Recreation of the Humphrey Cole Theodolite, 1586 in the Collection of The Museum of the History of Science, Oxford University

Jeffrey Lock

I was invited by Stephen Johnston to give a lecture on engraving and the construction of surveying instruments to the Master Class at Oxford in 2004. While there, I had the opportunity to view many important instruments constructed by makers including Humphrey Cole, John Worgan, Thomas Wright, Benjamin Cole and a small group of unsigned but beautifully manufactured instruments from the 17th and 18th centuries in the collection at the Museum of the History of Science, Oxford.

The one instrument that was the most impressive to me was the Humphrey Cole Theodolite dated 1586 (see p. 1). As a restorer and engraver, I felt that the only way to fully understand how Humphrey Cole built this instrument was to fabricate a replica of a larger proportion. Original photographs of the Humphrey Cole Theodolite can be found in *Elizabethan Instruments Makers* by Gerard L'E Turner, 2000, and *Humphrey Cole: Mint, Measurement and Maps in Elizabethan England*, British Museum Occasional Paper Number 126 edited by Silke Ackermann, 1998.

My impression was that the most difficult item to fabricate on the theodolite would be the tapered, dovetailed basket surrounding the plumb bob used to accurately level the theodolite. Under closer inspection, I noticed that the four sides and bottom of the tapered basket were dovetailed together as a unit. I knew that cutting and aligning the dovetails from five different pieces of brass, to be assembled as one unit, would be extraordinarily difficult to reproduce.

Both the beautiful design and quality workmanship were incredibly impressive as I studied details of the instrument. The original azimuth plate was assembled from many individual pieces. As I inspected the underside of Cole's azimuth plate on display, it appeared that the shadow square and circular azimuth plate were two individual units joined by separate, narrow stabilizing bars extending from the centre socket circle plate under the shadow square to the inside diameter of the azimuth plate. Similar stabilizing bars were attached to the four corners of the shadow square connecting it to the azimuth plate. The accuracy of Humphrey Cole's joinery of these support pieces was done at such a high skill level that, when viewed from the upper engraved surface, it appeared to be a single unit.

I taught myself to engrave several years before beginning this project, and my expertise was in the late 17th and 18th centuries' styles of engraving. Before I could engrave the letters and numbers in the same style of Humphrey Cole and replicate the late 16th century style, I chose to study the lettering and numbering of the Mercator style to practice the proportions and angular displacements to accurately recreate Cole's lettering and numbering style.

It was also quite a challenge to devise a procedure of hand dividing the degrees on the azimuth plate and protractor, as well as the divisions on the shadow squares on both the protractor and the azimuth plate.

The artistic nature of Humphrey Cole can clearly be seen in the construction of the semicircle above the compass box and its attachment points to the vertical arms holding up the protractor and the sighting arm, as well as the design of the ends of the alidade. A design similar to that of the alidade ends was used on the altitude reading sights.

Because there was only one original existing sight vane on the Humphrey Cole Theodolite, I chose to model my reproduction sight vanes after an Elias Allen Theodolite, which was on display at the Louvre. The offset design at the base of the alidade sight vanes of the Elias Allen Theodolite were so like the design patterns of Humphrey Cole's alidade ends that I decided to use those as patterns for my reproduction.

Another theodolite I considered for the sight vane patterns was made by Augustine Ryther, dated 1590, one of the instruments taken to Florence by Robert Dudley in 1606. Because they were designed only as two short folding sight vanes on the alidade, I chose not to use those patterns for my re-creation.

Highlights in the Process of Recreating the Theodolite

Fig. 1 *Engravings of Altazimuth Theodolite from Aaron Rathborne's book,* The Surveyor, *1616. For the Oxford instrument see the Editorial Page.*

