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Swedenborg's Lunars

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Abstract

The celebrated Swedish natural philosopher and visionary theologian Emanuel Swedenborg (1688-1772) devoted major efforts to the establishment of a reliable method for the determination of longitude at sea. He first formulated a method, based on the astronomical observation of lunar position, while in London in 1710-12. He issued various versions of the method, both in Latin and in Swedish, throughout his career. In 1766, at the age of 78, he presented his scheme for judgment by the Board of Longitude in London. The rich archive of Swedenborg's career allows an unusually detailed historical analysis of his longitude project, an analysis rather better documented than that available for the host of contemporary projectors who launched longitude schemes, submitted their proposals to the Board of Longitude, and have too often been ignored or dismissed by historians. This analysis uses the longitude work to illuminate key aspects of Swedenborg's wider enterprises, including his scheme to set up an astronomical observatory in southern Sweden to be devoted to lunar and stellar observation, his complex attitude to astronomical and magnetic cosmology, and his attempt to fit the notion of longitude into his visionary world-view. Swedenborg's programme also helps make better sense of the metropolitan and international networks of diplomatic and natural philosophical communication in which the longitude schemes were developed and judged. It emerges that his longitude method owed much to the established principles of earlier Baroque and Jesuit natural philosophy while his mature cosmology sought a rational and enlightened model of the universe.

'It may be surprising to put forward a new and sure method of finding the longitude of places…by means of the Moon, when the Moon in this respect has yet defeated the foremost astronomers, since it seems as if the Moon has deceived each of those who thought he'd found the longitude, and given them a good sense and a happy feeling that they would attain what was sought after; but, as soon as they advanced to practice, the Moon made moonshine and mockery of it, as it were, and so gave them a false appearance of truth…But if one examines the cause of their failure, it's by no means to be found in the Moon itself, which God seems to have established and ordained to guide mariners on their course, but in the way in which she's been observed' (Emanuel Swedenborg, *A New and Sure Method to find Longitudes of Places, both at sea and on land, by means of the Moon*, 1717)[1]

The meeting of the Board of Longitude held in London on 18 June 1768 was in many ways uneventful. The professors, naval officers and administrators who gathered that day routinely assigned various amounts of cash to printers, mathematicians and instrument makers for a range of new astronomical devices and computation methods. They continued their ponderous consideration how best to secure a continuous record of astronomical observations still held by the heirs of previous Astronomers Royal. Then they heard a series of judgments from the current Astronomer Royal Nevil Maskelyne on novel longitude schemes. Those he approved were unoriginal so unworthy of reward. The rest were deemed simply unworkable. It had become extremely common for the Board either to reject or to shelve the very large number of such schemes sent them by projectors. Amongst them was a method for observing the position of the Moon against the fixed stars: 'the method proposed is not new or capable of exact observations, and moreover the Author is mistaken in his mode of Calculation by supposing the Moon to have no Latitude but what is owing to Parallax'.[2]

What picks out this method for historical attention is that its author was Emanuel Swedenborg, natural philosopher and religious visionary, founder of one of the most significant eighteenth century spiritual projects in illumination and theosophy, commissioned after a series of visions in his late fifties to act as mediator between God and humanity. His spiritual writings and angelic visions would furnish ample materials in the revolutionary conjuncture of the 1780s for a range of millenarian and radical programmes, drawing enthusiastic and hostile responses from contemporary polemicists. For Swedenborg, there was a profound correspondence between the spiritual and earthly realms, a relation rich with significance for the truths of a new revelation of cosmological order. Spiritual agents were the true causes of the material entities to which they corresponded: 'He who knows how to elevate his Mind above the Ideas of Thought which are derived from Space and Time, such a Man passes from Darkness to Light…Angels do not know what Space is, but comprehend clearly when it is said without any idea of Space that the Divine fills all Things', declared Swedenborg in 1763 in his *Wisdom of Angels concerning Divine Love and Divine Wisdom*. 'Excellent', agreed the revolutionary London poet and artist William Blake, an erstwhile disciple of the Swedish sage, in a marginal annotation to his own copy of this book in 1788.[3]

Swedenborg's principal astronomical project on the ideas of space and time was his work on longitude. It was of much longer standing than this visionary cosmology. It was substantially formulated well before the passage in Britain of the 1714 Longitude Act and its establishment of a group of Commissioners to adjudicate on such projects, so helps indicate the wide range of enterprises from which that limited institution emerged. Furthermore, none judged Swedenborg's proposal irrational, however erroneous its details. Yet it also played a part in his assumption of the authoritative role of visionary and sage, a man capable of immediate communication with spirits and angels in the name of a new prophetic cosmology. Thus instead of using the viability of a longitude scheme as a means of judging the unreason of its promoter, it seems better to adopt more historically sensitive approaches to what eighteenth century cultures deemed authoritative, plausible and effective, and to recognize the passions and enthusiasms in play in even the most legitimate schemes to find longitude at sea.

Swedenborg first proposed a lunar method for determining maritime longitude in London at the end of 1711 and maintained his interest in the plan ever after. He had initially 'examined closely all propositions for finding the terrestrial longitude, but could not find a single one; I have therefore originated a method by means of the Moon, which is unerring, and I am certain that it is the best which has yet been advanced. In a short time I will inform the Royal Society that I have a proposition to make on this subject'.[4] He published accounts of this lunar method in Swedish in 1717 and in 1718 with a dedication to Edmond Halley; two editions of a revised Latin text in 1721 and 1727; and a new version in Amsterdam in 1766. This combination of a lifetime's interest in longitude schemes with the remarkable ambitions of a spiritual cosmology makes the case of Swedenborg's lunar method unusually significant. It's been common to associate allegedly visionary or impracticable longitude schemes with eighteenth-century cultures of enthusiasm and unreason populated entirely by 'cranks and opportunists'. It's also been common wrongly to associate an interest in visionary cosmology with the outdated culture of Baroque piety but to refer the techniques of scientific navigation to the ambitions of rational enlightenment. The case of Swedenborg's lunars throws a somewhat different light on these assumptions: he used resources from Baroque culture to forge a method for determining longitude and design a progressive and enlightened form of piety. Nor, significantly, was he unusual in the early decades of the eighteenth century in combining public work on religious reform with fascination with the challenge of determining position at sea.[5]

Swedenborg was born in 1688 into an eminent and wealthy Swedish family, his father Jesper Svedberg later theology professor at Uppsala University and a distinguished pietist bishop. Swedenborg's brother in law Erik Benzelius, brilliant young librarian at Uppsala and an active member of the republic of letters, a correspondent both of Gottfried Leibniz and of Hans Sloane, also exercised important influence on the new graduate's career. The longitude project was first developed when, with Benzelius's encouragement, Swedenborg spent the time between August 1710 and the end of 1712 as a studious visitor in England 'that I might thereby profit somewhat in mathematics or, which is said to be their chief pursuit, in Physics and Natural History'.[6] The timing of this visit was telling, since the entire kingdom of Sweden was then in crisis through catastrophic military defeat in its long war with Denmark and Russia under the charismatic if erratic leadership of Charles XII, while

Swedenborg's home university suffered from plague. Uppsala shut, Benzelius established a small group of learned scholars, the *Collegium curiosorum* (1710-11), which would help direct Swedenborg's activities in Britain and in its future institutional incarnations as a Literary Society (1719) and Royal Society (1728) provide resources for his later projects in publication and natural philosophy.[7]

In war-weary Augustan London, suffering the eighth year of its exhausting conflict with Bourbon France, this was also a decisive period in the polemical institutionalization of metropolitan natural philosophy. In late 1710 Isaac Newton's Royal Society, to which Swedenborg had asked Benzelius for an introduction, shifted to its new house in Crane Court set amidst the principal instrument makers and lecturers of the capital. The Society and its networks were wracked with controversies. There was a telling connexion, important for the development of Swedenborg's own work, between conflicts in public religion, in the interpretation of natural philosophical authority, and in rival estimates of the worth of novel instruments and practical projects in astronomy, navigation and calculation. Thus in autumn 1710 Newton's ally William Whiston, who would soon also become a protagonist of the longitude debates, was expelled from his Cambridge mathematics chair for heresy and forced to move to London as public lecturer. Throughout 1710-11 fights raged between the London naturalist John Woodward and the Society's secretary Hans Sloane. At the end of 1710 Newton and Halley, then the Oxford geometry professor, launched their long campaign to seize the Greenwich astronomical observations from the Astronomer Royal John Flamsteed, a fight that culminated with the destruction of Halley's edition by Flamsteed in August 1714. And in late 1710 the Oxford mathematician John Keill inaugurated the vicious and long-running calculus dispute with his printed accusation that Leibniz had plagiarized Newton's mathematics, a dispute closely entangled with the imminent accession of the Hanoverian regime to the British throne. These struggles dominated the milieux that saw the announcement of Whiston's scheme for longitude at sea in summer 1713 and the passage of the first Longitude Act the next year. Significantly, young Swedenborg was in personal touch with all these fights: as visitor, shopper, student and schemer, he learnt much from these British enterprises.[8]

In London, Swedenborg established links with the émigré community, including Johann Esdras Edzard, pastor of the German-Swedish church in the East End, the energetic Anglo-Swedish merchant Jonas Alströmer, based in London since 1707 and keen to introduce novel machines into Swedish industries, and the cunning Swedish ambassador Carl Gyllenborg, elected FRS in December 1710: there's been a suggestion the diplomat hired Swedenborg as agent in a complex international Bourbon and Jacobite plot directed against the new Hanoverian regime.[9] There was a standard itinerary followed by foreign visitors to London's instrument shops and learned academies. As Jim Bennett points out in the case of Zacharias Uffenbach, the Frankfurt scholar who reached London just a couple of months before Swedenborg, it was common to call on instrument makers of repute, to witness their newfangled practical shows, and to seek original or idiosyncratic devices for purchase.[10] This system sustained the important shift of demonstration experiments into the world of Fleet Street and Ludgate instrument shops, and complemented the tours of scholars' studies, collections and cabinets common amongst citizens of the republic of letters. Thus between June and November 1710 Uffenbach and his brother also frequently visited the Lutheran pastor Edzard, from whom they purchased scholarly books at prices below those of the St Paul's booksellers. They learnt glass cutting from the optician John Marshall and purchased his telescopes, saw air pump shows at the shop of Francis Hauksbee and bought his *Physico-mechanical experiments*, and visited John Woodward's natural history collections, containing great rarities, even if they found the virtuoso 'a conceited fool'.[11] They went downriver to Greenwich where Flamsteed showed them the observatory, its equipment, and 'a vast number of his written observations taken during 30 years', while the Astronomer Royal grumbled that 'the mathematical and physical sciences, and the Royal Society, seemed drooping'.[12]

