MIRLAR

EML 4501 - Fall 2021

Group 1: Tomas Bertone, Sheelagh M. Dunn, Zeyuan Jin, Dana E. Kendall, Ryoma Molnar, Cameron M. Nann, Brooke S. Ohlsson

Abstract:

This design consists of a special material for the mirror reflecting surface, known as Mylar. This lightweight polyester film is cheaper than standard glass-silver mirrors. With an aluminum paint coating, the Mylar mirrors are protected from ultraviolet radiation. The film is wrapped and heat shrunk around four PVC foam boards that are press fit into sheet metal boxes. Each sheet metal box has a hole on the back to allow a technician to stamp out the foam blocks with a dowel pin if the films are damaged. Each mirror is mechanically linked by a series of timing belts, allowing a single 5V servo motor to control every mirror simultaneously. The pulleys are attached to the mirrors through steel axles and are secured with set screws. A 5.3V stepper motor is used to control the altitude angle by rotating the frame similar to a cradle rocking. A HiLetgo microcontroller with built-in Wi-Fi capabilities relays signals to each motor. Having a lower amount of motors aids in keeping the cost of the overall design down. The structure of the system is mostly made of PVC piping with tee joints and elbow joints. The motors and actuation system are housed inside the PVC piping allowing for all electronic components to be sealed from the outside environment. Every design choice, from the Mylar mirror technology to the PVC frame, optimizes cost and simplicity without sacrificing effectiveness.

Product Functionality:

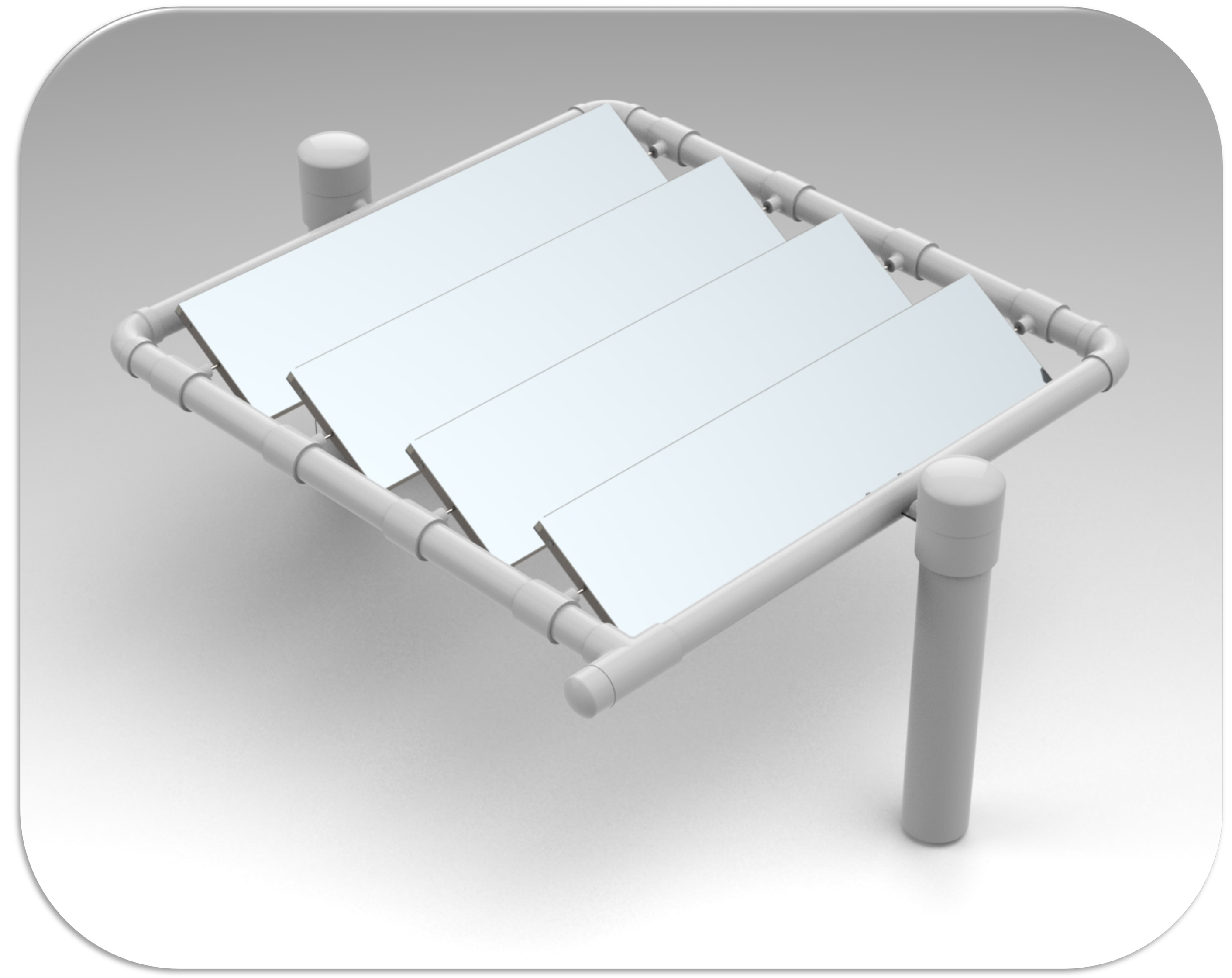
The heliostat array receives its commands from a Wi-Fi signal originating from a central computer. This signal is intercepted by the controller, a HiLetgo ESP-32 microcontroller, which has built-in Wi-Fi capabilities. Power is supplied by a cable, which enters the PVC pillar housing the controller through a hole, which is sealed by caulk. The controller, in turn, provides power and commands to the two motors, which are placed close to the opposite pillar to provide distance between the controller and motors so that the stray emf does not interfere with the Wi-Fi signal.

