Text for a Brochure Describing the UT - Pan American Sundial

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La Plaza del Sol

Strolling down the sidewalk next to the new Engineering Building on the UT Pan American campus in Edinburg, Texas, one sees a beautiful thin obelisk in the distance, rising vertically from the new Plaza of the Sun, or *Plaza del Sol*. Walking around the plaza, one sees in its surface strange rune-like markings inlayed into the concrete. Some are shaped like large disjointed figures-of-eight. Between them are simpler lines, curving gracefully outward, seeming to emanate from a point several feet to the south of the obelisk.

If the sun is shining, a pronounced shadow from the obelisk can be seen, crossing this pattern of odd markings on the plaza floor. Adding to their apparent complexity is another set of 7 additional curved lines, crossing the former lines and extending roughly east and west from one edge of the plaza to the other. The color of the concrete exhibits subtle shifts from one area to another. Inside the figures-of-eight, for example, there is a slightly greener color, a shift that accentuates the shapes of the graceful curves surrounding these areas.

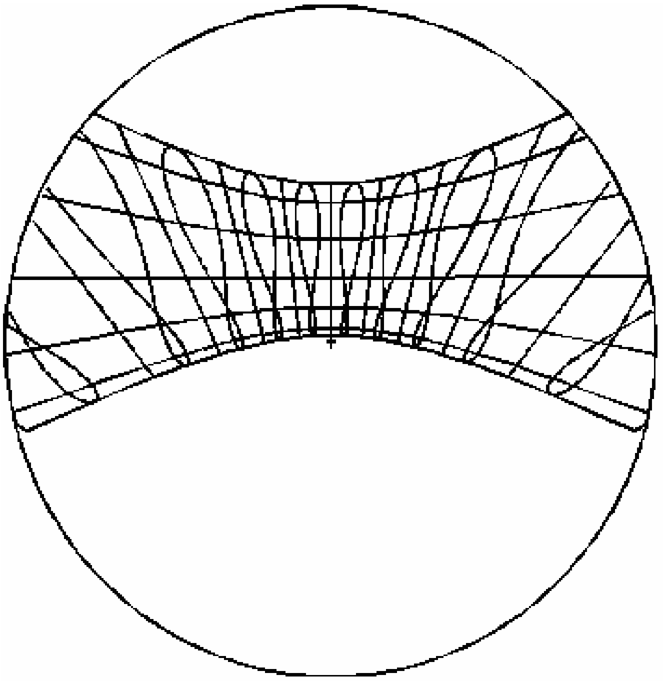


Fig. 1. Pattern of markings on the Plaza of the Sun at the UT - Pan American campus in Edinburg.

The obelisk is topped with a beautiful, shining dark blue sphere, which casts a noticeable shadow on the plaza floor below. Putting these observations together, the alert visitor may think there's a connection between these mysterious markings and the fact that they are located on a University campus, in an area of the campus noted for its technical focus.

By now it is evident that this must be some kind of sundial (*Reloj de Sol).* There are no numbers on the plaza to indicate the hour lines, however, and the complicated pattern of markings is probably an enigma to the casual observer. "How do you tell time with this crazy thing?" would be a natural response. The sundial's pattern of markings is shown in Fig. 1. The obelisk position in the center of the circular plaza is indicated by the "+" sign and north is "up" on the drawing.

Solar Time and Standard Time

To answer the puzzle of how to tell time with this dial, we need first to understand the difference between the *standard time* kept by our clocks and watches and another kind of time, called *solar time.*

Standard time is the time kept when the year is divided into precisely equal intervals of time, delineated by hours, minutes, and seconds. The master standard for time is kept by very accurate clocks in national standards laboratories around the world.

Standard time was introduced fairly recently in human history, mainly to accommodate a need of the railroads to keep accurate schedules when crossing vast land areas. Throughout most of human history, standard time has not been available, and every town and city generally followed its own time, synchronized to the sun's position in the sky. Through some eras and in some locations, time was referenced to sunrise or sunset; in others it was referenced to the sun's highest position in the sky each day. Standard time has changed all that, putting nearly all the cities of the world on a more coordinated, synchronized, time schedule.

