Herbert Wertheim College of Engineering
UNIVERSITY of FLORIDA

Sunflower Heliostat

By Electric Sunflower Technologies

Section 13335, Group 2

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POWERING THE NEW ENGINEER TO TRANSFORM THE FUTURE

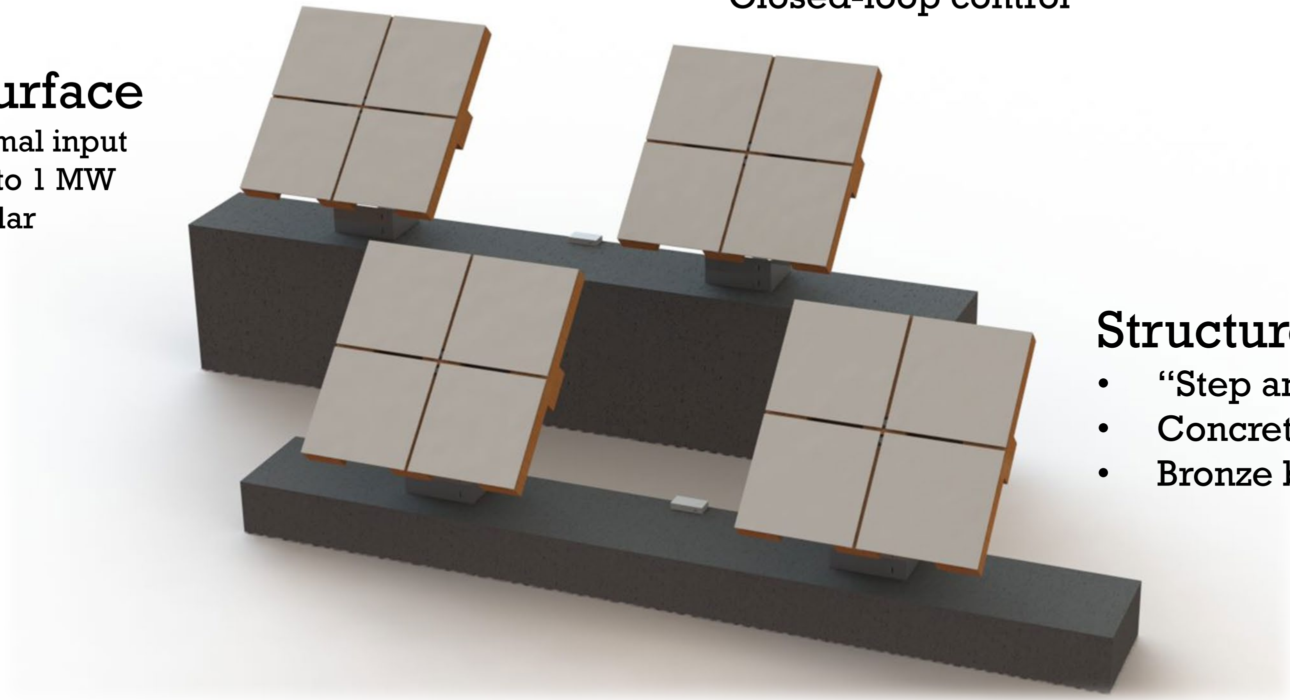
Our Motivations

- Mechanical manipulation and clever design
- Sleep
- Want to have a job!
  - Satisfy customer needs

Sunflower Heliostat

Electronics
- Raspberry Pi 0W
- Sealed enclosures
- Closed-loop control

Reflective Surface
- 176.41 W Thermal input
- 5,669 Modules to 1 MW
- 1,635 Suns of solar concentration



