EML4501 | Spring 2022 |Group 4

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OPERATION CONCENTRATION

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ABSTRACT

The design of Operation Concentration's heliostat is based on our hedgehog concept to create a low-cost, modular heliostat system with two axes of rotation that is easy to manufacture and easy to install. The group is passionate about creating something new and challenging to push what is possible.

The four subsystems of this design include the mirror, controller, heliostat base, and module base subsystems. Each subsystem has been designed with these goals in mind to create innovative ideas and lessen the cost as much as possible. This was achieved by each module of four heliostats only needing two motors total to rotate the mirrors about two separate axes.

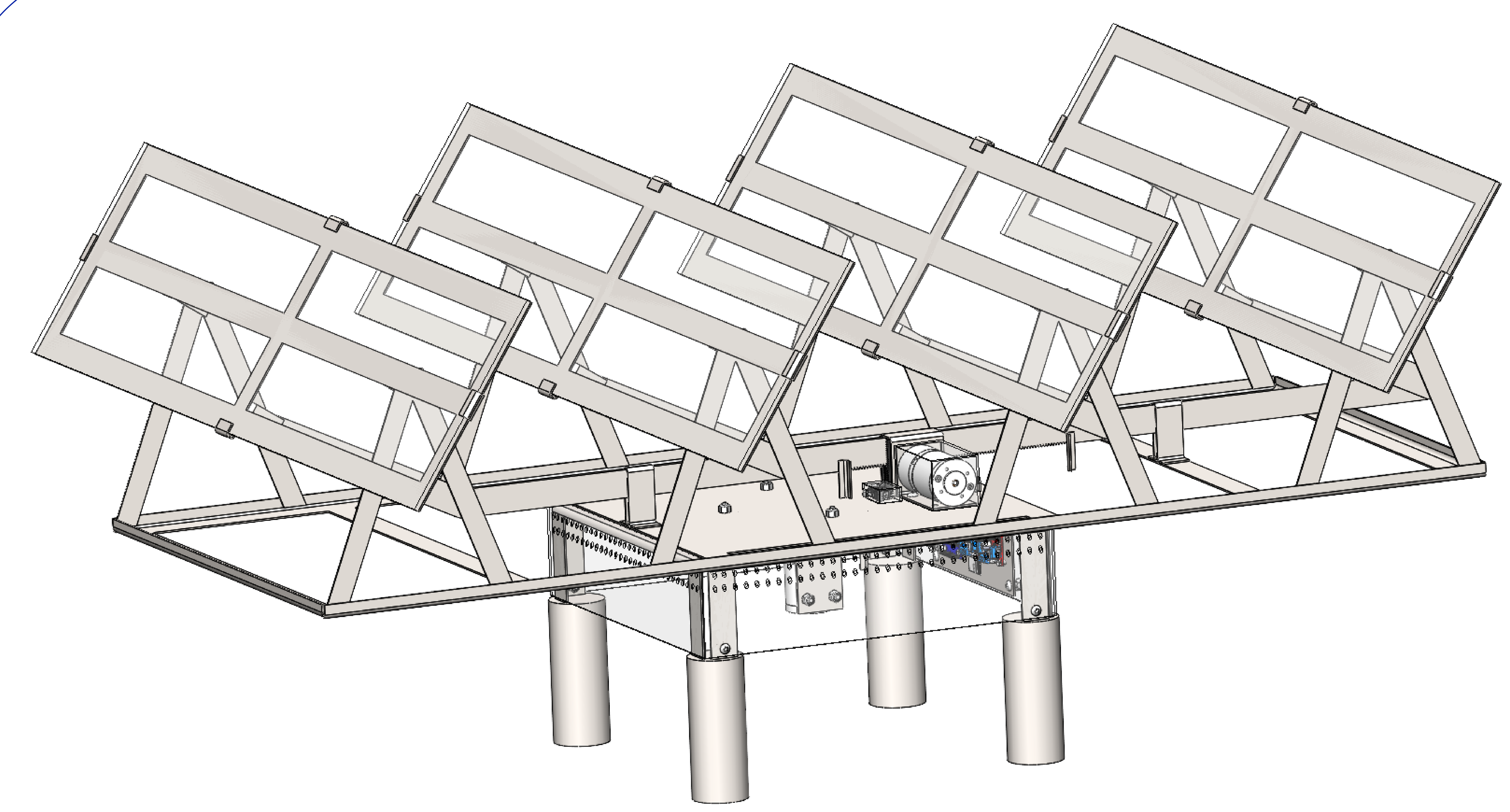
These motors are controlled via an Arduino Uno that receives inputs through an ESP-W2 micro-controller via Wi-Fi signals. The signals are then relayed to the motors with encoders. The encoders with their respective gear ratios allow for an accuracy below 0.5 degrees which maximizes the light reflected to the target tower and therefore the energy produced by the solar farm.

