Herbert Wertheim College of Engineering
UNIVERSITY of FLORIDA

Sunseekers Heliostat

Section 20722, Group 284H

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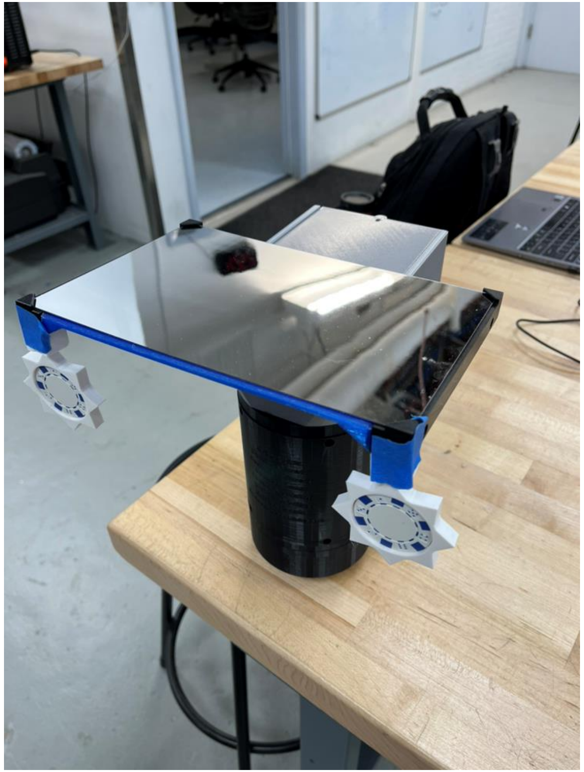
POWERING THE NEW ENGINEER TO TRANSFORM THE FUTURE

Hedgehog Concept and Value Proposition

Low maintenance and easily serviceable heliostat

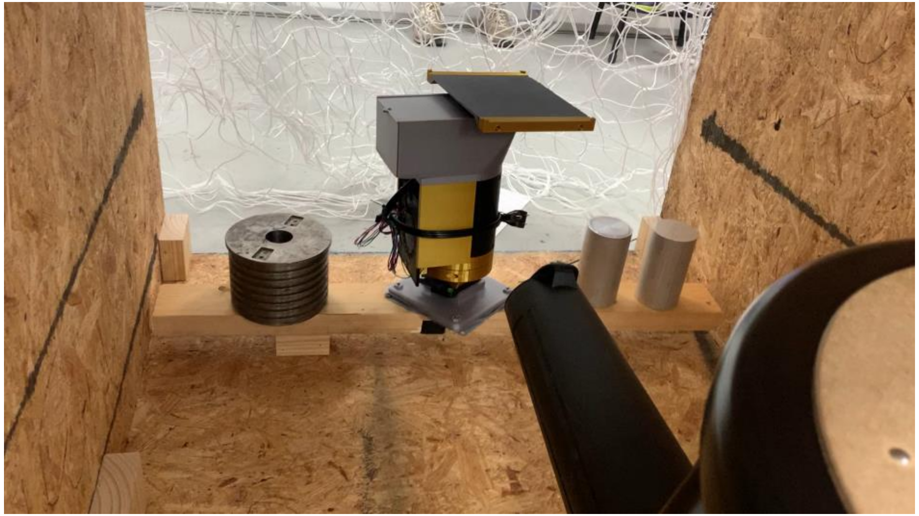
- Motors, wiring, electronics, and most moving parts contained within the body
- Conventional bulkhead plug to exterior power source
- Multiple ports of entry to service internal parts
- 3D-printed structural components



Key Specifications

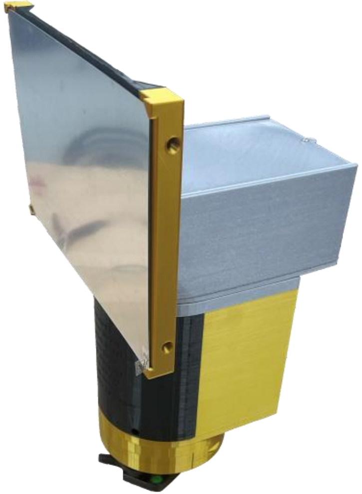
- 360 degrees of azimuthal rotation, 90 degrees of elevation
  - Azimuth resolution: 0.08°
  - Elevation resolution: 0.12°
- Survived winds of over 120 MPH in testing
- OTS power supply, motor drivers, stepper motors, mirror, sensors, limit switches, microcontroller, and motor drivers
- Compact size: 23.5 cm x 18.0 cm x 35 cm
- High resistance to back-drive

Wind Survivability Test



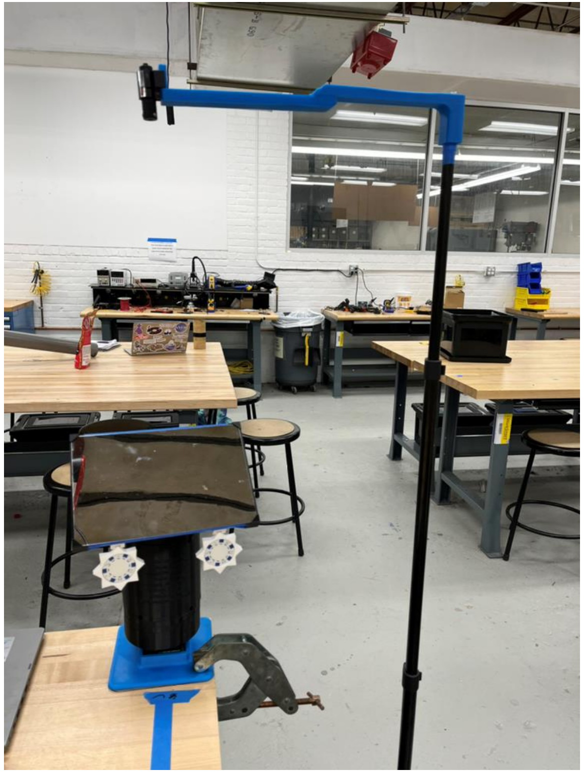
Video courtesy of Dr. Matthew Traum, University of Florida

