

Locating Liberty: The 1769 State House Observatory

TODD M. BABCOCK

Professional Land Surveyor
United States

EDWIN F. S. DANSON

Independent Consulting Chartered Surveyor and Geospatial Engineer
United Kingdom

The early years of the 18th century saw the beginning of a radical philosophical movement across the 13 American Colonies. Known as the American Enlightenment, the ideas that originated in Europe developed a distinctly American ethos (Ferguson 1997), particularly in the fields of religious tolerance, political attitudes, reason, and liberty—ideas enshrined in the Declaration of Independence. Where the European Enlightenment made giant strides in scientific thought and discovery, “American science was a branch of British science and depended on Europe for inspiration and ideas . . .” (Greene 1968, 22). However, all that changed in 1769 with the merging of the Philosophical Society with the American Society for Promoting Useful Knowledge to form the American Philosophical Society, with Benjamin Franklin its first President (Bell 1964, 7).

In the same year of 1769, the new American Philosophical Society, in correspondence with the Royal Society of London, joined the international effort to observe a rare transit of Venus across the face of the Sun on June 3 of that year. Transits of Venus occur in pairs, eight years apart, repeating only every hundred years or so.¹ The results of the previous transit of 1761, which occurred in the middle of the Seven Years’ War, had been disappointing, and it was hoped that the 1769 transit would be more successful. For the scientists of Europe, the major difficulty was that the transit would not be visible across most of their continent necessitating sending skilled observers around the world. To observe the entire transit, Britain dispatched an expedition to Tahiti under the command of Captain James Cook. There was no certainty that Cook’s mission would arrive in time (or at all), hence the

¹ Transits follow a predictable 243-year cycle with intervals between transit pairs occurring at 121.5 years and 105.5 years.

importance of the American Philosophical Society’s campaign in America (Table 1). In the event, the results from Tahiti were less than optimal; nearly a third of the crew died from fever, including the Royal Society’s astronomer Charles Green.

The 18th century’s two transits yielded the first reliable distance to the Sun and proved Venus, like Earth, had an atmosphere. Of more practical importance, the precision of the various celestial observations from so many locations around the Earth enabled the scientists to calculate accurate longitudes for their locations, thus improving the accuracy of maps and sea charts.

For the American Philosophical Society’s observations in Philadelphia, a timber-framed astronomical observatory was erected in the Pennsylvania State House yard. The observatory was employed again to observe the transit of Mercury in November of the same year. The location of the site for the observatory was not recorded and there is no convincing surviving evidence of its location or of any remains.

The Pennsylvania State House, now Independence Hall, was constructed on a 396-foot by 255-foot lot of ground on Chestnut Street between Fifth and Sixth Streets at what was then the edge of the city. Building commenced in 1732 and continued over a period of some 20 years. Of importance for the rediscovery of the observatory are:

- Two side wing buildings added in 1736 with connecting hyphens or piazzas constructed in 1743
- A seven-foot brick wall erected around the property’s south, east, and west sides in 1740–1741, extended in 1770 to enclose a newly acquired lot at the south end of the block (Toogood 2004)
- The bell tower and steeple added in 1753
- Wooden sheds built in c.1759 (Riley 2008) between the wing buildings and the walls of Fifth and Sixth Streets to house visiting Native American deputies and dignitaries (Westcott 1877)

	Ingress	Midway	Egress
London (GMT)	19:15 hrs 3 June Sunset 20:08 hrs	22:25 hrs 3 June Not visible	01:35 hrs 4 June Not visible
Philadelphia (GMT -5 hrs)	14:13 hrs 3 June	17:23 hrs 3 June	20:33 hrs 3 June Sunset 19:24

TABLE 1. 1769 Transit of Venus. Only the planet’s ingress could be observed from Britain.

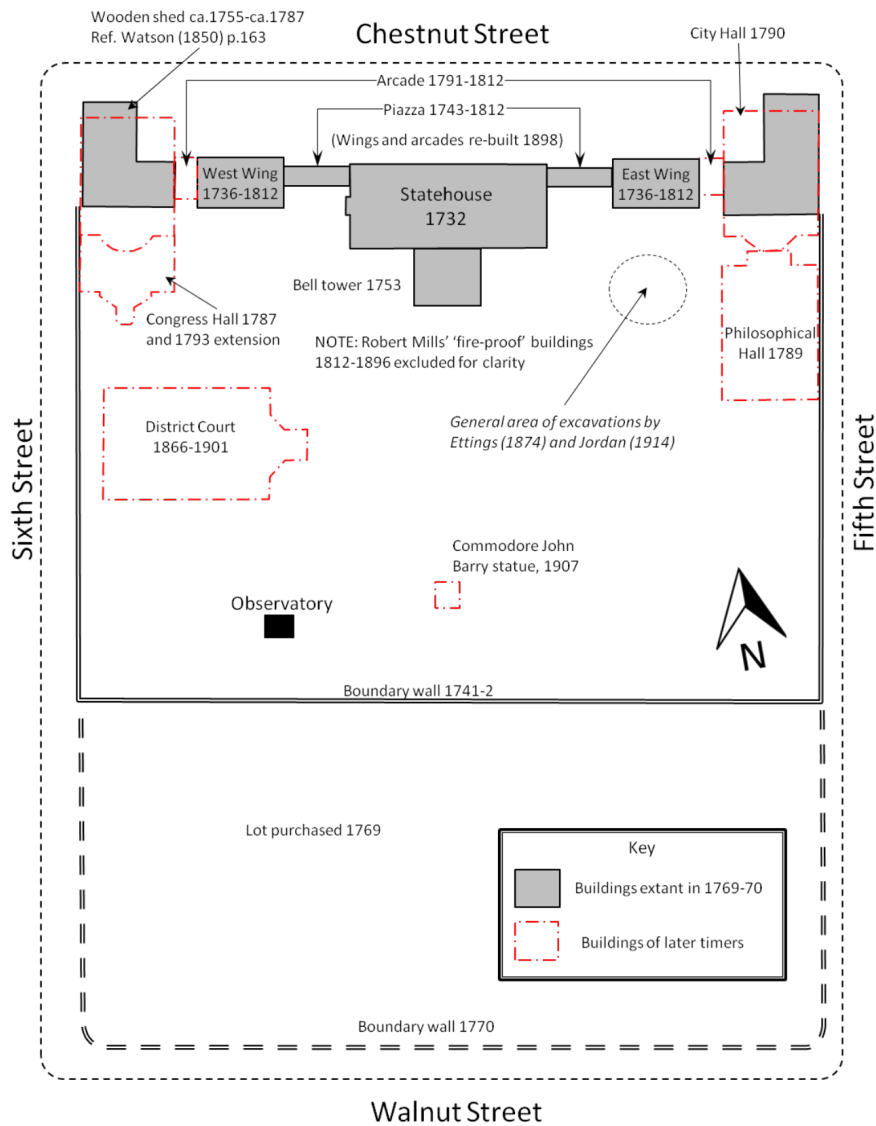


FIGURE 1. Schematic showing the buildings extant in 1769–1770 and later buildings.

