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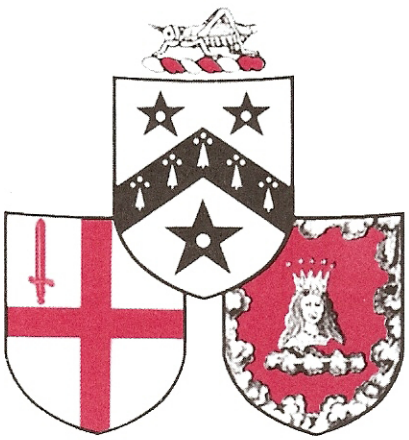

THE LEGACY OF SIR THOMAS GRESHAM

TRUE AND IMPARTIAL OBSERVATIONS: THE WORK OF ROBERT HOOKE FRS GRESHAM PROFESSOR OF GEOMETRY 1664-1703

A Lecture by

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TRUE AND IMPARTIAL OBSERVATIONS

The Science and Professional Practice of Robert Hooke FRS, Surveyor to the City

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1. Introduction

Robert Hooke was a notable exemplar of the legacy of Sir Thomas Gresham. As Curator of Experiments to the Royal Society and Gresham Professor of Geometry he played a leading part in the "new learning" and its dissemination. But he also served the City of London to great effect in his daily work in the streets as City Surveyor for rebuilding after the Great Fire. Hooke's combination of learning and practical usefulness to the City is part of Gresham's legacy.

Hooke was a close observer of what was going on around him and he made extraordinary use of what he saw, even in childhood at Freshwater on the Isle of Wight where he grew up, the second son of the parish curate.[1, 2, 3] In maturity he made use of these qualities in all his work. He observed and questioned what he saw in order to know and understand better the natural world. Through such knowledge and understanding, mankind he thought, could avoid error brought about by dogmatizing, and by assisting the works of nature, receive due benefit. When man's natural powers of observation are inadequate, it is necessary to find ways to improve them.[4] Hooke's exceptional ability in devising optical and mechanical instruments for specific scientific investigations set a precedent which has led to contemporary scientific instruments such as the Hubble telescope and super-colliders. Each of these contains elements that were originally devised by Hooke.[5]

The purpose of this paper is to examine a few of Hooke's many reports to the Royal Society on his experimental, or scientific, investigations alongside a small sample from the much greater number of his reports to the City of London in connection with rebuilding after the Great Fire. These two kinds of report indicate that Hooke was not only Britain's first professional experimental scientist, but also its most important professional surveyor who practised in many areas of that broad activity (geodesy, hydrography, land surveying, building surveying, quantity surveying, etc.).

2. Gresham College, the Royal Society, the City[6] and Hooke in the 1660's

In 1662, aged 27 years, Hooke was appointed Curator of Experiments to the Royal Society which at that time met regularly in Gresham College. In 1664 he was engaged by Sir John Cutler, merchant, to give the Cutlerian Lectures on mechanics under the auspices of the Royal Society. In the same year he was appointed Gresham Professor of Geometry and for the next 39 years he lived in rooms in the south east corner of the courtyard of Gresham College until he died there in 1703, aged 68 years. At the time of the Great Fire of London in September 1666, Hooke was a well-known figure in Gresham College.

As soon as the Fire allowed, the City resumed its business. Unable to use ruined

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Guildhall, the City wasted no time in transferring its business to Gresham College. The first meeting of the Court of Aldermen after the Fire took place there on 6th September 1666 in the room the Royal Society had been using for its meetings.[7] This intrusion of the City into the College was not welcomed by all incumbents. Dr George Gifford, Gresham Professor of Divinity, hearing that his rooms were to be used by the Deputy Town Clerk and the City Swordbearer, locked his doors, but quickly found other accommodation when the City Artificers were ordered to break the locks and clear his rooms. The Royal Society continued for a time to meet in the College, in the lodgings occupied by Dr Walter Pope FRS, Gresham Professor of Astronomy.

