UF Herbert Wertheim College of Engineering
UNIVERSITY of FLORIDA

Azim6 Heliostat

Section 13337, Group 6

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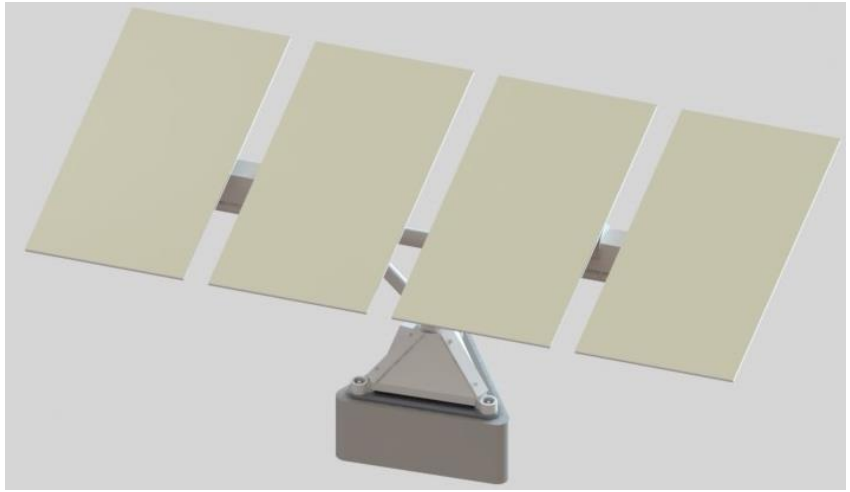
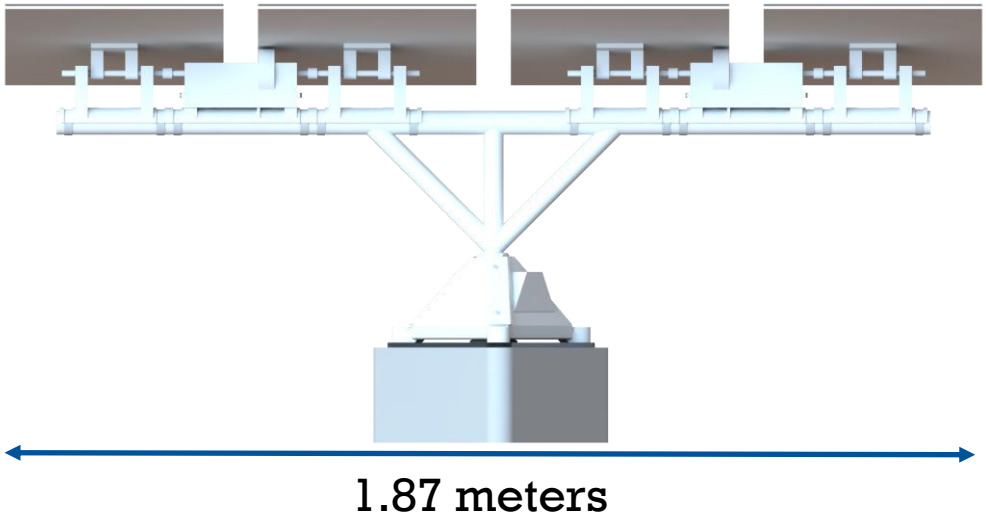
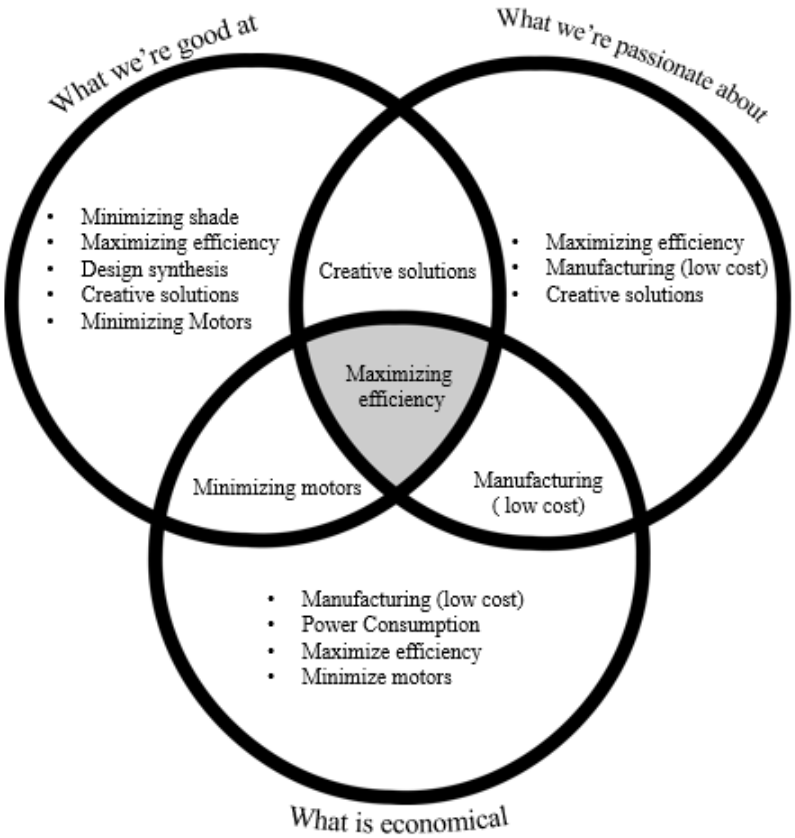
The Azim6 Heliostat

