Andreas Schöner's Stereographic Sundial Design

Fred Sawyer, John Schilke & Nicola Severino

In the seventeenth century, when sundials were still to be found at the frontiers of science and technology, it was the double horizontal sundial that truly stood in the first rank of sophisticated design. As dialing historian A.J. Turner has noted:

> That it was makers of... extremely high reputations both in their own day and later... who alone seem to have made the horizontal instrument and dial, suggests that not only did it retain its attraction throughout the century... as a challenging and unusual piece to have, to understand, and... to make, but that it also acted as a kind of symbol of competence among the better instrument-makers of the later seventeenth century. (A.J. Turner, *William Oughtred, Richard Delamain and the horizontal instrument in 17th-century England*, Annali dell'Istituto e museo de storia della scienza de Firenze 6/2. pp. 99-125, Florence, 1981).

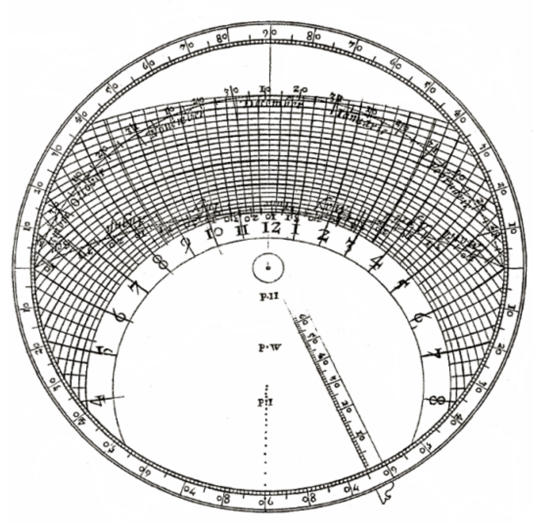

Fig. 1 The stereographic dial or horizontal instrument according to William Oughtred – a stereographic projection of the celestial sphere onto a horizontal plane. When used as a sundial, this instrument not only indicates the time but it also solves most astronomical problems relating to the sun's position in the sky.

In its fullest form, this instrument consists of a traditional horizontal dial combined with a 'horizontal instrument' or stereographic projection of the sphere (Fig. 1) that serves not only as a second sundial, with a vertical gnomon at its center, but also as a versatile computer that can solve many astronomical problems and can be drawn using only straight lines and circular arcs. Its invention in England is now generally attributed to the mathematician William Oughtred, but in the seventeenth century it was the subject of a bitter priority dispute between Oughtred and Richard Delamain. The dispute centered primarily on the use of the stereographic projection as a dial, although it also extended outside the realm of gnomonics to cover conflicting claims concerning the invention of the circular sliderule! (For a fascinating discussion of this dispute, see Turner's article cited above. Readers may also review summaries of both sides of the debate in their own words in the PowerPoint file *Oughtred vs. Delamain: The Inquest*, provided by Fred Sawyer with this issue of *The Compendium*).

Given all the heat generated by this dispute, it comes as a bit of a surprise that the stereographic dial was in fact not an uncommon device on the continent throughout the century before Oughtred's 1600 'innovation'. A.J. Turner has pointed out (*op. cit.* p. 101) that a similar instrument was described in Oronce Finé's 1532 *Protomathesis* (volume 4, book 3), that there are 6 extant 16th century examples from makers in Southern Germany, and that, in Turner's estimation, it may actually have originated as a product of Islamic science. [*Note: See the additional information from John Davis in this issue's Tove's Nest.*]

So William Oughtred's claim to priority should probably be restricted at least to the boundaries of England. Outside the community of English writers and instrument makers, the stereographic dial had been described and implemented many years earlier. But where are these descriptions – other than the *Protomathesis* already mentioned? This is a question that Nicola Severino always keeps in mind while trawling through the libraries, both real and digital, that he searches for little known or forgotten works on dialing. In 2008, he came across a sketch of a stereographic dial in an anonymous manuscript notebook in the Bayerische Staatsbibliothek (*Astronomische Zeichnungen* - BSB Cod. icon. 182, Vienna, 1508 – 1520. See the sketch at *http://tr.im/En3b*). Given that the notebook has been dated to the period 1508-1520, it appears to predate Finé's work. It shows construction lines on the dial, thus giving some indication of a technique for laying it out. However, all we have is a sketch; there is no associated text. Severino produced an article on this find (*L'orologio solare di Oughtred un secolo prima di Oughtred! See http://tr.im/EmRB*), but he did not stop looking for other traces of early publications of the dial. His next find, from Andreas Schöner's 1562 *Gnomonice,* proved more fruitful.