Hooke acted quickly in preparing a new layout plan (now lost) for rebuilding the city. He showed it to the Royal Society at its meeting in Gresham College on 19th September 1666. He had evidently shown it earlier to the City because Sir John Lawrence (the former Lord Mayor, elected FRS in 1673 and later a member of Council of the Royal Society) who was present at that meeting said the City much preferred Hooke's plan to that put forward by Peter Mills, its own Surveyor. The President of the Royal Society, Lord Brouncker, told the former Lord Mayor that the Society would be very glad if any of its members could be of service and that Hooke should assist the City in presenting his plan to the King if the City so wished.[8] Lord Brouncker could not at that time have known how great Hooke's assistance to the City would be and what detrimental effects it would have on his work for the Royal Society. The formal association between Hooke and the City began on 4th October 1666 when Peter Mills (the City Surveyor) Hooke

"Reader of the Mathematicks in Gresham Collidge" [9]

and Edward Jerman, a surveyor and architect, were ordered to work with the King's Commissioners to compile what would have been in effect a Land Information System for the City of London. However, rebuilding could not be delayed until the information was collected so the grand scheme came to nothing.

Despite this inconsequential beginning, the range of Hooke's work for the City in rebuilding exceeded that of any other individual. He helped to draft the new Building Regulations which were included in the Rebuilding Acts; supervised the mapping of the burnt city; staked out new and widened streets; staked out and certified foundations for rebuilding - all his certificates are perhaps now lost; he surveyed ground taken away for new streets and quays and issued certificates to the owners for compensation; he supervised land surveyors and cartographers producing maps and plans of the City's properties; he examined materials, workmanship, bills of quantities and craftsmen's bills on behalf of the City in connection with its own rebuilding; he designed hangings for Guildhall; examined matters in dispute between neighbours and accusations of infringements of the Rebuilding Acts, reporting to the City on how the disputes should be settled; and he worked almost daily with Wren on rebuilding the City churches.[10] The effect on his scientific endeavours of this intense work in the half dozen years following the Fire has yet to be assessed.

3. Examples of Hooke's Scientific Observations

I have chosen gravitational and microscopical investigations as two examples of Hooke's scientific work undertaken in the few years preceding his appointment as City Surveyor to illustrate the extent of his experimental investigations at that time and the manner in which he

reported them to the Royal Society.

In the early 1660's one of the many interests of Fellows of the Royal Society was in the earth's gravitational attraction and its variation with distance from the surface of the earth. Dr Henry Power in 1662 reported some experiments he had made in coal mines. One of these experiments was intended to discover the change in the weight of an object as it was removed downwards from the earth's surface. He found that a lump of brass lost at least an ounce in weight when lowered 68 yards from the surface to the bottom of a mine shaft. When trials using other substances were attempted, the thread he used for lowering them broke. The experiment gave the result which was expected: a body should lose weight if it were lowered beneath the surface of the earth because of the "attractive power" of the earth above it. Power's account of his experiment[11] is uncritical; his inability to repeat the test with other substances does not seem to have been a matter of concern to him. A few months later when Hooke reported to the Royal Society a similar experiment he had made at Westminster Abbey, quite a different state of mind is apparent.[12] Hooke took a pair of

> "exact scales and weights"

to a convenient place on Westminster Abbey that he had found by measurement to be 71 feet vertically above the roof leads of an adjoining building. He there weighed a piece of iron and a length of thread sufficient for lowering the iron weight to the level of the roof below. He then tied the iron to the thread, lowered it to just above the leads and weighed the thread and iron again. The first weighing gave 17 ounces and 30 grains troy weight and the second

> "preponderated the former counterpoise somewhat more than 10 graines."

Although this result, like Power's, confirmed what was expected (in this case that a body should gain weight if it were lowered towards the surface of the earth from above because the earth's "attractive power" increases as the distance of an object from it decreases) Hooke did not thereupon end the experiment, saying that it had been "successful" as others of the time would have done, satisfied that because the experiment confirmed the hypothesis, it had "wrought well". He continued the experiment by drawing up the iron and thread

> "with all the Diligence possibly I could that it might neither gett nor loose any thing by touching the perpendicular wall."

He then placed the iron and thread in the scale and found their weight was the same as it was when the iron was 71 feet lower - different from the value found at the first weighing. He therefore concluded that there was no sensible difference between the weight of the iron at the top and its weight at the base. Nevertheless he repeated the experiment, with the same result: no change in weight

> "which made me guess that the first preponderating of the scale, was from the moisture of the air, or the like that had stuck to the string, and soe made it heavier."

Still not satisfied, he moved to another position in the Abbey that was about the same distance from the ground as the earlier place was above the leads

> "And upon the repeating the tryall there with the former Diligence, I found not any sensible alteration of the equilibrium; either before or after I had drawn it up, which further confirmed me that the first alteration proceeded from some other accident and not from the differing gravity of the same body."

