The Transitarium of Washington Shirley, the 5th Earl Ferrers, F.R.S.

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Unique among planetary machines is the transitarium designed by Washington Shirley, 5th Earl of Ferrers. Engineered and engraved by Benjamin Cole senior *circa* 1761 (Fig. 1) it is a device that has been photographically reproduced in numerous books, articles, and press releases, but it is also a device that has a poorly understood origin and history.[1] It has been widely assumed that the purpose of the transitarium is to illustrate the conditions under which transits of Venus, when the planet is seen against the disk of the Sun from the Earth, can occur, but what has been found from a new investigation is that the device was not solely, or indeed, specifically, intended for such a purpose.

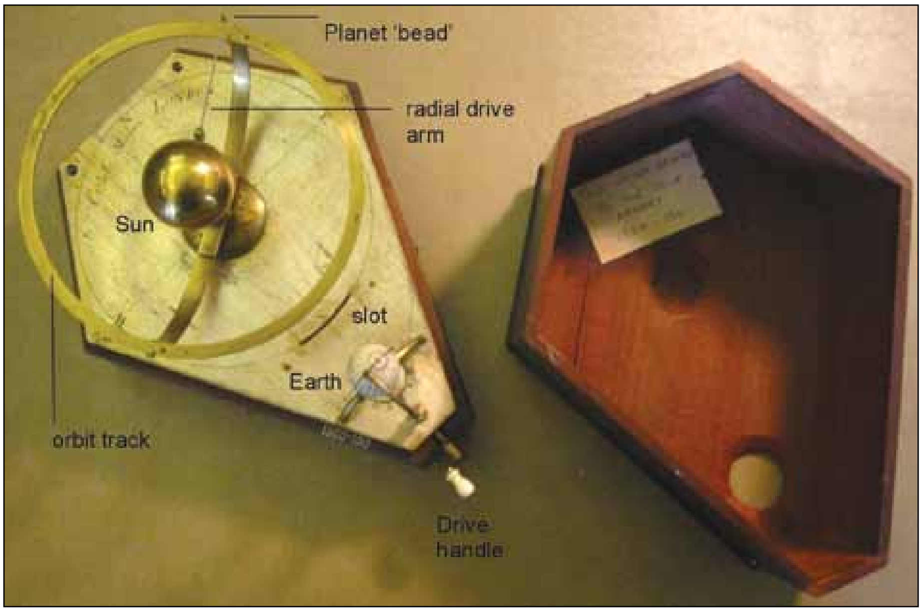

Fig. 1 *The transitarium (left) and its cover (right). Image by the author and courtesy of the Royal Society.*

A Brief Transit Review

Transits of the planet Venus occur in pairs eight years apart separated by successive intervals of 105 and 125 years - as regular as clockwork. The first successfully predicted cytherean transit was that observed by Jeremiah Horrocks and William Crabtree[2] in 1639, and since that time all six successive transits have been observed by astronomers, right up to the most recent such event which occurred on 6th June 2012. Indeed, much has recently been written[3] on the heroic efforts made during past expeditions to measure transit ingress and egress times - such information being used to determine the size of the Earth's orbit (the astronomical unit). How transit of Venus measurements might be used to determine the astronomical unit were first described in detail[4, 5] by Edmund Halley in a short treatise read before the Royal Society in 1716, and it was in this work that he predicted the viewing circumstances for the 1761 and 1769 transits.

The reasons for the various time intervals in the cytherean transit cycle result from the fact that Venus must be located at, or very close, to the line of nodes (where the orbit of Venus cuts through the ecliptic – the plane of Earth's orbit) at the same time that it is situated between the Earth and Sun. The transit times are related therefore to both the orbital periods of the Earth and Venus as well as the rate at which the line of nodes for Venus rotates about the Sun.

Transits of Mercury across the Sun's disk are much more common than those of Venus, occurring at intervals separated by 7, 13 or 33 years. The geometrical conditions underlying Mercurian transits, however, are identical to those for Venus – just the physical scale of the orbit and the occurrence time intervals change. While the two-dimensional geometry of a transit is relatively straightforward to draw, the full three-dimensional circumstances are, for the non-expert, perhaps less than obvious (Fig. 2), and this is where a transitarium model might be usefully employed to explain the details to a student audience.

Two Letters to Philip Carteret Webb

The story of the transitarium (Fig. 1) begins with a set of letters[6] by Washington Shirley, the 5th Earl of Ferrers, dated 10th September and 24th November 1761. The letters were addressed to Philip Carteret Webb[7] and were concerned with observations of the 1761 transit of Venus. The contents of these letters were later read to the assembled fellows of the Royal Society on 10th December 1761. The Society's Journal Book for that meeting contains an account of the letters and notes that the Earl "presents to the Society an orrery, or transitarium, invented by his lordship, to facilitate the conception of future transits".

