Did Egyptians Use the Sun to Align the Pyramids?

by Glen Dash, Glen Dash Foundation for Archaeological Research

The Egyptians aligned pyramids of the 4th Dynasty, including the Great Pyramid of Khufu and its neighbor Khafre, to cardinal points with amazing accuracy.* The casing of the Great Pyramid is aligned to true north to within 4 minutes of arc, better than 1/15 of 1 degree. For the most part, scholars who have written on the issue have concluded that the Egyptians must have used the stars to achieve such accuracy. Wrote one, "[I]t is nearly impossible to attain such a high precision using solar methods."[1]

Martin Isler, an American illustrator and sculptor, disagreed. Though not formally trained as an archaeologist, Isler had earned professional recognition for his studies on the methods the Egyptians had used to work and move stone.[2] On the issue of pyramid alignments, Isler argued that the Egyptians could have used a technique known as the "Indian Circle Method," thought to have been pioneered on the Asian subcontinent.[3]

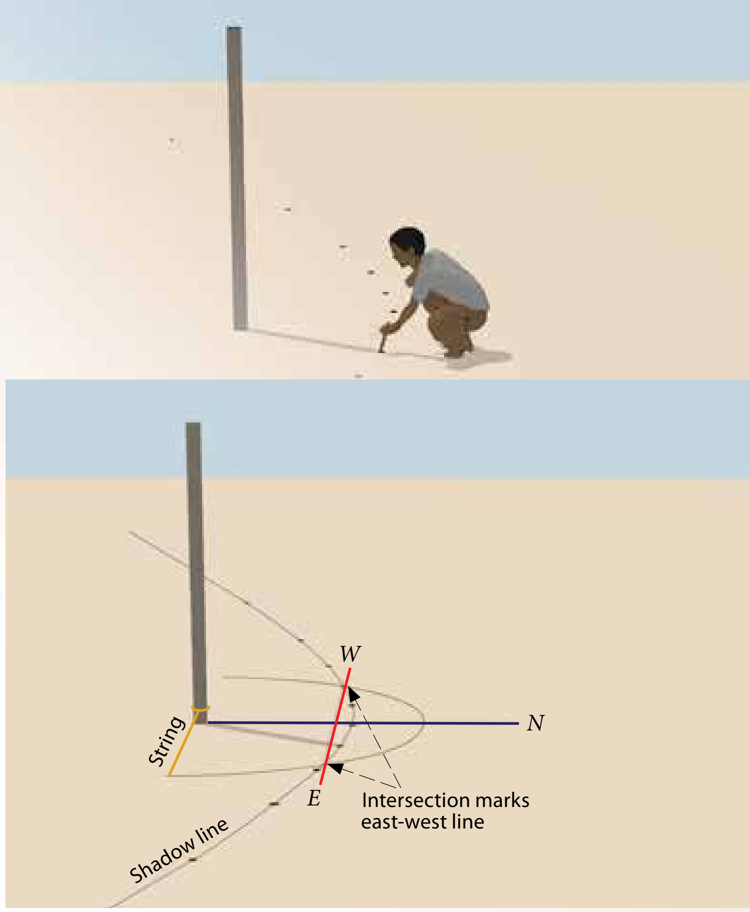
In this article, I put the Indian Circle method to the test. I find that, with one critical modification, the method works, and *is* capable of yielding results sufficiently accurate to account for the alignment of the pyramids' casings.

The Indian Circle method is illustrated in the figure on the right. An observer starts by setting a rod vertically in the ground. The rod is known as a *gnomon*, Greek for "one who knows." As the day passes, the shadow produced by the gnomon is tracked by the observer, who marks its position on the ground every few minutes, eventually producing a curve called the shadow line. At the end of the day, the observer fixes a string to the base of the rod and draws a circle that intersects the shadow line at two points. In theory, a line drawn through those two points will run exactly east-west.