In his report, Hooke goes on to say that he thinks it very desirable for somebody to examine Dr Power's conclusions that the body weighed less at the base of a 68-yard shaft than at the top, in order to try to find out what the explanation might be. He suggests many possible

influences on the weighing: differences in air density, pressure and temperature; condensation; and magnetism. He proposes instruments, materials for weighing and experimental procedures, including observing what changes in gravity take place every ten or twenty feet down the shaft, which

> "if accurately made would afford a great help to ghess at the cause of this strange phenomenon."

He carried out more experiments himself, weighing objects at ground level and then either above or below, and reported these to the Royal Society from time to time during the next few years.

On 21 March 1666 he presented a paper *On Gravity*[13] to the Royal Society in which he summarised his results and conclusions. He concludes from his experiments at Westminster Abbey described above and from similar trials at the top of St Paul's that if gravity does vary with height above the earth the variation is so small as to be undetectable by the methods he used

> "such were the Inconveniences, this way was subject to, from the vibrations of so long a line, and from the motion of the interposed Air, that nothing of certainty could be collected from these Tryalls; save only, that if there were any difference in the gravitation of the body, it was but very small and inconsiderable, since I found in the Tryalls made from the top of the Abbey, that a few graines put into this or that Scale, would manifestly turne the beam this or that way, notwithstanding the former inconveniences but to distinguish, whether there be any the least variety there must be attempted some other way; of which by and by." [14]

This manner of concluding an experimental report was unusual at that time. Because careful and independent experimental procedures and equipment had been devised and used, the absence of evidence that the weight of the body altered is not an indication that the experiment had failed; on the contrary it can be concluded that if the weight of the body altered as its height above the earth's surface changed, the alteration was so small that it could not be detected by the methods used. This self-critical analysis of experimental procedures and instrumentation is one of Hooke's major contributions to the work of the Royal Society.

Another characteristic of Hooke's scientific discourse at this time was the circumspection of his criticisms of the work of others - a characteristic he was later to abandon. Hooke continues his paper with a critical discussion of results of experiments carried out by others to discover whether or not there is any variation of gravity with depth below the earth's surface

> "Next if all the parts of the Terrestrial Globe be Magneticall then a body at a considerable depth, below the surface of the Earth, should loose somewhat of its gravitation, or endeavour downwards by the Attraction of the parts of the Earth placed above it. This Opinion, some Experiments, made by some worthy persons of this Honorable Society, seem to countenance. But considering the vast proportion of the decrease of gravity at so small a depth, it seemed not improbable, but that the motion of the Air, or some other unheeded accident might intervene in the Experiment which might much contribute thereunto:" [15]

Accordingly, Hooke carried out experiments of his own at some deep wells near Banstead, Surrey, but despite weighing on a very sensitive balance and taking great care at height differences as great as 300 feet he was unable to detect any difference. Realising that these experiments contradicted those of others, including the great Bacon, he was very circumspect about condemning their methods. Hooke says perhaps the ground at the wells in Surrey ("pretty solid Chalk") or some other cause he can not define made his results differ from those of Bacon and Power. He does not explicitly say that the procedures followed by the other experimenters

were inadequate. Instead he is very careful to stress his own painstaking and repeated procedures, independently verified, and leave it at that.

We now know that the variation of gravity with height above Mean Sea Level (the "free air reduction") is about -10 Gravity Units (or -1 mGal, which is -10 $\mu m\ s^{-2}$) for every 3 metres increase in height[16] or, in S.I. units, about -3 $\mu m\ s^{-2}\ m^{-1}$ which is $-3 \times 10^{-6}\ s^{-2}$. In attempting at Westminster Abbey to find the difference in the weight of a body of mass 1 pound troy when lowered by 71 feet, Hooke was trying to detect a change in weight equivalent to a mass of about $^1/_{25}$ grain, or 3 μg, a clearly impossible task out of doors at that time. He typically concludes his paper, not by any mathematical representation of possible functional relationships between height and attraction, but by proposing new experimental procedures, more sensitive than the method with the balance, for empirical determination of such a relationship.