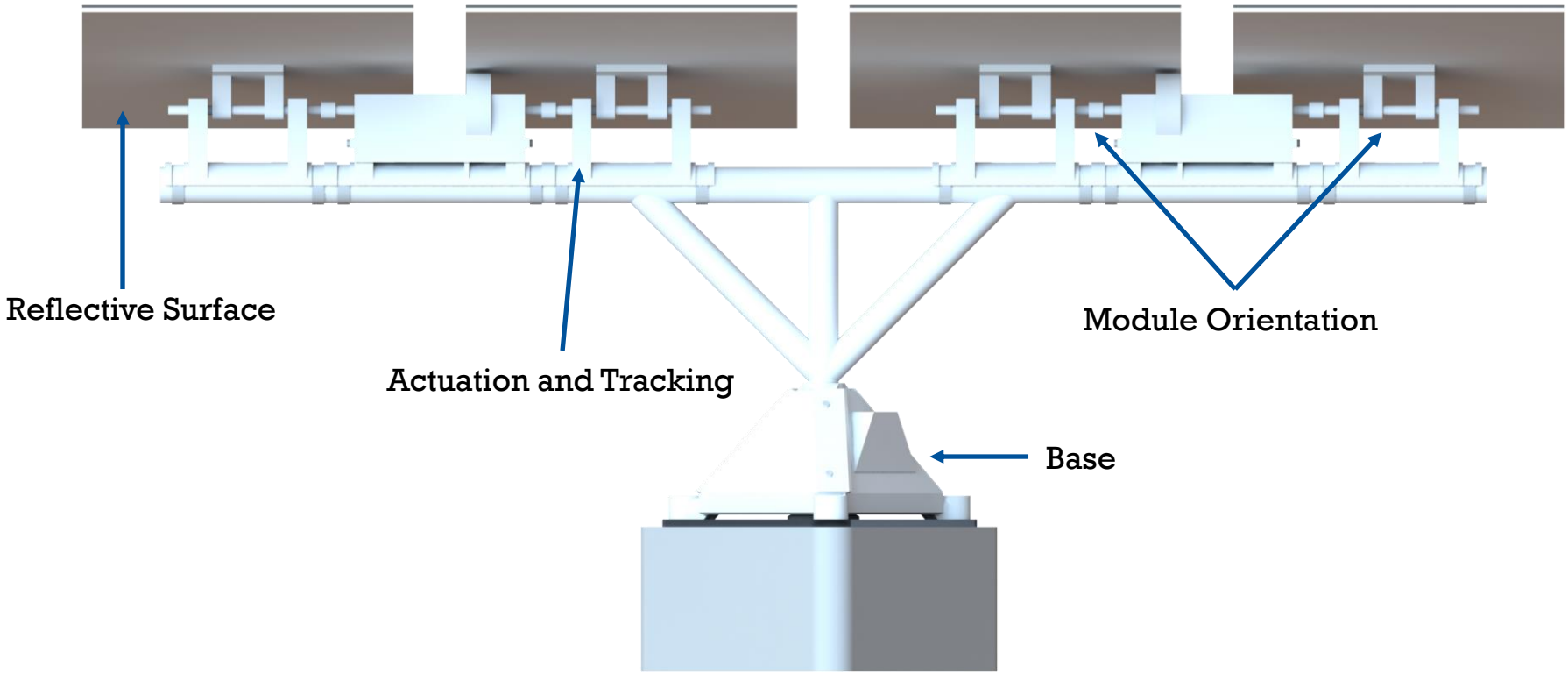


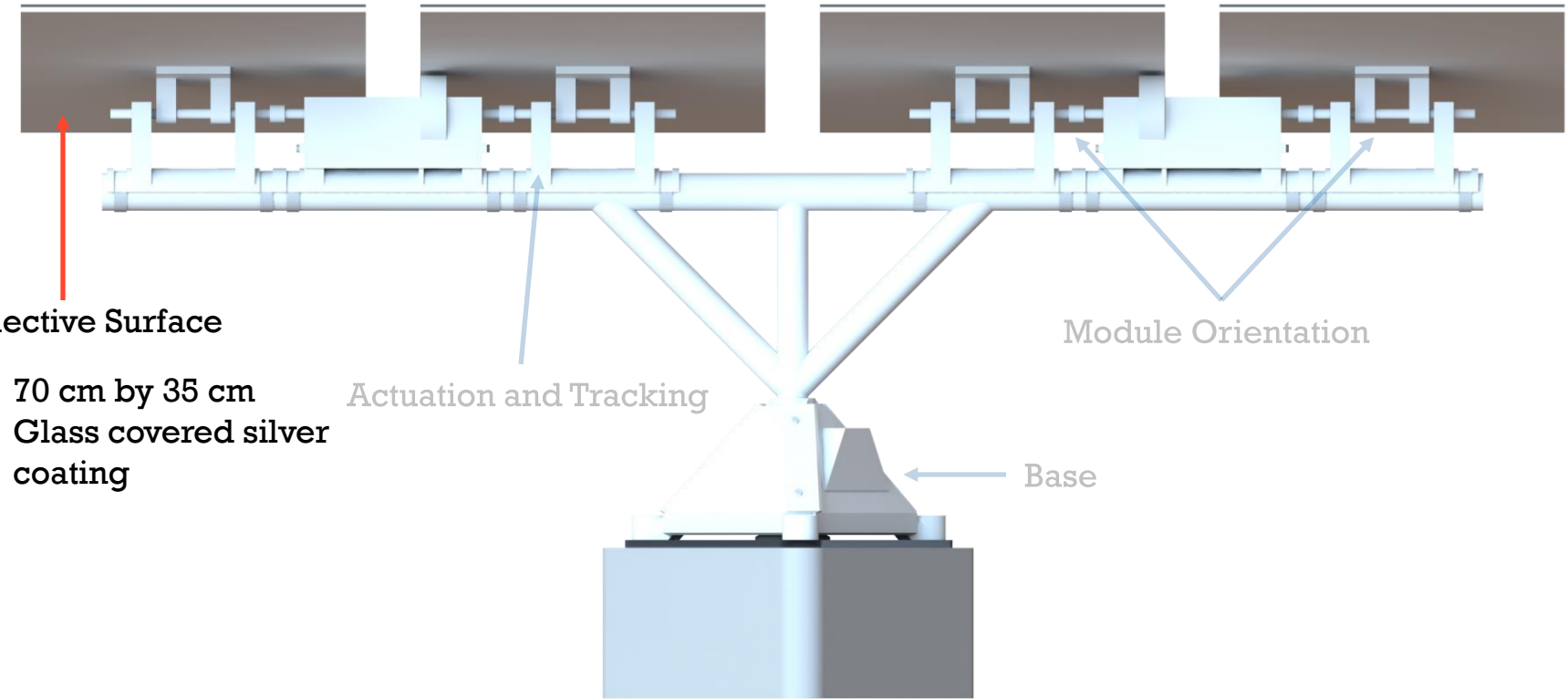


Guiding Design Principles

- **Maximizing Efficiency:** Added mirror modularity to eliminate downtime.
- **Reducing motor count:** Incorporated a revolving base.
- **Creative Design Solutions:** Single piece inject modeling to reduce parts.
- **Minimizing Manufacturing Processes:** Utilize 3-D printing to eliminate as many machined components as possible.



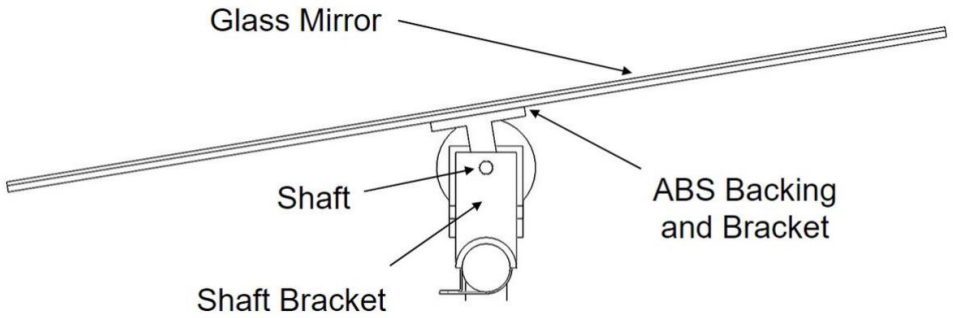

Reflective Surface
Actuation and Tracking
Module Orientation
Base



- 70 cm by 35 cm
- Glass covered silver coating

Reflective Surface

- 3mm thick glass over silver coating
- Reflectivity of 89-94%
- Coating seal integrity up to 300 ° F
- Supported by ABS backplate



