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THEMATIC DOSSIER
SMALL SCIENCE: PERSPECTIVES ON CONTEMPORARY SMALL-SCALE RESEARCH

Small by Design? Acting, Being, and Feeling Small in the History of Quantum and Mechanical Computation

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Abstract: Accounts of the relationship between eighteenth century artisanal practice and the development of modern scientific practice and culture have produced an influential range of concepts that have aided historical and sociological accounts of contemporary scientific practice: invisible technicians, tacit knowledge and artisanal thriftiness have all served as tools to understanding the integration, processes and development of more contemporary scientific practice. However, despite the seemingly apparent evocation of artisanal practice as something related to—but eventually "less than"—scientific practice in terms of authority, resources and geographical reach, concepts alluding to smallness has been frequently evoked but received little attention as an analytical category tool in its right. This paper will offer two case studies to interrogate the relationship between "smallness" and practice with an emphasis on counterposing actor's categories with the social relations of knowledge/technical production. The first case explores the relations between the London clock and watch making community and the (human) computers and calculators employed by the Royal Observatory in Greenwich. The second traces and analyses the development of quantum technologies in Europe in the twenty-first century. By analysing the different uses and meanings of "smallness" in these two contexts, this paper will highlight the strategies, intentions and debates within techno-scientific and artisanal groups and point to the different ways in which "smallness" operates. This paper will suggest that through paying attention to "smallness," concepts such as experience and feeling may offer a useful way into thinking about issues of scale and development in contemporary science.

Keywords: Computation; quantum technology; artisans; markets; clocks

Introduction

On 2 October 1813, the London-based surveyor Joseph Steevens wrote to the president of the Spitalfields Mathematical Society (SMS) to explain the purpose of the society's newly unveiled *Receptacle*. Complimenting the 179-page publication of "plans, drawings, designs and descriptions of Canals, Docks, Rivers, Roads and Bridges" that had been kept by its members since the 1780s, the *Receptacle* made clear its political motivation:

> The most powerful stimulus that can be offered to the industrious mind, is an assurance of enjoying the fruits of its own labour, this then is the object of the Receptacle, which is intended chiefly as a Register for the Inventions and Improvements of Members and others, who may frequent the Society, and who's productions have been so frequently pirated and claimed by those, who have had scarcely merit enough to copy them.[1]

The Spitalfields Mathematical Society was founded in 1717 in the Spitalfields area of London. Originally a society for the weaver-artisans of the area, it was said that its early membership was limited to sixty-four (the square of eight). The membership of the society gradually grew from its modest numbers such that by the 1760s, its membership is thought to have been around three hundred, before declining gradually through to the 1820s. The society's location changed over time—typically in rented rooms above pubs - but by the 1790s it had permanent rooms—including a library of books and instruments—in a former French chapel on Crispin Street which also likely housed a nonconformist chapel.[2] Over time, the membership of the society broadened out from those trades directly associated with silk-weaving to including clockmakers, apothecaries, seedsmen, distillers, brewers, brick-makers and optical and mathematical instruments makers.[3] At the same time, the scope of activities of its members moved from beyond calculation and arithmetic to a wide range of practices associated with natural philosophy, including experimental pneumatics, chemistry and electricity.[4]

In the 1820s, the Royal Astronomical Society (RAS) was formed and later took over the SMS's instruments and rooms, acquiring the *Receptacle* and designating it as a "Scrapbook," the term still used to describe it today. Despite the clear statements of intent and resistance

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[1] University College London ADD 75, "Receptacle for Plans, Drawings and Descriptions, Canals, Docks, Rivers, Roads and Bridges," 3.

[2] J. W. S. Cassels, "The Spitalfields Mathematical Society," *Bulletin of the London Mathematical Society* 11 (1979): 241–58. This is likely to have been No. 36 Crispin Street, which also served as a noncomformist chapel,

[3] UCL ADD 75, "Scrapbook of the Spitalfields Mathematical Society," 3.

[4] Larry Stewart and Paul Weindling, "Philosophical Threads: Natural Philosophy and Public Experiment among the Weavers of Spitalfields," *The British Journal for the History of Science* 28, no. 1 (March 1995): 42–43.

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by the society's members to protect and promote their vision of just authority of labour against unmeritorious appropriation, the particular political character of the SMS and its members of the early nineteenth century were quickly forgotten. In its place, the SMS was remembered as being *either* an amateurish group of unruly and unthreatening artisans and craftsmen, *or* a group of aspiring, respectable merchants striving for acceptance into London's metropolitan elite.

The RAS counted amongst its first members influential London figures including the astronomer William Herschel, the mathematician and early advocate for mechanical computation Charles Babbage, and the banker-turned-economist Francis Baily. Despite incorporating much of the Spitalfields Mathematical Society's materials and library, its members were keen to distance themselves from the social background and political concerns of the Spitalfields mathematicians. By the 1840s, the president of the RAS Augustus de Morgan contrasted the type of members of the RAS with the intellectual state of working people who had traditionally made up the SMS. De Morgan suggested that artisans or working people had long abandoned scientific activities and so no longer were in place to join the RAS:

> The only question which could arise was whether the members of the society of working men—for this repute still continued—were of that class of educated men who could associate with the Fellows of the Astronomical Society on terms agreeable to all parties. We found that the artisan element had been extinct for many years. . .The fact was that life in Spitalfields had become harder: and the weaver could only live from hand to mouth, and not up to the brain.[5]