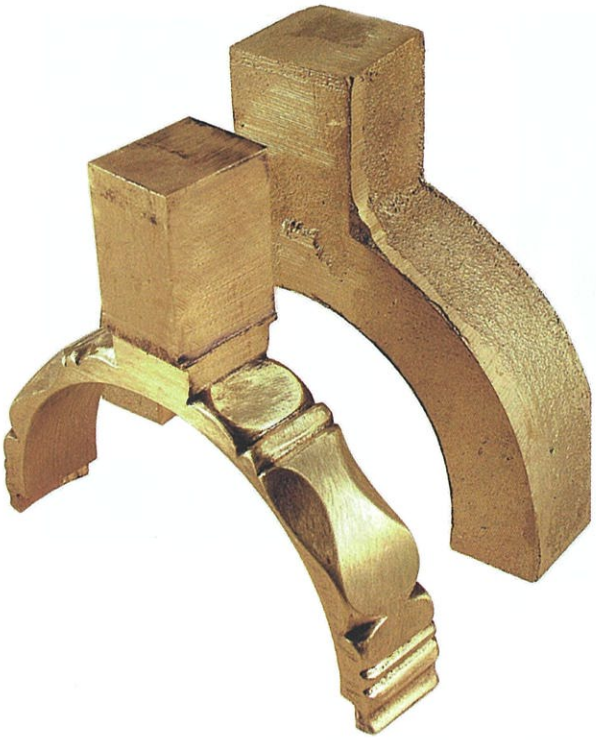

Fig. 2 *As you can see, to be accurate with the casting procedure, the casting at the front was hand-filed to duplicate the pattern of Humphrey Cole's design for the semicircle over the compass body surround. I had two castings prepared, making sure there were no casting flaws that would have failed under the weight of the altitude reading protractor and sights.*

Fig. 3 *Hand-filed decorative arched hoop over the compass cylinder surround with the swinging plumb bob installed.*

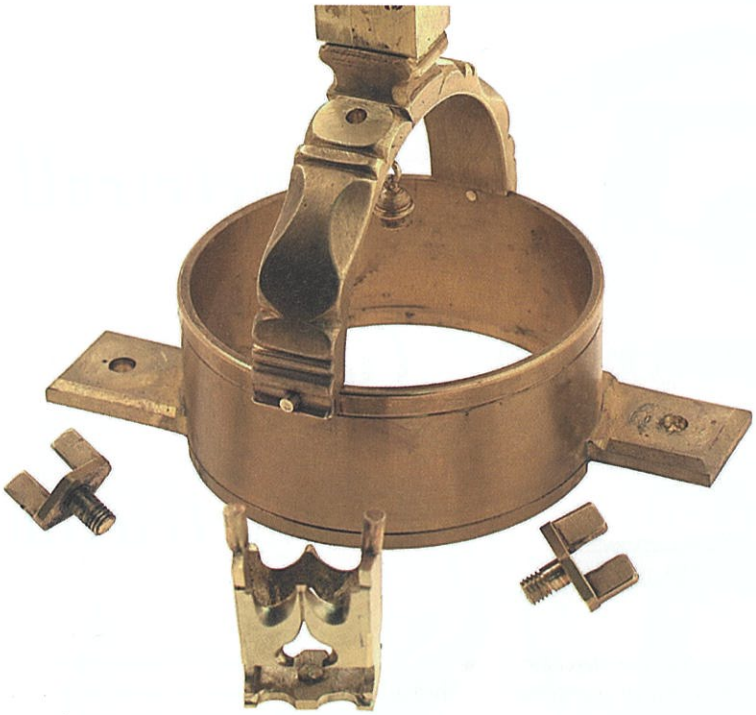

Fig. 4 *This photo details the pieces of the compass surround basket with offset tabs to attach the assembly to the rotating alidade, protecting the compass body which remains stationary during rotation in relationship to the azimuth plate.*

