UF Herbert Wertheim College of Engineering
UNIVERSITY *of* FLORIDA

HelioWAVE

The World's Most Elite Sun-Tracking Heliostat

Section 13337, Group 7

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POWERING THE NEW ENGINEER TO TRANSFORM THE FUTURE

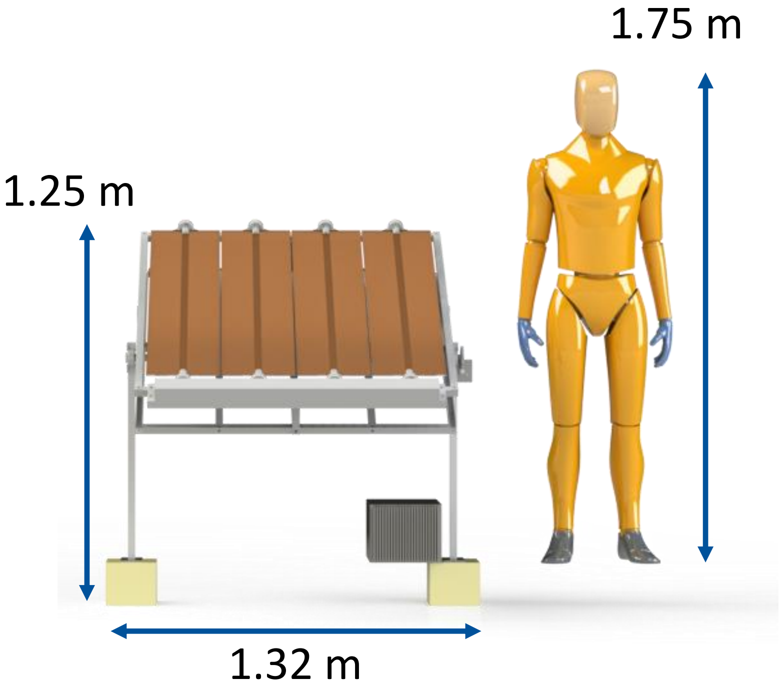
Product Overview

Project Description

- Design a small-scale heliostat capable of being mass produced for a large array configuration.
- Will be used to reflect sunlight towards a desired location in order to obtain maximum concentrated solar energy.

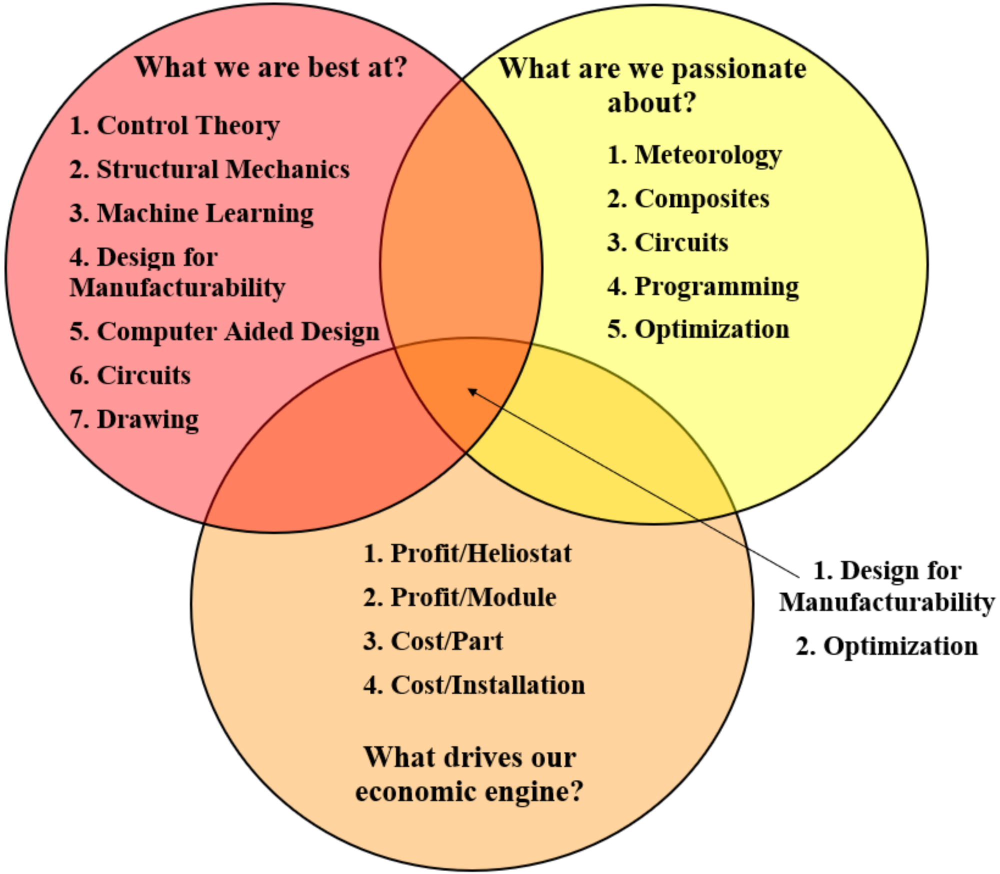
Project Goals

- Withstand the ambient conditions of Las Vegas
- Achieve dual axial tracking system
- Present greatest reflective accuracy and efficiency

