HELIODON: A HANDS-ON DAYLIGHTING EDUCATIONAL TOOL

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ABSTRACT

In addition to the critical thinking and design skills taught in architecture school, architectural students must learn how passive and active strategies of sustainability interact within the buildings they design. This technical education includes learning about the sun's path and how it interacts with the built world.

Given the complexity and variability of the sun, it can be difficult to visualize how it moves in relationship to the earth. The heliodon is a machine that can be used to physically simulate the sun's path across the sky at any equinox or solstice for any latitude. Because the machine is not automated, the student must physically interact with the conceptual ideas that would otherwise be simulated by a computer. In this way, students intimately learn how the sun interacts with the buildings they design, giving them a deeper understanding that will allow them to incorporate daylighting and passive heating concepts into their designs from the beginning.

Our team of three architecture students began by looking at a heliodon designed by Norbert Lechner, and spent several months designing a version that would be simpler, less expensive, and able to be fabricated using the university's resources. After collaborating for two semesters with professors from both the Architecture and Engineering Departments, as well as the staff in various model shops around campus, the end result is a $500 heliodon that will be used in several architectural courses at The Pennsylvania State University.

1. INTRODUCTION

Because solar energy fuels and perpetuates all other energy sources, it is crucial that architects understand its relationship to the built environment. This includes both project location and design details. The interaction of the sun with architecture is paramount, and cannot be ignored or overlooked.

To emphasize this importance, much time is spent educating architecture students about how the sun's place in the sky affects the buildings we design. As a part of our third-year engineering course, we were asked to design and build a miniature make-shift heliodon to deepen our understanding of how the sun moves in the sky. Unsatisfied with the parameters of the project, we chose to expand the assignment to the design of a much larger, more accurate heliodon.

The first iteration of the design was stationary, cumbersome, and difficult to maneuver. However, this heliodon was more accurate than the assignment originally called for. More importantly, for our purposes, it visually described the sun's interaction with the earth more clearly (Fig. 1). This design thoroughly accomplished the assignment's goal: to help the students clearly visualize and comprehend the sun's path across the sky.

In order to alter the design of the heliodon to be mobile, elegant, and user-friendly, we extended the project to an independent study, applied for, and received a $500 grant from Penn State to construct our final design.

We spent several months designing the main frame for the project. Using Norbert Lechner's heliodon as a precedent, we determined which portions of our prototype were redundant, inefficient, or unnecessary. By considering these guidelines, we arrived at a design which is more streamlined and efficient.

Fig. 1: The original prototype.

2. FUNCTION AND OPERATION OVERVIEW

The main function of the heliodon, besides its educational applications, are to evaluate how the sun interacts with a proposed design. This works best with a small-scale site model. Because the distance between earth and the sun (the platform and the light) is so great, it is impractical to portray this distance to scale with larger models.

Surrounding the platform are metal rings on which a halogen lamp is attached. These rings rotate around the platform, representing the sun's movement throughout the day. The rings may rotate at a continuous rate, or may be stopped at any given hour, as indicated on the ring itself.

Each ring represents a different time of year. Our version has three rings: one for each solstice, and one for the equinox. (Norbert Lechner's version has seven rings.) Each ring's light has its own on/off switch and rolling track, and thus can be controlled independently.

These three rings are mounted on a carriage which rotates at a perpendicular angle to the rotation of the ring. This allows for the precise manipulation of the latitude of the site. The frame rotates a full 90º, allowing all latitudes to be explored.

The maneuverability of the machine allows all aspects of the sun's interaction with earth to be analyzed, visualized, and fully understood. The rings' rotation about the central platform (representing the time of day), the rings' location relative to the center (representing time of year), and the carriage's rotation (representing the site's latitude), allow the complex concepts of the sun's altitude and azimuth to be demonstrated in three dimensions.