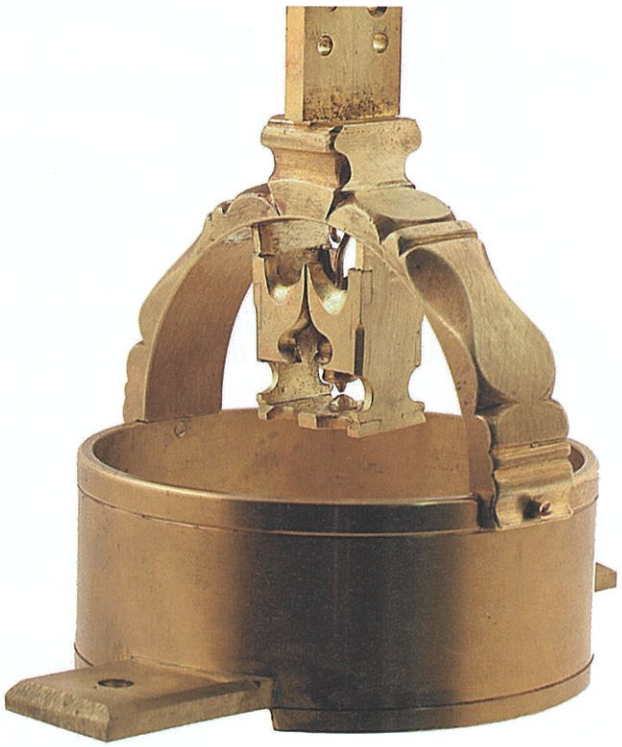

Fig. 5 *Initial test fitting the assembly of the plumb bob basket to the decorative semi-circle, which is attached to the cylinder that surrounds the compass body.*

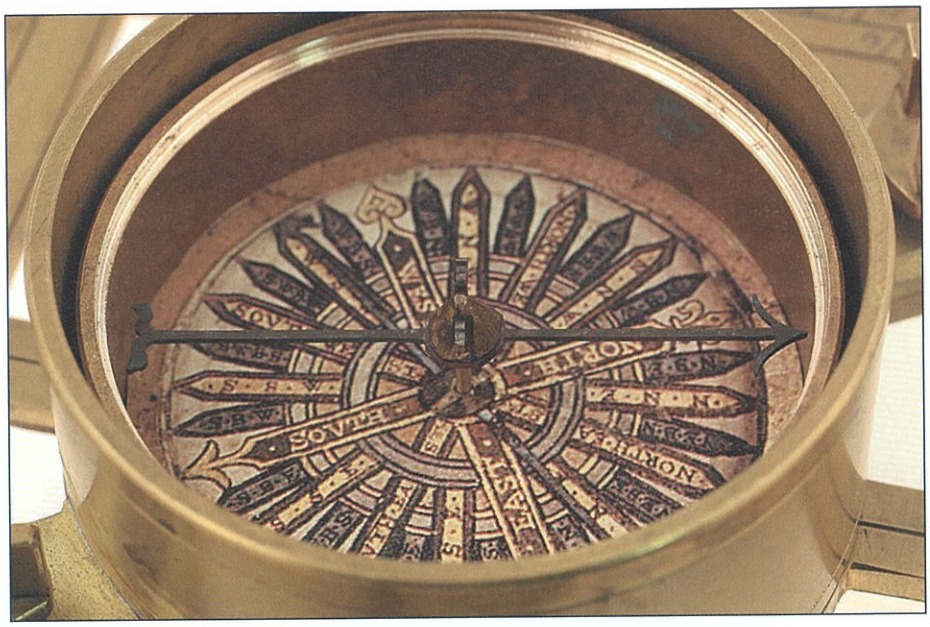

Fig. 6 *Printed reproduction compass card with newly fabricated compass needle installed in the compass assembly. The original needle for the 1586 Cole Theodolite was missing, the design for the reproduction needle was taken from Humphrey Cole's Simple Theodolite dated 1574.*

