Chapter 64
Robert Hooke's Fire Monument: Architecture as a Scientific Instrument

Maria Zack

Introduction

After the Great London Fire of 1666, Robert Hooke was appointed to work in the office of the City Surveyor of London. With that appointment, a scientist best known as the Curator of Experiments for the Royal Society, whose research encompassed both the microscopic (*Micrographia*) and the astronomical, embarked on a second career as an architect and surveyor. For the next several decades the massive effort to reconstruct London was led by Hooke and his long-time friend, fellow scientist and co-founder of the Royal Society Christopher Wren.

Hooke was involved extensively in all aspects of the rebuilding of London, both the mundane (widening streets and establishing property boundaries) and the creative (designing churches and civic buildings). Very little of Hooke's architectural work has survived the passage of time. However, one shining example of his creativity remains in London: the Monument to the Great Fire.

At the time of the monument's design, Hooke was conducting experiments on both the motion of the earth and the effects of gravity. The monument is an elegant column that was constructed to contain a zenith telescope to further Hooke's research. This ingenious building is an excellent example of the intersection between Hooke's architectural and scientific work.

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Hooke the Scientist

Robert Hooke was born in Freshwater on the Isle of Wight in 1635. Hooke was the youngest of four children of John Hooke, an Anglican priest with deeply Royalist leanings. In 1648, Hooke's father died "by suspending himself" (Aubrey 1957: 165) leaving him "forty pounds of lawful English money, the great and best joined chest, and all my books" (Cooper 2003: 12). John Aubrey, the diarist and friend of Robert Hooke tells us:

> When his father died, his Son Robert was but 13 years old, to whom he left one Hundred pounds, which was sent to London with him with the intention to have bound him Apprentice to Mr. Lilly the Paynter, with whom he was a little while upon tryall; who liked him very well, but Mr. Hooke quickly perceived what was to be done, so, thought he, why cannot I do this by myself and keep my hundred pounds? (Aubrey 1957: 164).

By 1649 Hooke had left Mr. Lilly (Lely) and was a student of Dr. Richard Busby at the Westminster School. At Westminster, Hooke's talent for mathematics and mechanical devices became apparent.

> H[ooke] fell seriously upon the study of Mathematicks, the Dr. encouraging him therein, and allowing him particular times for that purpose. In this he took the most regular Method, and first made himself Master of Euclide's Elements, and thence proceeded orderly from that sure Basis to the other part of the Mathematicks, and thereafter to the application thereof to Mechanicks, his first and last Mistress (Hooke 1705: iii).

Through connections at the Westminster School, Hooke entered Oxford in 1653 as a "servitor" student with a choral scholarship and was awarded a Master of Arts degree in 1662 or 1663 (Cooper 2003: 19). At Oxford Hooke developed the scientific relationships that would define the rest of his professional life. Hooke and Christopher Wren began a life-long friendship while they were both students and in 1656 Hooke became Robert Boyles's experimental assistant. By the early 1660s Hooke and many other virtuosi had moved to London, and this active group of scientists formed the Royal Society. In 1662 Boyle nominated Hooke for the position of Curator of Experiments for the Royal Society. Hooke's duty was "to furnish them every day, on which they met, with three or four considerable experiments" (Cooper 2003: 28). Hooke became a Fellow of the Royal Society in 1663 and would take an active role in the affairs of the Society until his death in 1703.

The Royal Society saw itself as a "Baconian" scientific institution. The members knew Francis Bacon's writings intimately and reflected them in their own philosophy and work.

> [I]t was Bacon's general statements about the aims and methods of modern science that early English experimentalists based themselves on. In Bacon's view the business of modern science was to amass a great corpus of precise information based on experiment and observation, to generalize from this by the process of induction, and to do all for useful ends (Espinasse 1956: 19).

In his role as the Curator of Experiments, Hooke himself performed many experiments ranging from the microscopic to the astronomical. He used his mechanical genius to design a wide variety of instruments and to manufacture them in partnership with many of London's most skilled craftsmen (Cooper 2003: 45). Hooke believed that instruments were an essential part of experimental science. He said:

> It is the great prerogative of Mankind above other Creatures, that we are not only able to behold the works of Nature, or barely to sustain our lives by them, but we have also the power of considering, comparing, altering, assisting, and improving them to various uses. And as this is the peculiar privilege of human Nature in general, so is it capable of being so far advanced by the helps of Art, and Experience, as to make some Men excel others in their Observations, and Deductions, almost as much as they do Beasts. By the addition of such artificial Instruments and methods, there may be, in some manner, a reparation made for the mischiefs, and imperfection, mankind has drawn upon itself (Hooke 1665: Preface).