Swedenborg followed a very comparable routine to that of his German contemporaries. He declared his principal interests were 'especially for astronomy and mechanics. I also turn my lodgings to some use, and change them often; at first I was at a watchmaker's, afterwards at a cabinet maker's, and now I am at a mathematical instrument maker's; from them I steal their trades, which some day will be of use to me'. Just as Uffenbach had studied glass works with Marshall, so the Uppsala astronomy professor Per Elvius encouraged his former student Swedenborg to become expert in glass grinding 'even to the minutest detail'.[13] As early as October 1710 Swedenborg had obtained 'a small stock of books for the study of mathematics, and also a certain number of instruments, which are both a help and an ornament in the study of science; such as, an astronomical tube, quadrants of several kinds, prisms, microscopes, artificial scales, and a camera obscura', hoping all this would leave enough cash for an air pump.[14] He obtained a copy of *Principia mathematica* (the first 1687 edition is mentioned in his library catalogue), claimed he studied it daily, and offered his Uppsala colleagues copies of Newton's mathematical writings.[15] When the sceptical Elvius, who got a copy of *Principia* back in 1698, asked 'what the learned mathematicians think about Newton's theory of the motion of the planets: inasmuch as it seems to be a pure abstraction without any physical ground, viz. how one planetary body could gravitate towards another, &c., which seems to be an absurdity', Swedenborg bluntly answered that 'in this matter no Englishman ought to be consulted, because he is blind to his own concerns' and none in Britain dared contradict Newtonian authority.[16]

Commissions from Benzelius and Elvius helped direct his custom, though Swedenborg reported real difficulties getting cash advances from the Swedish merchants in London.[17] His letters back to Sweden remain the sole sources of our information about his life among the instrument makers and sellers. At John Marshall's shop he negotiated on Benzelius' behalf for the lenses for a twenty-four feet refractor, though again complained of their very high price ('I do not know whether they are not cheaper in Holland'). A new Marshall microscope, of impressive magnification, was simply too pricey to purchase.[18] Swedenborg also patronized Hauksbee, encouraging the Uppsala fellows to buy an air pump with 'the improvements invented by members of the Royal Society' and the book that accompanied it, since Russian rivals had already purchased three pumps from London.[19] In July 1711 the Uppsala *Collegium curiosorum* agreed that Swedenborg should indeed establish the price and description of Hauksbee's air pump, along with astronomical globes and copies of the Royal Society's *Philosophical transactions*: he managed all these purchases in autumn 1711.[20] He may also have seen the newfangled steam engine erected by Thomas Savery at Campden House in Kensington, and by summer 1712 he'd met Woodward, thus gained introductions to other fellows of the Royal Society. He sent home Marshall's lenses as well as

Hauksbee's *Physico-mechanical experiments*: Hauksbee promised to send the air pump pictured in the book, if so desired.[21] Swedenborg also made himself an authority on the mathematical and philosophical literature available in London. He sent the Swedes three volumes of Halley's *Miscellanea curiosa* and strongly recommended purchasing John Harris' vast collection *Lexicon technicum* (1710), full of details of Flamsteed's and Newton's astronomy with sets of tables, as well as the Huguenot journalist Michel de la Roche's *Memoirs of literature*, whose May 1712 issue contained Leibniz's incendiary riposte to Newtonian charges of plagiarism and irreligion.[22]

Thus during 1710-12 the Swedish traveller became a habitué of the range of London instrument shops, experimental showrooms and learned publishing. This was how his initial enthusiasm for the longitude scheme emerged. The interest was of course a commonplace in European learned circles. In May 1710, just weeks before Swedenborg left Uppsala, his teacher Elvius had already presided at a thesis there that catalogued the various hitherto unsuccessful methods, whether magnetic (using compass variation) or astronomical (using eclipses of the Moon or of Jupiter's satellites) to determine maritime longitudes, and breathlessly exclaimed at the vast prizes on offer from European governments for any solution.[23] Learned travelers keenly sought advice on these methods: the immediate prompt for Swedenborg's passion, no doubt, was his encounters with Flamsteed at Greenwich and Halley in Oxford. Similarly, in October 1710, a few months after Uffenbach's Greenwich journey, the German scholar visited the Oxford astronomy professor John Caswell, who praised his colleague Halley's 'invention of the longitude and said none had advanced therein so far as he'. Caswell explained to Uffenbach the obvious problems: long telescopes and accurate clocks would not work on board ship, so conventional methods of observing Jupiter's satellites would fail.[24] The source for these views was Halley's edition of Thomas Streete's *Astronomia Carolina*, published in London in February 1710. The work's appendix contained Halley's observations of the Moon and stars made at Islington between October 1682 and February 1684, just before his celebrated visit to Newton in Cambridge. Halley claimed 'it only needed a little practice to be able to manage a five or six feet telescope capable of shewing the appulses or occultations of the fix'd stars by the Moon on ship board in moderate weather'. What was needed, so Halley now urged, was published data from the Paris and Greenwich observatories and the perfection of Newton's lunar theory. Halley promised his readers a treatise on this lunar distance method.[25]

Swedenborg knew of *Astronomia carolina*, mentioning it to Elvius as one of the commonest sets of lunar tables.[26] And he soon heard about Halley's work, telling Benzelius that the 'incomparable quadrant' the astronomer used at Islington and in his voyage to the south Atlantic had been bought by the Russian tsar Peter in 1698 for £80.[27] Swedenborg also read Halley's *Miscellanea curiosa*, which contained the 1708 English version of Newton's lunar theory. The Swede pithily noted that 'Newton has laid a good foundation for correcting the irregularities of the moon in his *Principia*; he has however not yet published the tables, but simply the theory'.[28] Swedenborg's meetings with Flamsteed encouraged this interest. The Astronomer Royal had held for at least four decades that 'observations of the Moon's distances from the fixed stars were the most proper expedient for the discovery' of longitude. In late 1705 he'd told the secretary of the Admiralty, somewhat irascibly, what stern tests must be passed by any 'discoverers of the Longitude if they pretend to find it by observations of the Moon'. They should be asked if they could calculate the Moon's apparent and true places, as well as lunar and solar eclipses, from tables. If they claimed to be able to do so, they must be told to perform there and then; if instead they pretended to perform the task by instruments, such devices had to be made and shown to the Lords of the Admiralty or their deputies.[29] And just as Flamsteed had proudly shown Uffenbach his mass of lunar observations in June 1710, so in winter 1710-11 Swedenborg at Greenwich learnt that Flamsteed's lunar data, 'together with the Paris Observations, will give us some day a correct theory respecting the motion of the moon and of its appulse to the fixed stars; and with its help there may be found a true longitude at sea; for he has found that the motion of the moon has as yet been by no means well determined, and that all theoretical lunar tables are very imperfect'.[30] This meeting with Flamsteed coincided precisely with the stormy beginning of the fight between the Astronomer Royal, Newton and Halley for the possession of these data. By February 1711 Halley had demanded all the Greenwich observations be handed over.

From this moment, Swedenborg's longitude project began to be formed in earnest. He set himself to compute 'several useful tables for the latitude of Uppsala, and all the solar and lunar eclipses which will take place between 1712 and 1721' as well as 'the motion of the moon outside the syzygies'. He also asked Elvius to send him an accurate determination of Uppsala's longitude derived from a 1706 lunar eclipse, data that the astronomy professor had presented in the 1710 Uppsala dissertation on longitude at sea. Swedenborg requested Benzelius to commission a five-feet brass quadrant divided to one-fifth of a second from his collaborator the eminent Swedish natural philosopher, instrument maker and mechanic Christopher Polhem ('I think my father will not refuse to pay for it').[31] Elvius promptly sent Swedenborg details of his eclipse observations, and a host of queries from the *Collegium curiosorum* about the notoriously reclusive Flamsteed: he should get a catalogue of the Astronomer Royal's writings for the Uppsala library, and should 'try to be present, at all hazards, while Flamsteed is making some observations; that you notice how he conducts them; that you describe his instruments with all the apparatus belonging to them', whether he followed Tycho, Hevelius or Hooke in mounting his angular instruments, whether he used micrometer lenses, and 'how the instrument is placed parallel with the horizon'.[32] When Swedenborg returned to Greenwich, he passed on Elvius' data to Flamsteed, who provided information allowing the calculation of the Uppsala longitude.[33] Swedenborg assiduously described the Greenwich layout, including the great mural instrument and the quadrants, whose design he reported he was himself improving 'by which observations may be made without trigonometrical calculations'.[34]

