EML4501 Fall 2021 Group 13
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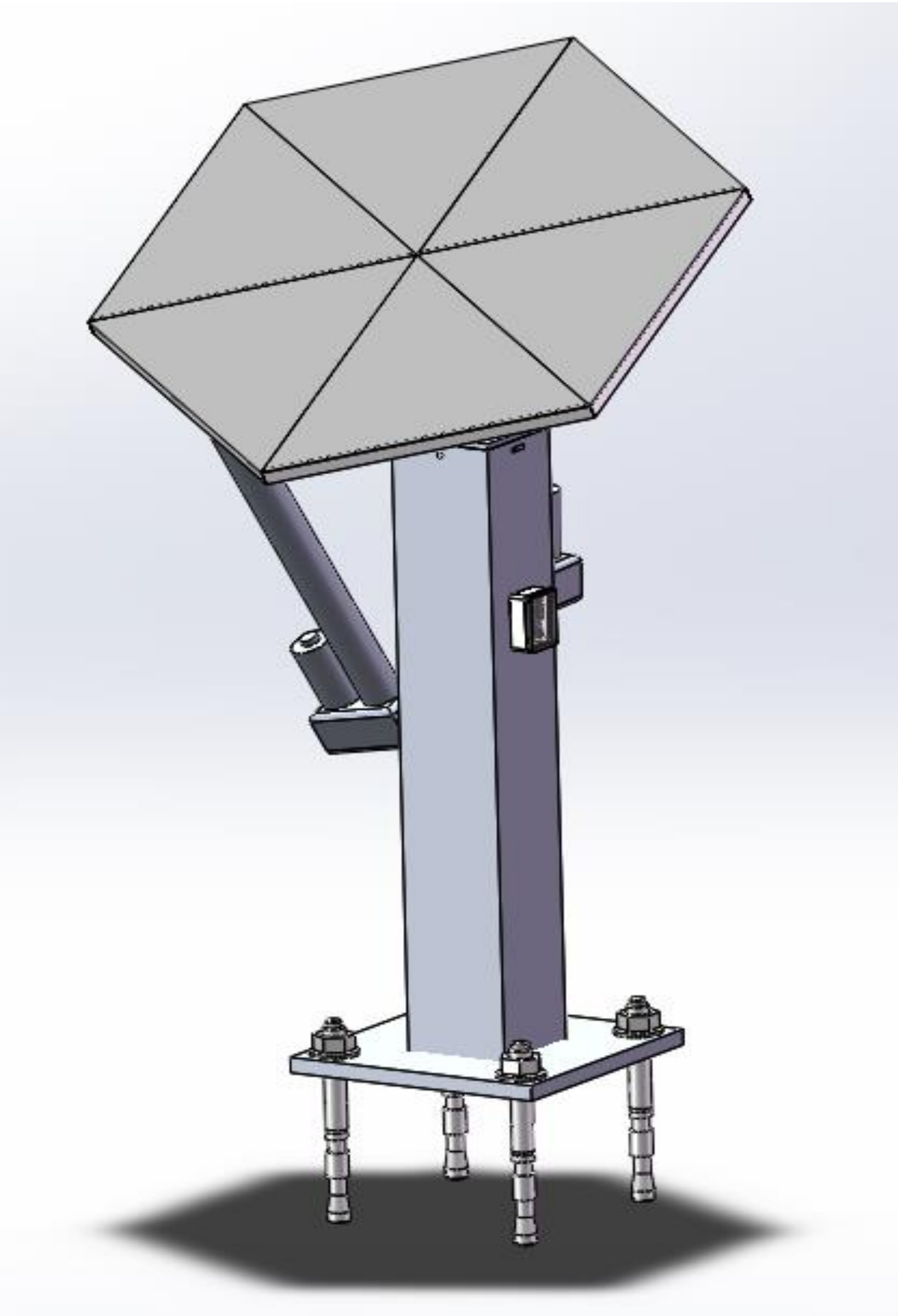
# Hive-Stat