From the very beginning Hooke also made use of buildings as instruments. As early as 1662 he conducted experiments on gravitational attraction by dropping items from the top of Westminster Abbey (Cooper 2003: 46) and he conducted additional experiments from the top of the pre-fire St. Paul's Cathedral, leading to his 1666 paper *On Gravity* (Cooper 2003: 54–65). Certainly the monument provided another great height for Hooke's gravitational experiments, but its unique role was as a telescope. The telescope was designed to gather data to measure the parallax and thus resolve one of the great scientific questions of the time, the motion of the earth.

The Parallax

Hold a finger at arm's length and look at a distant object beyond your finger. Close each eye in turn. The position of your finger relative to the distant object appears to change because of the alteration in your viewing angle. This apparent shift is known as a parallax. This simple phenomenon was at the heart of 2,000 years of debate about the nature of our universe.

Aristarcus (c. 310–230 B.C.) calculated that the sun was significantly larger than the earth, and thus much more likely to be the centre of the solar system. Aristarcus believed that the earth revolved around the sun and rotated on an axis.

> [H]e realized that his model gave him a method for measuring the distance to the stars because the motion of the Earth from one point in its orbit to the extreme opposite point would cause the stars to show a parallax, that is, they would appear slightly shifted in the sky (Wilson 1997: 32).

However, because his instruments were too crude for the distances involved, Aristarcus was unable to detect a parallax. This lead Aristarcus not to abandon his theory, but rather to conclude that the universe was very large (Wilson 1997: 33).

Ptolemy's (c. 100–170 A.D.) elegant *Almagest* was used for roughly fourteenth centuries to calculate with a high degree of accuracy the motion of the sun, moon, planets and stars based on a geocentric model of the universe. In *De Revolutionibus Orbiun Coelestium* (1543) Copernicus proposed a heliocentric universe with the sun in the centre of a fixed sphere of stars and the planets rotating around the sun. Copernicus launched significant debate in the scientific community.

> There were no astronomical observations that specifically favoured the Copernican system over that of Aristotle and Ptolemy. The heliocentric model made the specific prediction of stellar parallax—the apparent wobble in the position of the star as the earth moved from one side of its orbit to the other side—whereas the geocentric model predicted none, and, indeed none had been detected....[A]t the time, the only argument in favour of the heliocentric system was an aesthetic one—it had great simplicity and form—yet this was sufficient to convince the most important scientific minds who were to follow Copernicus in the Renaissance period (Wilson 1997: 54)

Those who gazed at the sky looking for signs of a parallax included Tycho Brahe (1546–1601), Galileo Galilei (1564–1642), John Flamsteed (1646–1719) and Robert Hooke. They knew that if they could find a stellar parallax this would prove that the earth moves through space.

Zenith Telescopes and the Motion of the Earth

Tycho Brahe held to a "modified Copernican" cosmology. He believed that the planets orbited the sun but still maintained that the Earth was stationary and fixed at the centre of the universe (Wilson 1997: 62). Galileo agreed with Copernicus and believed that the Earth joined the planets in revolving around the sun. In *Dialogue Concerning the Two Chief World Systems* (1632), Galileo suggested using two stars, a near star and a background star, as a way to compute the parallax (Hoskin 1997: 210) and thus prove that the heliocentric theory is correct.

In 1669, Hooke proposed a series of experiments to attempt to measure stellar parallax. His stated purpose was "to furnish the Learned with an experimentum crucis to determine between the Tychonick and Copernicuan Hypotheses" (Hooke 1674: 2). He chose the star Gamma Draconis primarily because it is bright and it daily passes directly overhead (near the zenith point) in London (Hooke 1674: 13).

Picking a star that passes near the zenith simplifies the experiment because gravity defines the zenith exactly, so the telescope could be aligned simply by using a plumb bob. Hooke said "by this way of observing I avoid all the difficulties that attend to the making, mounting and managing of great Instruments." In addition, because the star's light passes perpendicularly through the Earth's atmosphere, calculations did not need to be adjusted to account for refraction (Hooke 1674: 15).

Hooke described his experiments in *An Attempt to Prove the Motion of the Earth from Observations*. In this paper he gave details of the construction, installation and alignment of his 36 foot telescope (Hooke 1674: 17–23). To accommodate it, he needed to cut a hole through the floor and ceiling of his lodgings at Gresham College (Fig. 64.1).