PRODUCT FUNCTIONALITY

Our design utilizes four mirrored heliostats per module that each can rotate about an independent axis. The four mirrors are arranged and connected so that they can all be rotated with the same motor, through a rack and pinion. This controls the pitch of all four mirrors simultaneously. Additionally, the entire module rotates about one central axis using spur gears and a Lazy Suzan. This controls the yaw of the entire system.

The heliostat module features a low reflective area to base area ratio, limits the shading effects from the mirrors and is designed to withstand the climate of southern Nevada for over 20 years.

With a field comprising of 1,500 heliostat modules, a solar input power exceeding 1MW would be delivered to the receiver target after losses are accounted for.

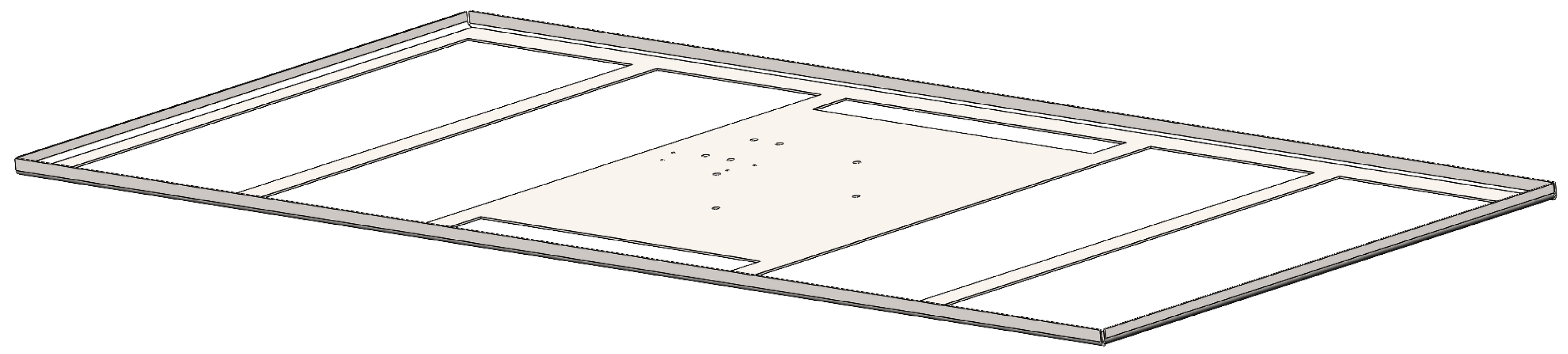


HOW IS IT UNIQUE

Our design is capable of actuating four mirrors while only needing two motors to achieve the azimuth and elevation rotations necessary. This was possible due to the connecting rod that our design utilizes to rotate multiple heliostats at once about their own independent axes, parallel with one another, while the entire module rotates about its own central axis.

