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Samuel Morland and his calculating machines *c.*1666: the early career of a courtier–inventor in Restoration London

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Abstract. This paper presents the story of two calculating machines invented by Sir Samuel Morland (1625–95) in the 1660s. These instruments are the earliest known mechanical calculators made in England. Their designs are unusual and very much of their time. They appealed to some, especially at court, and were dismissed by others, such as Robert Hooke. The first part of the paper introduces Morland and the courtier–inventor's world, in which a reputation as a 'machinist' or an engineer could accompany high social status. It considers why a former diplomat and postal spy would turn to invention in general and to mechanical calculators in particular as a career move in the Restoration court. The second part addresses the instruments – attention to their design reveals Morland's inspiration. The paper concludes with an examination of the market for the calculators in London, Paris and Florence. While it is notable that the calculators circulated both in court and in the commercial sphere, even more interesting is the contrast between their receptions in these two spheres. The story of these machines and their maker helps flesh out the poorly understood world of the courtier–inventor in early modern England.

In a 1970 biographical study, H. W. Dickinson concluded that his subject, Samuel Morland, was, in his words, merely an 'also ran' of seventeenth-century science and technology.[1] Morland made no outstanding contributions to the recorded march of science and technology. Although it uncovered many interesting things, Dickinson's study found no reason to claim that Morland had been unjustly overlooked by

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1 H. W. Dickinson, *Sir Samuel Morland: Diplomat and Inventor 1625–1695*, Cambridge, 1970. Other than Dickinson, who relied to some degree on J. O. Halliwell Phillipps, *A Brief Account of the Life, Writings, and Inventions of Sir Samuel Morland*, Cambridge, 1838, only a few articles have been written on Morland or his instruments. See D. J. Bryden, 'Sir Samuel Morland's account of the balance barometer', *Annals of Science* (1975), **32**, 359–68; A. Buonafalce, 'Sir Samuel Morland's Machina Cyclologica Cryptographica', *Cryptologia* (2004), **38**, 253–64. Also see A. Crinò, 'I rapporti di Sir Samuel Morland con Cosimo III dei Medici', *Biblioteca Dell'Árchivum Romanticum* (1959), **1**, 213–61; and *idem*, 'Una descrizione contemporanea del funzonamento della macchina calcolatrice di sir Samuel Morland', *Physis* (1965), **7**.

Figure 1. Samuel Morland at the age of thirty-three. From a painting by Peter Lily in the possession of the Carolina Art Association. Reprinted in H. W. Dickinson, *Sir Samuel Morland: Diplomat and Inventor 1625–1695*, Cambridge, 1970.

historians. Yet now there are other ways in which Morland and his instruments emerge as a compelling subject. In the decades since Dickinson's work, historians of Restoration science have largely focused on the Royal Society and its members. Robert Hooke has emerged as the period's iconic inventor. His complex social status with respect to Boyle and other Royal Society members has emerged as a focal point for studies of the social context of invention at the time.[2] In Morland's case we explore a different context: invention as a career move within that other royal society, the courts of Europe.[3] Courtier science and the Royal Society were both aspects of government science in Restoration England. But there seem to be important differences between the two contexts, perhaps especially with regard to the relationship between social status and scientific or technological labour. Hooke has often been described as a shield

2 On this analysis see M. Hunter, *Robert Boyle: Scrupulosity and Science*, Woodbridge, 2000; S. Shapin, *A Social History of Truth*, Chicago and London, 1994; *idem*, '"A Scholar and a Gentleman": the problematic identity of the scientific practitioner in early modern England', *History of Science* (1991), **29**, 279–327, 304–7; and other works by Hunter and Shapin. While they disagree on some points, both Shapin and Hunter depict the relationship between Hooke and Boyle in this way.

3 In suggesting there has been some overemphasis on the Royal Society in recent studies of science in early modern London, I follow the argument presented by Larry Stewart: 'Other centres of calculation, or, where the Royal Society didn't count: commerce, coffee-houses and natural philosophy in early modern London', *BJHS* (1999), **32**, 133–53. Similarly, Moran has argued that institutional histories of early modern science have focused too exclusively on societies, and that the court has not been studied enough. B. T. Moran, *Patronage and Institutions: Science, Technology and Medicine at the European Court 1500–1700*, Rochester, 1991.

for Boyle's gentlemanly status because it was Hooke who performed the labour of invention and experimentation. In the case of the courtier–inventor, two apparently inconsistent categories of gentleman and philosopher or gentleman and mechanick were straddled, uncomfortably but successfully, by one individual. For example, Morland was a Gentleman of the Privy Chamber. He also built diving bells, gun carriages, trumpets and water pumps. Such contrasts can only be explained with a fuller understanding of the government science that existed beyond the territory of the Royal Society.[4]

In histories of calculating machines, Morland's calculators also have a similarly disappointing status. Though they can claim the status of oldest surviving English calculating machines, they have drawn little recent interest. This is primarily because, although mechanical, they do not have a carry mechanism.[5] Nevertheless, the story of Morland's calculators provides new views of a rarely seen aspect of Restoration science. Many of the courtier–inventors and engineers have left almost no historical record, but in the case of Morland and his calculating machines there is a significant amount of surviving primary material, including six of his machines. Although Morland's archival record is flimsy compared to Hooke's diaries and correspondence, it is much more extensive than that so far uncovered for many contemporary court inventors. Very little is yet known about the life and works of such individuals as Cornelius Drebbel, Monsieur De Son or Kaspar Kalthoff. In this case, however, there is a relatively detailed picture of the origins of an English invention and its propagation through the commercial market, philosophical societies and courtly circles of Europe. This provides a better understanding of the way courtier–engineers engaged with the wider culture of seventeenth-century commerce, technology and natural philosophy.

The world of the courtier–inventor: science and technology in the other royal society

When Samuel Morland appears in accounts of Restoration science it is usually in the context of pumps and steam engines. He appears most frequently as a distant English

4 Another example of a study that does examine Restoration government science beyond the Royal Society is F. Willmoth, *Sir Jonas Moore: Practical Mathematics and Restoration Science*, Woodbridge, 1993.

5 A mechanism to automatically handle rounding over from one place column to the next in addition or multiplication. It would be difficult to understate the centrality of the carry mechanism within the historiography of calculating machines. It is often taken to be basically identical to the concept of mechanical calculation – that is, it is identified as the labour-saving mechanical process. Later calculators are often said to have 'evolved' from the designs of Pascal and Leibniz, which were among the first to employ carry mechanisms. The position taken here is that it is not clear what the value of the carry mechanism was at the time. See, for example, M. R. Williams, *A History of Computing Technology*, Los Almitos, 1997, 119. Williams, while placing the usual emphasis on carry mechanisms, also gives full accounts of machines such as Morland's that do not carry. Evolution-style histories of computing technology can be found in G. Ifrah, *The Universal History of Computing: From the Abacus to the Quantum Computer*, New York, 2000; J. Marguin, *Histoire des instruments et machines a calculer*, Paris, 1994; J. Shurkin, *Engines of the Mind: The Evolution of the Computer from Mainframes to Microprocessors*, New York, 1996; F. Soresini, *Storia del Calcolo Automatico Vol. 1*, Rome, 1977.

precursor to James Watt.[6] Morland was best known in his own time as a hydraulic engineer. His steam engine theory was little known, however. It was published in a small treatise in French after Morland had been hired by Louis XIV to advise on the notorious Machine of Marly, a gigantic waterwork at Versailles.[7] Before gaining success in waterworks, Morland first established his identity as an inventor within the more established field of mathematical instruments. Even earlier, he was employed in Cromwell's regime as diplomat, secretary and expert in postal espionage. The story of his transformation into a courtier–engineer begins there.