- Leaf blower (very high tech)
- 120 mph wind
- No damage

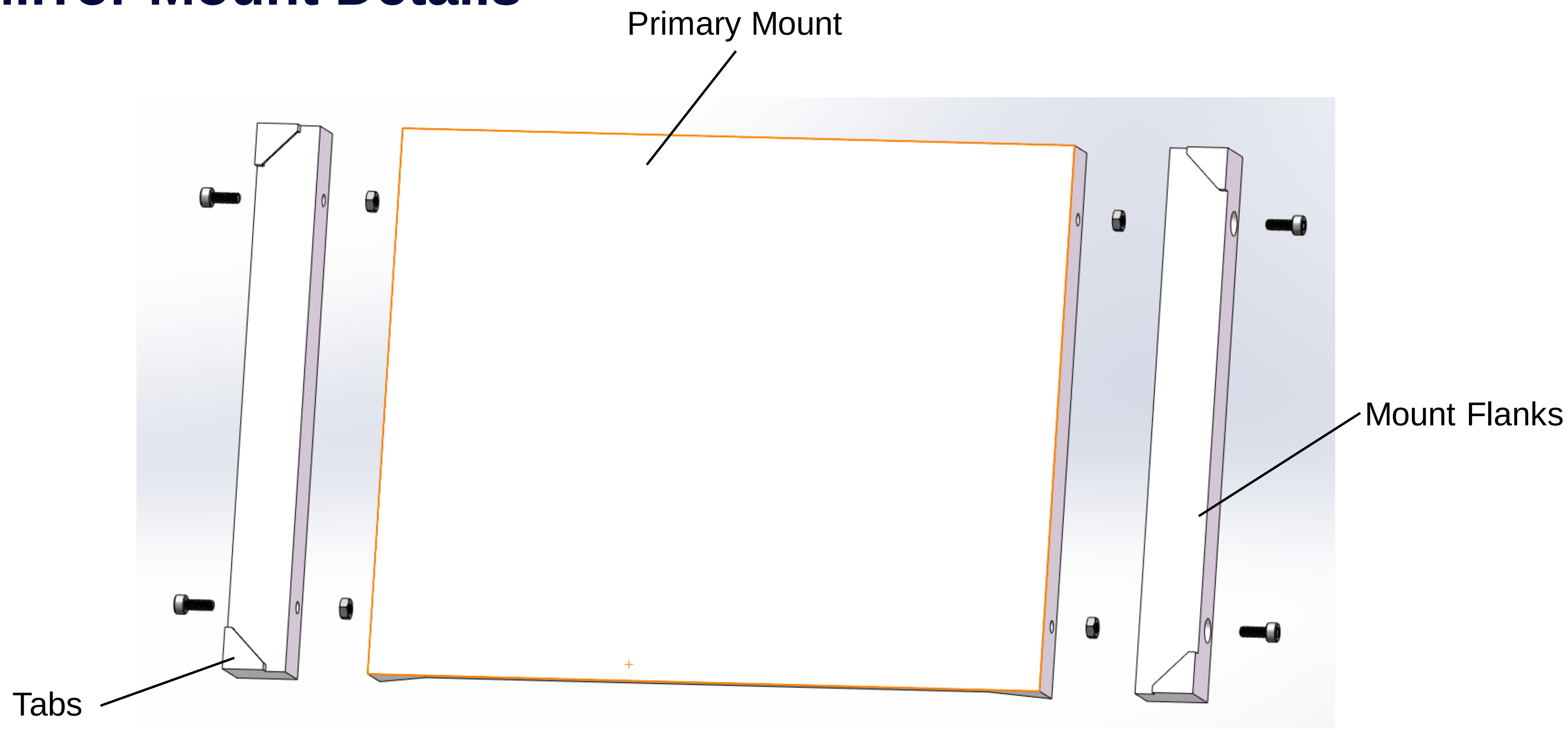


Rain/hail safety mode

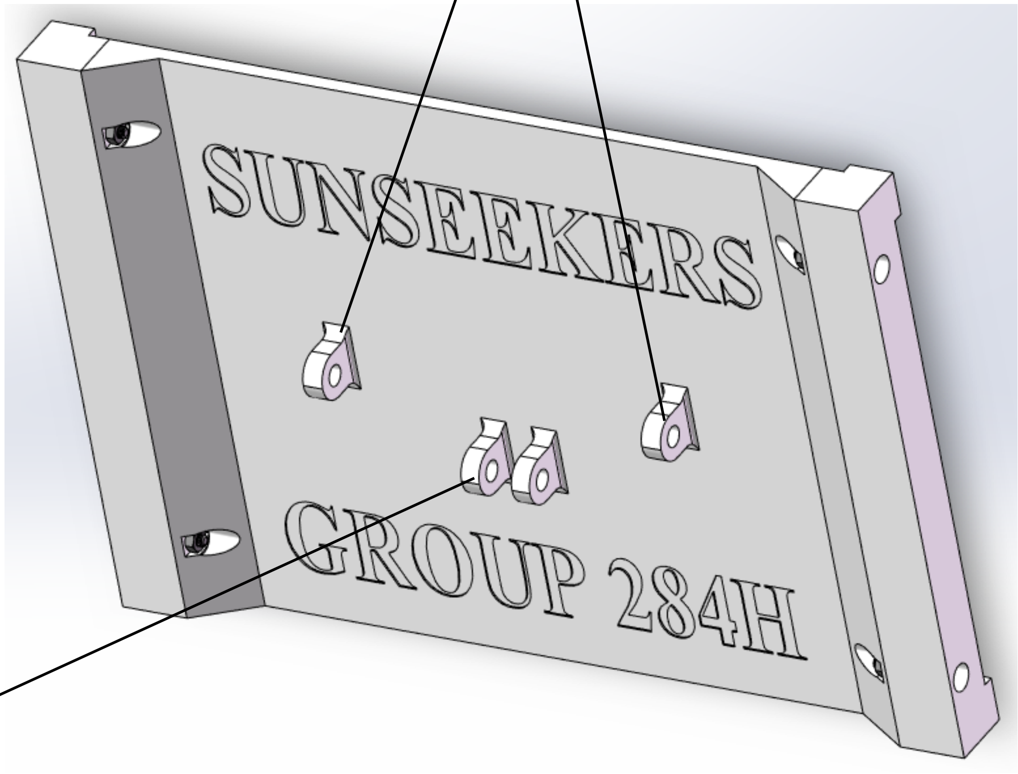