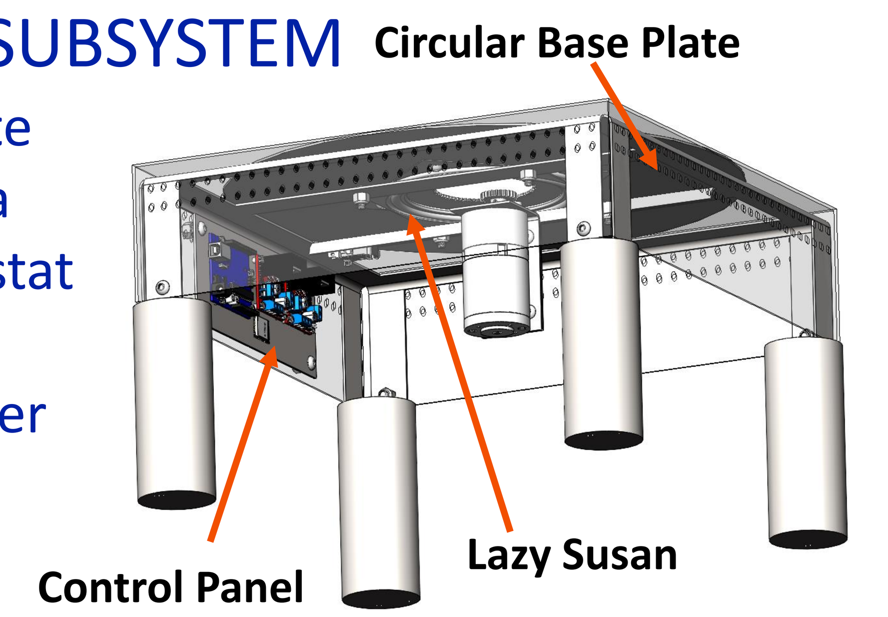
HELIOSTAT BASE SUBSYSTEM

This subsystem was designed as the platform holding the weights of the mirrors and controller subsystems. Due to this the primary design concern was failure strength. It ultimately had a factor of safety of 60.



MODULE BASE SUBSYSTEM

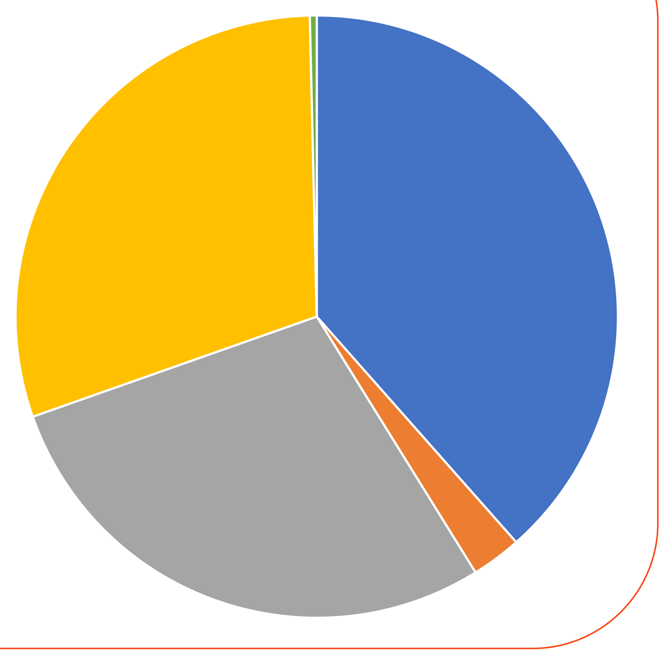
This subsystem allows the heliostat to rotate around a central axis using spur gears and a Lazy Susan. The design allows for the heliostat to be in the optimal azimuth position to reflect the most sunlight to the central tower throughout the day. It also houses and protects the electronics of the heliostat.