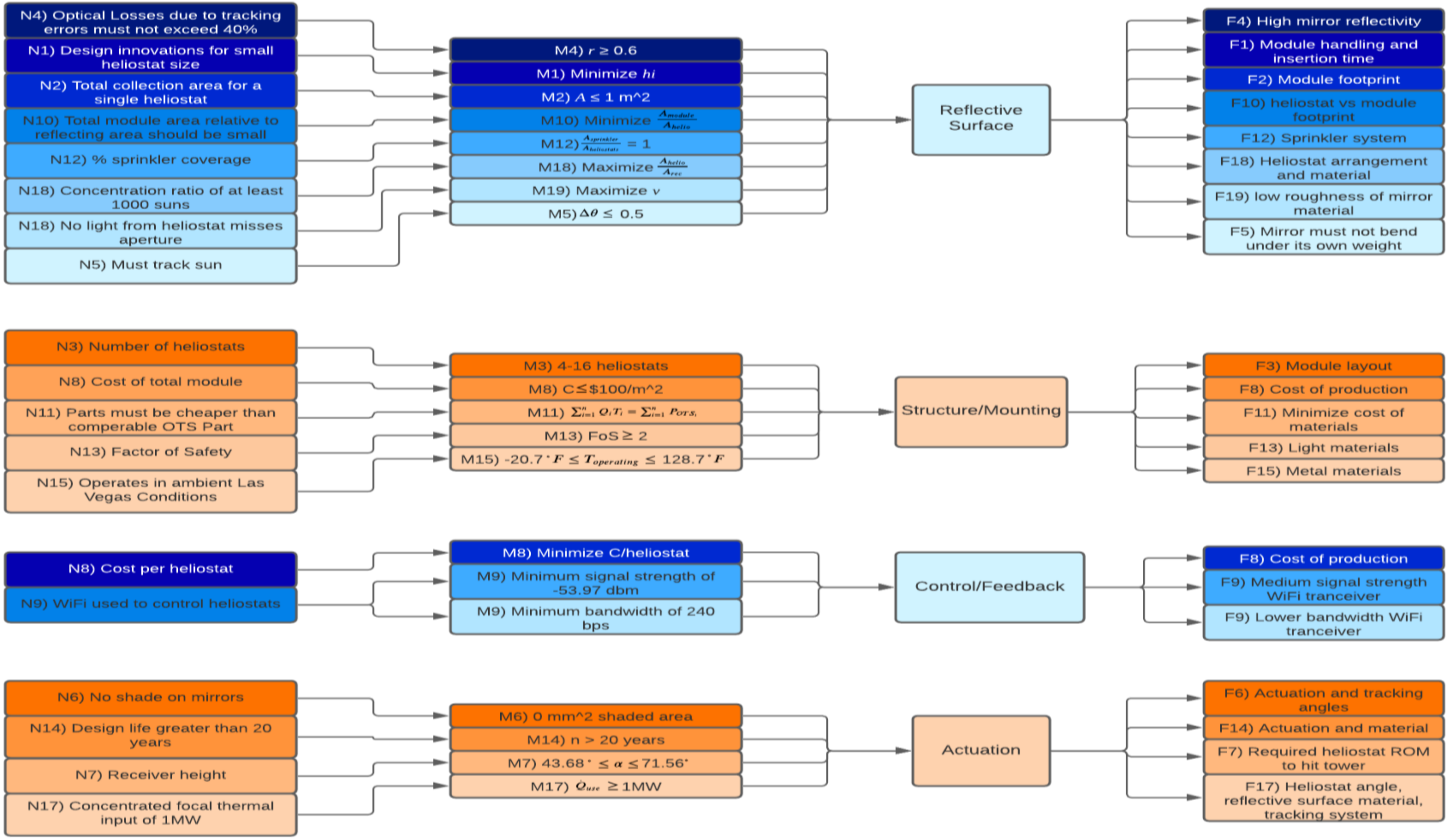


Product Motivations

- Our team's design is based on:
  - Design and Manufacturability
  - Optimization



Customer Needs Flow Chart

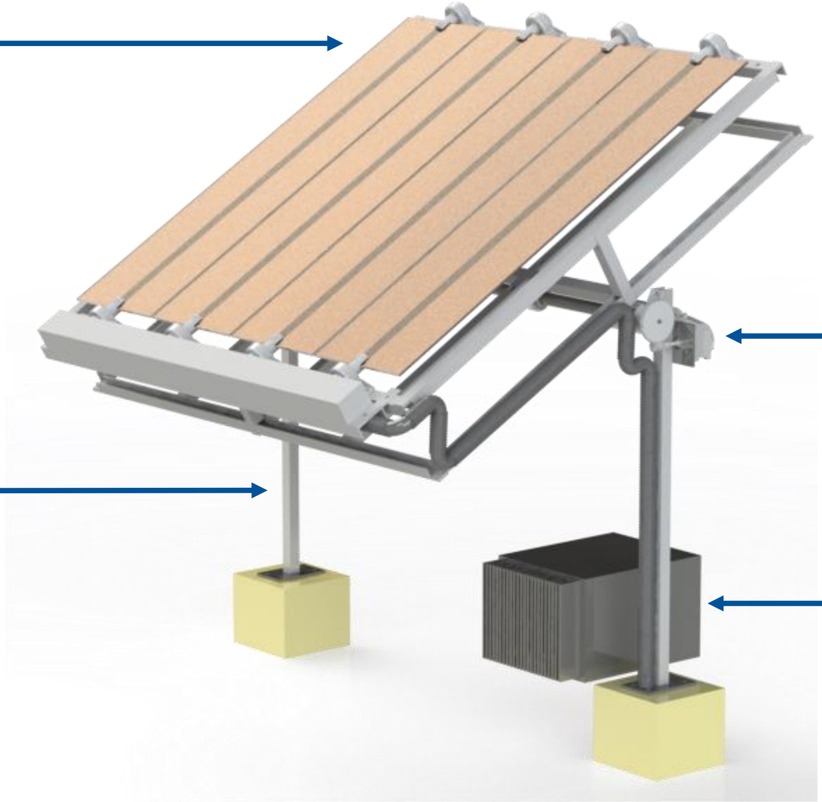


Reflective Surface

- **1.025 MW** $\dot{Q}_{use}$
- Safety Mode FoS of **39**

Structure/Mounting

- Bending FoS of **10**
- Buckling FoS of **10.8**



Actuation

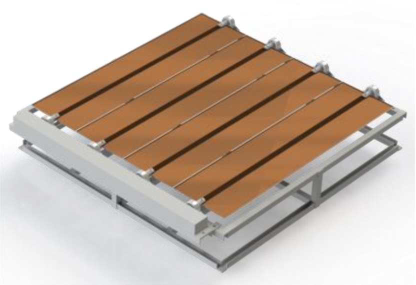
- **56.7 year** design life
- **360 degree** ROM per motor

