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Accu-Stat

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Abstract

The Accu-Stat is a small-scale heliostat design that specializes in accurate solar tracking while remaining cost efficient. Compared to other proposed designs, the Accu-Stat's accurate tracking allows it to optimize the efficiency of the heliostat field by reducing losses of reflected light between the heliostat and the receiver, which allows the field to maintain a higher solar concentration ratio, producing more energy for the same cost as other designs.

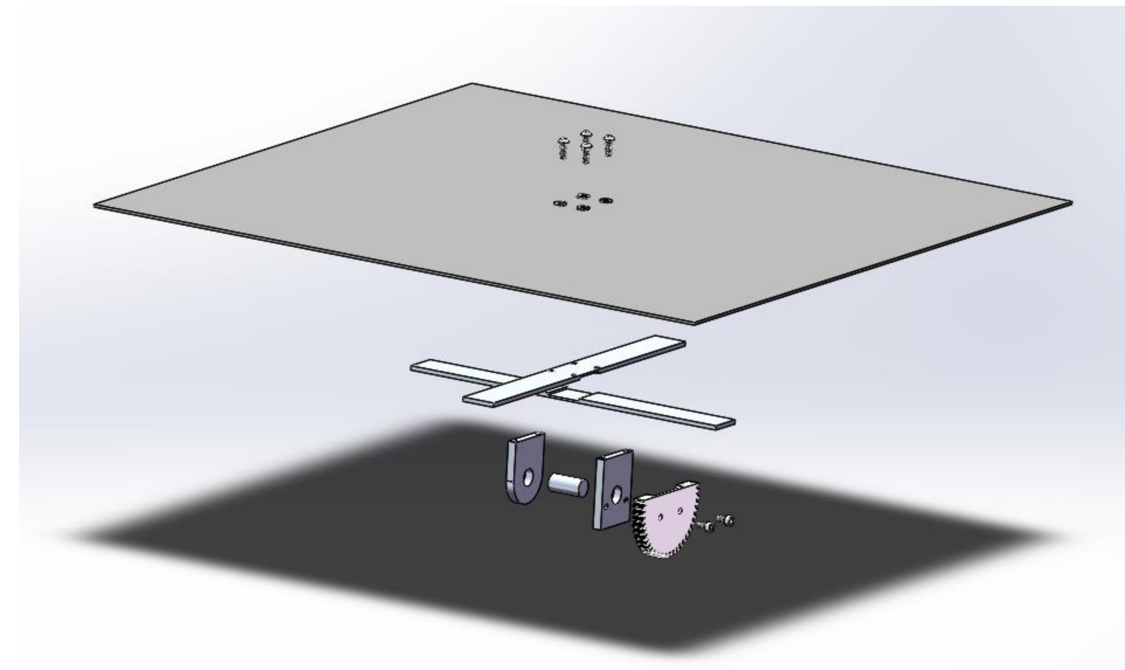
This accuracy is accomplished through two features of the Accu-Stat. The first of these is a set of cameras mounted on the central tower of the heliostat field. A maximum of 4 cameras are required to capture images of the entire field, which are then subject to an image processing algorithm that determines the orientations of the heliostats. When combined with the initial tracking algorithm of the heliostats, this provides closed loop feedback control, which is significantly more accurate than the open loop control systems of the other designs.

The second notable feature of the Accu-Stat is its actuation system, which utilizes a stepper motor and gear system to provide slow but precise movement of the heliostats. The actuation system has a minimum angle change of 0.45˚, a significantly smaller angle than the change in solar angle both altitudinally and azimuthally. This allows the heliostat angle to be closer to the required angle for a larger portion of the day, ensuring the increased accuracy of the Accu-Stat.