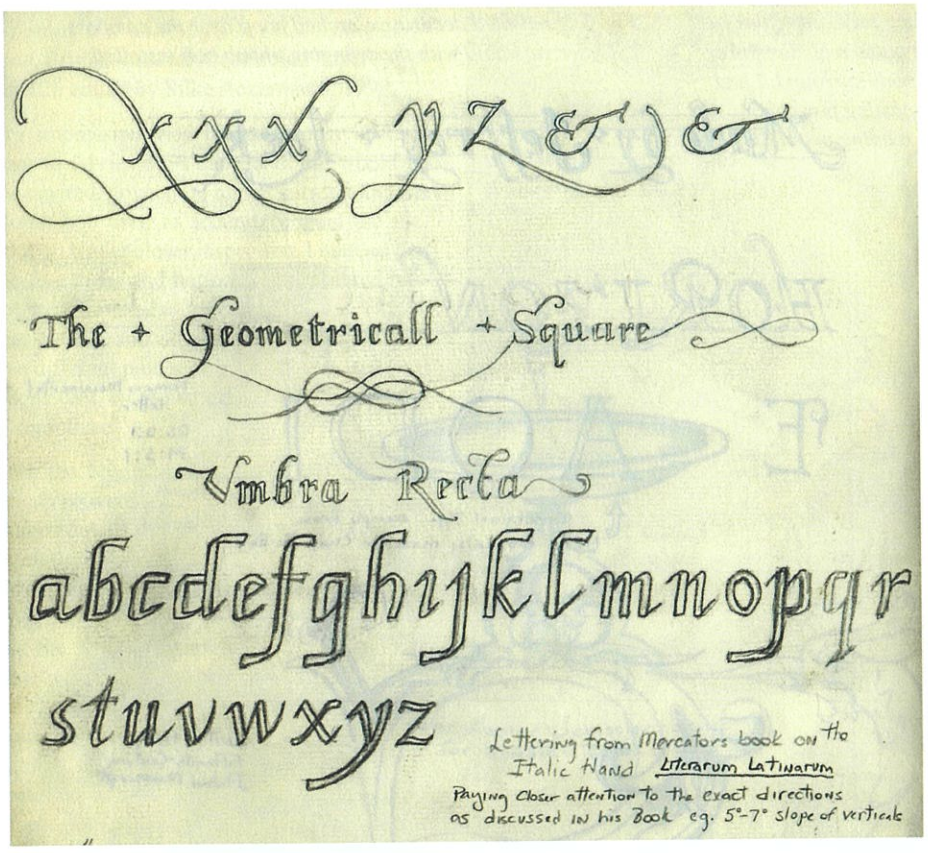

Fig. 7 *Before beginning to practice engraving on sheet brass, I chose to study the Mercator style of lettering and numbering to accurately re-create Humphrey Cole's style of engraving. This page is from my notebook where I practiced drawing Mercator's lettering prior to engraving.*

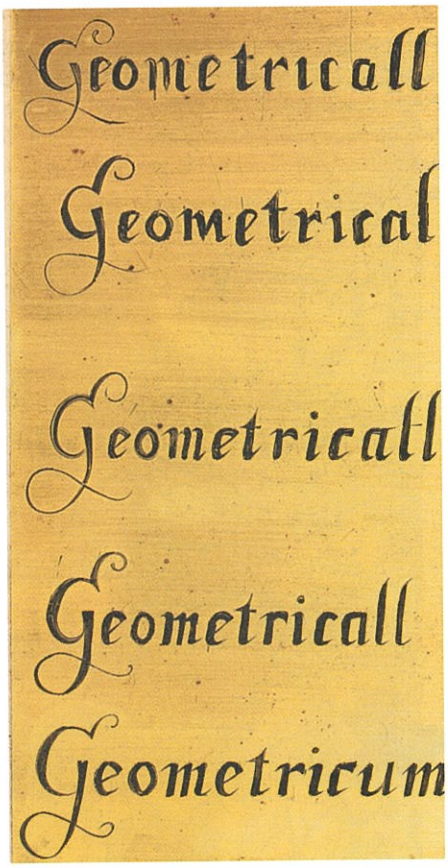

Fig. 8 *'Geometricall' and 'Geometricum' practice engraving. You can see the slow rate of improvement with spacing and angular displacement as I engraved the words from top to bottom. The first two on the top are quite inconsistent, while the last two are closer to my desired result.*