The letters from Earl Ferrers indicate that the transit observations were made, "in a convenient house situated on a high hill at Staunton in Leicestershire" and that a room in the house was converted into a *camera obscura* by use of a specially constructed window shutter. Shirley and an unidentified assistant, recorded the passage of Venus across the Sun's disk for several hours, and the times of first and last contact were deduced along with the time of mid-transit and the latitude of Venus at that time. Although the exact mathematical details are not provided, Shirley explains his methods of reduction and also compares his results with those derived by Horrocks in 1639 and the 1716 predictions of Edmund Halley. He further goes on to note that his observations might eventually be compared with those collected at other locations from around the globe in order to deduce the Sun's horizontal parallax[8] (that is determine the astronomical unit).

The Journal Book for 10th December 1761 also records the following detail, "Mr. Davis attended from the Earl of Ferrers, and explained the structure and use of the instrument or Transitarium, presented to the society. And thanks were ordered to his Lordship, and to Mr. Webb, for the said very curious present and communication". It is not clear if Mr. Davis was the assistant observer referred to in the letters by Shirley, but the transitarium that he explained is

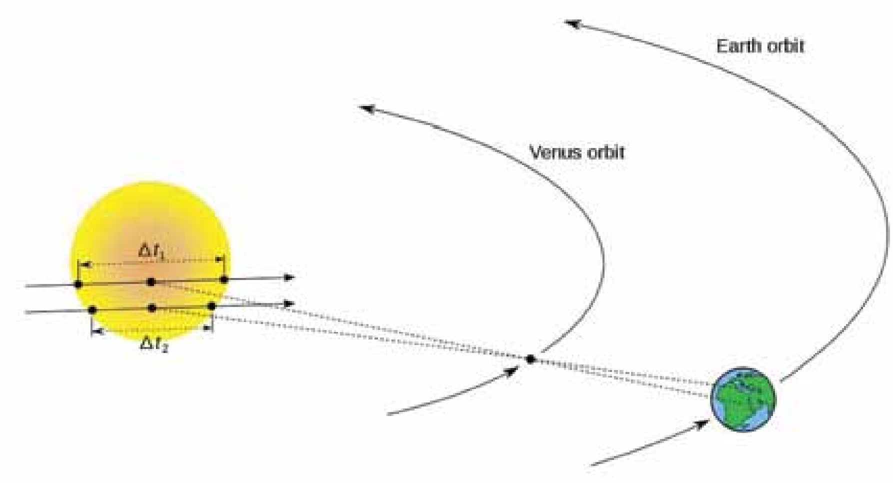

Fig. 2 *Transit time ΔT observations from different Earth latitudes can be used to determine the scale of Earth's orbit. (Image courtesy Wikimedia Commons).*

taken to be the device constructed by Benjamin Cole senior (see King and Millburn, note 1) circa 1761, and shown here in Fig. 1.

Following Mr. Davis's account of the transitarium the Journal Book additionally records that, "Washington Earl of Ferrers was proposed by the President, and elected a Fellow of the Society". The President at that time was George Parker, 2nd Earl of Macclesfield, well known for his interest in astronomy and for conducting observations from his Oxfordshire seat at Shirburn Castle.[9]

The Transitarium Measured

While the transitarium has been on public display for over a century, and has received much attention from the general media1, no detailed account of its construction has ever been published. Recently, the author had the opportunity to view the transitarium at the Royal Society's Centre for the History of Science at Carlton House, and was afforded the opportunity to make notes upon the external construction and action of the device. Fig. 3 is a scale diagram of the brass baseplate of the transitarium, and the essential dimensions of the device are 200mm long, 165mm maximum wide and 107mm high. The distance between the centres of the Sun and Earth spheres is 94mm, and the radius of the brass ring representing the orbit of the transiting planet is 61.5mm. These last two measurements are particularly telling and immediately indicate that the transitarium was not constructed to a true astronomical scale; the relative radius of the orbit being 0.65 'astronomical units' rather than the appropriate 0.39au for Mercury or the 0.72au for Venus. The diameter of the brass Sun sphere is 35.5mm, while the bead representing the transiting planet is just 2mm across. Once again, therefore, the model does not reproduce the true relative Sun to Venus or Sun to Mercury scale; the device giving a ratio of 17.75 rather than the actual 285 for Mercury or 115 for Venus. It was not possible to study the internal gearing of the transitarium during my visit, but this turned out to be of little direct concern (but see below) since the model does not reproduce the correct rotational rates for either of Mercury or Venus, as would be expected, for example, in a true orrery design. The transitarium is driven by a small crank with