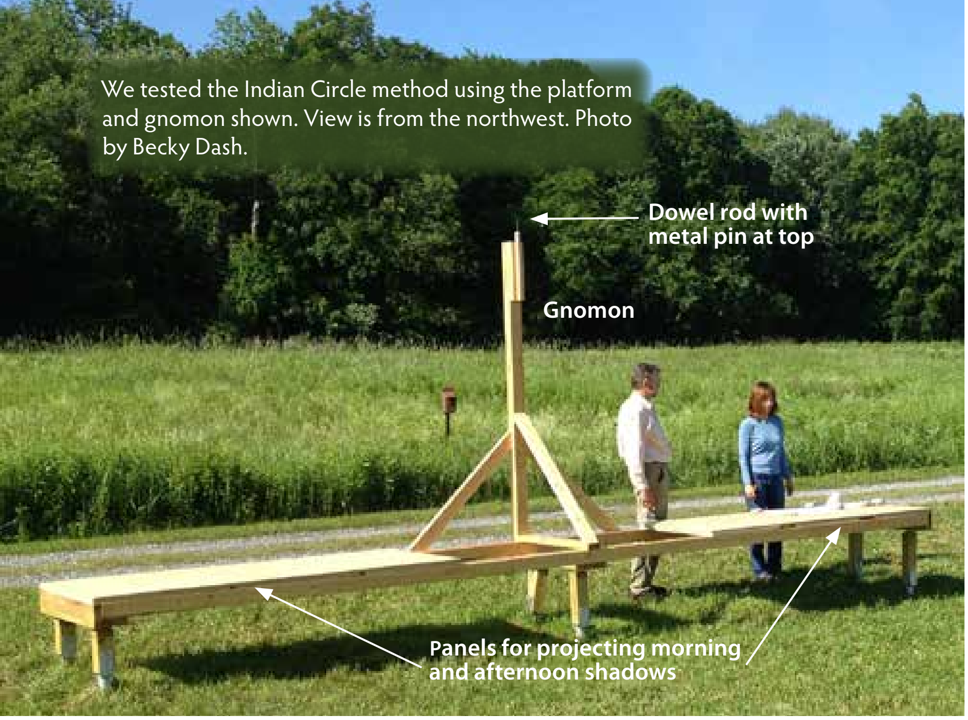
I tested the Indian Circle method at my home in Pomfret, Connecticut, in mid-summer near the solstice when the sun was high in the sky and shadows sharp. Because the ground around my house was uneven, I built a raised wooden platform with a horizontal surface for projecting the gnomon's shadow, (see facing page, upper left). I attached the gnomon's supporting post to the platform's south side along its midline. For convenience, I wanted to start the test around eight in the morning. At that time, however, the sun was almost due east, so I needed to shift the position of the gnomon's tip slightly to the north of the platform's southern edge so its shadow would fall on the platform. I did this by bolting a short length of 2-by-4 to the supporting post and attaching the gnomon's tip to it as shown on the facing page, upper right. I constructed the gnomon's tip out of a 1.25-inch (3.18 centimeters) diameter dowel rod and capped it with a rounded wooden half ball. I used the shadow cast by the dowel rod and half ball to track the movement of the sun. In all, the entire gnomon stood 6 foot, 11 inches (2.11 meters) above the platform's surface. I also threaded a quarter-inch (6.4 millimeters) metal pin into the top of the gnomon's tip. I used the metal pin to anchor the string I used to draw the circle around the gnomon at the completion of the tests.

For the Indian Circle method to work well, the gnomon's shadow must be projected onto a level surface. As I discussed in "North by Northwest: The Strange Case of Giza's Misalignments" in a recent issue of *AERAGRAM* (Spring 2012), an east-to-west slope to the surface will cause a clockwise rotation of the results. I used a spirit level to verify that the platform was reasonably level.

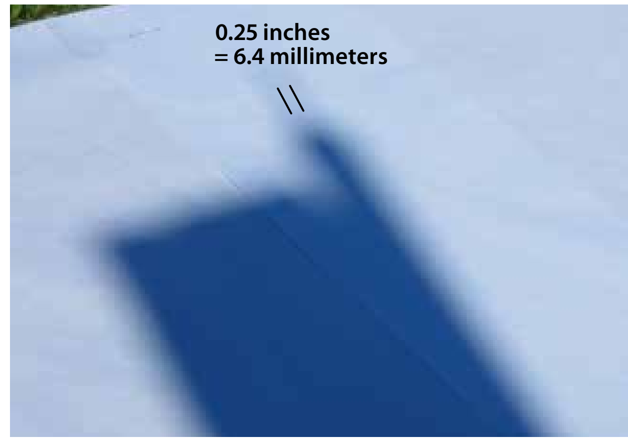
The Indian Circle Method



*For more on this topic, see Glen's previous *AERAGRAM* articles: "North by Northwest: The Strange Case of Giza's Misalignments," Vol. 13-1, pages 10–15, 2012; "New Angles on the Great Pyramid," Vol. 13-2, pages 10–19, 2012; and "How the Pyramid Builders May Have Found Their True North," Vol. 14-1, pages 8–14, 2012. All back issues of *AERAGRAM* are available for free download at our website: aeraweb.org.