Laser Reflection Targeting Test



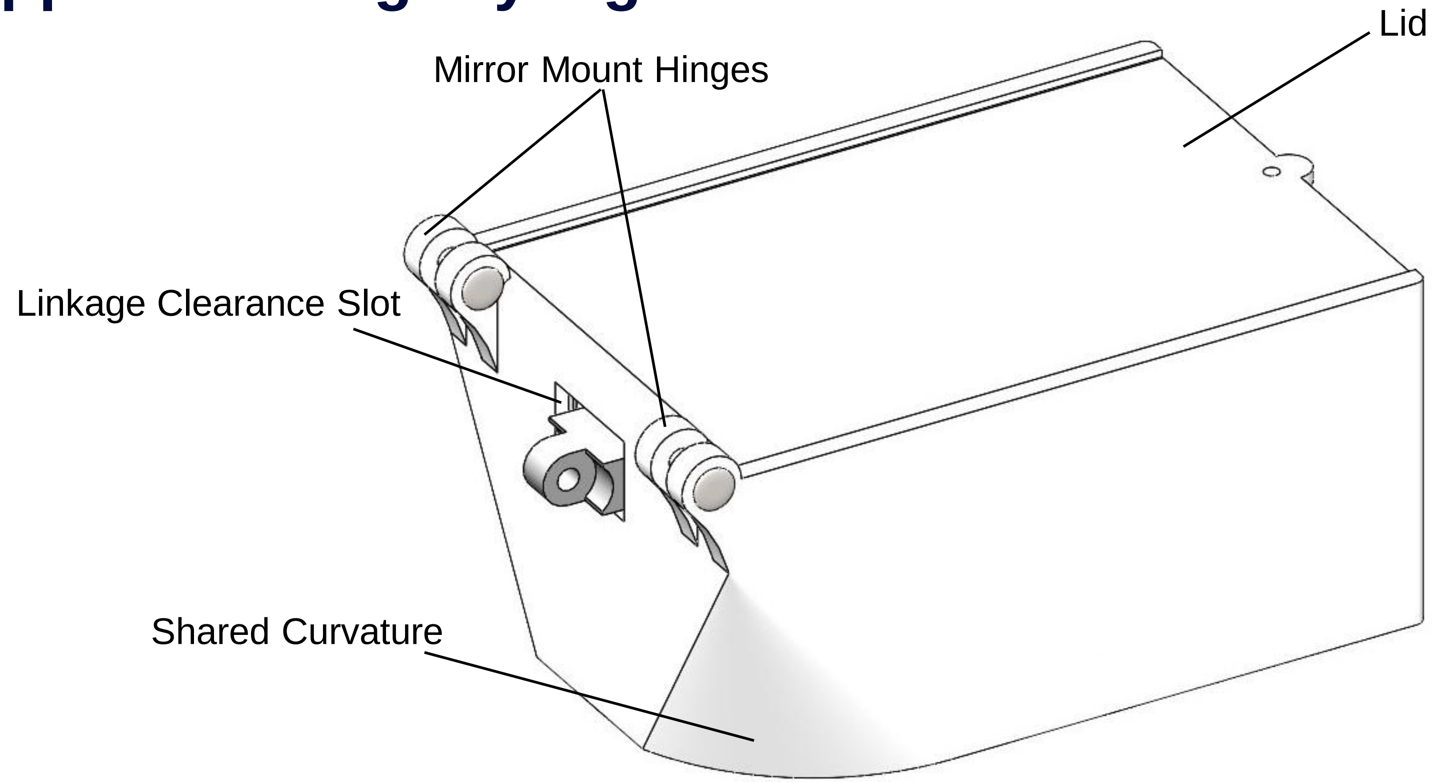
Mirror Mount Details



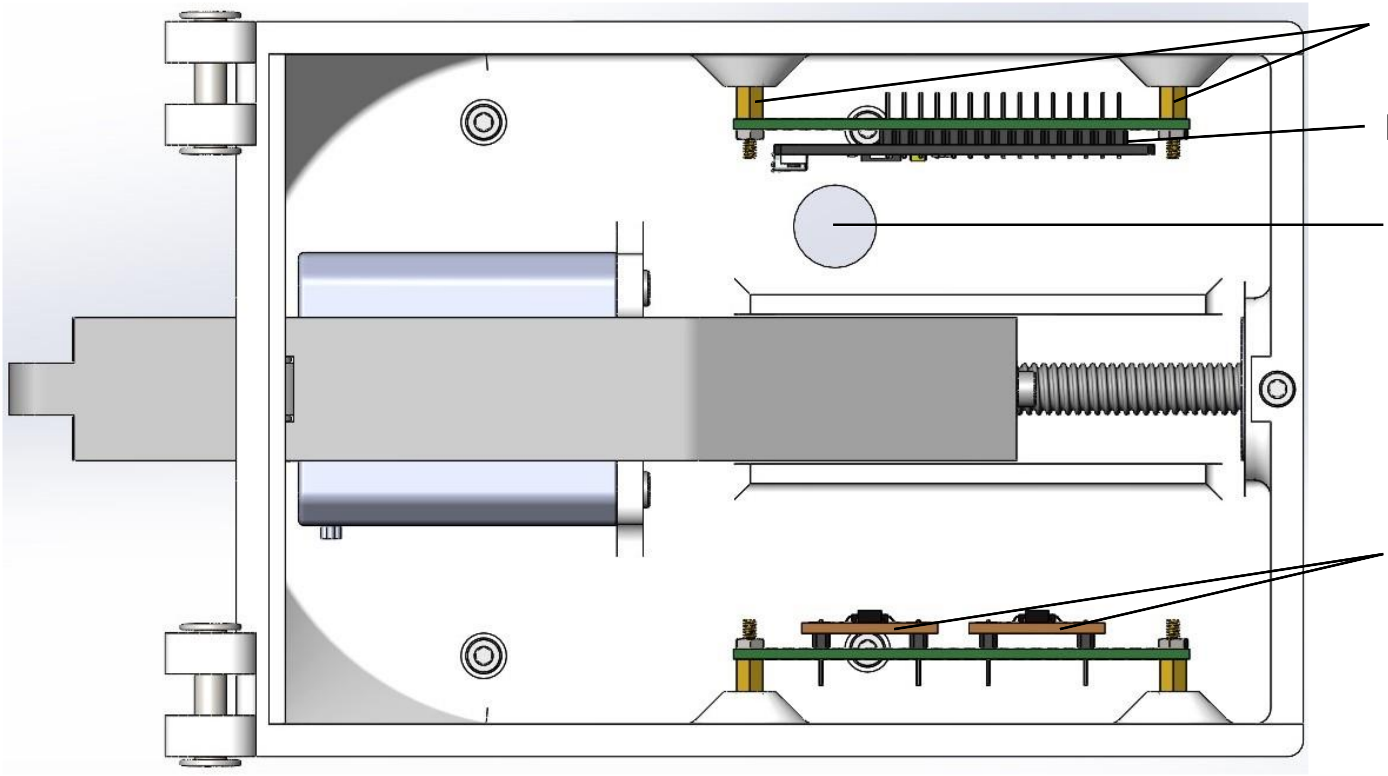
