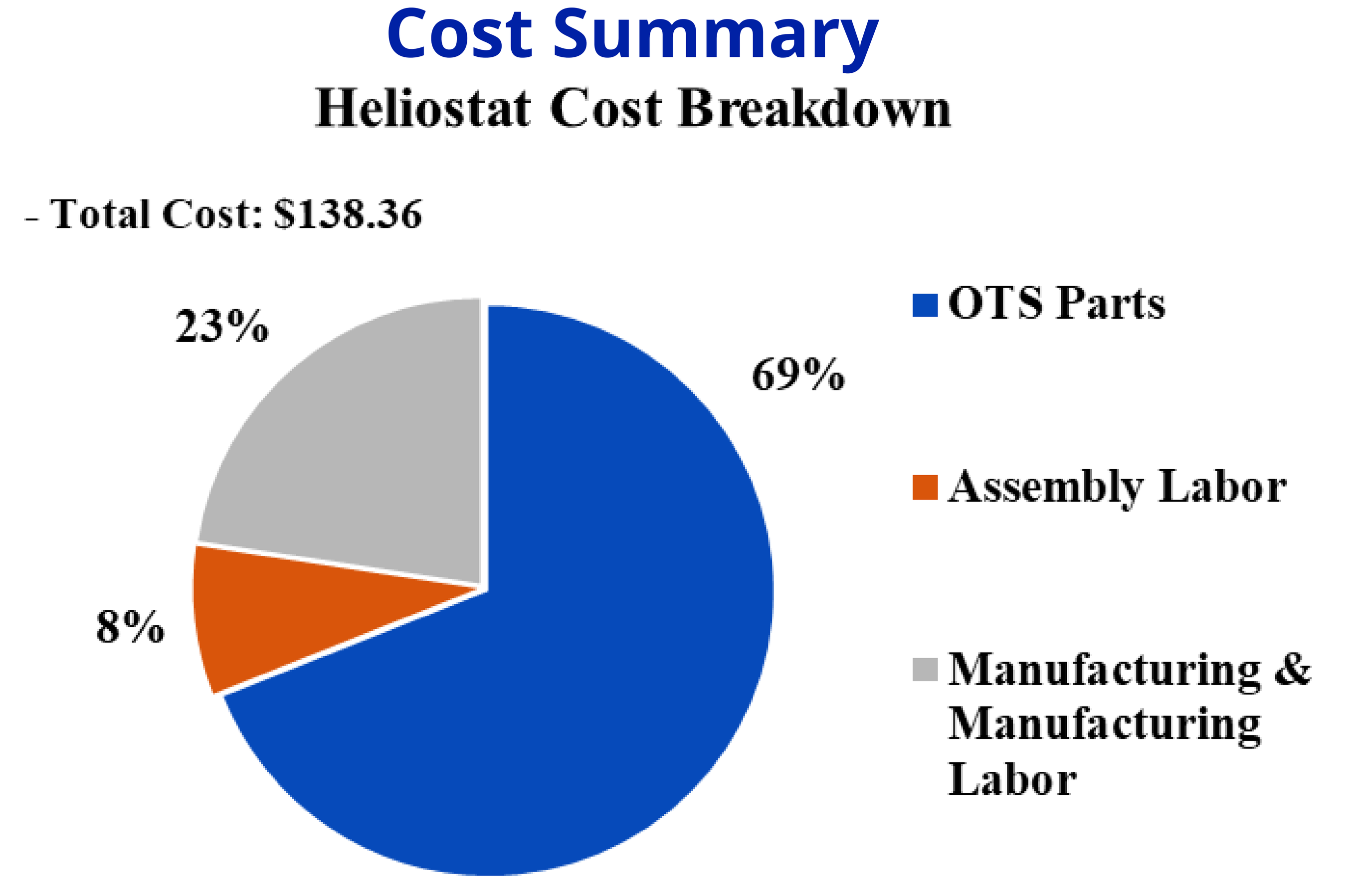


The actuators used are two motors attached to rim drives that adjust the position of the mirror on the Azimuth and Elevation axes. These motors are attached to the structure made of a UV-resistant PVC tube and a concrete slab as the base.