After ten years at Cambridge, Morland joined Cromwell's government in 1650. One of his most important political roles was in a diplomatic mission aiding a Protestant group in the Valais threatened by violent repression by the Duke of Savoy. Upon returning from Piedmont, Morland published a gruesomely illustrated account of the rumoured atrocities in *The History of the Evangelical Churches of the Valleys of Piedmont together with a most naked and punctual relation of the late Bloudy Massacre in 1655*. This anti-Catholic phase of Morland's life would later be a source of trouble once the Medici became some of his most important patrons. Some references to Morland from the 1650s already describe him as an ambitious and idealistic inventor. The writer Samuel Hartlib, who met him in 1655, said Morland was 'altogether Mathematical and Mechanical' and that he had 'laboured much in the Perpetuus Motus'.[8] On other occasions, Hartlib described Morland's pursuit of flight: 'Mr Moreland hath much experimented on the nature of flights of Birds, their Wings and bodies, and had made for himself a paire of wings to flye with.' Hartlib also referred to a grand plan for a 'College of Arts' in which Morland would employ 'a thousand workmen or mechanicks'.[9] Though it is not known how seriously Morland pursued these ideas, it is clear that even when his political career was secure Morland was at the very least interested in building a reputation for himself as (to use the words of another contemporary) an 'ingenious mechanist'.[10]

In Hartlib's circle, especially, the work of invention had a strong moral overtone. Invention was linked to salvation, by relieving mankind from the burdens of original sin.[11] Morland seemed to present himself to Hartlib in ways that put his own work in just that light. However, talk of perpetual motion and flying machines aside, the only inventions or instruments one can be certain Morland produced before 1660 were those he used as a postal spy for Cromwell. As Clerk of the Signet, his most substantial role

6 He developed and exhibited to Charles II a 'fire-engine' that used the motive power of steam to pump water. In the course of this project he determined the ratio of the volume of steam at atmospheric pressure to that of water, which at 2,000:1 was not improved upon until the time of James Watt.

7 S. Morland, G. Martin and J. Jombert, *Elevation des eaux par toute sorte de machines* …, Paris, 1685.

8 S. Hartlib, *The Hartlib Papers: A Complete Text and Image Database of the Papers of Samuel Hartlib (c.1600–1662)* (ed. J. Crawford), Ann Arbor, MI, 1995, ephemerides (1655) part 1.

9 Hartlib, op. cit. (8), ephemerides (1655) part 2.

10 Bulstrode Whitelocke, quoted in Dickinson, op. cit. (1), 8.

11 See, for example, John Wilkins's introduction to *Mathematicall Magic*, London, 1648. Wilkins describes the work of invention 'being (as it were) but so many Essays whereby men do naturally attempt to restore themselves from the first general curse inflicted upon their Labours'. J. A. Bennett and S. Mandelbrote, *The Garden, the Ark, the Tower, the Temple: Biblical Metaphors of Knowledge in Early Modern Europe*, Oxford, 1998, 61.

under Cromwell was in intelligence-gathering, including developing devices for postal espionage: instruments for opening, deciphering, copying and resealing intercepted communication.[12]

Morland was aged thirty-five in 1660. His income was more than comfortable. His social position, boosted by marriage to a baron's daughter, seems to have been solid. In 1659, about a year before the fall of the Protectorate, Morland had become a double agent. He is said to have given warning of an impending plot to murder Charles II and afterwards very nearly lost his own life when Cromwell became suspicious of him.[13] After the Restoration, in the mêlée to secure positions within the new government, Morland did decently. He received a knighthood and a baronetship for his undercover service to the Royalists. But Morland would claim much later in life that those benefits were in titles only, not in land or income or any substantial terms. Left in a financially precarious situation, he would explain, he sought new ways to improve his standing:[14] 'Now finding myself disappoynted of all preferment and of any real estate, I betook myself too the Mathematicks, and Experiments such as I found pleased the King's Fancy.' Charles II's fancy was for Morland to continue using his 'several engines and utensils' in the inspection of mail.[15] Until at least 1666, when the Great Fire destroyed the post office and Morland's intelligence-gathering instruments with it, Morland was active in postal surveillance, working alongside the mathematician John Wallis, who helped crack ciphers, and future secretary of the Royal Society Henry Oldenburg, who translated documents written in obscure languages.[16]

Despite Morland's later complaints, gossip gathered by Dickinson from various diaries suggests that Morland and his wife were doing very well in the early 1660s.[17] This was when Morland began to build calculating machines.[18] In 1663 Morland made a gearwork trigonometrical instrument and in 1666 made his instruments for addition and subtraction and for multiplication and division. Beyond the post office, these were

12 Morland is said to have invented a cryptographic system and a 'double-writing machine' for copying intercepted letters. See Buonafalce, op. cit. (1). Interestingly, Morland justified his work in espionage in the very same terms that Hartlib described invention. In a secret memorandum on 'the Nature and Reason of Intelligence' Morland argued that the fallen nature of mankind ensured that no man could be trusted to do the right thing for his state if his personal interests were threatened, thus a successful government required vigilant intelligence-gatherers. See A. Marshall, *Intelligence and Espionage in the Reign of Charles II, 1660–1685*, Cambridge, 1994.

13 This affair is covered in Dickinson as well as in M. Hollings, 'Thomas Barret: a study in the secret history of the Interregnum', *English Historical Review* (1928), **43**, 33–65; D. E. Underdown, 'Sir Richard Willys and Secretary Thurloe', *English Historical Review* (1954), **69**, 373–87.

14 *Autobiographical Letter to Dr. Thomas Tenison* (1689), reprinted in Dickinson, op. cit. (1). Dickinson lays out some reasons to doubt Morland's frequent claims of poverty. At the very least, government grants and other sums of money regularly passed through Morland's hands.

15 Arlington, the secretary of state, quoted in Marshall, op. cit. (12), 54.

16 Marshall, op. cit. (12).

17 Dickinson, op. cit. (1), 37–8.

18 The mechanical trigonometers are dated as invented by Morland in 1663, and made by Sutton and Knibb in 1664 (Science Museum, London) and by John Marke in 1670 (Istituto e Museo di Storia della Scienza, Florence). All three surviving adding machines are dated as invented in 1666, with no maker signature. Confusingly, the one multiplication machine is dated as invented by Morland in 1666 and made by Sutton and Knibb in 1664.

among his very first inventions designed for patronage and financial gain. They would successfully set him on course to a steady supply of both royal favours and public interest. He produced a total of three calculating machines – one for trigonometry, one for addition and subtraction and one for multiplication and division. They were sold, in some cases made, not only by Morland but also by established makers such as Humphrey Adamson and the firm of Henry Sutton and Samuel Knibb. It is important that these instruments came from the Sutton workshop, one of the best-known makers of practical mathematical instruments. According to the diary of Conrad von Uffenbach, London instrument-makers were still selling Morland's calculating machines as late as 1710.[19]

In 1667 Morland made the significant move to Vauxhall House in Kennington. This house stood on the site of the Ordnance Factory established by Charles I. It was next to the Vauxhall Armoury where the engineer Kaspar Kalthoff ran a shop and where Kalthoff and Edward Somerset experimented with steam engines in the early 1660s.[20] Vauxhall was adjacent to glassworks and foundries, near 'forges, furnaces, mills, and all manner of tooles'. It was set in a neighbourhood occupied by skilled Dutch immigrant artisans.[21] Contemporary descriptions and Parliamentary warrants concerning the Vauxhall site give the impression it was considered the state 'elaboratory' and had been so, through rising and falling cycles of support, since the early 1620s.[22] For example, in 1649 Benjamin Worsley wrote to Samuel Hartlib about a recent government proposal for Vauxhall in which he argued, along Hartlib's ideological lines, that the site should be set apart for public use in the following ways:

> 1. to keepe all manner of Ingenuities rare Models and Engines which may bee useful for the Comon-wealth. 2. to make Experiments and trials of profitable Inventions, which curious Artists ofttimes cannot offer to the knowledge of skilful men and to public use for want of a place of Addresse to meet with them, and of other necessarie conveniences to show a proofe of their skill, wherof in Faux-Hall is great store. 3. to bee a place of Resort whereunto Artists and Ingeniosi from abroad and at home may repaire to meet with one another to conferre together and improvise in many ways their abilities, and hold forth profitable Inventions for the Use of the Comon-wealth.[23]

19 G. L. Turner, *Scientific Instruments and Experimental Philosophy, 1550–1850*, Aldershot, 1990, p. xi. The trigonometry machine in Florence is signed by John Marke (fl. 1665–79), an assistant to Sutton who took over his workshop when Sutton died in 1665. Marke was also employed by John Flamsteed, the Royal Society and Robert Hooke. The multiplication instrument is signed by Sutton & Knibb. On Marke, Sutton and Knibb, see E. G. R. Taylor, *The Mathematical Practicioners of Tudor and Stuart England 1485–1714*, Cambridge, 1970.

