William Ross and a misguided means of finding longitude

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The Longitude Act of 1714 offered prize money for methods of finding longitude 'practicable and useful at sea'. Promising proposals could be funded by the Longitude Commissioners with up to £2000 for development and trials. William Ross (1701–?) of Hanley Castle, Worcestershire, was one such aspirant. With his portable universal sundial – the so-called *Rossipher* – or his fixed garden sundials, Ross claimed to undertake observations and provide solutions to many problems in astronomy without recourse to complex calculations. His sundial designs, together with his belief in their application for finding longitude at sea, are here placed in the context of local and national scientific activities of the time. Ross understood the basic mathematics of astronomy, but lost touch with advancing observational techniques and related computational methods. Like many land-bound projectors, he had a misplaced belief in the value of his approach and craved acknowledgment by the establishment, decrying the fact that his proposals were largely ignored.

1. William Ross of Hanley Castle

William Ross was a shadowy figure about whom little has previously been known.[1] Research by the current author has established that he was the second son of Richard and Elizabeth Ross, baptized at St Mary's Church, Hanley Castle, Worcestershire, in 1701 December, and serving as church warden 1734–38.[2] His father died when he was only six. Presumably Elizabeth Ross managed the land-holding until her sons grew up.[3]

As a Hanley Castle Freeholder, William appears in the 1741 Worcestershire parliamentary poll book.[4] On 1745 June 1 he was licensed as yeoman and a bachelor 'aged about forty one' to marry Mary Hart, spinster, also of Hanley Castle, 'aged about 35 years'. The licence provided for marriage at either Hanley Castle, Welland, or the chapel at Bransford; it was presumably solemnized at the latter.[5] Ross possibly lived in London towards the end of his life, but did not relinquish his connections with Hanley Castle.

A glebe terrier (i.e. an inventory of land holdings from which the rents go to the local church) of 1761 notes him owning several adjacent parcels of land, all held by tenants.[6] Ross had sufficient income to travel to London and stay there in 1735, and again in 1759 and in the 1760s, if not at other times. He could afford to commission the printing of books and make representations to those in the establishment who he thought would be interested in his discoveries. Neither the place nor date of his death has been established.

1.1. *The publications of William Ross*

Two books by William Ross are known, both published in London 'for the author'. First of these was *The New Astronomer*, elaborated by the subtitle: *Or, Astronomy made easy by such instruments that readily shew by observation the stars, or planets places either in the equator or ecliptick, or of Luna in her own proper orb, in any part of the world; they also take the latitude, find the variation of the needle, and a true hour of the day. Likewise they are instruments as ready and useful in surveying, as any hitherto in use*.

Five hundred copies of this 100-page book, with many woodcut text diagrams and three folding engraved plates, were printed in 1735 October by the London printer William Boyer.[7] It was listed at 2s 6d by the London bookseller J. Roberts in 1736 December.[8] Unsold copies were reissued in 1760, expanded with a 32-page supplement described as 'A further addition to the New Astronomer. To the Right Honourable The Lords Commissioners for the Discovery of the Longitude, A Complete Meridian, Is humbly dedicated by their Lordships Most humble, and most obedient, Subject and Servant, 1760. W. Ross.'

The *Further Addition* does not appear in the ledgers of the original printer, so it is likely that Ross commissioned another London printer to do the work. Only nine existing copies of *The New Astronomer* are known to me, four with the supplement.

His second book appeared in 1765, known from a single 49-page copy, bearing the title-cum-description *A Complete Longitude is here mathematically and instrumentally set forth, by tables and propositions, such that are founded on principles that are entirely new; and are composed for clock or watch, in a sexagenary way suitable to his garden dial*. It is attributed to 'the author, N.A.', meaning that it was written by the same person as *The New Astronomer*.

Ross was strangely reticent in proclaiming authorship of his publications. The title page of *The New Astronomer* says only that it is 'By W.R.', although the plates are signed with his name. In contrast, the supplementary opening page of the sheets that were added to the reissue names the author as W. Ross, while his 'To the Reader' is signed with the initials 'N.A.', i.e. the author of *The New Astronomer*. When advertising the reissue Ross failed to give his name, nor did he indicate where copies could be purchased.[9] In a subsequent advertisement he again designated himself simply 'N.A.'[10] This pseudonym reappears on the title page of *A Complete Longitude* of 1765, although the dedication carries his name.

Fig. 1: The Rossipher, the portable universal sundial invented by William Ross. Its base is 270 mm diameter and made of wood, probably walnut. The instrument itself is about half a metre high. (University of Oxford, Museum of the History of Science.)

Ross had *The New Astronomer* printed in London because the capital had specialists to make the woodcut diagrams found throughout the text. As to the engraved plates, if Ross did not cut them, then he insisted that his own drawings were slavishly copied, because the overall style differs from London technical illustration of the period. In Worcester he would have had little choice of printer, and there is no evidence that the city had a rolling press to print the plates.[11]

No advertisements for Ross's books have been located in Worcester newspapers around the period of their publication. What was printed and published in 18th-century Worcester was primarily aimed at a local market. An analysis of book advertising in the Worcester press for the period 1713 to 1741 records only 57 separate titles, of which just six were books on applied science.[12] So far as the local booksellers were concerned, Ross's publications would have been unlikely to find buyers.

It is clear from Ross's comments in *The New Astronomer* and the *Further Addition* that some copies of these books were destined for those whose support and recognition he was soliciting. In contrast, *A Complete Longitude* was an integral part of the package for pupils responding to his offer of tuition advertised in London in 1766. Copies might have been restricted to those who paid for and attended the course in which his garden dial, or the portable version of it, was central to his novel method of finding longitude.

1.2. *The Rossipher, a portable universal sundial*

In 1966 the English science historian Eva Taylor first linked William Ross with an unusual instrument known as the Rossipher that is preserved in the Museum of the History of Science in Oxford (Fig.1).[13] The Museum describes the Rossipher as combining the features of the medieval torquetum and the equinoctial ring dial.

Its combination of base plate, adjustable equatorial plate, and ecliptic plate, with an adjustable vertical circle, allows the instrument to be used at any given latitude to follow the movements of any celestial object (the Sun, Moon, star, or a planet) with a single motion. It enables conversions between altazimuth, equatorial, and ecliptic coordinates which would otherwise require mathematically demanding calculation.[14] It is made of brass on a wooden base and stands just over half a metre high, depending on how it is configured.

The altitude circle is engraved: '*Wm. Rofs* Inventor | of this his Rofsipher | INST^{MT} | 1731' (Fig. 2). However, we can be reasonably sure that 1731 was not the true date of manufacture. Ross did not use the term Rossipher in *The New Astronomer* of 1735, so the instrument at Oxford was mostly likely made after that book was published. The Oxford instrument must have been made before 1752, because the ecliptic scale is calibrated for the Julian calendar rather than the Gregorian one which was not adopted in Britain until 1752. The style and execution are consistent with London

Fig. 2: Inscription on the altitude circle of the Rossipher, attributing it to Wm. Ross and with the date 1731, although the true date of manufacture was probably some years later. The circle is 205 mm in diameter. (David Bryden, reproduced by permission of Museum of the History of Science, University of Oxford.)

work with a date of 1740 ±10 years, which is about as close as we can get to dating it.

The instrument bears no maker's signature. This is not surprising, as it was a specially commissioned piece, and the wording prominently engraved on the altitude semicircle was stipulated by Ross. However, there are good reasons for supposing that the manufacturer was the London instrument maker Jonathan Sisson (1690–1747).

For one thing, the Rossipher has strong design similarities with the 'New Theodolite' designed and made by Sisson, published in 1725, and more particularly with his 'latest improved Theodolite' that appeared in 1737.[15] In particular, the geared rack-and-pinion motion of the base circle, the azimuth circle, and the altitude semicircle is something that Sisson introduced in 1725. This feature was sometimes used by other London instrument makers, notably by Thomas Heath (*fl.*1720–53) in his 'new improved theodolite' of 1731, but the racked altitude circle in Heath's design is inverted.[16] What's more, it seems possible that making the Rossipher might have stimulated Sisson's own design ideas, as we shall see at the end.