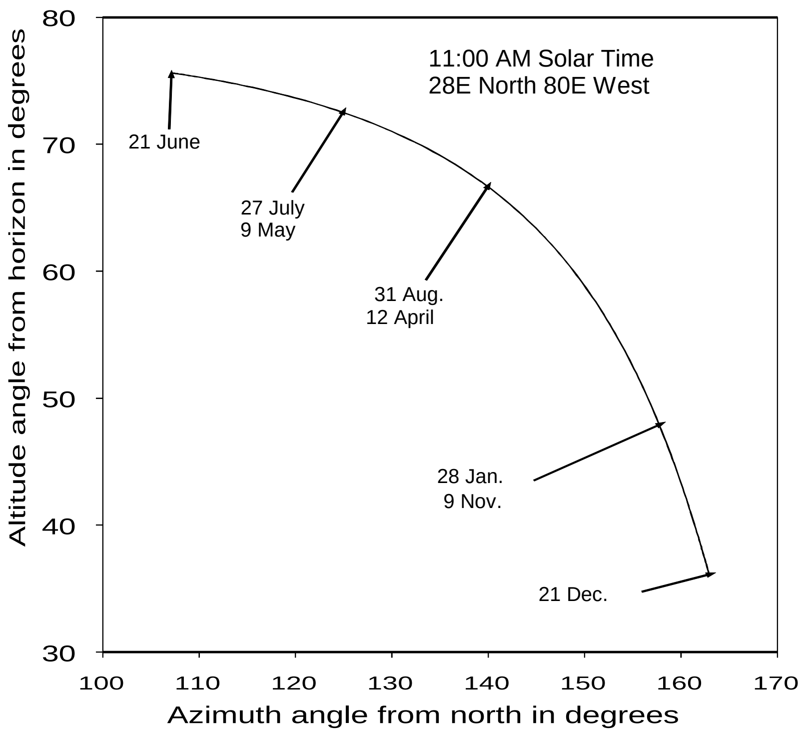
Time Zones

Since the earth rotates 15 degrees about its axis each hour, the earth was divided up into 24 standard time zones, at roughly 15 degree spacings around the globe. Whenever you travel from one time zone to the next, you change your clocks and watches by exactly one hour. (There are some exceptions, such as in Australia, with its half-hour time zones.) Each time zone is linked to what is called a *standard meridian* or line of longitude. The standard meridians start out with the *zeroth* one at 0 degrees, 0 minutes, and 0 seconds (0E 0' 0"), which passes through Greenwich England and is called the *Greenwich meridian*. It is sometimes also called the *prime meridian.* Standard time in the zeroth time zone is called *Greenwich Mean Time* (also denoted GMT, ZULU, or universal time). Counting westward, the Eastern Standard Time (EST) zone in the U.S. is the fifth zone from Greenwich and its standard meridian is at 75E west longitude. The Central Standard Time (CST) zone is the sixth one from Greenwich and has its standard meridian at 90E west longitude.

The standard meridians lie roughly at the centers of each of the time zones around the earth. Ideally their boundaries should lay exactly half way between the standard meridians. However, the actual boundaries have been drawn by the relevant political bodies to more closely match practical political and geographic boundaries. In consequence, some time zone boundaries are considerably deformed from the ideal, and many actually cross the standard meridians of other time zones. China, for example, has but *one* time zone, synchronized to the time in the country's capital, Beijing. This is true even though this one time zone includes almost 5 standard meridians! Other apparent anomalies can be found around the world. Australia, for example, has a time zone that is but one-half hour different from the ones on either side of it.

Solar time, in contrast, is different from this. First of all, *solar noon* is the time when the sun is at its highest point in the sky each day, and is due south in the northern hemisphere and due north in the southern hemisphere. The other solar hours in the day are spaced in equal intervals of earth rotation about its axis, every fifteen degrees of rotation. Solar time is referenced to solar noon at whatever location you are in. If you try to keep solar time with your wrist watch, you will have to reset it each day throughout the year to keep accurate solar time.

The earth makes one complete revolution in 23 hrs 56 minutes hours and there are 365.26 days in a year. Thus, at the end of each year we actually come up short about 1/4 of a day in time. This is why every four years we have to remove one whole day from the “leap year” calendar to make up the difference and get our clocks back on track. There are other very small corrections that astronomers insist on making in our master time clocks from time to time, but these are too small to be of much interest here.