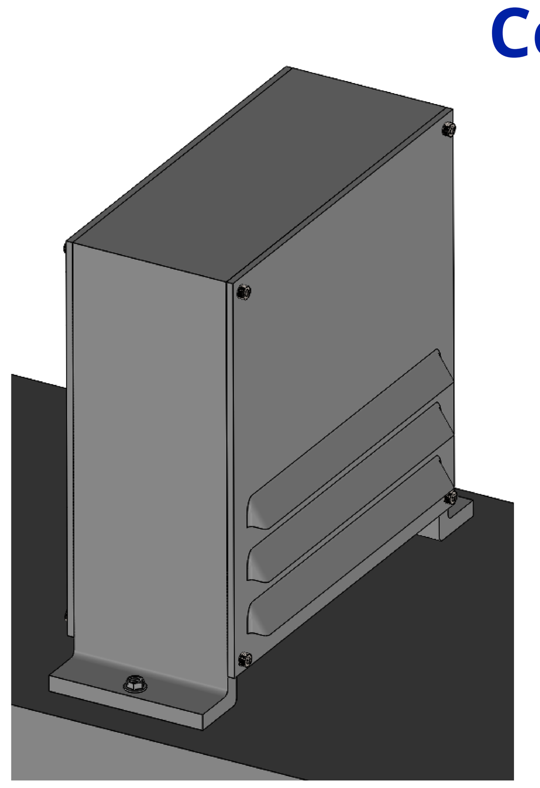


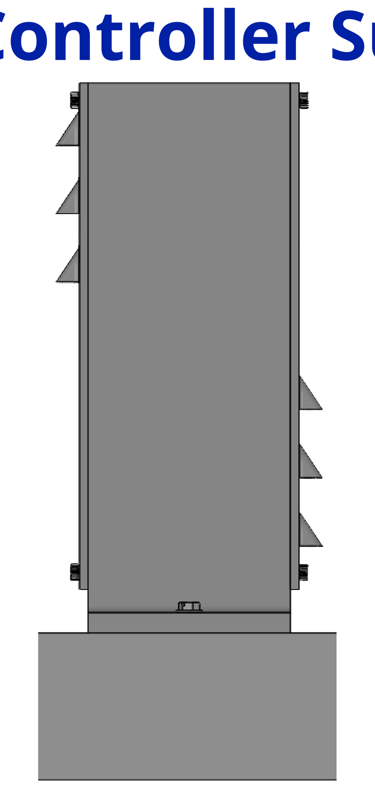


Cost Summary

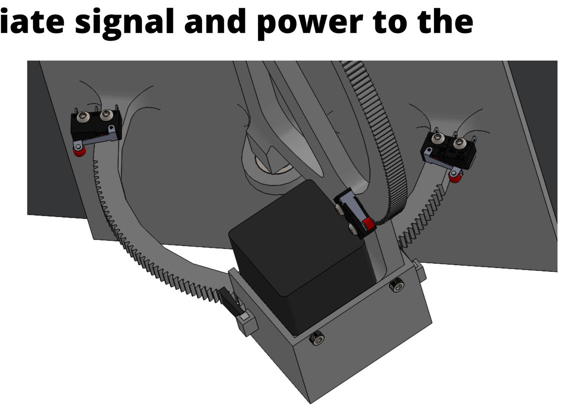


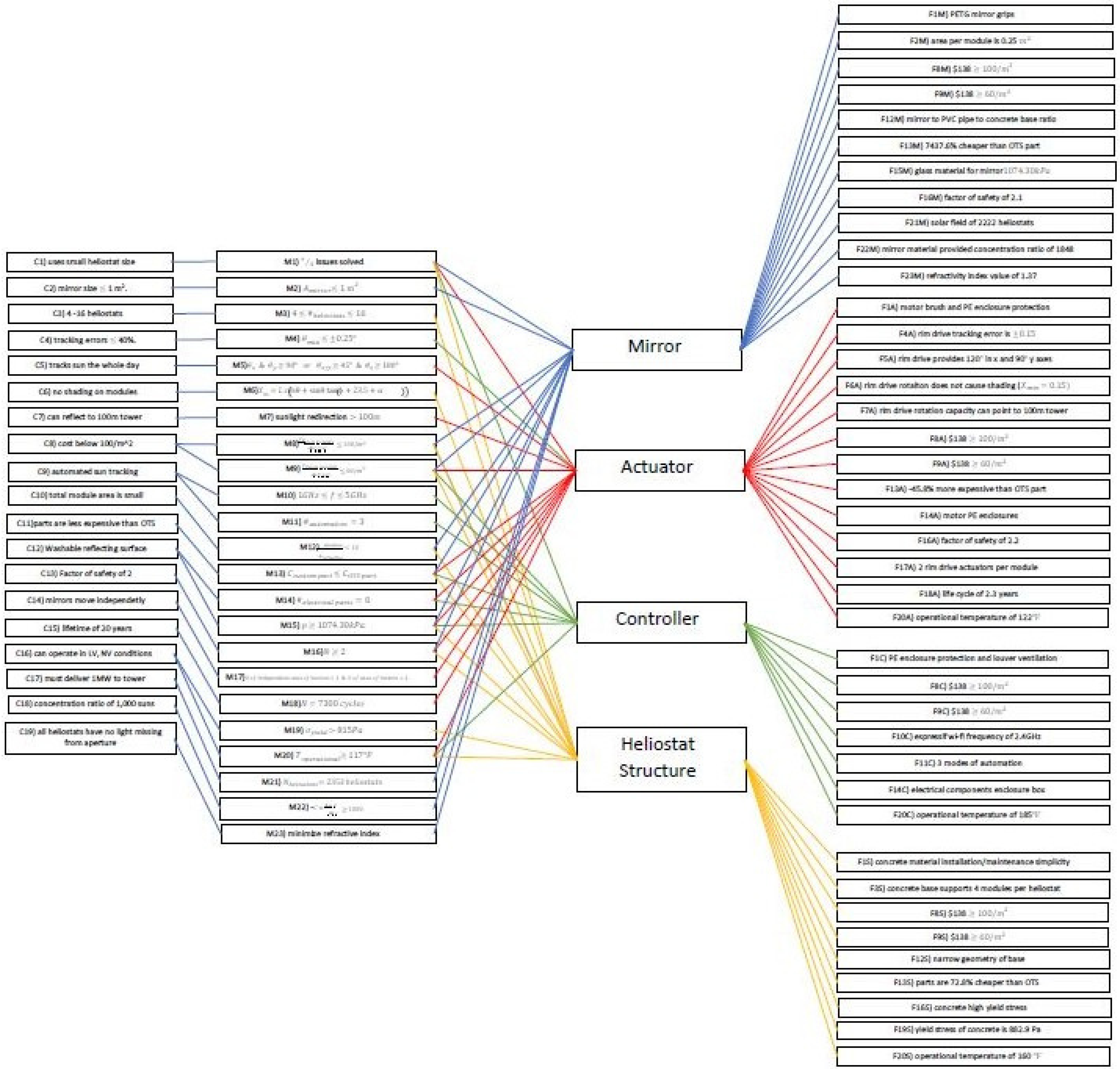
Controller Subsystem





The controller subsystem is enclosed in a tower-like structure below the mirrors that utilize convective cooling through the side vents. Within this structure is an Espressif ESP32 Development Board along with stepper motor drivers that sends the appropriate signal and power to the motors.




C1) uses small heliostat size
C2) mirror size ≤ 1 m².
C3) 4 -16 heliostats
C4) tracking error ≤ 40%.
C5) tracks sun the whole day
C6) no shading on modules
C7) can reflect to 100m tower
C8) cost below 100/m^2
C9) automated sun tracking
C10) total module area is small
C11)parts are less expensive than OTS
C12) Washable reflecting surface
C13) Factor of safety of 2
C14) mirrors move independently
C15) lifetime of 20 years
C16) can operate in LV, MV conditions
C17) must deliver 1MW to tower
C18) concentration ratio of 1,000 suns
C19) all heliostats have no light missing from aperture
M1) issues solved
M7) sunlight redirection
M23) minimize refractive index
Mirror
Actuator
Controller
Heliostat Structure
F1M) PETG mirror grips