20 Dickinson, op. cit. (1), 53–4. Somerset is also the author of *Century of Inventions* (1666).

21 Benjamin Worsley (1649) in J. J. O'Brien, 'Commonwealth schemes for the advancement of learning', *British Journal of Educational Studies* (1968), **16**, 30–42, 35.

22 As Worsley called it. For further description of the importance of Vauxhall see A. F. C. Wallace, *The Social Context of Innovation*, Princeton, 1982; F. Willmoth, 'Mathematical sciences and military technology: the Ordnance Office in the reign of Charles II', in *Renaissance and Revolution: Humanists, Scholars, Craftsmen and Natural Philosophers in Early Modern Europe* (ed. J. V. Field and Frank A. L. James), Cambridge, 1993, 117–32. Willmoth points out that Vauxhall was sold into private hands in the 1650s (to Edward Somerset). But according to Wallace the state had some control over it when Morland took out his lease on the property. Dickinson (op. cit. (1), 53) says that Morland obtained a grant of £400 from the government to take out the long lease on the property, which then was in the hands of Kalthoff's relatives.

23 O'Brien, op. cit. (21), 34–5.

A Parliamentary inventory in the same year describes two 'modell roomes' containing a kind of state archive of inventions.[24] According to visitor accounts, Morland transformed Vauxhall into a showcase for his products. He installed elaborate waterworks throughout the property and offered virtuoso entertainment to his visitors. After one such visit Roger North said, 'though his entertainment was exquisite, the greatest pleasure was to observe his devices; for everything showed art and mechanism'. Gearwork (the signature feature of Morland's calculators) was abundant. North was especially impressed by Morland's coach, in which he had installed a 'portable engine which moved by clockwork' so that 'an egg, put into that, would roast according to art; and if a piece of meat were stuck upon it, it was dressed by clockwork'.[25]

When Morland moved to Vauxhall he established for himself a visible position among London's mechanical and mathematical practitioners. It is clear that this position was strongly associated with practical investigations for the state. But there is a vagueness to Morland's status within both the court and the government, especially because he held none of the standard government posts often occupied by mathematicians or engineers in the Ordnance, the Mint or the Admiralty. Eventually a new office would be created for Morland, entitled Master of Mechanicks, though his occupancy of that post does not help clarify the place of Morland and his inventions within the government.[26] Despite being given this title, Morland appears to have remained first and foremost a courtier whose access to the court via his inventions was never entirely secure.

This is the impression given by Lorenzo Magalotti, secretary of the Accademia del Cimento, who visited London just after the Restoration and later published a profile of the new court.[27] Magalotti's survey of London court society around 1668 helps situate Morland within the court as well as offering some perspective on the relationship between the court (thus, to a degree, Morland) and the Royal Society, which Morland never joined. Magalotti describes how he stopped short of attending a regular meeting of the society because of the negative connotations it held at the court: 'I did not want to get a place for myself as a scholar, firstly because I am not one, and secondly because even if I were I should not consider it the most advantageous character for getting into courts.'[28] Magalotti had heard the rumour that Charles II referred to the Fellows of the society as 'his fools' and later assessed the king's interest in natural philosophy in more detail:

> To hear him talk, he seems to take great delight in every noble curiosity, not excluding the new experiments and natural science; but even if he manages to have some taste for these things, he is not capable of having any esteem for them, nor for those who practise them.[29]

24 Wallace, op. cit. (22).

25 Dickinson, op. cit. (1), 54.

26 It is interesting that the next Master of Mechanicks would be the instrument-maker John Rowley (*c.*1668–1728), a succession that suggests that the role of this post centred on instrument-making.

27 W. E. Knowles Middleton, *Lorenzo Magalotti at the Court of Charles II: His Relazione d'Inghilterra of 1668*, Ontario, 1980.

28 Knowles Middleton, op. cit. (27), 8.

29 Knowles Middleton, op. cit. (27), 5, 28.

Magalotti was harsh on natural philosophers but his attitude switched in the case of engineering, especially if pursued by an aristocrat. Magalotti highly praised the manual experience in engineering of the king's cousin Prince Rupert:

> And really his skill in the arts of the sailor and the engineer is incredible. He manages to perfect with his own hands – which are always scratched and calloused by the continual use of the file, chisel, and adze – whatever mechanical device it comes into his head to make. He delights in odours and in chemistry and has a very good knowledge of a great deal of natural history.[30]

For those not born into the court, the challenge inherent in attempting to gain entry through practical technique is very well described in Magalotti's assessment of Morland, the only engineer or inventor besides Prince Rupert included in Magalotti's assembly of characters:

> Sir Samuel Morland is a man who because of a certain extraordinary ability in arithmetic, in mechanics, and in cryptography is held in some esteem by the King ... His temperament is melancholy and a little queer, and his machines have given room to his competitors to discredit him with the King, making him pass for a philosopher, so that apart from being amused by these curious things, the King holds him in little esteem. In truth his talent for politics is not wonderful.[31]

Obviously the successful courtier–inventor had to construct his identity with extreme care, but Morland was not alone in this respect.[32] Evidence of an active and coherent network of courtier–inventors who had similar interests and pursuits continues to accumulate. There is no evident pattern to their background or origins, but there is often similarity in lines of invention pursued. There are clear fashions for different areas of invention at different times. For example, a recent study of the inventor usually referred to as Monsieur De Son (also known as Du Son, Dession, and De Lisson) reveals that the record of De Son's output parallels that of Morland's in many ways. In the 1650s both claimed to have built flying machines and had a reputation for working on perpetual motion. By 1675 both were producing 'fire engines' and waterworks to pump water up to the top floors of palaces.[33] Other courtier–inventors or engineers involved in pumping and waterworks include Cornelius Drebbel, Dennis Papin, Thomas Savery and Thomas Newcomen. Glassworking was also an area of common ground among courtier–engineers: De Son, Burattini, Papin and Digby were involved in glass instrument-making or glassworks factories. Kitchen science was another: Papin invented the pressure cooker, an application drawn from his steam engine work, as his involvement in the glassworks may also have been. Kenelm Digby (1603–65) wrote a

30 Knowles Middleton, op. cit. (27), 39.

31 Knowles Middleton, op. cit. (27), 61.

32 For another case that examines the difficulty of straddling gentlemanly and philosophical circles see L. T. Sarasohn, 'Who was then the gentleman?: Samuel Sorbière, Thomas Hobbes, and the Royal Society', *History of Science* (2004), **42**, 211–32, 211: 'Sorbière's rise and fall vividly depict the changing nature of determining worth within the community of natural philosophers: he demonstrated the complex interweaving of old and new patronage styles by his disastrous failure fully to grasp either.' Also see Shapin, '"A Scholar and a Gentleman"', op. cit. (2).