The first proposal is to use a pendulum clock at different heights above and depths below the earth's surface. Although the effect on the clock would be negligible after only a few vibrations

> "yet in many thousands of them, it would not be difficult to find it." [17]

Hooke said the clock should be sealed in a glass, otherwise changes in the air might affect its rate, and suggests that trials be carried out at the top and bottom of a high hill. The second method makes use of a new instrument devised by Hooke specifically for the purpose which is very similar in principle to gravimeters which came into use 200 years later in physical geodesy.

Hooke's *Micrographia*[18] is probably his best known work. It contains 57 illustrated descriptions of objects observed through his microscope (including instructions on how to make such an instrument) one description of atmospheric refraction and two observations made by telescope. Pepys was fascinated by the book, recording in his diary:

> "Thence to my bookseller's and at his binders saw Hookes book of the Microscope, which is so pretty that I presently bespoke it." [19]
>
> and so to my booksellers and there took home Hookes book of Microscopy, a most excellent piece, and of which I am very proud." [20]
>
> Before I went to bed, I sat up till 2 a-clock in my chamber, reading of Mr Hookes Microscopicall Observacions, the most ingenious book that I ever read in my life." [21]

One particular microscopical observation[22] is relevant to Hooke's subsequent activities with Wren in building construction because it is an examination of what he called "Kettering-stone" and was probably the same as the Ketton stone used by Wren on some of the façades of the Chapel of Pembroke College Cambridge at the time Hooke was making his microscopical observations. In a recent study[23] D. Hull illustrates the impressive accuracy of Hooke's graphical and written descriptions by comparing them with images of fracture surfaces of Ketton stone obtained from modern optical and scanning electron microscopes. The difficulties Hooke would have had in seeing and sketching detail at different depths of field are also explained.

In a philosophical discourse, Hooke warned that as drawings to convey objective observations had to be made with circumspection, so they should be viewed with caution and judgement, for they could by themselves and unaccompanied by words divert and disturb the mind by serving only as pleasing ornaments.[24] Perhaps he regarded the general enthusiasm which the publication of *Micrographia* was received was not entirely because of its true and impartial delineations and descriptions of natural objects, but more from its contents providing amusement and ornamentation.

4. Examples of Hooke's reports to the City

I will now show some examples of Hooke's work as Surveyor to the City. On 14th March 1667 Hooke swore before the Court of Aldermen the oath of office of Surveyor:

> "You shall sweare that you shall well and duly see that the Rules and Scantlings sett down and prescribed in an Act of this present Parliament for building within the Citty of London and Libertyes thereof bee well and truly observed And that in all other things you shall truly and Impartially Execute the place or office of Surveyor or Supervisor within the said Citty and Libertyes as by the same Act of Parliament is directed and intended according to the best of your skill knowledge and Power Soe helpe you God." [25]

After staking out streets, surveying, staking out and certifying foundations for rebuilding, the City Surveyors measured and certified areas of ground taken away by the City for streets, wharves, markets and other works. Persons who had lost ground presented their certificates to the City and received compensation for their loss. A not unusual example of the detailed verbal descriptions of measurements taken by Hooke and certified in his hand follows

> "These are to certify that I have examind the Dimensions of a toft of Ground Lying on the west side of Fleet Ditch and on the north side of a passage commonly calld Curriers ally and I doe find the same to contein in bredth on the East side next fleet Ditch Sixty nine foot or thereabout taking in the whole bredth of the Passage on the south side. and to conteine on the west side seaventy and two foot or thereabouts including also the whole bredth of Curriers ally. where it abutts upon a toft of ground belonging as I am informed to one Mrs Dillingham. and conteineth in Length on the south side where it abutts upon the Almes houses of St. Brides Parish seaventy and six foot and to contein in Length on the north side from the Ditch westwards eighty foot or thereabouts abutting upon the Interest of Florentine Dr Plures the superficiall content of all which is five thousand four hundred ninety and nine foot or thereabout, all which said Parcell or toft of Ground belonging as I am informed to Mr. Rutten (as he will make more evident by his deeds) is cut off for the Inlargment of fleet Ditch and the key on the west thereof excepting a slip of the same at the west end thereof conteining nine foot in Depth at the south end and seaventeen foot and six inches or thereabouts at the north end and conteining in bredth seaventy two foot or thereabouts the superficiall Content whereof is nine hundred and fifty and fowr feet: which Deducted from the totall Sum of the whole toft the Remainder to be laid into the Ditch & Wharfe is fowr thousand five hundred fowrty and five foot or therabouts In testimony whereof I have hereunto set my hand this 16th Day of February 167$^{0}/_{1}$
>
> [signed] Rob: Hooke" [26]