All these structures were extant in 1769 and are important factors when identifying the location of the observatory (Figure 1).

Independence Square’s landscape has been developed and much altered over the years (Toogood 2004), and while there are a number of accounts testifying to the *existence* of the observatory after 1769–1770, the most reliable authentic source regarding its position appears to be *Correspondence between William Penn and James Logan*

prepared under the auspices of the Historical Society of Pennsylvania (Armstrong 1870, xlv–xlvi):

Several different statements have been made as to the place from which, and the person by whom the Declaration of Independence was first read to the people. One writer asserts that it was read from the steps of the tower, another from the south window of the same, another from the front steps of the building. All these accounts are wrong. The accurate Christopher Marshall, who was present on the occasion, sets both these questions at rest. He says, in his *Remembrances*, under date of July 8th, 1776: . . . “Warm, sunshine morning. At eleven, went and met [the] Committee of Inspection at [the] Philosophical Hall; went from there in a body to the lodge; joined the Committee of Safety, (as called;) went in a body to [the] State House yard, where, in the presence of a great concourse of people, the Declaration of Independency was read by John Nixon. The company declared their approbation by three repeated huzzas.”— Christopher Marshalls *Remembrances*, edited by William Duane, Jr. Philada., 1839.

This account, it will be seen, is confirmed by Mrs. Logan, who stood, on Fifth Street, upon the fence belonging to her father’s garden, at a point, of course, to the south of the southern wall of the hall of the American Philosophical Society, but whose view was obstructed by a frame building, which was probably some structure built on Independence Square. It is also confirmed by John Adams, who was present and heard the Declaration read, and in a letter describes the reading as having taken place from that “awful platform”²—words which had a deep significance, when we consider the perilous position of those who signed the instrument . . .

The late Mr. Thomas Pratt, who died in 1869, at the great age of 95, perfectly remembered this structure; and in a conversation with the editor, a few weeks before his death, described it to him as a rough wooden stage, which stood on the line of the eastern walk, about midway between Chestnut and Walnut Streets. It was used for many years as a place from which speakers were in the practice of addressing popular assemblies.

This often-repeated description of the observatory would have been how it appeared after the British occupation of 1777–1778 when it was modified to serve as a guard post, and shortly before its demolition in 1783. The earliest recorded archaeological excavation was in c.1874

2 A misquote of John Adams’s letter of July 9, 1776 to the Maryland jurist, Samuel Chase, who actually referred to it as “that awful stage in the State-house yard.”

by the historian Frank M. Etting, who was of the opinion that “the foundations [of the observatory] were discovered when recently perfecting the sewerage of the Square. It appears to have been of circular shape and was erected about 40 feet due west from the rear door of the present Philosophical Hall, and about the same distance south from the wall of the present (eastern) wing” of the State House (Etting 1876, 65). In 1914, an excavation by Independence Hall curator Wilfred Jordan claimed that “his dig had uncovered [the observatory’s] site.” A confirmatory exploration in the following year by the Archaeological Institute of America reported that “no conclusive evidence for the observatory’s location, however, resulted,” contrary to Jordan’s claims and Etting’s account (Toogood 1998, 146). Further excavations between 1953 and 1974, which revealed much of the 17th and early 18th landscape of the square, found no trace of the observatory, concluding: “Unresolved at the end of these endeavors and remaining as a challenge for future archeologists and historians is the location of the Venus Observatory” (Toogood 1998, 146).

It will be shown that the northeastern quadrant of the State House yard, where these explorations took place, could not have offered a site for the observatory.

THE OBSERVATORY AND ASTRONOMICAL REQUIREMENTS

Very little is known about the form of the observatory; however, it is possible to get some idea of what it may have looked like from the records of the observation teams. In January 1769, the American Philosophical Society appointed a transit committee to organize, coordinate, and observe the transit of Venus. The observatory was erected at an expense of £60 from £100 provided by the Pennsylvania Assembly. The construction of the State House yard observatory was given to James Pearson (1735–1813), a master builder and member of the American Philosophical Society (Moss 1972). The structure was completed by the end of March 1769.

The site chosen for the observatory was of course dictated by the astronomical requirements for observing the transit. From John Ewing’s report to the American Philosophical Society (1771), the observers and their instruments have been compiled in Table 2. Ewing notes that the observatory committee’s meetings began in February 1769, before the observatory was completed, and that some trees or tall bushes obstructing the sky view first needed removal or trimming.

As well as telescopes, the team was equipped with an astronomical regulator (a long-case pendulum clock) for timing the observations (Figure 2). The regulator was “fixed to a large post sunk into the

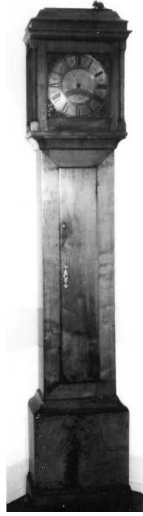


FIGURE 2. Regulator by Isaac Jackson of New Garden Township, Chester County. New Garden Historical Commission. <http://historic.newgarden.info/index.htm>.

ground four or five feet, secured from shaking by a brick wall at the bottom, and no ways communicating with the sides of the building” (Ewing 1771, 45). The regulator would have been installed beneath the observing platform to protect it from the weather and the heat of the June Sun. The manufacturer of the regulator is not recorded, but it could have been the clock made by Isaac Jackson of Philadelphia for the Mason and Dixon survey (1763–1768), which, together with John Bird’s transit and equal altitude instrument, was stored at Joseph Shippen’s house in 1768 (Bell 1997, footnotes on 371). What is known is that it was replaced with a “new Time-Piece made by Mr. Duffield of this city [Philadelphia]” for the November 1769 transit of Mercury (Ewing 1771, 82).

The clock required careful and regular calibration, achieved by timing the passage of the Sun and some stars across the local meridian by the method known as equal altitudes employing Mason and Dixon’s transit and equal altitude instrument (Figure 3). These calibration exercises to “compare the correspondent observations at Philadelphia and Norriton [began] on the 16th of February, the 12th of April, the 5th of May, and the 7th of June 1769, the difference of our meridians will be found from the mean of them to be 57 seconds of time . . .” (Ewing 1771, 56). A meridian mark, set to the south of the State House observatory, was a prerequisite of the process, therefore elevating the observatory platform would have been an advantage when sighting the distant mark across the wall that, at the time, stood at the south end of the yard (Watson 1850, 397).