One servo motor controls the azimuth of every mirror. The axles of every mirror are mechanically linked using a belt and pulley system to allow simultaneous rotation. The motor, as well as the belt and pulley system, are housed within the PVC 'cradle' holding the four mirrors to provide protection against the elements.

A stepper motor controls the altitude. This motor is connected to the axle connecting the cradle to the pillars.

Ultimately, the system is capable of 2 DOF motion, allowing the heliostat array to track the sun. The mechanical linking between the mirrors, allows two motors to perform the job of five, saving costs on actuation.

Full Assembly:



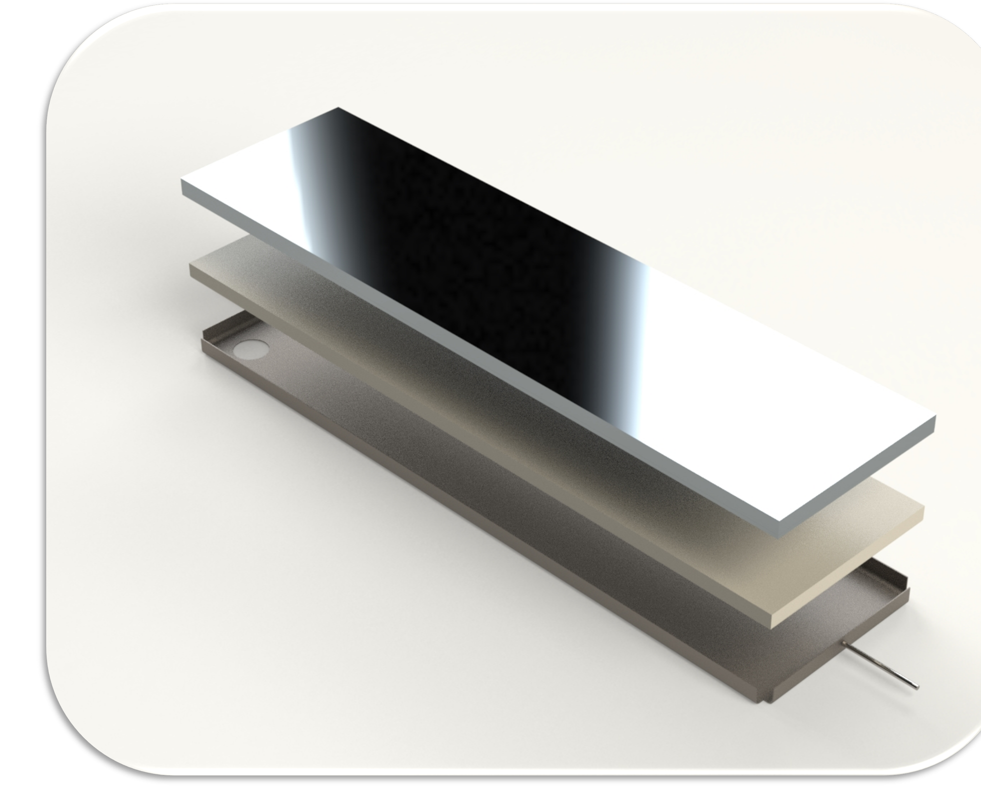
- The total reflection area is 1 m^2
- Mylar mirrors' life-time are 5 years, with easy to replace mirror subassemblies
- The overall structure is completed sealed from the environment
- A unit in the North section of the field would have the long edges of the mirrors facing east and west.

