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The Compendium*

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The first grand discovery was time, the landscape of experience.

– Daniel Boorstin

* *Compendium*... "giving the sense and substance of the topic within small compass." In dialing, a compendium is a single instrument incorporating a variety of dial types and ancillary tools.

The Chinook Trail Sundial

John Carmichael (Tucson AZ)

Fig 1. Overhead View

Early in 2006 I was asked by Chris Coulter, the head contractor for The Academy School District 20 in Colorado Springs, to design a giant monumental sundial for the new Chinook Trail Elementary school. I had worked with Chris the previous year on the large stone equatorial dial at the Discovery Canyon School, but this time, he wanted a much larger dial that would be the architectural centerpiece of the new school. I was stunned by the size available for the dial face and by the huge budget that they had designated for the sundial project. It is not often that I get the chance to do something this big with a large budget, so I eagerly accepted the commission. (figures 1 & 2)

Fig 2. Original Site Plan

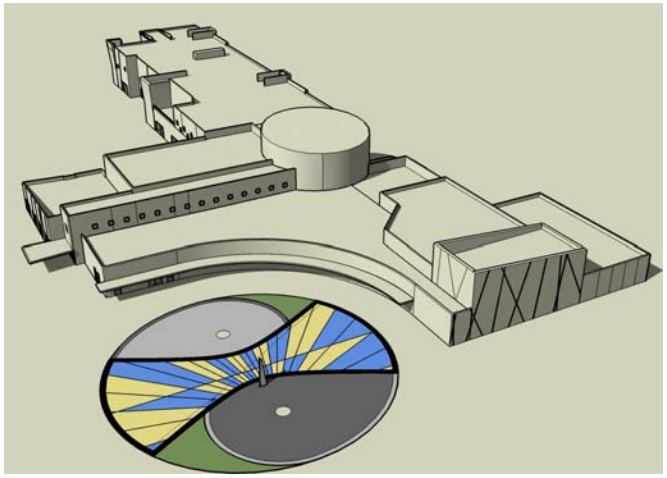

Fig 3. Site Plan 3D Drawing with Giant Sundial

The entire face is circular and looks like the Chinese symbol for Yin Yang with a bowtie shaped sundial in the center. The school chose a design that looks like a Yin Yang symbol since the school specializes in Chinese studies for gifted children. Curved green grass landscaping adds the proper color contrast of the symbol. (figure 3). The two differently colored dots in the symbol are represented on the face by two six foot round ceramic mosaic maps of the earth's western and eastern hemispheres made by artist Juanita Canzoneri. (figure 4)