It was at this point in late 1711 that Swedenborg first announced his possession of his 'infallible' longitude method, his intention to present it to the Royal Society, or else send it to France if the Londoners proved hostile.[35] In January 1712, Swedenborg travelled to Oxford to meet Halley in person. Their encounter was crucial. Halley certainly later obtained some of Swedenborg's works on natural history and magnetism and personally discussed observations of the variation of the length of the pendulum made at St Helena, while Swedenborg would obtain a copy of Halley's invaluable sea chart of magnetic variation.[36] There's some evidence they also discussed wider questions of ancient cosmology. In the wake of Thomas Burnet's notorious *Telluris theoria sacra* (1681-9), which proposed an originally pristine and hollow Earth whence waters had burst forth to change the position of the poles and cause the great Flood, many English writers such as Keill and Whiston debated properly natural philosophical modes in which the great events of Scriptural history, notably the Fall, the Deluge and the Apocalypse, might be explained. In the 1690s Halley had actively taken part in these debates, proposing in 1687 and 1694 that a passing comet might have shifted the poles and caused the Flood, and, more significantly, that there seemed to be spectacular errors of as much as thirty minutes in the longitudes the ancients such as Hipparchus and Ptolemy had derived from their observations of lunar eclipses. In 1692 Halley had explained these longitude errors: the Earth must be slowing down as it orbited the Sun, so the year was getting longer, because of the resistance of an interplanetary luminiferous ether whose existence had been demonstrated by the discovery of the finite velocity of light. The astronomer had of necessity been cautious with these views. Under Newton's stern counsel, his argument about the Earth's retardation was swiftly corrected and never published, while his cometary story about the Deluge was not published for more than three decades with an equally prudent caveat about its scriptural meaning.[37] But within five years of their meeting at Oxford, these themes of orbital retardation and the cause of the Deluge were soon to be revived by Swedenborg in his own work on cosmology. And above all, in 1712 Halley apparently confirmed Swedenborg's claim that the lunar distance method was the only viable scheme for longitude at sea. 'Suppose the motion of the moon were really rectified, no other method, of all those that have been projected by others, can be used for this purpose, except mine alone; this much, at least, Dr. Halley has admitted to me orally'.[38]

The indispensable capacity of astronomical observations to determine marine longitude was, of course, also Newton's view: 'it is not to be found by Clock-work alone. Clockwork may be subservient to Astronomy but without Astronomy the longitude is not to be found'. The problem, the Royal Society's president reckoned, was that 'Astronomy is not yet exact enough', and its improvement would be achieved not by 'Watchmakers or teachers of Navigation or people that know not how to find the Longitude at land, but by the ablest Astronomers'.[39] At Oxford, Halley and Swedenborg discussed the difficulties, notably the lack of adequate lunar tables. Halley communicated 'a method as to how the east and west longitude might be found by the eclipse of the larger stars by the Moon', Swedenborg recorded.[40] Decisive both in Newton's views, and in Halley's proposals, was the obvious need not merely for superior mathematical skill, but for most precise observational instruments. The interdependence of superior aptitude and the supply of reliable hardware played a vital role in Swedenborg's schemes.

This focused attention on Greenwich, with whose astronomer Newton and Halley were engaged in a vicious fight: the lunar data 'are promised by Flamsteed', Swedenborg recorded, 'and he has constructed such good ones, that I am sure, they will always and without error serve to show the Moon's motion. If this is really so, I have won the whole game'. But there was a further difficulty frustrating his victory, so Swedenborg told Benzelius: he could not convince the British that his lunar method was of value. If so, he would be forced to leave for France, where Paris mathematicians could better judge its value. Back in late 1711, when he formulated his longitude method, he had planned to stay in London for three more years; but now in 1712 he planned his departure.[41] His financial troubles stayed acute, prompting complaints about his father's failure to send adequate funds. When William Whiston's advertisement for his rocketry scheme for longitude at sea appeared in the London newspapers, Swedenborg reported that 'Whiston has given out that he has discovered the longitude; for this reason I wish to make haste with mine. This man has written on astronomy', he sneered, 'but has never before invented anything'.[42] But by the end of 1712 he'd left London and would not return to Britain for almost three decades.

The longitude scheme that Swedenborg formulated in London and would then publish in various versions over the next half century differed rather little from the range of lunar distance methods astronomers had propounded since the initial account proposed by the Nuremberg priest Johann Werner in his 1514 writings on mathematical geography, then widely publicized in Peter Apian's much reprinted cosmography from 1524. These Renaissance cosmographers argued that if lunar places against the fixed stars (later to be known as 'lunars') were predictable and celestial angles measured with enough precision, then it would be possible to determine longitude from the changing distance between the Moon and select zodiacal stars. Just as these scholars had first studied the means through which terrestrial longitude could be ascertained through observation of lunar eclipses, then extended these principles to the determination of longitude at sea by the observation of the changing apparent distances between the Moon and select fixed stars, so

Swedenborg first tried the derivation of longitude from eclipses before he formulated his lunar distance method for maritime longitude.[43]

In early versions of his scheme, Swedenborg summarized the failings of all prior longitude projects: pendulum clocks, water clocks and sand glasses were unreliable; dead reckoning could easily err; rocketry and signaling such as that suggested by Whiston was utterly hopeless. He mentioned and dismissed magnetic schemes, such as those of the mid-seventeenth century Jesuit masters Athanasius Kircher and Giovanni Battista Riccioli. He owned copies of Kircher's treatise on the magnet (1643) and Riccioli's massive work on astronomy, the *Almagestum novum* (1651). Kircher had launched a vast geographical plan from Rome to turn the Jesuit network into a system of magnetic data gathering intending that regular patterns in compass variation could help determine ship's places at sea. Riccioli in Bologna was rather peremptorily ordered to join the enterprise. In 1646 Kircher printed a magnificent Catholic Horoscope that showed the local times of Jesuit missions across the globe, remarking that 'nothing's easier to understand than the theory of longitude, while nothing's harder than to determine it, so that it can not unreasonably be called a Gordian knot that each and every mathematician has made great efforts to untie, but in which not one of whom has succeeded'. He dismissed almost all lunar methods for longitude as either fallacious or too complex, claiming that 'whoever discovered this method would have to be regarded as having achieved no less a task than if he'd squared the circle'.[44] His colleague and rival Riccioli echoed these sentiments, summarizing most prior longitude methods and the many errors of parallax and instrument design committed by Werner, Apian, and their successors, noting that a reliable clock would solve the problem but was as yet utterly unachievable, and, like Kircher, thus backing the more tractable methods of magnetic geography.[45]

As Swedenborg later recalled, 'in my youth I applied my mind for some time to the science of astronomy, and for that purpose studied Riccioli, where I saw that the methods of several learned men for finding the longitude by means of the Moon had been examined, but condemned on account of the difficulty presented by the parallaxes, or by the reduction of the moon as it was observed, or seen apparently, to its true position'.[46] The problems canvassed by Riccioli were certainly known in Uppsala and discussed there in the 1710 dissertation on maritime longitude. At least one of his critics spotted Swedenborg's consistent reliance on the Jesuit's work.[47] He followed the Jesuit in summarizing the astronomical methods, especially eclipses, which though viable on land would fail on board ship since for the Moon these would be too infrequent while Jupiter's satellites 'can only be seen with telescopes, and when all is still and perfectly at rest'.[48] Indeed he confessed that the track record of consistent failures in what he called this 'new Olympic game' might give his audience 'reasons for overthrowing and demolishing the thoughts and imaginations that I have embraced with respect to this method, and also to give others a strong prejudice that no such method can any longer be discovered'. In this sense, Swedenborg was able to argue, the establishment of a maritime longitude method resembled the accomplishment of ancient prophecy. He noted that Kircher and Riccioli 'conclude their investigations with the wish and hope that in time some one will come forward who will show how to observe and point out the Moon without these obstacles and difficulties: him they call by anticipation, the *Discoverer of the Longitude*'. Swedenborg put himself forward as this prophetic Discoverer.[49]

The Discoverer's strategy was then massively to oversimplify the principles on which the method of lunar distances could be made to work and to avoid any method in which the Moon must pass in front of a given star. Rather, he proposed selecting two stars whose position was known; mark the local time when the Moon was in the same line as the two stars; observe its altitude with a quadrant, and from a parallax table work out the true lunar position **(see figure 1)**. Were an almanac available that provided times at a fixed meridian for each lunar position, the longitude could then be derived by trigonometry. 'I feel assured that the longitude of places can be found by this method, and as yet I see no reason that can overthrow and demolish this assurance, save the uncertainty of the astronomical tables of the motion of the Moon. This cannot be taken as any reason whatever since, so far as I know, no astronomer has yet used it to overthrow earlier investigators who sought to find the celestial and terrestrial longitudes by means of the Moon'.[50] He initially reckoned that it would be best to observe between twenty and fifty star pairs, that ordinary instruments 'used by sailors for taking altitudes and distances' would suffice, that observations should be made far from the horizon lest refraction disturb the observation, and that 'any able seaman ought to be able to take the time from the sun at noon and from the northern stars' by calibrating his watch against a clepsydra or sandglass.[51]

This was of course an entirely utopian if not illusory scheme. Its author was aware of the visionary quality of the proposal, if not entirely of its errors. He'd apparently neglected the problem of the Moon's latitude and assumed that the difference between the moon's true position and its observed place on the ecliptic was the same as its parallax, he'd severely underestimated the difficulty of angular observation and, obviously, he'd simply taken it for granted that adequate astronomical tables and almanacs would be available. 'Before one can put our invention into practice, one must have accurate and sufficient tables of the longitudes, latitudes, right ascensions and declinations of all the stars. One awaits these from the learned and experienced Flamsteed in England'.[52] The essence of Swedenborg's vision was that if any such a method were feasible, then the one he'd proposed must work, but there was as yet no means of showing this in practice. He would much later declare that 'if it is feasible to get the longitude by means of the Moon and stars, this is the only way; moreover, it has the advantage that it can be used every night when the Moon and stars shine. Until ephemerides are made for 20 to 30 stars and for every month of the year, and this for three or four years, and then put into practice, no approbation can be expected from abroad'.[53] It was unsurprising his scheme found no welcome in Newton's London in 1711-12 nor in Maskelyne's London in 1766-8. More striking was his life-long commitment to the scheme and thus to the status of Discoverer.