According to the ideology of people like de Morgan, hard times forced working people to abandon activities like mathematical and scientific associations, which, in this vision were additions to—rather than part of—their working lives. Had de Morgan taken the *Scrapbook/Receptacle* more seriously, he would have found it hard to ignore the clear expressions by members of the society that the point of their association was precisely to protect their work against from those they perceived as "copiers:" people who take credit without undertaking the *work*. De Morgan is not unusual in this apolitical reading of working people's scientific associations. Historical interpretation to account for of the end of artisan-led societies is sorely lacking, pointing to the more general trends of socio-economic pressure on leisure time, rather than the active expropriation of scientific experimentation and discussion as a means of politics and control of work. As such, historical debate accounting for the emergence and purpose of the mechanical institutes that appeared in industrial centres from the 1830s-40s suggest that their members were interested in acquiring social status

[5] Augustus de Morgan, *A Budget of Paradoxes*, Vol. 1, 376–78.

(aspiration) and their architects founders were compelled a need for social control.[6] What was not mentioned by de Morgan, nor by more recent interpretations of the society, was the struggle on the part of members of the SMS *through* mathematics, engineering and computation to assert a different kind of social organisation of labour and intellectual production. Simply because they ultimately lost, did not mean that they accepted a model of production that transformed conceptions of their labour as being that of hand to mouths, rather than that of hands and brains.[7]

In place of remembering the principled stance and resistances made by members of SMS, early members of the RAS revelled in contrasting the raucous culture of the artisan-mathematicians of the SMS against the RAS's more sober, diligent, practices. In a letter to de Morgan from the banker-astronomer Benjamin Gompertz, meetings of the SMS were apparently smoke- and drink-fuelled. Gompertz reminisced that members sung an "Astronomer's Drinking Song," including the following verses:

> Descartes took nought but lemonade,
>
> To conquer him was play, sir;
>
> The first advance that Newton made
>
> Was to drink his bottle a day, sir!
>
> "D'Alembert, Euler, and Clairaut,
>
> Though they increased our store, sir,
>
> Much further had been seen to go
>
> Had they tippled a little more, sir!
>
> Lagrange gets mellow with Laplace,
>
> And both are wont to say, sir,
>
> The *philosophe* who's not an ass
>
> Will drink his bottle a day, sir!
>
> "Astronomers! what can avail
>
> Those who calumniate us;
>
> Experiment can never fail

[6] Steven Shapin and Barry Barnes, "Science, Nature and Control: Interpreting Mechanics' Institutes," *Social Studies of Science* 7, no. 1 (1977): 31–74.

[7] For older conceptualisations of the society in the history of science, see Cassels, "The Spitalfields Mathematical Society" and Stewart and Weindling, "Philosophical Threads."

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> With such an apparatus:
>
> Let him who'd have his merits known
>
> Remember what I say, sir;
>
> Fair science shines on him alone
>
> Who drinks his bottle a day, sir! [8]

As any seasoned drinker can tell you, there are much worse drinking songs to be remembered by. Yet, the function of this kind of exotic "rememberance" is to create a sharp contrast between the calibre of the two groups, by practice, temperament and aims. Indeed, de Morgan was keen to separate the "high" culture of the two societies from the "low" of the artisans:

> We are very high in the newest developments, and bid fair to take a place among the scientific establishments. . .But not a drop of liquor is seen at our meetings, except a decanter of water: all our heavy is a fermentation of symbols; and we do not draw it mild. There is no penny fine for reticence or occult science; and as to a song! not the ghost of a chance.[9]

The ostensibly light-hearted comparison of the culture of the RAS compared to the SMS in fact served to make an important distinction: by exorcising any "ghosts" of past practices through the enforcement of "high" and "heavy" developments, the RAS were relying on metaphors of status and credit that had become matter of fact by members of the scientific establishing by the 1840s.

As historians have shown, the deployment of language of hierarchy and difference in the London of the 1790s-1810s—high versus low; heavy versus light—were used to justify an apparatus of expropriation upon which such differences were maintained.[10] Yet, groups like the SMS saw that their particular association could challenge ruling assumptions and practices. In their *Receptacle*, members of the SMS chose another set of analogies to make sense of their collective endeavour and intellectual labour:

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[8] Letter from Benjamin Gompertz to Augustus de Morgan, quoted in de Morgan, *A Budget of Paradoxes*, 380-383.

[9] De Morgan, *A Budget of Paradoxes*, 383.

[10] See Peter Linebaugh, *Red Round Globe Hot Burning: A Tale at the Crossroads of Commons and Closure, of Love and Terror, of Race and Class, and of Kate and Ned Despard* (Oakland: University of California Press, 2019) and Peter Linebaugh and Marcus Rediker, *The Many-Headed Hydra: The Hidden History of the Revolutionary Atlantic* (London: Verso, 2012).

> As large streams are produced by the confluence of many smaller ones, so will the scientific productions of many (however trivial in themselves) form an aggregate of magnitude and intrinsic worth.[11]

In contrast to de Morgan's emphasis on *apriori* weight and size of scientific institutions to produce high-status knowledge, the members of SMS chose instead the metaphor of confluence: trivial and small-scale enterprises were only problems if they were prevented from coming together. This was the politics of association. Being small was not something inherently de-legitimising, but rather something that was fundamental for the production and replenishment of knowledge. What mattered was precise and carefully planned ways to allow water (knowledge) to come together.