Reflective Surface Analysis

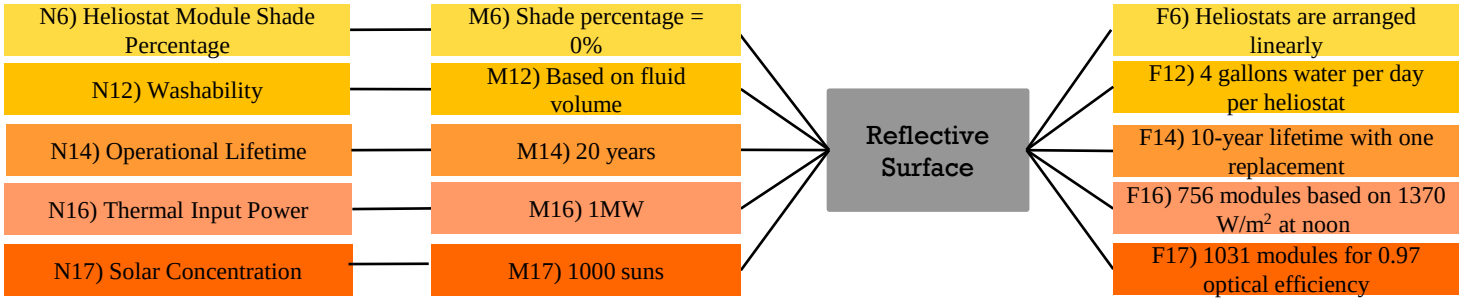
The solar energy collection field made of individual heliostat units must deliver to a central receiving tower target a concentrated focal thermal input power of 1 MW after losses.

- $\dot{Q}_{use} = \dot{Q}_{in} - \dot{Q}_{loss}$
- $\dot{Q}_{in} = \eta_{optical} \sum_{i=1}^{n} G_{bt,i} A_i$
- $\dot{Q}_{loss} = \sigma {T_{rec}}^4 A_{rec}$
- $CR = \frac{\dot{Q}_{in}}{G_{bt,i}} = \eta_{optical} n A_i$

- $\dot{Q}_{use}$: Usable Thermal Input Power
- $\dot{Q}_{in}$: Thermal Input Power from Heliostat; $\dot{Q}_{loss}$: Radiative Heat Loss
- $\eta_{optical}$: Optical Efficiency of Material Selected = 0.97
- G_{bt}: Radiative Flux to Earth $\approx 1370 \frac{W}{m^2}$
- A_i: Area of Heliostat = 0.98 m^2
- A_{rec}: Area of Receiver =10 m^2
- A_{rec}: Temp of Receiver, Ambient Temp of Vegas = 47.22 $°C$
- σ: Stefan-Boltzmann constant = $5.67 * 10^{-8} \frac{W}{m^2} \cdot K$
- n: Number of Modules in Field = 1000 modules

Analysis Continued

- $\dot{Q}_{in} = 1.433$ MW
- $\dot{Q}_{loss}$ =5972.97 W
- $\dot{Q}_{use} = 1426581.23$ W $= 1.427$ MW
- The usable thermal input power produced is over the requirement of 1 MW
- $CR = 1045.66\ suns$
- Solar concentration ratio exceeds customer requirement of 1000 suns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N14) Operational Lifetime
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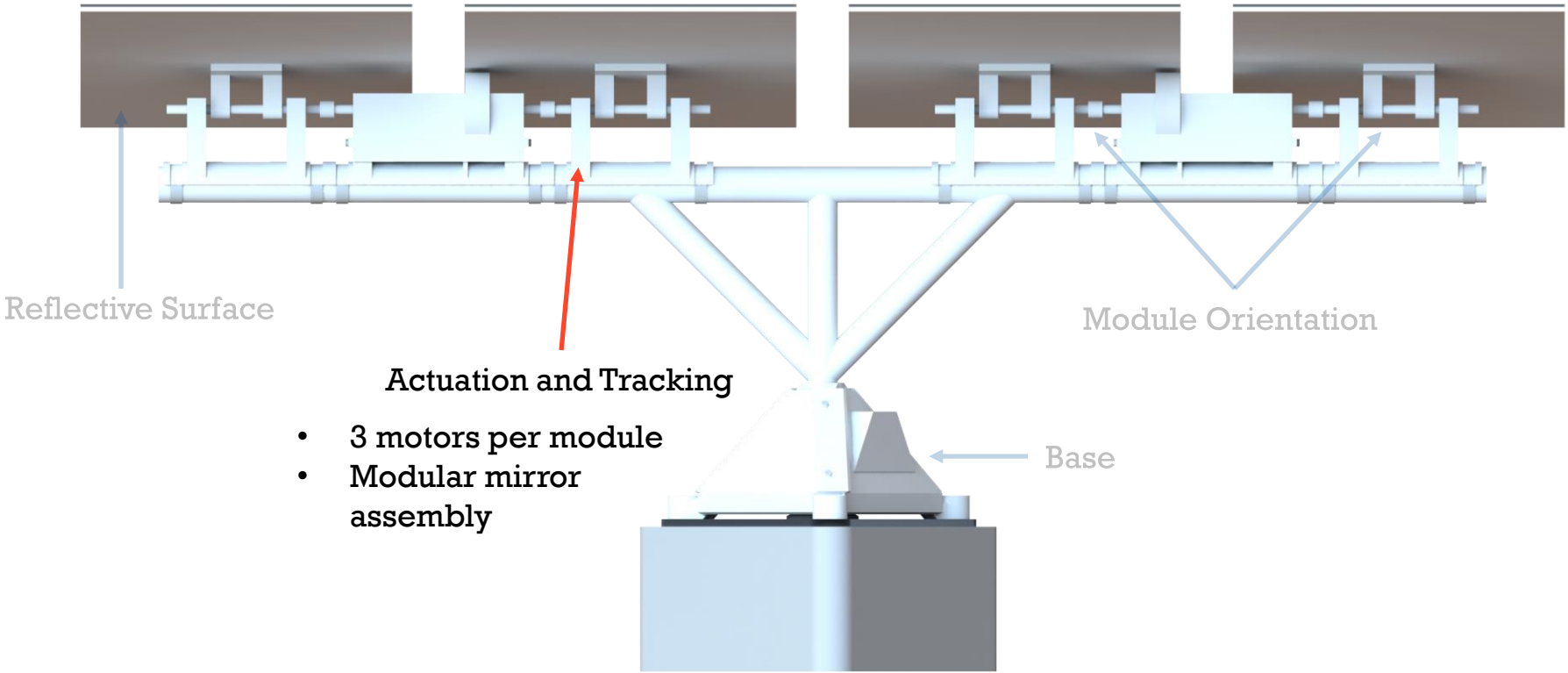
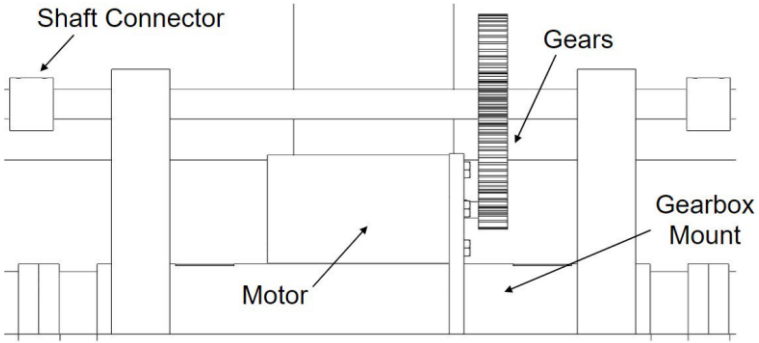