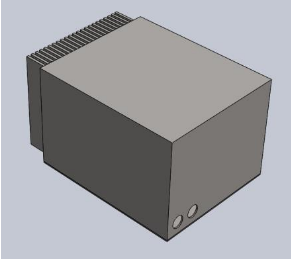
Control

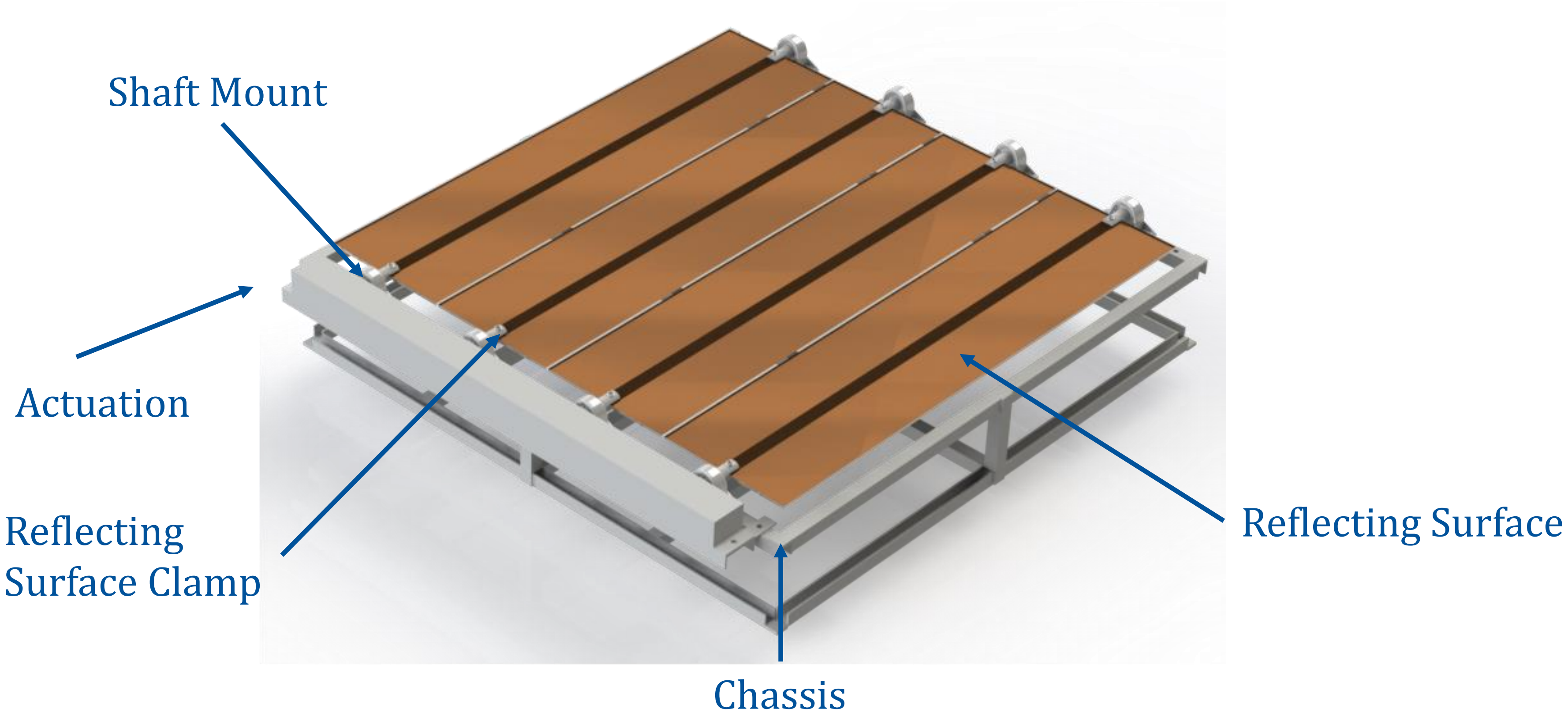
- **-91 dbm** & **11 Mbps** WiFi Module
- **0.5 degree** tracking accuracy

Sub-Systems

Reflective Surface	Structure/Mounting	Controls	Actuation

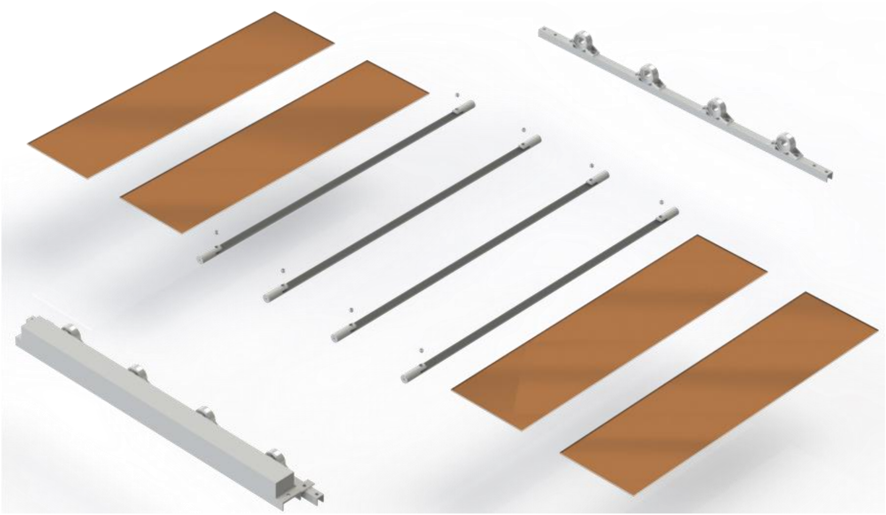





Shaft Mount
Actuation
Reflecting Surface Clamp
Reflecting Surface
Chassis

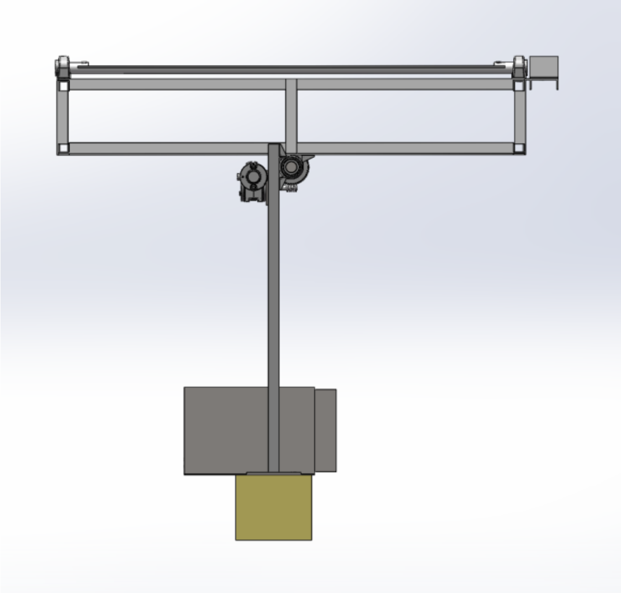
Reflective Surface Key Features

- High Concentration Ratio:
  - Silver-backed silica glass provides high reflectivity
  - Low surface:module ratio prevents shading
- Wind Resistance:
  - Horizontal safety mode allows module to withstand 50 mph winds



