HPD Model 126 Heliodon (Sun Emulator)

User's Guide

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Introduction

Buildings use up to 50% of all the energy consumed, most of which is used for heating, cooling, and lighting. This energy consumption can be greatly reduced by means of solar responsive design. In solar responsive design, the primary goals are to harvest as much of the winter sun as possible and to reject the summer sun as much as possible (while still allowing a small amount of summer sunlight to enter the building so that the electric lights can be turned off during the day). A thorough knowledge of solar geometry and its consequences is necessary for successful designs.

By using the Model 126 Heliodon, it is easy to determine the solar access for passive, active, or photovoltaic solar systems no matter how complicated the building or site conditions may be. In hot climates, shading is often the most important solar consideration. Complexities of the shading devices, the building design, or the site are no problem when using the Heliodon to create a shading system that is fully effective for any required time of day, time of year, or latitude.

Sophisticated day-lighting (sun-lighting) systems can also be designed more easily using this Heliodon.

These goals are not achieved by examining a few specific moments in time when the sun comes from very specific points in the sky, because the summer sun comes from a whole **region** of the sky while the winter sun comes from a different **region** of the sky. Thus, solar responsive designs must account for the sun's impact coming from a **region** of the sky and not just a few points in the sky. A conceptually clear heliodon not only demonstrates these regions, but also allows for a simple and rapid analysis of the sun coming from a whole region of the sky. For example, testing a design for June 21 at 12 noon will indicate very little about how the design performs in the summer - from May to August and from sunrise to sunset. Graphical studies and to some extent computer studies tend to focus on specific moments in time. However a heliodon is dynamic and by its very nature easily *examines a design over a period of time*.

The significant energy savings achievable through solar responsive design are most easily attained by the help of a conceptually clear heliodon such as the Model 126 Sun Emulator Heliodon. Such conceptually clear heliodons have many functions: they clearly and simply demonstrate the basics of solar geometry, they can be used to develop a solar responsive design, they can provide feedback through analysis, and they can be used in presentations to communicate design strategies with clients unfamiliar with solar geometry and architectural drawings.

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Understanding the Heliodon

The Model 126 Heliodon is based on the concept of a very large imaginary sky dome that is centered over the building site being considered (Fig. 1). The part of the sky dome through which the sun passes is called the solar window (Fig. 2). The rest of the sky dome could be painted black without the loss of a single direct sunray heading to the building at the center of the dome – only skylight would be blocked. The rings of the Model 126 Heliodon define that solar window (Fig. 3).

At different latitudes the solar window remains essentially unchanged except that it will be higher or lower on the sky dome. The full solar window is defined by the summer and winter solstices (June and December 21) and the ground plane where the sun rises and sets. Note the daily symmetry about 12:00 noon (solar time*) when the sun is always coming from due south. Notice also the annual symmetry about the equinoxes (March and September 21), which are the only 2 days when the sun rises due east and sets due west. The heliodon also makes clear that the sun rises north of east and sets north of west for 6 months of the year. Similarly, the sun rises south of east and sets south of west the other 6 months.

The hoops represent the sun's path across the sky dome for the 21st day of each month. Only 7 hoops are required because of the annual symmetry. For example the sun's path across the sky is the same on November and January 21, May and July 21, etc. The full rotation of any hoop simulates a 24 hour day; note the hour markings on the support hoops. At 12 noon the sun is always toward the south and at its highest point for that month. As any hoop is rotated, the light simulates the daily motion of the sun in solar time.