In the wake of the frustration of his ambitions in Augustan Britain, Swedenborg adopted a number of connected strategies to further both his repute and his longitude project. A frequent traveller on diplomatic and technical missions, he continued active studies of the range of methods and hardware on show across western European institutions. In early 1713 he was in the Netherlands during the negotiations that terminated the war between France and its enemies at the Treaty of Utrecht. In contact with the Swedish ambassador Johan Palmqvist and his secretary Joachim Fredrik Preis, he discussed his mathematical projects, learnt celebrated Dutch techniques of lens grinding, and visited the Leiden observatory, then managed by the instrument maker Jan van Musschenbroek. The observatory was an important stop on the journeys of learned travelers: Uffenbach, for example, had also been there a couple of years before, and noted the great wooden quadrant originally made by Willem Blaeu in the early seventeenth century. In 1705 the Amsterdam maker

Coenraad Metz had been commissioned to build a new two-foot brass quadrant equipped with a pair of telescopes and a pointer of Hooke's design allowing readings of high accuracy.[54] Swedenborg recorded the very high cost and efficient use of this new instrument, which he so admired that he intended (but never managed) to use it for his lunar project.[55] In Paris later in 1713 he confirmed his intention to pursue longitude work further, presented an outline of his scheme to the eminent Jean-Paul Bignon, president of the Royal Academy of Sciences, and met the Academy's principal mathematicians, Philippe de la Hire and Pierre Varignon, who was given a copy of Swedenborg's longitude method by Bignon. Varignon was an interesting choice to evaluate the Swedish longitude scheme: a protagonist of Leibnizian analysis and a significant agent in the calculus dispute, in summer 1713 he expressed his anger at the assaults of British mathematicians, but in autumn 1713 gratefully received a copy of the new edition of *Principia mathematica* from Newton and by the following year had won election to the Royal Society.[56]

Swedenborg thus became aware of the intense Anglo-French rivalry in mathematics, and of the comparative weakness of the French scientific publishing trade. These discussions prompted him to propose printing the longitude methods 'that I may communicate them more easily to the learned', at least in a highly abbreviated version.[57] He was already well aware of the challenge of establishing and then communicating his project, and was entirely convinced of the need for new more potent resources: 'My Method for finding the Longitude is contained on small scraps of paper', he told Benzelius. 'I gave only a few outlines and points of it in Paris, so that those who wished to see it, and to understand how it operated, could acquire some knowledge of it. But as I had no observations by which I could confirm it, I thought I would let it rest, until I had worked it out fully, and had confirmed it by observations; lest I might lose all my trouble, as well as any reward I might expect from it. I am afraid I might bring forth blind whelps, if I produced it before its proper time.'[58]

Lacking such resources, Swedenborg tried to keep abreast of publications on methods for longitude at sea. In London and Paris in 1710-13, he'd not at all been working in a world with an officially sanctioned reward for longitude at sea. But after the passage of the first Longitude Act in 1714, a host of pamphlets and schemes went to press seeking validation and reward from the new Commissioners, Halley and Newton among them.[59] Back in Sweden, Swedenborg got hold of a Latin treatise by the Venetian military and naval writer Dorotheo Alimari, *Longitudinis aut terra aut mari investiganda methodus*. Alimari's technique was first presented in summer 1714 to the new longitude Commissioners in London by his collaborator the fashionable Venetian painter Sebastiano Ricci, then in England to execute works for a range of wealthy Whig patrons. The Venetians summarized their scheme in parallel Latin and English texts in a brief and badly printed pamphlet, before releasing the complete Latin treatise at the start of 1715 with images of navigational instruments, solar tables and an added method for predicting the time of the tides. Alimari's scheme relied on manufacturing an extremely exact almanac for a given meridian and to make observations of the Sun's local position to compare with the almanac. He reckoned that since mariners might not be expert enough to fulfill these demands, an accurate clock would serve their purpose. Swedenborg (like Flamsteed) bluntly dismissed the project as 'speculation and nothing more: the difficulty of reducing it to practice is immense'.[60]

Metropolitan instrument and publishing networks continued to exert their power over Swedenborg's plans. He was also sent from London a copy of *Methodus inveniendi Longitudinem Meridianorum* (1726), a work by a Jena writer Johann Biester, who'd come to the British capital to present his scheme for discovering longitude by observing the Moon's distance from a known star as it crossed the meridian. Biester called on Newton, told the aging mathematician that he would willingly compare his lunar theory with Halley's data, and added proposals to observe the eclipses of Jupiter's moons using a *portatoris*, an instrument set on bearings, which could be obtained from a Tower Hill instrument maker. He later lobbied the Royal Society for approval of his lunar meridian scheme.[61] As Richard Dunn has noted, it was Biester's project that prompted the Pennsylvania judge James Logan to tell Halley in 1732 of a local glazier Thomas Godfrey's remarkable invention of a sea quadrant equipped with a double reflector, a device crucial for taking lunars on board ship. According to Logan, 'Dr. Biester's late Proposal of a Method for taking the Difference of Right Ascension between the Moon and a Star, if that should prove practicable with sufficient Exactness, would undoubtedly Answer the intention of all that is to be expected from the Moon, if her place were taken on or near the

Meridian'. But simultaneous sighting of Moon and star in the meridian with accuracy and ease was a real challenge, and this was exactly the task the new-fangled quadrant might accomplish. Once again, Swedenborg was entirely unimpressed by Biester's scheme: it was hard to time the transit of the Moon across the meridian, especially at sea; and 'it is just as difficult to get the parallax there correctly as in any other place'.[62]

These unsuccessful schemes reinforced the fact that longitude project would require the mobilization of the entire resources of a group of instrument makers and astronomers like those present in London, and the commitment of a specialist observatory to generate an adequate almanac. In the years after his return from his first European tour, Swedenborg sought to use his rapid if fragile acquisition of authority in the Swedish public administrative system to set up such an institution. In a manner comparable with the ambitions of London and Paris projectors in search of crown patronage, Swedenborg canvassed mechanical and mathematical projects partly drawn from his British experiences, such as ship designs and steam engines, to be pursued in close collaboration with the master mechanic Christopher Polhem, whom he'd already hoped would manufacture a supremely precise brass quadrant. In 1714 on his way back to Sweden from France, Swedenborg compiled lists of such projects, revised his longitude scheme, and planned a mathematical society to publicize Polhem's enterprises.[63] In 1716 he launched a vernacular journal, *Daedalus hyperboreus*, to publicize this work, and won decisive royal patronage, notably through extraordinary appointment to the Swedish Bureau of Mines, for which, despite evident resistance from existing expert Bureau members to this official intrusion of an inexperienced upstart well below the age at which assessors were normally appointed, he was ordered to pursue his work with Polhem.[64]

The Bureau became a characteristically cameralist regulatory body that oversaw the state's invaluable copper and iron industries, furnished with chemical and mechanical laboratories and a large team of administrators. Hjalmar Fors shows how the Bureau eventually provided key resources for Swedenborg's work in mineralogy, chemistry and natural history, while Svante Lindqvist has demonstrated that the Bureau's network included lobbies about new engine designs from several Swedish agents in England such as Swedenborg's contact the entrepreneur Jonas Alström and the enthusiastic young natural philosopher Martin Triewald.[65] For these protagonists, the question of the higher social status of mathematical and philosophical theory with respect to more plebeian forms of engineering and instrument design was moot. The tension between theory and practice was all too evident in the longitude project as well. The new government official Swedenborg certainly showed the details of his longitude scheme to Polhem, who identified problems with the range of lunar methods involving eclipses, meridian position or parallax: 'a plan that pretends to perfection in this matter is certainly entitled to a hearing', responded the great engineer, 'it is therefore well worth following out these things a little more, if not for the sake of gain, at least for that of curiosity'.[66]

Swedenborg at once understood the link between his longitude scheme and the need for a dedicated observatory: he projected a kind of Swedish Uraniborg or Greenwich. Uppsala University scarcely met this need. The University library held a carefully preserved if rarely used set of instruments, including telescopes and quadrants.[67] In summer 1715 Swedenborg mentioned his need to study these instruments and described his plans to survey a suitable rural and elevated site for his observatory 'where I intend toward winter to make some observations belonging to our meridian, and to lay the foundation for the observations whereby my invention about the longitude of places could be confirmed'. He waxed lyrical about the prospects of his observatory site: 'he who dwells on that height may appear to be its Jupiter and the hill a small Olympus and heaven, as the nature of the air has partly its origin thence. In a word, it is a height which Nature has intended as the most unique observatory in the world, were there only men like Cassini, Tycho, or Hevelius who would give their name and fame to it.'[68]

His father Bishop Svedberg at once reported to the royal court on these observatory plans and their promise for maritime longitude, 'a discovery on which many rulers have provided great sums of money for the person who should find it'. Cash proved crucial. At Uppsala, Benzelius also backed the observatory plan: by spring 1716 measures had been taken to fix an astronomical site at a castle tower in the town and fund instruments by establishing a lucrative monopoly on almanac production.[69] Swedenborg was delighted, proposing presenting the plans to the King, along with models of overseas observatories such as those at Leiden or Greenwich.