Hooke hardly ever included a sketch in his certificates of areas of ground taken away, although it might seem that to have done so would have made his measurements and the location of the site clearer. There can be no doubt he knew that the measurements he made were insufficient to define the shape of the ground. Angles between adjacent boundaries were never measured. Calculation of area was based on assumptions that the plots were either rectangular or trapezoidal (or made up from such figures). Bearing in mind his cautionary remarks about misuse of graphical illustrations (discussed above and in Endnote 24) perhaps he wanted to avoid the possibility of anyone using dimensions scaled from a plan which could not have been drawn to scale. The verbal description was in any case sufficient for legal purposes and satisfied the claimants. Whether or not he drew sketches in his survey books will probably never be known

because they are lost. He refused to hand them to the City, unlike the other two Surveyors Mills and Oliver whose books were transcribed. The transcripts have been published, but the originals are now lost.[27] The loss of Hooke's manuscript survey books is very much greater, but his obduracy was typical.

Hooke and the other two City Surveyors were ordered to take "Views" of matters in dispute during rebuilding and report to the City on how they should be settled. One report of a view signed by all three Surveyors, but written by Hooke, illustrates how true and impartial observations formed the basis of Hooke's recommendation to the City

> "In pursuance of an order of your Lordship bearing Date Dec the 4th 1669 we whose names are underwritten have viewd the matters in Controversy between Mr. John Conway and Mr. Knowles. and have heard the allegations on both sides, and upon the whole we find that the said Mr. Conway formerly had divers lights through a certiane brick wall into the ground of Mr. Knowles but upon discoursing the busness with both party we find that they may be both accomodated and they are both consenting to the same if the said wall shall be deputed a party wall and that the middle of the said wall shall be the middle of the party wall to be rebuilt, and that the said Mr. Conway shall dispense with the lights he formerly had into the said ground of Mr. Knowles, and that in consideration thereof the said Mr. Knowles shall build half the said party wall, or otherwise pay the moyety of the same unto the sayd Mr Conway according to the Act of Parliament. All which nevertheless we leave to your Lordships Grave wisdome to Determine.
>
> [signed] Peter Mills
> Dated Dec: 14th [signed] Rob: Hooke
> 1669 [signed] Jo: Oliver." [28]

In many cases, witnesses had to be called, old deeds examined, earlier foundations revealed and measurements made in order to collect enough evidence not only to support a recommendation to the City but also to satisfy contending parties that what was being recommended was reasonable and fair. There is very little evidence in the City records after the first few months following the Fire that disputes between neighbours about rebuilding were not generally settled on the basis of the Surveyors' recommendations. Hooke's part in reporting on Views was at least as great as Mills' and Oliver's. It called for a different manner of arriving at truth than did his scientific investigations. It could be argued that he performed his duties for the City more efficiently than his duties for the Royal Society. Sir Thomas Gresham would surely have been content with this appraisal of his Professor of Geometry.

Conclusions

It has been possible to discuss only very few examples of Hooke's reports to the Royal Society and to the City. Hundreds more exist, particularly in City records where they are almost completely unindexed. Papers have been written and accepted for publication in the next 15 months (Endnote 10) which give many more detailed descriptions of some of Hooke's surveying in the few years after 1666 than has been possible in this lecture. His scientific endeavours are receiving attention[29] but even here much remains hidden. Until Andrade's forthright praise of Hooke in his 1949 Royal Society Wilkins Lecture[30] he had been generally regarded as a miserly, cantankerous and ill-natured employee of the Royal Society who made claims to have been the first to discover laws and make devices which more properly belonged to others. In some cases

that view is probably still correct, but it is far from complete; he had much to be cantankerous about. Details of his work in rebuilding London after the Fire are only now emerging and they already show that his desire to use scientific observation to understand nature, and his practical work in and around the streets of London had the same objective: to make life better for his fellow citizens. He played major roles in rebuilding London and creating modern experimental science from the ruins of their mediaeval predecessors.

No London memorial to the man who achieved so much within the square mile of the City remains, as far as I am aware. The Victorian memorial window in St. Helen's Bishopsgate (where Hooke lies buried) was blown out by the bomb attack in 1993 and has not been replaced. The restored church is now bright and beautiful, serving the people who work in the city (and in the City). It seems an appropriate place for a lasting memorial to Robert Hooke. The year 2003 will be the tercentenary of his death.