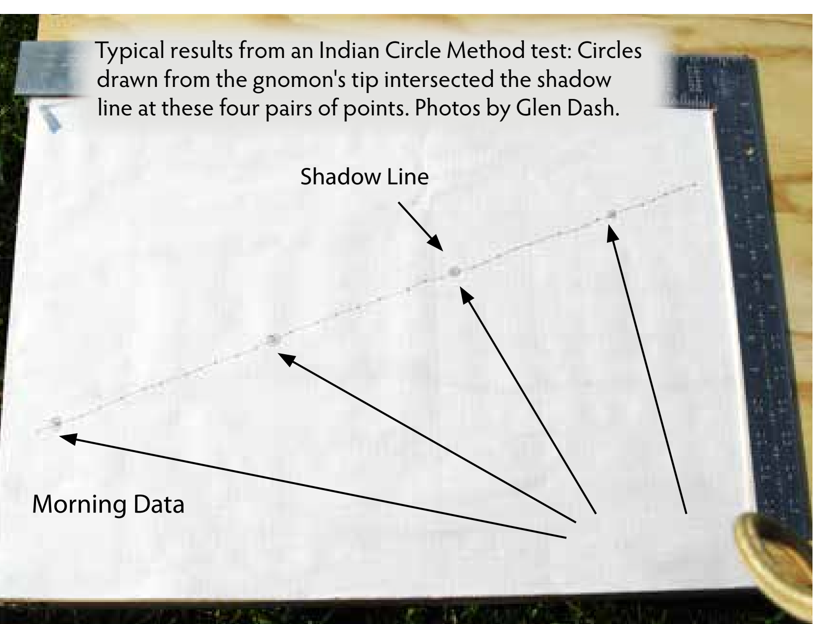
We tested the Indian Circle method using the platform and gnomon shown. View is from the northwest. Photo by Becky Dash.



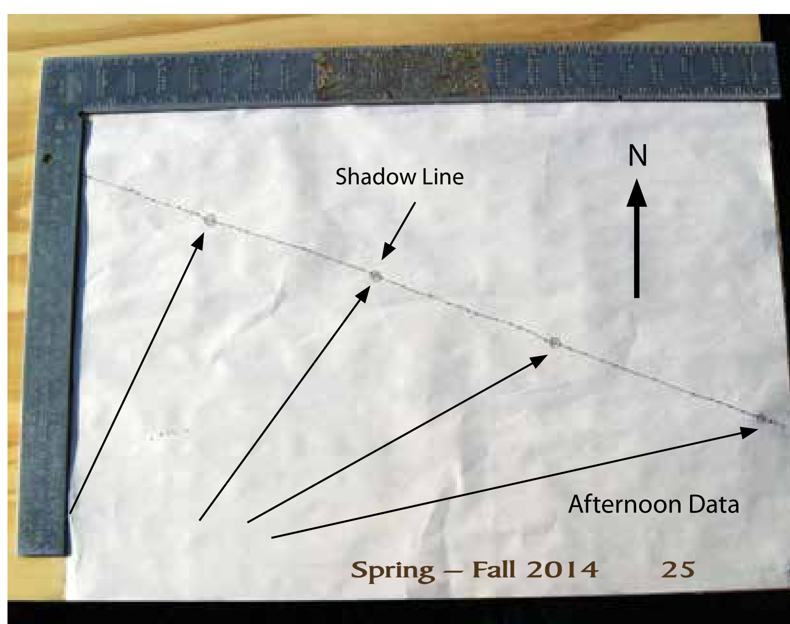
At top, a close up of the gnomon tip. Below, the gnomon's shadow. Photos by Glen Dash.

Indian Circle method tests in progress. The tests were filmed by a team from the History Channel's show "The Universe." Photo by Becky Dash.