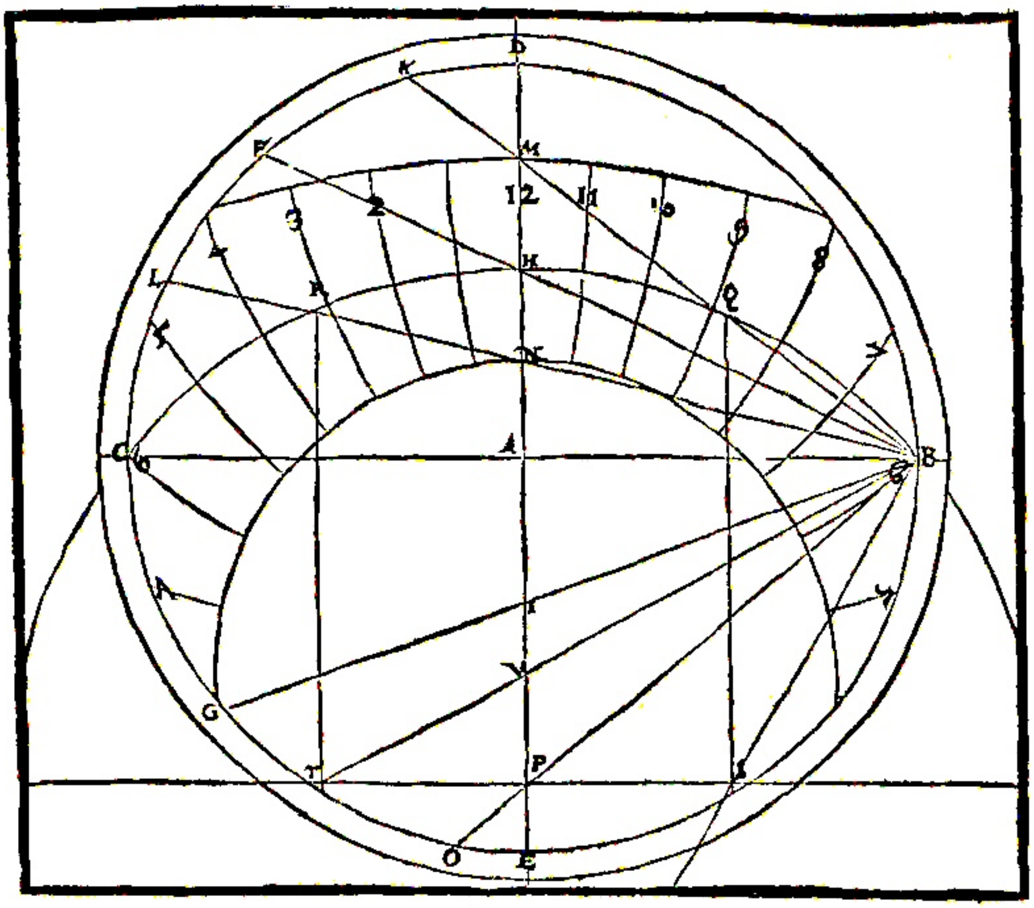

Fig. 2 Illustration from Andreas Schöner's 1562 *Gnomonice*, p. 85v

Andreas Schöner (1528-1590) was the son of the famous Nuremberg mathematician Johannes Schöner. The younger Schöner worked as astronomer to Landgrave Wilhelm IV and in 1562 published *Gnomonice*, his major work on gnomonics. The first two books of this volume dealt with sundials on flat and curved surfaces, respectively. The third dealt with other varieties such as quadrants, and cylindrical and ring dials. The text also included brief works on a method of determining the noon line and a technique for drawing an astrolabe.