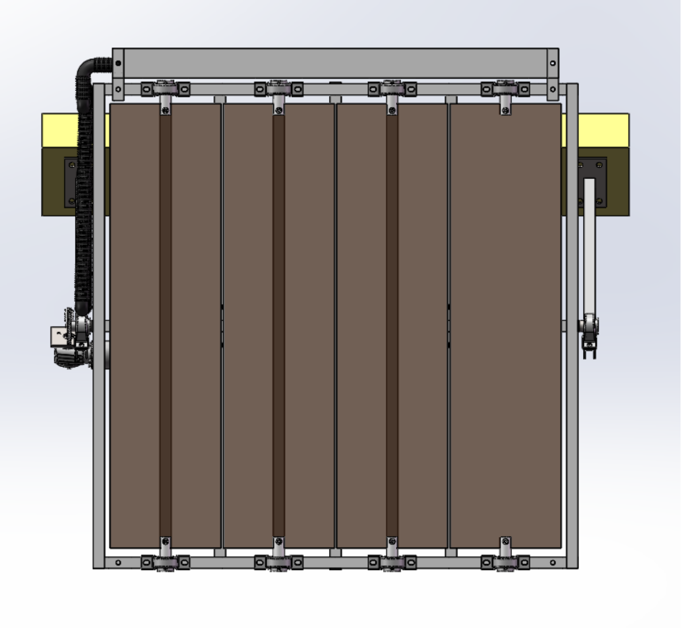
Reflective Surface Analyses

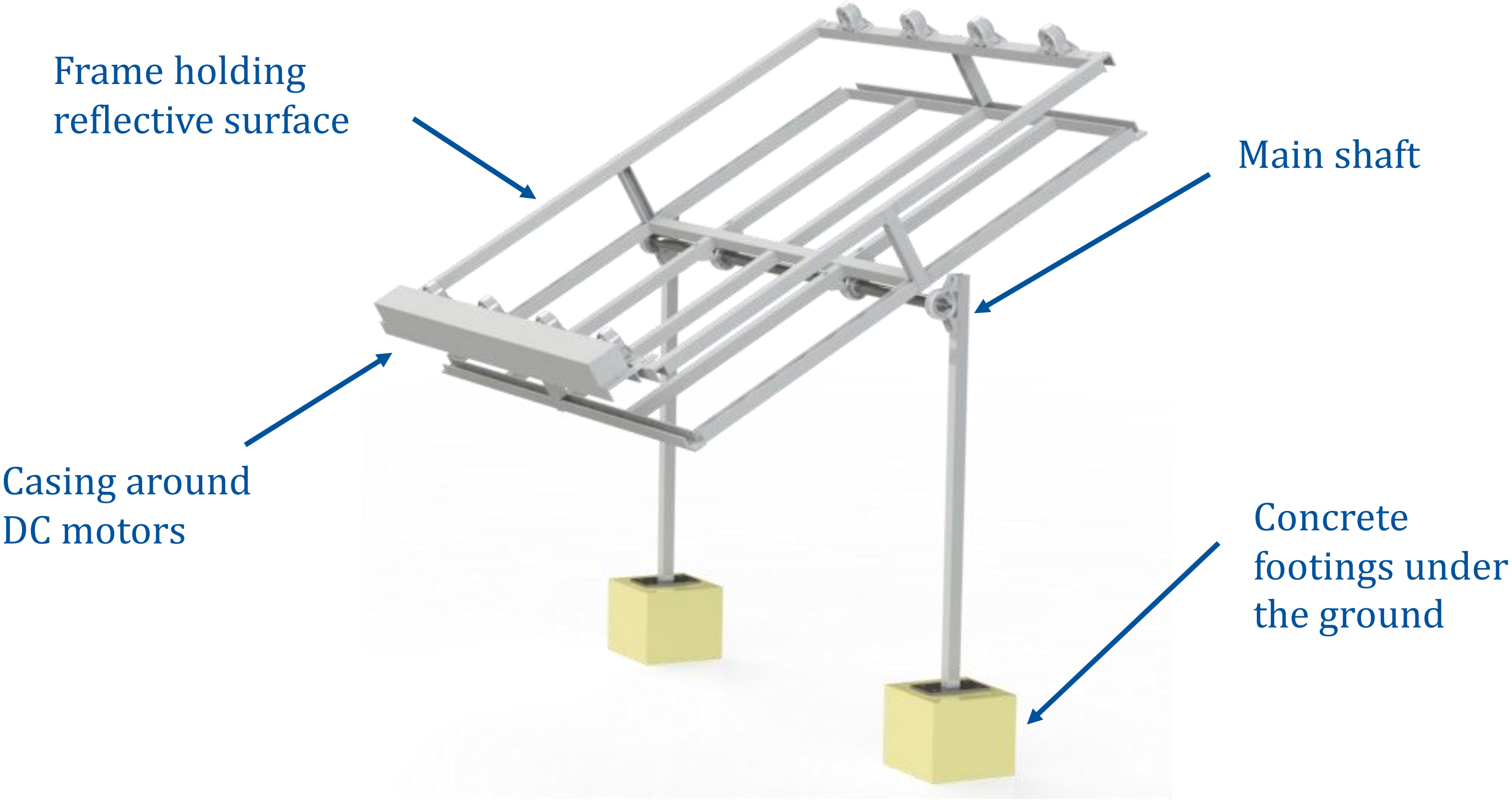
- Factor of Safety:
  - $F_L = \frac{1}{2} C_L \rho A v^2 = \frac{1}{2}(0.8)\left(1.225\frac{kg}{m^3}\right)(1.1m)^2\left(22.35\frac{m}{s}\right)^2$ **=296.2N**
  - $F_{shear} = \frac{0.557 S_{sy} A_{bolts}}{2} = \left(\frac{1}{2}\right)(0.557)(248.11MPa)\frac{(\pi)(10.32mm)^2}{2}$ **=11560N**
  - $FoS = \frac{F_{shear}}{F_L} = \frac{11560N}{296.2N} = \mathbf{39}$