The engraving on the Oxford instrument has stylistic differences in the layout and weight of hand on separate parts. One obvious difference is in the marking of half-way points between lettered or numbered parts of the scale. The degree scale and 32 lettered points of the compass on the base plate have no sub-markers (Fig. 3); the altitude scale uses a grouping of three arrowheads, as does the declination scale on the sighting mechanism (Fig. 4); the equatorial hour scale and calendar circle use a fleur-de-lis (Fig. 5); while the upper hour and ecliptic scale use a single arrow (Fig. 6). This latter scale and the sighting mechanism are in a distinctly lighter hand than the others.

The evidence of workshop practice is fragmentary, but some London makers sub-contracted the lettering and figuring of scales once they had been divided, while larger workshops had in-house specialists to do such work. If Ross was a customer willing to pay a premium for early delivery, the maker (presumably Sisson) might well have had the lettering and the division done by more than one of his journeymen, perhaps even sub-contracting to other workshops.

In setting the lowest circle with its internal compass into a wooden base the maker has saved commissioning a bespoke brass casting from a foundry, something that he might be unlikely to use again. This is a factor against attributing the piece to Heath's workshop, which made standing universal sundials using heavy brass castings for the base, whereas the Sisson business apparently did not. The curved supports that hold the assembly above the compass box are squat and make reading the compass quite difficult. This is evidently a design compromise, as greater height would have lifted the centre of gravity and made the instrument less stable. Overall,

Fig. 3: Base plate of the Rossipher, divided by 10° subdivided to 1°, with 32 compass points. The compass box and the whole mounting are rotated using a pinion working on a hidden rack.(David Bryden, reproduced by permission of Museum of the History of Science, University of Oxford.)

Fig. 4: The vernier read-out on the altitude semicircle, allowing latitudes to be set to the nearest 5 seconds. Note the use of the three arrowheads to mark the 5° interval, and the rack-work on the edge of the circle. (David Bryden, reproduced by permission of Museum of the History of Science, University of Oxford.)

although bespoke, the piece looks as if it has been put together utilizing stock castings and parts wherever possible.

Whoever made it, and in which year, the Rossipher provides conclusive evidence that William Ross was no desk-bound designer. He was keen to demonstrate the instrument's multitudinous applications whenever and wherever he had the opportunity, as we shall see.

2. William Ross and the Royal Society

The archives of the Royal Society provide the earliest evidence of William Ross's scientific activities. On 1732 March 9 members heard a paper 'Description of a Dial invented by Mr Wm Ross of Hanly [sic] Castle in the County of Worcester'. Into the records the clerk copied the description sent by Ross.[17] The drawings sent with the account were pasted into the volume. They are signed, and dated 1731/2 (Figs. 7 and 8). Although Ross acknowledged that his contribution had been 'courteously received', that appears to have been the sole encouragement from the scientific establishment.

He sent the Society a copy of *The New Astronomer* after publication in 1735, describing his dial in its expanded forms, together with worked examples of how it should be used. There is no record of what the Society made of it. Their archives preserve a manuscript sent in 1736 June, endorsed 'Mr. Wm. Ross Ephemeris for June 1736 … not read nor to be enter'd.'[18] This does not indicate lack of interest – a tabulated ephemeris was unsuitable for reading at a meeting.

The final evidence of Ross's interaction with the Royal Society is a letter he wrote from Hanley Castle, dated 1744 September 28. It opens with the phraseology of one who feels he has been ignored but who does not wish to appear pressing: 'I fearing that my last have miscarried, occasions me to write to you in the same words'. He refers to his 1732 contribution and to *The New Astronomer* of 1735: 'I have much improved my first Instrument'.[19] Reading between the lines, we can deduce that Ross is angling for an invitation to submit an expanded treatise to be read and considered for publication in the Society's *Philosophical Transactions*.

Unfortunately for Ross, his 1732 account was written just as interest in dialling was on the wane. Around the time he made his first approach to the Royal Society others were submitting papers relating to dialling. In 1731 March Richard Graham (1693–1749) had read to the Society his 'Description and use of an improv'd equinoctial dial for shewing the hour by the Sun or any of the Stars, with great exactness',[20] followed in December by 'Description and use of an instrument for taking the latitude of a place at any time of the day'.[21]

Graham's second dialling paper was published in the *Philosophical Transactions*, but after that the Royal Society's published proceedings contained no articles related to sundials or their application for another 30 years, when James Ferguson (1710–76) published 'A new method of constructing sundials, for any given latitude without the assistance of dialling scales or logarithmic calculations'.[22] That was the final paper dealing with sundials to appear in that august journal. Given the declining interest in dialling, it is not surprising that the Society was unresponsive to Ross's *New Astronomer* in 1735, the ephemeris he sent the following year, or to his letter of 1744.

Fig. 5: Equatorial scale of the Rossipher. A fleur-de-lis marks the 30′ (half hour?) points and there is a decorative wheat-ear border. Note the knurled-head turnscrew. The rack work is cut on the inside of the hour ring, and hidden by the inner circle of months – this revolves when the pinion is turned via the knurled-head screw. Equivalent times for Boston, Damascus, Fort St George [Madras, India], Pekin, Xalisco [Mexico], and New Severn [Hudson Bay, Canada], can be read on the equatorial hour scale. (David Bryden, reproduced by permission of Museum of the History of Science, University of Oxford.)

Fig. 6: Ecliptic scale of the Rossipher. A single arrowhead marks 5° intervals. Note that the first point of Aries is at March 9½ indicating that the dial was made for the Julian calendar. Hence the instrument must date from before 1752, the year the Gregorian calendar was introduced into England. (David Bryden, reproduced by permission of Museum of the History of Science, University of Oxford.)

Although dialling had lost its status as a leading-edge science, the subject was taught for its own sake and as an introduction to practical astronomy. Dialling proficiency remained a sign of mastery of the three-dimensional geometry of solar astronomy. Throughout the Hanoverian era sundial design remained a matter of considerable interest, if only because until the spread of the electric telegraph in the early Victorian period the sundial remained the readiest means of setting domestic clocks and watches.

Ross was not alone in proposing design variants. In 1746 *The Gentleman's Magazine* published drawings of a 'new-invented Universal Dial' which the Northampton Philosophical Society had commissioned for their use. That monthly publication, only tangentially interested in scientific matters, published three further sundial designs over the next forty years, in addition to reprinting Ferguson's article on sundial design from the *Philosophical Transactions of the Royal Society*.[23]

3. Ross and the Commissioners of Longitude

Isolated from the scientific mainstream in rural Worcestershire, Ross felt he was being cold-shouldered by the scientific establishment, his efforts ignored, and his ideas stolen. In 1760 the resentment surfaced:

> I Long ago had printed the following Schemes and their Uses; but foreseeing that Disadvantages might arise from so rash an Attempt, I made it my utmost Endeavour to find on what Basis any Oppositions might be founded; I diligently apply'd my self for Security to the Hon^{ble} the R.S. of London in 1731; what I then offer'd was courteously receiv'd, and desired I would proceed; and to the Right Hon^{ble} the L—ds of the Adm—ty in 1732, and to several whom I thought it might concern, and might be in their Power to prevent any Oppressions, suddenly I was repulsed with Loss; and as I then did imagine it to be for some private Ends, I publish'd in 1735 a small Pamphlet, and apply'd to such as I had entirely serv'd, for Security; and still I found some private Ends were more prevailing, and myself to undergo an Oppression, a Wrong, a design'd Project, and an Heathenish Prosecution of Body and Soul, which could only tend to the utmost Extent of Ruin and Destruction.[24]

Ross dedicated the 1760 supplement of his book to 'the Lords Commissioners for the discovery of the Longitude'. The 1714 Act gave the Commissioners limited operational guidance. A Commissioner receiving an application responded as he thought fit, drawing in other members and taking external advice only if he considered the proposal promising, and where resources were required from the Admiralty for development costs or sea-trials. Such was the ad hoc nature of the Commissioners' activities that 1737 marks their first recorded formal meeting. Ross in 1732 would have found it difficult to navigate the administrative morass, particularly from outside London.