F2M) area per module is 0.25
F12M) mirror to PVC pipe to concrete base ratio
F13M) 7437.6% cheaper than OTS part
F15M) glass material for mirror
F16M) factor of safety of 2.1
F21M) solar field of 2222 heliostats
F22M) mirror material provided concentration ratio of 1848
F23M) refractivity index value of 1.37
F1A) motor brush and PE enclosure protection
F4A) rim drive tracking error is
F5A) rim drive provides 120° in x and 90° y axes
F6A) rim drive rotation does not cause shading
F7A) rim drive rotation capacity can point to 100m tower
F13A) -45.8% more expensive than OTS part
F14A) motor PE enclosures
F16A) factor of safety of 2.2
F17A) 2 rim drive actuators per module
F18A) life cycle of 2.3 years
F20A) operational temperature of 122°F
F1C) PE enclosure protection and louver ventilation
F10C) espressif wi-fi frequency of 2.4GHz
F11C) 3 modes of automation
F14C) electrical components enclosure box
F20C) operational temperature of 185°F
F1S) concrete material installation/maintenance simplicity
F3S) concrete base supports 4 modules per heliostat
F12S) narrow geometry of base
F13S) parts are 72.8% cheaper than OTS
F16S) concrete high yield stress
F19S) yield stress of concrete is 882.9 Pa
F20S) operational temperature of 160 °F