Acknowledgements

Many individuals have helped me in different ways with the research on which this and other papers soon to be published are based. Full acknowledgements will be made in due course, but I would like here to thank the Council of Gresham College for the grant to City University which enabled me to take sabbatical leave last year and attempt scholarship of a different kind for a little while. If this has been in any way successful, it is primarily because of the encouragement and clarity of advice about research into historical documents I received from the late Professor Peter Nailor, formerly Provost of this College. The shortcomings and any solecisms are all my own.

Endnotes

Abbreviations used

CD Comptroller's Deeds
CLRO Corporation of London Records Office
Cl.P. Classified papers
Jor. Journal of the Court of Common Council
RBC Register Book Copy
Rep. Repertory of the Court of Aldermen
RS Royal Society

1. Richard Waller, Hooke's first biographer relates the following:

> "... seeing an old Brass Clock taken to pieces, he attemted [sic] to imitate it, and made a wooden one that would go: Much about the same time he made a small Ship about a Yard long, fitly shaping it, adding its Rigging of Ropes, Pullies, Masts, &c. with a contrivance to make it fire off some small Guns, as it was Sailing cross a Haven of a pretty breadth."

From page ii of Richard Waller's *Life* (of Hooke) in: *The Posthumous Works of Robert Hooke, M.D., S.R.S.* (xxviii + 572 pages, Index and 15 pages of Figures) published in 1705 and edited by Waller, who was acquainted with Hooke.

2. According to John Aubrey, who knew him well when he was an adult, the young Hooke had a natural talent for drawing:

> "John Hoskyns, the Painter, being at Freshwater, to drawe pictures, Mr. Hooke observed what he did, and, thought he, Why cannot I doe so too ? So he gitts him Chalke, and Ruddle, and coale, and grinds them, and puts them on a Trencher, gott a pencill, and to worke he went, and made a picture."

This extract is from Aubrey's *Brief Lives* edited from the original manuscript by Oliver Lawson-Dick, published in 1949 as *Aubrey's Brief Lives* by Secker & Warburg, London (cix + 341 pages) and reprinted by Mandarin Paperbacks, London in 1992.

3. Perhaps this innate graphical skill explains why, on the death of his father when Hooke was 13 years old, he was sent with his legacy of £100 to London

> "... with an 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 donne, so, thought he, why cannot I doe this by my selfe and keepe my hundred pounds?"

Ibid.

4. Hooke sets out at length his ideas on the importance of observation and inquiry in his Preface to *Micrographia or Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses with Observations and Inquiries thereupon By R. Hooke, Fellow of the Royal Society.* Published in 1665 and ordered by Lord Brouncker, President of the Royal Society, to be printed by John Martyn and John Allestry and sold at their shop at the Bell in St Paul's Churchyard, it soon sold out and was reissued in 1667 with a new title page. In the Preface, Hooke also gives details of an instrument for grinding lenses, a dial barometer, a device for measuring the refraction of liquids, and advice on how to make a compound microscope and illuminate the object under investigation.

5. Respectively: telescopic sights for astronomical observations; and the vacuum pump.

6. "City" is used here for convenience to mean the various Committees, Courts and Officials who were responsible for managing and directing the affairs of the City of London; "city" should be taken to mean the geographical City and Liberties of London.

7. CLRO Rep. 71 ff.168^{r}-169^{v}.

8. *The History of the Royal Society of London,... Volume II*, by Thomas Birch, London, 501 pages + 3 plates (1756) p.115, dated 19th September 1666.

9. CLRO Jor.46 f.123^{r}. The King had proposed what was in effect a Land Information System for London. A large scale survey plot showing all existing property boundaries, thoroughfares, streets and alleyways to be accompanied by a survey and record of ownerships, rents and reversions of each property would be a spatial and legal context for administering the building of a splendid new city from the ruins of the old. Despite attempts on the part of the City to compile information through the Aldermen and Deputies of each Ward, and begin the survey measurements, the ambitious scheme

foundered. It was soon realised that its completion would take too long. Streets were strewn with rubble and unrecognisable in places. The accurate survey could only proceed as quickly as rubbish could be removed to reveal the old streets and building foundations for measurement. Many inhabitants could not be found, so deeds and other reliable documentary evidence about rights, leases and rents was generally difficult to obtain. Fees of 18d charged to each property holder for a boundary survey and entry into the records were never received.. The Land Information System and the great new city remain unrealised to this day, put aside so that the citizens could rebuild at their own expense and more or less on their old foundations and so return to normal life as quickly as possible. They had no desire to be made to move away whilst a great new city arose to the glory of the King and the City who in any case had neither had the will nor means to make such an imposition on their citizens.