Charles XII and his troops were at the same time preoccupied with war in Norway, and by summer 1716 the plan had stalled.[70] Over the winter of 1716-17, Swedenborg therefore drafted a new four-page memorandum on the virtues of a new Swedish observatory: he summarized the staffing and design of other European observatories, and stressed the advantages of such an institution in the north, its tasks to include magnetic dip and variation, charts of the fixed stars, and determination of parallax.[71]

It was at this same moment, too, in discussion with Polhem, that Swedenborg decided at last to publish his longitude scheme, as an essay in the fourth number of his *Daedalus hyperboreus*. It was complete by the end of 1716 and released in spring 1717. It soon received a brief but laudatory mention in an Uppsala astronomical dissertation on the planet Venus by one of Elvius' students, Birger Vassenius, whom Swedenborg then sought to patronize.[72] This was the first reference in print to Swedenborg's status as a learned author. The longitude paper and the observatory project were supposed to sustain each other. During the first half of 1717, Swedenborg relaunched his observatory proposal for the crown, but met with hostility from the royal officials and frustration at the university.[73] The longitude plan might save the day. Swedenborg and Benzelius planned to produce a very much enlarged and separate longitude treatise. By April 1718 it was published at Uppsala with a politic dedication to Halley, 'who has also done something in this subject'. A copy was apparently presented to the King, who was then about to launch his renewed and fatal Norwegian campaign. Swedenborg maintained mathematical discussions with the King, and in September 1718 showed him a lunar eclipse that they observed together.[74]

Though Charles XII's death and eventual regime change in the early decades of the Age of Liberty had somewhat adverse implications for his client, Swedenborg and his closest colleagues sought to ensure wider publicity for these practical ambitions. Benzelius arranged for the mathematician Erik Burman, secretary of the Uppsala Literary Society, to give a laudatory review of the scheme in the Society's new journal, *Acta literaria Sueciae*. Burman was a keen correspondent of the Royal Society of London and lectured in Uppsala on Whiston's version of Newtonian lunar and planetary astronomy. Swedenborg counseled these allies on the best way to discuss the theory: 'I wish that it be done with some care, so that it may find favour abroad, especially since it can be of such great use to the public; I am sure that, in some respects, this is the easiest method among those that have been invented'. The following year a summary also appeared in the new Leipzig journal, *Neue Zeitungen von gelehrten Sachen*, a publication designed to offer rapid summaries of learned print through the Republic of Letters.[75] From then on, his longitude project turned into but one aspect of an increasingly prolific and highly charged programme of cosmological and natural philosophical writing.

Swedenborg's attempt publicly to offer a revised version of his longitude project to the learned world, first promised to Benzelius from Paris back in 1713, was at last launched in spring 1721: he turned the Swedish text into a briefer Latin pamphlet of about 50 pages in octavo, published in Amsterdam in October of that year as *Methodus nova inveniendi Longitudines locorum terra marique ope lunae*, and reprinted there some years later. He'd been in the Dutch city since July as part of a journey through the Netherlands and the German lands to inspect mines and metal works, mineralogical deposits and chemical laboratories, and to conduct discreet political lobbying with German princes as Sweden entered a diplomatically critical phase following the conclusion of the war with Russia and the loss of all its Baltic provinces to tsar Peter's regime. The pamphlet was accompanied by essays on a range of maritime and hydraulic projects he'd pursued in Sweden since 1715, including dams, dry docks, and the testing of ship models. The *Methodus* was crafted for erudite readers, omitting many of the simpler explanatory passages of the original Swedish-language version. Like that earlier version, it was noticed in Leipzig journals, and also won a full summary in the prestigious *Acta eruditorum*, chief organ of the republic of letters. Swedenborg presented copies both to his old friend Preis, now the Swedish ambassador in the Netherlands, and to Hermann Boerhaave, doyen of medical chemists, with whom he studied in Leiden.[76]

A copy also reached the mathematics professor at Lund, Conrad Quensel, who published a brief critique of the method, insisting that the parallax of lunar longitude was not the same as the difference between the Moon's true position and its apparent position on the ecliptic. 'If navigators were content with this, they themselves will judge whether a knowledge of the longitudes sufficient to meet their desires is to be obtained by this method', Quensel waspishly remarked, concluding that perhaps partial advance was better than complete ignorance: 'the day, even though cloudy, is better than mere nocturnal darkness'. Swedenborg answered the Lund professor when he returned to Sweden in 1722: 'in the present case, since the facility of the new Method consists mainly in the fact that only one parallax, the parallax in longitude, is desired, seconds are ignored, but not minutes'. He was forced to explain that his Latin method had necessarily omitted clarifications for the less erudite readership present in the original Swedish version, 'lest, as I have already said, by minute details he obscure a matter which otherwise is clear', and though his Amsterdam pamphlet promised both observations of the longitude by his method, as well as a complete almanac, none were to be forthcoming.[77]

Swedenborg never again devoted much literary effort nor astronomical labour to this enterprise. Indeed, his hopes of finding a longitude method seemed somewhat to switch back to the original magnetic schemes he'd read in Kircher and Riccioli and debated with Halley. He began energetically to make himself a cosmological authority and mineralogical expert, formulating an entire world-system forged both from his own field work through the Bureau of Mines and his increasingly bold theories of the origin and fate of the globe. He turned himself into the heir of the great Uppsala naturalist and medical professor Olaus Rudbeck, whose four-volume work *Atlantica* (1675-1702) had set out in astonishing details the arguments for the primordial Nordic paradise and Swedish as the original Adamic language. Leibnizian models of vortex motion and celestial physics provided crucial resources for Swedenborg's ambitious new cosmology; so, too, did the English tradition of physico-theology he had first encountered through the responses to Burnet of Woodward, Whiston, Halley and their associates in London. Theories of planetary movement and the shape and history of the Earth fitted into these schemes.[78]

In 1717, just as he published the first Swedish version of the longitude essay, Swedenborg also drafted 'A new theory about the retardation of the Earth', which argued that the Earth was gradually diminishing in size and slowing down its orbit because of ether resistance, themes Halley had canvassed in the 1690s. Most significantly, Swedenborg inferred from this retardation the existence of a primeval paradise of perpetual spring, when the Earth was a perfect sphere rotating rapidly, a model consistent with Burnet's own visions of the 1680s, a copy of which he owned.[79] These doctrines were then developed in two substantial essays of early 1719, on 'the motion and position of the Earth and planets' and 'on 'the height of waters and strong tides in the primeval world', which set out the history of a primeval paradise, when Sweden was an Atlantean island, a gradually slowing and diminishing Earth flattening at the poles, and a change in the length of the meridians. This would help explain the Deluge and the eventual apocalypse of cold and famine when all life would be extinguished.[80]

None of this was unusually visionary or heterodox: indeed, in the first printed reference to Swedenborg's writings outside Sweden, the Lübeck priest Jacob van Melle swiftly pointed out how much this cosmology owed to such writers as Woodward and the eminent Swiss professor Johann Jakob Scheuzer, who'd written at length on the relics of the Deluge in the marine deposits found on high mountains, and offered comparably naturalistic accounts of the process of eschatology and decay.[81] Swedenborg told Benzelius in late 1719 that Newton's *Principia mathematica* explained how as a planet slowed it would move nearer the Sun and sought to reconcile this with his vortex theory of celestial motions. The two colleagues also discussed the recently published views of a Kentish parson, Tobias Swinden, who had argued for the Sun as the site of Hell. Swedenborg insisted that changes in the terrestrial vortex were evidenced by the changes in the shape of the horizon, that the apocalypse would be caused by the near approach of the Earth to the Sun, and that 'there are more grounds for believing that God has His seat in the Sun', where the elements were in a more refined and spiritual state.[82] Thus Swedenborg's astronomy began to be absorbed into a much more ambitious cosmology of spiritual and eschatological significance. By the time he reached Amsterdam in 1721 to publish his Latin longitude essay, he was simultaneously concerned with a fuller development of these views about material composition and divine judgment. No doubt this project was much aided by the telling combination of his energetic work for the Bureau of Mines in Sweden, and his frequent journeys across northern Europe, especially to Amsterdam and London, as diplomatic agent and inspector.

These activities helped nourish Swedenborg's cosmological works, in which his readings of and debates with the natural philosophical tradition were put before the public. The most significant of these was certainly his *Principia rerum naturalium*

(1734), a vastly ambitious attempt to produce a universal cosmology of mechanical motion, including discussion of the movements of the planets and the plurality of worlds, the origin of the solar system and the formation of the Earth. Swedenborg added long treatises on the magnetic cosmology, reprinted Athanasius Kircher's tables of magnetic variation, adding several eighteenth century geomagnetic surveys as well as Edmond Halley's chart of magnetic variation across the globe.[83] Magnetic schemes for longitude flourished in the wake of the Longitude act, and Swedenborg was entirely representative in devoting attention to this alternative method for determining position at sea. For example, in a speech on astronomy and navigation at the Swedish Royal Academy of Sciences, the Uppsala astronomy professor Mårten Strömer set out the various longitude methods, pointed out the difficulties of observing Jupiter's moons at sea, entirely ignored horological techniques, and instead backed a geomagnetic scheme.[84] Swedenborg attempted to construct an algorithm to predict the variation at any place, and he questioned the prestigious experiments published in the *Philosophical transactions* by the eminent London instrument maker George Graham, who had demonstrated dramatic temporal changes in the magnetic variation at London. Swedenborg insisted instead that were the variation well mapped, as Halley had so impressively attempted, then 'the longitude of places, which is so much sought after and desired, would be determined thereby, to the great advantage of navigation, geodesy, and geography. In that case also the unnecessary talk and controversies about the inconstant nature of the course and progress of magnetic variation, and many other things that unnecessarily worry and disturb the experiments of the learned, and obstruct an advance, would cease'.[85]

Swedenborg's magnetic geography drew extremely hostile comments in Stockholm from his astronomical nemesis, the precocious Uppsala professor Anders Celsius, protagonist of the celebrated survey expedition to Lapland in 1735 to determine the length of a degree and the figure of the Earth, for which Graham had supplied invaluable instrumentation. Celsius worked in London to commission these instruments, met both Sloane and Halley, joined the Royal Society, then promoted teaching of Newtonian astronomy at Uppsala. His collaborator, the brilliant instrument maker Daniel Ekström, trained in London under Graham in 1739-40 as well as visiting Halley's observatory at Greenwich. Celsius then rapidly achieved the institutional success that neither Benzelius nor Swedenborg had managed more than two decades earlier under the absolute monarchy. In 1738 he raised cash for an observatory, next year issued a manifesto for its public utility in tasks such as longitude determination, then opened the Uppsala establishment equipped with fine quadrants and pendulum clocks in 1741.[86] Alongside his publication of a nautical almanac, Celsius staged at Graham's direct prompting a series of trials reported to the new Royal Academy of Sciences to show how magnetic variation changed with time, thus ruled against its predictability or its use in maritime longitude. He charged Swedenborg with errors in astronomical calculation and pointedly praised Halley's magnetic expertise, noting the startling differences between Swedenborg's and Halley's theories. Swedenborg bluntly riposted that it would still be worth computing a table of variation for every five degrees of longitude across the globe and that 'it might be determined thereby as well by land as by sea under what degree in an eastern or western direction any one is or sails'.[87]