Observer	Telescopes	Magnification	Probable Observing Positions
John Ewing	4-foot focal length reflector, 7-inch aperture + Dollond micrometer	300x	Platform
Joseph Shippen	18-inch focal length reflector, 4.15-inch aperture	80x	Platform
Dr. Hugh Williamson	24-foot focal length refractor	90x	Ground level
James Pearson and Charles Thompson	12-inch focal length reflector	60x	Platform
Thomas Prior	18-inch focal length reflector	100x	Platform
For latitude by zenith distances	6-foot zenith sector		Ground level
For meridian (by equal altitudes)	Transit and equal altitude instrument		Ground level

TABLE 2. State House observers, their instruments, and probable observing positions.



FIGURE 3. John Bird’s transit and equal altitude instrument made for the Mason-Dixon survey, as restored by Jeffrey Lock. Courtesy Jeffrey Lock, Colonial Instruments.



FIGURE 4. Gregorian Astronomical Telescope, circa 1765, by Heath and Wing, London. Museum of New Zealand, Te Papa (NS000010/1).

On the day of the transit the committee appointed two assistants to observe the clock, one to count and call out the seconds and the other to record the times. Dr. Williamson observed the transit with a 24-foot-long refractor, noting in his report, “I determined to stop a watch which I had in my hand, to ascertain the time of my observation, least some accident should prevent my hearing the assistant, who stood at 5 or 6 yards distance by the clock counting seconds” (Ewing 1771, 48). Such a long telescope would have been too unwieldy to operate from the platform and would almost certainly have been ground mounted on a tall tripod/quadrupod, hence the comment about the position of the clock assistant.

In his report of the observations, James Pearson noted using a small reflecting telescope. After observing the external contact of Venus, he handed it over to Charles Thompson to observe the internal contact. Thompson commented, “The tremulous appearance of the rays of light, I at first attributed to my telescope resting against the side of the observatory . . .” (Ewing 1771, 50), suggesting that his telescope or its mount was in contact with a part of the structure. This could be explained by the common practice of standing these types of small instruments, with their short tabletop tripods, on top of a barrel or cask as stated by MacFarquhar (1797): “The instrument should be set on a stone pedestal, or, what is better, a cask filled with wet sand” (Figure 4).

The need for a clear view of the sky from south around to the northwest would have heavily influenced the choice of site for the observatory. Although the astronomers did not record the azimuths (clockwise angular direction from true or astronomical north), the

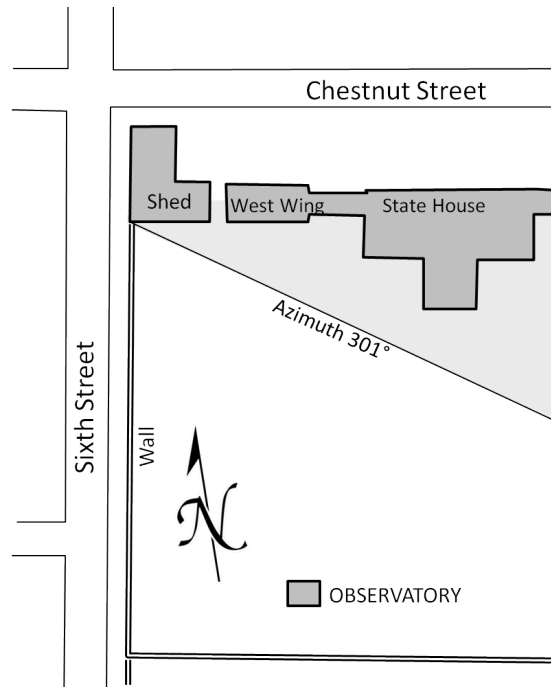


FIGURE 5. Angle of setting Sun precludes the northeast quadrant of State House yard as a site for the observatory.

sweep of the transit has been reconstructed using the astronomical program CyberSky5. The transit began with first contact occurring at about 14:13 hrs LAT (Local Apparent Time) when the Sun's azimuth was 249° and its altitude around 55° . However, from the committee's records of the transit, observations began at least an hour earlier, therefore the clear sky view would have been from due south, when the Sun passed the meridian at local noon, clockwise to its setting point at 301° . The last observation of the Sun made by the observing team was recorded at 19:12 hrs LAT, 12 minutes before sunset at 19:24 hrs, on an azimuth of $298^\circ 57'$ and at an altitude above the horizon of $1^\circ 39'$, from which it can be concluded, it being midsummer, that there was a clear view to the horizon for at least a quarter to half a mile. This geometry precludes the northeast quadrant of the State House yard as a viable location because of the presence of the State House building, the tower, west wing, and the adjacent wooden shed (Figure 5).

Nicholas Scull's map of 1752 supports the contention for a southwest quadrant observatory location. Philadelphia was expanding, and by 1777 development was in progress on the blocks between Sixth and Seventh Streets north of Walnut Street, as seen on William Fadan's update of Scull's map, further supporting the argument.

To maximize the viewing angles, and overcome the yard's shallow slope, the observatory platform would have been elevated (as accounts suggest). Further reasons for an elevated platform were for a clear view of their southern meridian mark, to clear the bushes and vegetation that then covered most of the yard, and, from a practical point of view, an elevated platform would have offered some element of wind cooling for the instruments and observers, and space to keep onlookers at bay.

From the foregoing and the more reliable descriptions and noting that the astronomical instruments were stored at the observatory, it would appear that the most probable description would be of an elevated timber platform with stout posts set deeply into the ground and probably concreted into place, possibly with brickwork reinforcement. A platform dimension of 15 feet square is not unreasonable for four observers, their instruments and assistants, although 20 feet would have been better. The structure would have been very solid, suggesting at least nine corner, midway, and center posts of, say, 8–12-inch square timber, and cross-braced. The regulator clock on its timber post, buried into the ground and reinforced with brickwork (Ewing 1771, 50), would most certainly have been beneath the platform from where everyone could hear the time-caller's voice.

John Watson (1779–1860), the Philadelphia annalist, commenting on the reading of the Declaration of Independence as related to him by “An elderly gentleman,” stated that “[the observatory] was about twenty feet high, and twelve to fifteen feet square, at fifty to sixty feet south of the house, and fifteen to twenty feet west of the main walk” (Watson 1850, 402). It is doubtful Watson saw the observatory before it was demolished, being an infant at the time, and he has the name of the Declaration's reader incorrect; the description should be regarded with a degree of caution. An unnamed diarist, present at the reading of the Declaration, recorded that “Passing through the assembled crowd the procession of officials, who had charge of proclaiming this state paper to the people [the Declaration], reached the platform . . .” where Colonel John Dixon then read the Declaration aloud (Alexander 1925, 663; Hart 1877, 196).