Cost Summary:

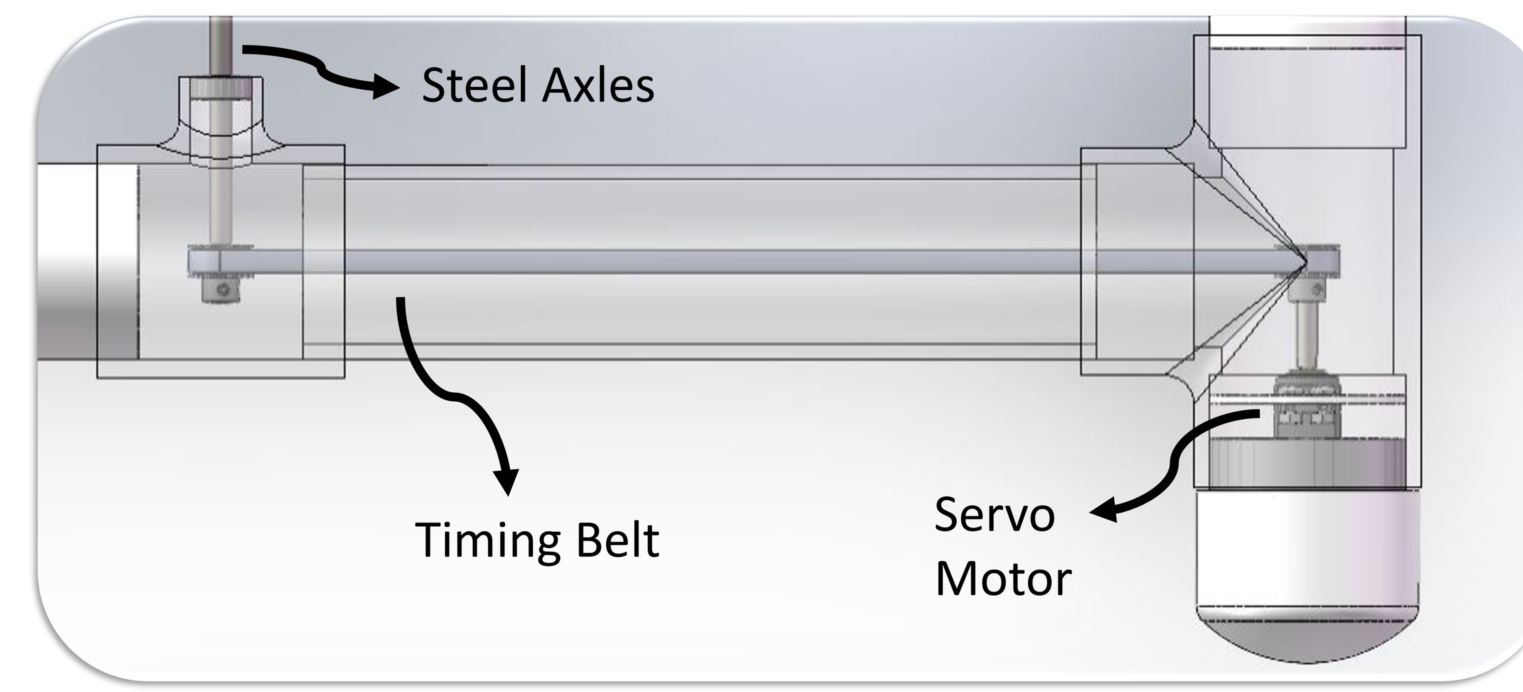
Expense	Cost
OTS Parts	$37.16
Modified OTS	$22.85
Raw Materials	$7.74
Manufacturing Labor	$16.59
Assembly Labor	$15.17
Energy Consumption	$0.41
Total	$99.92