Reflective Surface Analyses

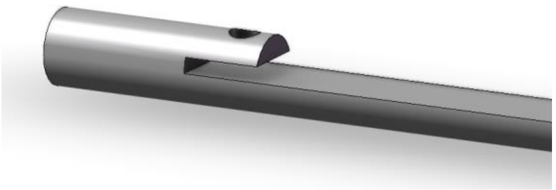
- Concentrated focal thermal input of 1MW for entire field:
  - $\dot{Q}_{use} = \left[\frac{modules}{field} \times \sum_{i=1}^{n} G_{bni} A_i \cos(\theta_i)\, \eta\right] - \sigma T_{rec}^4 = [1500 \times \sum_{i=1}^{4} 1368 * 0.25 * \cos(17.48) * 0.6] - (5.67e-8)(1273)^4 =$ **1.025 MW**




Frame holding reflective surface
Main shaft
Casing around DC motors
Concrete footings under the ground

Structure/Mounting Key Features

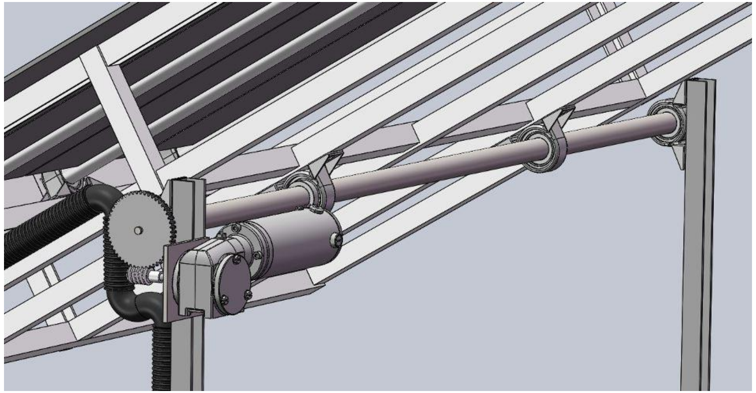
- Balanced chassis to reduce moment
- C-channel chassis for reduced mass
- Open-frame design for water flow during cleaning and aerodynamics
- Pillow blocks for stability, reduced friction
- Functional shaft for mirror clamping

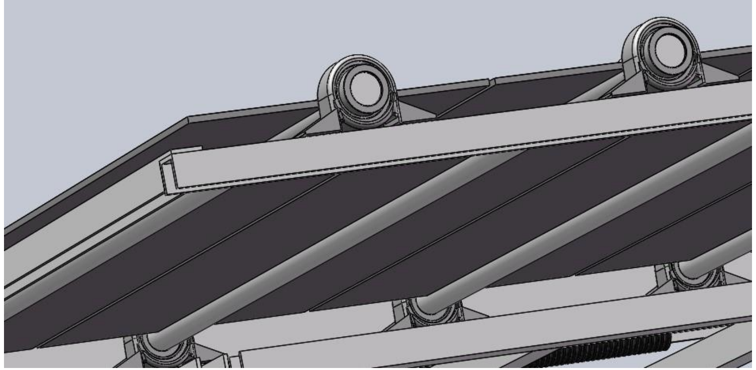


Structure/Mounting Analyses

Shaft Design

- Achieve a factor of safety of 2 or more for all parts of design
  - $\sigma_{bmax} = \frac{Mc}{I} = \frac{26.36\left(\frac{N}{m}\right) * 1.164m^2 * 0.00635m}{12 * 1.021 * 10^{-8} m^4} = \mathbf{1.59\ MPa},$
    - $FS = \frac{276\ MPa}{1.59\ MPa} = \mathbf{173}$
  - σ_{bmax}= **27.7 MPa**, FS=$\frac{276MPa}{27.7MPa} = \mathbf{10}$