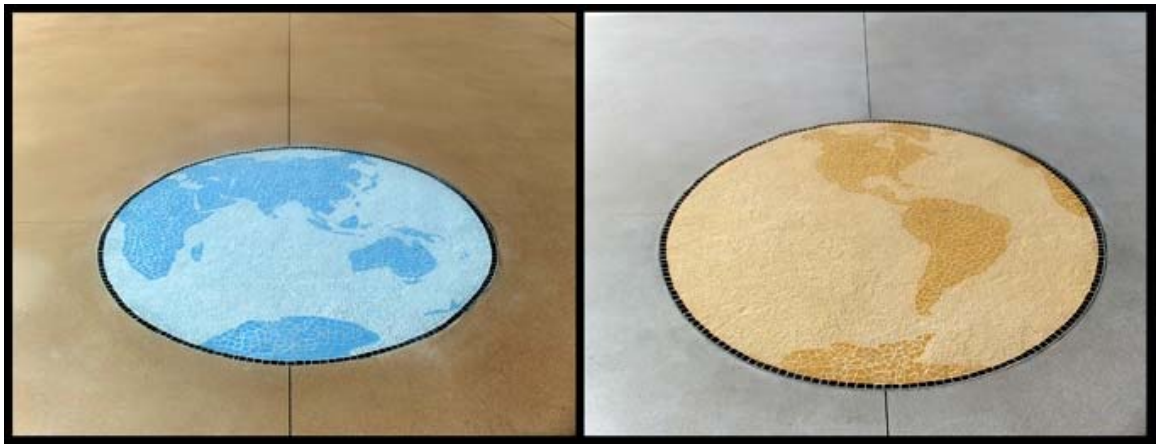

Fig 4. 6 ft Wide Mosaic Hemispheres

At this point in my dialing career, I was a bit tired of making dials with traditional triangular polar axis gnomons, and I was most interested in developing the ideal design for a perpendicular vertical gnomon. Based on shadow casting experiments with cardboard models that I had done for a painted wall dial, I really wanted to design this dial with a wide blunted conical gnomon. When you select a gnomon design you must consider the way the shadow's shape changes at different times of the day when the sun hits the gnomon from different directions. A conical gnomon is great because it is symmetrical and its shadow always looks like a cone no matter where the sun is. But the shadow cast by a three sided pyramid

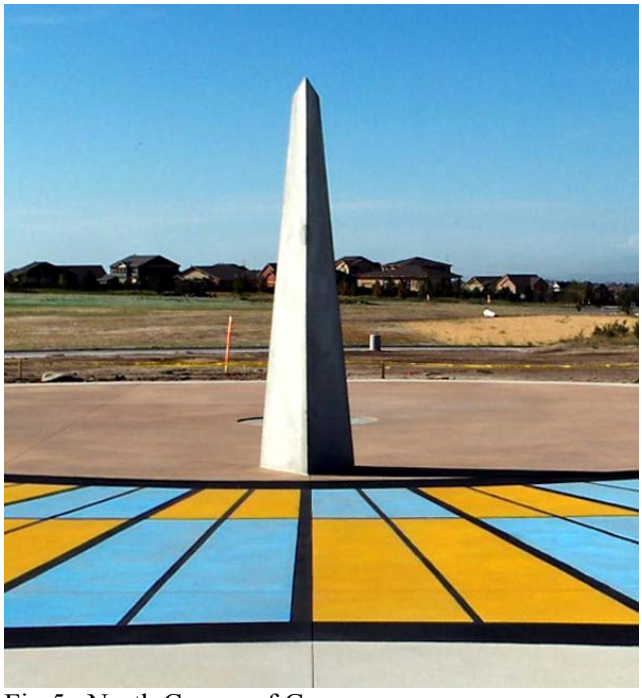

Fig 5. North Corner of Gnomon

Fig 6. South Side of Gnomon

changes shape depending on the sun's position. Chris wanted to be able to cast the gnomon from concrete in a mold, but he thought that that the mold would be a difficult thing to make for a cast conical gnomon and he liked the idea of a pyramid. So we opted for a three-sided equilateral inclining truncated pyramid gnomon instead. (figures 5 & 6)

The gnomon design for such a large sundial is tricky and not as straightforward as you might think. Since the sundial's face width measured one hundred and twenty feet, I had to be careful to design the gnomon so that its tip's shadow would be visible in the early mornings and late afternoons when the shadow casting distances are largest. I've always thought that the best way to design unusual gnomons is to make models and experiment with them, so that is what I did. I wanted the shadow of the bottom part of the gnomon to be wide so that it really stood out on the face. This meant that the pyramid would need to be wide at its base. But I also wanted the pointed tip of the gnomon to be as small as possible so that the dial readings would be precise.

Here's the problem: If you make the tip of the gnomon too slender and pointed, then its shadow becomes fuzzy and disappears completely when cast from a great distance. This occurs in the early mornings and late afternoons, especially in the winter months when the sun is low and the shadows are long. But if you make the tip of the gnomon too fat and wide, then you lose precision. So you need to compromise to find a shape and size of the gnomon tip (the nodus) that minimizes shadow fuzziness and maximizes precision. My experimental models quickly showed me that a pointed pyramid would not cast a visible shadow in the early mornings and late afternoons. This would make the shadow shorter than it should be and negatively affects time and date readings. So we considered adding a sphere to the top of the pyramid. But previous experiments showed me that a sphere's shadow is also problematic when the shadows are long because it elongates into a long thin ellipse making it hard to read. What should I do? More experiments of course! I made several 12 inch tall cardboard gnomon models of differently shaped pyramids. By tilting my models in the sun, I was able to place the sun anywhere around them and I could also lengthen or shorten the shadows. They showed that I should discard the ideas of using an attached sphere or of using a slender pointed gnomon, and that I should use a truncated chopped-off pyramid instead. I needed to truncate the top of the gnomon to make the tip fatter so that it would cast a visible shadow in the mornings and afternoons. But how much of the pyramid should I chop off? And at what angle and direction should it be chopped off? Also, how should I orient the gnomon? Should I put a corner of the pyramid on the north or should a side of the pyramid face north? Should the north side or corner of the gnomon be vertical or angled? (figure 7)