From the late 1750s reports in the press of the sea-trials of Christopher Irwin's marine chair and John Harrison's chronometer ensured wide awareness of the potential financial reward for solving the longitude problem. The publicity created pressure on the Commissioners to be seen to evaluate proffered designs, and forced the pace of the formalization of the Board of Longitude. By the late 1750s it had become easier to get a hearing from the nascent Board, but the academic astronomers, led by the Astronomer Royal and the Professors of Astronomy at Oxford and Cambridge, did not suffer gladly those they considered fools.

After 1760 the Board continued to deal with Harrison's case and Tobias Mayer's lunar tables, but concluded that Irwin's chair was of no value. It also dealt with various other proposals sent by hopeful inventors. Ross felt frustrated by the difficulty of getting a hearing: 'In Pursuit of redress in London, in 1760 … I had wrote and printed several letters and petitions in all Obedience to the Right Hon^{ble} the L—ds appointed; and to several, desiring they would promote my Intentions'.

Specifically he had written to 'L—d Mac – s—d' [George Parker (*c.*1697–1764), Second Earl of Macclesfield and President of the Royal Society], and 'L—d A-s-n' [the circumnavigator George Anson (1697–1762), subsequently First Baron Anson, at that time First Lord of the Admiralty]. In 1759 June Ross had inserted advertisements in the London press, although withholding his name:

> IT is with humble Submission and Obedience and to fulfil their Majesties most gracious Requests; to the Right Honourable the Commissioners appointed, I come now to offer and prove my long proposed methods of a perfect Meridian, at this Season of the Year, when they may be fairly proved by Truth and by Day-Light; I can represent more than 100,000 different Planes of Horizons by Instrument, and from it determine for what Place: I can ascertain Hours, alter the Latitude more than one Degree, more or less than the true Latitude and it will shew that it is a perfect Meridian, and the Variation of the Needle to a Truth: In the perfect Meridian, I conceive that the Poles, the Observer, and Moon, (that they, their Verticals and Perpendiculars) are all in a right Line; so let there be ever so many Observations taken in one Day (in such sort) and at as many different Places, then will their differences of Meridians be in Proportion one with another, without an Equation, with certainty. At certain Hours, I can alter the Latitude to two degrees more or less than the true Latitude, and will not alter the Hour any single Minute of Time. All this I can confirm and prove by Mathematical Problems, suitable for such Latitudes that I represent, and such that are mostly

thousands of Miles from this Kingdom. I further perceive by the several alteration of Latitude at certain Hours, that these will greatly give P[illegible] for the Ship's Motion, where the Naked eye is capable of discerning without Levels of any sort is near the balance; besides the durations are too long, as one Quarter of an Hour or more, that there is Time and Times may be repeated to prove their Truth in Observation.

> N.B. The Author proposes this Day, and Tomorrow giving his attendance at the Saracen's Head, Friday-street, Cheapside, where he will shew some Particulars what he has asserted, and if the Day permits, in some Measure make Proof of the same, in order, to find the Neglected of this that has been so long and oft tendered for fair Play.[25]

Given the short notice, one wonders whether anyone came to Ross's demonstration, and quite why he withheld his name. Few competent astronomers or navigators would be drawn to an exposition by an anonymous author making claims that bore little relation to contemporary practice.

Many others besides Ross had found it difficult to ensure a hearing from the Commissioners of Longitude and turned to alternative outlets. In 1736 one projector had his longitude proposal published at length in *The Gentleman's Magazine* and as late as 1760 another addressed the Commissioners of Longitude through the same channel, while in 1759 an inventor was offering to sell his ideas to the highest bidder.[26]

Ross was by now firmly committed to the belief that his small analogue instrument could sight the Sun, Moon, or stars with sufficient precision to provide accurate indications of time, latitude, and longitude. He was also convinced that his design had been unacknowledged and stolen.

In the late spring of 1762 in an advertisement headed 'The New Astronomer' Ross, identifying himself as 'N.A.', made further strong claims for the validity of his approach and again vented his ire on the establishment:

> These Extents of Longitude (in Degrees) long ago, might have been made Public, but dreading, that if they were directed to the Ambitious, such that will promote Shipwreck to be an annual Property to themselves, they will not regard it: if to the more covetous, that will think all they can take off other People's Properties their lawful Gain; it will be no Purpose; therefore the Author has delayed these Works for many Years, and now publishes them to be examined by the skilful, and to know whether the Sea-Clock would have given that true Point of Compass, *already mentioned* in the *New Astronomer*, which was wanting to the Association, the Dolphin, the Dodington or Bideford, where there w[as] Sea Room.[27]

In 1763 February the members of the Board of Longitude agreed on further sea trials and funding for Harrison's chronometer, as well as an additional sea trial, without further funding, of Irwin's marine chair. They postponed a decision on an award to the widow of Tobias Mayer for his lunar tables, and invited the Royal Society to examine a machine for finding longitude which had been the subject of a presentation to them by the mechanic to the King of Denmark. They also postponed considering a scheme sent in by an inventor who failed to attend to explain his proposals. One other hopeful supplicant appeared with an instrument; the minutes tersely record that it was judged 'to be of no kind of utility'.

Letters were tabled from six persons who had submitted proposals to find longitude. Among them was one 'From Wm. Ross, dated the 3d Feby 1763, by instrumental and other methods', but no further detail of the contents were given.[28] There was also a statement of future policy, designed to deter time wasters: all applicants would be told 'they must obtain Certificates from persons of known Skill & judgement that their schemes have been tried & have been found to answer what they propose by them; or that there is a very great probability that they will do so upon Experiment, before this Board can take any notice of them'. No Ross correspondence survives in the Board's papers, and his name does not reappear in their minutes.[29]

Although largely occupied with the final stages of evaluating Harrison's chronometer, the Board continued to consider new supplicants. At its meeting of 1766 April the Board asked the Astronomer Royal to report back on proposals for discovering the longitude sent in by five named persons, but Ross was not among them.[30] Nevertheless just five days before that meeting took place Ross advertised in the London press, promoting his own solution to the problem of finding longitude and scorning the successful trials of Harrison's chronometer:

> LONGITUDE taught after a new and correct method, and with an entire new apparatus now before the Board of Longitude, and submitted to the opinion of the Regius Professor of Astronomy, by W. ROSS. This Complete Longitude is now printed, and will be communicated by the author, who has made it his study for upwards of forty years, on such terms as he shall agree for with his pupils. The operations are performed by the points of the heavens, which are ever and invariably the same; and demonstrated mathematically and instrumentally by draughts and by figures, and clearly proves the errors of watches and watchmakers, whose machines, if credited, would prove the heavens to be in a state of confusion. Those methods of the inventor, when explained by himself, will also serve as a sufficient check to those who prefer silence before speaking the truth, when required, with a view, it is supposed, to convert the author's labour and contrivance to their own profit and emolument. In fine [sic], the Complete Longi-

tude is now printed, and offered thus to the public, to prove the certainty of the principles therein advanced, which so many have spent their time and exhausted their learning to controvert. Watches are like common animals, only made useful by the care and correction of their makers or masters. The author may be heard of at the Burying-ground in St. Mary le Bon.[31]

A Complete Longitude continued Ross's application of his sundial designs of *The New Astronomer* but with special reference to what he called his 'Garden Dial'. The grandiose 'sexagenary way' of the title page alludes to minutes of time having a base of sixty to the hour. The book gave examples of how to add and subtract in that base, an indication of the relative innumeracy of the students he was expecting. His rambling and simplistic books indicate that, like many other longitude projectors, Ross was out of touch with what the scientific establishment considered to be preferred solutions. Those with experience of shipboard navigation knew he was no judge of what was effective, practical, and accurate in a technically demanding area of applied science.