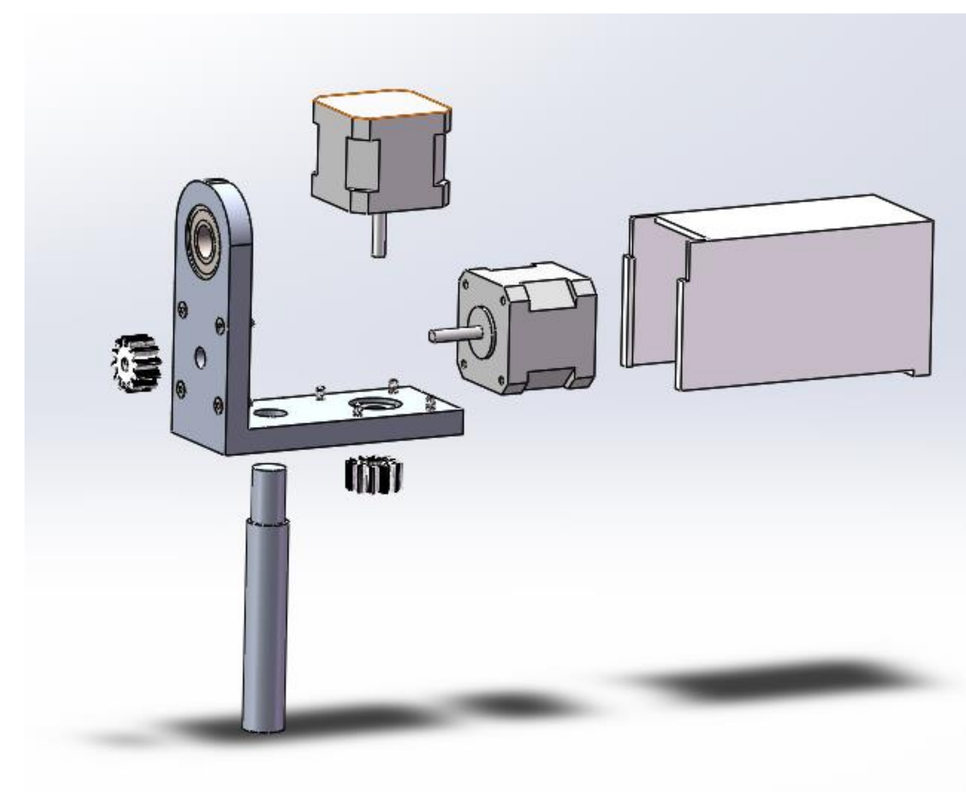
Full Assembly

Subsystems

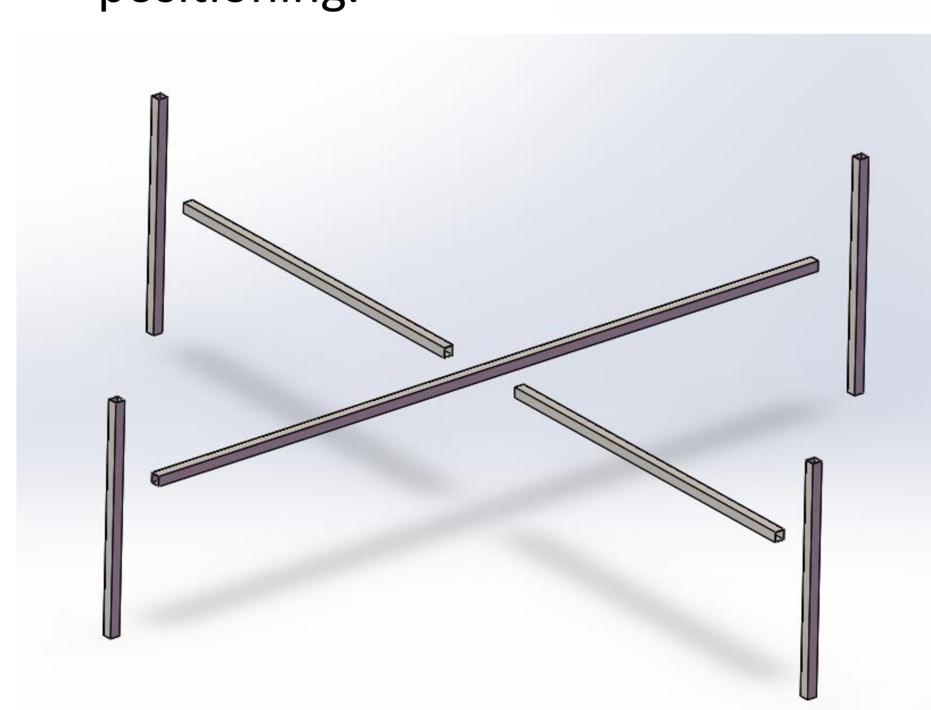
The Accu-Stat consists of four main subsystems: the reflective, actuation, frame, and tracking systems.