In June of 1669, Hooke began his experiment; however, he made only four observations (July 6, July 9, August 6 and October 21, 1669) before declaring:

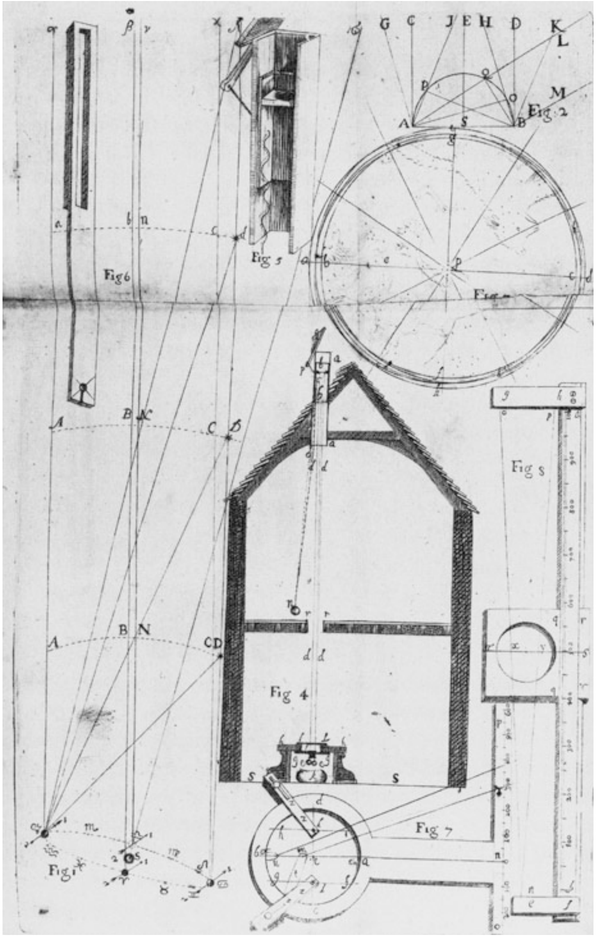

Fig. 64.1 Hooke's drawing of his zenith telescope. Image: Hooke (1674: Table III)

> Tis manifest then by observations . . . that there is a sensible parallax of the Earths Orb to the fixt Star in the head of Draco, and consequently a confirmation of the Copernican System against the Ptolomaick and Tichonick (Hooke 1674: 25).

Hooke was however conscious of the possibility of experimental error particularly in setting the plumb bob and keeping the telescope in position (Hooke 1674: 24). By the 1660s astronomers realized that the distance between the two extremes of the earth's orbit around the sun was relatively small compared to the size of the universe, thus slight instrumental inaccuracies could invalidate an observation. Hooke's 1669 parallax angle of 27 arc sec seemed unexpectedly large (Chapman 2005: 93). Hooke believed that there was more to be learned using a longer telescope. In his paper he considered the benefits to be gained from building a 144 ft telescope and described the possibility of putting such an instrument in a well to provide greater stability (Hooke 1674: 22). Hooke knew that the longer the focal length of a telescope, the larger the image and hence the greater the ability to see a difference in the parallax angle. The monument was designed to provide his desired long (nearly 200 ft) focal length.

The Monument

On October 4, 1666, just a few weeks after the Great Fire of London, the City of London appointed Robert Hooke to the Rebuilding Commission and King Charles II appointed Christopher Wren to the same Commission (Jardine 2004: 144). There were four others appointed to the Commission, but less than 6 weeks after the fire Henry Oldenberg (the Secretary of the Royal Society) wrote to Robert Boyle stating that the rebuilding of London "is to be forthwith taken in hand, and that by the care and management of Dr Wren and Mr Hooke" (Jardine 2004: 147). For the next 37 years, Hooke and Wren's scientific collaboration was expanded to include architecture. The collaboration ended only with the death of Hooke in 1703.

The 1670 City Churches Rebuilding Act provided funds for a monument to "preserve the memory of this dreadful visitation" (Jardine 2002: 316). Not all of the destroyed parish churches were to be rebuilt. The parish of St. Margaret's Church on Old Fish Street was merged with St. Magnus the Martyr and the new church for the joint parish was constructed on the previous foundations of St. Magnus. Because of its proximity to Pudding Lane where the fire began, the location of the destroyed St. Margaret's was deemed ideal for the construction of the memorial pillar and a surrounding square (Cooper 2003: 198–199). The memorial was intended to be viewed from a great distance (Fig. 64.2) and that was the case until the relatively modern construction of high rise building around the square (Fig. 64.3).

Hooke's diaries from the 1670s show Hooke and Wren meeting almost daily for both professional and social reasons (Batten 1937: 83). Certainly Hooke and Wren collaborated on the Monument to the Great Fire, but it is now generally accepted that Hooke was the designer of the Monument. There is a single drawing of the Monument by Wren (at All Souls in Oxford), but it is not the design that was built. Hooke's drawings for the Monument and for the urn at the top are the ones that were executed. These drawings are in Hooke's hand and are part of a collection of "Dr Hooke's drawings" housed in the British Museum/Library. The confusion over attribution is most likely rooted in the fact that these drawings, along with several other designs of Hooke's, were published by the Wren Society in vol. V of the twenty-volume collected works of Wren (Robinson 1948: 51–52).