- 3 motors per module
- Modular mirror assembly

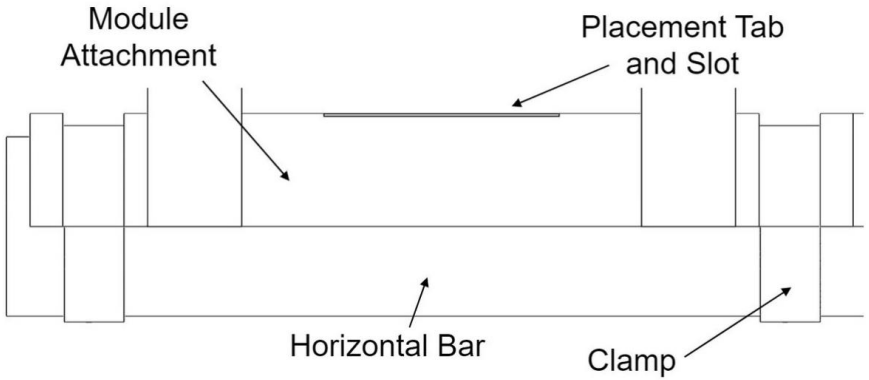
Actuation and Tracking

- Single piece drivetrain for mirror control
- Fully modular mirror assembly
- Full module rotation from base motor
- Only 3 motors needed for module tracking
- Shrouding to protect from harsh conditions



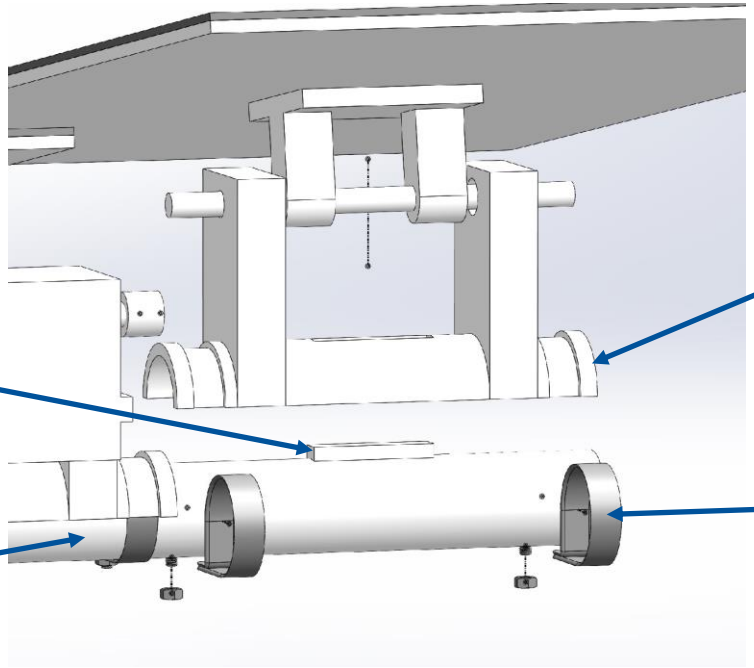
Modularity

- Each mirror Assembly contains:
  - Mirror and backplate
  - Gear
  - Driveshaft
  - Mounting mechanism

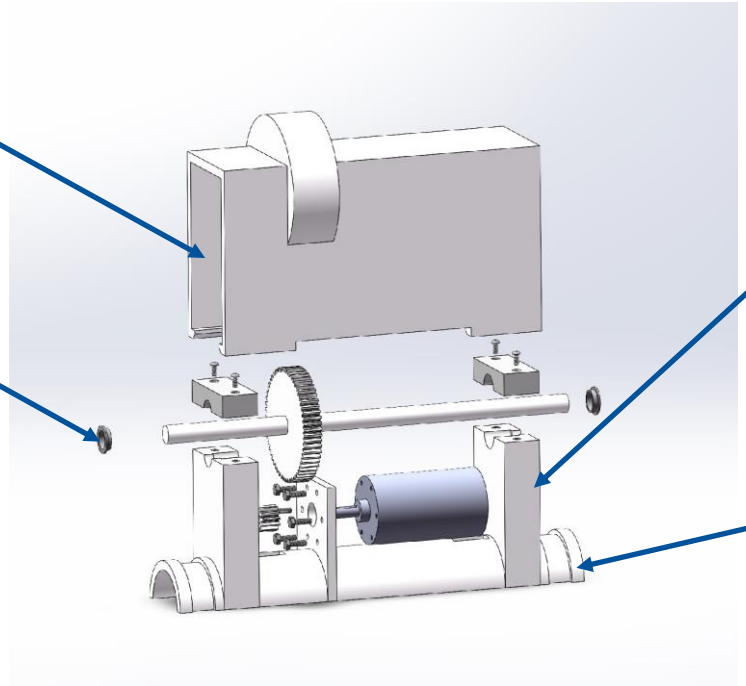


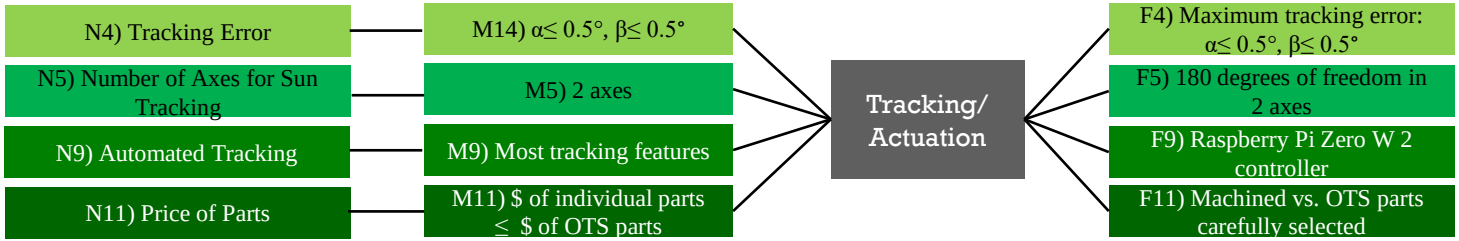
- Allows for easy cleaning and repair without losing operational time

Exploded View of Module



Exploded View of Actuation System




N4) Tracking Error
N5) Number of Axes for Sun Tracking
N9) Automated Tracking
N11) Price of Parts
M14) α≤ 0.5°, β≤ 0.5°
M5) 2 axes
M9) Most tracking features
M11) $ of individual parts ≤ $ of OTS parts
Tracking/ Actuation
F4) Maximum tracking error: α≤ 0.5°, β≤ 0.5°
F5) 180 degrees of freedom in 2 axes
F9) Raspberry Pi Zero W 2 controller
F11) Machined vs. OTS parts carefully selected