- *Although solar time varies slightly from standard time or daylight savings time, it is not necessary to convert to clock time because the goals of solar responsive design are not based on clock time. For example, we want to keep the sun out when it is too hot, harvest the sun when it is too cold, and collect quality daylight all year to allow the electric lights to be turned off. Clock time is not necessary to achieve any of these goals. I can think of only one case where solar geometry based on clock time would be important. If one were to design a temple to the sun god and a beam of light were desired to fall on the altar on a specific day and time. Since these projects are rare nowadays, solar geometry need not be based on clock time. (Back)

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Initial Set-up of the Heliodon

1. **Table position:**
A gas spring holds the table in its vertical position (for storage) and in its horizontal position (for operation). Grip the table near the top **South** marking and push backwards tilting the table to horizontal. Engage the two latches under the table to ensure that the table will remain in its horizontal position during use. (See Figures 3 & 4).

2. **Electrical power connection:**
Plug the power supply into a power receptacle. Plug the output wire, from the power supply, into the receptacle on the side of the switch box (See Fig. 5)

3. **Rotary switch and cradle connections:**
The coiled cable from the rotary switch and the cable from the hoop cradle should already be secured into the twist lock receptacles on the side of the switch box (Fig. 5). These cables are designed not to detach. Secure the control end of the rotary switch in the holder when not in use.

4. **Lamps:**
The Model 126 Heliodon uses standard MR-16 Halogen lamps. When

replacing the lamps, be sure to purchase lamps of the following specifications: 12 Volts, 50 Watts, and a beam spread of about 24-25 degrees is best. However any beam spread can be used, if necessary.

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Operation of the Heliodon

1. **Power on:**
Flip the power switch on the panel at the control end of the Heliodon to the **ON** position (Fig. 5). One of the seven lamps will light immediately as selected by the rotary switch at the end of the coiled cable. The rotary switch is used to select the month simulated by the Heliodon. **Please note that each lamp will turn off momentarily as it passes the horizon brackets of the hoop cradle at 6am and 6pm. This is a normal condition.** Flip the power switch to the **OFF** position when you are finished using the Heliodon. This will conserve electricity and the lamps will last longer.
2. **Latitude adjustment:**
At the control end of the heliodon is a graduated disc for latitude adjustment (Fig. 5). Set the latitude by loosening the clamp knob and tilting the hoop cradle. Grip the cradle by the large black hoops. **Do not pull on the seven stainless steel lamp hoops.** Once the graduated disc reads the correct latitude for the building site, secure the cradle by tightening the clamp knob.
3. **Time of year adjustment:**
Use the rotary switch at the end of the coiled cable to select the month desired. Note that all the hoops are for the 21st day of each month.
4. **Time of day adjustment:**
Rotate the selected monthly-hoop, by hand, to observe the sun angle at different times of the day.
5. **Position of the model:**
Place a model of a building or a site model at the center of the table. For greatest accuracy the model should be small: approximately 6" in width and depth. Orient the model to face the proper direction with regard to the compass directions marked on the table. (See the Suggestions on Architectural Models for more information).

WARNING: The lamps get hot during use! Please keep hands off the lamps! Rotate the lamp-hoops by gripping the hoops themselves, not the lamps.

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Teaching Mode

The Model 126 Heliodon can be used to teach both solar geometry and specific architectural strategies of solar responsive architecture.

In Teaching solar geometry the heliodon clearly demonstrates that:

1. The sun only comes from the "solar window" part of the sky.
2. The solar window is symmetrical at about 12:00 noon.
3. The solar window moves up or down in the sky depending on latitude.
4. The depth of the solar window (the June 21 to December 21 dimension) does not change with latitude. At 12 noon, the angle between the solstices and the equinoxes is 23.5°, and therefore the change in altitude between December 21 and June 21 is **47°** everywhere on the planet.
5. The hoops are not equally spaced because the height of the sun's daily path across the sky (sunpath) varies throughout the year. The greatest change in sunpaths from day to day occurs at the equinoxes. The change of sunpaths from day to day becomes less and less until at the solstices the daily change approaches zero and then reverses. For example, the sunpath on September 21 is significantly lower than on August 21, while there is much less change in sunpaths from November 21 to December 21.
6. Rotate all the lamp hoops to sunrise (each lamp will be just above the surface of the table. The sun rises north of east and sets north of west from March 22 to September 20. During the other 6 months, it rises south of east and sets south of west. Only on 2 days does the sun actually rise due east and set due west – on the equinoxes (March 21 and September 21).
7. The number of daylight hours varies with latitude.
8. At the Arctic Circle (66.5° N. Lat.) the sun never sets on June 21 (i.e. there are 24 hours of daylight) as can be seen by the fact that the June 21 hoop stays above the table. Meanwhile, on Dec. 21 the sun never rises and there are 24 hours of darkness (the Dec. 21 hoop is completely below the table).
9. At the North Pole (90° the hoops are all horizontal to the ground plane (table), which means that for 6 months the sun is in the sky for 24 hours each. On June 21 the altitude is 23.5° all day long. Every day before or after June 21 the altitude is a little lower until the equinoxes (March and September 21) when there are 24 hours of sunrise (or sunset) as can be seen by the fact that the equinox hoop is hugging the ground plane. All of the other hoops are below the horizon which indicates that for 6 months there is complete darkness.
10. North of the Tropic of Cancer the sun is never directly overhead. Not until we get down to the Tropic of Cancer (23.5° N. Lat.) is the June 21 hoop directly above the center of the table at 12 noon.
11. South of the Tropic of Cancer, the sun shines into the north windows even at noon.

12. At the equator, the north and south walls receive equal and symmetrical sunshine, and the sun is directly overhead at 12 noon on the equinoxes.

13. During the hot months (around June 21), the east and west facades receive the strongest and most direct sun. The solar radiation hitting the roof is even stronger because the roof receives the sun all day long and especially when it is most intense – around the noon hours.

14. During the hot months, when the sun does shine on the south façade, the sun is high in the sky (large altitude angle) and therefore easily shaded.*

15. During the hot months, the sun shines into the north windows, but its heating effect is relatively weak either because the sun's altitude is low or because it hits the windows at a very glancing angle from east or west. Although the heat gain through northern windows is mainly a problem in very hot climates, the sun shines more through northern windows in higher latitudes. As a matter of fact, at the Arctic Circle, the sun shines from due north at 12 midnight. **

16. During the cool months (around December 21), the sun shines most strongly and directly on the south façade.

17. During the cool months, the east and west windows receive little solar radiation because the sun is either near the horizon low altitude angle) or the sunrays hit the east and west façades at a glancing angle. And, at best, for only half of a day.

18. A flat roof receives much more sun during the summer than in the winter. Thus, skylights receive the most sun in the summer and the least in the winter, which is exactly the opposite of what is desired. South facing clerestories, on the other hand, collect the most sun in the winter and the least in the summer – very logical and desirable. ***

19. Set the hoop cradle to the Equator (0°). Set all the hoops to sunrise and observe that the sunrise proceeds from slightly north of east to slightly south of east, from June 21 to December 21. Also observe that the time of sunrise is 6 am every day. Now set the hoop cradle to a northern latitude (such as 60°). Set all the hoops to sunrise and observe that the sunrise proceeds from far north of east to far south of east, as the seasons progress. Also observe that the time of sunrise varies greatly from much earlier than 6 am to much later than 6 am. The maximum number of daylight hours varies from 12 at the Equator to 24 at the Arctic Circle.

20. Set the latitude to 23.5° (the Tropic of Cancer). Observe that in the summer (June) the sun is straight overhead.
Set the latitude to 0° (the Equator). Observe that the sun in summer comes from the northern sky, and that the sun in winter comes from the southern sky.
Set the latitude to 66.5° (the Arctic Circle). Observe that the sun never sets in the summer, and never fully rises in the winter.

Set the latitude to 90° (the North Pole). Observe that the sun is up all day long for half the year, and that it never rises at all for the other half of the year.