Mirror Mount Details



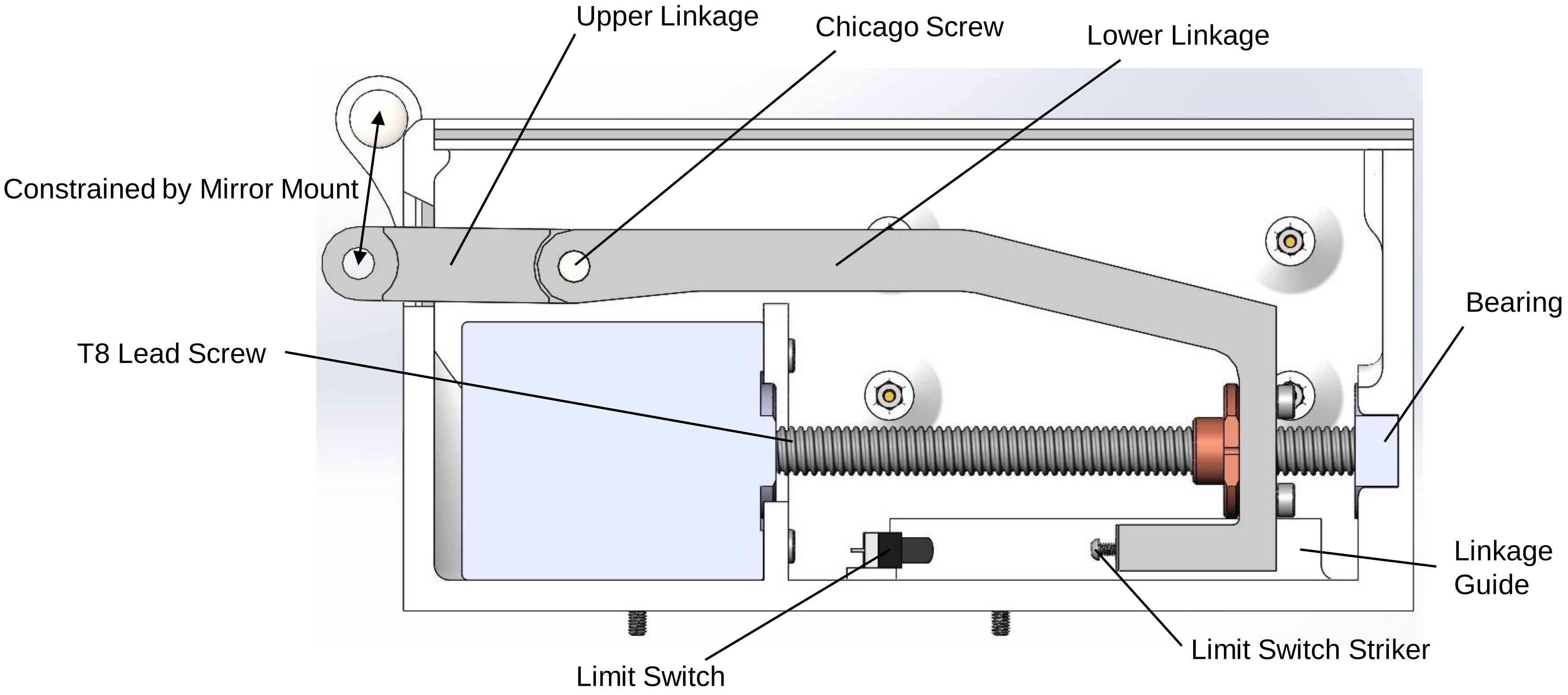
Upper Housing Styling



Upper Housing Electronics and Wiring Provisions

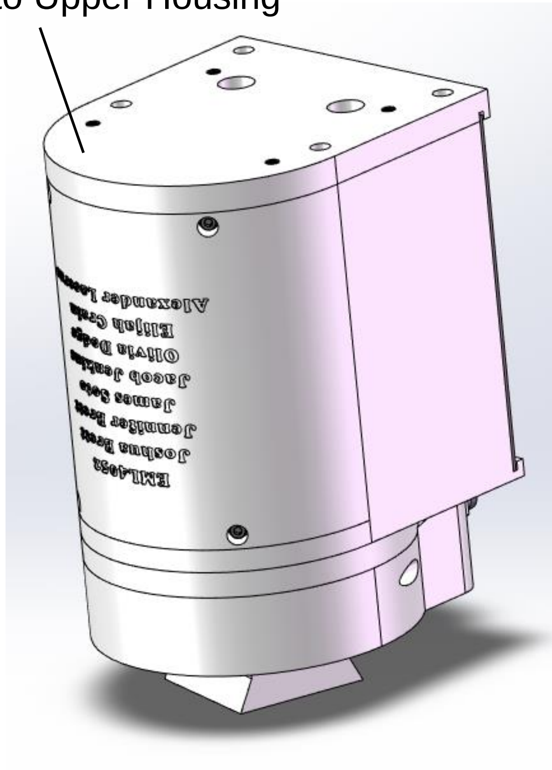