On January 26, 1671 the Court of Alderman considered "the draught now produced by Mr Hooke one of the Surveyors of the new buildings of the Pillar to be erected in memory of the Late dismall Fire." Approximately 2 weeks later the design was approved, the drawing signed by Wren and construction authorized to begin (Cooper 2003: 200).

By 1673, the Monument was under construction. Hooke's diaries indicate that he was involved in each step of the construction process. On October 19, 1673 he

Fig. 64.2 The Monument To The Great Fire as depicted by engraver Sutton Nicholls, ca. 1750

wrote "perfected module of Piller"; on June 1, 1674 "At the pillar on Fish Street Hill. It was above ground 210 steps"; on August 7, 1674 "At the Pillar in height 250 steps"; on September 21, 1675 "at fish-street-hill on ye top of ye column"; and on April 11, 1676 he was with Wren "at the top of ye Pillar" (Batten 1937: 84). Lisa

Fig. 64.3 Contemporary view of the Monument to the Great Fire. Photo: author

Jardine speculates that Hooke used the same attention to detail in the construction of the Monument that he employed when designing other scientific instruments:

> From the precision of the elements in the column as built (the accuracy of the height of each individual stair-riser, the breadth of the circular apertures) it appears that Hooke took very particular care with the construction of this single, vertical shaft, exercising close control over its execution, which increased the period of completion significantly (Jardine 2002: 317–318).

With a bit of political manoeuvring, Wren ensured that the Monument would be a scientific instrument. The City Lands Committee had thought it appropriate to place a statue of the King at the top of the column, which would have made it difficult to see straight though the column to the sky and would have ruled out its use as a zenith telescope (Cooper 2003: 202). In July of 1675 Wren sent the Committee a letter with some proposals for what might be placed at the top of the column. He offers several suggestions: a gilt ball, a statue, a copper ball with flames of gilt or a phoenix. He rules out the phoenix as being dangerous and emphasizes the usefulness of either of the spherical options, claiming that they would "give Ornament to the Town at a very great distance" and because "one may goe up into it; & upon occasion use it for fireworks" (Jardine 2002: 316–317).

Fig. 64.4 The sphere and urn at the top of the Monument to the Great Fire. Photo: author

Though Wren carefully keeps the option of a statue as a possibility, he discourages it because of the great expense. Fortunately Wren was persuasive and the Monument's use as a telescope was preserved.

The Monument was completed in 1677 and its use as a scientific instrument began. It has an underground chamber set in a bed of gravel, which was the location of the eyepiece of the telescope. The objective lens of the telescope was mounted 200 ft above, near the top of the pillar inside the ball but below the hinged doors to the flaming urn (Fig. 64.4). The accuracy of the observations made by this zenith telescope depended on maintaining the alignment of the eyepiece and objective lens. Unfortunately, the vibrations caused by air currents traveling down the core of the column and from the wheeled traffic passing by the pillar caused a misalignment in the lenses that was greater than the changes in parallax that Hooke was trying to measure (Cooper 2003: 201). In *An Attempt to Prove the Motion of the Earth from Observations* Hooke discussed alignment difficulties with his 36 foot telescope:

> I was forced to adjust the Instrument at every observation I made, both before and after it was made, which hath often made me wish that I were near some great and solid Tower, or some great Rock or deep well, that so I might fix all things at once, and not be troubled continually to adjust the parts of the said Instrument (Hooke 1674: 22).

Though the Monument was built on a foundation of gravel to help provide stability, his "solid Tower" was not solid enough. Perhaps he would have had better success with a well, though architect Michael Cooper says "as so often was the case with Hooke's ingenious instruments ... the methods and materials available to him prevented him from making instruments accurate enough to do what he wanted" (Cooper 2003: 201). It would be another 165 years before technology advanced sufficiently to measure the parallax. In 1838 Friedrich Bessel computed the parallax for 61 Cygni, whose angle of change is much greater than that of Hooke's Gamma Draconis (Wilson 1997: 101). Once again, Hooke was ahead of his time.

Hooke did conduct some experiments on barometric pressure at the monument. On May 16, 1678 his diary says "At Fish Street pillar tried mercury barometer experiment. It descended at the top about 1/3 of an inch." The proceedings of the Royal Society for May 30, 1678, contain a report from Hooke about these barometric experiments. He also continued some of his gravitational experiments with pendulums at the Monument (Jardine 2001: 300–301).

Though the Monument was not as successful a scientific instrument as had been hoped, it has remained an enduring memorial to the Great Fire of 1666 as well as a symbol of Hooke and Wren's enduring partnership in both architecture and experimental science.

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