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* In tropical regions, this is also true for the north façade. Back

** This is true north of the Tropic of Cancer. South of 23.5° north latitude the north façade picks up increasing solar radiation until at the equator the north and south facades get equal solar radiation. Back

***In the southern hemisphere, change “south” to “north” in items 13-18 above. Back

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Teaching solar design strategies with the heliodon

For the collection of passive solar, active solar, photovoltaics, and daylighting the heliodon is used to guarantee access to direct sunlight. A model of the building with all surrounding obstacles will quickly show any conflict with solar access. Shading, the controlled access of sunlight is much more complicated because of the desire to maintain views and often to maintain access to the winter sun. Consequently, the following discussion pertains mainly to shading systems. For a more complete understanding of shading strategies, see Chapter 9 in the book *Heating, Cooling, Lighting: Design Methods for Architects*, by Norbert Lechner © 2001, John Wiley & Sons.

1. Illustrate the principles of effective collection and rejection of solar energy –

   A model of a building should be prepared to reflect impact of the following: building form, window size and placement, eaves and awnings, clerestories and skylights, landscape design, and color (Fig. 6). Also, by rotating any building model so that different sides face south, one can demonstrate the importance of building orientation and street layout. Substitute “best practice” and “worst practice” models on the table and observe the solar effects at different times of day, different months and even at different latitudes.

2. Horizontal overhangs on a south window - The abstract building of Figure 7 has a moveable overhang to show how long an overhang is needed for any latitude and any climate. Once the date of the end of the “overheated period” is established (to the nearest 21st day of any month) the length of the necessary overhang can be established. Similarly, the size of the overhang is established for the winter so that full sunlight is collected during the whole “under heated period”. It quickly becomes apparent that any fixed overhang will be either too short for the summer season or too long for the winter season. This unfortunate situation exists because the

solar year and thermal year are out-of-phase. However, a perfect fit is possible with a moveable system such as an adjustable awning.

3. Horizontal overhang on east or west windows - Since east or west windows receive little winter sun and very large amounts of summer sun, the goal is clearly to shade the windows during the "overheated period" while maintaining as much of a view as possible. In any attempt to fully shade an east or a west window, it quickly becomes apparent that any overhang needs to be infinitely long (Fig. 8). Thus, it is best to avoid east or west windows if at all possible.
4. Skylights and clerestories - A heliodon will quickly and clearly show that a skylight receives the most sun in the summer and the least sun in the winter (Fig. 9). This totally inappropriate collection of solar radiation can be reversed by means of a south facing clerestory (Fig. 10).
5. The dynamic pattern of sun puddles - The model in Figure 11 shows how the location and size of a sun puddle from a certain window is a function of latitude, time of year, and time of day. By rotating a particular hoop, the daily sweep of a sun puddle can be illustrated. This same model shows how a window can be used to generate a sun dial on the floor inside a window.
6. Unwanted self-shading - The model in Figure 12 shows how buildings can block their own winter access by creating inappropriate shade. Furthermore, this arrangement provides no summer shading.
7. Outflanking by the sun - Shading devices designed in plan and section are often inadequate because of the compound angles of sunrays. For example, a south facing window, that is shaded by an overhang that is adequately long but only as wide as the window, will be seriously outflanked from the east before noon and from the west after noon (Fig. 13). As a matter of fact, the window will be only fully shaded for the instant of high noon when the sun comes from due south.
8. The importance of street layout - This model of a typical suburban street illustrates the impact of street orientation on the success of building design (Fig. 14). It is easily shown that an east-west street orientation is far better than a north-south orientation. With the east-west orientation, buildings will have more south windows and fewer east and west windows – thus performing much better in both seasons. Unfortunately, the north-south street will result in the opposite – more summer sun and less winter sun for each building.
9. Model of an ideal development - Figure 15 shows a model of an actual development called Village Homes located in Davis, California. In this development, every house is on an east-west street, and every house receives ample winter sun and little summer sun – every house is a winner.
10. Shadow patterns - Heliodons can easily generate shadow patterns for

solar responsive site designs. For example, to find the best location for a bench relative to a large tree, it would be appropriate to know which areas are in shade in the summer and which in the winter. Figure 16 shows how the shadows for June 21 and Dec. 21 were recorded at hourly intervals. By connecting the shadows for June 21 and those of December 21, the shadow patterns for those days are established and the location for a bench which gets summer shade and winter sun can be determined.