Lead Screw, Linkage, and Elevation Limit Switch

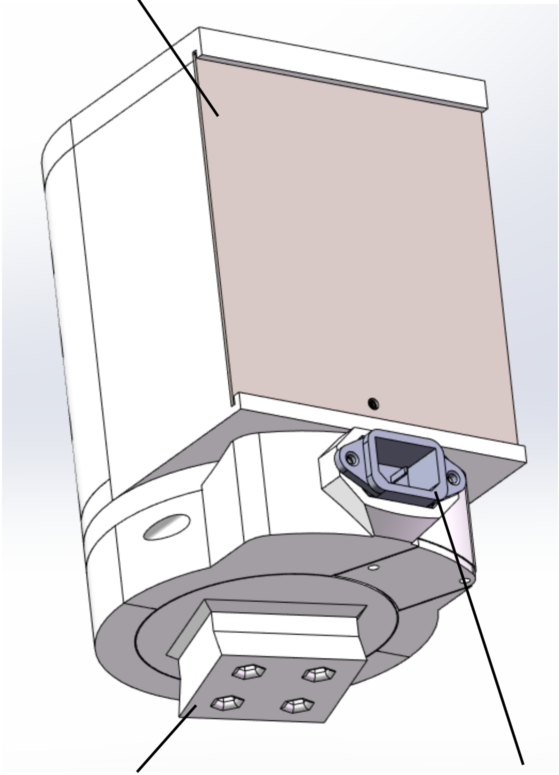


Lower Housing Styling

Attachment to Upper Housing