Motors

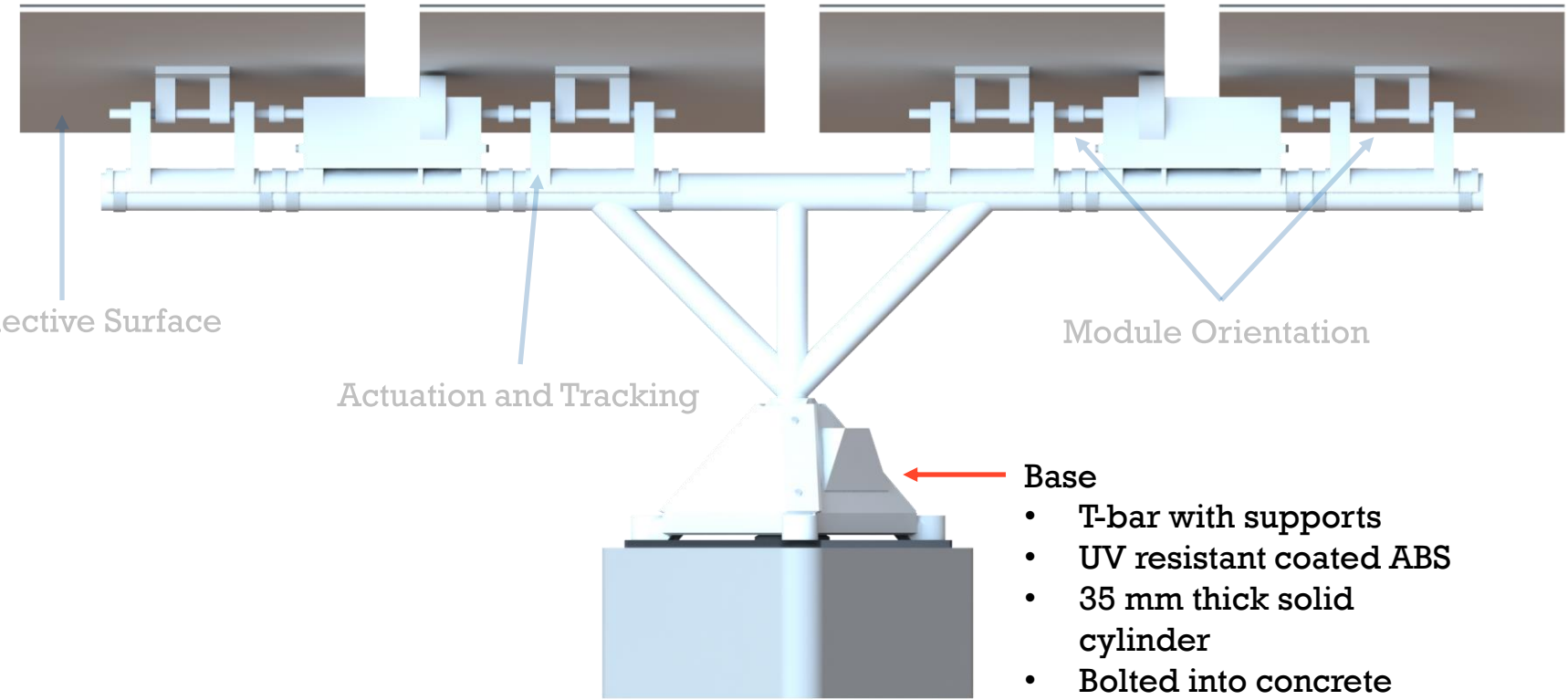
- All motors are supplying 1.47 Nm torque.
- The mirrors are equipped with a 5:1 gear reduction.
- The base is equipped with a 16.5:1 gear reduction.
- The base is actuated using a belt drive system to obtain its gear ratio.

ABS Covering Heat Transfer Analysis

Assumptions: Opaque Surface : $\rho + \alpha = 1$, Diffused Surface : $\varepsilon = \alpha$

- $\frac{dE_{sy}}{dt} = \dot{Q}_{in} - \dot{Q}_{out} + \dot{W}_{in} - \dot{W}_{out}$
- Steady State: $\frac{dE_{sy}}{dt} = 0,\ \dot{Q}_{out} = \dot{Q}_{in} + \dot{W}_{in}$
- $A_{cover}\ \varepsilon_{ABS}\ \sigma\left({T_{ABS}}^4 - {T_{surr}}^4\right) = A_{cover}\varepsilon_{sand}\sigma\left({T_{ABS}}^4 - {T_{surr}}^4\right) + 4.12W$
- $T_{ABS} = \sqrt[4]{\frac{A_{cover}\varepsilon_{sand}\sigma\left({T_{ABS}}^4 - {T_{surr}}^4\right) + 4.12W}{A_{cover}\ \varepsilon_{ABS}\ \sigma}} + T_{surr}$
- $T_{ABS} = 79.43\ °C$

- A_{cover}: Surface Area Heat Transfer $= 0.0342\ m^2$
- ε_{sand}: Sand Emissivity = 0.91
- ε_{ABS}: ABS Emissivity = 0.92
- T_{sand}: Sand Temp = 65.65 $°C$
- T_{surr}: Ambient Temp of Vegas = 47 $°C$
- σ: Stefan-Boltzmann constant= $5.67 * 10^{-8}\ \frac{W}{m^2} \cdot K$



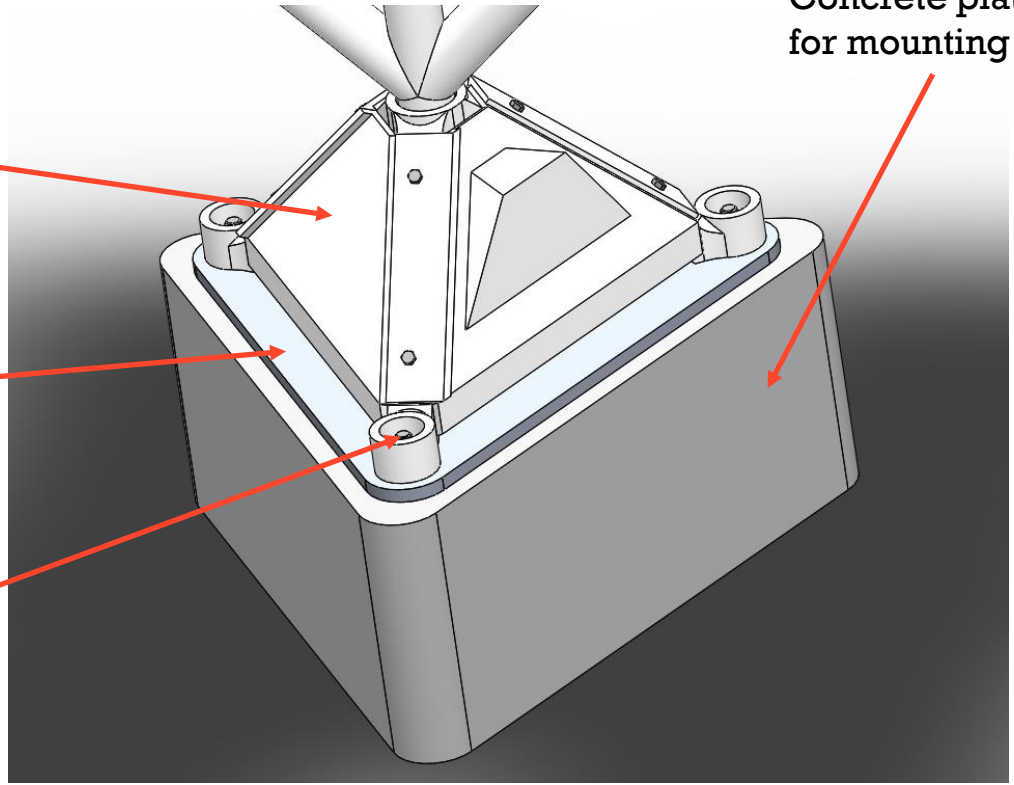
Base
- T-bar with supports
- UV resistant coated ABS
- 35 mm thick solid cylinder
- Bolted into concrete