11. Deciduous trees - Show how placement of deciduous trees helps cool a house in summer, and allow solar gain through southern windows in the winter (Fig. 17).

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Using the Heliodon for Analysis

After a solar responsive design has been created, it is important to get feedback on the success of the design. By creating a study model and testing it on the heliodon, it becomes immediately clear which design features succeeded and which did not. Since the model support table is always horizontal, it is easy to modify the model right on the heliodon to make alterations to the design. As a matter of fact, many design features can be designed right on the heliodon in the first place. For example, the length of an overhang can be determined quickly by a trial and error method. By turning on the lamp representing the “end of the overheated period”, the length of overhang needed for full shade is immediately apparent. Then, the lamp for the “end of the under-heated period” is turned on, and it becomes equally obvious how much of the winter sun, if any, is shaded.

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Using the Heliodon for Presentations

Usually, clients just have to believe that the design presented to them does what the designer claims. Using the conceptually clear Model 126 Heliodon, the client will understand with confidence the solar responsiveness of the design. The conceptual clarity of a model is especially important for clients that are not trained to fully understand a building from drawings only. The increased clarity of physical models is especially important for explaining how the geometry and orientation of the design, often at no additional cost, can achieve something for nothing (i.e. free winter heat and less summer heat gain). Clients, usually find it hard to believe that it is possible to save energy without additional first cost, but solar responsive design can do exactly that.

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Suggestions on Architectural Models and Accuracy

The Model 126 Heliodon has been optimized as a teaching and demonstration tool. When it is being used to evaluate architectural models for their solar responsiveness, certain procedures should be followed to achieve the highest accuracy.

Since the lamps are not located 93 million miles from the model in order to create parallel sunrays (as the sun is from the earth), there is a single point where the Heliodon is most accurate. That point is at the table center, 1" above the table surface. The smaller the model, the more accurate the analysis will be. On any size model, the best result will be achieved by moving the model so that the point of interest is right over the table center, while making sure that the alignment with north is preserved. The table is purposely designed to be one inch below the ground plane so that the model base does not add to the vertical error.

A 6" long model will yield a very good analysis since 3 inches in every direction from the center still has very good accuracy. Larger models can be moved around so that the area being investigated is moved over the center of the table where the accuracy is greatest. This is very effective for site models that have many small buildings; but it does not work at all for skyscrapers since they cannot be lowered to be closer to the tabletop. Thus avoid models much over 4 inches high.

The recommended procedure when great accuracy is desired is as follows: first build a small-scale model where the building is less than 6 inches long. When issues at that scale have been resolved, build a larger scale model of a critical detail such as a typical window (or portion of a building as shown in Figure 18). Build the window so that it is 3 to 4 inches in actual size. That size allows great accuracy in building the model and also allows great accuracy in analysis. If the same window detail is used on more than one elevation or orientation, then the same model can be rotated on the Model 126 Heliodon to simulate different exposures.

The Sun Emulator was designed to be a conceptually clear and practical heliodon primarily for use in architecture schools. The accuracy is more than sufficient for teaching solar geometry, for design, analysis, and for presentations. Heliodons that generate more parallel light rays to allow for larger models and or more accuracy are either not conceptually clear or much larger and more expensive. The Model 126 Heliodon is the largest conceptually clear heliodon that can be manufactured in a factory, shipped pre-assembled, and that fits through a standard 3 foot door.