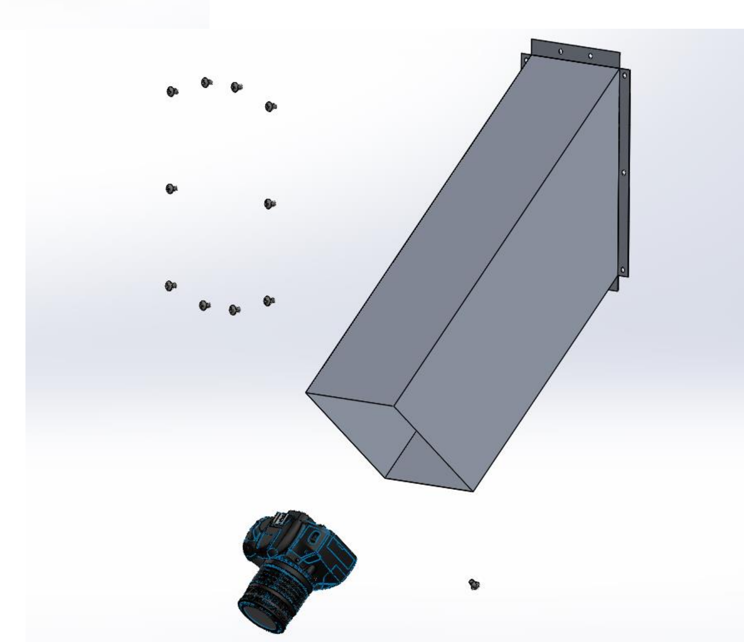
- Flat Acrylic mirror with attachments.
- The acrylic material is cheaper and lighter than standard glass.



- Nema 17 Stepper motor actuation system with 4:1 gear reduction.
- System is a compact, space-saving design.
- Small motor step size results in increased accuracy of positioning.



- ASTM A500 Grade B Carbon Steel tubing support structure.
- Choosing steel tubing over traditional bar stock leads to lower costs, while meeting required strength.