A 20-foot-high observatory suggests that there might have been an 8–10-foot-high structure on top of the platform; Rittenhouse's Norriton observatory was such a building with hinged openings for the telescopes. However, the State House observers needed clear views from the south-southeast around to the northwest with a vertical angle of sight extending from 73° (noon Sun) down to the northwest horizon. It is difficult to envisage such a structure or an arrangement where the observers did not get in each other's way. The roof and sidewalls would have had to be hinged in some fashion. The most likely explanation is

that the platform was open and the frame itself was timber clad, providing a secure room for storing the instruments.

THE COORDINATES

The 1769 Venus observations at Norriton and Philadelphia yielded longitude coordinates for the State House observatory, viz., 5 hours 00 minutes 35 seconds (of time) = $75^{\circ} 08' 45''$ W of Greenwich. The latitude of $39^{\circ} 56' 54.4''$ N was derived from chain-and-compass traverse surveys.

At the time, and for many years after, the deflection of the vertical, referenced by Charles Mason as the most probable cause for positional errors (Mason 1969, 194), was not fully understood and hence its corrections could not be applied. When converting their chain-and-compass traverses (discussed below) to differences in latitude and longitude, the observers had only Bougeur's ellipsoid parameters to hand and Mason and Dixon's meridian arc degree of latitude observed across the Delaware flats in 1767–1768.

To derive a modern geographical position from the 1769–1770 observations and calculations for pinpointing the observatory site would be pointless. The differences on, say, the ellipsoids used by GNSS systems are sufficiently large to introduce significant differences. Further, the zero longitude of Greenwich in 1769 fell some $5.3''$ W (102 meters, 335 feet) of the modern (ITRF) international geodetic longitude origin.

For interest's sake, the authors applied the spatial corrections and deflection of the vertical to the 1769 geographical coordinates to arrive at an approximation in the International Terrestrial Reference System (ITRS). The latitude difference was $2.1''$ S, and longitude 1.6 seconds of time ($23.3''$) E^3 —a remarkable result demonstrating the diligence and competence of all the observers.

TRAVERSE SURVEYS

During 1769 and in May 1770, four compass traverse surveys were run by the APS astronomers to tie together, in geographical terms, David Rittenhouse's observatory at Norriton, the State House Observatory in the City of Philadelphia, the Lewes observatory, and two of Mason and Dixon's primary points—the Southernmost Point of Philadelphia, and the cupola of the New Castle Courthouse at the center of the 12-mile circular boundary dividing Pennsylvania, Maryland, and

3 It was the practice of the day to cite longitude in time units.

Delaware. Of the three datum points only the New Castle Courthouse is extant. The site of the original house of Joseph Huddle marking the Southernmost Point of Philadelphia disappeared prior to 1895 with the construction of a sugar refinery and warehouses. The original location of the house was recovered using surveys and deeds from the city archives provided by Mr. James Shomper, a surveyor and former Regulator for the City of Philadelphia. Map-matching contemporary surveys and city maps with the modern city's mapping provided a reliable position (± 2 m).

The position of Rittenhouse's observatory in Norriton is uncertain and the best eyewitness estimate suggested it was about 50 feet north of Rittenhouse's home, which still exists as part of the Valley Forge Medical Center.

In commenting on the traverses, it must be stressed that the works were only ever meant for establishing the differences in latitude and longitude (in time units) between the various observatories, and hence should not be compared with the normal land surveying standards of the time.

Norriton to State House Observatory Traverse

The survey from Rittenhouse's Norriton observatory "to the Observatory in the State House Square . . . and thence to the Observatory of Messrs Mason and Dixon, at the South Point of the City . . ." (Smith 1771, 114–117) was in response to Astronomer Royal Nevil Maske-lyne's request that the geographical relationships of the observatories of Norriton and Philadelphia were determined. The work was completed in two days (July 3–4, 1770) by William Smith, John Lukens, and David Rittenhouse assisted by Archibald McClean and Jesse Lukens.

The connection between the two observatory locations comprised of a traverse with a surveyor's compass and measuring chain calibrated to 66 feet. The instrument's magnetic variation (declination) on true north was determined from Rittenhouse's meridian line at Norriton to be $3^{\circ} 08' \text{ W}$.

From the records of the observations it is apparent that only the forward magnetic bearing was observed, i.e., no back sight/reciprocal bearings. The traverse was unbalanced with some very long legs intermixed with relatively short ones, and not surprisingly there were no adjustments for temperature or refraction (Table 3). In computing the traverse, its origin at David Rittenhouse's observatory in Norriton was an estimated position, therefore the final station's coordinates were

expected to present a significant error: the State House observatory was the last station to be observed.

Total length	39.2 km (24.4 mi)
Minimum distance	36 m (118 ft)
Maximum distance	1,830 m (6,000 ft)
Average distance	475 m (1,560 ft)

TABLE 3. Norriton to State House observatory traverse distance statistics.

New Castle to State House Observatory Traverse

The traverse survey was run in May 1770, at the request of the American Philosophical Society, from the New Castle Courthouse to the State House observatory as part of a connection with the observatory at Lewes (Biddle and Bailey 1771, 89).

A description of the survey was not provided; however, what can be ascertained from the records is that the connection was another compass traverse with distances recorded in perches (16.5 feet), and probably measured using a braced timber “level.” The magnetic variation (deviation) on true north was determined to be 3° 15’ W (Table 4). The same comments per the Norriton survey apply. The traverse origin (the courthouse cupola) was and is a well-defined coordinated point. The last station in the traverse was the observatory.

Total length	53.08 km (33 mi)
Minimum distance	18 m (59 ft)
Maximum distance	4,748 m (15,577 ft)
Average distance	885 m (2,904 ft)

TABLE 4. New Castle to State House observatory traverse distance statistics.

Comments on the Two Long Traverses

It has been stressed that the traverses were only for tying together the observatory sites, therefore great precision was unnecessary. However, the traverses were critical to solving the enigma of the State House observatory’s position, not for their absolute accuracy, but for their inherent geometrical strength.