10. For an account of Hooke's work for the City in the years immediately following the Fire, see M.A.R. Cooper "Robert Hooke's early work as Surveyor to the City of London Parts 1, 2 & 3" to be published in *Notes and Records of the Royal Society of London* **51**(2) July 1997, et. seq.

11. Henry Power FRS was a Physician living in Halifax.

> "We took a thread of 68 yards long (which is as long as the deepest pit is with us) and fixing a brass lump of an exact pound weight to it, we counterpoised both it and the thread with a weight in the other scale; then fastening the other end of the thread to one of the scales, we let down the pendent weight near to the bottom, and there we found it to weigh lighter, by an ounce at least, than it did at the top of the same pit. We had tried this with a bladder full of water, and other substances also; but that pur thread, by often turning, broke itself. "

Thomas Birch, *op. cit., Volume I*, London. 511 pages + 3 plates (1756) pp.134-134.

12. RS Cl.P.xx.7 dated 24th December 1662.

13. RS RBC II pp.223-228 dated 21st. March 1666.

14. Ibid.

15. Ibid.

16. Bomford, G., *Geodesy, 4th edition, with corrections*, Clarendon Press, Oxford, xii + 855 pages (1983) page 356.

17. RS RBC II pp.223-228.

18. *Micrographia: or Some Philosophical Descriptions of Minute Bodies Made by Magnifying Glasses with Observations and Inquiries Thereupon. By R. Hooke, Fellow of The Royal Society...London. Printed by Jo. Martyn and Ja. Allestry, Printers to The Royal Society* was published in 1665. Published in reduced facsimile by Dover Publications, New York in 1961.

19. Samuel Pepys' *Diary Volume VI (1665)* page 2, dated 2nd January 1665. The Diary, in 11 Volumes, is edited by R. C. Latham and W. Matthews and published by Bell & Hyman, London from 1972 to 1976.

20. Ibid., page 17, dated 20th January 1665.

21. Ibid., page 18., dated 21st January 1665.

22. Hooke's *Micrographia* op. cit. (Note 18) Observation XV pp.93-100 and Schema IX Figure 1.

23. Derek Hull, "Robert Hooke: a fractographic study of Kettering-stone" *Notes Rec. R. Soc. Lond.* **51**(1), 45-55 (1997).

24. Waller, (ed.) *The Posthumous Works of Robert Hooke* op. cit. (Note 1) p. 61.

25. CLRO Rep.72 f.80v, dated 14th March 1667.

26. CLRO CD Box K/R/8b.

27. *The Survey of Building Sites in the City of London After the Great Fire of 1666*, by Peter Mills and John Oliver was published by the London Topographical Society (LTS) in five Volumes: *Volume I, Index to Volumes I to V*, with an Introduction by P. E. Jones and T. F. Reddaway, LTS 103 (1967) 166 pages; *Volume II, Mills' Survey Volume 1 of the Manuscript*, LTS 101 replacing LTS 79 & 89 (1964) 171 folios; *Volume III, Mills' Survey Volume 2 of the Manuscript*, LTS 97 (1962) 168 folios; *Volume IV, Oliver's Survey Volume 1 of the Manuscript*, LTS 98 (1962) 197 folios; and *Volume V, Oliver's Survey Volume 2 of the Manuscript*, LTS 99 (1962) 195 folios.

28. CLRO Misc. Ms. 93.116.

29. Evidence in the last decade of growing interest in his science can be found in *Robert Hooke New Studies*, Woodbridge, Suffolk, The Boydell Press, 310 pages (1989) edited by M. Hunter and S. Schaffer, and in *Notes and Records of the Royal Society of London*, passim.

30. A. N. da C. Andrade's 1949 Royal Society Wilkins Lecture 'Robert Hooke' in: *Proc. Roy. Soc. Lond. Series A* **201**, 439-473 (1950).

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