Mirror Subsystem:

- Reflecting surface Mylar film is wrapped and heat shrunk around a foam block
- PVC foam boards (10.83-inch x 40.37-inch)
- 16-gauge low carbon steel sheet metal box with technician accessibility to replace foam Mylar mirrors



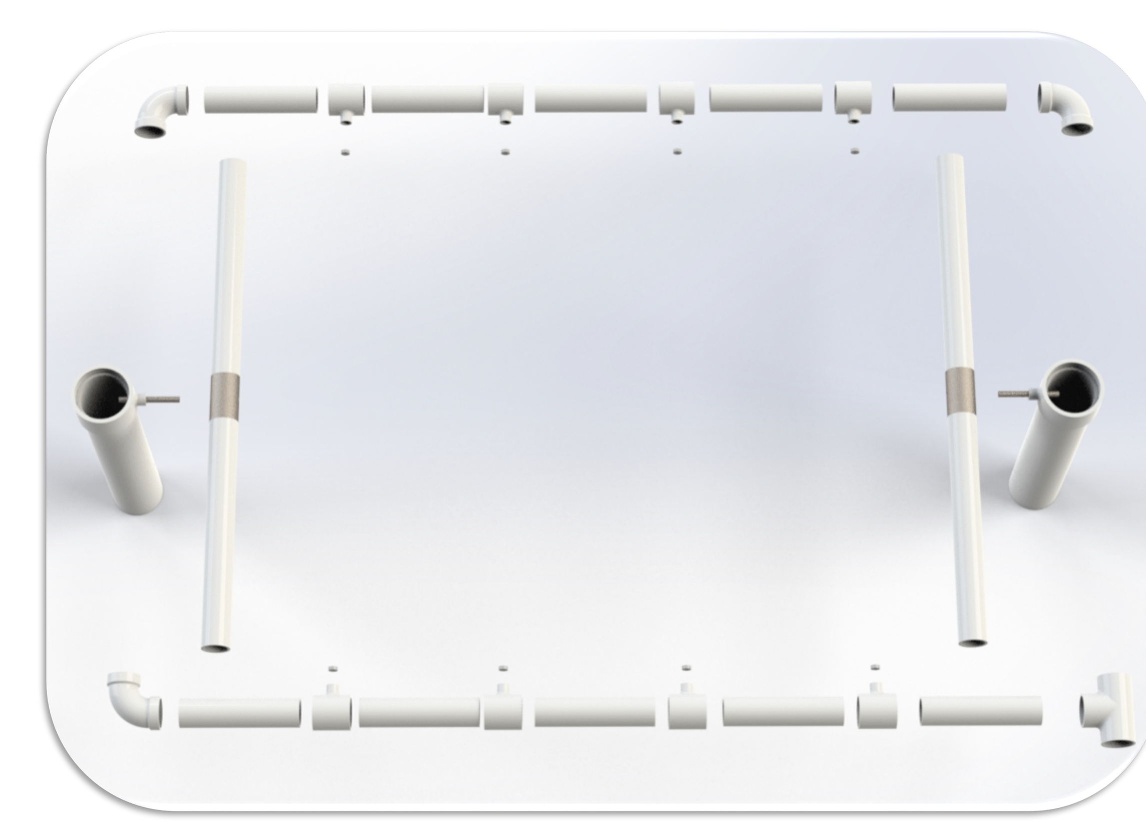
Actuation Subsystem:



- 5.3V stepper motor housed inside PVC frame
- 5V servo motor attached to timing belt pulleys to turn mirrors
- Second motor is similar yet turns entire frame to control altitude angle

Structure Subsystem:

- 2-inch PVC frame with elbow and tee joints
- 4-inch vertical PVC piping 6-inch in ground with concrete to secure frame
- Axles with bearings to allow for rotation in azimuth and altitude angles



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C2) Collection area ≤ 1 m2	M2) A ≤ 1 m^2	Mirrors	F2) The total collection area is 1 m^2
C15) Ambient conditions in Las Vegas, NV	M15) Coefficient of thermal expansion ≤ 2 x 10^{-4}		F15) $\alpha = 1.7 \times 10^{-5}$ in/in/°C
C12) Reflecting surface must be washable	M12.1) Days before rinse ≥ 3 days		F12.1) 4 days before needing the next rinse
	M12.2) Weeks before soap and rinse ≥ 2 weeks		F12.2) Rinse with soap every 2 weeks
C16) Thermal input power of 1 MW	M16) Area of Mirror ≥ 0.0625 m^2		F16) Surface area of single mirror = 0.25 m^2
C17) Solar concentration ratio > 1000 suns	M17) Geometric Concentration Ratio ≤ 1		F17) Geometric concentration ratio = 1
C3) 4-16 heliostats	M3) 4 ≤ Heliostats ≤ 16		F3) The number of heliostats is 4
C6) No shading of other heliostats	M6) Mirror distance from ground ≤ 2 m		F6) Mirror distance from the ground = 0.48 m
C10) Module area relative to reflecting area is small	M10) Ratio ≤ 1.5		F10) Ratio = 1.48
C18) Account for light dispersion	M18) Reflectivity ≥ 50%		F18) The reflectivity of the Mylar mirrors is 95%
C8) Cost below $100/m2	M8) Actuation cost ≤ $60/$m^2$	Actuation	F8) Cost = $26.90/$m^2$
C7) Redirect sunlight up to 100 m tall	M7) Range of motion in degrees ≥ 90°		F7) Azimuth = 360°; Altitude = 113.2°
C4) Optical losses not to exceed 40%	M4) θ accuracy ≤ 0.9°		F4) θ = 0.9°
C5) Track sun throughout the day	M5) Independent axis of motion ≥ 1		F5) Independent axes of motion = 2
C9) Sun tracking computer controlled	M9) Number of unique signals ≤ 4		F9) 2 signals: Servo motor and stepper motor
C13) Factor of Safety ≥ 2	M13) FOS ≥ 2	Structure	F13) N = 2 at 91 mph
C10) Module area relative to reflecting area is small	M10) Ratio ≤ 1.5		F10) Ratio = 1.48
C14) Lifetime > 20 years	M14) Lifetime ≥ 20yrs		F14) The service life of PVC = 100 years
C11) Custom part price ≤ OTS part price	M11) Part cost ≤ OTS part	All Subsystems	F11) All custom parts price < OTS price
C1) Capitalizes on innovations from small size	M1) Top 3 customer rated innovation questions score ≥ 3 on a 1-5 scale rating from instructor		F1) Cost: 4 Durability: 3 Uniqueness: 3