The figure above shows the shadow produced by the gnomon during the tests. I found that it took two people to efficiently record the shadow's position. At left, Dr. Joan Dash marks the location of the shadow while I view it from about 1 meter away. The two of us would agree on a location every minute or so, when Joan would mark the agreed location on the quarter-inch (6.4 millimeter)-ruled graph paper. We could time a minute interval simply by watching the shadow's movement. We found that we only needed to take data for about an hour in the morning and an hour in the afternoon to complete the test. The figures below show a typical set of results.



Typical results from an Indian Circle Method test: Circles drawn from the gnomon's tip intersected the shadow line at these four pairs of points. Photos by Glen Dash.

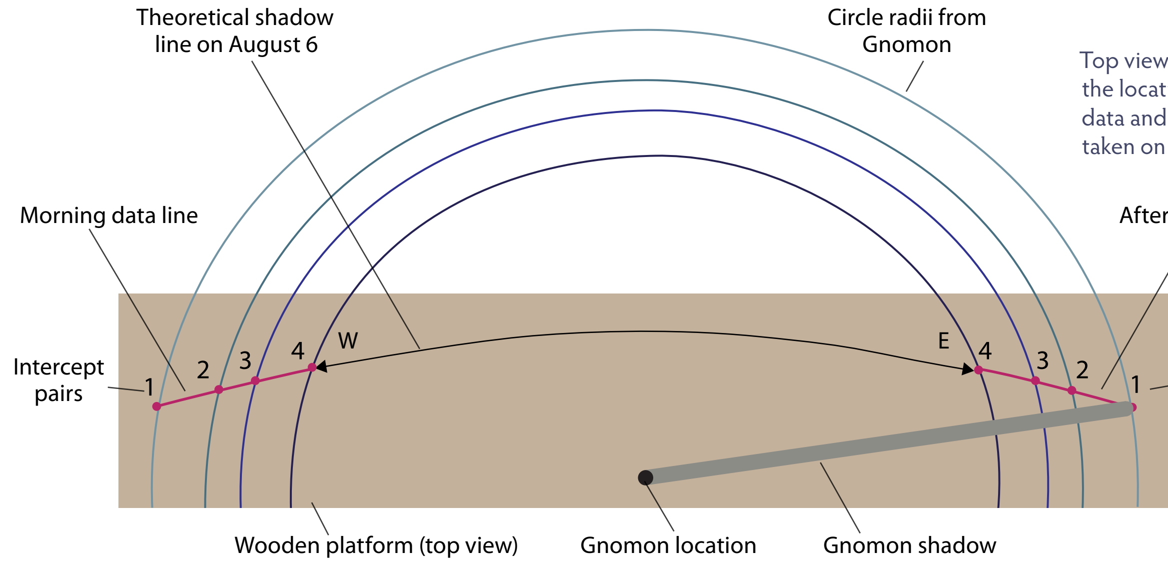


Drawing the circle. After the shadow line is established, a string is pulled from the top of the gnomon and matched with the shadow line on one side of the platform (a). The length of the line is then fixed and pulled over to the other side of the platform (b and c). The string is matched to the line there (d). The two points where the string and the line intersect should run straight east-west. Photos by Becky Dash.

In the Indian Circle method, the next step is to attach a string to the gnomon's base and use it to draw an intersecting circle with the shadow line. For the method to work well, however, the circle must be precisely centered on the part of the gnomon which produced the shadow. If I drew the circle from the base of the rod, as Isler had proposed, the gnomon would have to be set perfectly straight and vertical, something which is difficult to do using only the tools the Egyptians had. Therefore, I modified the technique by drawing our string from the top of the gnomon instead of the bottom (see figures a-d, this page). I threaded the string over the metal pin I inserted at the top of the dowel rod, and drew it out to a point on the afternoon data. I chose a point on the afternoon's data where the shadow line ran smooth. I marked the exact point where the string touched the shadow line on the string. I then pulled the string over to the morning's data and marked the location where the point I marked on the string matched the morning's data. I repeated the process four times and circled the four sets of intersecting points.

Prior to the test, I had set up a total station and aligned it with true north.† Now, using the total station, I measured the four sets of points and determined the true angle of the lines running through them (top figure, next page; table 1).