Little of Swedenborg's astronomical standing survived this controversy at the Royal Academy. But the final sections of Swedenborg's great work drew on his impressive experience as assessor for the Bureau of Mines, with detailed accounts of the iron and copper works of Sweden and other nations. The book received reviews and critiques across learned Europe, and was sent to London by the British ambassador in Sweden Edward Finch Hatton. In late 1737 it was reviewed at the Royal Society by the financier and timber merchant James Theobald, a virtuoso with considerable Baltic interests, whose review concentrated almost entirely on the fascinating account of metallurgy and mining.[88] The Royal Society's secretary, the physician Cromwell Mortimer, also praised the Swedish expert's work on metallurgy, and the Swedish government's policy of dispatching inspectors overseas to inspect such works abroad. In 1742 the first of Swedenborg's writings to appear in English were published in a collection dedicated to Martin Folkes, president of the Royal Society, including a version of his argument about the evidence of the Deluge. And when Swedenborg returned to London two years later, Mortimer presented him in person at the Royal Society, while in spring 1745 both Mortimer and Folkes welcomed Swedenborg and arranged for a report on his work in natural history to be provided to the Society.[89] Thus at the very moment of his great spiritual revelation, in April 1745 commissioned to interpret Scripture speak to humanity on behalf of God after a visionary experience at dinner in a London tavern, Swedenborg was also at the centre of the milieu of natural philosophical debate. And this milieu was peculiarly concerned with the question of longitude. Folkes was of course a major patron of John Harrison's clock-work, promoter of the new Copley Medal system at the Society, and presidential eulogist at the award of the Society's Copley medal to Harrison in 1749.[90]

The Harrison affair reached its significant climax in the early 1760s, culminating in the Barbados sea trial of March-June 1764. His clocks had already become major objects of foreign interest: French and other experts came to witness the achievement. Swedenborg remarked of the success of Harrison's marine chronometer that 'time will perhaps determine and settle this, for Holland, France and Spain will, with their own masters, make an independent trial of this clock on voyages to the East Indies'. In 1759-60, as Jakob Orrje has pointed out, the Uppsala astronomer Bengt Ferrner visited Harrison to view his chronometer H4, met the instrument makers James Short and John Bird, as well as Jeremiah Sisson, who showed him a set up of Christopher Irwin's notorious 'balance chair', an equilibrium device intended to stabilize astronomical observations for longitude at sea.[91] In autumn 1765 the Swedish ambassador in London sent home a report on Harrison's machines, and in early 1766 the Paris clockmaker Ferdinand Berthoud was in London privately to negotiate with Harrison and with Thomas Mudge for details of its workings.[92] Back in Stockholm, this was when Swedenborg planned one last edition of his longitude work. He discussed the project with Celsius' student the astronomer Pehr Wargentin, secretary of the Academy of Sciences, manager of the well-equipped Stockholm Observatory, and an especial expert on the movements of Jupiter's moons. In July 1766 Wargentin contributed his satellite tables to Maskelyne's plans for an astronomical ephemeris for longitude. He simply dismissed Swedenborg's proposal: 'he has not read anything fresher than what Riccioli has written', Wargentin sneered, remarking sarcastically that 'one could expect something better from one who knows heavenly secrets and can ask the spirits about everything'.[93]

Swedenborg was not deterred, and in spring 1766 sent copies to academies in Paris and Berlin, Copenhagen and Amsterdam. On 19 May 1766 he was in London in person to give a copy to the Royal Society's president James Douglas, Earl of Morton, an enthusiastic astronomer, promoter of the Society's control over Greenwich and chief patron of the Transit of Venus project. This was exactly when

Maskelyne and his colleagues the clockmaker Larcum Kendall and the Board's secretary John Ibbetson took Harrison's watch to Greenwich to start its ten months of strenuous land trials at the Observatory. At the next meeting of the Board of Longitude, on 24 May, Kendall was charged with making a copy of the marine chronometer for trial at sea, while Maskelyne was ordered to publish his notes on the 'discovery of the principles of Mr Harrison's time keeper'. According to Swedenborg, he also attended the Admiralty on that day, passed a copy of his own longitude scheme to Ibbetson, who showed his work to the Board members.[94] There's no record of Swedenborg's pamphlet at that meeting, but, as we know, over two years later Maskelyne did indeed report on its contents, in characteristically dismissive terms.[95]

Swedenborg himself seems finally to have recognized the implications of the Board's activities. When quizzed by the Lund astronomy professor Nils Schenmark with the familiar problems that he had ignored effects of refraction, had assumed the Moon was on the ecliptic and thus with zero latitude, and had thus confused the question of parallax, the eighty year old Swedenborg confessed that 'my thoughts are now far removed from that study' so could not give details, insisted that a common cross staff would be enough to determine the local time, and admitted that since he'd never provided 'any practical rules which depend on ephemerides, it could not be used by seafaring men'. He was also now aware that Maskelyne was preparing a nautical almanac that would serve precisely this function. 'As soon as these ephemerides are constructed, the correctness of the method will appear', Swedenborg prophesied. In 1766, the same year as Swedenborg's unsuccessful presentation to the Board of Longitude, Maskelyne's *Nautical Almanac* and its accompanying *Tables requisite* appeared in print.[96]

This story cannot end with these rival if somewhat complementary publications of 1766. It is striking that Swedenborg also presented a series of his explicitly visionary works to the Royal Society of London: *The Wisdom of Angels concerning Divine Love and Divine Wisdom* (1763) presented in summer 1764; *A brief exposition of the doctrine of the New Church*, *The interaction of the soul and the body*, and *The delights of wisdom relating to conjugial love*, published from 1768, all offered to the Society in 1769.[97] These works contained much of importance to the concerns of cosmology and natural philosophy, and to Swedenborg's lifelong engagement with their improvement. *Divine Love and Divine Wisdom* reported, for example, a posthumous conversation in heaven between two past presidents of the Society, Sloane and Folkes, about whether Nature or Deity produced life on Earth, with his friend Martin Folkes adopting the pious position, and Hans Sloane eventually convinced by a spiritual vision that materialism was false.[98] He also recorded an exchange between Isaac Newton and the angels about the void, during which the Royal Society's late President was convinced of the plenum: 'Newton said that he knew that the Divine which is, filleth all things'.[99] This was certainly not an uncommon eighteenth century conceit: many Augustan writers envisaged the great astronomer in heaven, in conversation with angels, debating the true system of the world. Swedenborg was unusual only in the specificity of his doctrine and the immediate mode through which he reported these chats. In his spiritual diary for 1763, he recorded that in fact he'd spoken with the celestial Newton several times, learnt he'd retracted his optical theories as well as his commitment to a vacuum, and now accepted that 'The Lord is the Sun of the angelic heaven'.[100]

By the mid-eighteenth century, Swedenborg's astronomically proficient readers such as Celsius, Schenmark, Wargentin and Maskelyne judged his longitude project redolent of Baroque cosmology's notions of lunar and magnetic actions. The project did not stand outside the realm of reason. This raises questions about the fraught relationships between the sage's natural philosophical and astronomical expertise and the ambitions of his spiritual programme. A properly enlightened religion, it was urged, should explicitly forge connexions with the reasons of the sciences. Perhaps most suggestive is the sole appearance of the term *Longitudo* in *Divine Love and Divine Wisdom*, in the decisive passage about spiritual space so admiringly annotated by William Blake. Swedenborg explained how natural humanity was confined to thinking within geometrical space, so could scarcely imagine the heavenly world. Spiritual beings thought not in terms of mere mundane length and breadth, but in terms of the correspondent principles of celestial virtue and truth. Thus an Angel 'thinks from the correspondence which is between things spiritual and natural, from which correspondence it is, that length (*Longitudo*) in the Word of God signifies the Good of a Thing'.[101] It was not entirely strange that in this work, offered in the 1760s to the London astronomers, Swedenborg explained with unusual spiritual clarity that Longitude, properly understood, signified the Heavenly Good.

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[1] Alfred Acton, *Life of Swedenborg* (Bryn Athyn, 1958), 125.

[2] RGO MSS 14/5 fol. 87. Maskelyne's judgment was first noticed in Wertha Pendleton Cole, 'Swedenborg's work on longitude', *The new philosophy* 36 (1933), 169-78 (177).

[3] Emanuel Swedenborg, *Wisdom of Angels concerning Divine Love and Divine Wisdom* (London, 1788), 57-8; Geoffrey Keynes (ed.), *William Blake: complete writings* (Oxford, 1966), 92; Clark Garrett, 'Swedenborg and the mystical enlightenment in eighteenth century England', *Journal of the history of ideas* 45 (1984), 67-81.

[4] R.L.Tafel (ed.), *Documents concerning the life and character of Emanuel Swedenborg*, 2 vols. (London, 1875), I, 218.

[5] Owen Gingerich, 'Cranks and opportunists: 'nutty' solutions to the longitude problem', in *The quest for longitude*, edited by William J. H. Andrewes (Cambridge, Mass., 1996), 133-48. For longitude as a problem of orientation, see David Dúner, *The natural philosophy of Emanuel Swedenborg: a study in the conceptual metaphors of the mechanistic world-view* (Dordrecht, 2013), 50-7.

[6] Alfred Acton (ed.), *Letters and memorials of Emanuel Swedenborg* (Bryn Athyn, 1948), 3.

[7] Lars Engwall, 'From Collegium Curiosorum to Royal Society', in *Scholars in Action: Past-Present-Future*, edited by Lars Engwall (Uppsala, 2012), 17-27 (18-19).