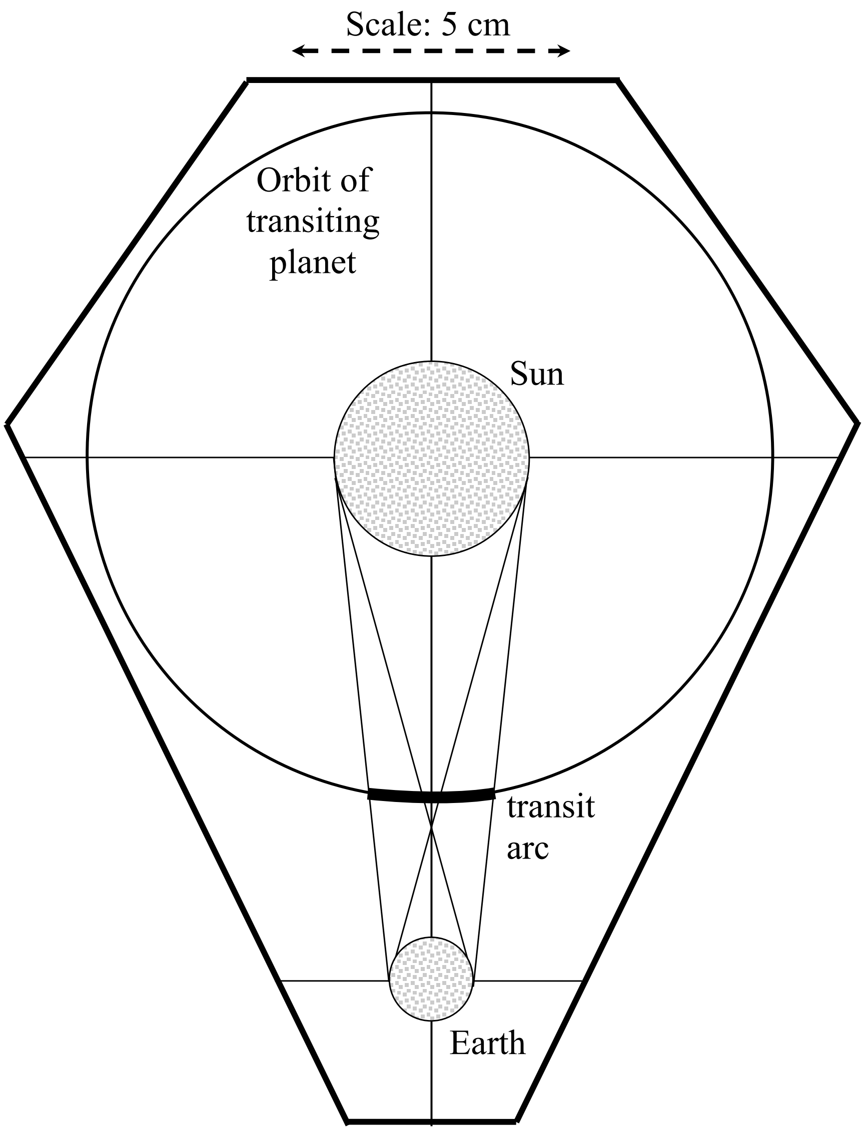

Fig. 3 *Scale diagram of the brass baseplate to the transitarium. A slot has been cut through the baseplate along the length of the transit visibility arc – this may have at one time accommodated a small (hand-moved) bead to represent the transiting planet.*

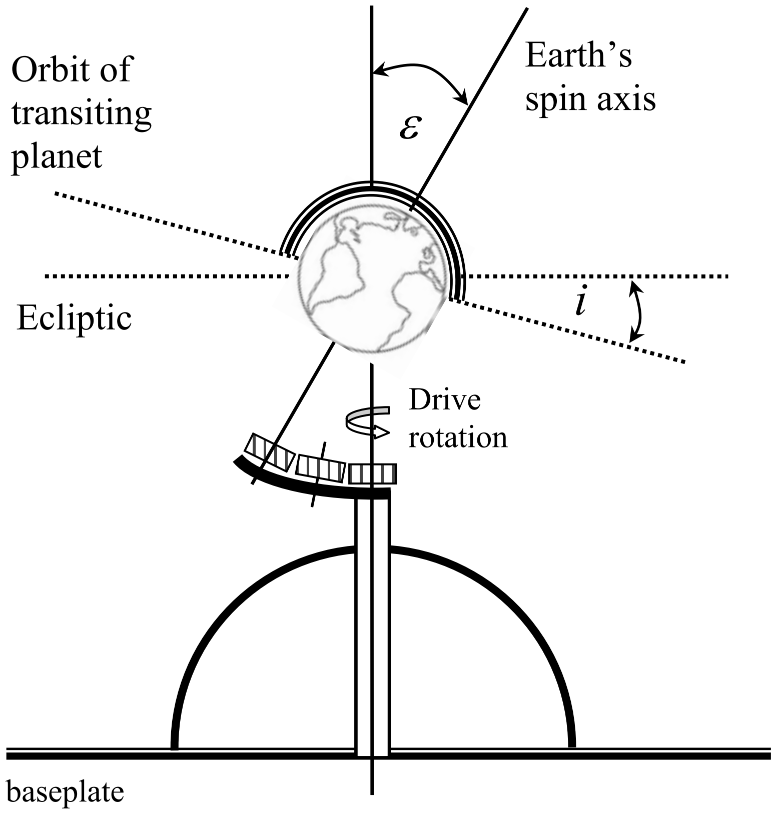

Fig. 4 *Schematic (not to scale) diagram showing the model Earth rotation mechanism and the orbital inclination plate marker (triple line arc). Angle ε is the obliquity of the ecliptic and angle i is the orbital inclination of the transiting planet – in the case of Venus, i = 3.4°, while for Mercury i = 7.0°.*