Fig 7. Cardboard Gnomon Experiment

I found out that the ideal shape and orientation of the pyramid gnomon would have these characteristics:

1) First, it is best to put one corner of the pyramid to the north and this corner should be vertical with the tip of the truncated pyramid at the top of the north corner. You need to make the north corner vertical because you need space on ground at the north side for the hour numerals. Also, you don't want the north corner to stick out too far or else the base of the gnomon will obstruct the tip's shadow when the sun is high around the summer solstice at noon. To make the north corner of the equilateral pyramid vertical means that you need to tilt the pyramid slightly to the north.

2) The tip of the gnomon needs to be truncated at an angle that slants up from the south side of the pyramid to the tip at the north. This angle should be parallel to the polar axis. Obviously, if you were to chop off the tip horizontally, you would not get a shadow that is as pointed as one cast from an angled truncation. Since this dial is located at about 39 degrees latitude, the gnomon was truncated at an angle of 39 degrees with respect to horizontal.

3) Using what I call "the fuzz factor ratio", I knew that the width of a shadow caster should be greater than about 1/107th of the maximum shadow casting distance. If an object's width is less than this, then its shadow will begin to disappear when longer than this. Since the maximum shadow casting distance of this dial is about 70 feet or 840 inches, I divided 840 by 107 and got 7.8 inches. This means that the truncation should at least 7.8 inches wide or wider. I chose to truncate the pyramid so that it is a little wider than the theoretical minimum to be certain that its shadow would be clearly visible when long. So I made the truncation 10 inches wide at the top of the gnomon's south side. (figure 8)