Giving the control to the students and allowing them to manipulate the path with their own hands helps to develop their understanding of how the sun moves about the earth and, specifically, about their project's site. Physically interacting with the machine produces a deeper understanding of the concepts than using solar simulation software, which produces results based on simple inquiries. Conducting automated analyses does not require active comprehension from the student. The hands-on approach required by the heliodon necessitates students to think critically about which time of year they are analyzing, how the latitude of their site affects the sun's relationship to their project, and how the sun changes throughout the day.

3. DESIGN AND CONSTRUCTION

The design of this project focused around its functionality, ease of use, constructability, and cost. It was also important that each element of the design communicated the natural forces that they emulated. We explored and developed these aspects of design through both two-dimensional drawings and three-dimensional models, using them to assess the connections, determine constructability, and refine the design to remove excess materials (Fig. 2-3). Throughout this process we gave careful consideration to the tools that we had available, the materials that we could afford, and the ability of the user to understand how to operate the heliodon.

After completing the design and purchasing the needed materials, we began construction. Throughout the construction process we prototyped parts and modified the design to improve the functionality and durability of the final product (Fig. 4-6).

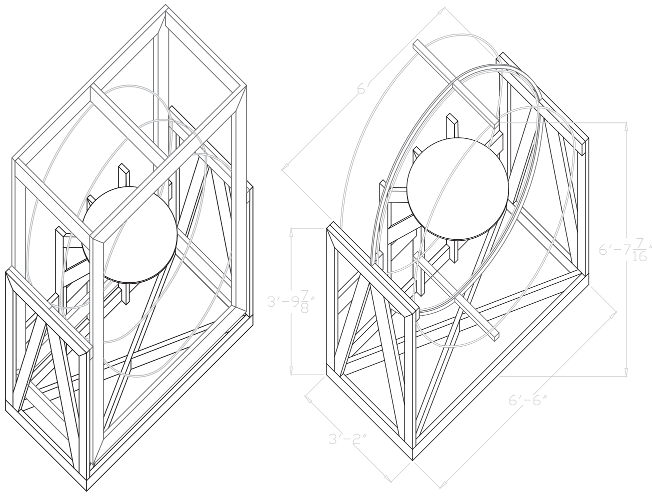

Fig. 2: Design development.

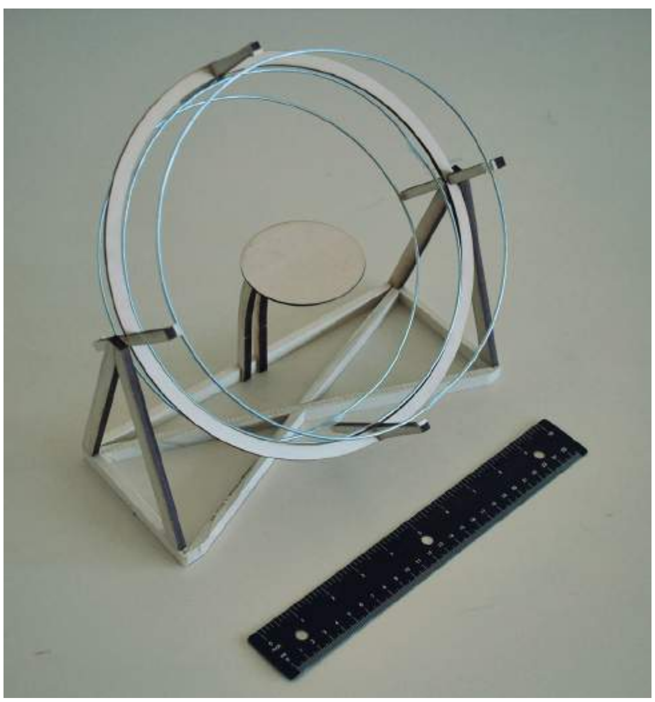

Fig. 3: Scale model. 1 1/2" = 1'

Fig. 4: Final product, front elevation.

Fig. 5: Final product, side elevation.