an ivory handle located close to the model Earth mechanism (see Fig. 1). The gearing and drive still feel firm, with no slippage or give being apparent, and one 360-degree rotation of the drive crank appropriately corresponds to one day, with the Earth model completing one full rotation. The drive rate of the planet radial arm about the Sun was found to provide an apparent synodic period of 148 days, which is about one-quarter of the true value required for Venus and about five-quarters of that required for Mercury. The brass Sun sphere does not rotate and is fixed to its support pillar. In addition, we note here, that the yoke which supports the brass ring (representing the orbit of the transiting planet) is not driven by the gear-work and must be rotated by hand. Furthermore, the orbit ring is hinged at the two yoke connection points, clearly allowing for a range of orbital inclinations to be modelled. An imaginary line drawn through the two yoke hinge points delineates the orbital line of nodes and a transit demonstration would require one of the hinges to be positioned directly in line and between the Sun and Earth spheres. The planet-bead radial drive arm is additionally hinged so that it can maintain contact with the tilted orbit ring. There are no graduation markings on the orbit ring, but the cardinal compass points N, S, E, and W are shown on the baseplate engraving.[10]

From the foregoing observations and measurements it seems clear that the transitarium was not intended to be a predictive (or even scale) device, and the claim that it could "facilitate the conception of future transits", as noted in the 10th December 1761 Journal Book[6], appears to imply a general usage rather than a cytherean specific one. In this manner the transitarium is clearly intended as a teaching / demonstration device but it is arguably a lesser machine that an orrery, lunarium or planetarium. We conclude, therefore, that the function of the transitarium is to show under what circumstances a transit in general can take place, and to then approximately show how the transit will appear from Earth. Assuming an early 1761 completion date for the transitarium's construction, then the transits that would be observable over the ensuing 55 years would be those of 6th June 1761, and 3rd June 1769 for Venus, and those of 9th November 1769, 9th November 1802, and 12th November 1815 for Mercury.

The path of the transiting planet across the Sun's disk is indicated on the transitarium with the aid of a crescent-moon shaped plate set centrally over the 20mm diameter ivory Earth model (Fig. 4) – the horns of the plate, we note, do not sit symmetrically about the model Earth and it is suggested that a line drawn through their ends indicates the plane (that is inclination to the ecliptic) of the transiting planet. This plate additionally delineates the boundary between the illuminated and the non-illuminated hemispheres of the Earth, and could in principle be used to illustrate when and if a transit would be visible from a specific location on Earth. Along with the two constant latitude circles corresponding to the tropics of Capricorn and Cancer and the circle representing the projection of the ecliptic, the Earth model shows great-circle arcs of constant longitude (that is meridians) at intervals corresponding to one hour separation around the equator. The direction of the model Earth's spin axis is fixed but inclined by about 20 degrees to the vertical (as appropriate for its actual obliquity ε) - its drive is provided by a train of three 22 tooth gears (see Fig. 4).

For all of its 250 years age, the transitarium is in remarkably good condition. It is, in fact, the cover to the device (shown to the right in Fig. 1) that indicates the most obvious wear and tear. The small wooden dome that once coved the top of the model Earth is missing and presumed lost, and a long split runs across the lid (seen to the upper left hand corner of the lid in Fig. 1). In spite of this natural decay, the lid is superbly constructed of 5mm thick mahogany with exquisitely crafted dovetail joints. Pasted to the top of the cover is a highly tarnished label that reads, "Royal Society 65". This same information is also engraved upon the brass ring that represents the orbit of the transiting planet – when this label was applied and the engraving made, and what the number 65 specifically refers to are presently unknown.[11] On the inner surface of the lid is a second label that reads, "This cover belongs to the Cole Orrery 1900-150"; separate to this label and written in pencil are the words, "orrery by

Cole London". The number 1900-150 (see Fig. 1) is repeated in white ink on the base of the transitarium and corresponds to its London Science Museum reference number. The Royal Society repository information page (item GB117) indicates that the transitarium was returned from loan to the Science Museum in 2003. The transitarium was later loaned to the National Museum of Australia from 2010 to 2011 where it formed part of the exhibition *Exploration and Endeavour: The Royal Society of London and the South Seas*.