† I used a Topcon GPT-3005LW reflectorless total station. I set a permanent control monument and placed the total station over it. To locate the meridian, I focused the total station's telescope on Polaris and recorded the time to the second. I used the US Naval Observatory (USNO) Multiyear Interactive Computer Almanac (MICA) Version 2.2.1 to identify the azimuth of Polaris at that moment and loaded that information into the total station. I then focused the total station on a second star, Kochab, and noted the time. The total station's readout of Kochab's azimuth matched the USNO data for the star to within 10 seconds of arc. Thus, the total station was calibrated and could be used to record the horizontal angle (azimuth) of any given point from that location with that accuracy.



Top view of the platform showing the location of the shadow line, data and intercept pairs. Data taken on August 6, 2013.

Table 1: Error Off True East-West Produced by the Indian Circle Method

Intersecting Pair	Clockwise Angle off Due East-West
1	-3 minutes, 26 seconds (-0.057 degrees)
2	-4 minutes, 34 seconds (-0.076 degrees)
3	-1 minute, 26 seconds (-0.024 degrees)
4	+50 seconds (0.014 degrees)
Average	-2 minutes, 9 seconds (-0.036 degrees)

Test performed on August 6, 2013.

Table 2: Error Off True East-West Produced by the Indian Circle Method Using an Angled Block as a Shadow Definer

Intersecting Pair	Clockwise Angle off Due East-West
1	No measurable error
2	-3 minutes, 17 seconds (-0.055 degrees)
3	-4 minutes, 58 seconds (-0.083 degrees)
4	-6 minutes, 54 seconds (-0.115 degrees)
Average	-3 minutes, 47 seconds (-0.063 degrees)

Test performed on June 19, 2013.

The average error was 2 minutes and 9 seconds, about 1/28 of a degree, better than the 3 minute 38 second alignment of the Great Pyramid's casing.[4] Three of the four lines ran just north of east, exhibiting a counterclockwise rotation from straight east-west (a clockwise rotation is denoted by a positive sign in the table). Data taken later in the morning and earlier in the afternoon were more accurate, probably because the sun was higher in the sky and the shadows sharper.

While this method might have sufficed, it does take some practice to reliably identify where the shadow falls. To make things easier, I tried using an angled block of wood as a "shadow definer" (figure below). The block, covered in white paper, was angled at 50 degrees so it would be more or less perpendicular to the rays of the sun during the test. While the angled block did make the shadow's tip easier to see, it produced its own set of errors which became greater later in the morning and earlier in the afternoon (table 2).

Joan Dash illustrates the use of an angled block as a shadow definer. Photo by Becky Dash.

Other cultures also used solar gnomons to perform such tasks as tracking the time of the day or the passing of the seasons.[5] Some used sophisticated shadow definers. To test the limits of the Indian Circle method, I used one described in the *Yuan Shih*, a history of the Chinese Yuan Dynasty.[6] It consists of a copper leaf with a pinhole in its center. The pinhole acts as a lens, focusing the image of the gnomon.[7] I made our shadow definer by drilling a 1/16-inch (1.6 millimeters) hole in a 6.75 × 5 inch (17.1 × 12.7 centimeter) sheet of copper, which I angled at 50 degrees to best catch the rays of the sun. I mounted it on a 19-inch-high (48.3 centimeters) wooden frame (top right, next page). The shadow definer produced a well-focused image of the gnomon's tip, so well-focused, in fact, that I could clearly see the quarter-inch diameter rod rising above the wooden dowel. I decided to track the sun by aligning the tip of the metal pin with the top of the image of the sun, and marked that location on the paper every minute or so. The results were impressive (table 3). The average error was just 19 seconds of arc or about 1/180 of a degree, close to what I can expect to achieve with a modern total station.

Table 3: Error Off True East-West Lines Produced by the Indian Circle Method Using a Pinhole as a Shadow Definer

Intersecting Pair	Clockwise Angle off Due East-West
1	No measurable error
2	36 seconds (0.010 degrees)
3	No measurable error
4	39 seconds (0.011 degrees)
Average	19 seconds (0.005 degrees)

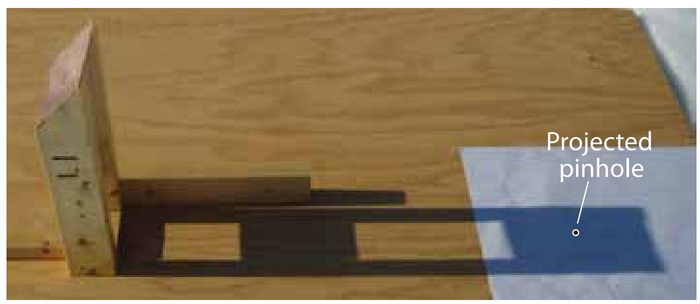
Test performed on May 30, 2013.