It is around the SMS's nineteenth century manifesto of being small that this article takes it cue: to interrogate certain uses of "smallness" through an exploration of the organisational modes of scientific production in the computational sciences from 1760 to the present day. In his work on technological systems building, Rosalind Williams has argued that there "is a shared, powerful cultural assumption that is the destiny of the West to promote circulation through technological system building."[12] It is one claim of this article that part of the Western-led cultural assumption of circulation and techno-scientific system building, an enduring supposition has emerged that "the small" is the necessary precursor to "the big." As such, smallness has been framed either as "absence of" or as "first stage" rather than an active claim and organisational form in its own right. This article seeks to present two moments in the shaping of these assumptions, as well as challenging some of the resulting consequences that have followed from it. It will do so in two case studies. The first case study explores the changing relationship between artisans and human computers with the Royal Observatory in Greenwich specifically and the pursuits of the British-imperial state more generally. In their struggle to maintain autonomy, customary forms of credit, and guarding against surveillance, the case demonstrates the important ways in which artisans attempted to resist the forms of dispersed, exploited and monitored work of the human computers and calculators whose activities were the key to the Royal Observatory, which itself was positioning itself as a site to test and judge the work of artisans. The second case study presents research on the emerging area of quantum technological development. It will show how conflicting ideologies of big state funding (bad) and free market activity (good) have led to forms of discourse and representations of being small that whilst not accurate in themselves, allow us to make some distinctions of the uses of small science as a discourse. It is suggested that a system that rewards "acting-small" but which results in

[11] UCL MS ADD 75, "Scrapbook of the Spitalfields Mathematical Society," 3.

[12] Rosalind Williams, "Cultural Origins and Environmental Implications of Large Technological Systems," *Science in Context* 2, no. 3 (1993): 377–403.

actors "feeling small" may shed light on the relationship between techno-scientific work and forms of alienation in the twenty-first century.

From the two case studies, the piece identifies four kinds of "smallness" that have formed in relation to the organisation of techno-scientific production in two different stages of the history of computation: acting small, feeling small, being small in itself, and being small for itself. The second case study identifies two kinds of "smallness" that unsettled the big. From this, the objective condition of *being small in itself* is contrasted with the much more active - potentially radical - status of *being small for itself*. The second case study attempts to show how "smallness" may be used as an ideological or discursive category to obscure the larger forms of financial and institutional organisation upon which its work directly relies. The second case study shows how in "big" systems, "smallness" can exist as the handmaiden of the big. It argues that two related forms of "smallness" may result from this "false consciousness" smallness: *acting small* and *feeling small*, where the first may have positive effects for its promotors, but the second typically will not.

Recent outstanding work by historians, including in this thematic dossier, has explored the subjective and objective ways in which scale effects the production, circulation and impact of modern techno-sciences. By exploring the meanings of "smallness" of scientific practice in their political and economic contexts, this article draws on an important historiographical tradition in which a labour history of the sciences may challenge rather than simply "add to" accounts of modern techno-scientific development. It is hoped that by identifying smallness as passive and active categories that we may better understand not just understudied processes of alienation and subsumption within the sciences, but also, perhaps, provide the tools to reorient practices away or against more totalising aspects of technological systems. This is all the more important as it is through those systems, as Rosalind Williams reminds us, that Western cultures assume circulation must occur.

Mechanical Computation: 1760s-1820s

In the early 1820s Charles Babbage, a founding member of the RAS, presented his first paper proposing a mechanical form of computation to replace the work of human computers, calculators and comparers who were employed by the Astronomer Royal from the Royal Observatory in Greenwich.[13] From the 1760s, state-funded observatories like the Royal Observatory developed two primary functions: the production of the *Nautical Almanac* and, increasingly, the regulation of navigational instruments, particularly mechanical

[13] Charles Babbage, "Note on the Application of Machinery to the Computation of Astronomical and Mathematical Tables," in *Babbage's Calculating Engines: Being a Collection of Papers Relating to Them; Their History and Construction*, ed. by Henry P. Babbage, 2010): 211–211

timekeepers. The *Nautical Almanac* was first published in 1767 and described the position of a range of celestial bodies for each hour of a year and their relative position to the earth's surface. Its purpose was to assist ship's crews to determine their location by longitude at sea through accurate shipboard astronomical observations. The contents of *Nautical Almanac* were based on the intensive records compiled by astronomical assistants—those human computers, calculators and comparers—and managed by the Astronomer Royal at Greenwich.

The work of human astronomical computers was seen by Babbage and other members at the RAS as both error prone and difficult to reform. The Greenwich system for the production and regulation of astronomical data has been described as a "cottage-industry" made up of a "computer," "anti-computers," "comparers," and a supervisor whose role was filled by the Astronomer Royal. Computers were based at the Royal Observatory in Greenwich and the work of "anti-computation" and "comparing" was "put out" to households of skilled mathematicians paid piecemeal for their work.[14] Although dealing with huge nbig-data sets, this was work made up of a few members, through scattered around England and Wales.