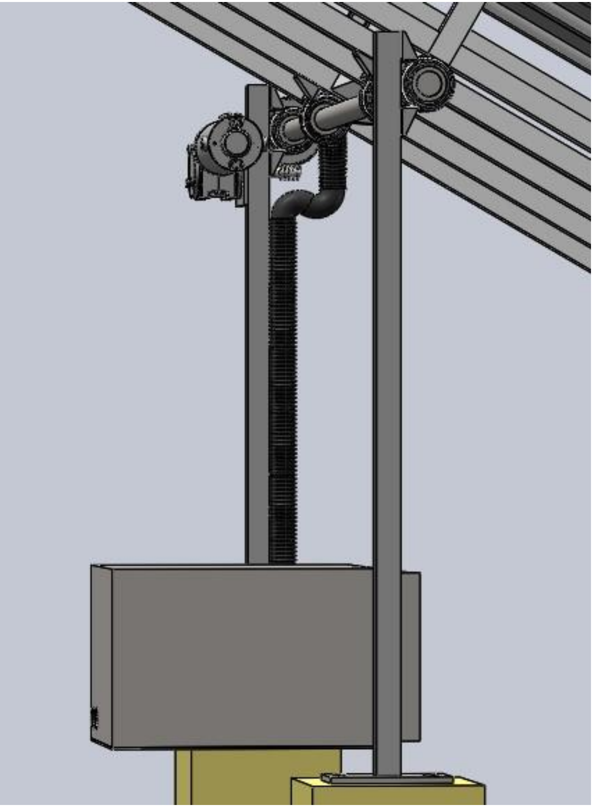




Structure/Mounting Analyses

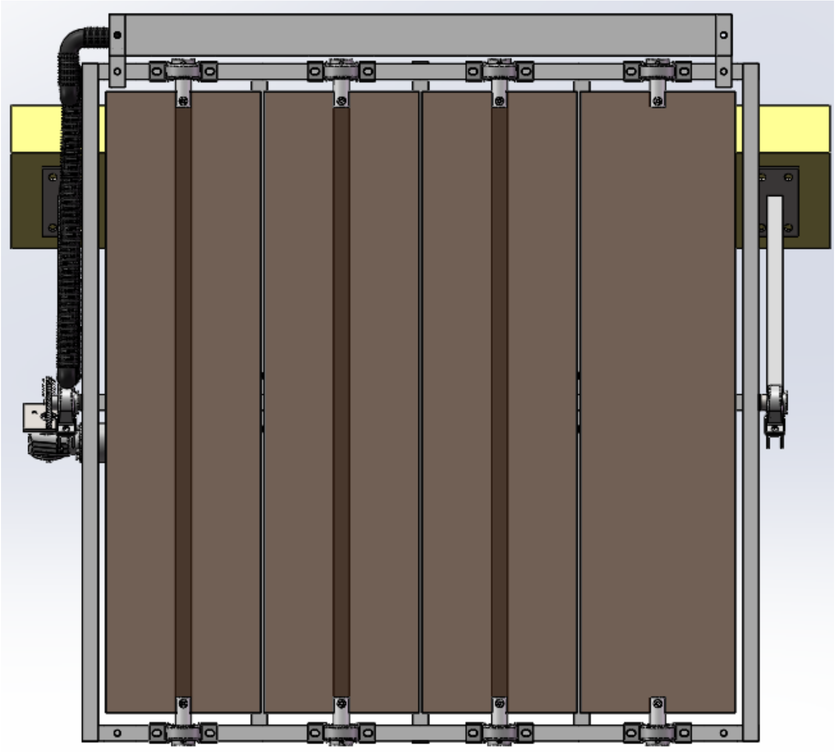
Structural Support Legs

- Achieve a factor of safety of 2 or more for all parts of design
  - $F_{buckle} = \frac{n\pi^2 EI}{L^2}$
  - $F = \frac{0.25*\pi^2*69GPa*1.50067\ x10-8m^4}{(0.7692m)^2} = 4318\ N$
  - $FS = \frac{4318}{400} = \mathbf{10.8}$

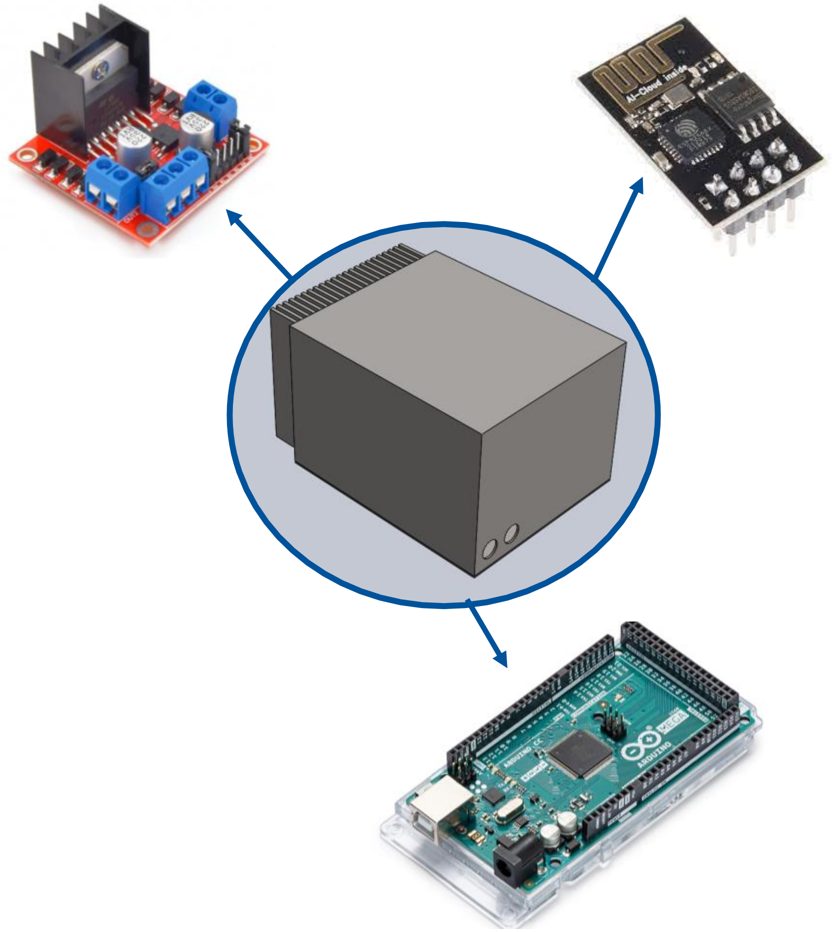


Structure/Mounting Analyses

- Number of heliostats: 4<n<16
  - Four independently actuated heliostats
- Operating temperature: 20.7 F>T>128.7 F
  - Steel Melting point: 2500° F



Controls Key Features

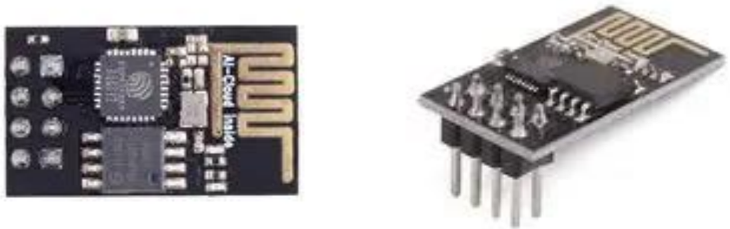


- Simplicity:
  - Only one Arduino Mega needed to control all components
  - Fits in 5.5 x 8 x 1.1 in sheetmetal box
- Accuracy:
  - Closed-loop angular feedback provides accurate tracking ability
  - High transceiver sensitivity can receive signals from over 100m away

Controls Analyses

- All heliostats in module WiFi controlled from computer in central tower:
  - Max required bandwidth: $\frac{10\ bits}{degree} \times \frac{0.005\ deg}{sec} \times \frac{4\ helios}{module} \times \frac{1500\ modules}{field} =$ $\boldsymbol{300\ bps}$ to control entire field
  - Min required receiver sensitivity: $\frac{-60\ dbm}{100\ m^2} \times 25mm^2 = \boldsymbol{-53.97dbm}$ per heliostat