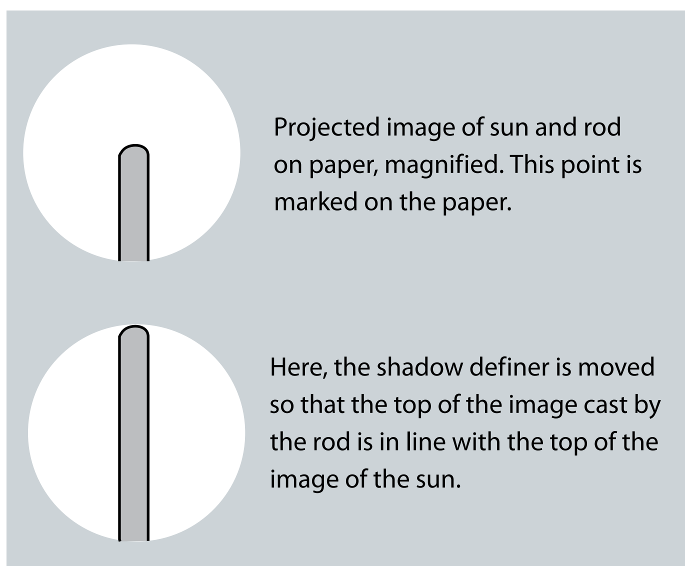
My tests showed that the Egyptians could have aligned the casing of the Great Pyramid to cardinal points using the Indian Circle method. The method is best performed near the summer solstice when the sun is high in the sky, providing sharp shadows. It requires an observer to track the motion of the sun for an hour or so in the morning and again in the afternoon. Using a string attached to the tip of the gnomon, the observer then draws a circle, identifying two points of intersection which will run east-west. While workable, the method requires a keen eye, and the Egyptians may have found that a "shadow definer," such as an angled block of wood, helps. On the other hand, had the Egyptians used the pinhole shadow definer described by the Yuan Dynasty Chinese, their results might have been even better.

The Egyptians of the Old Kingdom left us only scant records regarding the methods they might have used to align their great monuments. Therefore, I cannot say with any certainty that the Egyptians actually used the sun to align the casing of their pyramids with cardinal points. However, I can definitely say that they could have done so, and needed only the tools they had at hand: wood, rope, copper, and stone.

The author would like to thank Juan Antonio Belmonte for his review of this article and his comments.

Above: A pinhole punched in a copper sheet acts as a shadow definer. In our tests, the shadow definer was able to produce an image so sharp that we could see the rod projecting from the gnomon's tip. This aid would have allowed the Egyptians to resolve a true east-west line to within a minute or so of arc.
Below and bottom: The copper plate with a 1/16-inch pinhole projected onto the paper below. Photos by Glen Dash.





1. Magli, G., *Architecture, Astronomy, and Sacred Landscape in Ancient Egypt*, New York: Cambridge University Press, page 90, 2013.

2. Arnold, D., *Building in Egypt*, New York: Oxford University Press, page 104, 1991.

3. Isler, M., "An Ancient Method of Finding and Extending Direction," *Journal of the American Research Center in Egypt*, Vol. 26, (pages 191–206), page 197, 1989.

4. Dash, G., "New Angles on the Great Pyramid," AERAGRAM Vol. 13-2 (2012), page 16.

5. Isler, M., Ibid., pages 197–98.

6. The primary reference on the Chinese use of solar gnomons and shadow definers is J. Needham, *Science and Civilization in Ancient China*, Cambridge, 1959, pages 296–99. For its use generally among traditional peoples, see E. C. Krupp, *Echoes of Ancient Skies: The Astronomy of Lost Civilizations*, New York: Dover, pages 47, 58–61, 1994.

7. Isler, M., Ibid., page 198.