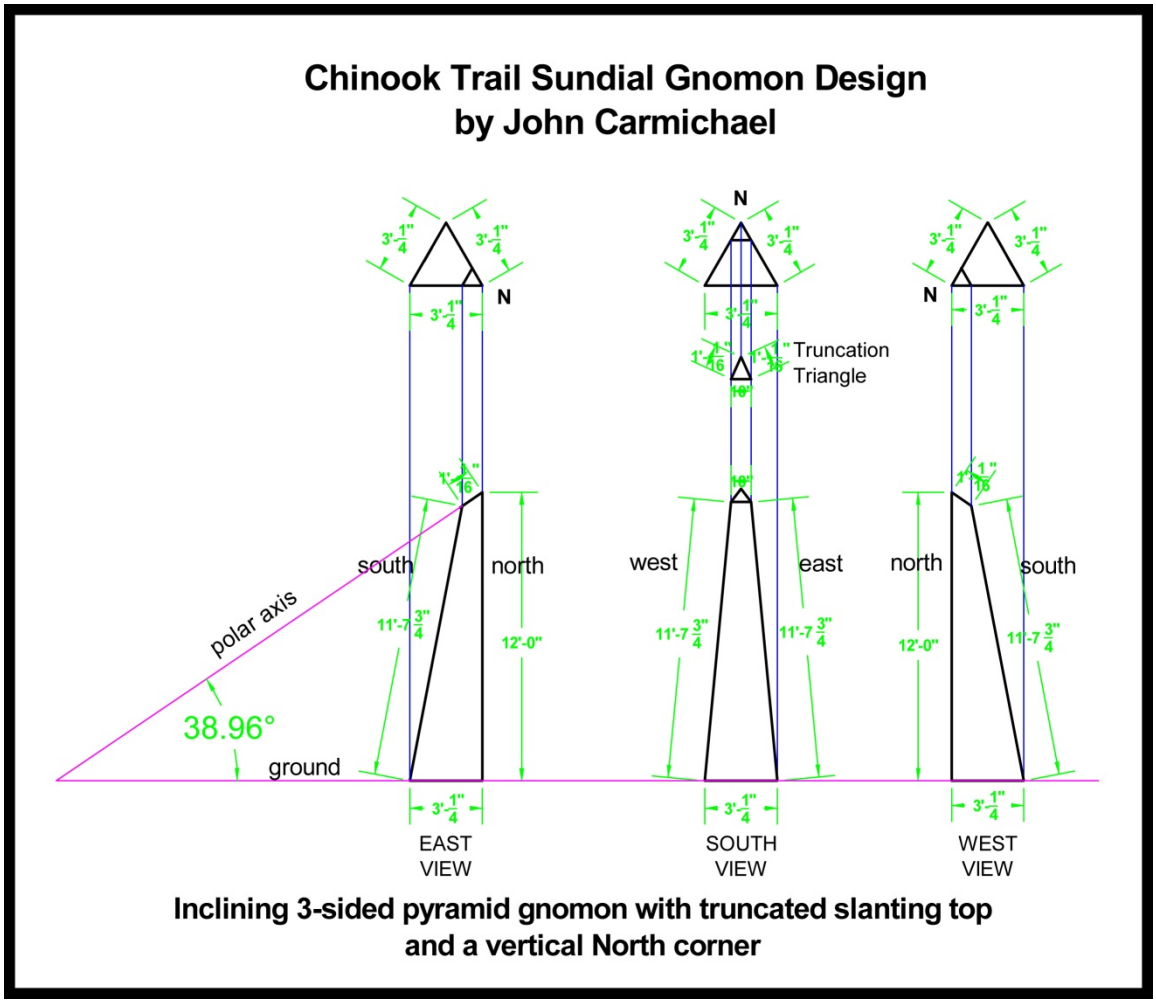

Fig 8. Gnomon Design Drawing

My cardboard model experiments verified that this was a good place to chop off the top of the pyramid. This was confirmed with the sundial on the Winter Solstice in 2007 when we saw that the tip's shadow was clearly visible and precisely on the Winter Solstice line all day long. (figure 9)

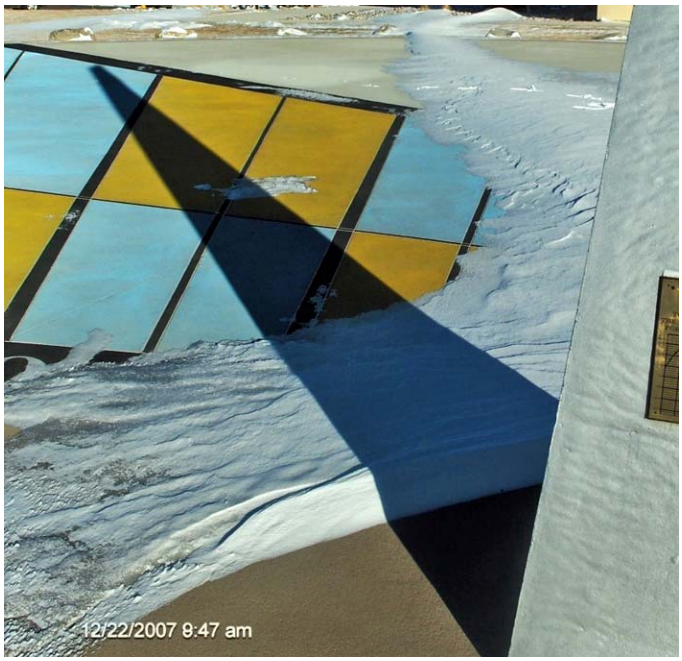

Fig 9. Winter Solstice 2007 photo


Fig 10. Gnomon Installation

In late June of 2007, the contractors fabricated and installed the massive twelve foot tall cast concrete gnomon using a heavy lift construction crane. We left a piece of rebar shaped into a ring at the top of the gnomon so that we could attach it to the crane. Once the gnomon was lowered onto its three foot deep cement foundation, it was bolted into place and we sawed off the rebar ring at the top. The masons patched all the scrapes and irregularities on the surface, and then it was sealed and painted a metallic silver color. (figure 10)