Structure
- "Step and Stagger"
- Concrete base
- Bronze bushings

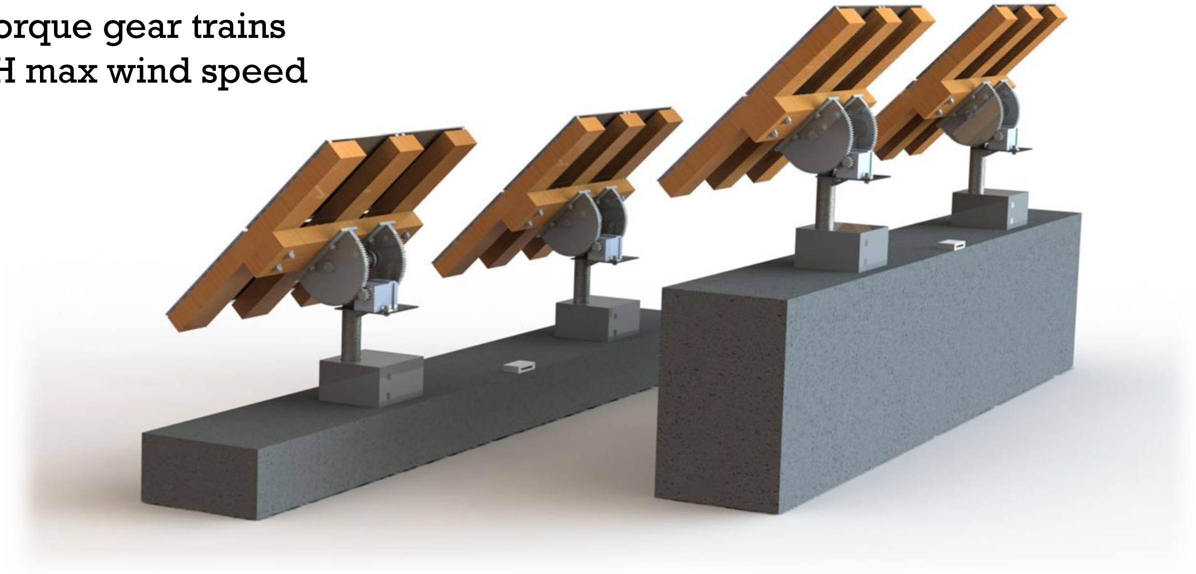
Product Overview

Reflective Backing

- Pressure treated 2" x 4" beams
- Pliable adhesive

Motion

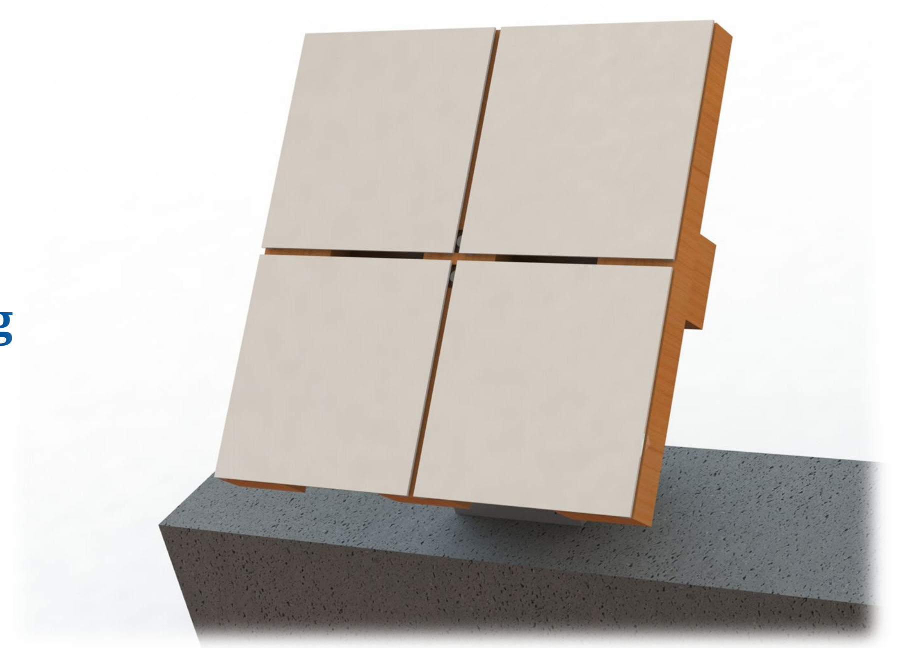
- Two axes of rotation
- High-torque gear trains
- 40 MPH max wind speed



Reflective Surface

Customer Needs Addressed: 1, 2, 4, 7, 16, 17, 18

- Four **0.0625 m^2** silvered annealed glass mirrors per heliostat
  - **3 mm** thick
- Heliostat reflective surface mass = **1.86 kg**
- Allows for easy handling and maintenance



Reflective Surface

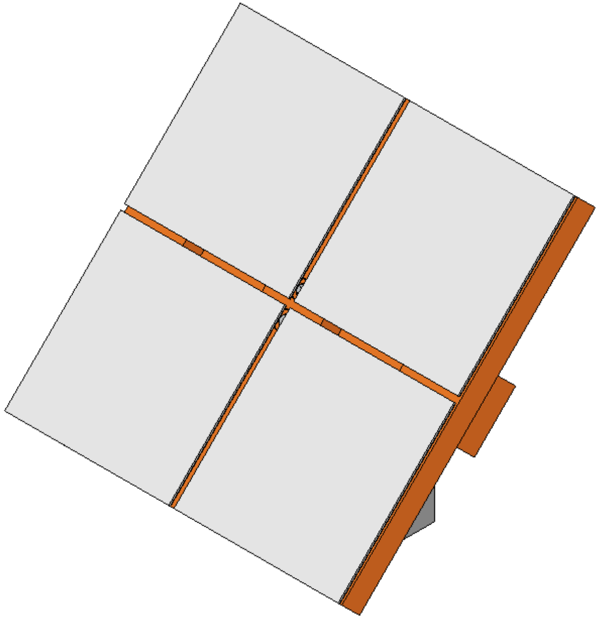
Key Feature: Multi-Mirror

- Thermal input per module = **176.408 W**
  - 1 MW is obtained with **5,669 modules**

$$Q = G_{bt} A \eta_{opt}$$
$$\eta_{opt} = 0.5\eta_{ref}$$
$$G_{bt} = G_{bn} cos\theta_{inc}$$

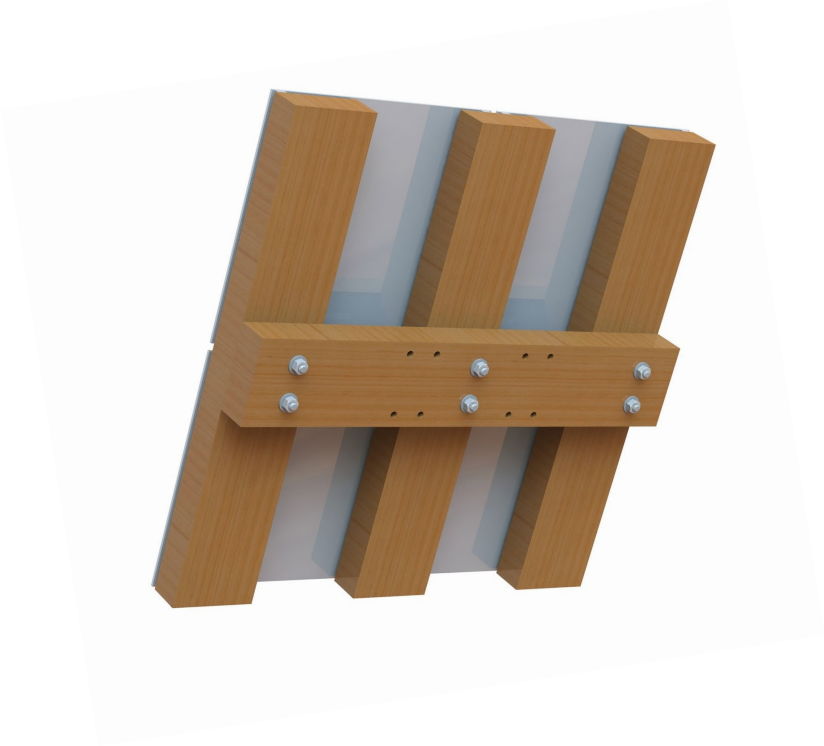
- Concentration ratio of **1,635 suns**

$$q_{solar} = G_{bn} C_{geo} \eta_{opt}$$
$$C_{geo} = \frac{A_{heliostats}}{A_{receiver}}$$