Base Platform

ABS covering, lightweight, sand-resistant

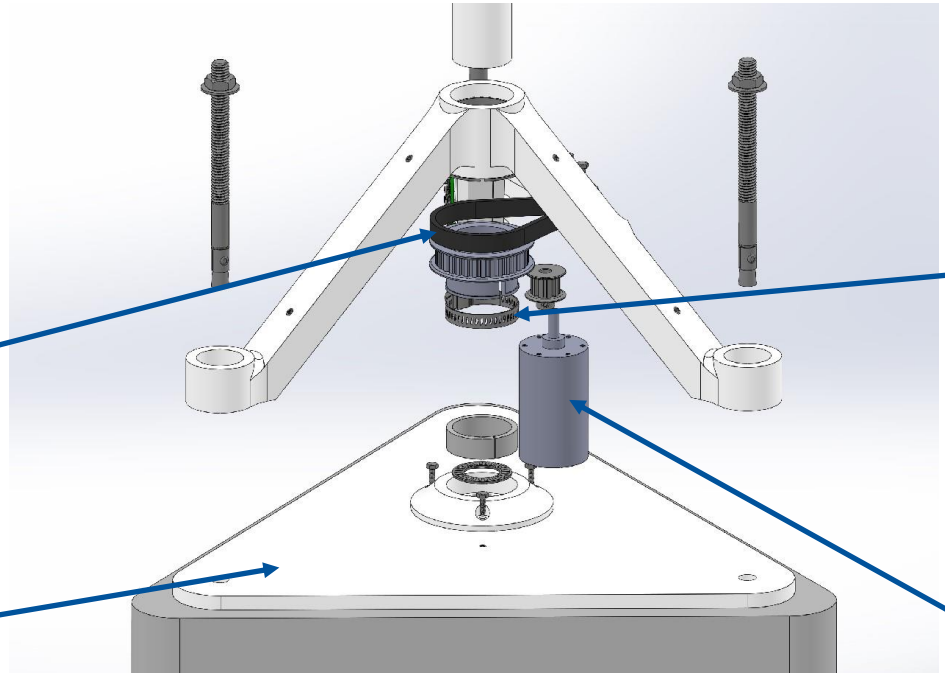
Rounded triangular base for stability and aesthetics

3x galvanized concrete anchors



Concrete platform for mounting

Exploded View of Base



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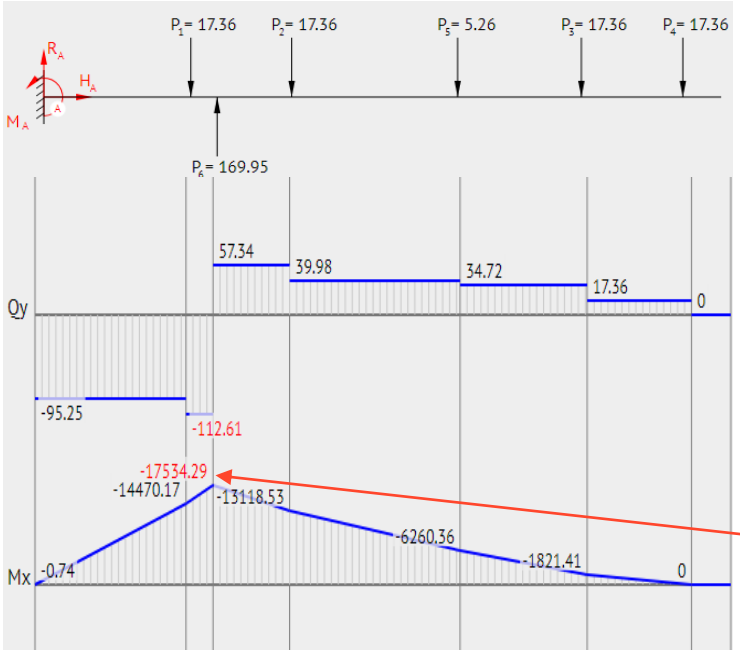
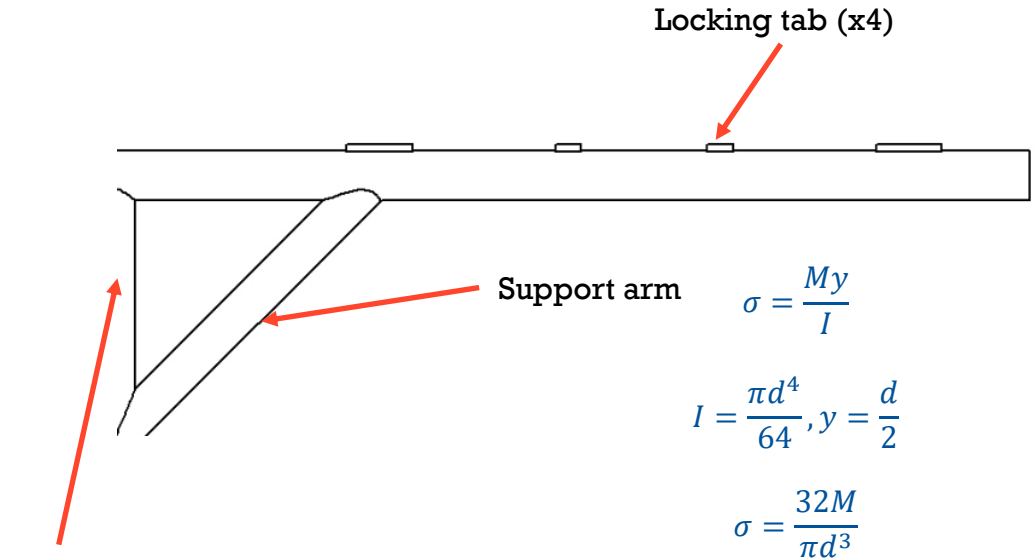