Possibly he got as far as having a meeting with the Astronomer Royal, or other members of the Board, in connection with his 1763 submission, for he terminates a long letter published in a London newspaper in 1765 October with the paragraph:

> It is to answer the reflections of the learned I write, as when they say what trade are you, what have you to do with the longitude? When we by our Globes and Right Ascent can answer all you speak of. Quere[sic], with submission, why not I, when so many years they have imitated my works as their own property, can't we reasonably think them to be such that had rather a thousand perish; and say, there is enough left behind to inherit their Income, tho' the cries of the distressed have so oft called for help, and the Parliament have so long requested it of the skilful![32]

So far as it went, his *New Astronomer* of 1735 was an adequate exposition of what could be achieved with the universal sundial that he had designed, although it contained nothing that could not be found in other dialling texts of the period. However, his own understanding of the nature and form of the astronomical problem to be solved did not progress. He certainly failed to appreciate that the 1763 publication of *The British Mariner's Guide* made finding longitude at sea by the method of lunar distances a realistic proposition.[33]

When the *Guide*'s author, Nevil Maskelyne, was appointed Astronomer Royal in 1765 (and *ex officio* a Longitude Commissioner), the die was cast. The Commissioners of Longitude paid for computation, printing, and annual publication of *The Nautical Almanac and Astronomical Ephemeris*. Occasional supplements explained new methods of computing latitude and longitude. For active practitioners of the subject, the age of scientific navigation had arrived. Navigation textbooks led the way in making the method of lunar distances accessible to mathematically competent navigators.[34] By the last decade of the 18th century, even the less mathematically demanding navigation texts were including treatments of lunars.[35,36] Rudimentary solutions like Ross's could no longer compete.

4. The sundials of William Ross

The context in which Ross first operated is illustrated by an advertisement printed in a Worcester newspaper over four decades later. In this, an artist and engraver named James Ross (1746–1821), no relation to William, advertised his skills, which included making 'horizontal sun Dials for Gentlemens' Gardens, elegantly engraven on Brass (skilfully calculated to shew every Minute distinctly, together with the Sun's Place &c. by Mr. James Beresford, Teacher of the Mathematicks in Bewdley.) Those Gentlemen who are desirous of having a Thing so usefully ornamental, may depend on having one carefully executed to any Size and truly calculated for any Latitude, on the shortest Notice'.[37]

James Ross trained in Worcester under Robert Hancock and had initially engraved for the Worcester Porcelain Company. He was brought up at Ribblesford, near Bewdley, and commissioned Beresford to design bespoke sundials for the local gentry as useful garden ornaments.[38] Forty years earlier William Ross had supplied a similar market with dials that would otherwise have to be ordered from London workshops.

If William Ross had local competition it could have come from the Irish-born surveyor and teacher of mathematics John Dougharty (1677–1755), who had left Bewdley for Worcester by 1711.[39] Dougharty's textbook, published in London in 1748, included the application of trigonometry to 'several important and curious problems in astronomy, navigation and dialling'.[40] He put sundials in the gardens of properties he developed in Worcester at Holywell Hill and Diglis, claiming credit for the one installed at Hartlebury Castle.[41]

Presumably William Ross attended the long-established grammar school at Hanley Castle. His *New Astronomer* of 1735 indicates that his mathematical skills were more advanced than would be taught in the conventional school curriculum of the time. Did he interact with John Dougharty? In addition, had he met the Swiss-born polymath Nicolas Facio or Fatio (1664–1753), an associate of Isaac Newton, who retired to Worcester about 1720 and continued to take part in the quest for finding longitude at sea?[42] As to Ross's interest in dialling, perhaps it was stimulated by a near neighbour, the painter Charles Ponty (dates unknown) of Hanley Swan, who in 1716 included in his repertoire the ability to paint 'any sort of dials with proper ornaments'.[43]

The sundial described by William Ross in his 1732 paper that was read at the Royal Society is an equatorial. The principle was long known. Ross's design for

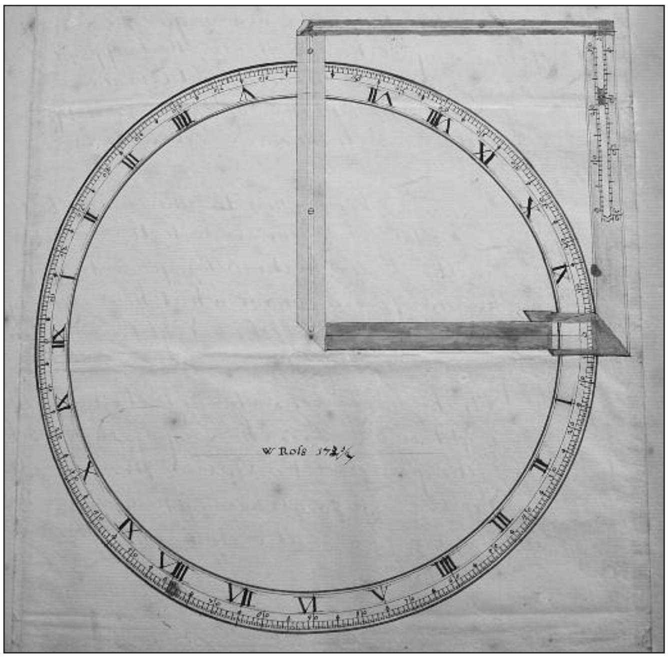


Fig. 7: The dial plate and sighting mechanism of Ross's dial of 1732. The dial plate is drawn in plan, while the sighting mechanism is drawn with distorted perspective so as to show the operational parts. The shaded portion is in the same plane as the dial plate, but the whole forms a square set perpendicular to it. Compare with Instrument No. I of Fig. 9. (David Bryden, courtesy the Royal Society; Archives RBO/17/6)

mounting and setting the pin-hole gnomon, and using it as a sighting device when making observations of stars (Fig. 7), is unusual, but the principle behind it was not.[44] The drawing for the mounting (Fig. 8) is not discussed in his text, but it includes features that had been integral to the portable universal equatorial sundial for well over a century. Craftsmen in London, Dieppe, Paris, Augsburg, Nuremburg, Munich, and Vienna had long been making and selling such dials.[45]

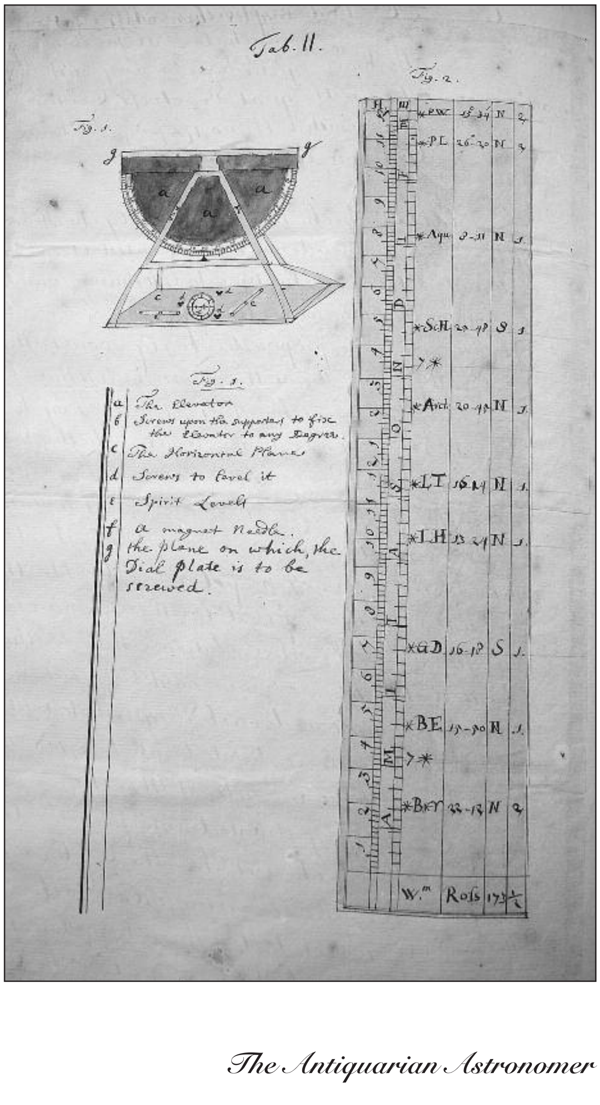
Ross's design applied his instrument to telling the time at night by observations of the stars. A user could sight any one of ten selected bright stars and then by a simple operation with a pair of dividers read off the time from the calibrated ruler (Fig. 8). Neither idea nor application was novel. Horary quadrants made in 1623 to the design published by the English mathematician and astronomer Edmund Gunter (1581–1626) typically included a table of five stars for undertaking a similar exercise, with a planispheric nocturnal on the back; in principle this allowed time to be measured at night provided some part of the sky was visible.[46]

Later in the 17th century the universal quadrants designed by the English mathematician and surveyor William Leybourn (1626–1716) had scales engraved upon them intended to be used in a manner similar to that described by Ross.[47] Hence Ross's design contained nothing that was inherently original. It was a variation on known dialling themes, but one that the Royal Society considered sufficiently interesting to read at a weekly meeting.