ESP8266 WiFi Module



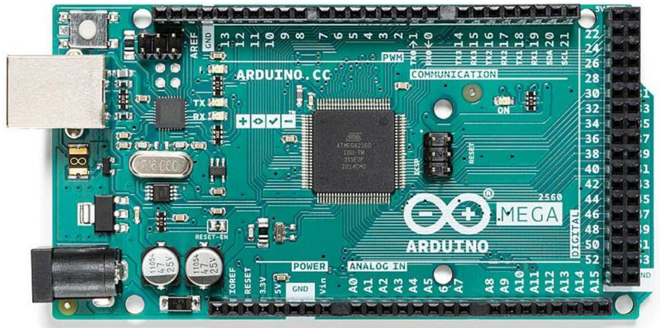
- Specs:
  - 11 Mbps
  - TX Power: +20 dbm
  - Rx Sensitivity: -91 dbm

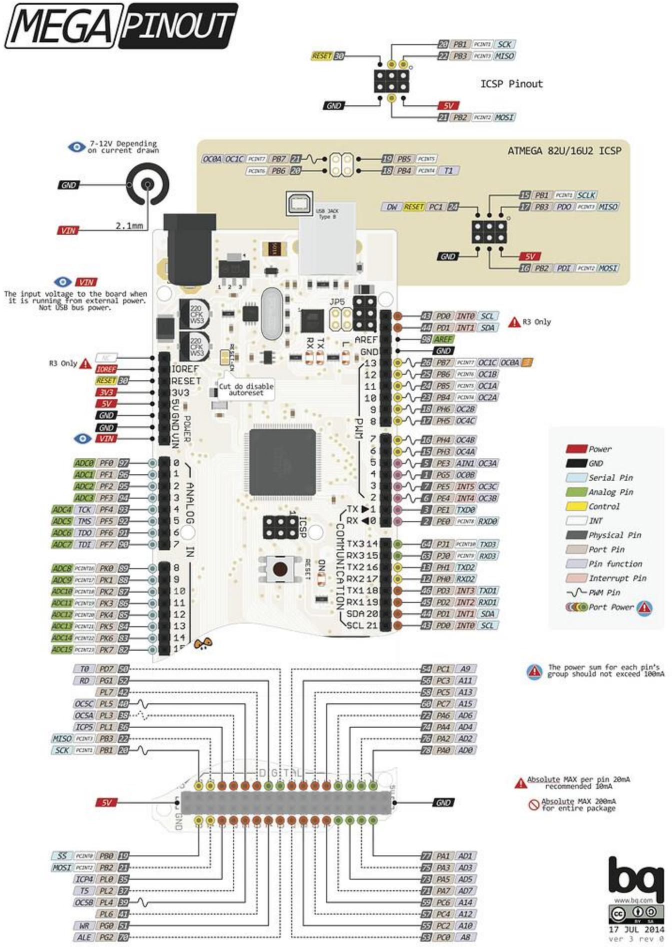
Controls Analyses

- Determination of required microcontroller:

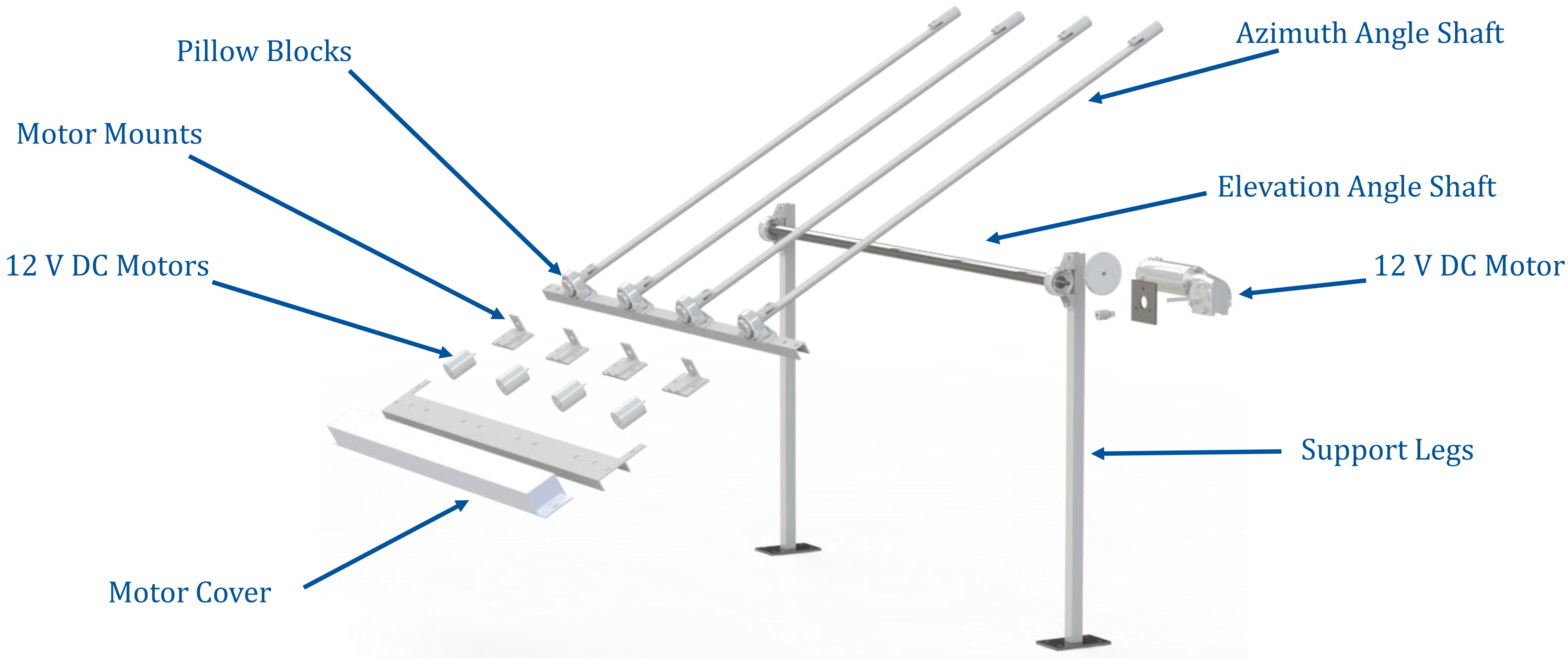
Component	Quantity	Required Digital Input Pins	Required Digital Output Pins	Required PWM Pins
Azimuth motor encoder	4	2	0	0
Stepper motor encoder	1	2	0	0
ESP8266	1	2	0	1
L298N Motor Driver	3	0	4	2
Total		12	12	7