Reflective Backing

Customer Needs Addressed: 1, 13, 14, 15



- 2” x 4” pressure-treated and kiln-dried cedar
- Max deflection = **0.017 mm**
  - Deflection of a composite cantilever beam

$$\delta = \frac{FL^3}{3EI}$$

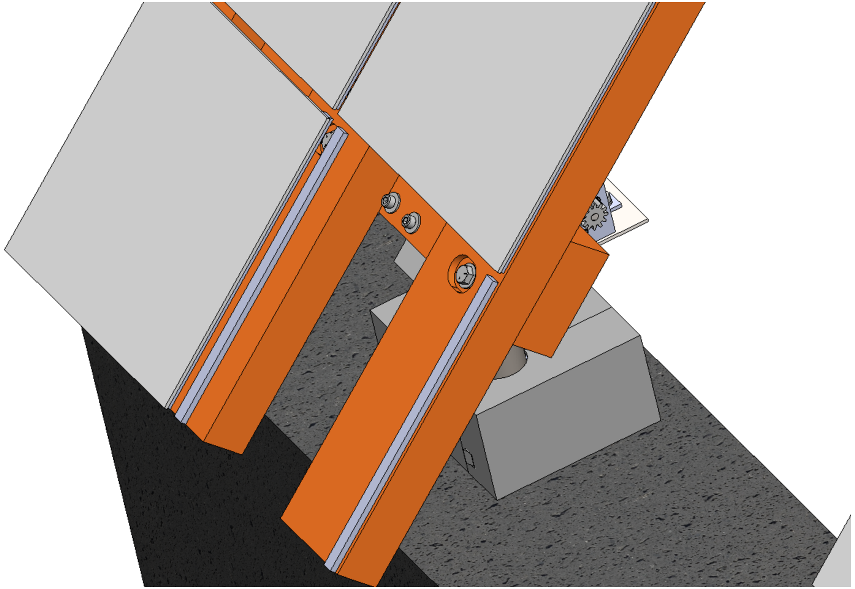
- Mass = **2.39 kg**
- FOS for bending = **4.66**

Reflective Backing

Key Feature: Epoxy Adhesive

- Differences in thermal expansion causes internal stresses
- Epoxy is **6.31 mm** thick

$$\alpha_{wood} = 30x10^{-6} {}^{\circ}C^{-1}$$
$$\alpha_{glass} = 9x10^{-6} {}^{\circ}C^{-1}$$
$$\delta = \alpha \Delta T L$$
$$\delta_{epoxy} = \frac{\tau t}{G}$$



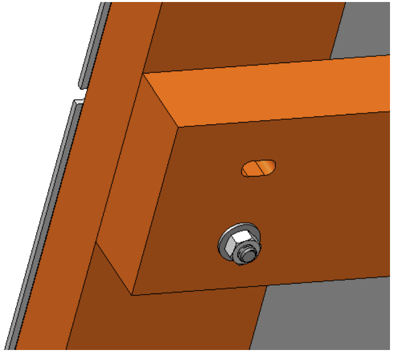
Reflective Backing

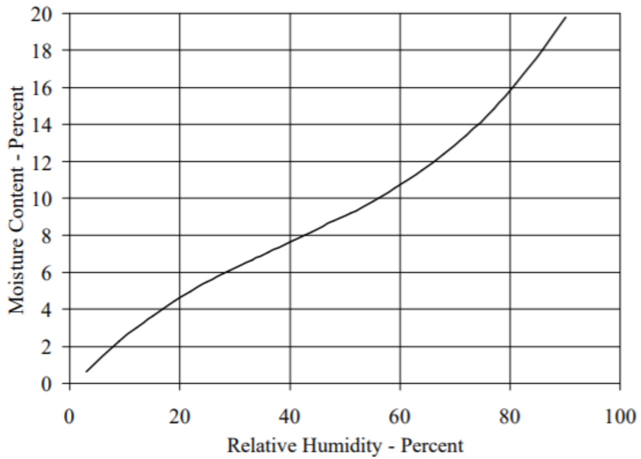
Key Feature: Fastener Slots

- Max deformation due to swelling or shrinking = **0.19 mm**

$$\Delta W = W\left(\frac{SC}{100}\right)\frac{\Delta mc}{30}$$

- Slots help deal with cracking near wood contact



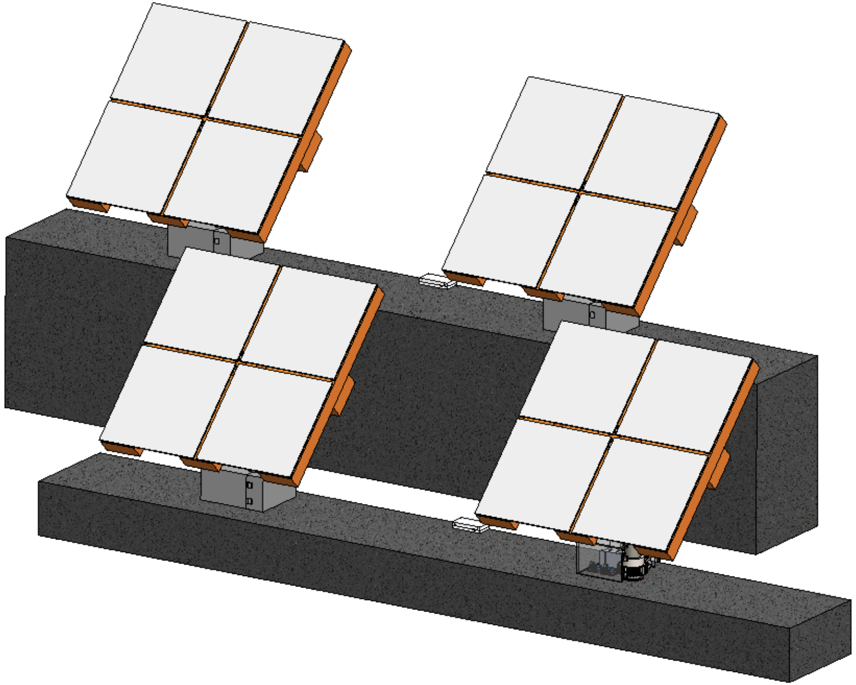


Carl Eckelman: *The Shrinking and Swelling of Wood and Its Effect on Furniture*

Motion

Customer Needs Addressed: 4, 5, 7, 8, 13, 14, 15

- Tracks sun azimuthal and elevation angle
- High mechanical advantage = Low cost