Fig. 6: Final product, axonometric.

4. <u>DESIGN FEATURES</u>

The final design consists of five key component groups. The first component group is the frame. Constructed of wood and reinforced by steel angles, the frame is mounted on wheels to provide easy mobility to the design (Fig. 4-6).

The second of these components groups are the lights (Fig. 7). Each light is operated individually by toggle switches (Fig. 9) located on one side of the frame. These lights simulate the three notable solar dates of each year; the winter solstice, the summer solstice, and the equinox.

Each light is each attached to a metal ring, the third of the five key components. Built from bent metal conduit, the rings are attached to the carriage element by rollers (Fig. 8). This allows the rings to rotate and simulate the sun moving across the sky at any time of day. The time of day is specified above a series of small holes that are located 15 degrees apart on the side of each metal ring to indicate each hour of a twenty-four hour day. A pin, which is attached to the frame, can then be slid into one of the holes, securing the metal ring and light in the desired position (Fig. 8).

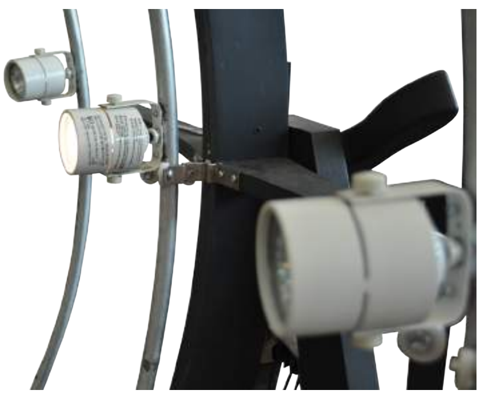

Fig. 7: Lights mounted onto each ring.

Fig. 8: Rollers connecting metal ring to carriage and pin indicating time of day.

The fourth component group is the rotating carriage (Fig. 5). This element holds the metal rings and lights and allows them to be angled to simulate the sun's path at various latitudes. The latitude indicator is attached to the side of the frame. By loosening the handles on each side of the frame, the carriage is then allowed to rotate to the desired latitude angle (Fig. 9).

Fig. 9: Latitude indicator and toggle light switches.

Finally, attached at the center of the frame is the model stand. Site models are placed here to be analyzed. The stand includes a rotating table-top, which allows the user to turn the model in relationship to the sun, thus investigating the best site placement and passive solar strategies (Fig. 10). If the scale of the model is too large, then the accuracy of the analysis will be compromised.

Fig. 10: Model stand.

Each of these elements work together to give students a hands-on understanding of how solar paths work, and how these factors can effect the designs of their building and landscape designs (Fig. 11, 15-16).

5. HELIODON IN USE

The heliodon is currently kept in the fifth-year studio of the Stuckeman Family Building at Penn State and is available for use by all studios. Students are encouraged to use the machine in early design phases to explore site massing options. Figure 12 shows a demonstration of the heliodon to third-year architecture students, while Figures 13-14 display a student using the heliodon to study the sun on a site model. Figures 15-16 are sun studies completed by third-year students.

Fig. 11: Shadows on site throughout day during summer solstice; site model: Julie Thorton.