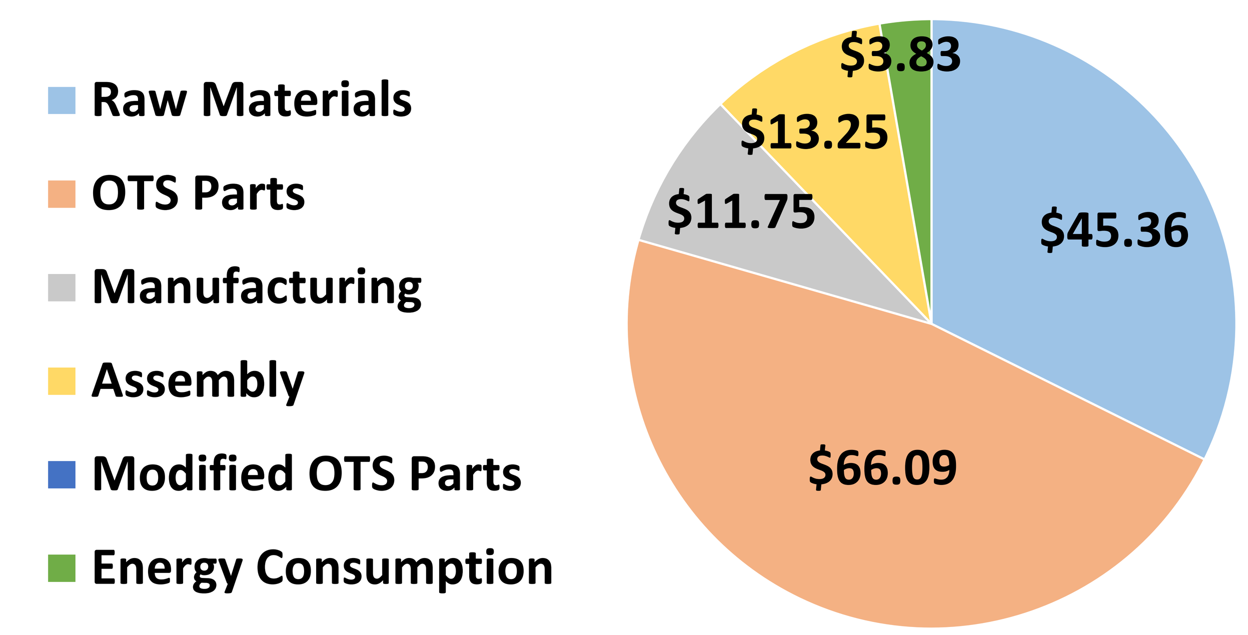


- Nikon D2X camera with a sheet metal mount for the central tower.
- Photos taken with camera will undergo image processing to determine heliostat orientation.
- The mount is four-sided to protect the camera from the elements.

Product Functionality

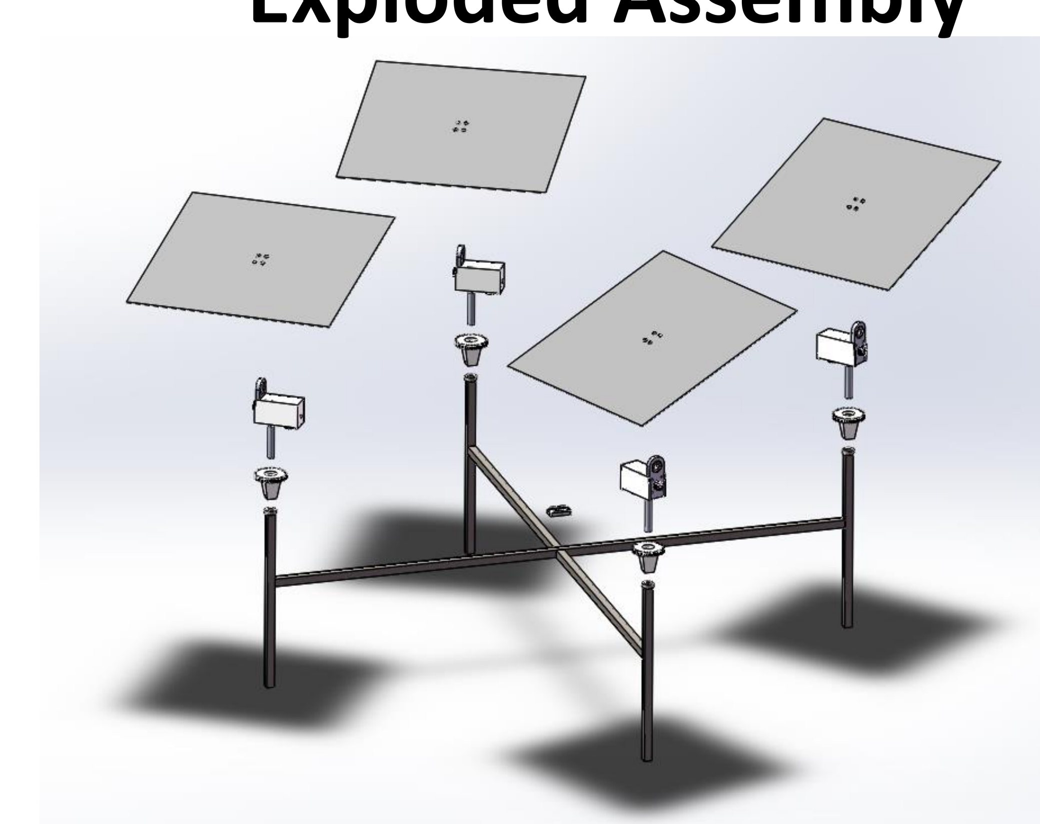
The Accu-Stat is a small-scale heliostat module with a focus on high-accuracy tracking at a low-cost price. Two Nema-17 stepper motors with a gear system are used for actuation in the azimuth and elevation angles for each heliostat. Tracking will be achieved through central tower calibration and the use of edge detection image processing software, which can determine the orientation of each heliostat and thus can be used with sun-tracking data to achieve optimal orientation for each heliostat. A NodeMCU control board will be used to direct each heliostat to its desired position, connected to a central computer hub through Wi-Fi. The heliostats themselves are made of acrylic mirrors, which when compared to standard glass mirrors are cheaper, lighter, and flexible, thus providing resistance to breaking. The lighter weight allows the mirrors to be moved with less torque. The frame is an x-shaped design comprised of ASTM A500 Grade B Steel tubing, which reduces the material needed for the module while providing sufficient support for worst-case wind forces in Las Vegas, Nevada. In total, the module will hold 4 heliostats with a total collection area of 1 m^2.