Close inspection of the transitarium suggests that several pieces associated with the transitarium may have been lost over time. Firstly we note that the pillar and its attached crescent moon-shaped plate, used (we suggest) to indicate the orbital inclination of the transiting planet, is not fixed in place and it is simply slotted over a smaller support post. This suggests that additional posts and orbital inclination indicator plates might have been produced – for indeed, there seems, otherwise, no reason for allowing the post to be removable and/or the orbital ring to be hinged at its two yoke support points. In addition, we also note that cut into the baseplate is a 25mm long slot along the engraved orbit for the transiting planet. This slot may have accommodated a small sliding bead (with an external locating pin) that could have been moved along the 2-dimensional transit path (see Figs 1 and 3). There are distinct smudge and wear marks on the baseplate either side of the slot which supports the idea that something could be inserted and moved by hand, as required, by the demonstrator. The presence of wear marks around the slot additionally suggests that the transitarium saw some considerable physical usage – but, of course, some (possibly all) of this wear may have occurred after the transitarium was donated to the Royal Society.

On the upper (that is wider part) of the brass baseplate are engraved the words, "Cole Maker London". *Circa* 1760, when it is presumed the transitarium was constructed, both Benjamin Cole senior (1695-1766) and Benjamin Cole junior (1725 – 1813) were working in London at the famed location *At the Sign of the Orrery*.[12] The engraving on the brass baseplate is crisp and clear, and shows the two dimensional geometry relating of a transit (Fig. 3).

Even though the construction of the transitarium is entirely general (that is not specific to transits of Mercury or Venus), it would be interesting to examine its interior; not just to see what gearing has actually been employed, but to see if there are any additional hints pertaining to its time and manner of construction. We note that the interior of the device may have been repaired or inspected at some time in the past since the screws in the upper part of baseplate appear modern and do not match the other baseplate screws located on either side of the engraved east-west line centred on the Sun.

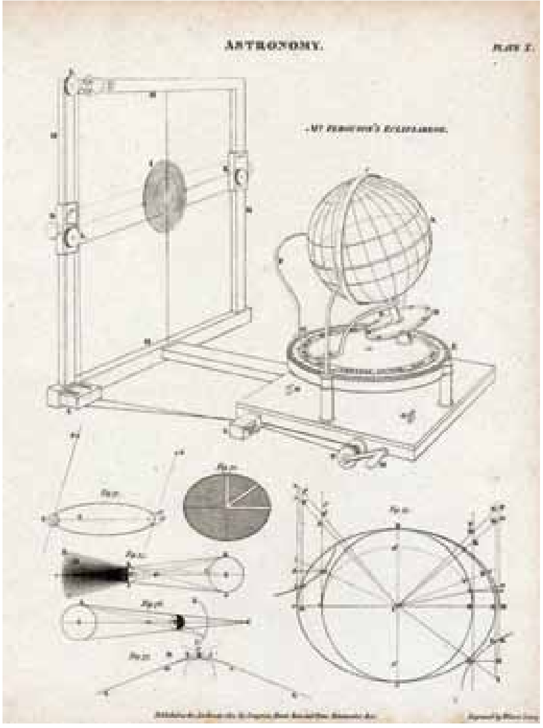

Fig. 5 *The eclipsareon as designed by James Ferguson in 1754. This image is reproduced from* Rees' Cyclopaedia *published 1802-1820.*

Connections and Speculations

Washington Shirley, 5th Earl of Ferrers (1722-1778) is a largely obscure figure. The Earl of Ferrers title was created in 1711, but the title and family estate fell into disrepute and trusteeship with the hanging, for murder, of Laurence Shirley, 4th Earl of Ferrers on 5th May 1760. Washington was the second son of Laurence Shirley 3rd Earl of Ferrers (1693-1745) and assumed, at age 38, his title and seat in the House of Lords two weeks after his elder brother's execution. The family estate was returned to the Shirley family by King George III in 1763 (but only confirmed by Parliament in 1771). In 1738 as a young boy of 15 years age, Shirley joined the Royal Navy. He was promoted to Second Lieutenant in 1741 and Captain in 1746. Towards the end of his life, in 1776, although having quit navy service in 1760, he was promoted to the rank of Vice Admiral. Shirley was Grand Master of Freemasons[13] from 1762 to 1764, and along with his wife Anne Elliot (1722-1791) is buried on the family estate at Staunton Harold in Leicestershire.