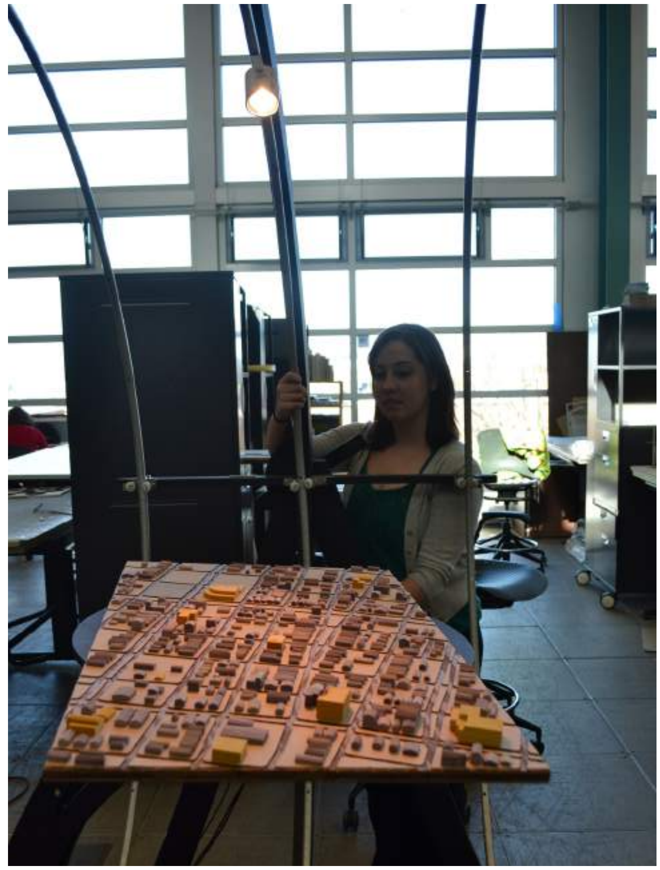

Fig. 13: Clarissa Costa Lima adjusting time of day.

Fig. 12: Demonstration of heliodon to third-year students.

Fig. 14: Student adjusting latitude.

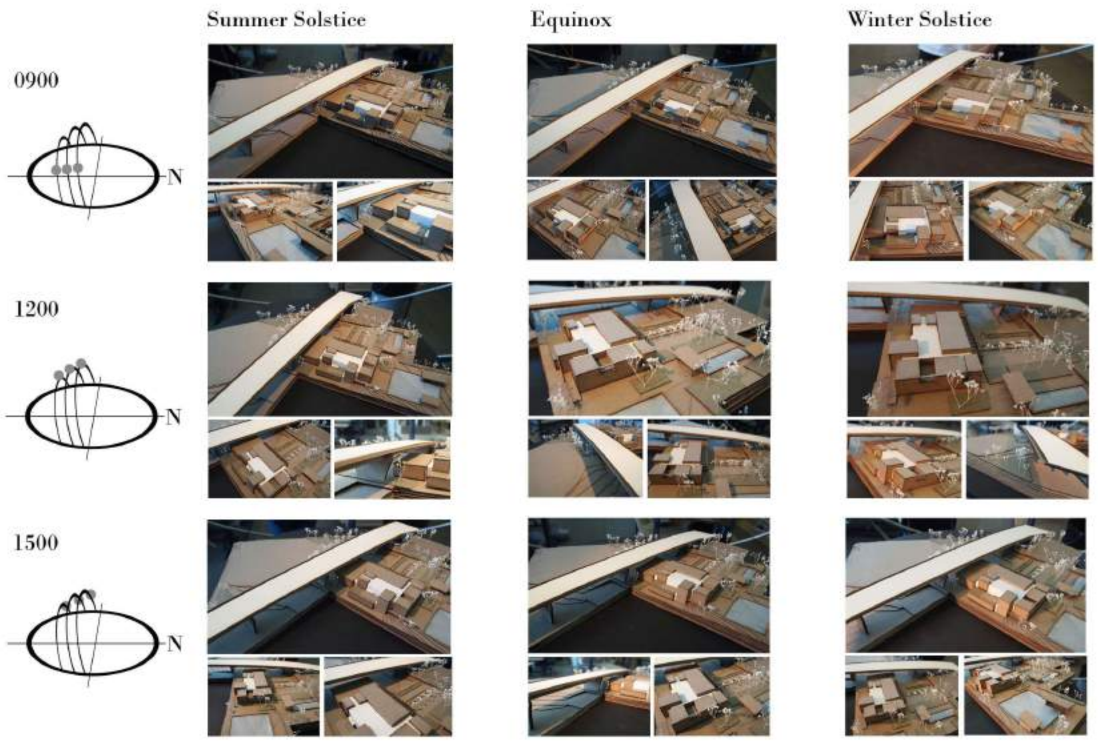

Fig. 15: Student sun study; Lauren Wandel.