To see how solar time is different from standard time, let’s suppose one goes outdoors each day, say at 11:00 AM, and takes a picture of the sky in the sun’s direction at precisely this same standard time each day, repeating these exposures in the same direction and on the same frame of film each day. Dennis DiCicco was the first to actually perform this experiment. You can order a copy of his photograph from Sky Publishing, (order P0023) phone: 1-800-253-0245.

This beautiful photograph reveals the changes in the sun’s position in the sky at a given time each day throughout the whole year. The “path” of the center of the sun as it moves through the sky over a year at 11:00 AM each day, in solar altitude and azimuth angle coordinates, is shown Fig. 2 above.

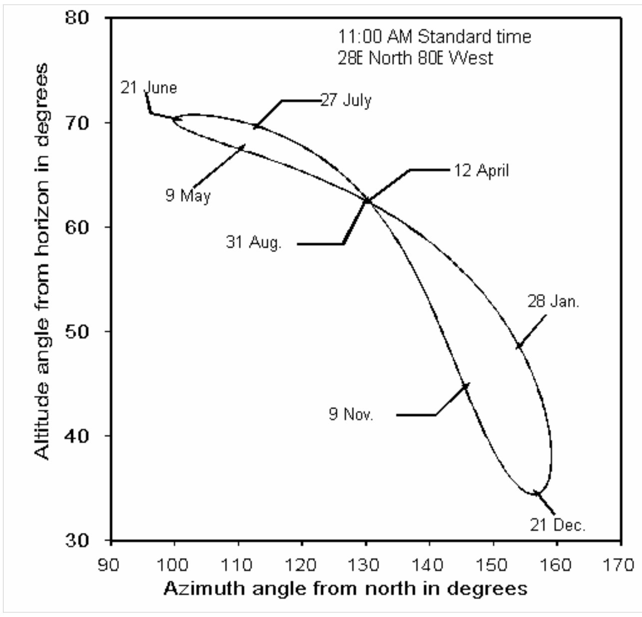


Fig. 3. Angular positions of the sun in the sky at 11:00 AM solar time each day in a year.

This plot shows that the sun "moves" through the sky from day to day, even though the exposures were all taken at precisely 11:00 AM standard time throughout the year.

Because of this, the shadow of a fixed object in the air, projected onto the ground, will also follow a pattern much like this from day to day at 11:00 AM standard time.

Because of the way solar time is defined, however, the sun follows a much simpler path in the sky at a fixed solar time, the one shown in Fig. 3. The shadow of this same object at 11:00 AM *solar time* each day also follows a simpler path.

Sundial Hour Lines

Comparing Figs. 2 and 3 with Fig. 1, it is clear that the UT sundial is really two sundials in one, a solar time one and a standard time one. It has hour lines for solar time and separate hour lines for standard time.

The solar time hour lines are displaced from the standard time hour lines. As you can see in Fig. 1, the solar time hour lines for the UT-Pan American campus fall in between the standard time hour curves.

The vertical straight line in the center of Fig. 1 is the solar noon hour mark. Knowing that, it is easy to figure out which are the remaining *solar time* hour lines on the plaza, just by counting down or up from 12.

The standard time hour *curves* shown in Fig. 1 are more of a mystery. Which parts of these complex curves are the portions delineating the hours? The answer can be figured out from the dates shown on the curve in Fig. 2. However, these positions of the sun in the sky have to be projected through the center of the sphere at the top of the obelisk and onto the plaza surface to be in the right relationship. When this projection is completed, one finds that it is the upper left and lower right half of each "figure-eight" standard time curve shown in Fig. 1 that must be used from 21 June through 20 December. During this half of each year, standard time should be read from the dial only using these portions of the hour curves, ignoring the other portions (upper right and lower left).

During the other half of each year, the reverse of this is true. One way to tell which portion of the figures of eight are to be read for a given day would be to visit the dial precisely on an hour and look at the dial to see on which portion of the appropriate hour curve the gnomon's shadow is centered. Following this exercise you can also use this unique sundial to reset your watch to correct standard time.

The Dial's Shadow Path Lines

Only a small part of each hour line is needed to tell time on any given day. During each day, the shadow of the gnomon (the shadow of the sphere on top of the obelisk) follows a slightly curved path across the dial from the 50 foot plaza radius on the western side to the 50 foot plaza radius on the eastern side. This path is called a *shadow path line,* since it is the path followed by the shadow during the course of a day. Each shadow path line crosses all the solar and standard time hour marks. To help keep track of the paths of the shadow across the dial face, and to know where to look for the shadow on partly cloudy days, shadow path lines have been added to the dial for 12 days in the year.