The original letters from Shirley to Philip Webb are no longer extant, and the Royal Society Journal Book account is the only known record of the formers interest in astronomy. As a navy Captain, however, Shirley would no-doubt have been familiar with the mathematics and methods of navigation, and accordingly his interest in the 1761 transit is perhaps not too surprising or aberrant. Indeed, although a direct link to Washington Shirley cannot be made there is within the archived records relating to the Shirley family a, "folded sheet of mathematical calculations with problems stated and explained with diagrams; one concerns navigation, another concerns distances on earth's surface…".[14] Furthermore, Washington Shirley was known to be friends with several prominent philosophers in the Derbyshire area - the surveyor, cartographer and keen astronomer Peter Perez Burdett (*c.* 1734-1793), for example, was known to be a frequent guest at Staunton Harold. It is through Burdett that we can further trace a link, albeit a tenuous one, between Shirley and the famed Lunar Society. While Shirley cannot be considered anything more than a peripheral (certainly not a formal) member of the Society, Burdett along with fellow Derbyshire clockmaker John Whitehurst (1713-1788) were key figures. Whitehurst was elected a Fellow of the Royal Society in 1779 and while a pioneer of geological stratigraphy he is probably best remembered for his treatise and early ideas on the origin and formation of the Earth (published in 1778). It is through Whitehurst and Burdett that we make a further connection of the painter Joseph Wright of Derby (1734-1797).[15] The loop of acquaintances now closes with Washington Shirley buying *circa* 1766 Wright's famous painting *A Philosopher lecturing on the Orrery, in which a lamp is put in place of the Sun*. This painting features Burdett as a student figure, and reputedly Whitehurst as the lecturer, and was brought by Washington Shirley[16] for the sum of £210. Wright's painting is the only one that Washington Shirley ever purchased - it may even have been a commissioned piece. The 6th Earl of Ferrers, Robert Shirley (1723-1787), did not share his elder brothers liking for Wright's painting, however, and within a year of Washington's death he had sold it on to the Christie and Ansell auction house in London. The painting now hangs in the Derby Art Gallery.[15]

It is generally believed that the scene depicted in *A Philosopher lecturing on the Orrery* is based upon Wright's perceptions of a lecture given by James Ferguson.[17] It is known[15] that Ferguson was lecturing in Derby in 1762, and although we cannot be certain it would be expected that, as a prominent local 'philosopher' and FRS, Ferrers might also have attended this event. Ferguson's Derby lecture series, however, is set too late in time to explain Shirley's inspiration for the design of his transitarium. This being said, Ferguson was writing about the importance of the 1761 transit in his widely read 1754 book *Astronomy Explained according to Isaac Newton's Principles*. In addition, Shirley may well have had the opportunity to attend lectures by Stephen Demainbray, James Ferguson, Benjamin Martin and (just) possible even John Desaguliers during his visits to London. All of these lecturers were well known for augmenting their talks with experiments and numerous mechanical devices, but at this stage Shirley's motivations for the design of the transitarium, and especially its intended audience, remain unclear – certainly there are no records or accounts to indicate that Shirley was interested in fostering public education (see, however, note 13) and/or speaking in public about the 1761 transit. Indeed, Shirley did not even attend the 10th December 1761 Royal Society meeting at which his device was demonstrated and at which he was elected a Fellow.

Perhaps the closest planetary machine, in terms of function, to Shirley's transitarium is the eclipsareon. The Danish astronomer Ole Rømer (1644-1710) developed the first such machine[18] *circa* 1680 and it is literally a device capable of predicting the times of lunar and solar eclipses. In contrast to the transitarium, however, the eclipsareon presents the user with an actual output date and is in essence an analogue computer. James Ferguson also designed and constructed an eclipsareon *circa* 1754 (Fig. 5). Indeed, Ferguson rated it as, "his best invention".[19] As with Rømer's machine, Ferguson's eclipsareon was a fully deterministic device, but further refined to indicate the duration and appearance (total, or partial) of an eclipse as it might be seen from various locations upon the Earth.[20] While describing similar geometrical alignments, there are no obvious similarities of design and/or basic construction between the transitarium and the eclipsareon.

We will probably never know the exact reasons behind Washington Shirley's decision to design and then have constructed his transitarium. It is a simple yet intriguing device that has a clear pedagogical underpinning but for all this, its intended audience and early usage remain a mystery.

Acknowledgments

I extend many thanks to the librarians and staff at the Centre for the History of Science at Carlton House for their help and kindness during my visit to Carlton House, and I am especially grateful to Felicity Henderson for sending me a copy of the exhibition catalogue to *The Royal Society: 350 years of Science.*

Notes and References

1. See e.g., figure 11.3 in F. Henderson, *The Royal Society: 350 years of Science* (exhibition catalogue, The Royal Society, 2010), and http://pictures.royalsociety.org/image-rs-3384. The transitarium is briefly described in H. C. King and J. R. Millburn, *Geared to the Stars: the evolution of planetariums, orreries, and astronomical clocks* (Toronto: University of Toronto Press, 1978, p.164 and figure 9.13). The term "poorly understood" is used to describe the transitarium since technically it is not an orrery although it is invariably described as being one. Indeed, the author has a postcard purchased from the Science Museum in the mid-1970s showing the transitarium with a caption explaining that, "Model made by W. Cole, London, at the end of the eighteenth century to explain the seasons of the year and the eclipses of the sun and moon" – in this case both the maker as well as the function of the device are incorrectly specified. The nomenclature and classification of planetary machines has been described in M. Beech, 'The Rise and Fall of a Curious machine', *Bulletin of the Scientific Instrument Society*, No. 115 (2012), pp. 2-10. See also J. R. Millburn, 'Nomenclature of Astronomical models', *Bulletin of the Scientific Instrument Society*, No. 34 (1992), pp. 7-9.