COST

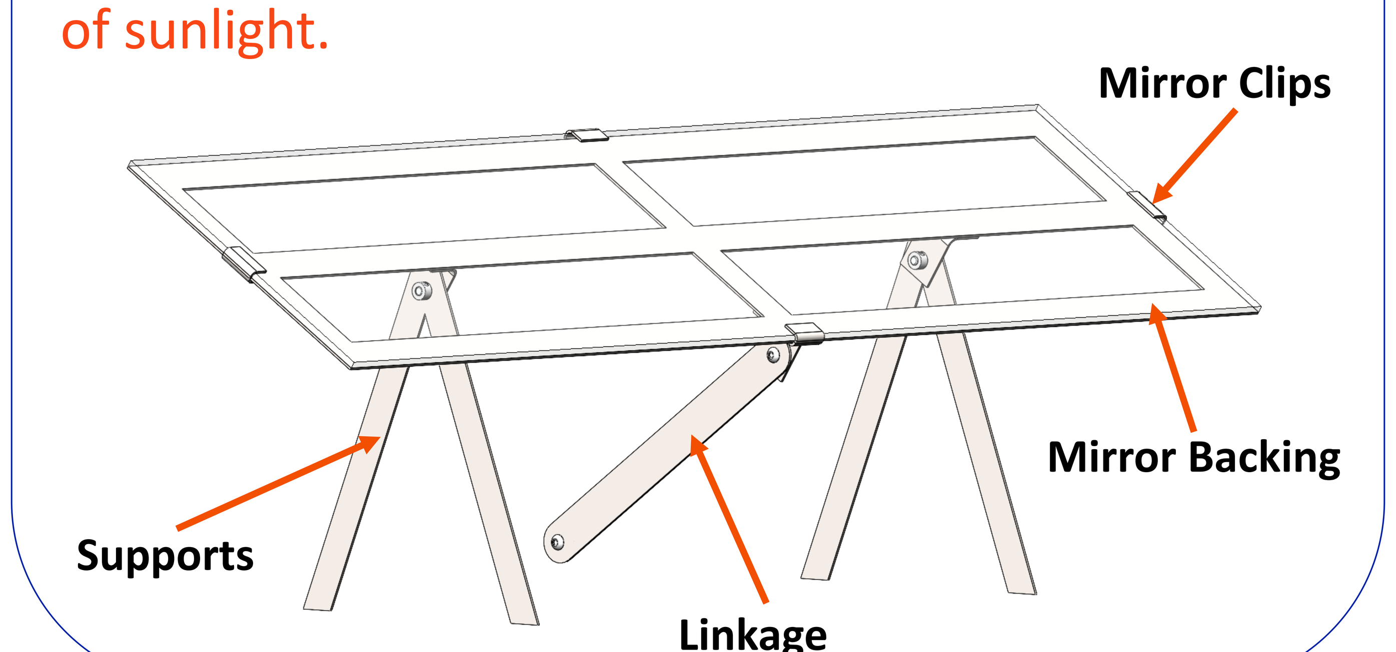
Manufacturing	$186.53
Assembly	$13.00
Raw Material	$137.90
OTS	$145.55
Modified OTS	$0.00
Energy	$1.79