$$\sigma = \frac{My}{I}$$

$$I = \frac{\pi d^4}{64}, y = \frac{d}{2}$$

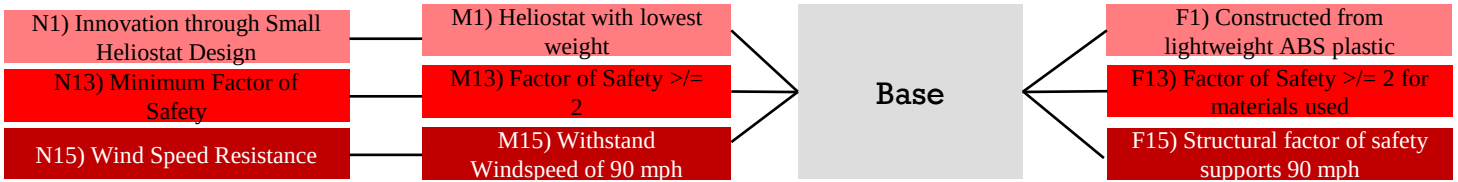
$$\sigma = \frac{32M}{\pi d^3}$$

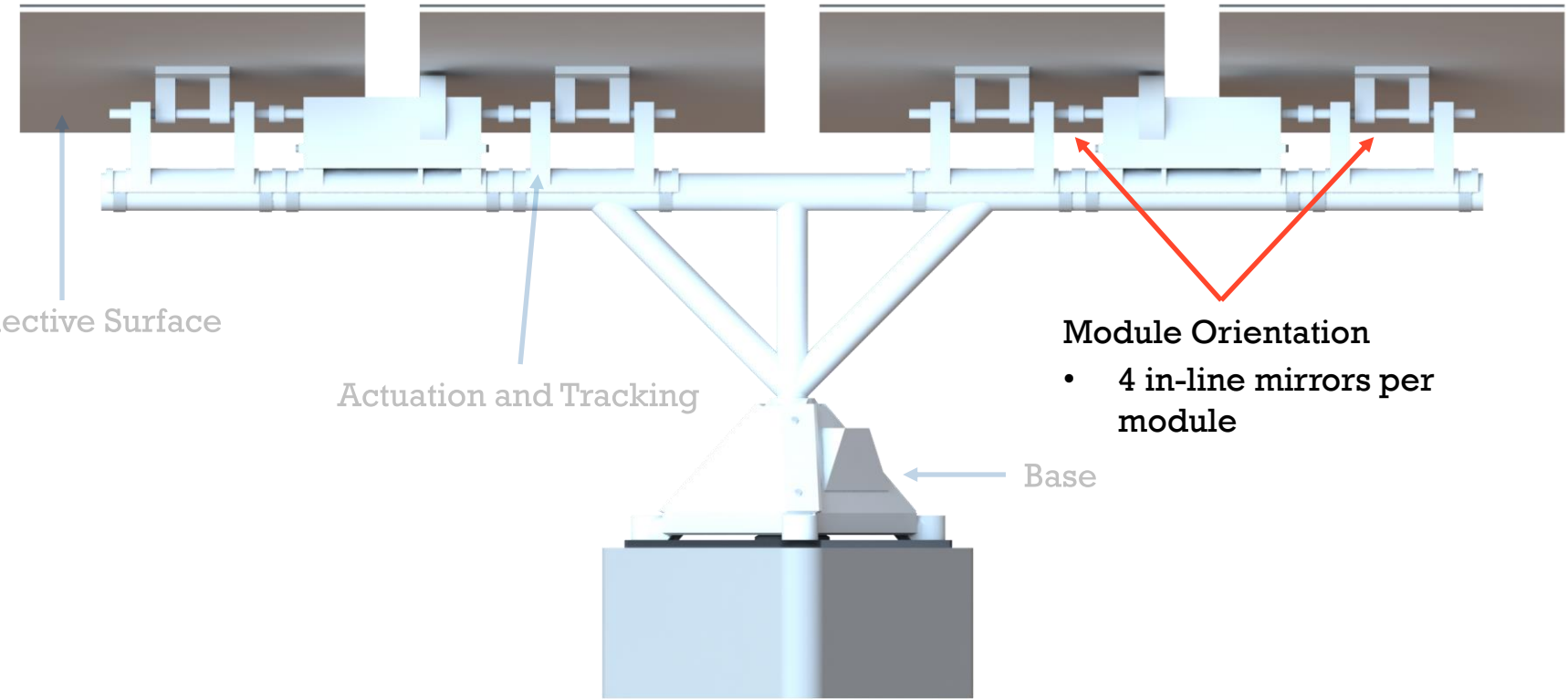
$$\sigma = 3.25\ MPa$$

$$n = \frac{\sigma_y}{\sigma} = \frac{13\ MPa}{3.25\ MPa} = 4$$

Maximum moment (Nmm)

Generated at: https://beamguru.com/online/beam-calculator/


N1) Innovation through Small Heliostat Design
N13) Minimum Factor of Safety
N15) Wind Speed Resistance
M1) Heliostat with lowest weight
M13) Factor of Safety >/= 2
M15) Withstand Windspeed of 90 mph
Base
F1) Constructed from lightweight ABS plastic
F13) Factor of Safety >/= 2 for materials used
F15) Structural factor of safety supports 90 mph