33 M. Keblusek, 'Keeping it secret: the identity and status of an early-modern inventor', *History of Science* (2005), **43**, 37–56.

popular book of recipes and is said to have invented the modern wine bottle. Drebbel sold the 'secret' of his bread-oven and water-distilling engine to the Duke of York, while Morland had his famous clockwork spit.[34] Likewise, submersible devices were devised by Morland (a diving bell for an individual), De Son (his 'war machine' of Rotterdam), Papin (a submarine) and Drebbel (a submarine with a means of chemically 'refreshing' the air).[35]

All these individuals moved within the ill-defined space of the courtier–inventor. Their pursuits collectively provide some evidence of the influence of the state on the direction of scientific research and technological development at the time. Keblusek has pointed out that it is difficult to uncover that aspect of seventeenth-century technological and scientific development because of the much more secretive nature in which courtier–inventors worked. Indeed, very little is known of Morland's early engineering work for the government. His political and engineering careers first intertwined at the post office and he would eventually exploit that connection, via Vauxhall House and the title of Master of Mechanicks, to secure a relatively successful career as a courtier–inventor. Much of Morland's life is still obscure. Yet with the calculating machines Morland sought to produce inventions for both government and public. In this case, more can be learnt of the world of the courtier–inventor.

The calculators

Numeracy is thought to have been low in seventeenth-century England, especially among those who did not work in financial or technical trades.[36] But for the sector of society that dealt regularly with numbers there were established ways of doing arithmetic and geometry. There were also associated sets of calculating aids such as logarithmic scales, drawing tools, counting boards, Napier's bones and the abacus. Morland's mechanical designs drew directly from these devices. They were in essence geared versions of some of the commonest mathematical instruments of his day. Instruments played an important role in learning arithmetic and, as often advertised, could ease the memory and concentration required for addition or eliminate the need to learn times tables.[37] It was within this niche, to the moneyed ladies and gentlemen who often had little experience in arithmetic, that Morland envisioned selling his calculating machines.

34 D. McKie, 'James, Duke of York, F.R.S.', *Notes and Records of the Royal Society of London* (1958), **13**, 6–18.

35 On Drebbel see L. E. Harris, 'Cornelius Drebble: a neglected genius of seventeenth century technology', *Transactions of the Newcomen Society* (1957–9), **XXXI**, 195–204. Savery, Papin and Newcomen often appear in histories of steam power, and all have *DNB* entries mentioning these interests. On Digby see B. Janacek, 'Catholic natural philosophy: alchemy and the revivification of Sir Kenelm Digby', in M. J. Osler (ed.), *Rethinking the Scientific Revolution*, Cambridge, 2000, 89–110.

36 K. Thomas, 'Numeracy in early modern England', *Royal Historical Society Transactions* (1986), **5**, 103–32.

37 See, for example, D. J. Bryden, 'A didactic introduction to arithmetick: Sir Charles Cotterell's instrument for arithmeticke', *History of Education* (1973), **2**, 5–18.

In 1663 he invented an instrument for trigonometry which he called the *Maccina Cyclologica Trigonometrica*.[38] Unlike the instruments for addition and multiplication, no contemporary references to the trigonometer have been found and it will not be detailed here. But in certain aspects the trigonometer's design was similar to Morland's other two instruments and these aspects deserve brief mention. The trigonometer allowed the user to perform trigonometry by 'drawing' out a problem and measuring the solution as with drawing instruments but without the need for pen and paper. It was a set of three rulers set into a divided circle that could be moved about using dials to form a triangle of any shape. The instrument clearly had precedents in earlier instruments such as universal triangulator instruments of the late sixteenth century.[39] But in its design and use it was most reminiscent of a set of common drawing tools. Morland even added thorn-tipped embellishments to the instrument's rulers to suggest the pointed tips of a compass. What made the instrument so unusual was the simple gear-work that created a smooth mechanical interface to the traditional drawing tool set. A design approach which took common instrumental aids and added a mechanical interface was also the defining feature of the multiplication machine and the adding machine.

Morland's instrument for multiplication, shown in Figure 2, may have been constructed as early as 1662, although the one surviving example, at the Istituto e Museo di Storia della Scienza (IMSS) in Florence, is inscribed with an inventor date of 1666.[40]

Behind the front plate is a long ratcheted arm that engages the ten semicircular posts arranged along the lower front of the instrument, as well as the pin sliding along the scale marked 1–9 at the centre. The key at the lower right is connected to a gearwheel which moves the arm. When the key is turned, the pin slides from one number to the next and the posts revolve by twenty degrees. Along the top of the instrument is stored a collection of silver-plated discs, numbered 0–9. Arranged around the edge of each of these discs is the multiplication table for the number indicated at the centre top. For each product inscribed on the disc tables, if greater than 9 and therefore comprising two digits, the number in the tens column is written on the left side of the disc and that in the units column directly across on the right side of the disc.

To multiply, for example, 23 by 7, the operator would first take the discs for 2 and 3, place them on the central posts and close the door so that in the window the number 23 appears (3 in the left-most window and 2 in the left side of the second pair of windows). Then the operator would turn the key until the pin on the slider scale pointed to 7. Each time the key is turned the discs are rotated once, which advances the display of the multiplication table for the selected numbers (2 and 3) by one. The windows are constructed so that a number on the leftmost edge of one disc appears next to the

38 Istituto e Museo di Storia della Scienza, inv. no. 689 and Science Museum inv. no. 1872136. They are very similar, but the instrument in Italy is slightly improved, with extra features and finer movements.

39 For example Erasamus Habermel's Triangulator (Museum of the History of Science inv. no. 47741) or Thomas Hood's Sector (Museum of the History of Science inv. no. 38251).

40 The earlier date, based on a possible reference to it in the correspondence of Cosimo III, is suggested in Crinò, 'Una descrizione contemporanea', op. cit. (1). The surviving instrument is Istituto e Museo di Storia della Scienza inv. no. 679.

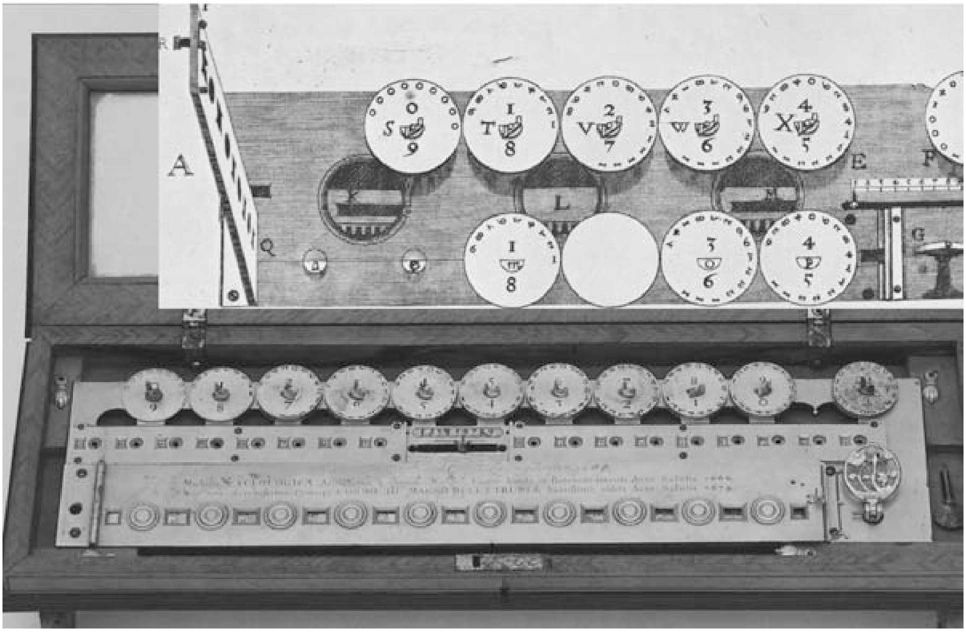

Figure 2. Samuel Morland's instrument for multiplication. The photograph is of the instrument at the Istituto e Museo di Storia della Scienza in Florence. The engraving is from Morland's *The Description and Use of Two Arithmetick Instruments, Together with a Short Treatise, Explaining and Demonstrating the Ordinary Operations of Arithmetick*, London, 1673.

number on the rightmost edge of the next disc. The final answer must be obtained by adding the adjacent numbers in the windows, either with pen and paper or, as Morland suggested, with the help of his instrument for addition. So, to finish the example, after the discs 2 and 3 have been rotated 7 times, the numbers in the display window would read: 1 4 2 1. The final result is found by adding the adjacent digits to give 161. There is no automatic or mechanical carry mechanism.