2. See, for example, Allan Chapman's article, 'Jeremiah Horrocks, the transit of Venus, and the New Astronomy in early seventeenth-century England', *Quarterly Journal of the Royal Astronomical Society*, **31** (1990), pp. 331-357. See also Peter Aughton's book, *The Transit of Venus: the brief, brilliant life of Jeremiah Horrocks Father of British Astronomy* (London: Weidenfeld and Nicolson, 2004).

3. See for example, Andrea Wulf, *Chasing Venus: the race to measure the heavens* (New York: Alfred Knopf, 2012); Mark Anderson, *The Day the World Discovered the Sun: an extraordinary story of scientific adventure and the race to track the transit of Venus* (Boston: Da Capo Press, 2012); and William Sheehan and John Westfall, *The Transits of Venus* (New York: Prometheus Books, 2004).

4. Edmund Halley, 'Methodus singularis qua Solis Parallaxis sive distantia a Terra, ope Veneris intra Solem conspiciende tuto determinari poterit', *Philosophical Transactions*, **29**, 454-464 (1716). A translation of Halley's dissertation was published in James Ferguson's pamphlet: *A plain method of determining the parallax of Venus by her transit of the Sun: and from thence, by analogy, the parallax and distance of the Sun, and of all the rest of the planets* (printed for and sold by the author, London: 1761).

5. For a detailed review see, D. W. Hughes, 'Six Stages in the History of the Astronomical Unit', *Journal of Astronomical History and Heritage*, **4** (2001), pp. 15-28.

6. Journal Book of the Royal Society. Vol. XXV 1760-1763.

7. Philip Carteret Webb (1702-1770) was a barrister, politician (for the rotten borough of Haslemere), and a leading figure in the 18th century antiquarian movement; he became joint-solicitor to the British treasury in 1756. Webb produced a number of antiquarian articles and also published in the *Philosophical Transactions* of the Royal Society - he was elected FRS in 1749. His exact connection with Washington Shirley is unclear, but his legal position essentially required him to council government ministers on matters where the law was uncertain and where the improper use of the royal prerogative might have been applied (*Oxford Dictionary of National Biography* - web page entry). Shirley may therefore have had dealings with Webb with respect to the return of the Ferrers family estate which had been placed under stewardship in the wake of a scandalous murder perpetrated by his elder brother Laurence Shirley, 4th Earl of Ferrers. Laurence Shirley, after a failed plea of insanity defence, was hanged at Tyburn on 5th May 1760.

8. Shirley specifically mentions the possibility of using transit observations obtained from Hudson Bay in Canada and from the East Indies. No specific expedition to observe the transit from Canada was undertaken in 1761, although numerous observations were made from across India, as well as Manila and Jakarta (see note 3). The Royal Society and East India Company did support an expedition by Charles Mason and Jeremiah Dixon to Indonesia, but following numerous (mis)adventures the pair ended-up observing the transit from South Africa. The two locations of Hudson Bay and the

East Indies were specifically mentioned by Edmund Halley in his 1716 pamphlet (see note 4), but the fact that Shirley was (apparently) unaware that no observations from Canada would be available suggests that he was not fully immersed within the then active astronomical community.

9. Observations of the 1761 Venus transit were made by Oxford University astronomer Thomas Hornsby (1733-1810) from Shirburn Castle. Hornsby published a comparative analysis of the 1761 transit in the article, 'A Discourse on the Parallax of the Sun' published in the *Philosophical Transactions of the Royal Society*, **53** (1763), pp. 467-495 (1763) – the data provided by Washington Shirley in his letters to Webb, however, were not used or even mentioned in Hornsby's study.

10. King and Millburn (see note 1) state that the orbit ring is graduated, but this, in fact, is not the case. The absence of graduation marks on the orbit ring is consistent with the device being designed to have a teaching and demonstration purpose rather than an analogue predictive function.

11. Prior to the transitarium being loaned to the Science Museum in 1900 essentially nothing is recorded of its whereabouts. In chapter 4 of his book *Establishing the New Science: the experience of the early Royal Society* (Woodbridge: The Boydell Press, 1989. p. 154) Michael Hunter notes, however, that the by 1752, shortly before the transitarium was presented, the repository (or museum) of the Royal Society was said to be in "a ruinous forlorn condition" requiring immediate attention and some considerable reorganization. Furthermore, in 1781 much of the Royal Society's repository was donated to the British Museum (first opened to the public in 1759). It has not been possible to confirm if the transitarium was initially part of the 1781 donation and then later returned to the Royal Society, or if it simply remained as one of the kept pieces.