Azimuth: $\theta_1 \leq 330°$

Elevation: $\theta_2 \leq 65°$

Motion

Torque Requirements: Worm Geartrain

- Friction

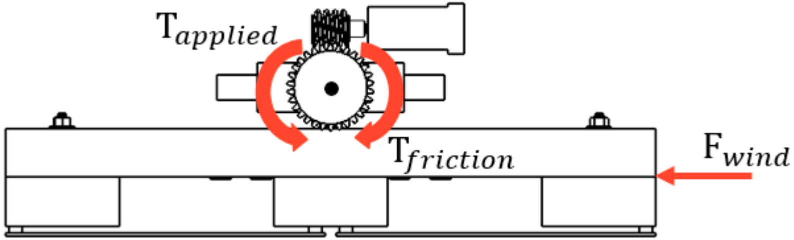
$$T_{bushing} = \mu_1 F_{wind} r$$

$$T_{slider} = \mu_2 W r$$

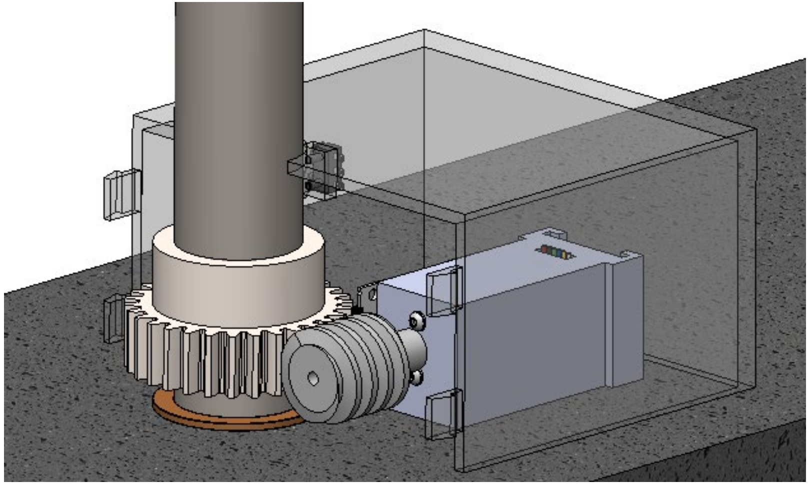
$$T_{friction} = T_{bushing} + T_{slider} = 3.85\ lb \cdot in$$

- Wind

$$T_{wind} = \frac{1}{2} \rho v^2 A_{2x4} * R = 4.42\ lb \cdot in$$



$$T_{applied} = \left(\frac{30\ teeth}{1\ teeth}\right) * 2.5\ lb \cdot in = 75\ lb \cdot in$$



Max Torque Required: 8.27 lb · in

Motion

Torque Requirements: Initial Servo Design

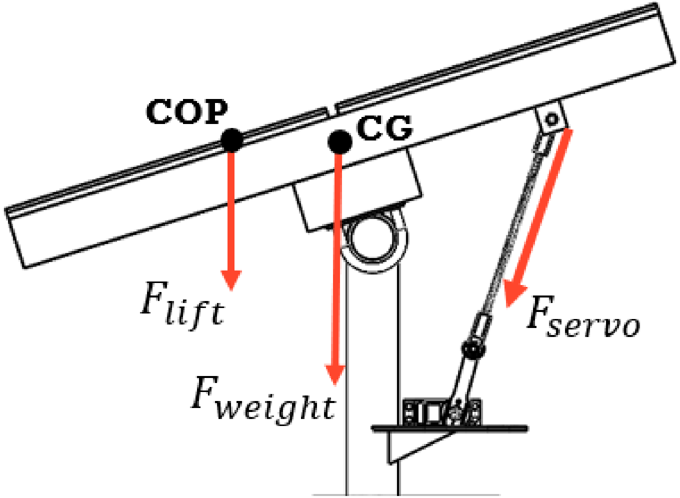
- Operational wind speed limited by motor torque

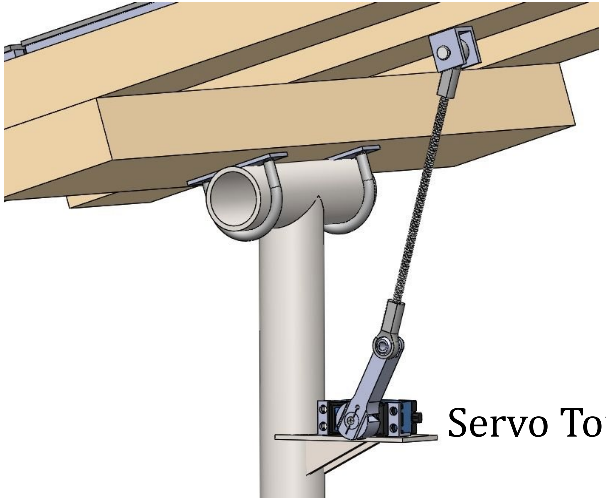
$$F_{lift} = \frac{1}{2}\rho v^2 A sin\theta C_L = 20.7\ lbs$$