4.1. *Finding longitude*

In *The New Astronomer* of 1735 Ross expanded on the account he had sent to the Royal Society three years earlier. His preface opens with an encomium to the lay reader in praise of geometry and its application to the useful arts, especially navigation: 'the Glory, Beauty, Bulwark, Wall and Wealth of Great Britain' as he put it. He continues: 'My chief design in printing the following treatise is to acquaint the world with such instrument that the inventor believes may be of good service in several parts of the mathematicks, and particularly in finding the Longitude by sea or Land with great readiness and exactness.'[48] The emphasis on finding longitude was the driving force behind the book's publication, and it remained at the core of the 1760 *Further Addition* and of his *Complete Longitude* of 1765.

Fig. 8: The mounting and the calibrated ruler. The scales on the ruler are headed H (hours) and M (months), with each month identified by an initial letter from April at the bottom to March at the top. Star names are given in the accompanying text as PW = Pegasus's Wing; PL = Pegasus' Leg; Aqu = Aquila; ScH = Scorpion's Heart; Arct = Arcturus; LT = Lion's Tail; LH = Lion's Heart; GD = Great Dog; BE = Bull's Eye; B ♈ = Bright Star of Aries. The fourth and fifth columns give the star's declination N[orth] or S[outh] and the sixth the magnitude. (David Bryden, courtesy the Royal Society; Archives RBO/17/6)*



Ross's belief that he had designed an instrument with some novel mechanical features which could be used for finding longitude was not totally misplaced. He knew that observations of the eclipses of Jupiter's satellites could be used, but that this required the use of telescopes that were too long to be used effectively aboard ship. He dismissed the use of a timepiece, on the spurious grounds that the length of a seconds pendulum varies with latitude – which is true, but irrelevant as pendulum clocks were no longer seriously considered for use at sea. In the event it was the spring watch and the subsequent development of the marine chronometer that provided the most generally practical solution.

Ross knew too that a prerequisite for computing longitude by measuring the angular separation between the Moon and the Sun or a star – the lunar distance method – was a reliable ephemeris of lunar motions. Yet, being inexperienced in practical astronomy, he failed to appreciate that his instrument of 250 mm diameter with pin-hole sights would give only approximate measurements of angular distance, of no use for serious position-finding.

His 'easy longitude' would attract the novice through mathematical simplicity and, like the exposition in his *A Complete Longitude* of 1765, allow the barely numerate amateur to get latitude and longitude figures by simple arithmetic using observation made with one of Ross's garden dials. But it was totally irrelevant to the new breed of scientific navigators who demanded far greater precision.

His worked examples give measurements to one second of arc, yet his instrument is only subdivided to one degree, and at best could be read to the nearest 15 seconds. In practice, the error in measuring angular distances using pin-hole sights set a few inches apart was likely to be of the order of at least a degree. His trigonometry was basic; he did not appreciate that an error of one second of arc in measuring a lunar distance leads to an error of half a degree in computed longitude.[49]

Ross failed to realize that his 1735 text had been left behind by advancing theory and practice. The theory of longitude by lunar distances was being actively worked on in Europe. The national observatories at Paris (1667) and Greenwich (1675) were established primarily to make radically better measurements of the position of the stars and the movements of the Moon and planets, so allowing the mathematically competent mariner to make a meaningful calculation of longitude. At the same time, theoreticians were making corrections for factors such as atmospheric refraction and lunar parallax. For ship-board use the Hadley reflecting quadrant was displaced by the more accurate sextant.[50]

The anti-establishment fulminations in the first half of *A Further Addition* of 1760 will not have assisted his case for a hearing, while the text that follows demonstrates that he had become out of touch. When Ross needed contemporary data he did not seek out the recently published observations based on John Flamsteed's painstaking work at the Greenwich Observatory, but an anonymous almanac maker publishing under the name of the long-dead astrologer John Gadbury.[51] No wonder the Board of Longitude refused to engage with him.

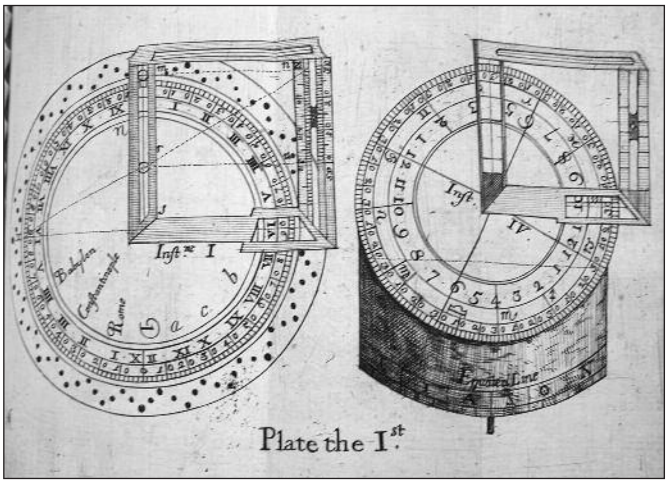


Fig. 9 (above left): Instrument I. This is essentially the same drawing of the sundial plate and sighting mechanism as Ross sent to the Royal Society in 1732. Babylon, Constantinople, and Rome are marked on the dial plate, enabling the time at those locations to be given with respect to the local time read from the dial. Compare with the different selection of locations marked on the surviving Rossipher in Figure 5. In his book A Complete Longitude, Ross provides a table of 60 locations east and west of London and explains how to find the local time using his dial.

Fig 9 (above right): Instrument IV. Mounted on a base that is set at 23° 30′ above the horizon, this represents the plane of the ecliptic. With this device local latitude can be observed.
(David Bryden, courtesy the Royal Society; Library R61378 & R61338)

4.2. *Dial making*

Ross claimed a local reputation as a diallist among his immediate neighbours. He wrote to the Secretary of the Royal Society in 1744 to announce that he had

> so much improved my first instrument by means of a Double Index's, and compacted it suitable for a Gentlem^ns Garden. I have imploy'd some leisurely Hours in serving some few Gentl^mn with them. I Strike the Letters with Punches, but they will not hold to strike rightly on Brass, therefore I strike them on Pewter, or such like Metall, which bears all sorts of we[a]ther exceeding well; some make use of Oak Posts for Pillars and couler them, some have them of the Yew tree wood, which will stand a Great many years; One I have fix'd on a Pillar made of the Bath stone, which is the best of all: The size that I have made are about 7½ Inches Diameter with Brass Index's'.[52]

By 1760 Ross seems to have solved the technical problem of calibrating on brass. The supplement to *The New Astronomer* notes: 'Dials of this sort may be had at very *reasonable Prices*, that will answer these Purposes, they may be had either in *Pewter*, or *Brass*; the *Pewter* will continue many Years, *barring Accidents*.' In an advertisement that year he wrote: 'There is another Sort of Instrument, that may be as a fixed Dial in a Garden, whose Uses Night and Day are nearly the same, for most Propositions; therefore will be good for Instructions. It may with Ease made suitable for any declining Wall, and moveable to and from any Sash Window.'[53] By this date Ross was often in London, and had ready access to workmen skilled at engraving brass. His own garden dials were no doubt used for 'many Years', but I have been unable to locate any surviving examples.