Morland's calculator is a nearly unrecognizable version (as Sir Jonas Moore would put it, a 'neat … but vastly chargable version) of Napier's bones, one of the most common contemporary tools for multiplication and division.[41] Like Morland's calculator, the concept of Napier's bones is based on setting up a multiplication table in such a way that the work of multiplication is efficiently reduced to addition. According to Morland, the greater virtue of his instrument over the traditional form of bones concerned what might be called the interface. Because his instrument hides 'all the other Figures from the Eye of the Operator', it

> far surpasses the Lord *Napiers Lamina* or *Bones* which expose a great number of figures to the Eye at the same instant of time (as well those that are not useful as those that are) besides that all the Figures in those Bones are placed Diagonally, which does very much strain and force the

41 As with Napier's bones, Morland's machine can also be used as an aid to long division by producing the times table of the divisor. See Bryden, op. cit. (37).

Eye of the Operator; whereas in this they lie all in a Straight Line, and as distinctly as can be desired.[42]

Morland was not alone in attempting the improvement of the traditional form of Napier's bones.[43] Sir Charles Cotterell's 'Instrument for Arithmeticke' (1667) attempted an improvement in much the same way as did Morland's device, although the construction and intended buyer of the instruments could not have been more different. Cotterell's device was made of plain boxwood with a metal plate, beads, paper and wire. It could be used to teach arithmetic to those who could not read. Morland's was made of gilt and silver-plated brass and housed within a carved hardwood case with a crystal top. Nevertheless, they function almost exactly alike. Instead of running through the times table by turning the key on Morland's instrument, a user of Cotterell's machine would slide a window up and down to expose different parts of the times table, reading off the multiplicand on the edge of the instrument frame. Among other things, the similarity of these two instruments reveals how limited in function is Morland's gearwork.

This point is also brought home by comparing Morland's instrument with Gottfried Wilhelm Leibniz's mechanical calculator, which owed nothing to Napier's bones. This machine, built between around 1672 and 1674, used a new gear design that could in theory automatically perform carrying during multiplication. In addition or multiplication, when the value of one column goes over 9, a 1 is automatically added to the column to the left of that column as it rounds over to 0. This is the 'carry' that Leibniz's design could perform mechanically. Yet as it was constructed Leibniz's machine, like Morland's, required some human intervention. One example of Leibniz's machine survives and is the only one known to have been built.[44] But the gear design, known as Leibniz stepped wheels, would later be reintroduced in the first mechanical calculators of the nineteenth century, beginning with the Arithmometer of Charles Thomas de Colmar.[45]

Four examples of Morland's adding machine survive.[46] The largest models can add up to one million, in either decimals or pounds, shillings and pence. Figure 3 shows the instrument in the Museum of the History of Science, Oxford. The instrument is made of two silvered brass plates held together by studs at the corners. It is about the size of the average modern pocket calculator, measuring roughly four inches by three inches by a quarter inch. It was designed for portability; the example in Figure 3 comes with a thin carrying-case lined outside with fish-skin and inside with green velvet and satin. The

42 S. Morland, *The Description and Use of Two Arithmetick Instruments, Together with a Short Treatise, Explaining and Demonstrating the Ordinary Operations of Arithmetick*, London, 1673, 10.

43 See, for example, Gaspard Schott's cylindrical bones or Pierre Petit's Arithmetical Cylinder. Bryden, op. cit. (37).

44 Williams, op. cit. (5), 129–36.

45 S. Johnston, 'Making the arithmometer count', *Bulletin of the Scientific Instrument Society* (1997), **52**, 12–21. It is this later appearance of the same gearwork that gives some histories of computing their evolutionary slant.

46 Two are in the Science Museum, London, and one is at the Museum of the History of Science, Oxford. The fourth, at the Istituto e Museo di Storia della Scienza, Florence, is in an unusual style and is unsigned and undated (discussed below).

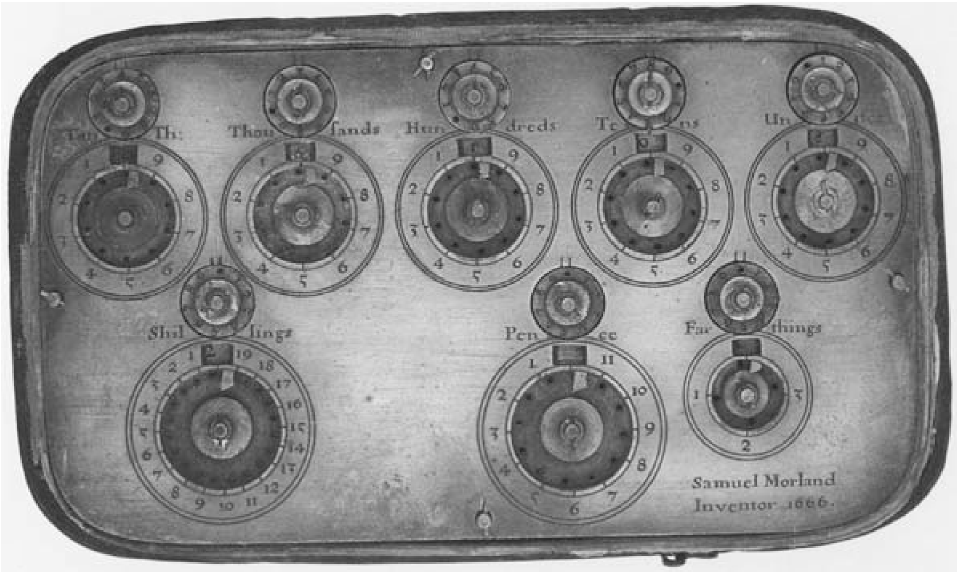

Figure 3. Samuel Morland's instrument for addition. From the Museum of the History of Science, Oxford.

only decoration on the flat, card-like face is Morland's signature, 'Samuel Morland, Inventor, 1666', which, in holding the name of the inventor rather than the maker, is an unusual and obvious form of self-promotion.[47]

As can be seen from Figure 3, there are eight pairs of small and large circular discs. Each large disc has one tooth that engages with the small wheel. Thus the small disc advances one number for each revolution of the large gear. In this way, the small disc keeps track of the number of revolutions the large gear has made, so this is the number to be carried or added to the next large wheel to the left. The five pairs of discs on the top row are divided into units of ten, descending clockwise, and are either to keep track of pounds or to count anything using the decimal system. Similarly, the three pairs of discs on the bottom row are for keeping track of shillings (divided into twenty), pence (divided into twelve) and farthings (divided into four). To add, the user sets the instrument so that the first figure appears in the windows, then the next number is added by putting the stylus in the hole next to the number to be added and turning it clockwise until the stylus is under the window. To perform subtraction, the user places the stylus in the hole under the window and turns it anticlockwise to the number being subtracted. There is no mechanical connection between one pair of disks and its neighbour (the absent carry mechanism) so the user must periodically 'discharge' the smaller plates, as Morland termed it, by adding the number indicated by the small plate

47 This 'inventor' signature, as opposed to a maker signature, is unusual for surviving seventeenth-century instruments; of the 350 or so objects from the sixteenth and seventeenth centuries in the inventory of the Museum of the History of Science in Oxford, only Morland's adding instrument is signed in this way.

between the two etched lines at the top to the larger neighbour to its left and clearing the small plate to zero.