$$C_L = cos\alpha sin\alpha\left(K_p cos\alpha + \pi sin\alpha\right) = 1.68$$

$$F_{weight} = 9.37\ lbs$$

$$T_{applied} \geq T_{wind} + T_{weight}$$



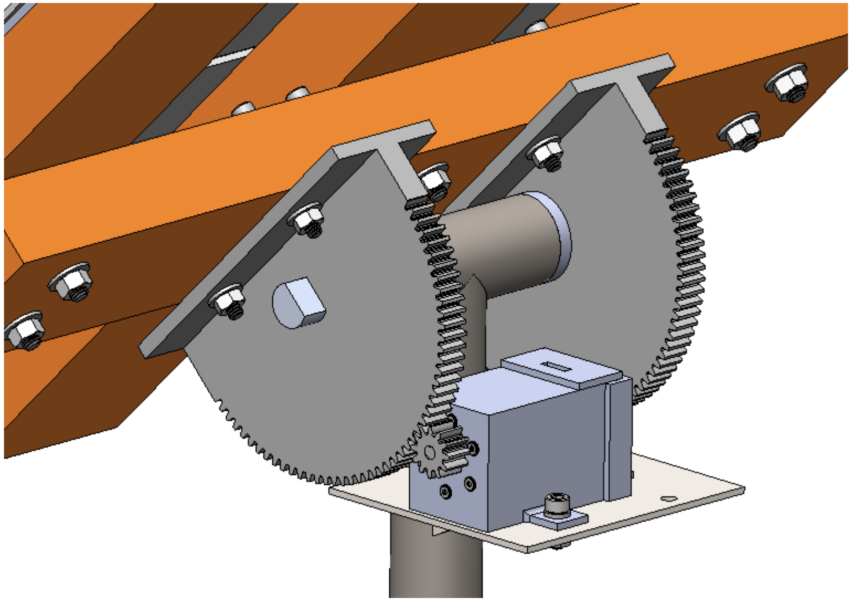


Servo Torque = 13 lb · in

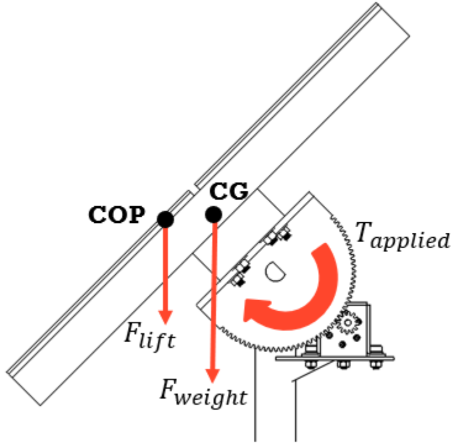
Max Torque Required: 92.3 lb · in

Motion

Key Feature: High Torque Gear Assembly



- 8:1 Gear ratio
- Reduced motor costs by 62%
- Max wind speed = **48 MPH**

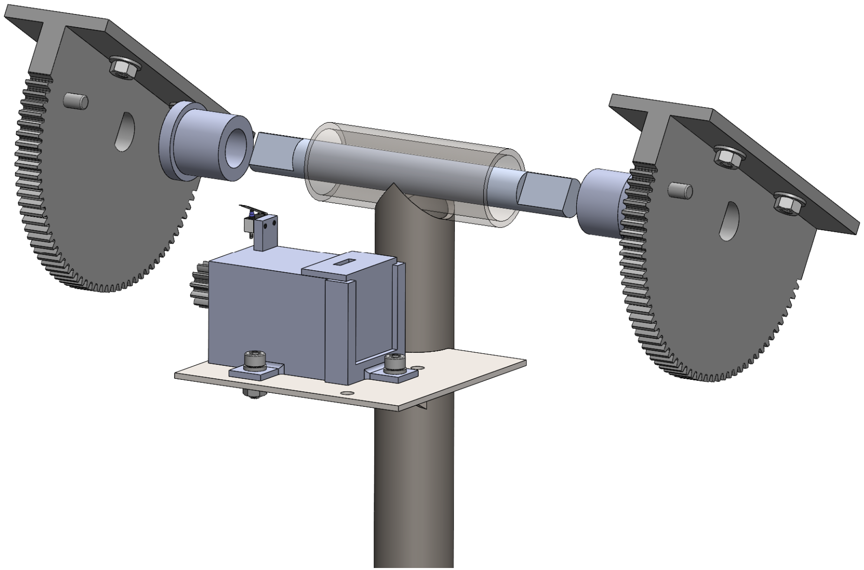


$$T_{applied} = \left(\frac{96\ teeth}{12\ teeth}\right) * 13\ lb \cdot in = 104\ lb \cdot in$$

Motion

Key Feature: Interchangeable Gears

- Injection molded Nylon
- Low speed = Low wear
- Identical parts for maintenance and cost