As the historian Mary Croarken has shown, the work of a computer at Greenwich was extremely arduous and involved making a huge amount of astronomical observations. Roughly eighty percent of the observations computers made would have been lunar and stellar transit observations.[15] The method that computers employed was called the "ear and eye method." This activity demanded that the computer observe using one of the observatory's telescopes the motion of a star across the grid of an eyepiece micrometre with five vertical wires; as the celestial object passed each wire, the observer had to note down the time on a transit clock which was a pendulum beating at one-second intervals nearby. To produce a result for the time the star passed an individual wire, a computer would have had to judge how far the celestial object was from the wire before it passed the wire and after it passed the wire—while carefully listening to each beat of the pendulum clock—and estimate its transit time to the nearest one tenth of a second. This was repeated for each wire to produce five separate observations that together made up the mean for one observation.[16]

To produce consistently accurate results using this method required a great deal of skill and concentration. The task was made even more difficult as it was required to be performed repeatedly throughout the day. Croarken has described the intensity of the observing

[14] CUL RGO 4/324, 'Maskelyne's orders to John Crosley for computing'

[15] Mary Croarken, "Astronomical Labourers: Maskelyne's Assistants at the Royal Observatory, Greenwich, 1765–1811," *Notes and Records* 57, no. 3 (2003): 290.

[16] Troughton quoted in Simon Schaffer, "'On Seeing Me Write': Inscription Devices in the South Seas," *Representations* 97, no. 1 (2007): 90–122, 108.

schedule, highlighting examples of certain two-week periods in which the assistant averaged only two hours sleep a night.[17] The standard intensity of workload required computers to be ready for observation from 7 o'clock in the morning until 10 o'clock at night. This long schedule was expected to be observed every day apart from Sundays, but even then, computers were required to make observations.

The payment for computers was significant compared to that of comparers and anti-computers—in the 1790s, computers earned approximately £96 a year—yet the work was known to be exceptionally tedious and dull.[18] As one computer put it in a letter to his family:

> Nothing can exceed the tediousness. . .of the life the assistant leads in this place, excluded from all society, except, perhaps, that of a poor mouse which may occasionally sally from a hole in the wall. . .Here forlorn, he spends days, weeks, and months, in the same long wearisome computations. . .frequently up three or four times in the night. . .to make his observations.[19]

One of the main problems for Astronomer Royals was finding someone skilled but also prepared to stay in the position. In 1811, John Pond was appointed as the new Astronomer Royal at the Royal Observatory. In his first year as Astronomer Royal he complained to a fellow member of the Royal Society that the computers employed at Greenwich were prone to error and distraction and therefore undermining the quality of the *Nautical Almanac*. What was needed, he thought, was a special kind of employee—a drudge—who would not be distracted by abstract thought.[20] In this way he was making the case for a distinction between two different kinds of labour: between that of the "head"—like those of an Astronomer Royal or a member of the Royal Society—and that of the hand—like that of a computer.[21]

Pond's new system extended went far beyond redefining the status of human computers and calculators—and therefore computational and calculative practice—as something akin to an unthinking task. In 1818, Pond devised a scheme at Greenwich for matching the ever-expanding demands of British imperial maritime system with enough mechanical

17 Croarken, "Astronomical Labourers," 290.

18 For the salary of assistants see: http://www.royalobservatorygreenwich.org/articles.php?article=941

19 "Letter from Thomas Evans, Computer at the Royal Greenwich Observatory 1796-98, to his family" quoted in Croaken, "Astronomical Labourers at Greenwich."

20 CUL RGO, "John Pond to William Hyde Wollaston."

21 For politics of head versus hand see, Lisa Roberts, Simon Schaffer, and Peter Dear, eds., *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialisation* (Amsterdam: Koninklijke Nederlandse Akademie van Wetenschappen, 2007). For later codifications of the role of astronomy and computation see William J. Ashworth, "The Calculating Eye: Baily, Herschel, Babbage and the Business of Astronomy," *The British Journal for the History of Science* 27 (1994): 409–41.

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timekeepers (by this period referred to as chronometers) to equip the expanding officer class to take longitudinal readings. Pond's scheme involved the creation of competitive trials, in which chronometers were given to the Royal Observatory for a period of testing. Those that were the best performing would win £300 and the second best would win £200.

Pond's chronometer system arose out of longstanding tensions between astronomers and members of the English government's Board of Longitude to communicate, understand and regulate London's well-established community of precision watchmakers. One of the key issues for the Board of Longitude, and indeed for the Royal Astronomer in Greenwich, was establishing a clear way to assess the performance of a timekeeper, and creating a clear basis on which basis to promote or award a certain watchmaker over another. One of the key issues was the collective ways in which watchmakers controlled access to the production and assessment of their work.

In the mid-eighteenth century, Robert Campbell pointed to the important role of "maker" or "master" in the clock and watchmaking trades: this was someone who though maybe had not "made in his Shop the smallest Wheel belonging to it," was still regarded as the maker of the watch, because the other members of the trade granted the maker the authority to be the "Judge of the Goodness of Work at first Sight, and put his Name to nothing but what will stand the severest Trial; for the Price of a Watch depends upon the Reputation of the Maker only." This authority granted to the master was on the collective understanding that the master *could* make the most technically demanding parts of the timekeeper.[22]

Authority and autonomy went hand-in-hand in the clock and watchmaking trades and huge attention went into keeping untrusted spectators or traders away from the site(s) of production. For example, the construction and assembly of a timekeeper could sometimes rely on the employment of at least forty-three different workmen. This process was not simply defined by a separation of tasks, but also by being dispersed over several locations. While the capital of the industry was firmly placed in Clerkenwell, important aspects of the industry were located across several parts of Lancashire, mainly in Prescott. In order to manage this distributed, heterogenous organisation, and at the same time maintain some kind of "opacity" of the work done by the trade, one of the main strategies used by clock and watchmakers was the use of a "caliper plate" (see Figure 5). According to Jonathan Betts, a calliper plate was "a brass disc made to precisely the same size as the frame of the [watch] movement, and with all the essential dimensional data either scribed on it, in the case of wheelwork etc, or drilled or dotted, in the case of pivots or screw-holes etc."[23]

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[22] Robert Campbell, *The London Tradesman, Being a Compendious View of All the Trades, Professions, Arts, both Liberal and Mechanic, now Practised in the Cities of London and Westminster* (London, 1747), 250–52.