After the gnomon was installed, work began on pouring the cement for the enormous 120 ft. sundial face. By law, the face had to have a slope of 1% for water drainage. This doesn't seem like much, but it meant that the high side of the face was 24 inches higher than the low side! The head architect said I could slope it in any direction, so I designed it to slope due south so that the dial face would look symmetrical and would maximize solar exposure. (figure 11)


Fig 11. Pouring Concrete Sundial Face

After the concrete hardened, I used the shadow cast from the string of a plumb bob at Solar Noon to determine and mark the concrete with the exact north/south meridian line from the north corner of the base of the gnomon. The next day, with a couple of helpers, some long measuring tapes, Sharpee pens, chalk lines and a theodolite, we transferred the hour and declination lines to the face. Although we could have done this without a theodolite using an x-y coordinate grid pattern, the theodolite really simplified things. After testing its precision, I was confident that we could use it to mark hour angles instead of using a grid pattern. However, we did need to use x-y coordinate measurements

to lay out the curved solstice lines. After all the lines were marked with chalk, they were sandblasted 1/8" deep to prepare them for staining. The hour lines are 4 inches wide and the half hour and equinox lines are 2 inches wide. (figure 12)

Fig 12. Finding North at Solar Noon

There are two numeral time notations: Mountain Standard Time numerals are on the north part of the face on a two foot wide black border, just outside of the Winter Solstice line, and Daylight Saving Time numerals are on the south part of the face just outside of the Summer Solstice line. Hour lines have built-in longitude shift to compensate for the distance and time shift from the Mountain Standard Prime Meridian. The longitude shift is quite small here being only .27° east of the Mountain Standard Time Meridian which is located at 105° W. longitude. For precision, the hour lines are corrected for this small longitude shift which equals only 1 minute and 5 seconds of time at this longitude.

We colorized the background in a checkerboard pattern of light yellow and light blue sections that alternate between the hour lines and the equinox line. The contractors of Colorado Hardscapes used lithium quartz, acid stains, and acrylics - sometimes with water carriers and occasionally with acetone. The concrete was placed with a retarder that when removed, left the exposed sand finish. With this finish they were able to stain the concrete. The stain was applied by roller with just one coat because two coats would make the surface look painted which we didn't want. It will last six to eight years and will diminish in time but will not vanish. It will need to be reapplied at that time to maintain its brilliance. For more information on our coloring materials and methods, see www.semcomfg.com. (figure 13)

When all was finished, we bolted bronze plaques of the Equation of Time graph and User Instructions to the south side of the gnomon. The dial installation was finished in August 2007 just in time for school opening. (figure 14 – back cover)

See high definition photos online at http://advanceassociates.com/Sundials/COSprings/ . The sundial is situated at Chinook Trail Elementary School, 11795 Grand Lawn, Colorado Springs, 80924 Colorado Springs CO at latitude 38.96° N. and longitude 104.73° W. on the south side of the building between the parking lot and the main entrance, and is available for public viewing.

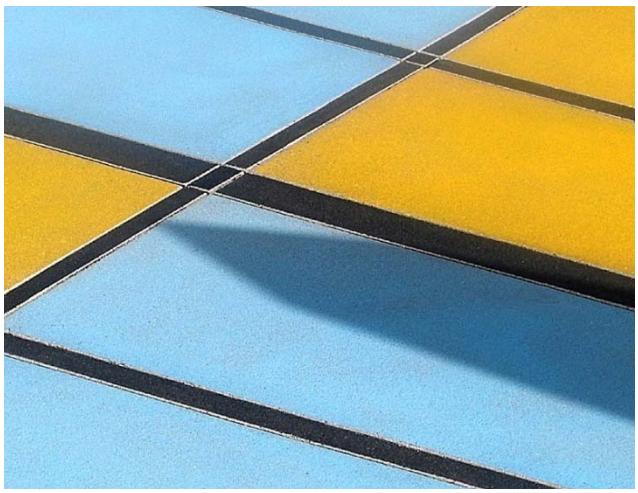
Fig 13. Shadow on The Equinox

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THE CHINOOK TRAIL SUNDIAL

JULY 2007

LATITUDE: 38.96° N. (38° 58' N.), LONGITUDE: -104.73° W. (-104° 44' W.)