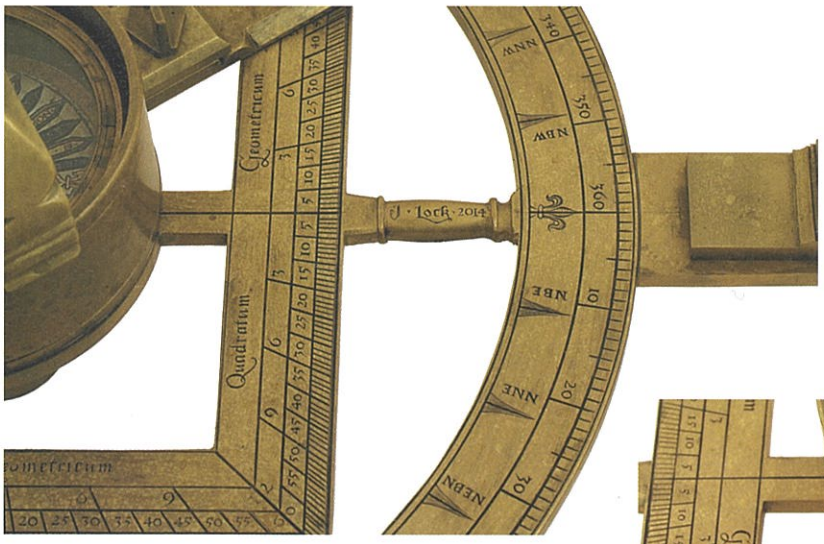

Fig. 9 *This photo displays the final engraving of the lettering, numbering and divisions on the shadow square, as well as on a section of the azimuth plate, including my signature and date.*

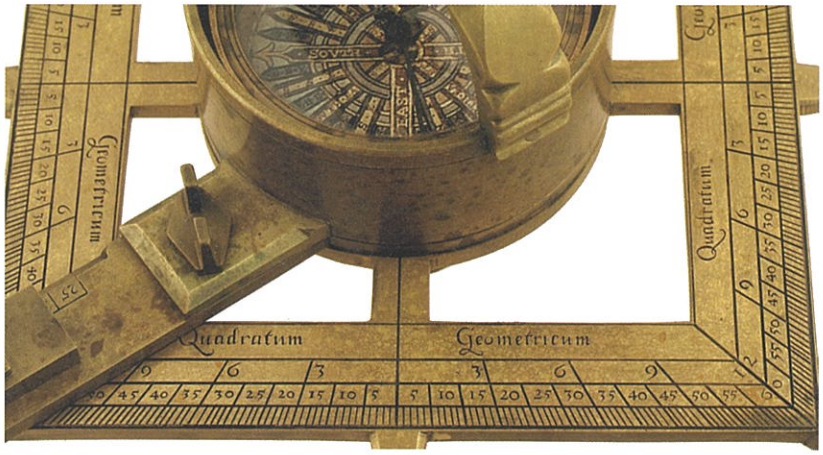

Fig. 10 *Close-up photo of the shadow square displaying the divisions and numbers as well as the engraving of the words 'Quadratum' and 'Geometricum'.*