5. The Instruments of *The New Astronomer*, 1735

The New Astronomer describes and explains the uses of seven instruments, illustrating them on three plates (Figs. 9, 10, and 11). The opening pages of *A Further Addition* of 1760 make clear that Ross felt that these designs had been plagiarized:

> I found my past Works pyrated and marketed from One to Another, as their own properties, and so had been for several years past … In some Cases I find they greatly diminish my true ROSSIPHER Instrument, using but a Part of it, such that is suitable to guide the Telescope aright in Observation … They continue their further Favours, and call it a Portable Observatory, an Equatorial Instrument, an Azimuth Instrument, an Equal Altitude Instrument, a Transit Instrument, a Theodolite, a Quadrant, and a Level; not only these, but I fairly pronounce my true ROSSIPHER Instrument to be such that will set to more than 100 000 different Horizons, and all are accountable.[54]

The unnamed target of these allegations was James Short (1710–68), an Edinburgh-born craftsman who moved to London in the late 1730s, specializing in making mirrors for reflecting telescopes. In 1749 Short's paper 'The description and uses of an equatorial telescope' was read at the Royal Society, and later published in their *Philosophical Transactions*.[55] Ross possibly saw the version reprinted by the popular lecturer Benjamin Martin (1704–82).[56]

Short wrote: 'In order to have the other Uses of this Instrument, you must make the Equatorial Plates become parallel to the Horizontal Plates; and then this Instrument becomes an Equal Altitude Instrument, a Transit Instrument, a Theodolite, a Quadrant, an Azimuth Instrument, and a Level.' Excluded from the reprinted version was Short's introduction, in which he explained: 'I do not pretend to anything new in the Combination of these Circles, of which this instrument consists, the same Combination having been made before me, by way of a Dial; but I believe the putting of so large a telescope upon this Machinery and applying it to the uses I have done, is somewhat new.'

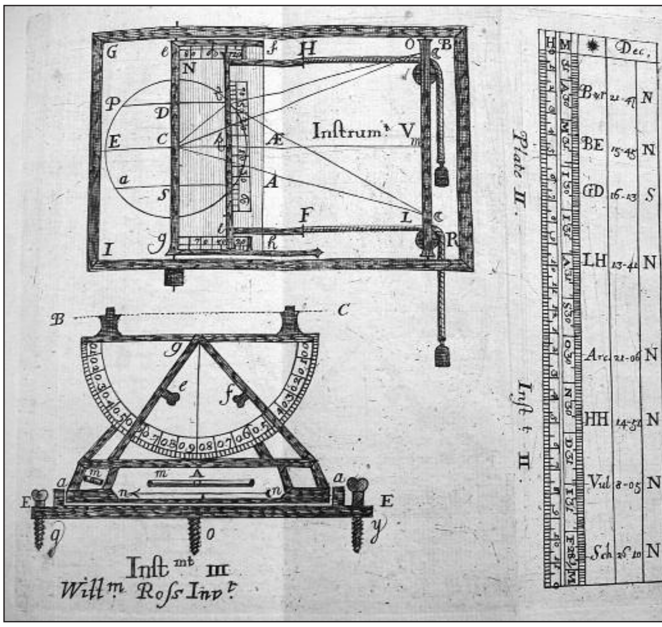


Fig. 10 (right of diagram): Instrument II. The calibrated ruler used to give the time at night from observation of one of the seven bright stars listed on the scale. In his submission to the Royal Society Ross identified each of the stars by name, but in the printed text he presumed his readers knew the shortened names. In the illustration he has reversed the order (top to bottom) and offered a slightly different and smaller selection of stars. His figures for declinations have been adjusted; there is no column for stellar magnitude. The scales on the ruler are headed H for hours and M for months, with each month identified by an initial letter. Star names are: B ♈ = Bright Star of Aries; BE = Bull's Eye; GD = Great Dog; LH = Lion's Heart; Arc = Arcturus; HH = Head of Hercules; Vul = Vultur (i.e. Altair); Sch = Scheat. The fourth column gives the declination N[orth] or S[outh].*

Fig. 10 (bottom of diagram): Instrument III. 'A pedestal, by which the first instrument may be made portable and universal'. Compared with the drawing sent to the Royal Society, there is a significantly larger compass needle. The text discusses how to use the dial to find the magnetic variation, a topic ignored in the 1732 submission. There is greater clarity over the placing of the bubble levels, m, which must be set at right angles, so that the pedestal can be levelled using the screws g, o, and y; these screws are more clearly delineated, and better placed than those on the 1732 drawing. The altitude semicircle mounting is set on a central bearing allowing it to rotate on the base plate. The bearing is not shown in the drawing, but is indicated in the text.

Fig. 10 (top of diagram): Instrument V. This is an analogue device. In essence it is an adjustable form of the woodcut diagram (Fig. II on page 16 in New Astronomer) for finding lunar ascension and declination. Instead of undertaking a trigonometrical calculation, measurements could be made directly from the instrument. It would be useful as an illustrative teaching device. Set within an oblong frame, GBIR, are three axes: NS, fixed, represents the axis of the Earth; OL represents the axis of the Moon – this axis can slide within the frame. The third axis slides within the sub-frame, efhg, and represents the apparent lunar axis. This axis slides over a scale and has to be set and fixed at the local latitude. The proportions of the drawing are misleading – it is drawn with a height:breadth ratio of about 2:3. Ross's description on p. 32 of his book indicates that it should be about 1:30. (David Bryden, courtesy the Royal Society; Library R61378 & R61338)

Indeed, as early as 1742 one of his reflectors had been mounted on a universal equatorial made by Jonathan Sisson, in essence constructed of two of the latter's theodolites, one mounted above the other.[57] In *The New Astronomer* Ross wrote that his instrument could be fitted with 'telescopes or reflecting glasses at the discretion of the artist', but gave no positive advantages of doing so.[58]

Ross might have been aware that prior to the publication of Short's universal equatorial the 1746 catalogue of another London mathematical instrument maker, George Adams (*c*.1709–73), advertised a 'double instrument' described as having

> two chief parts connected together, having four several motions, all moved by rack work. 1. A circular motion to shew all horizontal angles. 2. A semicircular vertical motion. 3. A circular equinoctial motion, or for any place at right angles to the vertical. 4. A motion through a double sextant, at right angles to the third, that has a refracting telescope fixed to it. By this instrument, all angles, either horizontal, or of elevation or depression, the azimuth and altitude of any star, the meridian and latitude of the place, with the hour of day or night, are directly given; also the right ascension and declination of the moon, a planet, comet or any star, at one observation.[59]

There is no doubt that Instrument VI described and illustrated by Ross in 1735 could be used for the purposes listed by Adams, and similarly for those described by Short. Indeed there might be some substance to Ross's claim that others had pirated his design.

The evidence appeared decades later. In 1793 Sir George Shuckburgh (1751–1804) provided the Royal Society with an account of the equatorial refractor made for him by Jesse Ramsden (1735–1800) and recently installed in his private observatory in Warwickshire. Shuckburgh prefaced this account with a survey of equatorial mountings, from antiquity to the present. He opened the 18th-century history with the Short universal equatorial, noting successive improvements in that design published by Edward Nairne (1726–1806), Peter Dollond (1730–1820), and Ramsden.[60] An anonymous reviewer of the article, presumably drawing on handed-down trade memories, criticized this section of the historical overview:

> When he comes to the invention of the modern instrument, and attributes it solely to Mr. Short, we find it necessary to put in a claim for a man of considerable merit, whose name ought, in this instance, to have the precedence. The equatorial instrument, which passes under the name of Mr. James Short, was the invention of the very ingenious Jonathan Sisson. The first was made for Archibald Lord Islay, afterwards Duke of Argyle … Jeremiah Sisson, son of the former ... applied endless screws to give motion to the different circles; but, in point of accuracy, this construction