Motion

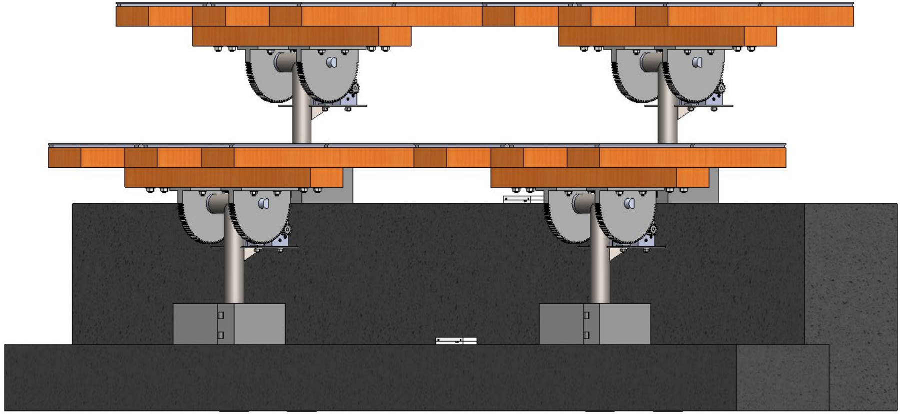
Key Feature: High Wind Safety Mode

- Triggered at **40 mph** wind speed
- Staggered defense mode

$$W_{module} = 15 \text{ lbs}$$

$$F_{lift} = \frac{1}{2}\rho v^2 A sin\theta C_L$$

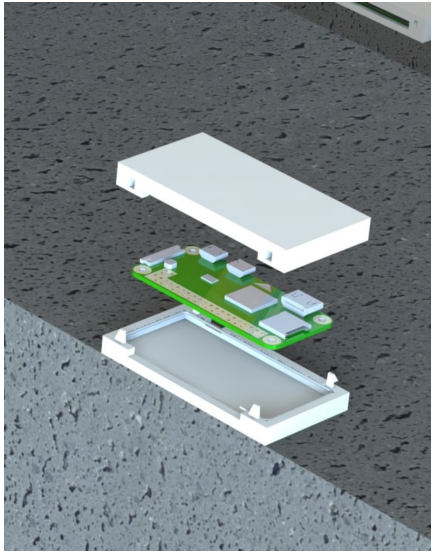
$$V = \sqrt{\frac{2W_{module}}{\rho A sin\theta C_L}} = 40\ mph$$



Electronics

Customer Needs Addressed: 8, 9, 11, 12

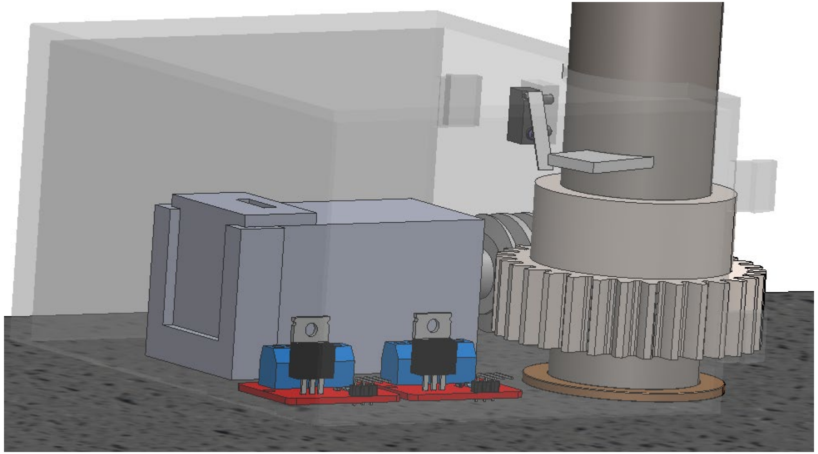
- Uses a Raspberry Pi 0W for control
- Manages two heliostats
- Control of both axes

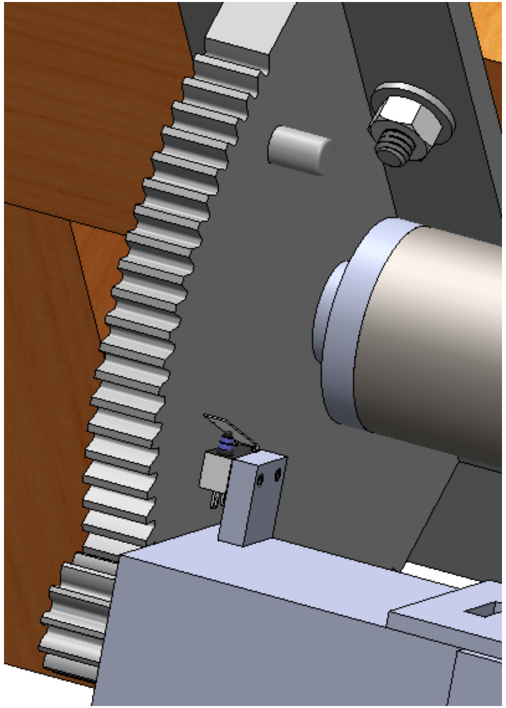


Electronics

Key Feature: Switches and Drivers

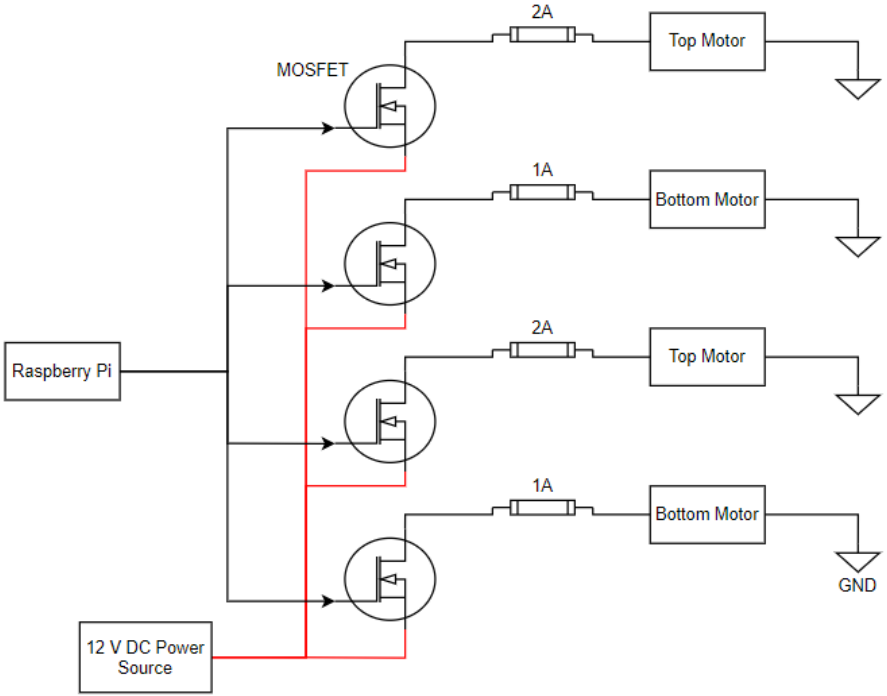
- Uses Omron Long Lever Switches
- IRF520 MOSFET as motor driver
- 2A and 1A fuses for overcurrent