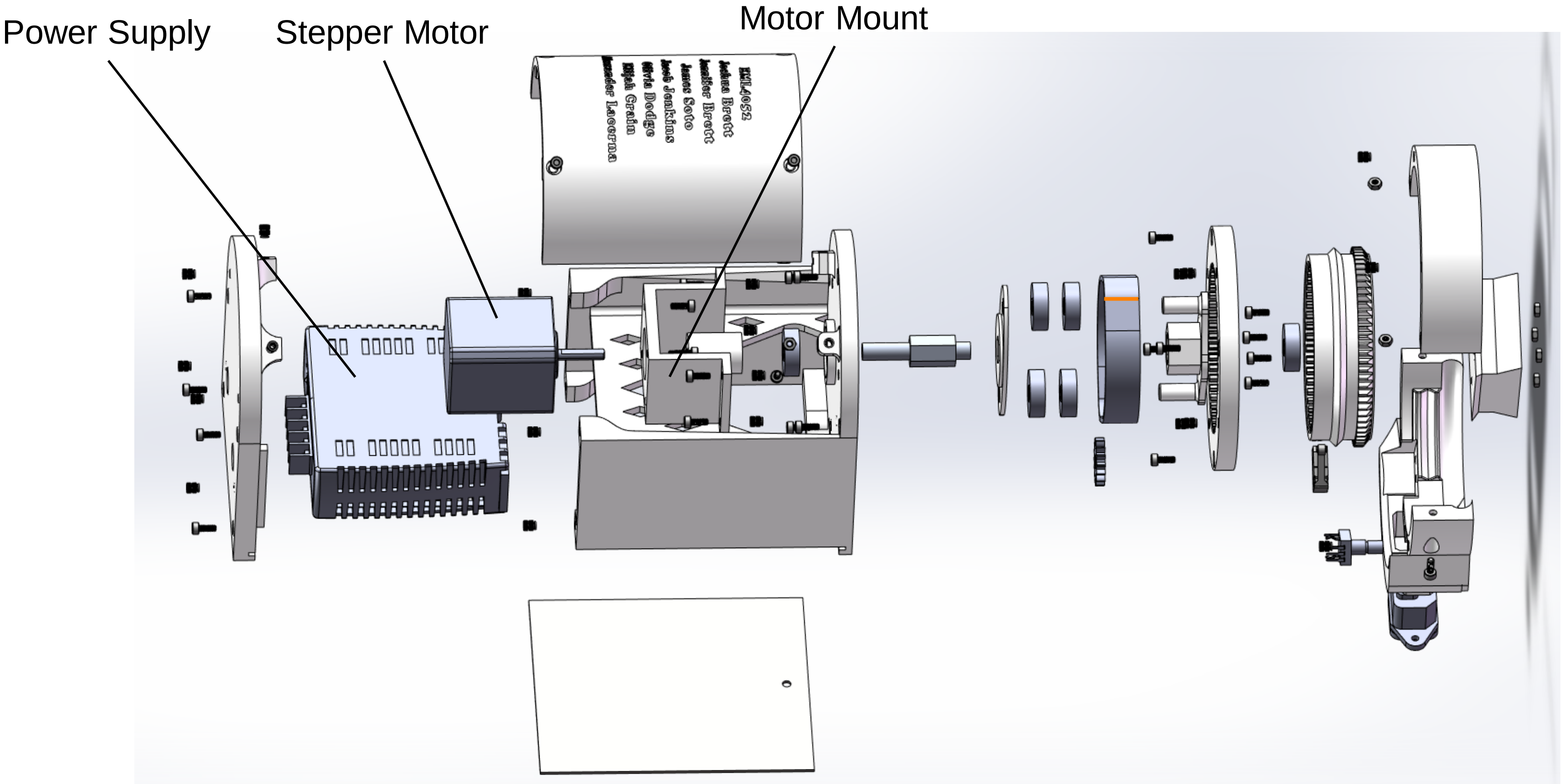
Sliding Panel



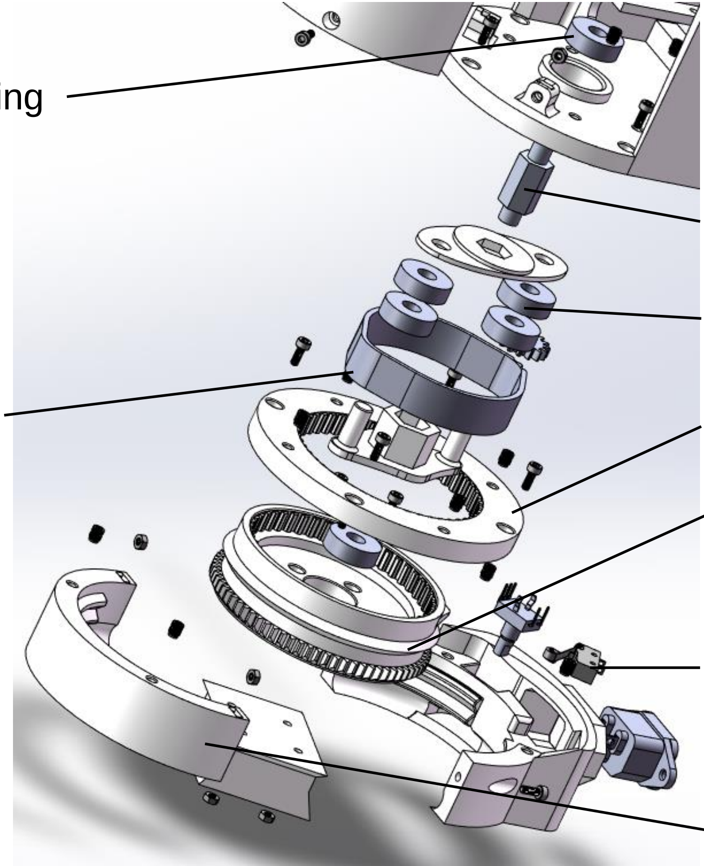
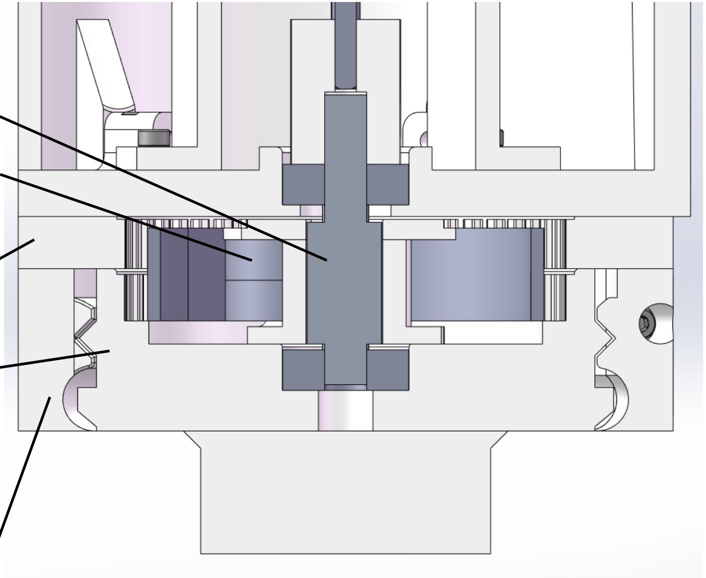
Quick-Release Mount