## Abstract

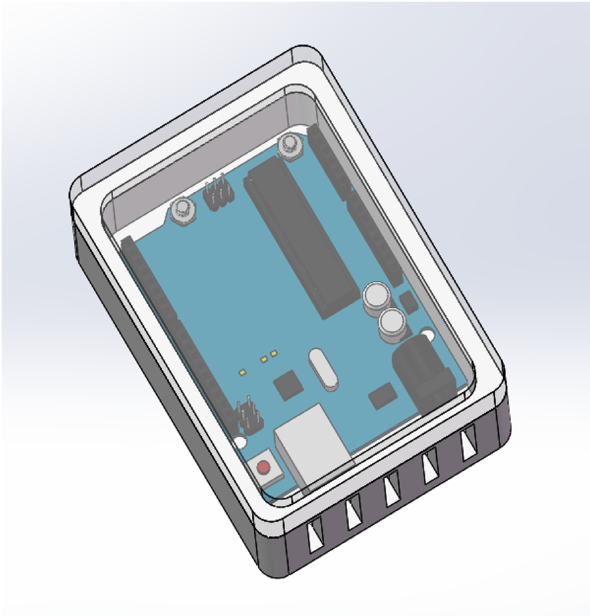
The Hive-Stat group believes in the simplicity found in nature and therefore used biomimicry to create a unique design with seamless and straightforward assembly. 'The Hive Stat' features a hexagonal reflective surface, designed after a beehive, to promote optimal tessellation between modules. The five major subsystems of the design can be classified as ground mounting, structure, angle actuation, controls, and reflective surface. Ground mounting is accomplished by expansion bolts, inspired by the mechanics of tree roots, which anchor into the ground by expanding once established. The structure body is a hollow Aluminum pillar, designed after a tree trunk, which maintains a minimal footprint, causing no shading of the surfaces to allow the reflective surface optimal solar radiation opportunity. The heliostat optimizes solar energy capture by repositioning the array with actuators to track the sun throughout the day. In this design, angle actuation is accomplished by the combination of a saddle joint and two linear actuators, mounted onto the pillar perpendicularly. The saddle joint is similar to the human opposable thumb joint, allowing for simultaneous motion across two axes. Control of the machine is accomplished by a computer with pre-coded solar location data. Lastly, the hexagonal surface is reflective due to mirrors that are clipped onto the hexagon and adhered. The Hive-Stat provides a low-cost design with high optical efficiency and a simple installation process. Nature has already selected these design systems, here they are simply implemented to form a heliostat.