The *solstices* are the two dates each year when the sun reaches its highest and lowest point in the sky at solar noon. The *equinoxes* are the two dates of the year when the sun rises exactly due east and sets exactly due west. These dates also have equal day and night, which is where the name comes from. The times of the solstices and equinoxes for Edinburg are tabulated below for years 1996 through 2000. Shadow path lines for these dates in 1998 were calculated and incorporated in the dial markings.

```
SOLSTICES AND EQUINOXES, 1996 through 2000
LATITUDE = 26:18:21     LONGITUDE = 098:10:14
TIME ZONE =  6  OR CST  Local times are central standard time

      MAR EQUINOX      JUN SOLSTICE     SEP EQUINOX      DEC SOLSTICE
      DA HR MIN SEC    DA HR MIN SEC    DA HR MIN SEC    DA HR MIN SEC
1996  20  2  4  18     20 20 24  52     22 12  1  28     21  8  7  24
1997  20  7 55  58     21  2 21   6     22 17 57  11     21 14  8  34
1998  20 13 55  54     21  8  3  45     22 23 38  37     21 19 58   1
1999  20 19 47  11     21 13 50  20     23  5 32  58     22  1 45  21
2000  20  1 36  37     20 19 48  55     22 11 29   2     21  7 39   0
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As can be seen in Figure 1, the equinox shadow path line is a very straight line, running due east and west. The others are curved slightly, the curvatures increasing out toward the summer and winter solstice sunpaths which have the maximum curvatures. Additional shadow path lines have been added, for the intervening months between the solstices and equinoxes, with the dates for these months chosen as follows. The days for the intermediate months from July through November were chosen to be approximately equally spaced in time between the nearest equinox and solstice. Then dates in the months January through May were selected which produced shadow paths that most closely matched those for the dates chosen in the July to November time period. The dates of the sun path lines on the dial are:

December 21			
November 20	and	January 21	coincident
October 22	and	February 19	coincident
September 22	and	March 20	coincident
August 22	and	April 19	coincident
July 21	and	May 21	coincident
June 21			

To make the process of reading the dial a little easier, annotations are added to the plot shown in Figure 1 and the result is shown in Fig. 4.

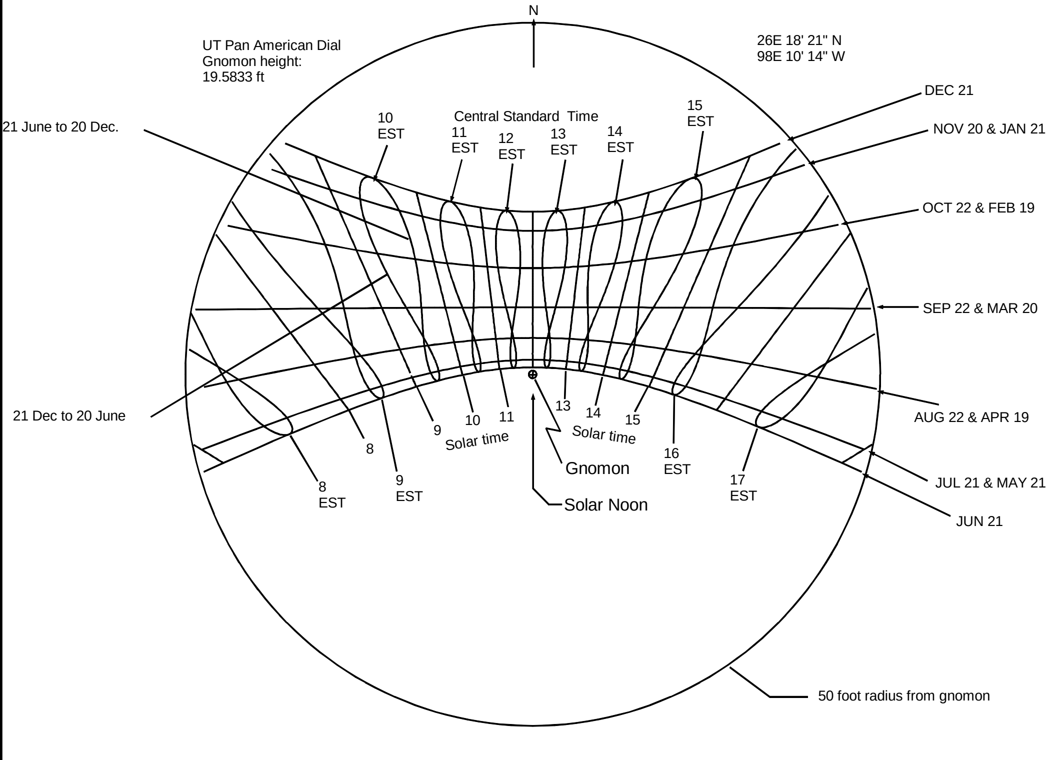

Fig.4. Annotated map of sundial markings.

A consequence of the widening of the distance between hour marks that occurs in going from the summer months to the winter ones is that the time scale between the hour marks changes from day to day. The presence of the other halves of the “figure eight” standard time curves and the solar time marks makes interpolation between hour marks somewhat difficult. This difficulty can be alleviated through the use of a simple mechanical instrument, like the one diagrammed in Fig. 5. The ends of this expanding and contracting scale are placed on adjacent hour marks and the intervening marks show the locations of the 10 minute interval points between the hour curves.

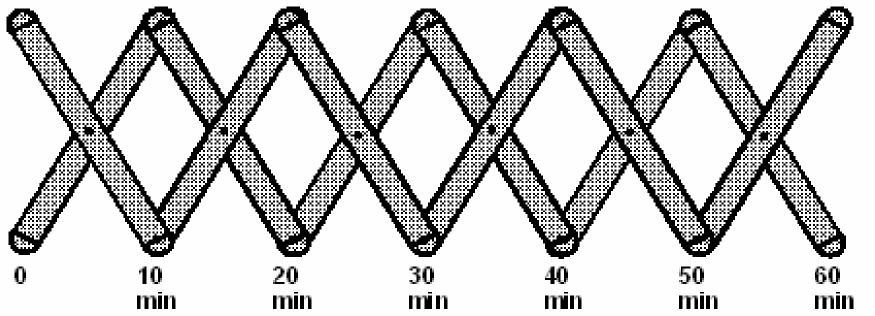

Fig. 5. Expandable Ruler for Determining Time Between Hour Marks

Converting Solar Time to Standard Time

Two corrections are needed to convert between solar time and standard time. The first one results from the fact that the sundial is displaced 8E 10' 14" west from the 90E standard meridian for Central Standard Time. This is equivalent to 8.17 degrees. Since the earth rotates 15 degrees in an hour, solar noon in Edinburg occurs 8.17/15 = 0.544 of an hour later than solar noon on the standard meridian. This means we have to add 0.544 hour, or 32 minutes and 41 seconds, to solar time, in order to correct it to the proper time on the standard meridian.