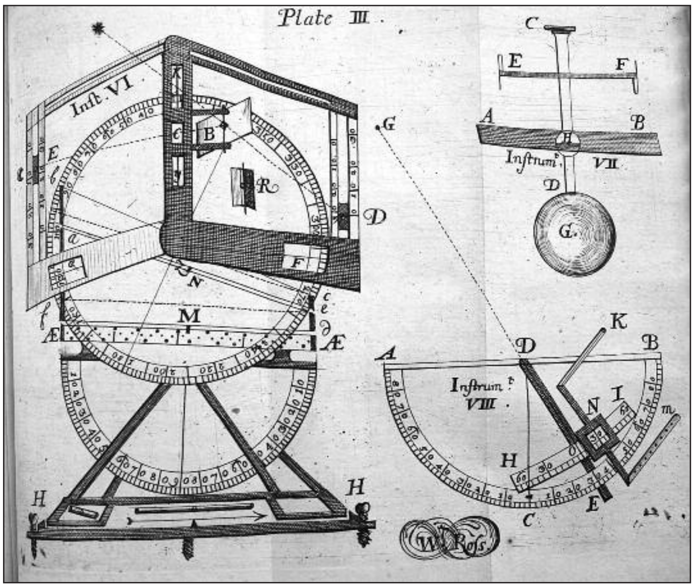


Fig. 11 (left of diagram): Instrument VI. This illustration breaks the rules of perspective drawing so as to better show all the relevant parts. The sighting mechanism is turned to show the 'double index', mounted on the ecliptic circle divided into 360°. The 'double index' was an improvement Ross mentioned in his 1744 letter to the Royal Society. In addition to the pin-hole gnomons at E and D there is an additional one at B. The effect of the hinge is to make the viewing slot adjustable in size; with the addition of a hair line stretched between K and y on the axis, this is intended to allow finer setting of the sliding pin-hole gnomon, resulting in a more precise reading of declination. The ecliptic circle is set at 23½° to the equatorial dial plate, AE, which is here shown in side elevation, and is set at right angles to the altitude semicircle. Overall the instrument is a form of portable universal equatorial, with the whole set on a central axis mounted on the base-plate. Again that axis is not shown on the drawing.

Fig. 11 (top right of diagram): Instrument VII. A device intended to keep instruments such as this dial steady on board a ship. CD is a rod hinged through the deck, AB, on what appears to be a universal ball joint at H, with a heavy counterweight G below. At this date, the ball joint effect would have been achieved by using gimbals. The instrument would be set on the stand at C, and in principle would remain still. Pendulous counterweights were tried before and after Ross as a means of counteracting the inevitable movement of instruments when used on ships. They were particularly favoured by designers with limited ship-board experience.

Fig. 11 (bottom right of diagram): Instrument VIII. 'An instrument that will take an observation to seconds of a degree', provided that the instrument had a radius of one yard (0.93 m). In the Further Addition Ross notes that a 'Long Radius Instrument' could be used for making accurate lunar distance observations, but he reserved further elucidation 'for another place'. What he does not cover is the major problem of constructing, dividing, mounting, or operating such a large instrument, let alone using one at sea. Even in a small instrument, performance depends on mechanical build quality, the accuracy of the dividing of the main scales, and of the read-out. The larger the instrument, the more significant becomes the first factor, and in particular there is a problem of flexure of the different elements of the mounting. Ross mentions that a telescope could be mounted on Instrument VI, but does not indicate that it would be advantageous to do so. (David Bryden, courtesy the Royal Society; Library R61378 & R61338)

> was much inferior to the wheel and pinion of Jonathan Sisson.[61]

There is physical evidence that Sisson had made a portable equatorial stand in 1742, seven years before Short published his design. As we saw in Section 1.2, the Rossipher preserved in the Museum of the History of Science at Oxford could well have been a product of Sisson's workshop. Was it making this instrument that put the idea into Sisson's head? If so, William Ross could have had a previously unheralded influence on scientific instrument design.

Conclusion

The surviving Rossipher openly proclaims William Ross as its designer, yet he remains an enigmatic figure. His books do not overtly name him as author. His 1759 public demonstration advertisement fails to give his name. His 1760 announcement of the reissue of his book is similarly silent, while his 1762 advertisement hides his identity behind the initials 'N.A'. An advertisement of 1766 is the last record of his activities.

Here was a provincial longitude projector whose ambition soared beyond a local reputation for designing and making sundials for gentlemen's gardens, and whose longitude quest was betrayed by a failure to grasp the complexities of the rapidly advancing science of navigation. The evidence suggests that the lure of a longitude award warped his judgement and led him to overvalue the performance of his Rossipher, leading to a lifetime of frustration and bitterness.

He had designed and commissioned a complex sundial that could be used to do far more than merely tell solar time. It could make a variety of measurements from which latitude, longitude, and magnetic variation could be ascertained. He presumed that such an instrument entitled him to join the longitude quest. He was ignored by the scientific establishment because he failed to appreciate that scientific navigation required the use of finely divided instruments, reading to minutes of arc, and adapted for use at sea, the whole married to advanced mathematics to compute precise results. A small-radius instrument with open sights had some value in teaching general principles, but it was not a credible contender for a longitude prize.

There were many others like Ross. With the benefit of hindsight the proprietor of a nautical academy in London, John Hamilton Moore (1738–1807), later commented: 'The Reward held out by Government for the determining of the Longitude has induced many to attempt it, especially in the mechanical Line, and … many of them have been visionary, whimsical Men, totally unacquainted with the Difficulties attending such a Discovery'.[62]

When Ross was making his case an anonymous contributor to a London newspaper in 1764 analysed contemporary press coverage of aspirants to the longitude prize. The Board of Longitude had, the writer said, been 'amused with *specious projects* and pretences (for the sake of the *premium*, more than the honour of discovery)'. Ill-informed, land-bound 'longitude schemers' were taken to task in verse. The opening stanza provides the flavour of a scathing analysis:

> ABOUT this Longitude, when all this doubt
> It is (*they say*) and yet 'tis not found out!
> Mechanic *Schemers* buzz about the Board,
> In hope they may some further aid afford!
> Some, with strange notions, run from truth away,
> And others, by as vain, are led astray.[63]

Acknowledgements

Malcolm Fare of Hanley Castle alerted me to Ross's appearance in the 1741 Worcestershire Poll Book and to the 1761 Hanley Castle vicarage terrier, as well as publicizing my search for surviving Ross garden dials in the parish magazine. Stephen Johnston of the Museum of the History of Science at Oxford facilitated my examination of the Rossipher, and drew attention to the variety of engraving styles. Stephen Price kindly copied for me the report on the Dougharty dial at Hartlebury Castle.

References and notes

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2. Hanley Castle Parish Registers: Worcestershire Archive and Archaeology Service: Mic X 985.66. The marriage of Richard Ross to Elizabeth Saunders, both of Hanley Castle, 1696 January 16 (NS); their first child, Edward, baptized 1698 April 7; a daughter, Frances, baptized 1704 January 16. William Ross's name appears as churchwarden at the end of the list of baptisms for 1734, 1735, 1737, and 1738.
3. Hanley Castle Parish Registers: WAAS: Mic X 985.66. Richard Ross, 'Yeoman', buried 1707 December 12; Elizabeth Ross, 'widow', buried 1729 March 28.
4. Worcestershire Poll Book for 1741: WAAS: BA3762/8, Vol III p. 14.
5. Worcester Diocese Marriage Licence records: WAAS, BA2030. The licence was valid for three months. No Ross/Hart marriage is recorded at Hanley Castle or Welland in 1745 or 1746, hence the presumption that the marriage took place at Bransford, although there are no extant registers from Bransford to confirm this.
6. 'A True and perfect Terrier ... of all the Lands, Tythes and Profits belonging to the vicarage of Hanley Castle 1 Jan 1761'. WAAS: BA 2358/5/41.
7. Maslen, K., and Lancaster, J., *The Bowyer Ledgers*

(London, The Bibliographical Society, 1991), p. 174.