Electronics

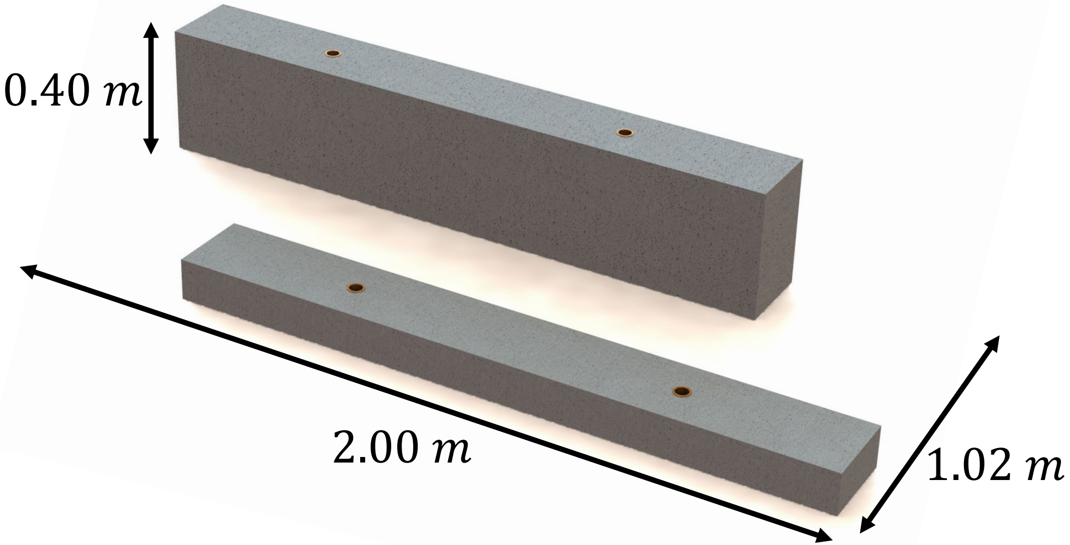
Key Feature: Power Diagram



Structure

Customer Needs Addressed: 2, 3, 6, 7, 10, 15

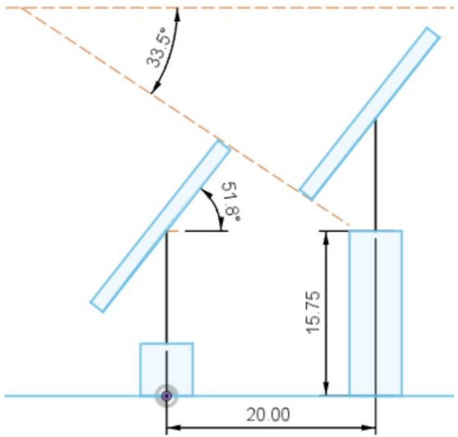
- 2.04 m^2 footprint
- Durable and Cheap

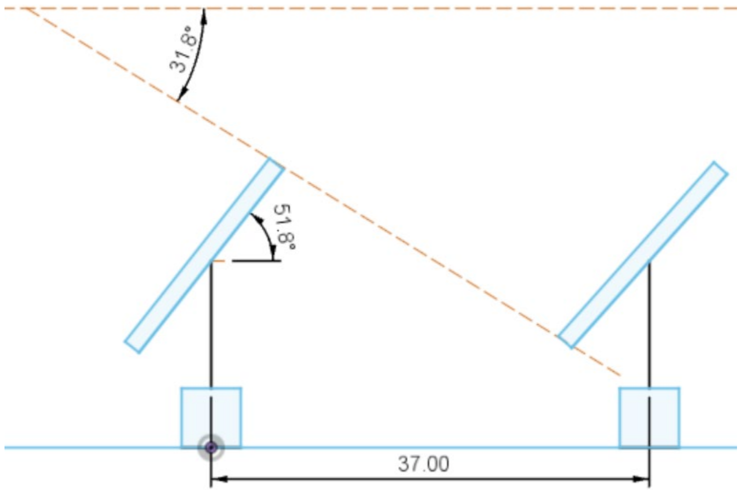


Structure

Key Feature: Shading Removal

- Winter Solstice
  - 33.5° Solar noon elevation





- Summer Solstice
  - 77 ° Solar noon elevation
  - Collection Period: 8:15 AM– 5:15 PM