Bulkhead Plug

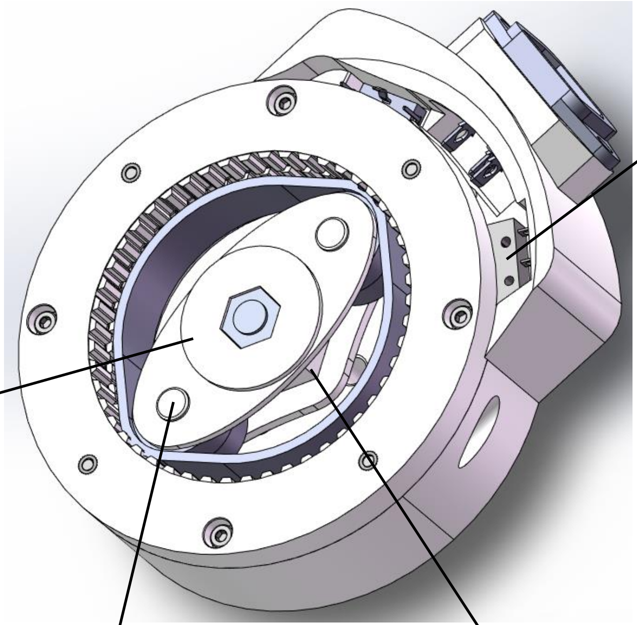
Lower Housing Key Features

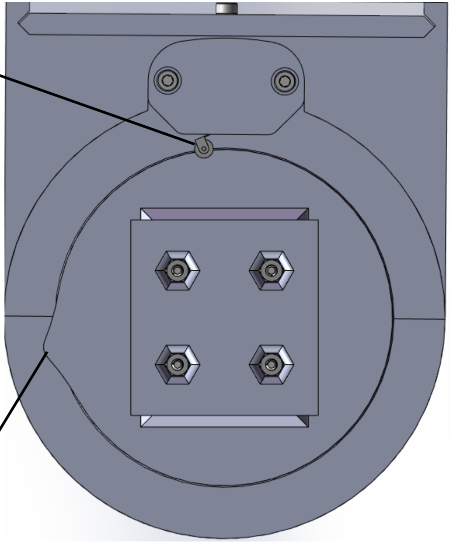


Lower Housing Key Features

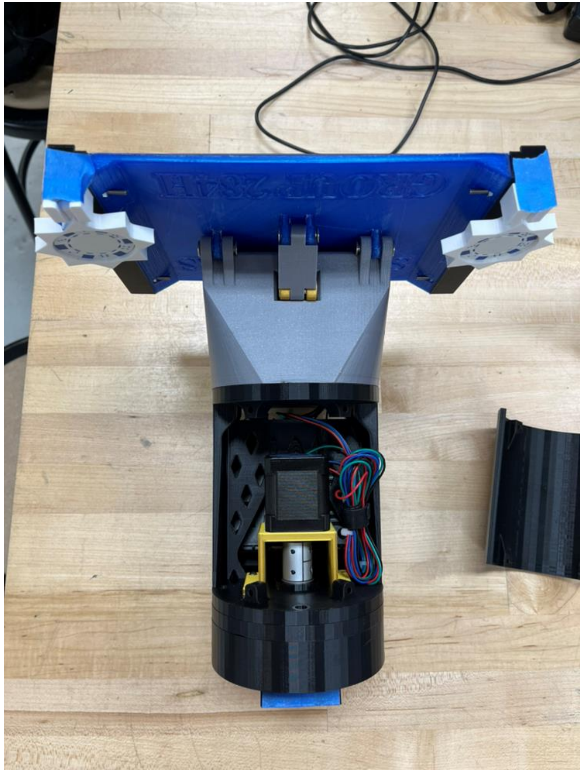



Azimuthal Rotation Mechanism





Internal Wiring & Power Connections



Design Analysis – Mirror Mount

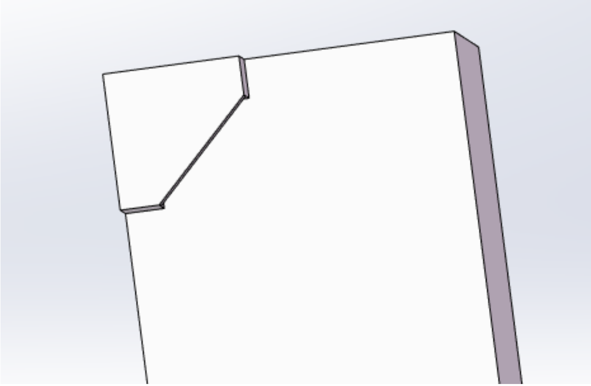
Bending analysis to determine required thickness

- Flat plate model
- Resultant load from 90 MPH wind pressure acting with a lever arm of 115 mm
- $\sigma_{max} = \frac{M * \frac{t}{2}}{I} = 7.5$ MPa for n = 2
- $F = qA = \frac{1}{2}\rho v^2 lw = 17.5$ N
- $I = \frac{bt^3}{12}$
- $t_{min} = 3.236$ mm
- $t = 4$ mm used in design

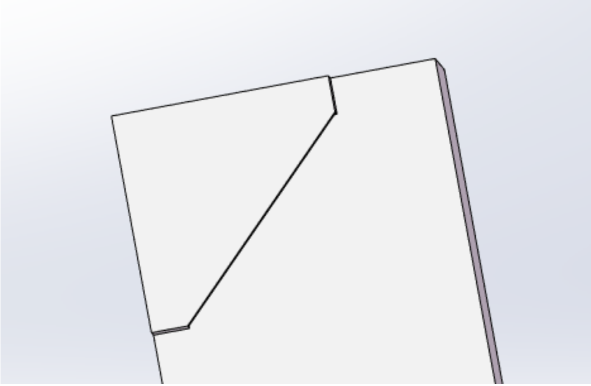
Design Evolution – Mirror Mount

Mirror attachment method

- Originally planned to use mirror adhesive
- V1: 5 mm leg tabs
- V2: 10 mm leg tabs



V1 mirror tabs

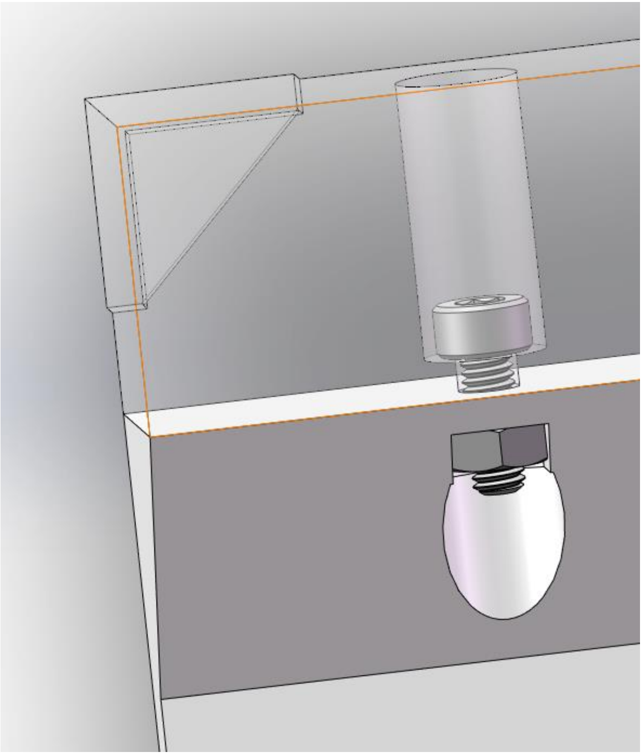


V2 mirror tabs

Design Evolution – Mirror Mount

Mount flank attachment method

- V1: Strong adhesive
- V2: M3 fasteners with pocket holes and hex profile
    - Already used in other parts of the assembly