## Product Functionality

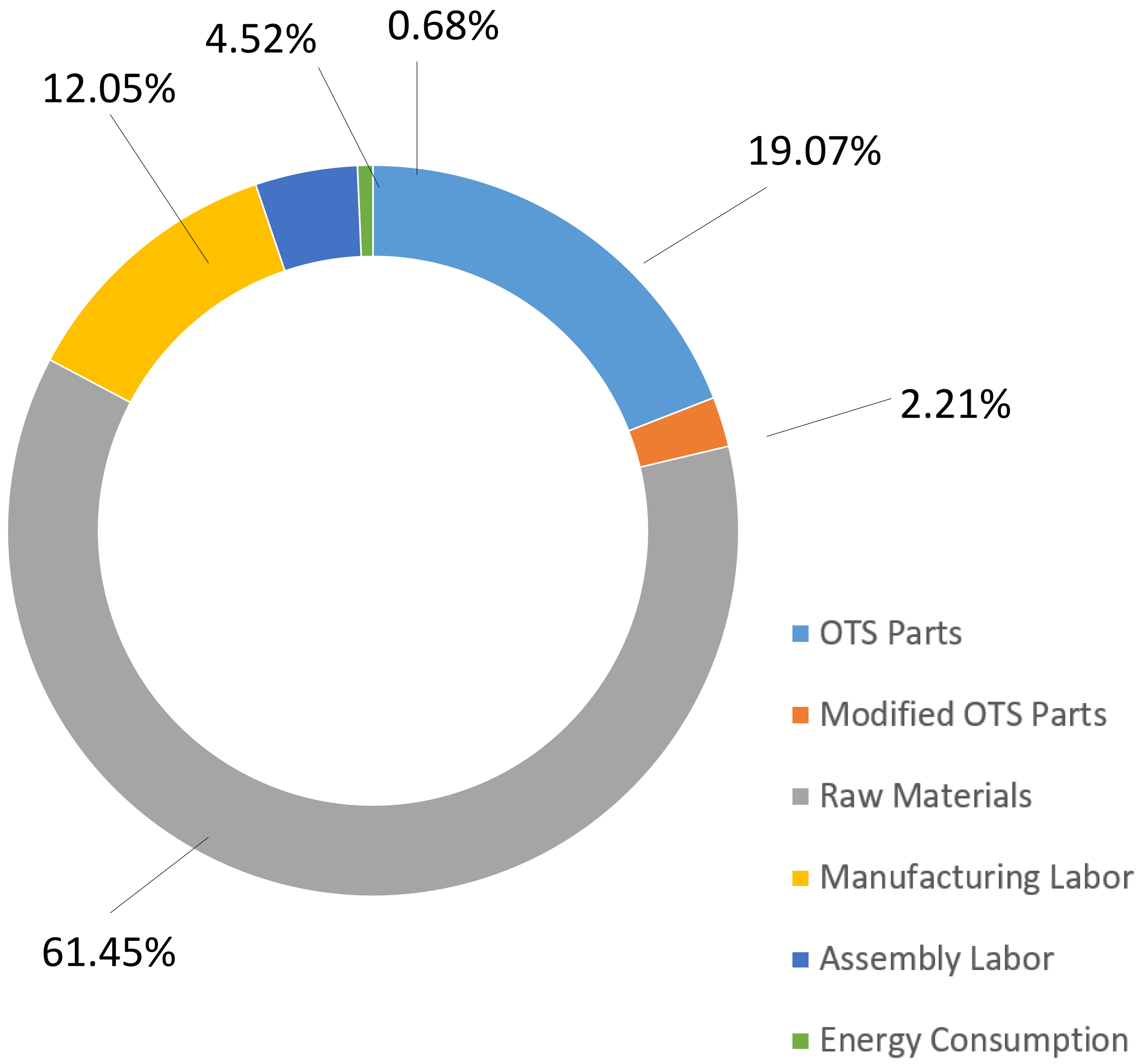
The Hive-Stat uses a tessellating hexagonal reflecting surfaces to minimize wasted space between modules. Angle control is accomplished using two linear actuators about a two-axis hinge using commands from a pre-coded solar path using the module location. The module is attached to the ground using expanding bolts.

## Controls

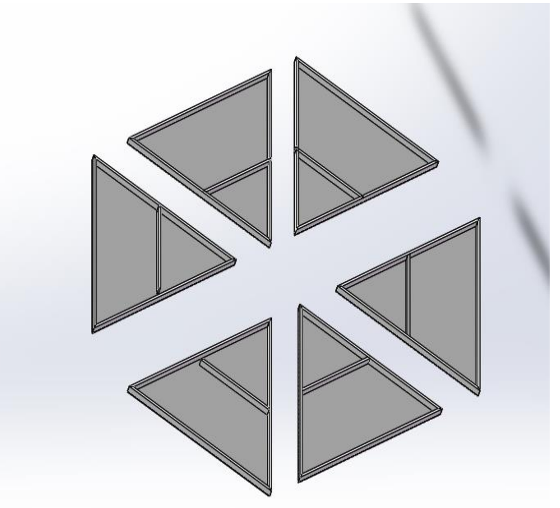


- The Sun's path is pre-coded for the module's location using astronomical data
- Arduino controller communicates with central computer and provides commands to actuators
- Controller box is waterproof, but slits at bottom provide airflow to prevent overheating