8. *Gentleman's Magazine*, 6 (1736), p. 751; *London Magazine*, 5 (1736), p. 704.
9. *Gazetteer and London Daily Advertiser* no. 9846, 1760 October 31.
10. *St James's Chronicle or the British Evening Post* no. 178, 1762 April 29–May 1.
11. Cooper, M., *The Worcester Book Trade in the Eighteenth Century*, Occasional Paper Number 8, (Worcestershire Historical Society, Worcester, 1997), *passim*. Freshwater, P. B. (ed.), *Working Papers for an historical directory of the West Midlands book trade, no. 1, to 1779*, (Birmingham Bibliographical Society, 1975) records no engravers in Worcester at this time. As late as 1759, when Richard Turner (1720–91), 'Professor of Mathematicks and Philosopher in Worcester', advertised for subscribers to his perpetual calendar in *Berrow's Worcester Journal* (1759 June 14 and 1759 August 2) he noted that the original was to be sent to London for engraving.
12. Cooper (1997), p. 38 and Appendix B.
13. Taylor (1966), p. 189. MHSO Inventory Number 39529. Founding gift of Lewis Evans, 1922, no other provenance. The MHS description is as follows: 'Turned wooden base with 3 levelling screws, magnetic compass and azimuth adjustment by rack and pinion; three curved supports to platform for latitude semicircle with rack motion, equinoctial circle, with racked adjustment for ecliptic circle with pivoted sighting arm and index.'
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16. Hammond, J., *The Practical Surveyor* (London, for Thomas Heath, mathematical instrument maker, 1725) – see frontispiece. For an example by Heath see Christie's Sale 8278 *Scientific and Engineering Works of Art* (London 2000 April 13), lot 47; see also an example in the National Museum of American History 309596, unsigned; and another, signed by Cole, Science Museum 1927-1923.
17. Archives Royal Society RBO/17/6 endorsed: 'Read March 9, 1731/2'. Ross's original submission is preserved at ARS: Cl.P/3ii/33 and is endorsed 'March 9, 1731 Copied'.
18. ARS: Cl.P/8ii/60.
19. ARS: MM/20/19.
20. ARS: RBO/17/7; see also Cl.P/3ii/34.
21. ARS: RBO/16/32; see also Cl.P/8ii/32.
22. *Philosophical Transactions of the Royal Society*, 38 (1735), 450–7; 57(ii) (1768), 389–93.
23. *Gent Mag*, 16 (1746), 477–8; see also 24 (1754), 17; 39 (1769), 287–8; 57 (1787), 49; 39 (1769), 143–4.
24. Ross (1760), pp. 1–2.
25. Ross (1760), pp. 4 and 6, cites *Daily Advertiser* 1759 June 4, and 'Gazetteer for his H–n—s's Birth Day in 1759'. The quoted text is from *Gazetteer and New Daily Advertiser* no. 5503, 1759 June 4.
26. *Gent Mag*, 7 (1736), 67–72; *Gent Mag*, 30 (1760), 261–2; *London Gazette* no. 9891, 1759 April 28.
27. *St James's Chronicle or the British Evening Post* no. 178, 1762 April 29–May 1. HMS *Association* was Sir Cloudesley Shovell's flagship, wrecked off the Scilly Isles in 1707; EIC *Doddington* was wrecked in 1755 with treasure destined for Clive of India; HMS *Bideford* was wrecked in 1761. Why Ross cited 24-gun frigate HMS *Dolphin* is unclear; she was in the ill-fated fleet of Admiral John Byng at the battle of Minorca (1756), but subsequently undertook two circumnavigations (1764–6 and 1766–8), assisting opening up the Pacific to British exploration and trade.
28. Cambridge University Library: RGO 14/5 'Minutes of the Board of Longitude' for 1763 February 26.
29. There was a William Ross in contact with the Board in 1806, but he was a printer and publisher from Philadelphia, born New York *c.*1746, died 1829 – see the biographical note in *Journal of the House of Representatives of The United States: John Adams Administration 1797–1801*, 2 (2nd session 1797–8) in the collected reprint series (Wilmington 1977), p. v.
30. CUL: RGO 14/5, 1766 April 26.
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32. *Public Ledger* no. 1816, 1765 October 30.
33. Maskelyne, N., *The British Mariner's Guide: containing, complete and easy instructions for the discovery of the longitude at sea and land...* (London 1763).
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39. Smith, B. S., 'The Dougharty family of Worcester, estate surveyors and mapmakers, 1700–1760', *Transactions of the Worcestershire Archaeological Society*, 3rd series, 15 (1996), p. 254.
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41. Smith (1996), pp. 253, 254. Dougharty (1748), p. 383, for horizontal dials of the sort 'commonly set upon a pedestal in a Garden'. Early in his career Dougharty had advertised that he was able to supply 'all sorts of Mathematical Instruments, for Navigation, Dyalling &c at very reasonable rates' – *Worcester Post Man* 536, 1719 September 25–October 2. Price, S., and Walker, P., 'The Sundial at Hartlebury Castle', (unpublished report for the Friends of Hartlebury Castle, 2012).
42. Facio, N., 'Of the quantity of the errors arising in the determination of the latitude and longitude from the neglect of the refraction of light in the Moon's atmosphere', *Gent Mag*, 8 (1738), 185–7, dated Worcester 1738 March 29. His publications included *Navigation Improv'd; being chiefly the method for finding the latitude at sea as well as by land* (London 1728). Green, V., *The history and antiquities of the city and suburbs of Worcester* 2 (London 1796), p. 93, includes Facio as an eminent Worcester man, settling in the city 'about the year 1720'.
43. *Worcester Post Boy*, 1716 June 15–22.
44. The universal equatorial ring dial designed by mathematician William Oughtred predates by several decades its first publication in *Mathematical Recreations* (London 1653). It was widely made by London instrument makers – see Bryden, D. J., *Sundials and Related Instruments: The Whipple Museum of the History of Science, Catalogue 6* (Cambridge 1988), item 220 *et seq*.
45. See, for example, Bryden, D. J., *Sundials and Related Instruments: The Whipple Museum of the History of Science, Catalogue 6* (Cambridge 1988), items 176–219; also Cowham, M., *A Dial in Your Poke* (Cambridge 2004), 101–12.
46. Gunter, E., *The description and use of the sector* (London 1623), p. 188 et seq. For surviving examples see Bryden, D. J., *Sundials and Related Instruments: The Whipple Museum of the History of Science, Catalogue 6* (Cambridge 1988), items 279–88; also Cowham, M., *A study of the Quadrant* (Cambridge 2014), 24–29.
47. Leybourn, W., *Panorganon, or a universal instrument* (London 1672). Leybourn, W., *Cursus Mathematicus* (London 1690), 716. See also Cowham (2004), 35–40.
48. Ross (1735), p. v.
49. Howse, H. D., 'The Lunar-Distance method of measuring longitude' in Andrews, W. J. H. (ed.), *The Quest for Longitude* (Cambridge Mass., 1996), p. 158.
50. Ibid., 150–61.
51. Job Gadbury took over publication of John Gadbury's almanacs after the latter died in 1704; Job died 1715. See Capp, B., *Astrology and the popular press: English Almanacs 1500–1800* (London 1979), 307–8. The Gadbury *Ephemeris or a diary astronomical, astrological, meteorological for the year...* appeared annually until at least 1760.
52. ARS: MM20/19. In the context of Ross's use of pewter, note that the co-signatory of his Marriage Allegation and Bond (see Ref. 5) was a Worcester tin-plate worker.
53. Ross (1760), p. 13. *Gazetteer and London Daily Advertiser* no. 9846, 1760 October 31.
54. Ross (1760), pp. 2–4.
55. *Phil Trans R. Soc*., 46 (1752), 241–6.
56. *A Supplement to the Philosophia Britannica, Appendix II*, (London 1759), 74–80.
57. For the Short/Sisson instrument see Bryden, D. J., *James Short and his telescopes*, (Edinburgh 1968), 21–22.
58. Ross (1735), p. 12; compare Ross (1760), p. 4.
59. 'A catalogue of mathematical, philosophical and optical instruments as made and sold by George Adams', in Adams, G., *Micrographia Illustrata*, (London 1746), p. 260.
60. Shuckburgh, G., 'An account of the equatorial instrument', *Phil Trans R. Soc*., 83 (1793), 67–73.
61. *The British Critic*, 2 (1793), p. 188. Archibald Campbell (1682–1761), Whig politician, was created Lord Islay in 1706 and succeeded his brother as 3rd Duke of Argyll in 1743.
62. Moore, J. H., *The Practical Navigator and seaman's new daily assistant*, (London: 9th edition, 1791), p. 228. The book was first published 1772 but the comment was first inserted in the 9th edition.
63. *Lloyd's Evening Post* no. 1136, 1764 October 19–22.

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Errata

On page 9 of *The Antiquarian Astronomer* Issue 7, March 2013 ('James Stuart and the Rochdale Pioneers' by Philip A. J. Barnard), in the second column, second full paragraph, 'Josephine' should read 'Laura'.

On page 49 of *The Antiquarian Astronomer* Issue 8, June 2016 ('David Gill: clock maker to global astronomer' by Paul A. Haley) the dates for John Hartnup should read 1806–85.