Structure

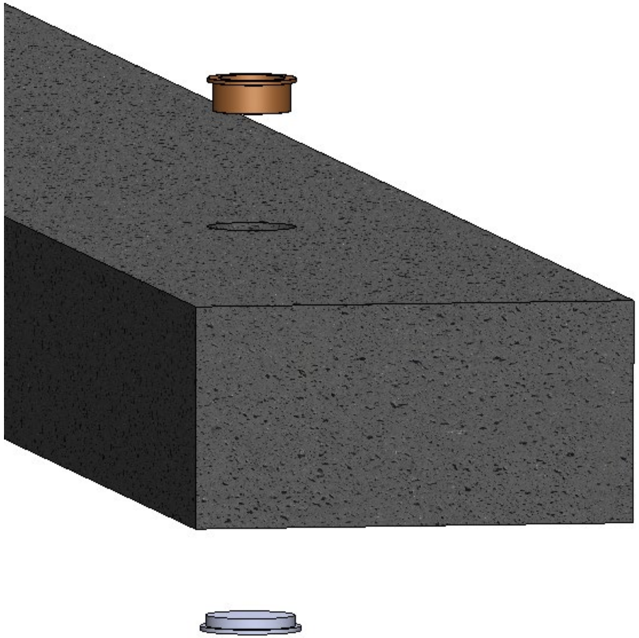
Key Feature: Furniture Sliders

- Low friction support

  $\mu = 0.20$

- Bronze bushings

  $\mu = 0.16$



Cleaning and Maintenance Procedure

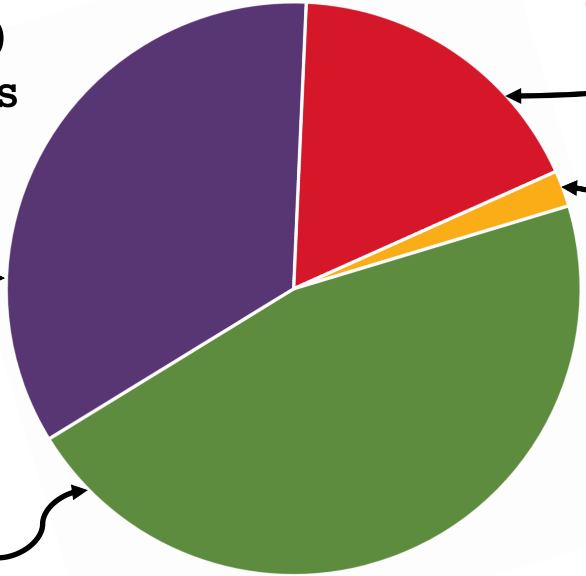
- Apply wood sealer every 2 years
- Compressed air every 2 weeks
- Water pressure with detergent if necessary

From: *Raising the Lifetime of Functional Materials for Concentrated Solar Power Technology*

Cost Summary

Raw Materials[1] ($129.09)
- Structural components
- Reflective surface

Manufacturing ($65.89)
- Raw material manipulation
- Injection molding



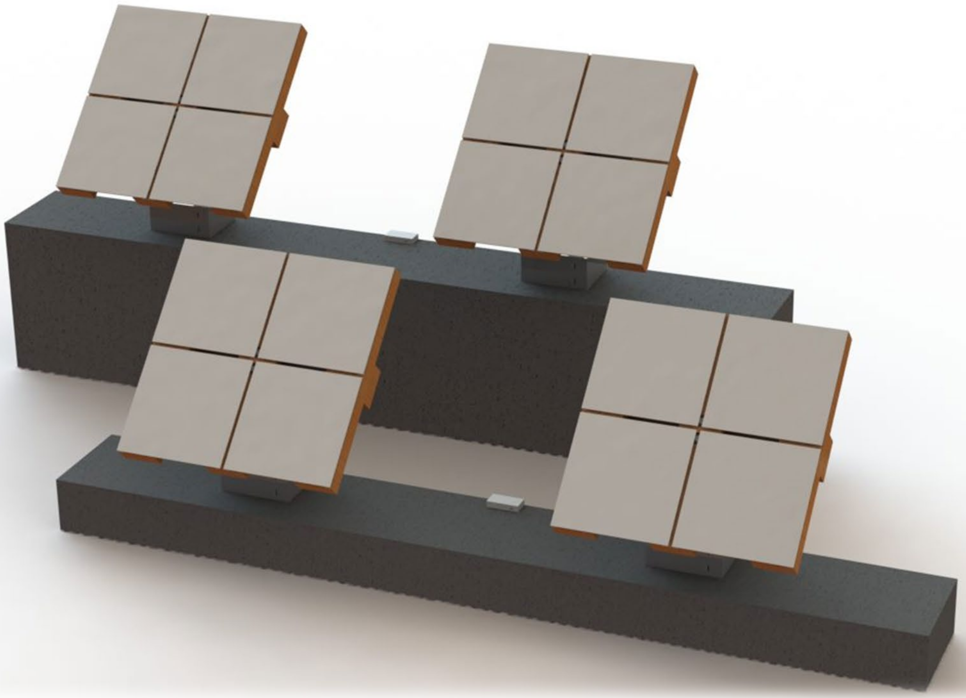
Assembly ($7.62)
- Handling time

OTS Parts[1] ($171.87)
- Electronics
- Actuators
- Hardware

[1]Some costs considered are for prototyping only. As more accurate quotes are obtained from suppliers, the overall cost is expected to decrease.

Why Us?

- Fully operational
  - Robust, reliable
- No cutting corners



Thank you!

- Questions?

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Reflective Surface

Thermal Input Calculations

$$Q = G_{bt} A \eta_{opt}$$
$$\eta_{opt} = 0.5\eta_{ref}$$
$$G_{bt} = G_{bn} cos\theta_{inc}$$

Solar Radiation striking Earth's surface:

$$G_{bn} = G_{on}\tau_b$$
$$G_{on} = G_{sc}\left(1 + 0.033\cos\left(\frac{360n}{365}\right)\right)$$
$$\tau_b = a_o + a_1 e^{\left(-\frac{k}{cos\theta_z}\right)}$$
$$a_0 = 0.4237 - 0.00821(6 - A)^2$$
$$a_1 = 0.5055 - 0.00595(6.5 - A)^2$$
$$k = 0.2711 - 0.01858(2.5 - A)^2$$

Angle of Incidence:

$$\cos(2\theta_{inc}) = \bar{S} \cdot \bar{H}$$
$$\bar{S} = cos\alpha_s sin\gamma_s \hat{\imath} - cos\alpha_s cos\gamma_s \hat{\jmath} + sin\alpha_s \hat{k}$$
$$\bar{H} = cos\alpha_t sin\gamma_t \hat{\imath} - cos\alpha_t cos\gamma_t \hat{\jmath} + sin\alpha_t \hat{k}$$

The sun is assumed to be at solar noon during the winter solstice to replicate the worst day of the year for thermal collection.

Reflective Surface

Solar Concentration Calculation

$$Q = q_{solar} A_{receiver}$$

$$A_{receiver} = \frac{Q}{q_{solar}} = 1m^2$$

$$q_{solar} = G_{bn} C_{geo} \eta_{opt}$$

$$C_{geo} = \frac{A_{heliostats}}{A_{receiver}}$$

$$q_{solar} = 1{,}635\ suns$$

Reflective Backing

Composite Cantilever Beam Deflection Calculation

$$F = \frac{E_{glass}}{E_{cedar}} = 12.73$$

$$I = \sum I_i + A_i d_i^2$$

$$\delta = \frac{FL^3}{3EI}$$

$$\sigma_{max} = F\frac{Mc}{I}$$

$$FOS = \frac{\sigma_{glassyield}}{\sigma_{max}}$$