Before considering the last of the three traverses, in the quest for geometric veracity there are factors that could have influenced the measurements in absolute terms:

- 1769 coincided with the rise to solar maximum and hence a possibility of electromagnetic disturbances introducing unpredictable variables into the bearings. To eliminate this possibility the authors compared the magnetic declinations, as observed, with the National Center for Environmental Information's magnetic field calculator (International Geomagnetic Reference Field model) and found that both traverses were well within the error envelope.
- The greatest angular errors were due mostly to the unbalanced geometry of the sight lines, very long and very short, and compasses that at best could be estimated to 10' of arc.
- The ambient daytime temperature in May/June 1770 was in the low 80s°F (c.26°C). In these temperatures, compounded by the ground-grazing nature of many of the sight lines, angular observations would experience displacements due to refraction and scintillation.
- On the ground, the steel chain would have expanded and hence measured short.
- The inevitable "chain stretching" during the course of the day would have delivered short measure, i.e., a stretched chain would measure an exact 66-foot length as <66 feet. This was not such a problem with the 16.5-foot timber "levels."

The two long traverses are insufficiently precise in themselves to provide a reliable absolute solution. Fortunately, it is unnecessary as the traverses are, for the purposes of the hunt for the observatory, geometrically sound (Figure 6).

Mason and Dixon's Observatory to State House Observatory Traverse

The last traverse to consider in locating the State House observatory was run the short distance from the Southernmost Point of Philadelphia to the observatory site and mentioned in the last part of Smith's account (1771, 117):

The courses and Distances from Norriton Observatory, the Observatory in the State-House Square, Philadelphia, and from thence to the Observatory of Messrs Mason and Dixon . . .

But the observatory in the State-House Square, with respect to the south point of the city of Philadelphia (to which Messrs. Mason & Dixon refer their observations), is:-

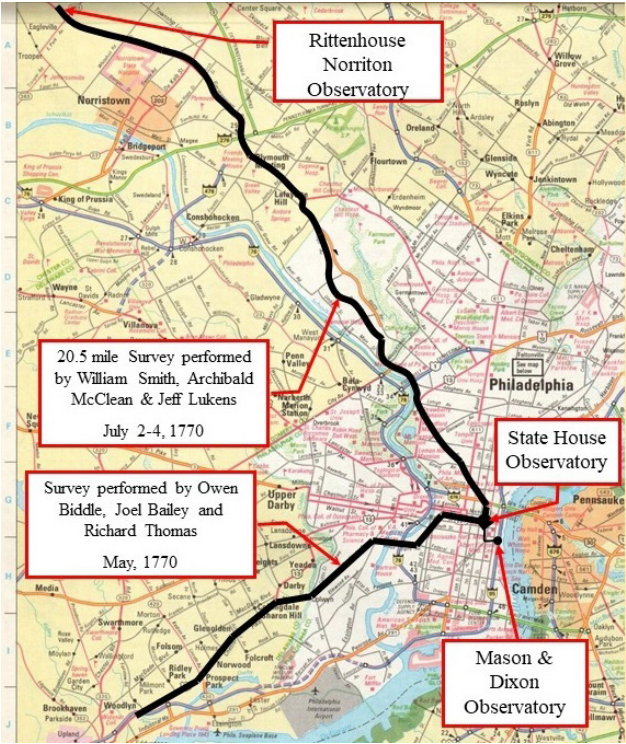


FIGURE 6. Routes of the traverse surveys run in 1770.

Chains Feet.

N. $40.0685 = 2644.5 = 26.16''$ diff. of lat

W. $28.7695 = 1898.8 = 1.6''$ of time

Although the datum point for Mason and Dixon’s survey was the Huddle house corner, the two English surveyors took their *observations* from a temporary observatory (Danson 2017, 89–93), the location of which was still extant in 1769. The veracity of this will be demonstrated. The original traverse observations were not recorded, rather only the difference west and north in chains, and as differences in latitude and longitude (as time), was appended to the Norriton traverse account. “The result by Messrs. Mason and Dixon’s work is got, by beginning at the south point of the city of Philadelphia (or the place of their Observatory,) on the north side of Cedar Street, between Front-Street and Delaware . . .” (Biddle and Bailey 1771, 96). The house was on the south side of the street, the observatory on the north (Figure 7).

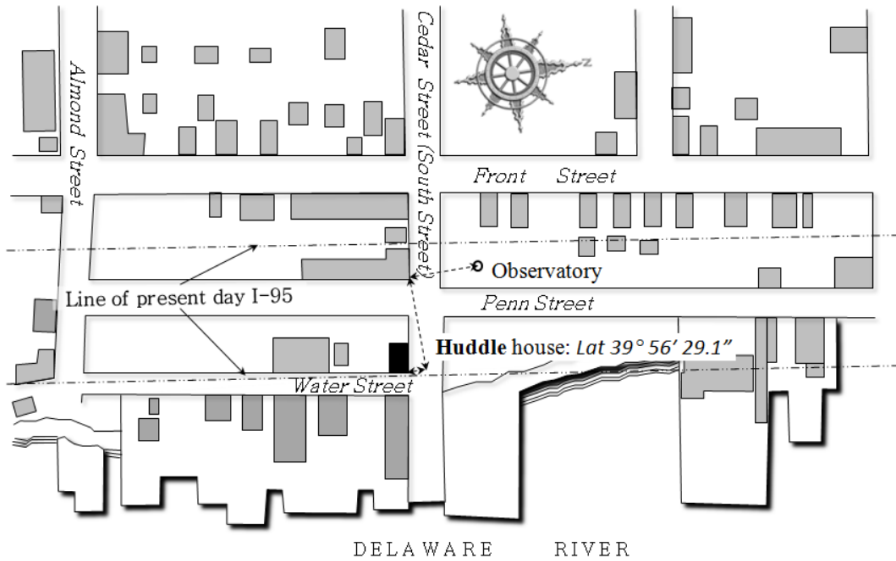


FIGURE 7. Joseph Huddle's house and Mason and Dixon's observatory.

COMPUTATIONS

For the purposes of locating the State House observatory, the traverses needed to show geometrical consistency with known street alignments. Each was computed independently by the authors, using different methods, in US State Plane/NAD83 (1986) terms, and in ITRS2008 geographical terms. The latter method was only a means to an end, therefore rather than treating the traverses as geodetic exercises, the volumetric radius for the Earth was used, the ellipsoidal point radius making no sensible difference to the required outcome.

Each traverse was separately computed in a spreadsheet using azimuths adjusted with the original magnetic variation. The authors anticipated from the outset that the surveys had employed the Philadelphia foot standard, the city's legal foot, being 0.03 inches longer than the imperial foot. However, this had to be proved, therefore the first computing runs kept the distances unchanged as if they were standard imperial units. As expected, the first runs demonstrated without doubt that the unit of length was the Philadelphia foot and not the standard imperial foot, i.e., a scaling factor of 1:1.0025 had to be applied (Shomper 2013). When running their surveys for the border between Pennsylvania and Maryland/West Virginia, Charles Mason and Jeremiah Dixon used the same Philadelphia foot, employing surveyors and chains provided by the colonial Proprietors (Danson 2016).