The only other contemporary surviving English instrument for addition is William Pratt's 'Arithmetical Jewel', made around 1615, a flat grid of brass wedges that can be swung into different positions with a stylus, arranged for counting money in Roman numerals. Morland's calculator was much more often compared to Blaise Pascal's adding machine of 1642. The 'Pascaline' was about two feet long, a foot wide and six inches deep. It performed addition but not subtraction (the gears only turned in one direction), it was much more expensive than Morland's instrument and it automatically carried from one column to the next, even in cases where adding one number led to a 'cascading carry' across multiple columns (as in $1999+1=2000$). With Morland's instrument, in contrast, the user must add the values to be carried by periodically 'discharging' the small top discs, and although these top discs automatically keep track of the values to be carried, they do so only up to ten. It is almost certain that Morland knew of the Pascaline and may even have seen an example at the Swedish court in 1653. Pascal had presented one to Queen Christina in 1652.[48] But although both the Pascaline and Morland's instrument are unique in using gearwork to perform addition, any similarity stops there. The operation of Morland's instrument most closely resembles addition simply by pen and paper. Pen and paper were the most common 'instruments' for addition and subtraction in the seventeenth century.[49] As with the thorn-tipped rulers of Morland's trigonometer, the design of this instrument with its stylus and flat, thin body was also suggestive of the method it could be used to replace.

In summary, all three of Morland's calculators represent an unexpectedly clear link between traditional instruments of practical mathematics and the new mechanical calculating machines of Grillet, Leibniz, Pascal and Schikard. In each of Morland's instruments there is an attempt to apply mechanism to traditional instrumental methods of arithmetic and geometry. While the devices of Pascal and Leibniz represented trials of the gearwork itself, in all of Morland's instruments the role of the gearwork, the use of 'art and mechanism', was an experiment on the place where mechanism could be applied. In each of these instruments the mechanism itself is relatively plain. This offers a key to the understanding not only of the instruments but also of Morland's style as an inventor and of the people to whom his calculators were intended to appeal.

The market

Morland's potential buyers were described in Sir Jonas Moore's *Mathematicall Compendium* and *New System of Mathematicks*. Moore's book, like John Aubrey's *Idea of Education of Young Gentlemen*, promoted arithmetic as 'the great Difference

48 Williams, op. cit. (5), 136.

49 In addition to pen and ink, typically used with arabic numerals, there was the counting board, typically used with Roman numerals. Counting boards were more common at the beginning of the century, but as use of the Arabic numeral system grew (and became known as 'English figures') and the use of Roman numerals declined and became archaic, counters gradually became a symbol of ignorance. See Thomas, op. cit. (36).

that distinguisheth us from Brutes and brutish Men'.[50] In discussing multiplication, Moore noted,

> Multiplication by memory is fit for those that have constant practice but for certainty and ease no invention ever came near that of the Lord *Napiar* by Rods, made either of Wood or Ivory, Sir *Samuel Moreland* has devised a neat way upon circles, but vastly chargeable, and this has been the reason why they have not been so well known.

Of adding sums, Moore advised,

> If any Gentlemen or other, especially Ladies, that desire to look into their disbursements, or layings out, and yet have not time to practise in numbers, they may from Mr. *Humphrey Adamson* dwelling near *Turn stile* in *Holborn*, have those incomparable Instruments, that will shew them to play Addition and Subtraction in l.s.d. and whole Numbers, without Pen, Ink or help of Memory; which were the invention ... of Sir *Samuel Morland*.[51]

Morland similarly directed his instruments both to the educated and the uneducated in *The Description and Use of Two Arithmetick Instruments, Together with a Short Treatise, Explaining and Demonstrating the Ordinary Operations of Arithmetick*.[52] The book is both a manual for the two addition and multiplication instruments and an introduction to the concept of decimal notation and to arithmetic in general.

Advertisement for Morland's instruments began much earlier. On 16 April 1668 Morland first printed short descriptions of the two instruments in the London *Gazette*.[53] As would now be expected, the instrument made its way into the pockets of modern young gentlemen. Just before the advertisement appeared, Samuel Pepys, formerly Morland's tutee at Cambridge, described his impression of one recently purchased by his employer: 'My Lord [Hinchingbrooke] had Sir Samuel Morland's late invention for casting up sums of £.s.d. which is very pretty but not very useful.'[54] Hinchingbrooke was the young Edward Montagu, eldest son of the first Earl of Sandwich, who was an old acquaintance of Morland's. Hitchingbrooke had recently returned from study in Paris and travel in France and Italy. His travels with Morland's calculator in early 1668 were followed by a burst of interest in the instrument in both France and Italy. This is documented in the correspondence of Henry Oldenburg, secretary to the Royal Society, and Henri Justel, secretary to Louis XIV. Justel wrote to Oldenburg in early May,

> I beg you to let me know whether Mr. Morland's machine is made like that of Mr. Pascal, which you have doubtless seen. It is difficult to believe that it can extract square roots. It can to all appearances be used only for little things. Mr Magalotti told me that it was small. I don't find it costly, considering its novelty. In time it will be cheaper.[55]

50 J. Moore, *A Mathematical Compendium*, London, 1681, 21.
51 Moore, op. cit. (50), 20
52 Morland, op. cit. (42).
53 Reprinted in Dickinson, op. cit. (1).
54 Pepys's Diary, 14 March 1668.
55 Justel to Oldenberg, 9 May 1868, in A. R. Hall and M. B. Hall, *The Correspondence of Henry Oldenburg*, Madison, 1967.

Justel's information may have been based on advertisements like that in the London *Gazette*, in which it was suggested that the adding machine (at a price of £3 10s.) be combined with the multiplication machine (at an unnamed price) in order to form an instrument to perform all the operations of arithmetic as well as square roots.[56] Justel's now familiar attitude towards the price of this new device, which implied imminent cheapening, suggests that there was an active trade in novel technology.

Although the capacities of Morland's instrument were not clear to Justel, it was the opinion of Pierre Petit, inventor of a cylindrical form of Napier's bones, that Morland's machines could not be capable of unassisted multiplication or division.[57] But the rumour of Morland's little calculator's exaggerated capabilities persisted. The correspondence continued until 15 July, during which time Justel wrote three more times asking for information. The important question to which Justel persistently returned was the comparison between Morland's calculator and the famous Pascaline:

> It is difficult always to have two machines [both the instrument for multiplication and the one for addition]; nevertheless, it is much more perfect than that of Mr. Pascal, because it is so small and a better bargain; but as many rules are necessary as for Mr. Pascal's. I should be very glad to learn the exact price.[58]

Interestingly, the initial impression was that Morland's instrument was no more difficult to use than Pascal's and that despite its automatic carry mechanism, the Pascaline was still considered difficult to use with rules of operation. This echoes an earlier description of the Pascaline in a letter from Balthazaar Gerbier to Samuel Hartlib in 1648. Gerbier noted, 'Butt a man must first be exact in Arithmetike before he can make use of this Instrument.' Together with the expense of the instrument, Gerbier was dubious about the practicality of the Pascaline, calling it 'a Rare Invention farre saught, and deare baught: putt them in the Storre house was the old Prince of Orange wont to saye and lett us proceede on the ordinary readdy [ready reckoning] way'.[59] We cannot assume that Pascal's machine was considered easy to use. The complex gearwork of Pascal's instrument was a potential drawback, as Pascal aimed to counter in his own advertisements:

> Although [the Pascaline] is composed of many different small parts, as you can see, at the same time it is so solid that, after the experience of which I have spoken before of ['carrying the instrument over more than two hundred and fifty league of road, without its showing any damage'], I assure that the jarring that it receives in transportation, however far, will not disarrange it.[60]

Morland's adding machine, in contrast, was made to be carried in the pocket. It would be an obvious improvement if, as Justel seemed to believe, an instrument the size and price of Morland's two machines could perform all operations of arithmetic. But

56 As with Napier's bones, Morland's multiplication machine could be used in theory as an aid in the extraction of square and cube roots, but no such claims could be made about the adding machine.