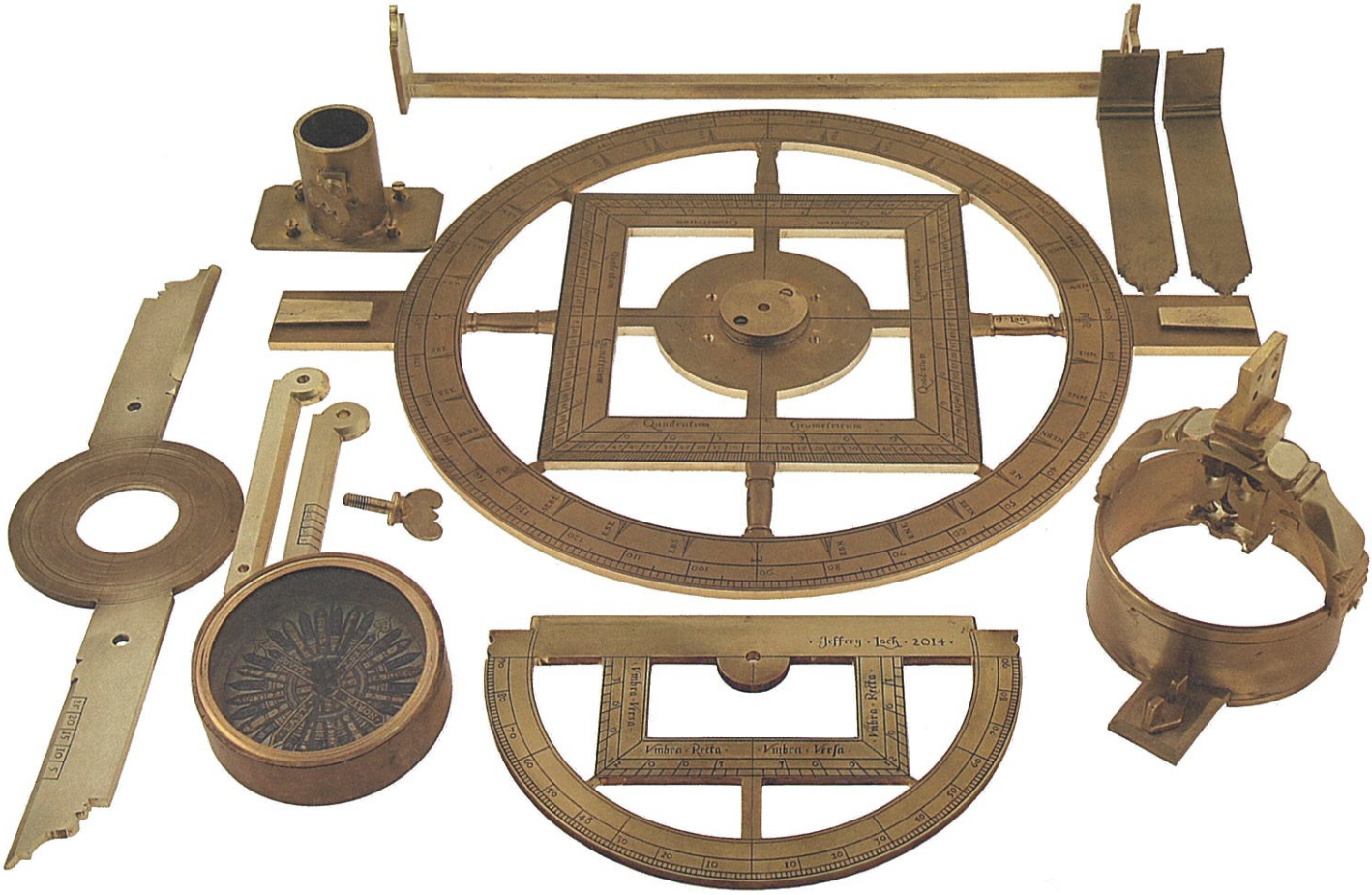

Fig. 11 *Dissembled pieces of the theodolite. As seen, the dovetails on the alidade have not been installed as well as the final sight vanes for the alidade, which were not fabricated when this photo was taken.*