Physical models will be used a long time yet in architecture. No computer program can compare with the learning and understanding that comes with building and analyzing a physical model. Often more than one model is made per project: a quick study model and then a presentation model. A study model can be quick and dirty. Only those aspects that impact solar responsiveness need to be carefully modeled (e. g. windows and overhangs).

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Benefits of the Model 126 Heliodon

1. **Conceptually Clear**
   Architectural models tested on the Model 126 Heliodon are not rotated or tilted, but remain fixed on a horizontal ground plane. This fixed-earth design simulates one's everyday experience, of the sun's motion across the sky, resulting in exceptional conceptual clarity.
2. **Easy to Operate**
   The Model 126 Heliodon requires minimal training for use and is very easy to operate. Just plug it in, unfold the table, place your model on the table, and go!
3. **Simple Model Construction and Adjustment**
   The model is stationary and placed on a flat table, the sun lamps are the only components in motion. Therefore loosely constructed study models may be easily used on this device. This allows for quick, simple changes to be made to the model during testing.
4. **Mobile**
   The Model 126 Heliodon is set up on locking castor wheels and designed to fit through standard doorways when folded, thus it can be easily moved from location to location, or stored away when not in use.
5. **Weather Independent**
   The Model 126 Heliodon is weather independent, as it is used indoors and doesn’t rely on actual sunlight for use.

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Limitations of the Model 126 Heliodon

In designing a heliodon, it quickly becomes apparent that great accuracy, conceptual clarity, and small size of the heliodon are mutually incompatible. For research or an unusually exacting design, accuracy is of high priority. However, for most design situations and for teaching, conceptual clarity is by far the most important priority. In most cases, the size of the heliodon is also an important consideration. Thus, the Model 126 Heliodon was designed to have great conceptual clarity and to be small enough to fit through a standard door.

The limited accuracy is of no consequence when the heliodon is used as a teaching tool because it is accurate enough so that concepts, principles, and solar strategies are all correctly presented. As a design tool, the limited accuracy can usually be accommodated by moving the model so that the point of interest is as close as possible to the center of the table which is the location of greatest accuracy. Thus, when examining the shading of a particular south window, the model is moved in such a manner that the window of interest is right over the center of the heliodon, and when the shading of a west window is investigated, then the model is moved so that the west window is directly over the center of the table.

The accuracy of the heliodon is sufficient for most design situations. When additional refinement is required, then the model can be taken outdoors and tested in sunlight by means of a sundial as explained on page 404 in the book, *Heating, Cooling, Lighting: Design Methods for Architects,* by Norbert Lechner, © 2001, John Wiley & Sons. Sunlight, although very accurate is very cumbersome to use. Thus, in those projects where accuracy is required, the heliodon can be used to achieve about 90% of the finished design, and sunlight can be used to refine the design the remaining 10%.
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Appendix