57 Justel to Oldenburg, 10 June 1668, in Hall and Hall, op. cit. (55).

58 Justel to Oldenburg, op. cit. (57).

59 Balthazaar Gerbier to Samuel Hartlib, 4 October 1648, in Hartlib, op. cit. (8).

60 D. E. Smith, *A Source Book in Mathematics*, New York, 1959, 171; insertion by the present author.

apparently a fuller description of the capabilities of the instruments left Justel disenchanted: 'I thank you for what you have told me about Mr. Morland's machine', wrote Justel to Oldenberg in late June, 'which is surely not very useful'.[61]

Though Morland was clearly seeking to tap into the wider market for mathematical instruments in London and beyond, his success would lie mostly within court circles. In August 1667 Charles II awarded a prize of £1,000 to Morland, 'being for providing severall mathematical Instruments for our own use according to Our particular Direction'.[62] Morland's *Description and Use of Two Arithmetick Instruments* was thus dedicated to the king. More importantly, the reference to Lorenzo Magalotti of the Accademia del Cimento in Justel's first letter links French rumours of Morland's instrument to Italy, where another crucial character found Morland's adding machine worth purchasing. This was Cosimo III de Medici. A detailed account of Cosimo's acquisition of an adding and a multiplying instrument, in addition to other inventions of Morland's, survives in the state archives of the Medici family in Florence. In 1959 Anna Maria Crinò reprinted some ninety-seven letters written about Morland by Cosimo III and his agents Terriesi, Brunetti and Bassetti.[63] Spanning the years 1668 to 1697, this collection of letters adds an entirely new dimension to Morland's biography that so far has not been appreciated in English-language accounts of his life. Not only does it make clear that throughout his career Morland was engaged in a generally successful patronage relationship with the Medicis, it also provides much more detail about the use and appreciation of Morland's machines by his major patrons. Cosimo III, grand duke from 1670 to 1723, had none of the love of natural philosophy for which his brother Leopold, founder of the Accademia del Cimento, was known. Cosimo III is often recognized as having been ruinous for Florence and its once great intellectual, cultural and financial repute.[64] Deeply religious, Cosimo III outlawed the discussion or teaching of atomism. The real focus of his collecting was on religious relics. Morland appears to have been among very few inventors who were in his favour. The existence of Morland's viciously anti-Catholic *History of the Evangelical Churches of the Valleys of Piedmont* makes their relationship all the more curious.

In the summer of 1668 Prince Cosimo, through his assistant Bassetti, told the London agent Brunetti that he wanted to have an example of a calculating machine that he had been hearing about. These letters record the commission and purchase of one of Morland's adding machines in detail. Bassetti wrote on Cosimo's behalf to Brunetti on 30 June 1668:

> The Prince has heard that a man named Samuel Morland (but perhaps this name is wrong) has invented an instrument that is similar to a box of 'occhiali' [eye glasses] which is made in such

61 Justel to Oldenburg, 27 June 1668 and 15 July 1668, in Hall and Hall, op. cit. (55).

62 Warrant of Charles II to Samuel Morland, 8 August 1667. Museum of the History of Science, Oxford.

63 Crinò, 'I rapporti di Sir Samuel Morland', op. cit. (1). Thanks to Mara Miniati for introducing me to Crinò's work, and to Mariella Guida and Carlo Triarico for their help in producing the translations contained here.

64 P. Strathern, *The Medici: Godfathers of the Renaissance*, London, 2003, 390. Also see G. F. Young, *The Medici*, New York, 1930.

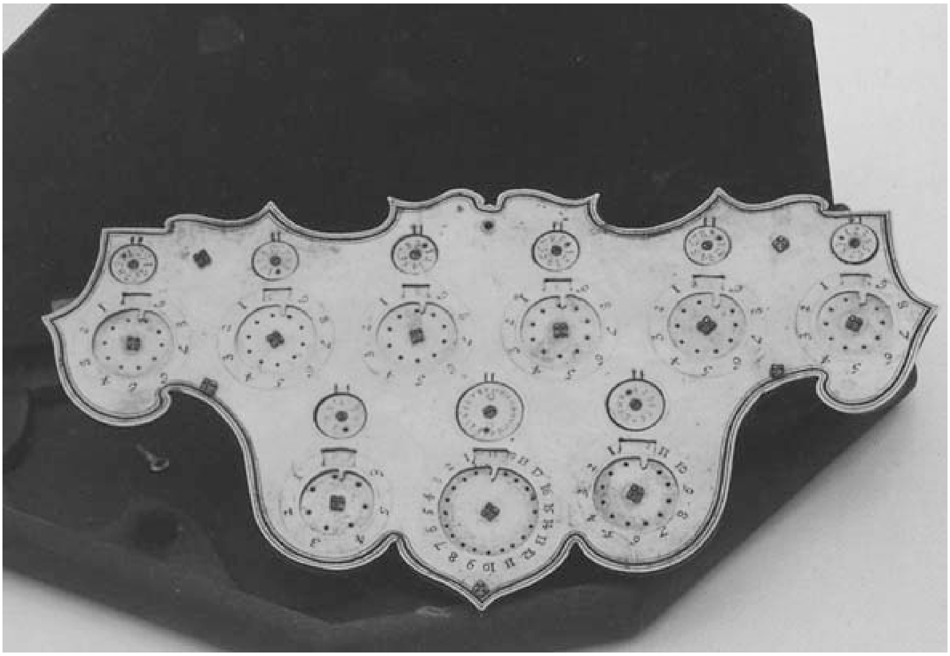

Figure 4. A Morland-type adding machine, mistakenly attributed to Tito Livio Burattini, at the Istituto e Museo di Storia della Scienza in Florence.

> a way that when you round some circles it is possible to see immediately the result of some reasoning or arithmetical calculation. If this is true, the Prince wants to have one of these.[65]

When Brunetti contacted Morland, there were no instruments in stock, but Morland acted quickly, assuring Brunetti he would find one and 'offer it to the Prince along with other curiosities because he is ambitious in his desire to help the Prince'. It took about one month for Morland to produce the instrument, and he charged the advertised price of £3 10s.[66]

Much of the Medici family's collection of instruments is housed today at the IMSS Firenze. Although none of Morland's trademark silver-plated, card-sized adding calculators exist in the collection, there is an unusual form of Morland's instrument, shown in Figure 4. The materials, shape, style and workmanship of the instrument are entirely different and it has often been attributed to Tito Livio Burattini. A close look makes it clear, however, that the instrument is Morland's calculator but adapted to a different currency, most likely to the Florentine base-six *scudo* in place of the English base-four farthing.[67] It is difficult to say whether this is an instrument hastily produced

65 Crinò, 'I rapporti di Sir Samuel Morland', op. cit. (1), 3 June 1668.

66 Crinò, 'I rapporti di Sir Samuel Morland', op. cit. (1), 5 July 1668.

67 An investigation of the early catalogues of the IMSS Florence (the *Guardaroba mediceo* of 1640–66 and the *Real Gabinetto* of 1776) has shown that the identification of IMSS inv. no. 3179s as the instrument given by Tito Livio Burattini to Ferdinand II in 1659 is incorrect. Close inspection of the accession description for Burattini's instrument confirms that it does not match that of the Morland-type instrument in question. In a

by Morland to a design he thought the prince would appreciate, or whether it is an Italian-made copy. Within the context of the court circles where Morland sought patronage connections, the adding machine was a successful venture. It is less clear what should be made of the sharp difference between the opinions of people such as Pepys and Justel and those of Charles II and Cosimo III. This dichotomy similarly defines the reception and reputation of Morland's multiplication machine, which eventually ended up in the hands of Cosimo III.