## Cost Overview

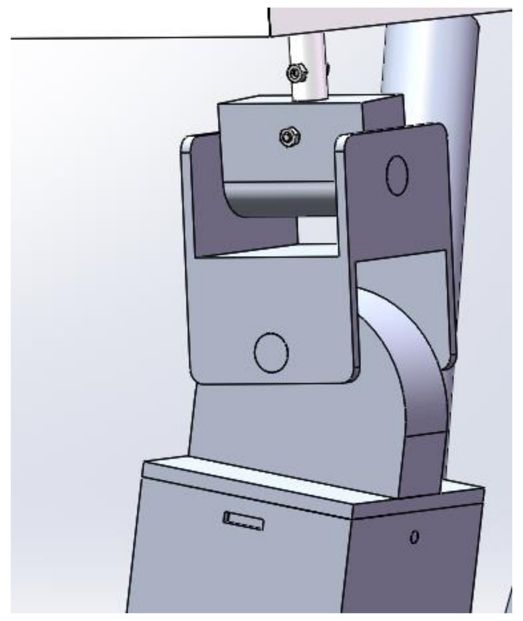



## Reflecting Surface



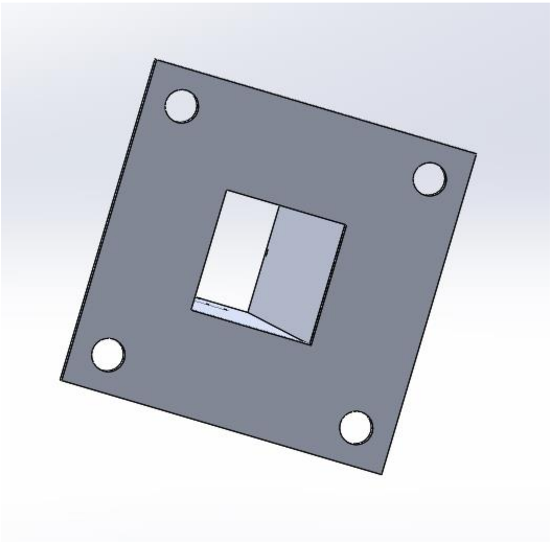
- Uses six interlocking panels to form a hexagonal shape that can tesselate with neighboring heliostats
- Attached to a plastic frame by adhesive
- A rod fits into the frame and connects the panel to the two-axis hinge

## Actuation



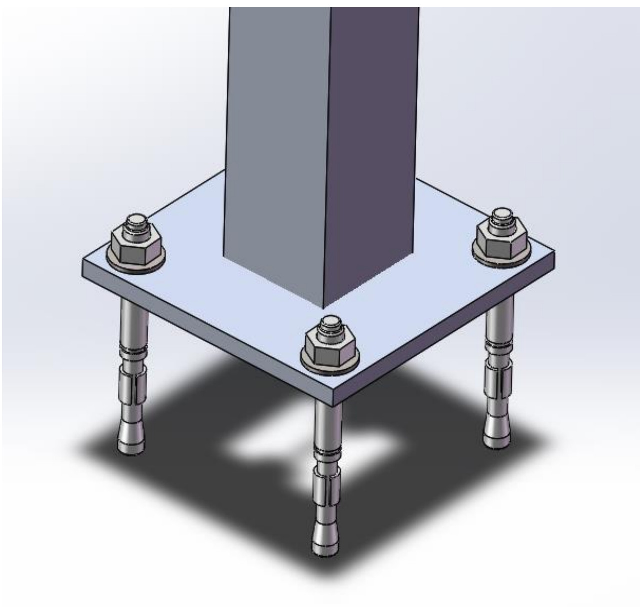
- Uses two linear actuators at opposite ends of the panel to control rotation
- Panel rotates about a two-axis hinge that allows full range of motion without interference