The second correction comes from the fact that the earth circles the sun in an elliptical orbit once every year, and it rotates around an axis (the polar axis) that is tilted 23½ degrees relative to the plane of the earth's orbit around the sun. This means that in addition to the earth's rotation speed of once per 24 hours, we have to add or subtract an additional amount resulting from the fact that the earth is moving around the sun in an elliptical orbit, and that, in consequence, the angular speed of that rotation relative to the sun varies from day to day throughout the year. Because of this, the sun appears to be in a slightly different place in the sky every 24 hours as it moves around the sun. This change in the position of the sun in the sky at 11:00 AM standard time is plotted in Figure 2.

The result of all this is that *solar time* sundials give times of day that speed up and slow down, relative to accurate *standard time* clocks, as we move through the days of the year. The amount of correction needed to account for this speeding up and slowing down is called the *equation of time*. The equation of time is plotted in Figure 6.

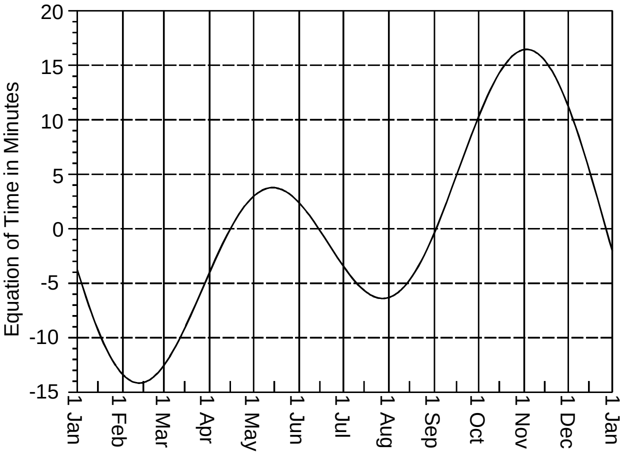

Fig. 6. Equation of Time

If the solar time in Edinburg on a given day is *Sundial* in hours past midnight, then to convert this time in decimal hours to standard time one first adds the fixed 0.544 hour to *Sundial* time to account for Edinburg's westward longitude of 98° W from the standard meridian at 90° W. Then one looks up the value of the Equation of time plotted in Figure 5 for that day and adds this to *Sundial* time as well. The result of these two additions is the standard time (or "clock" time) *Clock* in decimal hours. If we denote the value of the equation of time on day *D* with the symbol *EOT*, then the conversion from solar time to standard time in Edinburg is given by the equation

$$Clock = Sundial + 0.544 + \mathrm{EOT}(\ D\ )$$

This equation gives the standard time in decimal hours past midnight corresponding to solar time *Sundial* at Edinburg. To convert *Clock* into hours and minutes, multiply the fractional part of *Clock* by 60 to get the minutes. To get the seconds, multiply the fractional part of the minutes by 60 to get the seconds. For example, suppose the result of this calculation is a standard time of 14.324 hours past midnight. This is equivalent to 14 hours and .324 x 60 = 19.44 minutes past midnight, or approximately 2:19 PM. Since 0.44 minute is 0.44 x 60 = 26.4 seconds, a more accurate expression of this time would be 2:19:26 PM.

It is fortunate that Edinburg lies at a longitude approximately half way between two standard meridians (the 90W and 105Wones). The need for a half-hour fixed correction to account for the longitude difference is a consequence of this. This means that the standard time hour lines on the sundial lays approximately half way between the solar time lines, and they do not intersect or overlap them.

About the UT Pan American Sundial

The "Plaza of the Sun" sundial at the University of Texas Pan American Campus in Edinburg, Texas was designed by the architectural firm of Kell, Munoz, and Wigodsky of San Antonio. Calculations to determine the positions of the sundial markings were made by Dr. Ross McCluney of the Florida Solar Energy Center at Cocoa, Florida. Construction of the sundial was completed in October 1996 by BFW, Inc. of Dallas, the construction company in charge of the project.