New Castle Courthouse to State House Observatory

The traverse from the New Castle Courthouse to the State House Observatory was drawn in a CAD program using the known coordinate value of the cupola of the courthouse as a starting point. For preliminary assessment, no compensation was made to convert the ground distance measurements to the grid values of the State Plane Coordinate system. Shapefiles of the road edges and property lines along the corridor of the survey were imported into the drawing. These files were obtained from the Philadelphia and Delaware County Geographic Information System (GIS) and were used to assess how the traverse, performed in 1770, may have followed the current roadway system. It was immediately apparent that the 1770 survey followed the course of many of the roads that are still in use today with a few exceptions where it appears they crossed over land where no roads had yet been constructed.

Despite finding that the traverse followed the roads, it was not a simple matter of overlying the traverse on the roads to find the location of the observatory. Due to the variations of the compass, accuracy of measurement, and other variables, it was found there was too much variation over the course of the 53.08-kilometer-long traverse to use this method. Having determined with confidence that the traverse followed the existing roadway system, it was decided to focus on the last two legs of the traverse. As the surveyors approached the State House observatory, the penultimate course was run down Chestnut Street for a length of 325.8 chains (1,638.5 m). This segment of the traverse provides a relatively narrow corridor (± 18.3 m) within which the traverse could have been run owing to building obstructions to the north and south of the street. This would therefore limit the north-south window within which the observatory could have been located.

Norriton to State House Observatory

In 2004, Todd Babcock performed a survey using the Global Positioning System (GPS) to locate the house of David Rittenhouse at Norriton, features in the State House yard at Independence Hall, and the centerline of the road corridor of the supposed course of the traverse performed in July 1770. The purpose was to determine if the 1770 traverse followed the extant road system, and to determine the location of the observatory. As found with the traverse from New Castle, the 1770 traverse did in fact follow the current road system; however, there were too many variables to use this method to establish definitively the location of the observatory.

In plotting the course of the traverse, it was found that the penultimate course was run along Sixth Street for 34 chains (684 m). As with the traverse from New Castle, the traverse along Sixth Street had to have been constrained to a corridor no more than 15.2 meters wide owing to the buildings that would have existed on the east and west sides of the street. It was assumed that the surveyors would not have measured down the extreme east or west sides of the street and more likely measured down the edge of the roadway to avoid traffic and obstructions. This would create a more restrictive window within which the observatory could have been in an east-west direction.

An independent computation of the traverse from Norriton to the State House in geographical terms was processed in the same fashion as the New Castle traverse, except that the starting coordinates were of a point 50 feet due north of the rear center of the Rittenhouse building (the best available estimate).

Mason and Dixon's Observatory to the State House Observatory

Of the three surveys to the State House Observatory performed in 1769–1770, the shortest and most convenient was from Charles Mason and Jeremiah Dixon's temporary observatory. To use the recorded offsets, it was first necessary to determine where Mason and Dixon's observatory was located. The answer to that lay in the journal of Charles Mason (Mason 1969, 35) and the measurements made between the observatory and Joseph Huddle's house, marking the most southern point of Philadelphia (Graham 1850, 11).

In 2004, Todd Babcock performed a survey of the existing buildings and streets at the intersection of South (Cedar) Street and Front Street, west of the former location of the Huddle house. The house location was calculated using surveys and deeds from the city archives provided by Jim Shomper, a surveyor and former Regulator for the City of Philadelphia. The location of the Huddle house being established, the offsets taken from Charles Mason's journal were used to calculate the position of their observatory. An assumption was made that the measurements taken by Mason and Dixon would have been made to the northeast corner of the Huddle house, which would have been the most southern part of the building on the south side of South (Cedar) Street. The possibility that the measurements were taken from the center, or northwest corner, of the Huddle house was disproved because the resulting misfit with the measurements made in the surveys from Norriton or New Castle, and the consequent geometry, was excessive. Based on the calculated position of the Huddle house and the measurements from Mason's journal, it was possible to calculate

the position of Mason and Dixon's observatory, which was found to have been in the present-day southbound lanes of Interstate 95.

The positional results for the State House observatory demonstrated that the starting point could only have been the observatory and not the Huddle house as had previously been thought. Had the house been the starting point, then the State House observatory would have fallen south and east of the contemporary boundary wall (i.e., outside the State House yard). Further, the traverse from Norriton would have had to pass through the lots and buildings east of Sixth Street and through the State House building itself, while the Norriton traverse would have had to pass across the lots south of Chestnut Street and through the bell tower, all of which is improbable (Figure 8).

ESTABLISHING THE LOCATION OF THE OBSERVATORY

It was anticipated that the computed compass traverses would not converge at the one point of the observatory. The critical issue, however, was confirming that the final approach lines were at verifiable orientations (with the streets and the compass) and that the lines entered the State House yard through contemporary 18th-century openings. That said, the short and simple traverse from Mason and Dixon's observatory was expected to be close to the mark.

Geometrical Solution

All three traverses terminated at the State House Observatory; consequently, it was possible for the authors to construct an accurate and unique geometry for the observatory's position and, by matching the geometry with contemporary entrances or apertures, the location of the observatory itself (Figure 9).

The configuration of the State House yard and its buildings has changed significantly since 1770 when the surveys were performed. To understand what the area surrounding the observatory looked like in 1770, information acquired in a survey of the State House yard in 2004 was coupled with historical records provided by John Milner Associates, Inc. These records depicted the location of the wooden shed and west wing of the State House building; this showed that there was an 11–12-foot gap between the shed and the west wing that offered the only entrance to the park with a clear line of sight to the observatory (Figure 10).