At the end of the third book, Severino found an image (Fig. 2) which clearly appeared to be a stereographic projection. He passed it on to me to evaluate as another precursor of Oughtred. I found that the image had a number of interesting elements: it showed construction lines, suggesting a

Finding Schöner's Gnomonice

Go to the website of the *Istituto e museo di Storia della Scienza di Firenze*: *http://fermi.imss.fi.it/rd/bd*. Click on *English* in the upper right corner. Enter *Schoner Gnomonice* and click on *Search*. When the record appears, click on *Download* to obtain a copy of the entire text as a 41MB pdf file (see pp. 195-198), or click on *See* to review the text online (see the last 4 pages of Liber Tertius).

procedure different from that embodied in the *Astronomische Zeichnungen* sketch; for some initially unclear (but no doubt interesting) reason, it showed the hours progressing counterclockwise around the dial instead of the usual clockwise orientation for a horizontal dial in the northern hemisphere; and it was associated with an explanatory text. The only drawback was that the associated passages were in a rather dense Latin.

In order to make good progress with the necessary translation, I sent the *Gnomonice* extract to John Schilke. John is a retired physician who now occupies his time with a variety of activities including dialing and teaching Latin. John took on the challenge and was able to convert the essential parts of Schöner's text into English. He then passed it back to me with the challenge to make sense of the English! It took a while, but in the end it became clear that Schöner had indeed described an interesting variant of the stereographic dial. He did so with no great fanfare – with no suggestion that he was describing a new dial; rather he merely presented it as in interesting and useful instrument different in function than the traditional gnomonic projection dial.

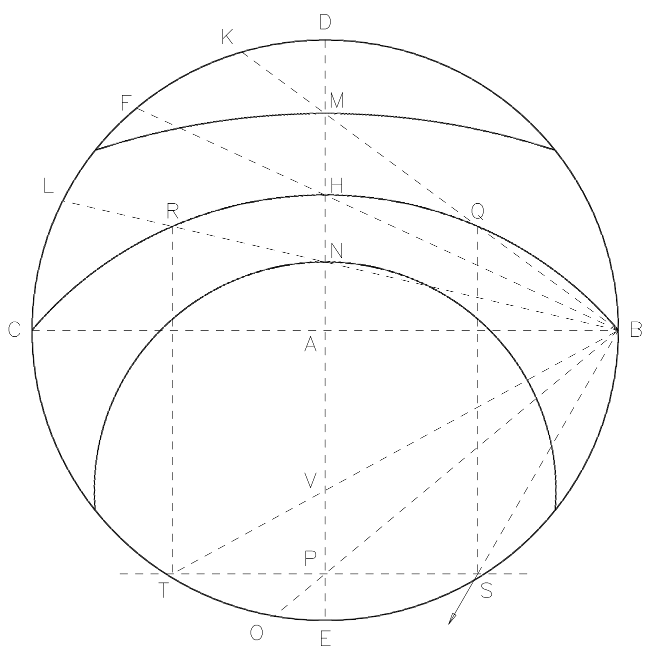

Figure 3

Schöner's Design

Schöner begins his discussion: *We propose an instrument on which the time is given… by an upright gnomon. Its construction is as follows….* He then proceeds to outline in detail a technique which we summarize here. Begin with a circle representing the horizon and having perpendicular diameters *CAB* and *DAE* as in Figure 3. Set off arc *BO* from *B* towards *E* equal to twice the latitude at which the dial is to be used and draw line *BO*. This is equivalent to setting $\angle CBO = 90^\circ - \varphi$. Let *P* be the intersection of *BO* and *DE*; *P* will be the center of the circular arc representing the equinoxes.

Set off arc *CF* from *C* towards *D* equal to the latitude, and draw line *BF*. This is equivalent to setting $\angle CBF = \varphi/2$. Let *H* be the intersection of *BF* with *DE*. Now draw the arc *CHB* passing through *H* with center at *P; CHB* will serve as the equatorial arc for this dial. [*Note – it is easy to show that the arc through H will always pass through C and B*.]

Set off arcs *FL* and *FK* as shown, and on *CHB* arcs *HR* and *HQ*, all four equal to 23.5° each. Draw lines *BL* and *BK*, intersecting *DE* at points *N* and *M*, respectively.

Draw line *TPS* perpendicular to *DE* and passing through *P*. Draw lines *RT* and *QS* parallel to *DE* and intersecting *TPS* at *T* and *S* as shown. Draw line *BT*, intersecting *DE* at *V*. Draw the summer solstice arc (from horizon to horizon) through *N* with center at *V*.

Draw *BS* and extend the line until it intersects *DE* [*not shown here or in Schöner's image to conserve space*]. Using the point of intersection as center, draw the winter solstice arc (again, from horizon to horizon) through point *M*.