Total Unit Cost = $484.77



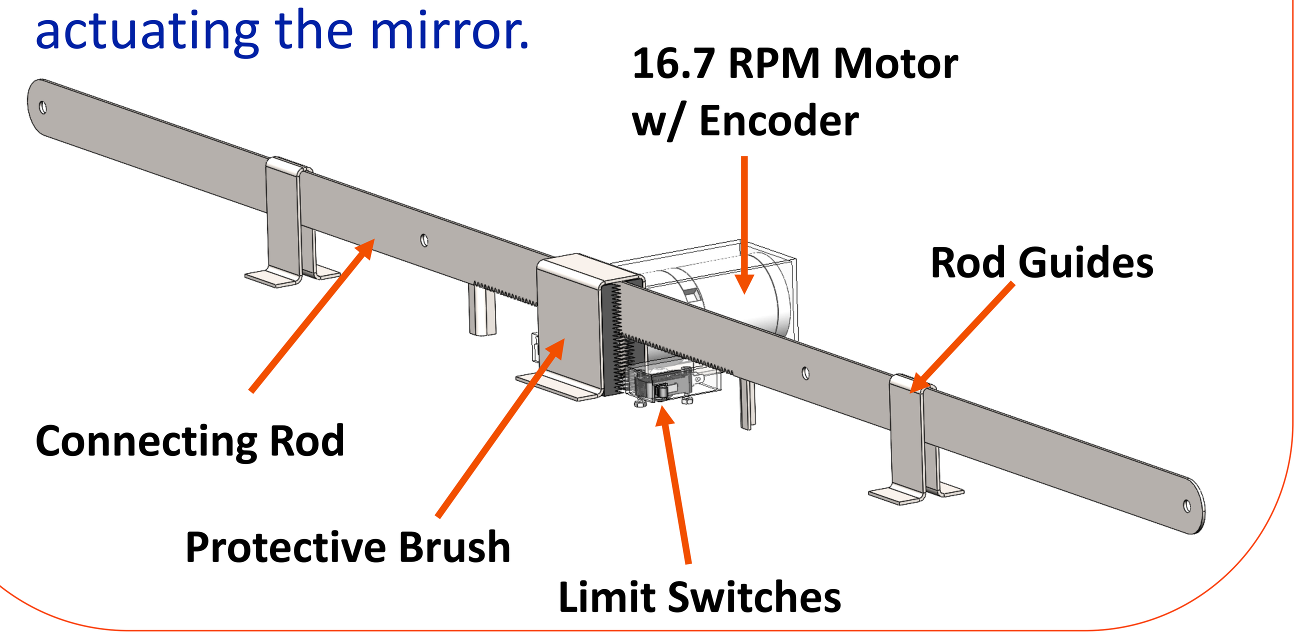
MIRROR SUBSYSTEM

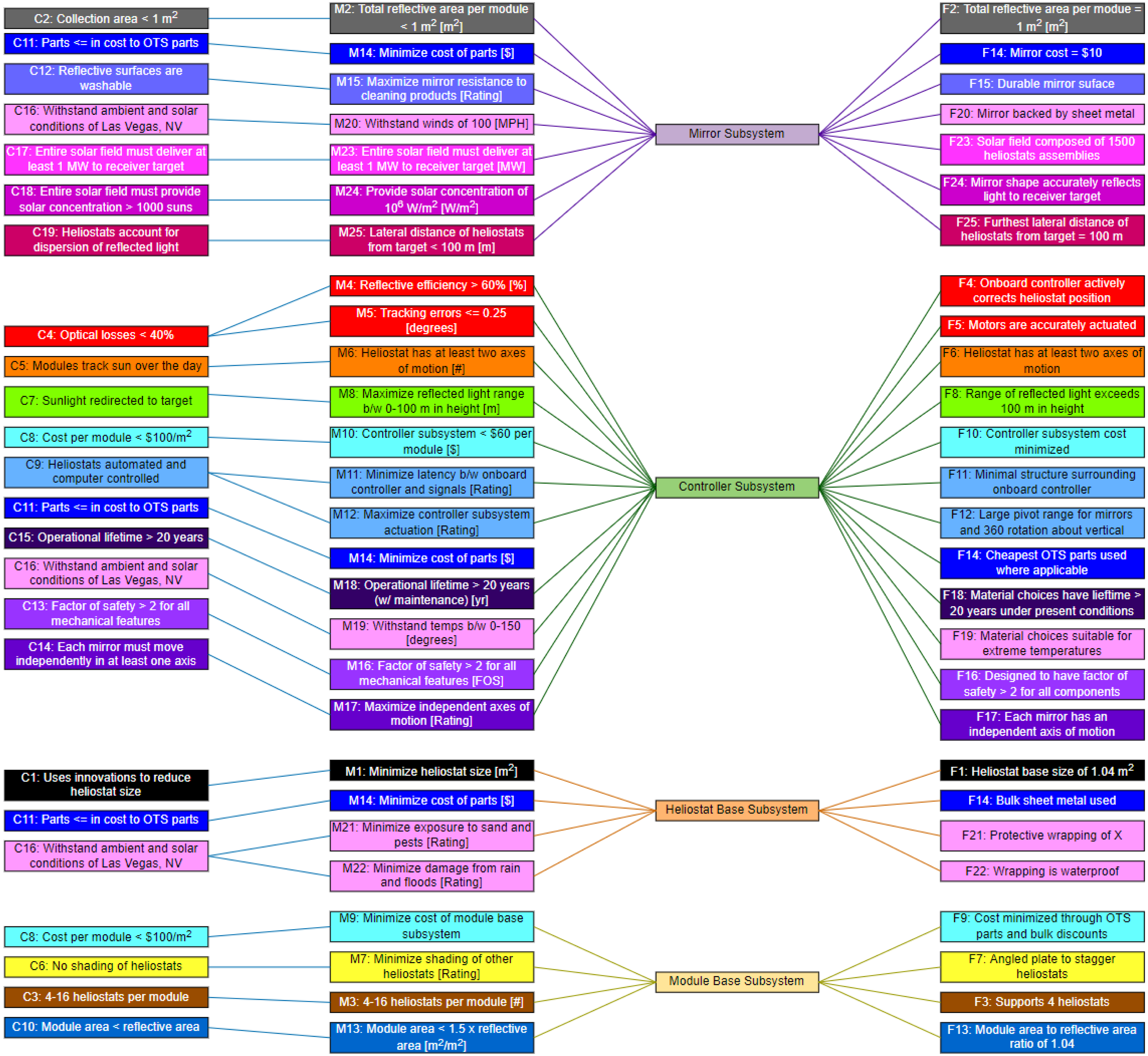
This subsystem uses a rectangular mirror to reflect sunlight to a central location which converts it into usable energy. Throughout the day, the mirror rotates to constantly reflect the maximum amount of sunlight.