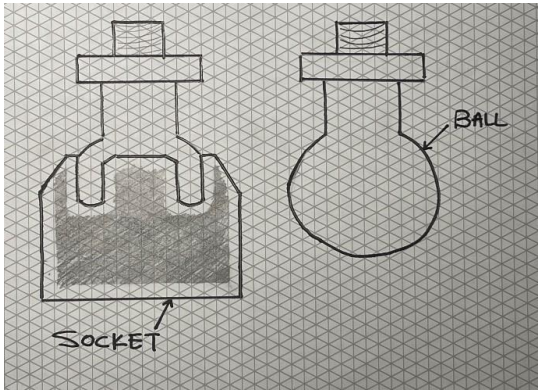
Module Orientation

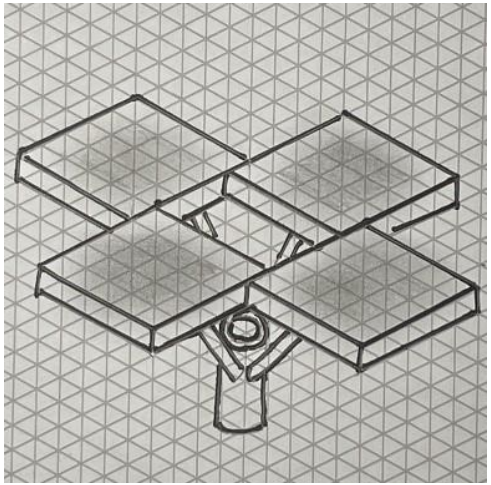
- 4 in-line mirrors per module

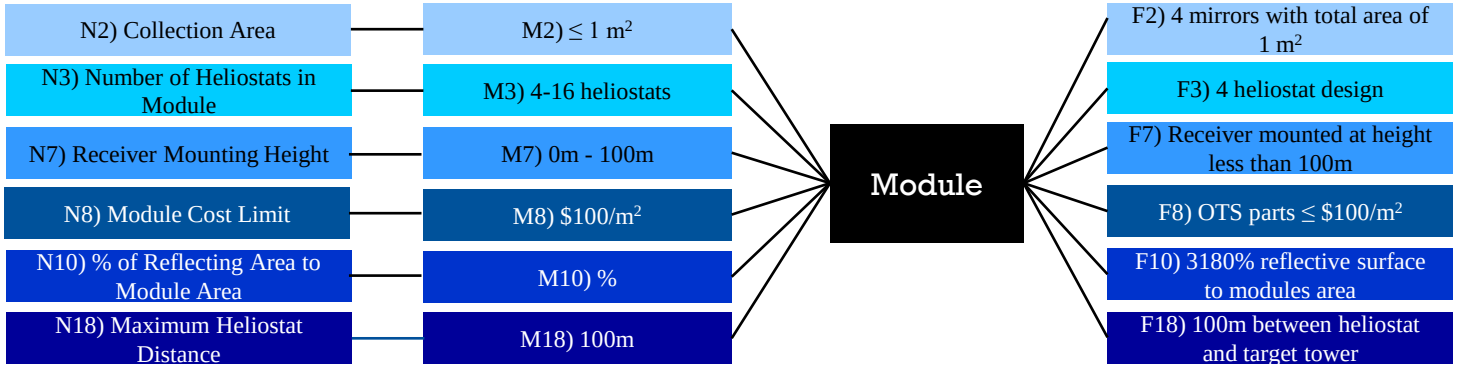
Module Orientation

- Each module has four 0.7 m by 0.35 m mirrors
- Total reflective area of 0.98 m^2 per module
- Eliminates shading of other mirrors in the module

Where we started…





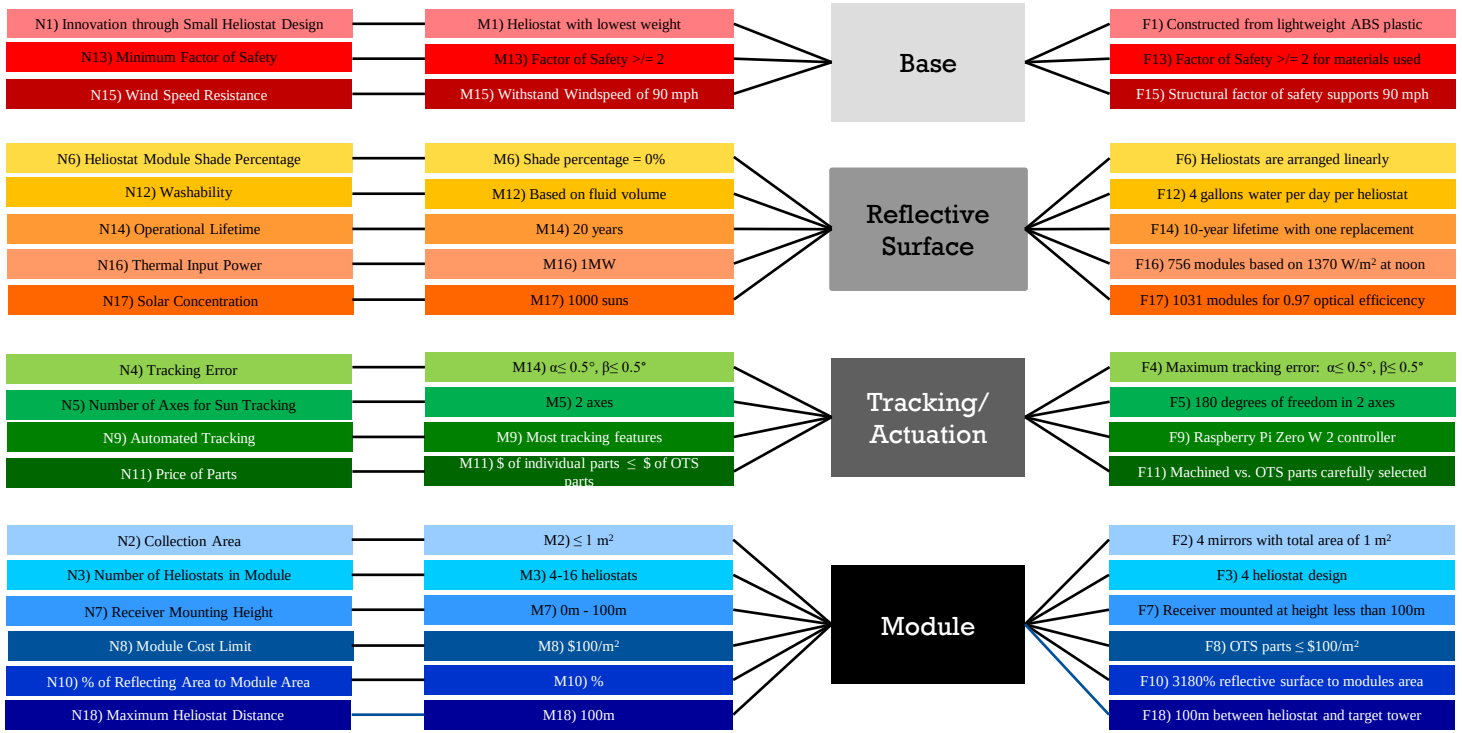

N2) Collection Area
N3) Number of Heliostats in Module
N7) Receiver Mounting Height
N8) Module Cost Limit
N10) % of Reflecting Area to Module Area
N18) Maximum Heliostat Distance
M2) ≤ 1 m²
M3) 4-16 heliostats
M7) 0m - 100m
M8) $100/m²
M10) %
M18) 100m
Module
F2) 4 mirrors with total area of 1 m²
F3) 4 heliostat design
F7) Receiver mounted at height less than 100m
F8) OTS parts ≤ $100/m²
F10) 3180% reflective surface to modules area
F18) 100m between heliostat and target tower

Full Scale Prototype Cost

Cost Breakup	Total Cost
OTS Cost	$103.57
Raw Material Cost	$26.40
Manufacturing Labor	$21.59
Assembly Labor	$4.38
Energy Consumption	$0.03
Total Cost	$155.97

Mass Production Cost

Cost Breakup	Total Cost
OTS Cost	$77.68
Raw Material Cost	$18.48
Manufacturing Labor	$21.59
Assembly Labor	$4.38
Energy Consumption	$0.03
Total Cost	$122.16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Conclusion

Our design:

- Leverages 3-D printing and injection molding to reduce costs
- Incorporates modularity to ensure lifetime needs
- Reduction of motors to reduce cost and part numbers

Thank You

We would like to thank our corporate sponsors, Northrop Grumman, Cummins, Carrier, and Aurigo, for their support for engineering education alongside UF Department of Mechanical and Aerospace engineering.