Although period illustrations of the State House (Figure 11) strongly suggest the rear (south) wall of the connecting hyphens or piazzas had no openings, for completeness the authors considered the

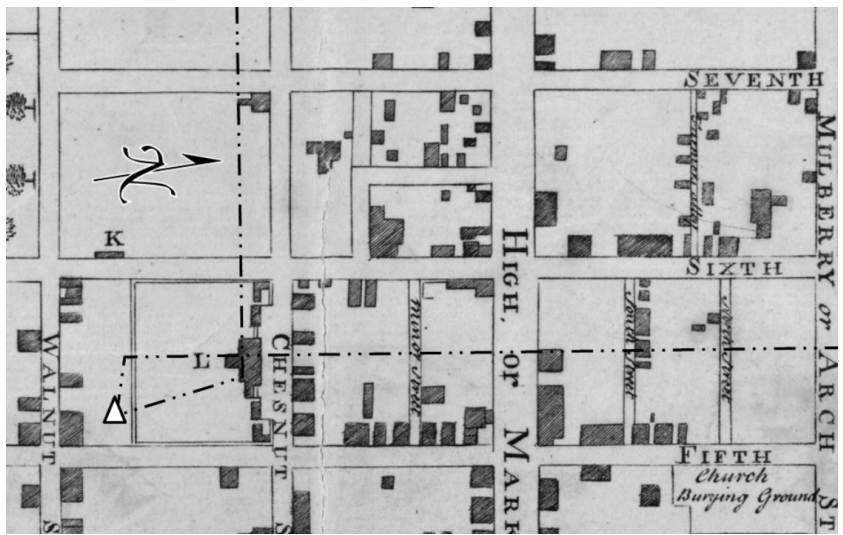


FIGURE 8. Clarkson-Biddle Map 1762 showing the traverse lines passing through buildings and back lots had the starting point been the Huddle house. The State House observatory falls south of the boundary wall. Note the timber sheds at either end of the lot and the position of the cross wall. Public domain via Wikimedia Commons.

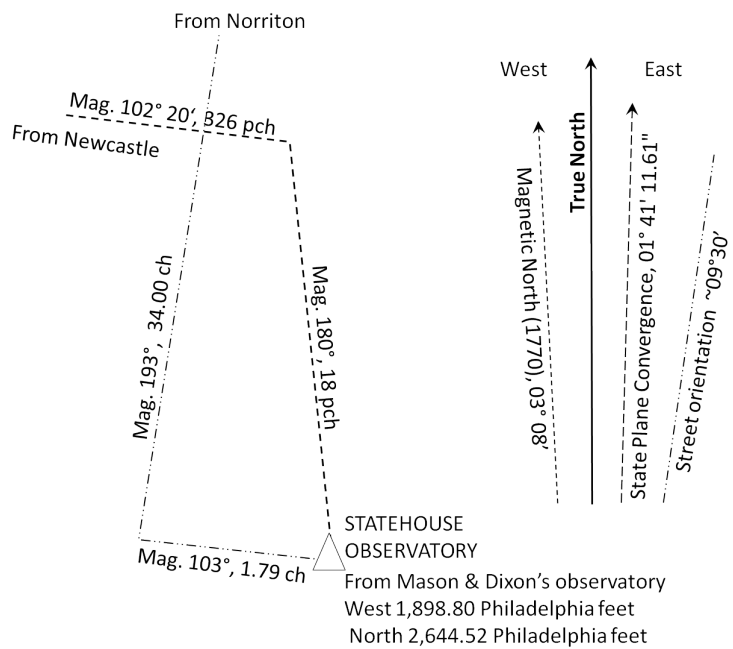


FIGURE 9. The unique geometry constrained by the three traverses.



FIGURE 10. The State House in Philadelphia, 1778 (Independence Hall), by Charles Willson Peale, showing the wooden sheds at either end of the lot.

possibility that there may have been a way through. Only the New Castle traverse could have used such an opening. However, the unique geometry would have required the Norriton traverse to pass through the gap between the shed and west wing. This, in turn, would mean the long traverse leg would have had to pass across the lots and through the buildings 55 feet east of Sixth Street and terminating at a point the same distance east of the observatory position, as established from the short traverse from Mason and Dixon's observatory on Cedar (South) Street.

The New Castle traverse, from map-matching the last mile or so of the traverse with the city street plan, strongly suggested that the survey was run on the south side of Chestnut Street. Further, a surveyor would avoid crossing a busy street if at all avoidable and as there was no reason to cross Chestnut to the north side, it can be confidently said that the traverse was run along the south side of the street, but clear or very close to the north wall of the wooden shed. The traverse then entered the yard via the gap between the wooden shed and the west wing on a magnetic bearing due-south directly to the observatory, a distance of 18 perches (90.3 m).

The Norriton traverse, from map-matching with the city plan, followed the east side of Sixth Street (since widened), across Chestnut Street and continued south along the line of Sixth Street to a point where it made a turn to the east to arrive at the observatory on a magnetic bearing of 103° at a distance of 1.79 chains (36 m). This last turn would have necessitated crossing the boundary wall; hence, a



FIGURE 11. The State House showing the wing buildings and connecting hyphens. Scull and Heap map, 1752.

surveyor would simply have observed the reverse magnetic bearing from the observatory to the crossing point at the wall on Sixth Street.

With a sound and unique geometry for the last legs of the traverse surveys, constrained by the contemporary architectural features offering access to the yard, the location of the old observatory has been established within a 4.6-meter (15-feet) square centered on Latitude $39^{\circ} 56' 53.927''$ N; Longitude $75^{\circ} 09' 1.718''$ W, NAD83 (1986) (Figure 12).

CONCLUSIONS

Placing the observatory in the northeast quadrant of the State House yard is a most unlikely position because the Sun would have been obscured by buildings during the latter stages of the transit. The eyewitness and later accounts for the observatory's location are therefore insufficiently reliable to provide an accurate position for the structure. The archaeological record confirmed no definitive evidence has been seen. The few mentions contained in the records of the APS observatory team are helpful in estimating what form the observatory took and the physical and astronomical limitations that controlled their choice of site.

The unique geometry offered by the three survey traverses (all of which terminated at the observatory structure), constrained by the known contemporary architecture, have provided a sufficiently precise location for justifying further archaeological investigations of one of America's oldest scientific sites and the place where the people first heard the immortal words of the Declaration of Independence (Figure 13).