[23] Jonathan Betts, "How the marine chronometer was made," *Marine Chronometers at Greenwich: A*

The purpose of the calliper plater was not only to provide immutable instructions, but also to maintain the autonomy and authority of watchmakers against that of manufacturers and philosophical reformers, looking to reorganise the mode of manufacture of scientific and navigational instruments. In this way, the use of the caliper plate found its place among several other practices in late eighteenth and early nineteenth century Britain. The Portsmouth Dockyards, for example, had developed a sophisticated practice of using "moulds"—portable templates used as specified guide for workmen to measure and cut the wood to construct the skeleton for a particular ship—to co-ordinate a range of different artisanal tasks without surveillance. Craft-practices that united technical experience with non-syntactical languages was the stuff of artisan work-relations against which reformers such as Samuel and Jeremy Bentham proposed ambitious plans to reform, expropriate and intensify the system of manufacture.[24]

Figure 1: "Chronometer Caliper Plate" by Joseph Preston. Source: National Maritime Museum, UK (ZAA0726).

Catalogue of Marine Chronometers at the National Maritime Museum, Greenwich (Oxford, 2018)

[24] Simon Schaffer, "'The Charter'd Thames': Naval Architecture and Experimental Spaces in Georgian Britain," in *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialisation*, ed. Lissa Roberts, Simon Schaffer, and Peter Dear (Amsterdam: Koninklijke Nederlandse Akademie van Wetenschappen, 2007), 281–82. For templates and the construction of medieval cathedrals, David Turnbull, *Masons, Tricksters and Cartographers: Comparative Studies in the Sociology of Scientific and Indigenous Knowledge* (London: Routledge, 2003), 55–90.

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Clive Behagg has shown that well into the nineteenth century, the ability to control access to the workshop formed one of the most important tactics of a master artisan's ability to secure their autonomy. Behagg argues that in the nineteenth century it was very difficult to enter a workshop as an "outsider." Yet, people did not necessarily avoid the workshop out of respect, but rather because the boundary was being determinedly guarded by workmen, seeking to "cling to a perceived 'traditional' status by adopting a variety of devices." These devices were informed by the elements of "a highly integrated culture" that used "secrecy, ritual, and folk violence" to protect what they saw as an attack on customary working relations and values by predominantly middle class and religious observers. Behagg recalls the concerns of one artisan, who in 1823 decried the presence of "foreigners:" "It is a well-known fact that when they have spent the day inspecting our most curious manufactories they devote the evening to making drawings and writing descriptions of the mode of working." To be a foreigner was not specific to nationality, but rather the degree to which a figure represented a threat to the ability of an artisan to maintain the "autonomous regulation" of work, in which the distinction between what was kept secret and was made public was of crucial importance.

Through these various tactics used by watchmakers to protect and insulate their organisation of production and credit, we might identify a different kind of "being small" as is in the active, conscious, sense of trying to "remain small," keep secrets, and maintain authority, against the pressure to "become big." The *active* nature of the clockmakers' determination to maintain authority and autonomy against bigger systems was exposed in the fallout to John Pond's controversial new chronometer system.

Pond's trial system was a deliberate move to eliminate any need for officers or the Admiralty in general to have to discriminate between the status or reputation of chronometer makers in order to choose the most suitable mechanical timepiece for use at sea. For the word or reputation of a clockmaker now stood for very little: what mattered was the assessment of the rate by observation at Greenwich. Furthermore, a competition based on the performance of a timekeeper by its rate and not by the word or reputation of the artisan opened up the competition to ambitions larger, non-artisanal, manufacturers.

In 1825, the *Mechanics Magazine* carried a letter from an anonymous author speaking on behalf of a "Real Workman." The letter challenged the government and the observatory for having awarded its chronometer prizes not to "real makers" but "to mere tradesmen by whom [the chronometers] might happen to be vended." This was, the author wrote, "little less absurd, than if the prize were given to the deputy astronomer for that chronometer to which he pays most attention."[25] The editor of the *Magazine* added that they "had

[25] William Parkinson, *Mechanics' Magazine*, 4 (1825), 134.

heard that, among "real workmen," it was a subject of very general complaint, that they were outstripped in the competition for the prize chronometers by masters who were not workmen."[26]

What followed in the pages of the *Magazine* was an exchange between the head of a prominent watchmaking firm called John French and a self-defined "real workman," George Muston. For Muston, Pond's chronometer trials had no way to discriminate between the claims of skilled or fraudulent makers and had done much to promote the activities of the latter: "a very large proportion of the chronometers that have been sent for trial; as they are known, to most of the practical workmen in the trade, and also to many gentlemen of science, not to have been made by the persons they bore."[27] John French had attracted the ire of Muston, because of his description of what a maker did. "It is well known," French argued,

> that a chronometer is not the production of a single mechanic, but the result of the combined labours of many: I must, therefore, protest, on general grounds, against the right of any individual workman to claim to himself the honours that exclusively belong to his employer; and if the workmen cannot complain individually, they cannot collectively. . .The laws that regulate master and workman are perfectly well understood; it is a voluntary compact, and the moment the workman has completed his contract, and received his wages, he is at liberty to work for another.[28]

Where masters could formerly assert their word that timekeepers would perform well, French now talked of his role as taking "the risk" that a timekeeper might not sell, or win a chronometer prize, or receive a bad report.