An actual dial will need to have several more declination arcs drawn if it is to be useful. Although we do not draw them here, this procedure can be used to draw as many arcs as one wishes. Simply continue with arcs drawn from *F* and *H* as before equal in size to the declination whose arc is to be drawn, and repeat the procedure we have just outlined.

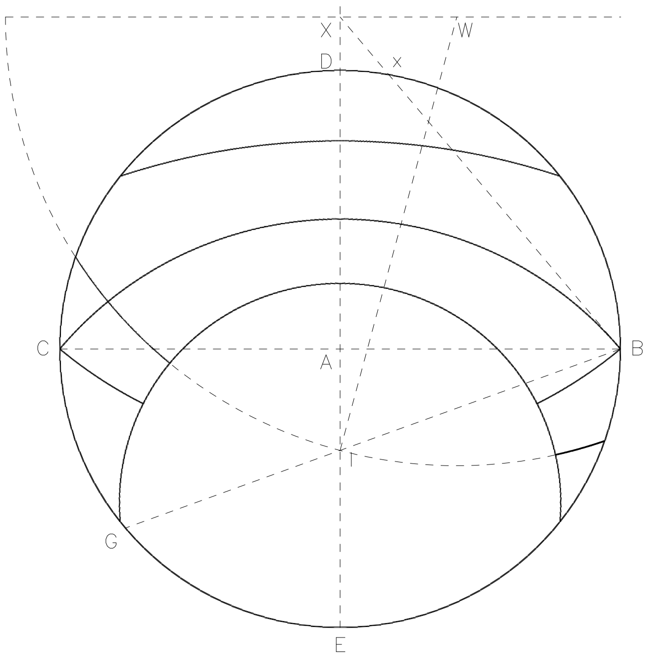

Figure 4

Having thus dispatched with the chore of drawing date curves, we now turn to the hour curves. Set off arc *EG* from *E* towards *C* equal to the latitude, and draw line *BG* (Figure 4). This is equivalent to setting $\angle CBG = (90^\circ - \varphi)/2$. Let *I* be the intersection of *BG* with *DE*. Point *I* will serve as the north pole of this projection; all hour curves will pass through it.

Set off arc *Bx* from *B* towards *D* equal to twice the complement of the latitude. This is equivalent to setting $\angle CBx = \varphi$. Let *X* be the intersection of line *Bx* with *DE* (not shown in Schöner's figure, thus complicating his explanation of the procedure). With *X* as center, draw an arc *CIB* through *I*; this will provide us with 6am and 6pm curves. All the other hour curves will be circular arcs drawn through *I* with centers on line *XW* perpendicular to *XE*. To find the center for, say, 5pm (one hour before the 6pm curve on the left of the dial) and 5am (one hour before the 6am curve on the right), draw angle *XIW* equal to 15° (corresponding to one hour). *W* is then the required center point on line *XW* for the 5pm and 5am curves which both lie on the same circle drawn through *I*. This procedure gives us all hour arcs between noon and 6pm and before 6am. A similar procedure, using angles *XIW* to the left of *DE*, provides hours between 6am and noon, and after 6pm. The noon hour arc is simply that portion of the straight line *DE* contained between the solstice curves. We thus have all required hour arcs, and the dial has been drawn.

At this point, since the stereographic projection is azimuthal, we would normally expect to raise a vertical gnomon at the center *A* of the dial face and to align the noon line with the meridian, with north at the top. In this configuration, we would note where the gnomon's shadow crosses the curve for the current date and would read the time at that point. However, we cannot do that in this case because Schöner has had us label the hour points counterclockwise.

Instead, Schöner instructs us to place a magnetized needle at point *A* and to raise a vertical gnomon at point *D*. Then place the dial in the sun and orient it so that the shadow of the gnomon falls on *DE*. Note where the needle crosses the arc for the current date and read the time at that point. As long as the magnetized (compass) needle lies on the true meridian, this method works quite nicely. Unfortunately, in reality the needle will decline from the true meridian by an angle which varies with geographic location and over long periods of time. We can salvage this design by simply displacing the gnomon. For example, if your magnetic declination is *d* degrees west of north, place the gnomon at a point on the horizon circle *d* degrees clockwise of *D*. Now place the dial in the sun and orient it so that the gnomon's shadow falls on the center *A* of the dial; note where the needle crosses the curve for the current date and read the correct solar time at that point. We now have a functional magnetic azimuthal dial, courtesy of Andreas Schöner.

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