Cost Overview



Total Cost: $140.28

Exploded Assembly



Customer Need		Metric Quantification
Design capitalizes on innovations enabled by small heliostat size	1	At least 1 innovation
Total collection area of a heliostat module must be small	2	≤ 1 m2
Multiple heliostats per module	3	4 - 16
Mitigate optical losses due to tracking errors	4	Not to exceed 40%
Capable of Tracking sun	5	Must rotate > 90°
Minimize Shading Effects	6	0% shading
Must reach receiver mounting height	7	0 - 100 m
Module cost must be low	8	Less than $100/m^2
Sun tracking must be automated/computer controlled	9	1 controller/computer per module
Minimize non-reflecting area of heliostat	10	Reflective area at least 90% of module area
Individual parts must cost less than OTS parts	11	Part cost ≤ OTS part cost
Reflective Surface must be washable	12	Must withstand 20MPa
	13	Material must not react with water
Must meet minimum factor of safety	14	Must exceed N=2
Must have a long lifetime	15	Must exceed 20 years
System operates under ambient conditions in Las Vegas, NV	16	Withstand Temperatures of 38°F to 105°F
	17	Withstand average wind speeds 8.1 mph, max 90 mph
	18	Operates in 36°N
Field must deliver minumum input thermal power	19	1 MW
Must provide minimum solar concentration ratio	20	1000 suns
No light can miss the reciever	21	100%
Must run off of conventional power grid	22	Conventional power grid

Subsystem		Functionality
Reflective Surface	1	Uses acrylic mirrors
	2, 3	4 heliostats, 0.5mX0.5m, totaling 1 square meter
	8, 11	Acrylic mirror only $1.44 per square meter
	12, 14, 17	Uses backing for extra support
	13	Acrylic mirror not reactive to water or cleaners
	16	Acrylic melting temperature is 320*F
Actuators	1	Uses cheaper smaller motors
	4	0.45 degree accuracy
	5	Can rotate over 100 degrees
	8, 11	Costs roughly $4.50 per motor, OTS parts
	14, 17	Can hold position in average wind speed
	13	Shielded from water from cleaning or rain
	15	Stepper motor lifetime is 10,000 continuous hours
	16	Operating temperature of stepper is up to 212*F
	22	Uses standard 12 volt source
Sun Tracking/ Calibration	1	Uses a camera to increase accuracy
	4, 21	Increased accuracy with closed loop control
	7	Mounted on the tower
	8, 11	Shared between several hundred heliostats, $3 per module
	19, 20	Can view/compute several hundred heliostats at a time
Base/Frame	1	Uses less material and remains sturdy
	3	Supports 4 heliostats
	6, 7, 18	Minimizes shading using sun paths and receiver height
	8, 11	Module costs under $20
	9	Onboard computer can mount easily
	10	Very little surface area of base
	14, 15, 17	Using max wind speeds, N=2.8
	16	Steel melting temperature is 2500*F