Muston, however, was very alert to the dangers posed to those in the trade by French's argument; French had failed to separate the qualities of highly skilled artisans who relied on experience to "bring a watch together" and those of a tradesman who could buy a complete timekeeper and stamp his name on it. French's arguments, Muston argued, "may deceive those who [have] imbibed certain ideas of *manufacturing,* but it would mean that the only particular property that might distinguish a skilled workman from a tradesman was the latter's 'possession of capital."[29]

For Pond and the Greenwich system, knowing *who* had made something, be it astronomical calculations, computation or marine chronometers meant very little. What mattered was the ability for someone—like him or like John French—to control and manage a system that produced the correct manufactured goods, and to ensure the obedience and discipline

[26] Ibid., 170.
[27] Ibid., 213.
[28] Ibid., 253.
[29] Ibid., 291.

of those that were doing it. As such, we might point to this system as one that explicitly aimed at a form of '*feeling small*' or alienation/estrangement.

In the two forms of struggle depicted around the computational and calculative functions centred on Greenwich in the late eighteenth and early nineteenth centuries, two other kinds of "smallness" might be identified: "being small in themselves" and "being small for themselves." In the case of the Greenwich computers, comparers and anti-computers, their combined work was based on extremely small groups, based in households on piece-meal wages, or in observatory activities, relying on relatively low pay with intense social and political isolation. Despite the combination of difficult work, low resources and small teams, they were also subject to being exploited and subjected to the threat of mechanical replacement, with little ability to resist except to leave. We might call these types of alienated workers (but not necessarily with a false consciousness) as "being small in themselves," to describe the objective situation of smallness, but also the subjective situation of not (necessarily) associating it with any virtues or possibilities.

The case of the London clock and watchmakers who found themselves in dispute with the Greenwich system (and then with each other) was quite different. As has been shown, chronometer makers initially made a keen distinction between those who "made" a timepiece, rather than those who merely sold them. This distinction was maintained by using forms of communication and trust to limit those people who might claim to be makers themselves. The use of the calliper plate and the intense forms of close-nit work on which completing a precision timekeeper relied —combined with the active guarding of workshop spaces—suggest that what these artisans were doing was "being small for themselves."

Quantum Computation: Barcelona and Brussels

Over the past twenty years, there has been increasing use of the term "Second Quantum Revolution" to refer to the new application of quantum principles to IT communication technology. The term "second quantum revolution" was first used in the early-2000s to describe the potential applications of merging of quantum theory and information theory in what is now known as Quantum Information Science.[30] Whilst the most eye-catching of these new technological projects has been the quantum computer, quantum-related development in cryptography, sensors, and simulations are part of the technological developments attracting wide-spread attention. Advocates have claimed that quantum technologies will dramatically reshape research (particularly biomedical research), business,

[30] Jonathan P. Dowling and Gerard J. Milburn, "Quantum Technology: The Second Quantum Revolution," *Philosophical Transactions of the Royal Society A* 361 (2003): 1655–74

economics and even society in general.[31] Governments at both the national and international level have declared the development of quantum technologies to be both a significant threat to regional security and a key policy area. We have been told that we have gone from one to two, or even three quantum revolutions.[32] Despite the significance of the discovery of Quantum Mechanics one hundred years ago, the term "quantum revolution" is now so widely used that it is simply stated as fact. Amidst the grand revolutionary rhetoric, more specific claims are being made related to the nature of quantum technological development that shed light on contemporary uses and meanings of smallness in the computational sciences. By contrasting the language of techno-scientific change with the specific institutional relations and social structures upon which these changes rest, a more complex understanding "smallness" can be developed.

Significant investment in quantum technological development is taking place across the USA, the UK, the European Union, Israel, and China. In Europe, Germany and Spain have emerged as significant centres of investment in Quantum Research. In 2022, the private consultancy firm Ametic reported that there were 67 firms or institutions involved in the development of quantum technologies in Spain.[33] According to the report the number of firms and institutions is taken to be evidence of the quantum revolution in Spain, and evidence that that this revolution is being powered by small-scale startups or SMEs.[34] Ametic's Spanish report, like industry reports of European quantum development, represent quantum technological activity by very specific kinds of output: patents, peer-reviewed articles, total funding allocated to quantum activity or total number of players. The currently available academic literature that exists tends to focus on the same aspects of development—such as the number of start-ups, patents or job expectations—implying that the specific organisational structure of quantum technological development is driven and measured by start-ups, patents and jobs in private industry.[35]

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[31] W. Castelein et al., "Quantum Technologies: Public Policies in Europe" (Kraków, Poland: QuantERA, 2023), https://quantera.eu/quantum-technologies-public-policies-2023/; A. García et al., Informe: La España Cuántica (Barcelona, Spain: AMETIC, 2022), https://ametic.es/publicacion/informe-la-espana-cuantica-2022-una-vision-empresarial/

[32] A. Celi et al., "Quantum Optics and Frontiers of Physics: The Third Quantum Revolution," *Physica Scripta* 92 (2016): 013003.