12. *At the Sign of the Orrery: the origins of the firm of Cooke, Troughton and Simms, Ltd*. From material collected by E.W. Taylor, J. S. Wilson and P. D. S Maxwell. Private printing *c*. 1960. A copy of this pamphlet can be downloaded from http://archive.org/details/AtTheSignOfTheOrrery. The reasons why Shirley chose Benjamin Cole senior to make and engrave the transitarium are not known, but we note that Cole had long standing interests in freemasonry and engraved the frontispiece to the 1756 *Book of Constitutions of the Ancient Grand Lodge of England*. Indeed, Benjamin Cole sr. became the official engraver to the Grand Lodge of freemasons (see note 13) in 1743. Cole continued this office until his death in 1766, at which time his son William Cole (1729-1802), who had become an engraver at the Bank of England in 1753, took over the responsibility.

13. In the 1767 edition of *The Constitutions of the ancient and honourable fraternity of free and accepted masons*, as revised by John Entick (W. Johnston, London. pp. 288-289), it is recorded that, "at Vintners-Hall, Thames-Street, the 3rd of May, 1762" there was an assembly and feast at which The Right Honourable, Lord Ward introduced the Grand Master elect, The Right Honourable Shirley, Earl Ferrers. The record further indicates that the feast was attended by, "the twelve Stewards, and near three hundred Brethren properly clothed". The Grand Lodge of London and Westminster (later the Grand Lodge of England) was founded in 1717. Famed lecturer and Newtonian popularist John Theophilus Desaguliers was Lodge Grand Master throughout 1719, and there was a long history of Royal Society Fellows becoming Grand Lodge members – see, for example, Audrey Carpenter's book, *John Theophilus Desaguliers: a natural philosopher, engineer and freemason in Newtonian England* (London: Continuum International Publishing Group, 2011).

14. See http://www.nationalarchives.gov.uk and record number 26D53/2655. A second record, 26D53/2654, is further described as containing, "fragments of a Philosophical Institution in which Earl Ferrers was courted as a patron". The author has not been able to verify that it was Washington Shirley who was being courted as a patron.

15. See, Judy Egerton, *Wright of Derby* (London: Tate Gallery Publications, 1990). See also, Jenny Uglow's discussion in, *The Lunar Men: the friends who made the future 1730-1810* (London: Faber and Faber, 2002. pp. 122-125).

16. A comparison of Wright's c.1782-3 portrait *John Whitehurst FRS* (oil on canvas, now on display at the Scottish National Portrait Gallery) and the central figure in *A Philosopher lecturing on the Orrery* reveals little similarity of feature. Indeed, the lecturer has a stylistics look characteristic of Isaac Newton. The rendition of Burdett, however, is consistent with his other known portrait of 1765: *Peter Burdett and his first wife Hannah* (oil on canvas, now on display at the National Gallery Prague). For a detailed discussion, see David Fraser's article, 'Joseph Wright of Derby and the Lunar Society' (note 15, pp.15-24).

17. Ferguson moved from Inverness to London in 1743 and began shortly thereafter to give public lectures on experimental philosophy. Itinerant lecturer William Griffis is also known to be active throughout the midlands region during the mid-1700s and Shirley may have additionally had the opportunity to attend some of his orations. A series of lectures by Griffis were advertised in Derby, for example, in 1743, where it was recorded that his equipment included, "a planetarium, a cometarium, a Ptolemaic sphere, and an improved orrery". Griffis later sold his "celebrated philosophical apparatus" to writer and lecturer Adam Walker (1731-1821) in 1766 - see, Paul Elliot, 'The birth of public science in English Provinces: Natural Philosophers in Derby, c.1690-1760. *Annals of Science*, **57** (2000), pp. 61-100.

18. Rømer's eclipsareon is described in H. C. King and J. R. Millburn, *Geared to the Stars: the evolution of planetariums, orreries, and astronomical clocks* (Toronto: University of Toronto Press, 1978, p.111 and figure 6.20).

19. E. Henderson, *Life of James Ferguson FRS; in a brief autobiographical account and further extended memoir*. (London: A. Fullarton and Co., 1867, pp. 179-185). No detailed construction notes for the eclipsareon were ever published by Ferguson, and upon his death it was auctioned off with his other instruments; the records indicating, "Lot 102 – an eclipsareon made by J. Ferguson, F.R.S., in a case, to W. Walker, for £3 3s." The device has since been lost. See also, P. Rothman's article, 'By 'the light of his own mind': The story of James Ferguson, astronomer', *Notes and Records of the Royal Society of London*, **54** (2000), pp. 33 – 45.

20. J. Ferguson, 'Description of a piece of mechanism for exhibiting the time, duration and quantity of solar eclipses at various places of the Earth', *Philosophical Transactions of the Royal Society*, **48** (1754), pp. 520-525.

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