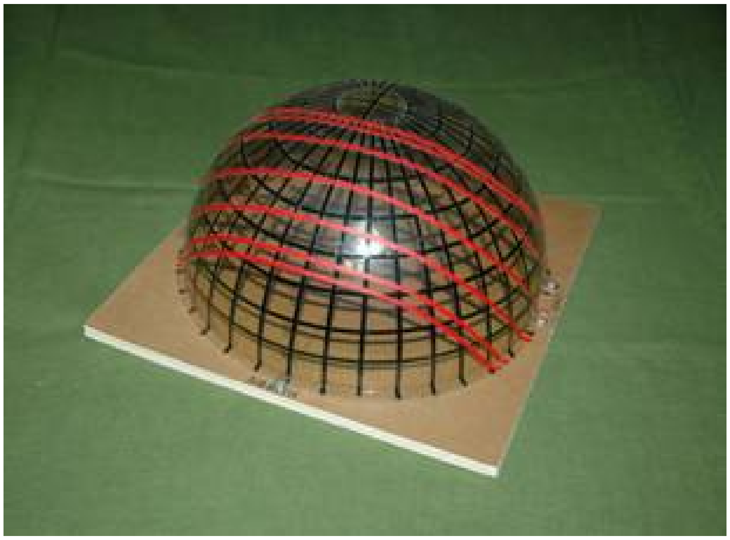

Fig. 1 (Back)
The imaginary sky dome with sunpaths for 32° north latitude

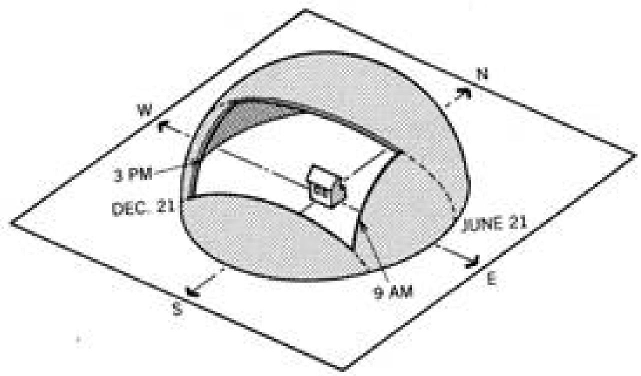

Fig. 2 (Back)

The solar window always extends from June 21 to December 21 and in this case from 9 am to 3 pm when most solar radiation is received.
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Fig. 3 (Back)
The Model 126 Heliodon simulates the solar window by means of 7 hoops which define all 12 months.

Fig. 4 (Back)
The Model 126 Heliodon is shown in its storage mode where the table is rotated up and the hoops are set for 0° latitude (the equator).
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Fig. 5 (Back)
View of the control end of the Model 126 Heliodon.

Fig. 6 (Back)
This model demonstrates solar response to a variety of building practices

Fig. 7 (Back)

This model of an abstract building to shows how to design a south facing overhang

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Fig. 8 (Back)

The same model is used to show the sizing of a horizontal overhang for an east or west window. Note how even extremely long overhangs cannot block the low sun.

Fig. 9 (Back)

The same base model is now used to show the performance of skylights.

Fig. 10 (Back)

The skylight has been replaced by a south facing clerestory.

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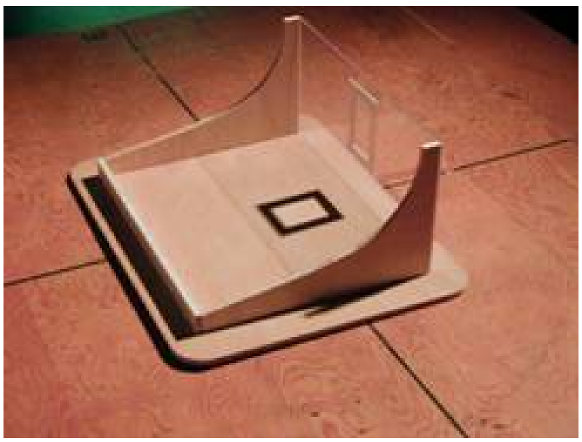

Fig. 11 (Back)

This model of a room with one window shows how sun puddles are a function of latitude, time of year, and time of day.

Fig. 12 (Back)

This model illustrates how the form of a building can shade the desirable winter sun and have no benefits in the summer.

Fig. 13 (Back)

Shading devices outflanked by the sun is both common and serious. Note how this south facing overhang is outflanked by the afternoon sun.