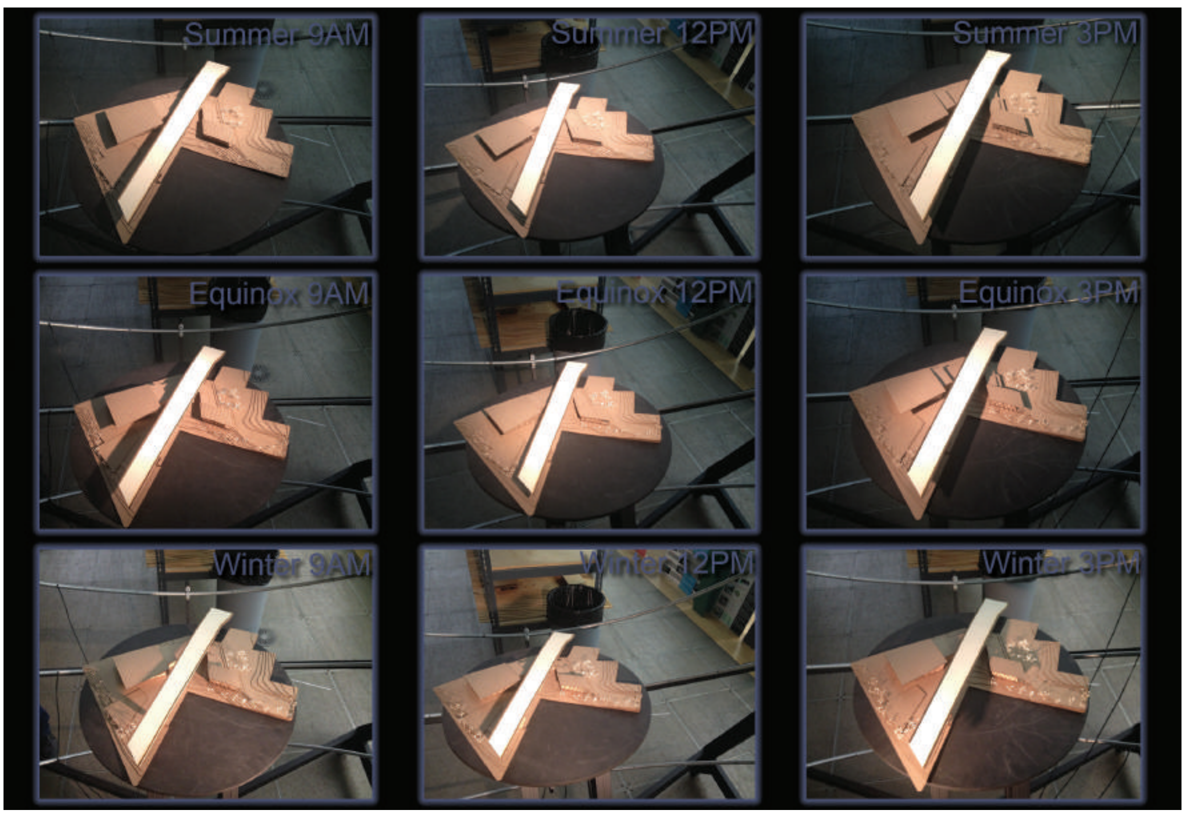

Fig. 15: Student sun study; Elizier Vazquez Luna.

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7. REFERENCES

(1) Lechner, Norbert. Model 126 Heliodon. Description: http://www.auburn.edu/~lechnnm/heliodon/Sun%20Emulator.html . Available for purchase from High Precision Devices, Inc.: http://www.hpd-online.com/heliodons.php