DESIGNED BY JOHN L. CARMICHAEL & CHRIS COULTER

DESCRIPTION

THE CHINOOK TRAIL SUNDIAL IS ONE OF THE LARGEST SUNDIALS IN THE WORLD, WITH A 120 FT. DIAMETER FACE AND 12 FT. VERTICAL GNOMON. IT IS SO LARGE THAT IT CAN BE READ FROM SPACE. IT WAS DESIGNED USING SPHERICAL TRIGONOMETRY AND ACCURATELY INDICATES THE TIME, THE DATE, AND THE CARDINAL POINTS OF THE MERIDIAN WHICH IS LOCATED AT 105° W. LONGITUDE. FOR PRECISION, THE HOUR LINES ARE CORRECTED FOR THIS COMPASS. IT IS AT 104.73° W. LONGITUDE WHICH IS JUST 0.27° EAST OF THE MOUNTAIN STANDARD TIME SMALL LONGITUDE SHIFT WHICH EQUALS ONLY 1 MINUTE AND 5 SECONDS OF TIME AT THIS LOCATION.

USER INSTRUCTIONS

TO OBTAIN SOLAR SUNDIAL TIME

TO TELL SOLAR TIME CORRECTED FOR LONGITUDE SHIFT, ESTIMATE THE TIME BY NOTING THE POSITION OF THE TIP OF THE GNOMON'S SHADOW IN REFERENCE TO THE HOUR LINES ON THE FACE. NOTE THAT SOLAR TIME IS NOT ALWAYS THE SAME AS WATCH TIME AND WILL SOMETIMES BE SLIGHTLY AHEAD OF OR BEHIND WATCH TIME. TO CONVERT SOLAR SUNDIAL TIME TO WATCH TIME, READ THE SECTION BELOW.

TO OBTAIN WATCH TIME

FIRST, DETERMINE SOLAR SUNDIAL TIME, THEN, USING THE EQUATION OF TIME GRAPH, ADD OR SUBTRACT THE NUMBER OF MINUTES SHOWN ON THE GRAPH FOR TODAY'S DATE.THE HOUR NUMERALS ON THE NORTH, THE EAST AND THE WEST SIDES OF THE DIAL ARE MOUNTAIN STANDARD TIME, AND THE HOUR NUMERALS ON THE SOUTH SIDE ARE DAYLIGHT SAVING TIME.

TO TELL THE TIME OF SOLAR NOON

AT SOLAR NOON, THE SUN IS DUE SOUTH AND IS AT ITS HIGHEST ALTITUDE ABOVE THE HORIZON FOR THE DAY. AT THIS MOMENT, THE SHADOW OF THE GNOMON'S TIP POINTS DUE NORTH. DUE TO THE SMALL LONGITUDE SHIFT, SOLAR NOON (DUE NORTH), IS AT 11:58:55 AM SOLAR SUNDIAL TIME WHEN STANDARD TIME IS IN EFFECT, AND AT 12:58:55 PM SOLAR SUNDIAL TIME WHEN DAYLIGHT SAVING TIME IS IN EFFECT. WHEN THE SHADOW IS AT THIS POINT, IF YOU APPLY THE EQUATION OF TIME, YOU CAN DETERMINE WATCH TIME OF SOLAR NOON.

TO TELL THE DATE

THE NORTH CURVED BORDER IS THE WINTER SOLSTICE LINE, THE SOUTH CURVED BORDER IS THE SUMMER SOLSTICE LINE, AND THE STRAIGHT EAST/WEST LINE IN THE CENTER IS THE EQUINOX LINE. ESTIMATE THE DATE BY NOTING THE POSITION OF THE GNOMON'S TIP IN REFERENCE TO THESE LINES.

TO TELL THE CARDINAL POINTS OF THE COMPASS

THE STRAIGHT EQUINOX LINE LIES DIRECTLY EAST AND WEST. THE GNOMON'S SHADOW AT SOLAR NOON POINTS DUE NORTH.

Chinook Trail Sundial - User Instructions