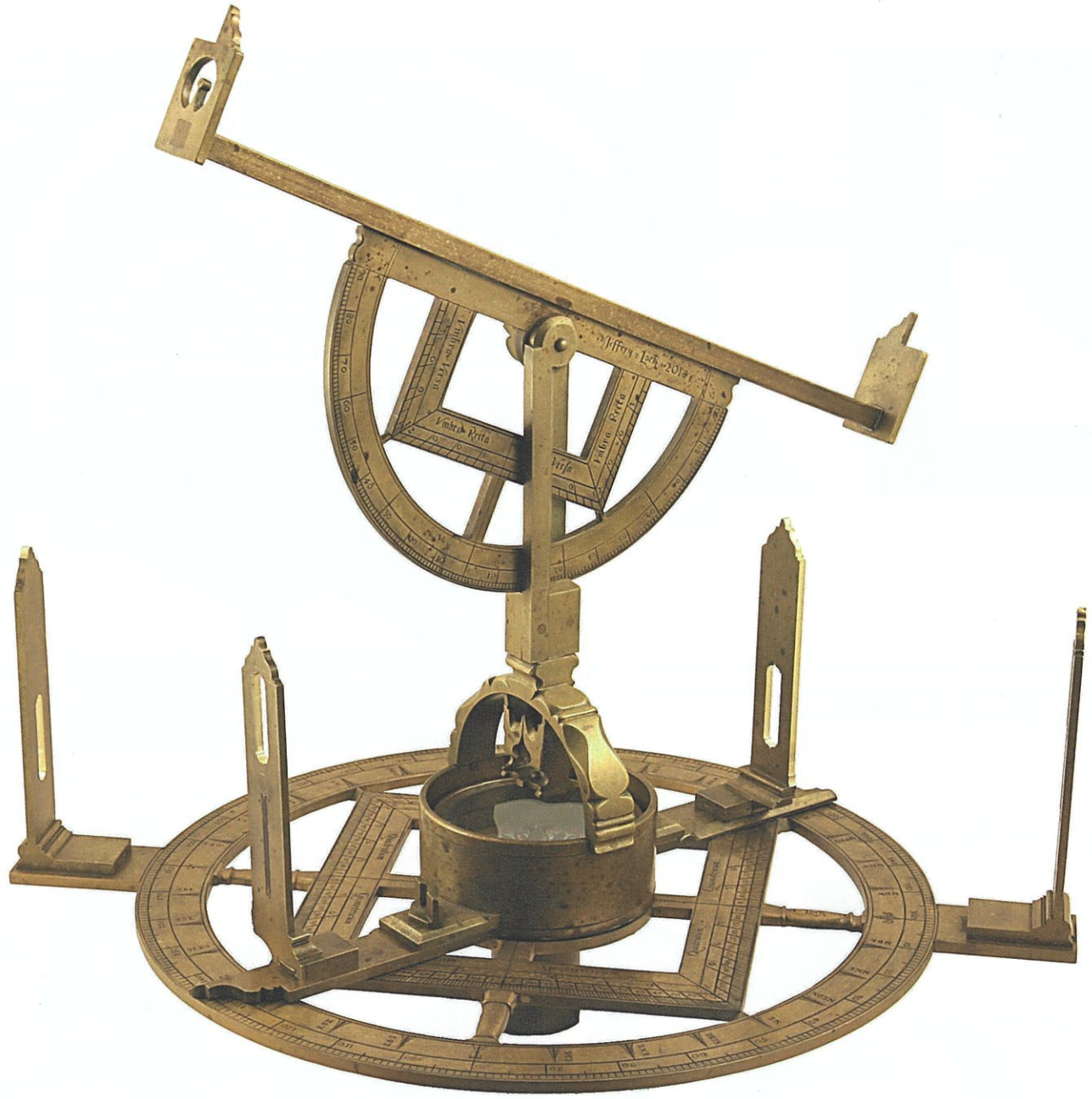

Fig. 12 *Final version of the assembled reproduction theodolite. The original Humphrey Cole azimuth plate was 200 mm in diameter, and I enlarged my reproduction to 333mm.*

Other Instruments

Other documented instruments by Humphrey Cole include an Astronomical Compendium, 1568 at the Museum of the History of Science, Oxford. The National Maritime Museum, Greenwich, has another Astronomical Compendium, 1569, as well as an Alta-azimuth Theodolite, 1574. The British Museum exhibits an impressive folding gunner's rule ('Humfray Coolle Mad This'). If one takes the time to study other instruments by Cole, you can see his dedication to mechanical accuracy, superlative engraving, as well as artistic design construction.

The replication of this instrument was a very rewarding project with the challenge of assembly using predominately pins, not screws. The accuracy that was required for the alignment of the assembled parts showed me that Humphrey Cole and other instrument makers of this period can be taken very seriously as their hand assembly process was at the highest level. The beauty of these elements of design, as well as the proportions of the original Humphrey Cole theodolite, display the fact that this was not built by just a mechanically inspired craftsman, but an individual with very strong artistic qualities.

Acknowledgements

I would like to thank Stephen Johnston, Museum of the History of Science, Oxford, for inviting me to give a lecture to the Master Class on engraving and the construction details of surveying instruments of the 17th and 18th centuries. While there, I was allowed to study other important instruments in their collection.

I would also like to thank Paolo Brenni who graciously took me on tours of several museums in Florence during my recent visit. One stop was the Museo Galileo where I was able to take a close look at the Augustine Ryther Theodolite, brought to Italy by Sir Robert Dudley.

Author's email address: jlock@neo.rr.com