The height of the obelisk which serves as the dial's *gnomon* or pointer is 19.58 ft above the concrete surface of the plaza. This is the distance from the base of the obelisk to the center of an 8" diameter stainless steel sphere at the top of the obelisk. Thus, the overall height of the obelisk, to the top of the sphere, is 23.58 feet. The plaza surface contains a series of curved metal marking strips, inlayed into the concrete, which serve as the hour and shadow path lines of this large sundial.

At solar noon each day, the shadow cast by the gnomon is centered on a straight line running true north-south. At the precise time of the summer solstice each year the circular shadow of the gnomon on the plaza reaches the southmost end of this noon line. The noon line is called a *noon* *mark* by dialists. Due to the southern latitude of Edinburg, this end of the noon mark comes very close to the base of the obelisk, almost touching it, since at solar noon on the summer solstice, the sun's center is but 2.86E south of the zenith (straight up), corresponding to a solar altitude angle of 87.144E. On the winter solstice, the solar noon shadow is centered at the other end of the noon line, since at this time the sun is 49.71E south of the zenith, at an altitude angle of 40.29E.

The UT Pan American dial is one of a small but select group of sundials that tell both solar time *and* standard time. It was the largest of this class of sundials known to exist at the time of its construction. One may ask why the numbers of the hours were left off of the dial. One reason is so that the graceful curves of the hour lines and sun path lines could be kept uncluttered by annotations. Another was to make the dial more mysterious, encouraging observers to try and figure it out on their own. The dial's presence on a University campus, a place of learning, made it easy for the designers to complicate the dial's appearance a bit by including both solar and standard time hour markings, and to leave off all but a few textual annotations giving the months of the shadow path lines.

Early Sundials and Sundial History

In the late 20th century there still exist examples of early sundials from 15th century Egypt. The earliest known records of sundials date from 2000 B.C. in Babylon. The first solar timekeeping device, probably dating from about 3500 B.C., consisted of a vertical shaft in the ground, called a *gnomon* in Greek, which cast a shadow of the sun to show the time. This is where the name gnomon comes from for the portion of a sundial that casts a shadow on the time markings. The UT Pan American sundial design therefore connects back through 40 centuries to the earliest known sundials, which were marked for solar time.

The UT-Pan American dial effectively bridges past and present. A modern computer program was used to calculate the locations of its markings and the stainless steel sphere atop the obelisk was given a special, high-tech coating to produce its lustrous appearance.

Sundials came into general use during the thirteenth century A.D. All early sundials kept solar time. Solar time is the time followed by our body clocks, known as the circadian rhythms. It can be argued that solar time is more natural than standard time, since it follows the sun rather than some mechanical contraption invented by humans.

The mechanical clock, which supplanted the sundial in the fifteenth century, divided the year into precisely equal intervals of time, the year being defined in terms of the earth's rotation around the sun. Clocks were expensive, however, and few kept good time, so sundials were still widely used until relatively inexpensive and accurate clocks and watches began to be marketed widely.