Arduino Mega



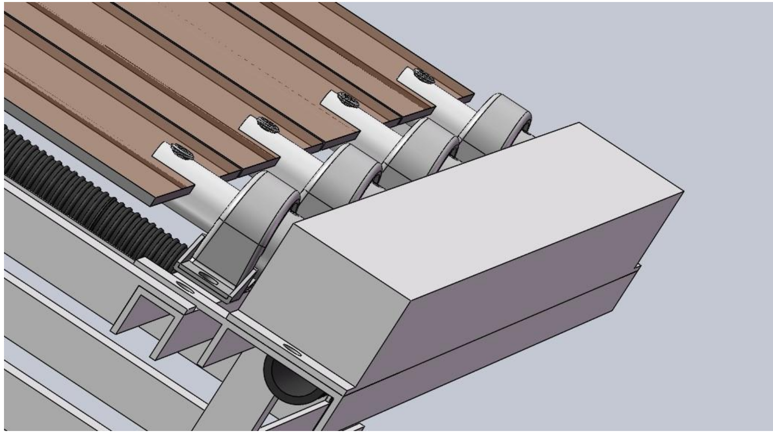


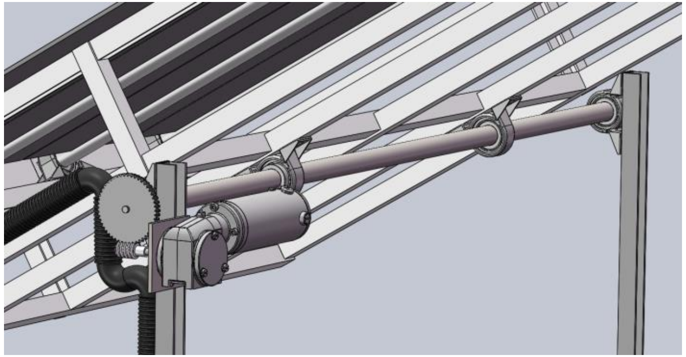
- Specs:
  - 39 digital I/O pins
  - 15 PWM pins
  - 5V DC Operating Voltage


Pillow Blocks
Motor Mounts
12 V DC Motors
Motor Cover
Azimuth Angle Shaft
Elevation Angle Shaft
12 V DC Motor
Support Legs

Actuation Key Features

- Singular azimuth rotation axis
- Lower motor to mirror ratio
- Denso gear motor





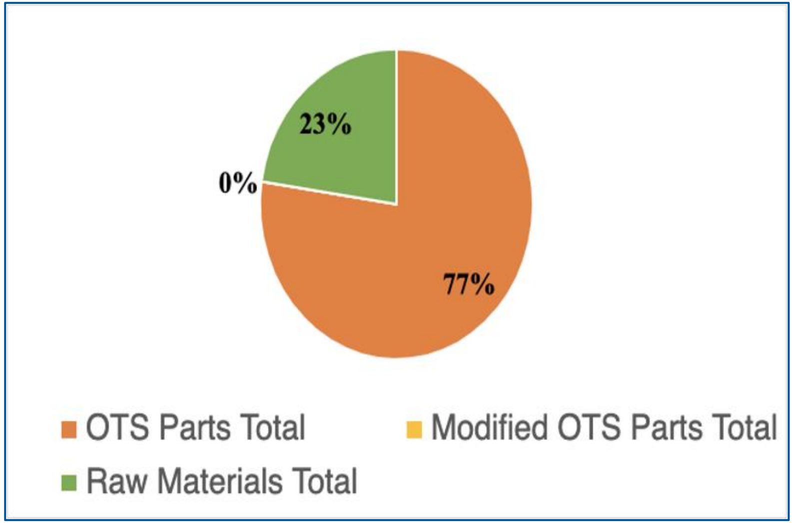
Actuation Analyses

- Required ROM analysis (43.68 < x < 71.56)
  - The max chassis height to allow for this ROM was found to be 0.123 m.
- Design life motor analyses
  - Distance traveled in 10 years 4.12 million mm
  - Distance traveled per day 199.3 mm/day
  - Motor Life:

$$(4.12\ million\ mm/199.3\ mm/day)(1\ year/365\ days)=56.721\ years$$

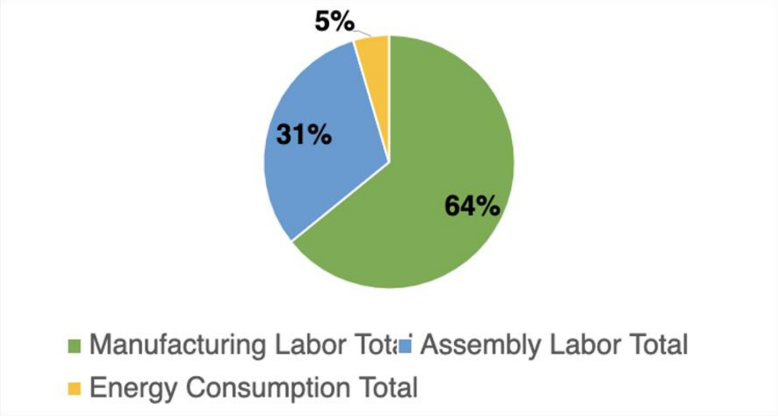
Cost Analysis

- OTS Parts
  - Motors, pillow blocks, fasteners, gears, and control box components.
- Raw materials
  - Steel, aluminum, reflective glass, concrete, U-channel, and shafts.



Cost Analysis

- Manufacturing and Assembly labor
  - 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.
- Energy Consumption
  - Cost of any manufacturing process that requires energy.



Category	OTS Parts	Raw Materials	Manufacturing Labor	Assembly Labor	Energy Consumption	Total Cost
Cost	$122.62	$36.29	$12.80	$12.76	$4.70	$189.17

Summary

- Our design is unique based on:
  - U-channel chassis provides aerodynamic frame to support reflective surface
  - Dual, independent axis tracking system for each reflective surface increases tracking accuracy
  - Reflective surface has a compact configuration to minimize heliostat design

Conclusion

- High cost compensated for with advanced tracking accuracy and structural robustness.
- Our design’s goal:
  - Simpler shape to have easy manufacturing
  - Optimization