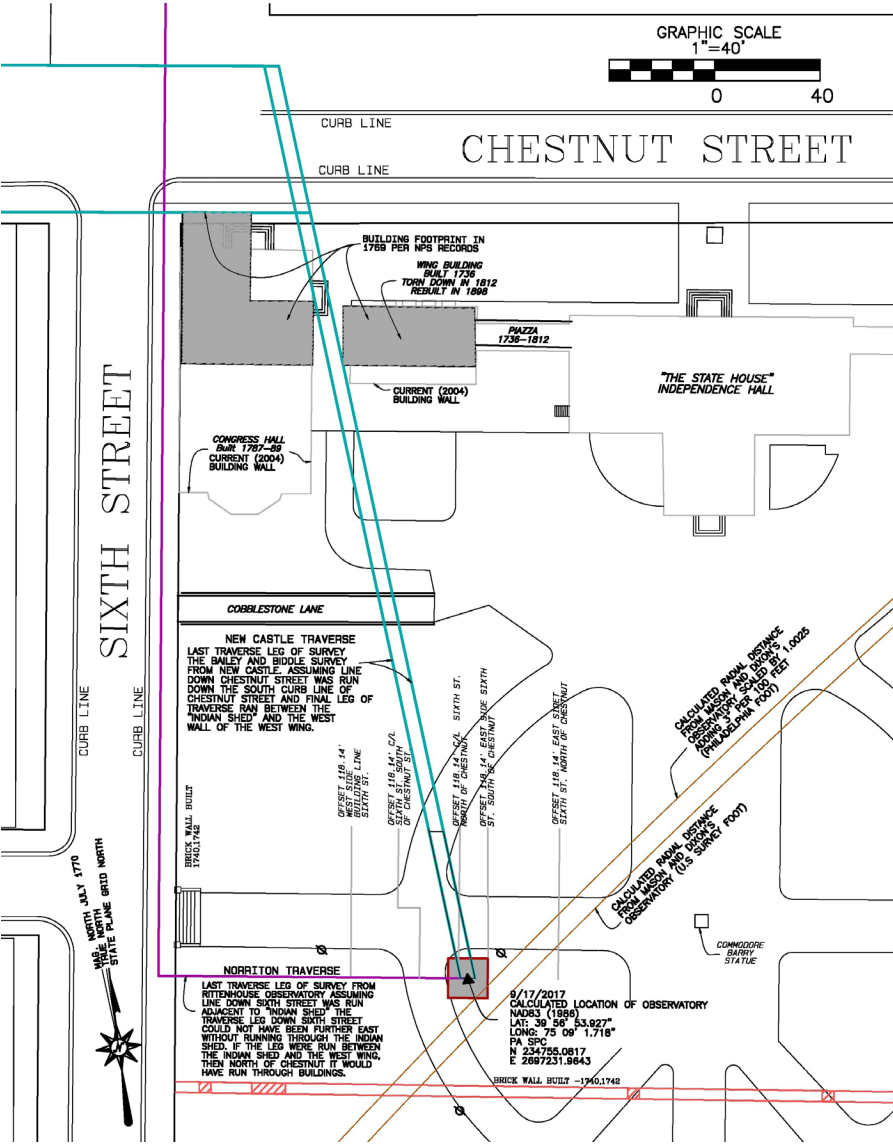


FIGURE 12. The geometrical solution for the State House observatory’s probable position.



FIGURE 13. Authors' impression of how the observatory might appear today, had it survived.

REFERENCES

- Alexander, M. D. 1925. "The Ringers of the Liberty Bell." *Journal of the Illinois State Historical Society* (1908–1984) 18, no. 3: 658–67. <http://www.jstor.org/stable/40188399>.
- Armstrong, E., ed. 1870. *Correspondence between William Penn and James Logan, Secretary of the Province of Pennsylvania, and others 1700–1750*. Philadelphia: Historical Society of Pennsylvania.
- Bell, Whitfield J. 1964. "Astronomical Observatories of the American Philosophical Society, 1769–1843." *Proceedings of the American Philosophical Society* 108, no. 1: 7–14. <http://www.jstor.org/stable/985991>.
- . 1997. *Patriot-improvers: 1743–1768*. Philadelphia: American Philosophical Society.
- Biddle, O., and J. Bailey. 1771. "An Account of the Transit of Venus, over the Sun's Disk, as observed near Cape Henlopen, on Delaware Bay, June 3d, 1769." In *Transactions of the American Philosophical Society*, vol. 1. Philadelphia: American Philosophical Society.
- Danson, E. 2016. "The Curious Matter of the Colonial American Mile." In *Civil Engineering Surveyor*, vol. 1, January 2016. Manchester, UK: SURCO.
- . 2017. *Drawing the Line: How Mason and Dixon Surveyed the Most Famous Border in America*, revised ed. Hoboken, NJ: John Wiley & Sons.
- Etting, F. M. 1876. *An Historical Account of the Old State House of Pennsylvania*. Boston: James R. Osgood & Co.
- Ewing, J. 1771. "An Account of the Observations on the Transit of Venus over the Sun, on the 3d of June, 1769." In *Transactions of the American Philosophical Society*, vol. 1. Philadelphia: American Philosophical Society.
- Ferguson, R. A. 1997. *The American Enlightenment, 1750–1820*. Cambridge, MA: Harvard University Press.

- Graham, J. D. 1850. *Message from the governor of Pennsylvania, transmitting the reports of the joint commissioners, and of Col. Graham, U.S. engineers, in relation to the lines between the states of Pennsylvania, Delaware and Maryland*. Harrisburg, PA: JMG Lescure.
- Greene, J. C. 1968. "American Science Comes of Age, 1780–1820." *Journal of American History* 55, no. 1: 22–41.
- Hart, C. H. 1877. "Colonel John Nixon." *Pennsylvania Magazine of History and Biography* 1, no. 2: 188–202.
- MacFarquhar, C., ed. 1797. *Encyclopaedia Britannica, or, A dictionary of arts, sciences, and miscellaneous literature*, vol. 18. Edinburgh: A. Bell and C. Macfarquhar.
- Mason, A. H., ed. 1969. *The Journal of Charles Mason and Jeremiah Dixon. Memoirs of the American Philosophical Society*, vol. 76. Philadelphia: American Philosophical Society.
- Moss, R. W. 1972. *Master Builders: A History of the Colonial Philadelphia Building Trades*. Ph.D. diss., University of Delaware. Accessed September 4, 2017. https://www.philadelphiabuildings.org/pab/app/ar_display.cfm/118111.
- Riley, E. M. 2008. *Starting America: The Story of Independence Hall*. Independence Hall Association. Accessed October 7, 2017. <http://www.ushistory.org/independencehall/history/indhall2.htm>.
- Shomper, J. 2013. "The Philadelphia Regulators: Surveying in Philadelphia Where a Foot is not a Foot." In *Proceedings of Surveyors' Rendezvous 2013*. Philadelphia: Surveyors' Historical Society.
- Smith, W. 1771. "An Account of the Terrestrial Measurement between the Observatories of Norriton and Philadelphia; With the Difference of Longitude and Latitude Thence Deduced." In *Transactions of the American Philosophical Society*, vol. 1. Philadelphia: American Philosophical Society.
- Toogood, A. C. 2004. *Cultural Landscape Report for Independence Square*, vol. 1. Philadelphia: National Park Service.
- . 1998. *Cultural Landscape Report for Independence Square*, vol. 2. Philadelphia: National Park Service.
- Watson, J. F. 1850. *Annals of Pennsylvania and Philadelphia in the Olden Time*, vol 1. Philadelphia: Private printing.
- Westcott, T. 1877. *The Historic Mansions and Buildings of Philadelphia*. Philadelphia: Porter & Coates.