Five years after Cosimo III's first purchase from Morland, the inventor was involved in one of the most successful projects of his career, an overhaul of the plumbing system of Windsor. At this stage he decided to make a gift of the multiplication machine to the grand duke. A series of letters beginning 17/27 February 1678/9 records the transaction. On this date Terriesi wrote to the grand duke,

> I received some letters, one inside another was by the knight Morland … he will also, I think, give you news of the present he wants to give you – an instrument he invented and made himself some years ago to exercise the four parts of arithmetic – addition, multiplication, subtraction, division – all of these without pain of the spirit or of the memory at all and without errors – all by simply revolving a trigger [*semplice voltura d'un grilletto*]. In this way you can do much of the work that many persons do with pencil and hand in the common way. He tells me that he has shown the beginnings of it to you when you were here. He says he has perfected it, and it is true, it is a very intelligent machine, made for the eye of a Prince like you, and he has told me that the instrument is very costly, expensively made, having cost him very much work, and after all this, now that he is old, he does not want it to remain in the hands of his young son, who is not able to understand its value, and he will be happy when he knows the machine is in your hands, where he knows it will shine for eternity.[68]

Note the focus on the interface design of the instrument, that all is set in motion with a single touch. Note also that, like Justel, Terriesi is really talking about using both of Morland's machines together. Morland often advertised them together as one instrument that could perform all operations of arithmetic. Cosimo replied that he would have 'infinite consideration' for Morland's 'ingenious invention' and that he would treat it 'like a gem – alongside the most precious things of mine'.[69] The exchange of gifts was central to courtier patronage culture. As Paula Findlen has argued, such gift-giving 'operated within a framework that emphasized memoria as one of the primary social motivations of collection and donation'.[70] This is precisely the context in which Morland made the offer of the multiplication machine to Cosimo, to be placed in his collection as a form of memorial to the inventor himself.

But Cosimo also apparently had a genuine interest in using the instrument, or at least in knowing how to use it. In December 1679 the grand duke received the *macchina*

number of sources, however, the instrument has incorrectly been described as Burattini's attempt at a Pascaline-type instrument. See G. and F. Tamis Cisilino, *Tito Livio Burattini: Scienziato agordino del '600*, Verona, 1983; Marguin, op. cit. (5); Soresini, op. cit. (5).

68 Crinò, 'I rapporti di Sir Samuel Morland', op. cit. (1), 233.

69 2 April 1679. Crinò, 'I rapporti di Sir Samuel Morland', op. cit. (1), 233.

70 P. Findlen, 'The economy of scientific exchange in early modern Italy', in *Patronage and Institutions: Science, Technology and Medicine at the European Court 1500–1700* (ed. B. Moran), Rochester, NY, 1991, 5–24, 21.

calcolatrice but was disappointed to find that no instructions had come with it. He was frustrated by not understanding its function. He taxed Terriesi until a copy of Morland's *Description and Use* finally arrived.[71] This exchange and the signs of wear on the machine itself suggest the patron had a deeper interest in the machine and in how it worked than might be assumed.

Morland's gift was successful in strengthening his connection to Cosimo. Other instruments were bought from Morland at the same time. Goods such as wine and silk were sent from Cosimo to Morland. Most importantly, Cosimo's interest in Morland and his works continued for years, even after the death of Charles II. In the 1680s Cosimo repeatedly asked Morland to move to the Medici court. But although life in London was increasingly difficult for Morland, he was also growing more and more convinced that the Medici were involved in a Catholic plot to murder him as revenge for his inflammatory anti-Catholic publication of 1655. This fear prevented Morland from ever even paying a visit to his patron.

Contrast this particularly successful use of the instrument within the context of patronage gift-giving with the reception Morland's instrument had received from Hooke and Oldenburg five years earlier. In January 1672/3, Leibniz visited London and brought along his new calculating engine. Leibniz attended the Royal Society and showed its fellows 'a new arithmetical instrument, contrived, as he said, by himself, to perform mechanically all the operations of arithmetic with certainty and expedition'.[72] Morland would have missed this demonstration, but through Oldenburg arranged a private meeting, asking Oldenburg to accompany Leibniz and his instrument to Vauxhall so that they could compare the two instruments.[73] It appears that Robert Hooke also attended this meeting. Morland and Hooke knew each other and were involved in some of the same projects. They served together on the board that evaluated Henry Bond's method of finding longitude by magnetic declination.[74] In addition, Morland's balance barometer was considered by some an improvement of Hooke's wheel-barometer design, while Hooke was asked by Charles II to produce some barometers of Morland's design.[75] The day of the meeting with Leibniz and Morland was set for 31 January. On that day Hooke wrote in his diary the words that have stuck to Morland's reputation for centuries: 'Saw Sir S. Morland's Arithmetic engine Very Silly –.'[76] This could easily be interpreted as a sour and territorial comment typical of Hooke, except that at other times Hooke praised Morland's work. In 1679 Hooke recorded that Morland had seen a prototype of Hooke's wheel barometer at Thomas Tompion's shop in 1679 and made 'very ingenious' improvements upon it.[77]

71 Crinò, op. cit. (1), 234.

72 22 January 1672/3, in Hall and Hall, op. cit. (55). This was an early wooden version of Leibniz's calculator.

73 Oldenburg to Leibniz, 30 January 1672/3, in Hall and Hall, op. cit. (55).

74 D. J. Bryden, 'Magnetic inclinatory needles: approved by the Royal Society?', *Notes and Records of the Royal Society of London* (1993), **47**, 17–31; Willmoth, op. cit. (4).

75 Bryden, op. cit. (1).

76 Robert Hooke, diary, 31 January 1672/3. Cited in Dickinson, op. cit. (1).

77 Bryden, op. cit. (1), 365.

Conclusion

Hooke's deflationary assessment of Morland's multiplication machine, a device later 'treated as a gem' in the Medici collection, echoes the opinions expressed about the adding machine by Justel, who judged it 'surely not very useful', and by Pepys, who saw it as 'Very Pretty but not Very Useful'. These machines were, however, appreciated both by Charles II and Cosimo III. This is one of the interesting puzzles of Morland's story and it is hard to know what to make of it. What is clear is that ultimately these machines functioned best as technical devices with a luxurious new appearance that pleased the king's fancy and were set to capitalize on the growing numeracy of the upper classes. In this way, Morland's unique contributions to London's thriving mathematical instrument trade, performing arithmetic with expensive gears and dials, were entirely characteristic of a courtier–inventor in Restoration London. This is the question that remains: how influential was courtier science in the Restoration? Were the people and products of the court typically regarded as frivolous in the way that Morland and his calculators so often seem to have appeared to practitioners and consumers outside the court? Or should the enigma of Morland – at the centre of court society (member of the Privy Chamber, Master of Mechanicks, resident of Vauxhall, courtier to the Medici and Louis XIV) and yet apparently so unimportant outside the court – be explained by some other means?

Samuel Morland and other similar courtier–inventors have yet to be securely situated within our understanding of Restoration science. Yet the case of Samuel Morland and his calculators does shed some light on an area of Restoration science that has been particularly difficult for the historian to explore. We have been able to trace the origins of an English courtier's invention and its propagation through the commercial market, the philosophical societies and the courtly circles of Europe. This study has illuminated Samuel Morland's establishment of himself as a courtier–inventor in Restoration London. It has confirmed the central importance of the role played by correspondents such as Magalotti, Justel and Oldenburg in influencing the reception of novel commercial technologies. Furthermore, it has demonstrated how the world of the court, the philosophical societies and the instrument-makers' shops were actively interconnected. This offers a better understanding of the way courtier–inventors engaged with the wider culture of seventeenth-century commerce, technology and natural philosophy. Such connections are important to recognize for two reasons. First, they draw attention to the world of the courtier–inventor as a basic component of Restoration science and technology. Second, by making more visible the extant system of state science and technology, we gain a better understanding of what it was against which the members of the new Royal Society were defining themselves.