[33] https://ametic.es/publicacion/informe-la-espana-cuantica-2022-una-vision-empresarial/

[34] Since 2021, more than twenty reports have been published seeking to describe the level of activity related to quantum technological development. Whilst some, like Ametic, have a regional focus, most tend towards positing generalisable trends, though largely based on discrete outputs rather than organisational relations.

[35] 1. C. Hughes et al., "Assessing the Needs of the Quantum Industry," *IEEE Transactions on Education* 65, no. 4 (2022): 592–601; Z. C. Seskir, R. Korkmaz, and A. U. Aydinoglu, "The Landscape of the Quantum Start-up Ecosystem," *EPJ Quantum Technology* 9 (2022): 27.

However, by paying attention to the specific financial relations between institutions with a declared interest in quantum technological development, a very different picture of the institutional character of quantum technological development emerges. Through interviews, ethnographies, and systematic reviews of scientific grant awards and funding criteria, a "map" of the actors, institutions and companies involved in quantum technology development has been created that offers a different impression of the organisational activity of quantum technological development.[36] To explore the degree of financial—as opposed to discursive—commitment to quantum technology development, the category of funding and investment into quantum research, development and training was taken and then compared against those companies, research groups, start-ups, projects and government institutions with a self-declared interest in quantum technology. Each actor was then classified according to their relationship to funding for quantum technological research. This provided the following criteria: (1) Providers, (2) Receivers, (3) Both, (4) Not Specified. There were 221 institutions (or actors) identified in total, which were then first categorised according to their funding/investment role.

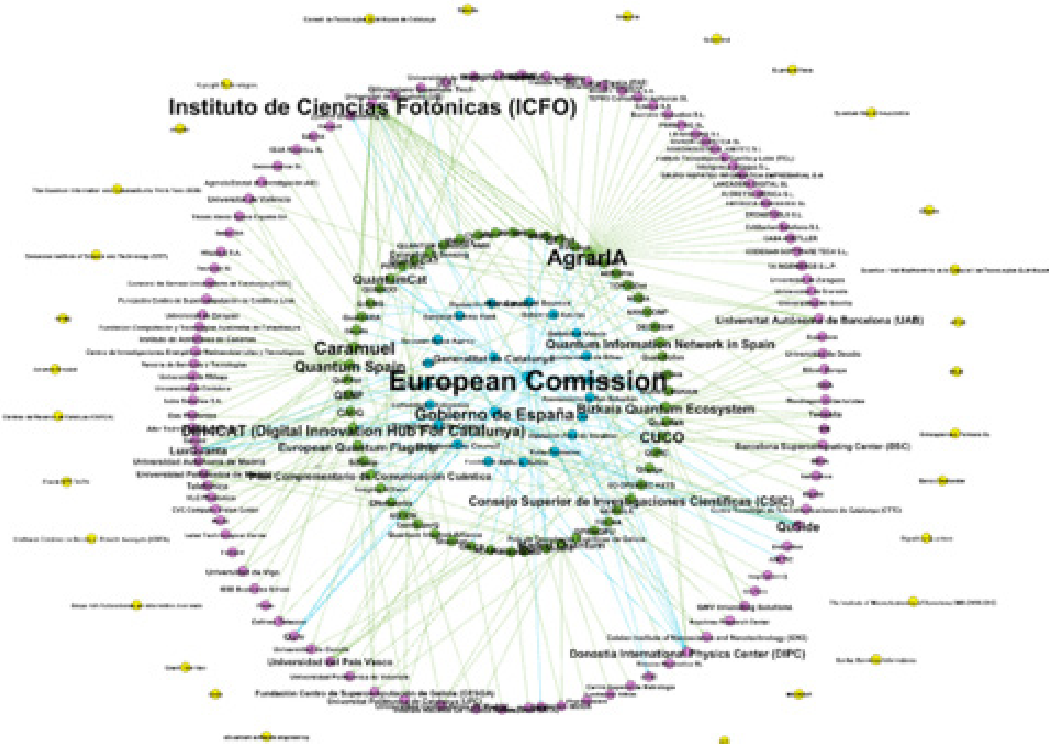

Figure 2. Map of Spanish Quantum Network.

[36] For some provisional findings related to Spanish quantum technological development, see O. Jiménez Farías et al., "Visualising Quantum Innovation: A Regional Case Study," *PLoS ONE* 19, no. 6 (2024): e0305140.

From this data, we have been able to produce a series of "maps" or visualisations of the funding and investment networks between institutions in Europe.[37] What you can see in Figure 2 above is a visualisation of all the quantum actors in Spain, based upon a network analysis. Those nodes represent those different institutions with a declared interest or statement of involvement in quantum technology activity in Spain. In the image above, each has been classified according to whether they are a funding provider (blue), a receiver and provider (green) a receiver (purple) and non-declared (yellow). The lines (links) emerge from a provider (blue node) or a receiver and provider (green node) and are connected to others only through the *tip* of an arrow. The non-declared nodes (yellow) have no lines connected to it or from it because no evidence of delivery or receipt of funding or investment was found. The blue lines emerge from pure provider nodes whereas green lines emerge from receiver-provider nodes. In the image above, the institutions are arranged in a circular layout where the providers of funds and investment are located at the centre of the circle, these are surrounded by those institutions that are receivers *and* providers, which are in turn surrounded by receivers, with the non-declared in the outermost ring.