CONTROLLER SUBSYSTEM

This subsystem controls the movement of the heliostat throughout the day. The beauty of this design is it controls all four mirrors from one motor using a rack and pinion system. When the motor turns, the rack and pinion slides left or right which causes the legs of the mirror subsystem to move up or down, actuating the mirror.





C2: Collection area < 1 m2
C11: Parts <= in cost to OTS parts
C12: Reflective surfaces are washable
C16: Withstand ambient and solar conditions of Las Vegas, NV
C17: Entire solar field must deliver at least 1 MW to receiver target
C18: Entire solar field must provide solar concentration > 1000 suns
C19: Heliostats account for dispersion of reflected light
M2: Total reflective area per module < 1 m2 [m2]
M14: Minimize cost of parts [$]
M15: Maximize mirror resistance to cleaning products [Rating]
M20: Withstand winds of 100 [MPH]
M23: Entire solar field must deliver at least 1 MW to receiver target [MW]
M24: Provide solar concentration of 106 W/m2 [W/m2]
M25: Lateral distance of heliostats from target < 100 m [m]
Mirror Subsystem
F2: Total reflective area per modue = 1 m2 [m2]
F14: Mirror cost = $10
F15: Durable mirror suface
F20: Mirror backed by sheet metal
F23: Solar field composed of 1500 heliostats assemblies
F24: Mirror shape accurately reflects light to receiver target
F25: Furthest lateral distance of heliostats from target = 100 m
C4: Optical losses < 40%
C5: Modules track sun over the day
C7: Sunlight redirected to target
C8: Cost per module < $100/m2
C9: Heliostats automated and computer controlled
C11: Parts <= in cost to OTS parts
C15: Operational lifetime > 20 years
C16: Withstand ambient and solar conditions of Las Vegas, NV
C13: Factor of safety > 2 for all mechanical features
C14: Each mirror must move independently in at least one axis
M4: Reflective efficiency > 60% [%]
M5: Tracking errors <= 0.25 [degrees]
M6: Heliostat has at least two axes of motion [#]
M8: Maximize reflected light range b/w 0-100 m in height [m]
M10: Controller subsystem < $60 per module [$]
M11: Minimize latency b/w onboard controller and signals [Rating]
M12: Maximize controller subsystem actuation [Rating]
M14: Minimize cost of parts [$]
M18: Operational lifetime > 20 years (w/ maintenance) [yr]
M19: Withstand temps b/w 0-150 [degrees]
M16: Factor of safety > 2 for all mechanical features [FOS]
M17: Maximize independent axes of motion [Rating]
Controller Subsystem
F4: Onboard controller actively corrects heliostat position
F5: Motors are accurately actuated
F6: Heliostat has at least two axes of motion
F8: Range of reflected light exceeds 100 m in height
F10: Controller subsystem cost minimized
F11: Minimal structure surrounding onboard controller
F12: Large pivot range for mirrors and 360 rotation about vertical
F14: Cheapest OTS parts used where applicable
F18: Material choices have lieftime > 20 years under present conditions
F19: Material choices suitable for extreme temperatures
F16: Designed to have factor of safety > 2 for all components
F17: Each mirror has an independent axis of motion
C1: Uses innovations to reduce heliostat size
C11: Parts <= in cost to OTS parts
C16: Withstand ambient and solar conditions of Las Vegas, NV
M1: Minimize heliostat size [m2]
M14: Minimize cost of parts [$]
M21: Minimize exposure to sand and pests [Rating]
M22: Minimize damage from rain and floods [Rating]
Heliostat Base Subsystem
F1: Heliostat base size of 1.04 m2
F14: Bulk sheet metal used
F21: Protective wrapping of X
F22: Wrapping is waterproof
C8: Cost per module < $100/m2
C6: No shading of heliostats
C3: 4-16 heliostats per module
C10: Module area < reflective area
M9: Minimize cost of module base subsystem
M7: Minimize shading of other heliostats [Rating]
M3: 4-16 heliostats per module [#]
M13: Module area < 1.5 x reflective area [m2/m2]
Module Base Subsystem
F9: Cost minimized through OTS parts and bulk discounts
F7: Angled plate to stagger heliostats
F3: Supports 4 heliostats
F13: Module area to reflective area ratio of 1.04