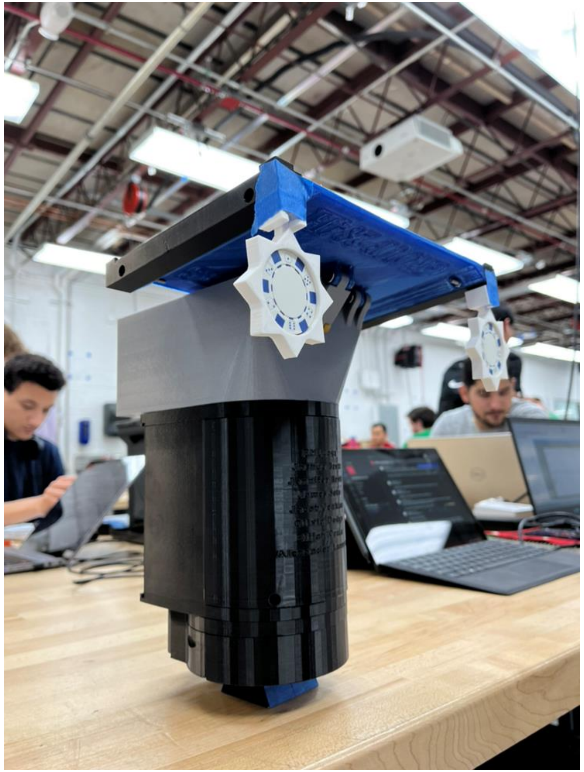


V2 mirror mount flank attachment

Design Evolution – Mirror Mount

Counterweights

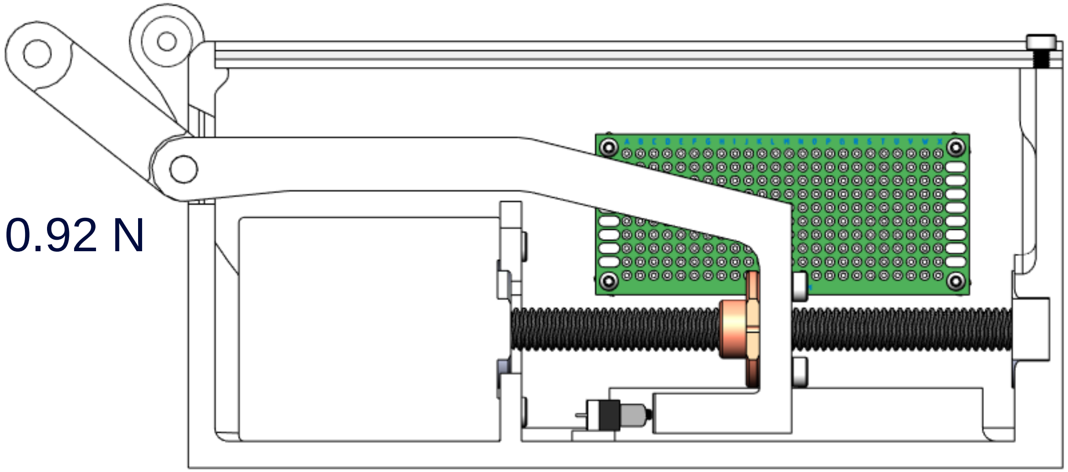
- Slack observed in elevation control
- Counterweights added to maintain consistency
- Final production weights will be heavier



Design Analysis – Linkage

Bending analysis to determine required thickness

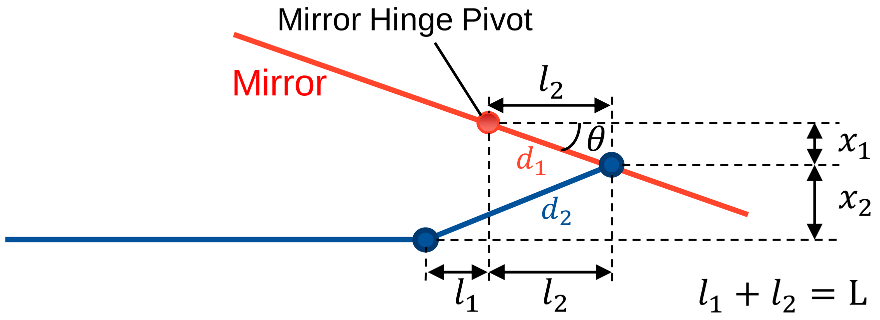
- Modeled as a cantilever beam
- $\delta = \frac{FL^3}{3EI}$
- Static loading force: 0.56 N
- Clearance: 0.565 mm
- Force to cause interference: 0.92 N



Design Analysis – Linkage Kinematics

Elevation range of motion

- Find required distance l_1 linkage must move for a desired elevation angle θ.
- Convert l_1 to a required step rotation by the stepper motor.



Side View Schematic

Design Analysis - Housing

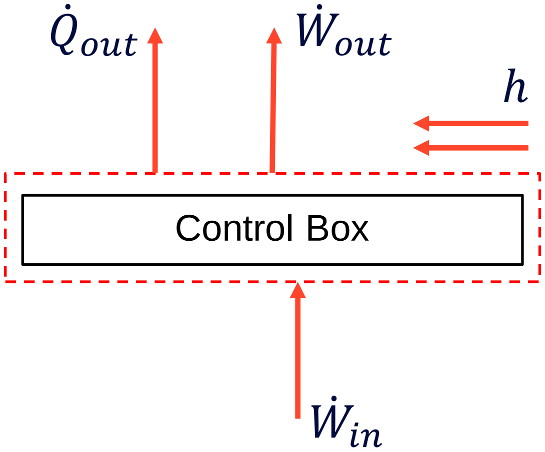
Internal Temperature Analysis (for electronics)

2 motor drivers (1A, 12V) = 24 W

Voltage regulator (4.5 A, 12V) = 54 W

Power out to motor (2 A, 12V) = 24 W

- $\dot{W}_{in} = 78\ W$
- $\dot{W}_{out} = 24\ W$
- $\dot{Q}_{out} = q_{rad} + q_{conv} = 54\ W$
- $q_{rad} = A_s(\varepsilon\sigma T_s^4 - \alpha G)$
- $q_{conv} = hA_s(T_s - T_\infty)$



- Solve for Ts:
- $A_s(\varepsilon\sigma T_s^4 - \alpha G) + hA_s(T_s - T_\infty) = 54\ W$
- $0.03775\ m^2\left[\left((0.39)\left(5.67\times10^{-8}\frac{W}{m^2\cdot K^4}\right)(T_s^4) - (0.31)\left(1367\frac{W}{m^2}\right)\right) + \left(20\frac{W}{m^2\cdot K}\right)(T_s - 313.55K)\right]$
- $T_s = 324.48\ K = 51.33\ ^\circ C$

Cost Table Summary

- Prototype and 3,000-unit production run unit cost

Prototype Cost		Mass Production Cost	
3-D printed parts	$28.75	3-D printed parts	$24.73
Machined parts	$13.72	Machined parts	$11.57
Provided OTS parts	$98.39	Provided OTS parts	$77.73
Chosen OTS parts	$39.14	Chosen OTS parts	$29.36
Total cost	$178.27	Total cost	$143.39
Total cost excluding provided OTS parts	$81.61	Total cost excluding provided OTS parts	$65.66

Summary

This design is focused on ease of construction as well as ease of maintenance. With multiple points of access all functional parts can be accessed and modified readily. Furthermore, this design is protected against its environment with fully shielded motors and electronics, dust and debris is no concern. The orthogonal drive system operates well under the required 0.5 degrees of accuracy to provide optimal power output to the receiving tower.

With readily removable paneling, integrated electronics, and simple thoughtful design, this heliostat is optimal for in field performance and maintenance.

Conclusion

Key Features

- 360 degrees of azimuthal rotation, 90 degrees of elevation
  - Azimuth resolution: 0.08°
  - Elevation resolution: 0.12°
- 120+ MPH wind stability
- Compact size: 23.5 cm x 18.0 cm x 35 cm
- Wi-Fi controllability
- Low compliance
- Simple assembly and maintenance
- Shielded motors and electronics
- Cost is $28.39 under budget