Sundials keeping solar time are still designed and built in the modern era, even though standard time clocks are widely available, but mostly as a curiosity or for interests other than the keeping of time.

Large Sundials

Until recently, the largest sundial in the world was the one at Jaipur, India. Built by Jai Singh in 1724, it is called the *Samrat Yantra*. Its sloping gnomon is 150 feet long and its peak is about 90 feet above the ground. (See "Stairways to Heaven" by Peter Engel in the 6 June 1993 issue of Natural History, p. 48.) A larger sundial was completed in May of 1991 as part of a regional headquarters office building at Disney World in Florida. The Disney sundial currently holds the world record as the largest and can be found in the Guiness Book of World Records, which refers to the outside diameter of the sundial (at its base) as 122 ft, corresponding to a wall thickness of a little over 1 foot. The Disney dial is 120 ft high, 120 ft in diameter at the bottom, 84 ft in diameter at the top, and the center of the top opening is offset from that of the base circle by 6.86 feet. It’s gnomon is a 2 ft diameter sphere located in the center of the top circular opening. The sundial structure is free-standing, unsupported by any of the building elements that surround it. Dr. Ross McCluney, technical consultant on the UT Pan American dial, also served in this capacity for the Disney dial.

Celebrating the Sun

Thank you for taking an interest in this sundial. It was designed to be a celebration of the sun and its importance in our lives. It calls us to reconnect with the source of all life on earth, that energy-giving star we call our sun, and to pay more attention to the natural, solar-phased rhythms our bodies would prefer to follow. Being located in an educational setting, and keeping civil time as well as solar time, the dial encourages us to learn more about the eternal dance of time our earth celebrates with the sun each day.

> “The sundial bridges past and future, earth and space, nature and technology. Sundials personalize and maybe even humanize time. Certainly the daily observation of a sundial projects our understanding of Earth's place in the cosmos. Sundials show change, motion, and relationships. They help us realize how dependent we are on the sun, not only for the keeping of biological time, but also for other important life-giving functions on earth, including photosynthesis, and the provision of heat and light.” -- David La Hart

More Information about Sundials

There are several books about sundials available through major public libraries, and a few are still in print, obtainable from major booksellers. Titles and authors include *Sundials Their Construction and Use* by R. N. and M.W. Mayall, *Sundials Their Theory and Construction* by Albert E. Waugh, *A Choice of Sundials* by Winthrop W. Dolan, and *Sundials, History, Theory, and Practice* by Rene R. J. Rohr.

The North American Sundial Society was formed in February 1994 by Ross McCluney, Fred Sawyer, and Bob Terwilliger as an international association of people from a variety of disciplines who are interested in the study, development, history, and preservation of sundials and the art of sundial design. Dr. McCluney, Technical Advisor on the UT Pan American dial, also served as the first President of NASS. The Society can be reached at the following site on the internet's world wide web: www.sundials.org. The Society publishes the *Compendium*, a quarterly journal, in both print and digital formats.