[8] Ernst Benz, *Emanuel Swedenborg: visionary savant in the Age of Reason* (West Chester, Pa., 2002), 29-44, and Francesca Maria Crasta, *La filosofia della natura di*

Emanuel Swedenborg (Milan, 1999), 33-36, describe these fights as part of Swedenborg's milieu in London.

[9] Marsha Keith Schuchard, *Emanuel Swedenborg: secret agent on Earth and in heaven* (Leiden, 2011), 38.

[10] James A. Bennett, 'Shopping for instruments in Paris and London', in *Merchants and marvels*, edited by Pamela H. Smith and Paula Findlen (London, 2002), 370-95 (374-5). For the London practical experimental scene at this period, see Larry Stewart, *The rise of public science* (Cambridge, 1992), 166-75. For a very comparable Swedish tour of London instrument shops, clubs and observatories by the astronomer Bengt Ferrner in 1759-60, see Jacob Orrje, *Navigating the neighbourhoods of longitude* (M Phil dissertation, Department of History and Philosophy of Science, University of Cambridge, 2011).

[11] J.E.B.Mayor (ed.), *Cambridge under Queen Anne* (Cambridge, 1911), 356-7, 361-2, 366-7, 404-5.

[12] Mayor (note 11), 351.

[13] Tafel (note 4), I, 212, 216.

[14] Tafel (note 4), I, 208.

[15] Tafel (note 4), I, 208, 219; for the library catalogue see Lars Bergquist, *Swedenborg's secret: a biography* (London, 2005), 492.

[16] Acton (note 1) , 14; Tafel (note 4), I, 216, 219.

[17] Tafel (note 4), I, 210.

[18] Tafel (note 4), I, 225.

[19] Tafel (note 4), I, 211.

[20] Tafel (note 4), I, 214.

[21] Tafel (note 4), I, 224-5. For Swedenborg and Savery, see Svante Lindqvist, *Technology on trial: the introduction of steam power technology into Sweden, 1715-1736* (Uppsala, 1984), 119.

[22] Tafel (note 4), I, 225. For Leibniz's attack in May 1712 and Newton's furious response see A.R.Hall, *Philosophers at war: the quarrel between Newton and Leibniz* (Cambridge, 1980), 184.

[23] [Per Elvius], *De longitudine geographica dissertatio…pro gradu…Andreas Duraeus* (Uppsala, 1710), 12, 19-21, 26-30.

[24] Mayor, *Cambridge*, 392.

[25] Edmond Halley, 'Design and use of the foregoing observations', in Thomas Streete, *Astronomia Carolina*, 2nd ed. (London, 1710), appendix, 67-70. The work and its appendix on longitude were advertised in *The Post Man* on 23 February 1710.

[26] Tafel (note 4), I, 220.

[27] Tafel (note 4), I, 211; Alan Cook, *Edmond Halley* (Oxford, 1998), 124.

[28] Tafel (note 4), I, 212.

[29] A.J.Turner, 'In the wake of the Act, but mainly before', in Andrewes (note 5), 116-27 (120); Flamsteed to Burchett, 5 December 1705, in Eric Forbes, Lesley Murdin and Frances Willmoth (eds.), *Correspondence of John Flamsteed*, 3 vols (Bristol, 1995-2002), III, 265.

[30] Tafel (note 4), I, 211.

[31] Tafel (note 4), I, 212-13. Elvius' longitude calculations from eclipse observations made at Bologna and Uppsala in October 1706 are in Elvius (note 23), 29.

[32] Tafel (note 4), I, 215.

[33] Tafel (note 4), I, 575.

[34] Tafel (note 4), I, 219. For the redesign of these devices and Hooke's interest in telescopic sights, see J.A.Bennett, 'Flamsteed's career in astronomy', in *Flamsteed's stars*, edited by Frances Willmoth (Woodbridge, 1997), 17-30 (25-29).

[35] Tafel (note 4), I, 218.

[36] Acton (note 6), 36; Tafel (note 4), I, 228. For Halley's ownership of Swedenborg's works see Schuchard (note 9), 62; for Swedenborg's use of Halley's magnetic chart see Emanuel Swedenborg, *The Principia*, edited by Augustus Clissold, 2 vols (London, 1846), II, 141-3. For Halley's magnetic mapping see Patricia Fara, *Sympathetic attractions* (Princeton, 1996), 109-12.

[37] Simon Schaffer, 'Halley's atheism and the end of the world', *Notes and records of the Royal Society* 32 (1977), 17-40. The theories of the shape of the Earth promoted by Burnet and Newton are discussed briefly and dismissed in [Elvius] (note 23), 2-3.

[38] Tafel (note 4), I, 223.

[39] A.R.Hall and Laura Tilling (eds.), *Correspondence of Isaac Newton* (Cambridge, 1976), VI, 212 and *Correspondence of Isaac Newton* (Cambridge, 1977), VII, 172.

[40] Acton (note 1), 52.

[41] Tafel (note 4), I, 221.

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[42] Tafel (note 4), I, 227. Whiston's advertisement appeared in the *Guardian* on 14 July 1713: see Stewart (note 10), 185-6.

[43] Derek Howse, 'The lunar distance method for longitude', in Andrewes (note 5), 149-61 (151-2).

[44] Athanasius Kircher, *Ars magna lucis et umbrae* (Rome, 1646), 552-3; Michael John Gorman, 'The angel and the compass: Athanasius Kircher's magnetic geography', in *Athanasius Kircher*, edited by Paula Findlen (New York, 2004), 239-59.

[45] Giovanni Battista Riccioli, *Almagestum Novum* (Bologna, 1651), 608-12 and Riccioli, *Geographiae et hydrologiae reformatae* (Bologna, 1659), 325-63. Riccioli mainly relied for his knowledge of navigation methods on Robert Dudley, *Dall'arcana del mare* (Florence, 1645-6), book 1, a work by an English émigré who became naval commander for the Medici regime in Tuscany.

[46] Tafel (note 4), I,591-2.

[47] [Elvius] (note 23), 18-19; N. V. E. Nordenmark, 'Swedenborg och Longitudproblemet, med anledning av ett nyfunnet brev från Wargentin', *Lychnos* (1944-5), 243-8 (248).

[48] Emanuel Swedenborg, 'A new method of finding the longitudes of places' (1721), translated in Swedenborg, *Some specimens of a work on the principles of chemistry*, edited by Charles Edward Strutt (Boston, 1847), 213-27 (218).

[49] Swedenborg (note 48), 215; Acton (note 1), 125.

[50] Acton (note 1), 126; Cole (note 2), 172-3.

[51] Swedenborg (note 48), 226.

[52] Acton (note 1), 125.

[53] Tafel (note 4), I,597.

[54] Huib Zuidervaart, *Telescopes from Leiden Observatory and Other Collections, 1656–1859: a descriptive catalogue* (Leiden, 2007), 26. The earlier Blaeu instrument is described in Zacharias Conrad von Uffenbach, *Merkwürdige Reisen durch Niedersachsen, Holland und Engelland* (Ulm, 1754), 3: 396.

[55] Tafel (note 4), I, 228.

[56] Acton (note 6), 49. For Varignon, see Benz (note 8), 52-3; Hall (note 22), 84, 186; Newton (note 39), VI, 42, 188.

[57] Tafel (note 4), I, 227.

[58] Tafel (note 4), I, 233.

[59] For the effects of the Prize on the pamphleteers, see Stewart (note 10), 198-202; the 'ferment of activity in longitude research' in the twenty years before 1714 is described in Turner (note 29), 122.

[60] Sebastiano Ricci, *The new method proposed by Segnior Dorotheo Alimari to discover the longitude* (London, 1714) and Dorotheo Alimari, *Longitudinis aut terra aut mari investiganda methodus* (London, 1715); Acton (note 6), 110. For Ricci in England see Francis Haskell, *Patrons and painters*, rev. edn. (New Haven, 1980), 279-80. For Flamsteed against Alimari see Flamsteed to Sharp, 22 October 1714, in Forbes *et al.* (note 29), III, 712.

[61] Newton (note 39), VII, 342-4; Jim Bennett, 'Catadioptrics and commerce in eighteenth-century London', *History of science* 44 (2006), 247-78 (263).

[62] Logan to Halley, 25 May 1732, Royal Society MS EL/L6/59; Tafel (note 4), I, 345.

[63] Acton (note 6), 59.

[64] Lindqvist (note 21), 158-63; David Duner, 'Daedalus of the North: Swedenborg's mentor Christopher Polhem', *The new philosophy* (July-December 2010), 1077-98.

[65] Hjalmar Fors, 'Occult traditions and enlightened science: the Swedish Board of Mines as an intellectual environment', in *Chymists and chymistry: studies in the history of alchemy and early modern chemistry*, edited by L. Principe (Sagamore Beach, 2007), 239-52; Lindqvist (note 21), 128-30, 194-7. For Triewald's adoption of the English model of philosophical entrepreneurship, see also Stewart (note 10), 362-3. For Swedish cameralism in the cases of Polhem and Linnaeus (who was Swedenborg's cousin), see Lisbet Koerner, *Linnaeus: nature and nation* (Cambridge, Mass., 1999), 102-5 and for Swedenborg's appointment as assessor see Jane Williams-Hogan, 'Swedenborg's career on the Board of Mines: the world of uses', *The new philosophy* (January-June 2010), 981-1015 (991-8).

[66] Tafel (note 4), I, 271.

[67] Sten Lindroth, 'Anders Celsius et l'observatoire d'Upsal', in Lindroth, *Les chemins du savoir en Suède*, edited by Jean-François Battail (Dordrecht, 1988), 111-20 (111).

[68] Acton (note 6), 66; for his reverie on the observatory site see Swedenborg, 'On the height of water', in *Scientific and philosophical treatises*, 2nd ed., edited by A.H.Stroh and William Ross Wolfenden (Bryn Athyn, 1992), part 1, 17-50, 20-21.