## Structure



- Design uses a hollow square pillar to support the reflecting surface and attach the actuation and controls components
- Flange at bottom provides wide base for expanding bolts to anchor the heliostat
- Cover at top of pillar prevents accumulation of dust or sand in the hollow section

## Ground Mounting



- Uses four expansion bolts to anchor base into the ground
- Bolts at each corner of pillar flange to provide stability in resisting high winds

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| Small Area Innovation | Heliostat designs must be innovative with respect to their small surface area. | Qualitative score measuring innovative aspect of design. | Winning concept received a 7 out of 10. |
| Small Reflecting Surface | The total reflecting surface of a module must not exceed 1 squre meter. | Surface area of each individual heliostat within a module, smaller meaning better. | Each reflecting surface is 0.1 square meters. |
| Heliostats per Module | The number of heliostats per module must be between four and sixteen. | The number of heliostats per module, with a larger number being rated higher. | Each module contains 6 heliostats. |
| Mitigation of Optical Losses | Tracking errors when following the Sun must be less than 0.5 degrees. | Tracking error using shortest adjustment time. | Tracking system is precoded, therefore close to exact. |
| Solar Tracking | The module must have the capability to track the Sun throughout the year. | Overall angle accuracy of control subsystem. | Rotating for 0.1 seconds gives angle control of 0.1 degrees. |
| Shading Minimization | Individual heliostats within a module must not shade each other. | Solar angle from zenith required to shade heliostat reflecting surfaces. | A 90 degree angle is required, so no shading is expected. |
| Tower Targeting | Heliostats must be able to reflect light to a tower up to 100 meters tall. | Maximum angle reflecting surface can rotate from vertical. | The surface can rotate at least 22.5 degrees from vertical. |
| Price Cap | A single module should not exceed $100 to manufacture and install. | Total cost of subsystem. | Cost exceeds $100 using retail prices, but is predicted to fall beneath with bulk pricing. |
| Heliostat Module Manipulation | Efficiency of the reflection must also consider frequency of angle adjustment. | Minimum time between angle adjustments. | Adjustment frequency is limited only by lifetime of actuators. |
| Use of Space | At least 90% of the module surface area should be reflective. | Proportion of non-reflecting area, with a lower number receiving a higher score. | Hexagonal shape ensures near 0 non-reflecting area. |
| Part Pricing | Individual part prices must not exceed off-the-shelf prices. | Ratio of off-the-shelf parts to total number of parts. | Around 20% of parts are off-the-shelf, with 60% being comparable to off-the-shelf. |
| Washable Surface | Reflecting surfaces must be able to withstand water jets used in cleaning. | Qualitative score of the surface's ease of cleaning with water. | The surface is glass with a regular shape, receiving a 10. |
| Factor of Safety | All mechanical factors of safety should be at least 2. | Lowest factor of safety of the subsystem. | Lowest measured factor of safety was around 3.5. |
| Lifetime | The module should be operational for at least 20 years. | Lifetime of the subsystem in years or cycles, depending on subsystem. | System should be able to perform for at least 20 years. |
| Operation Location | The module must be able to function in the environmental conditions at the site. | Thermal conductivity of reflecting surface, with the ideal dissipating heat quickly. | Thermal conductivity of glass is around 1.05 W/mK. |
| Thermal Input Power | The modules must be able to sustain the central plant running at 1 MW. | Energy in Watts reflected from one module, using average values. | Thermal Input Power of one module is around 300 W. |
| Solar Concentration Ratio | The modules must provide a concentration ratio of at least 1000 Suns. | Solar concentration ratio of one module, using average values. | Solar Concentration Ratio of one module is around 333 Suns depending on collector. |