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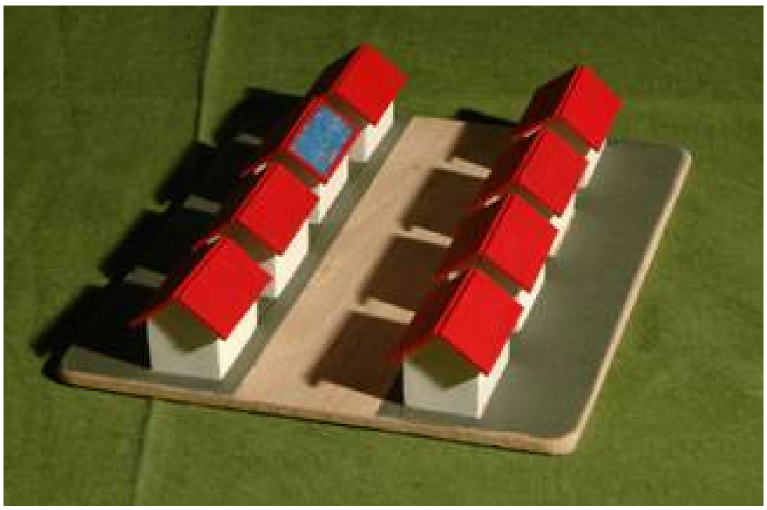

Fig. 14 (Back)

This model of a typical suburban street, illustrates the importance of street orientation.

Fig. 15 (Back)

A model of the subdivision called Village Homes. Note that all homes are on east-west streets.

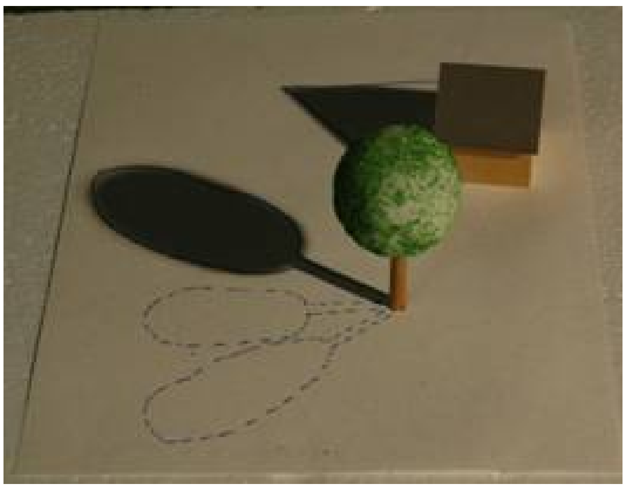

Fig. 16 (Back)

The heliodon can generate shadow patterns necessary for the design of solar responsive site and community designs.

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Fig. 17 (Back)

Models of deciduous trees shown in their summer and winter modes

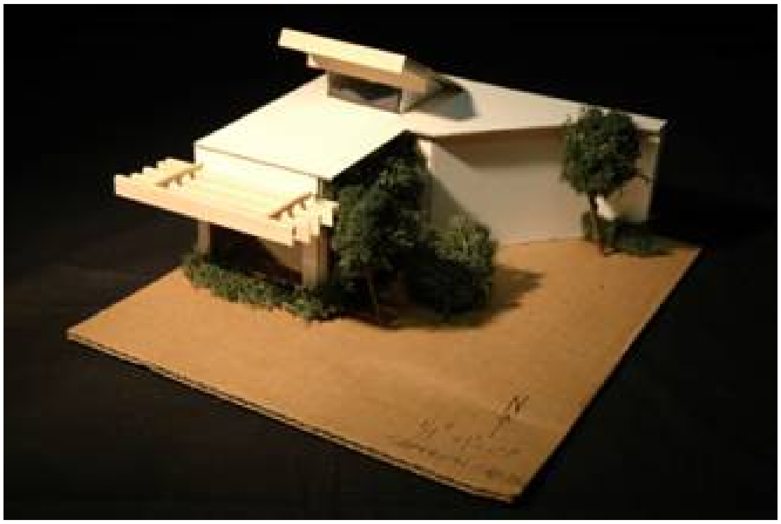

Fig. 18 (Back)
Solar analysis of a corner of a building
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For More Information

http://www.hpd-online.com/products/model_126_heliodon.asp
http://www.bsu.edu/web/ceres/heliodon/
http://www.cadc.auburn.edu/sun-emulator/mainpage.htm

Contact High Precision Devices, Inc.: (303) 447-2558, ntepper@hpd-online.com

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