[69] Acton (note 6), 65; Tafel (note 4), I,257; Lindroth (note 67), 113.

[70] Tafel (note 4), I, 259, 263.

[71] Tafel (note 4), II, part 2: 198; Crasta (note 8), 36 n.28.

[72] Acton (note 1), 125-6.

[73] Tafel (note 4), I, 281, 284-5.

[74] Tafel (note 4), I, 301-3.

[75] Acton (note 1), 233-4; *Acta literaria sueciae* (April/June 1720), 27-33; *Neue Zeitungen von gelehrten Sachen* (2 June 1721), 345-7.

[76] Acton (note 1), 238-40; *Acta literaria Sueciae* (July-September 1721), 209-11; *Neue Zeitungen von gelehrten Sachen* (8 May 1722), 418-20; *Acta eruditorum* (May 1722), 266-28.

[77] Conrad Quensel, *Acta literaria Sueciae* (January-March 1722), 270; Acton (note 1), 256; Cole (note 2), 175-6.

[78] Crasta (note 8), 43-46; Friedemann Stengel, *Aufklärung bis zum Himmel: Emanuel Swedenborg im Kontext der Theologie und Philosophie des 18. Jahrhunderts* (Tübingen, 2011), 71-76. For Rudbeck see G. Eriksson, *The Atlantic vision: Olaus Rudbeck and Baroque science* (Canton, Mass., 1994), 50 and Swedenborg (note 68), 47.

[79] The early essay is in L.H.Odner, 'A new theory about the retardation of the Earth', *The new philosophy* 52, 2 (1950), 43-56.

[80] Benz (note 8), 113-14; Emanuel Swedenborg, *The motion and position of the Earth and planets*, edited by L.P. Ford (London, 1900) and Swedenborg (note 68), 45-6 on the change of the Earth's shape and the Deluge.

[81] Acton (note 1), 233.

[82] Acton (note 6), 220-3; Tafel (note 4), I, 308-12; for Swinden see D.P.Walker, *The decline of Hell* (London, 1964), 39-40.

[83] Swedenborg (note 36), II, 104-13, 141-3; Benz (note 8), 121-22; Stengel (note 78), 104-6.

[84] For magnetic methods in the wake of the 1714 Longitude Act, see Fara (note 36), 215-17. For Strömer's speech see Orrje (note 10), 9.

[85] Tafel (note 4), I, 571. See George Graham, 'An account of the observations made of the horizontal needle at London', *Philosophical transactions* 33 (1724), 96-108 (99).

[86] Lindroth (note 67), 115-18; Olov Amelin, 'Daniel Ekström, maker of scientific instruments in eighteenth century Sweden', in *Proceedings of the eleventh*

International Scientific Instrument Symposium, edited by G.Dragoni, A.McConnell and G. l'E. Turner (Bologna, 1994), 81-83. For Celsius and Graham's instruments, see Rob Iliffe, ' 'Aplattiseur du monde et de Cassini': Maupertuis, precision measurement and the shape of the Earth in the 1730s', *History of* science 31 (1993), 335-75 (344, 351); Mary Terrall, *The man who flattened the Earth: Maupertuis and the sciences in the Enlightenment* (Chicago, 2002), 102-6, 141; Nicky Reeves, *Constructing an instrument: Nevil Maskelyne and the zenith sector* (Cambridge University PhD thesis, 2008), 29, 51, 195. For Celsius, Wargentin and the imperatives of measurement and longitude, see Sven Widmalm, 'Astronomy as military science: the case of Sweden', in *The heavens on earth*, edited by David Aubin, Charlotte Bigg and Otto Sibum (Durham NC, 2010), 174-98 (175).

[87] Anders Celsius, 'Anmerkungen über die stündlichen Veränderungen der Magnetnadel in ihrer Abweichung' and 'Von der Misweisung oder Abweichung der Magnetnadel', *Abhandlungen der Königliche Schwedischen Akademie der Wissenschaften* (1740, pb. 1749), part 2, 45-48, 161-4 (45, 164); Tafel (note 4), I,570. For Celsius's attack see Stengel (note 78), 111-13.

[88] Theobald's review is in Royal Society MS RBO 21/16, fols. 81-101; see John H. Appleby, 'James Theobald, merchant and natural historian', *Notes and Records of the Royal Society* 50 (1996), 179-89 (182).

[89] Schuchard (note 9), 299, 363-4, 383-5; Mortimer's praise of Swedenborg's metallurgical work is in Johann Cramer, *Elements of the art of assaying metals*, edited by Cromwell Mortimer (London, 1741), 427; Swedenborg's 'Some indications of the Deluge in Sweden' [a version of a 1721 letter to van Melle] is translated in *Acta Germanica, or the literary memoirs of Germany* (London, 1742), 66-68. Swedenborg's presence at the Royal Society is in Royal Society MS JBC 18:251 (24 May 1744), 369 (28 February 1745), and 374 (7 March 1745).

[90] Folkes' Copley medal speech, 30 November 1749, is in Royal Society JBC 20: 181-96.

[91] Tafel (note 4), I, 593; Orrje (note 10), 23-24.

[92] Schuchard (note 9), 616; Anthony Randall, 'The timekeeper that won the Longitude Prize', in Andrewes (note 5), 236-54 (250).

[93] Nordenmark (note 47), 248. See the English version of Wargentin's July 1766 letter to Maskelyne, 'A new method of determining the longitude of places from

observations of the eclipses of Jupiter's satellites', in *Philosophical transactions of the Royal Society abridged*, edited by Charles Hutton, George Shaw and Richard Pearson (London, 1809), XII, 352-55. For Wargentin's astronomical inventory at Stockholm, see Gunnar Pipping, *The chamber of physics*, 2nd ed. (Stockholm, 1991), 22-26.

[94] For distribution of the new edition see Tafel (note 4), 2, part I, 243. The Board minutes are RGO MS 14/5, fols. 68-69 (24 May 1766). For the Greenwich trials in 1766 see Jim Bennett, 'The travels and trials of Mr Harrison's timekeeper', in *Instruments, travel and science*, edited by Marie-Noelle Bourguet, Christian Licoppe and H.Otto Sibum (London, 2002), 75-95 (89-91). Swedenborg's description of his presentation is Tafel (note 4), I, 592-3.

[95] RGO MSS 14/5 fol. 87.

[96] Acton (note 6), 634-8; Cole (note 2), 176-77. A thousand copies of the *Nautical almanac* for 1767 appeared in early January 1767 with a 1766 imprint: Derek Howse, *Nevil Maskelyne* (Cambridge, 1989), 86.

[97] Schuchard (note 9), 583, 590-1, 676. The record of Swedenborg's publications at the Royal Society is in *Philosophical transactions* 59 (1769), xviii.

[98] Swedenborg (note 3), 314-15.

[99] Swedenborg (note 3), 67.

[100] Emanuel Swedenborg, *Spiritual diary*, edited by James F. Buss, 5 vols. (London, 1902), V, 193. For Newton and the angels, see Simon Schaffer, 'Newtonian angels', in *Conversations with angels*, edited by Joad Raymond (London, 2011), 90-122 (94-5).

[101] Swedenborg (note 3), 59. For the Latin original, see Johann Tafel (ed.), *Sapientia angelica de divino amore et de divina sapientia* (Stuttgart, 1843), 27 (part 1 para. 27). The notion of spiritual longitude was already developed in the 1750s in Swedenborg, *Arcana coelestia*, edited by John Faulkner Potts (New York, 1938), XI, 396-7 (para 9487) and is discussed in Bergquist (note 15), 371 and Dúner (note 5), 38, 56.

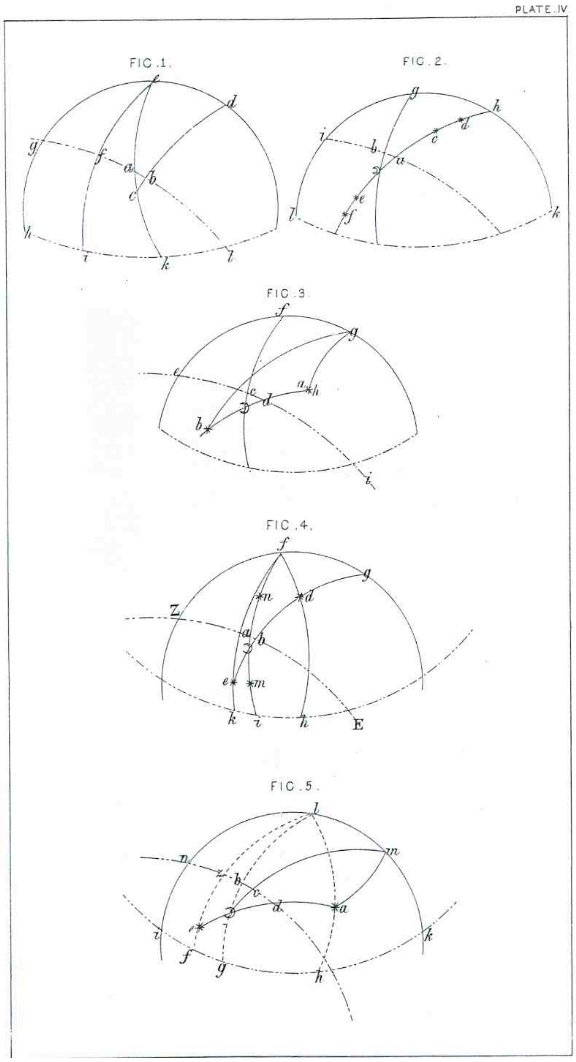

FIGURE 1 Swedenborg's 1721 version of a scheme for lunar determination of longitude: he offered a trigonometric example, illustrated here in fig. 4, in which the stars m and n are in the same latitude, the right line fi through m and n cuts the ecliptic ZE at a, and the Moon has zero parallax in longitude.