From this data visualisation, there are several important features for understanding the nature of quantum technological development in Spain/Europe from which we may compare certain features of quantum discourse. First, it can be seen that the number of institutions that have provided funding or investment for quantum projects in Spain is very low (this does not mean the sum of funding/investment amount is low). What is particularly notable is that these funders are almost exclusively public/state institutions. The European Commission accounts for a large share of the money invested, funding 43.9% of actors, followed by the Spanish and Catalan governments, with 42% and 13.9% respectively. In contrast, private institutions such as the la Caixa Foundation, Kutxa Fundation, or CUCO only fund one single actor respectively.

A second notable finding is that the type of actor/institution that makes up those that both receive and distribute funding/investment are almost entirely entities that are known as "projects:" consortiums made up of public research centres and private businesses. In the Spanish case, projects make up on quarter of the total number of actors but receive the vast proportion of funds/investments. The third feature is that projects not only receive money, but are responsible for distributing it. From our data, we can see that apart from those central providers of funds/investment such as the European Commission and Spanish government, the major distributors of funds and investment are projects such as European Quantum Flagship, CUCO, Agraria, Caramuel, and Quantum Spain. These projects are

[37] Ibid.

then themselves both made up of universities, research centres and businesses which in turn allocate funds to research centres, smaller projects, companies, and start-ups.

An important example of a "quantum project" in Europe is the European Quantum Flagship, which is itself made up of a large number of smaller projects and what it describes as its own "ecosystems." The project is not based solely in Spain and is in fact a European-wide project. It has an advisor board of twenty members, with at least members representing every "quantum technology pillar" (The Quantum Coordination Board Terms of Reference). The technology pillars include "Communication, Computing, Simulation, Sensing & Metrology, as well as including cross-cutting activities such Basic science, Engineering & enabling technologies, Education & workforce development, Industrial aspects [sic]." The Flagship is made up of two types of leadership: a Strategic Advisory Board and Quantum Coordination Board. Of the fifteen current members of the Strategic Advisory Board, six members are based full-time in universities and research labs. Of those, nine are working in private industry and six have PhDs and a former background in quantum physics. The remaining three members state their experience in terms of patents.[38] Quantum leadership, in this way, not only represents a close intertwining of academic research with business but also represents a movement from academic research *into* private industry.

The European Quantum Flagship states its mission and aims in the language of a revolution: "The future is Quantum: The Second Quantum Revolution is unfolding now, exploiting the enormous advancements in our ability to detect and manipulate single quantum objects. The Quantum Flagship is driving this revolution in Europe." By placing themselves as the drivers "the revolution," the Flagship defines what such a revolution will look like, with the development of scientific leadership, industry and investment as key priorities. For example, the Flagship state that their aims are to: "boost and drive EU Quantum industry, expand EU scientific leadership, make EU [sic] an attractive region for innovative business and investments."[39] Alongside leadership and business, the "unfolding revolution" is also meant to entail providing "strategic capabilities for security," developing "a new knowledge-based industrial ecosystem," the two of which will lead to "long-term economic, scientific and societal benefits. . .[which] will result in a more sustainable, more productive, more entrepreneurial and more secure European Union."[40]

The Flagship makes no secret that the purpose of it as a project is to promote the development of quantum technologies *through* the development of private enterprise, scientific leadership, and entrepreneurship. Importantly, the attention paid to the actual

[38] https://qt.eu/structure-governance/strategic-advisory-board
[39] For the explicit aims and makeup of the Quantum Flagship, see https://qt.eu/
[40] Ibid.

DOI 10.2478/host-2025-0012

specifics of the technologies that are—or will be—revolutionary is very low. Much more is made of assuming that the results will be "revolutionary" and that the mechanism for doing so will be market-oriented enterprise. This is in line with what Alexander Campolo and Helen Crawford have called "enchanted determinism," which describes the attributing of superhuman effects to a technology or set of technologies with the consequence of relinquishing responsibility for those effects.[41]

The enchanted language of the Quantum Flagship is representative of the language of quantum projects in general. Projects have combined the language of revolution with the stated aim to make quantum technological development attract investment, increase commercial and entrepreneurial activity and to address "global challenges." In this way, quantum technological development in Europe follows the pattern of what Marina Mazzucato has called the "entrepreneurial state." Mazzucato has described the entrepreneurial state as one in which the state is simultaneously trying to create and shape markets, but which has also been written "out" of the discourse about markets.[42] Mazzucato points to the ways in which major technology companies like Apple have relied to a huge degree on innovations and developments funded by the state. Yet, if one was to follow their account of innovation and—even more importantly—the uncritical repeating of their story by many other commentators, then you would think that the innovations that went into, say, the iPhone came solely from them.[43] In this way Mazzucato is explicitly following Tony Judt's directive to look for, to uncover, and to pay attention to the "discursive" problem. Judt has argued that

> our disability is discursive: we simply do not know how to talk about these things any more. For the last thirty years, when asking ourselves whether we support a policy, a proposal or an initiative, we have restricted ourselves to issues of profit and loss—economic questions in the narrowest sense. But this is not an instinctive human condition: it is an acquired taste.[44]

Mazzucato has refined the concept into something less passive and more urgent as the need to see "discursive battles."[45]

In this way, the reports produced by technological consultancies companies like Ametic—who effectively write the state out of their accounts by "flattening" the political and economic

[41] Alexander Campolo and Helen Crawford, "Enchanted Determinism: Power without Responsibility in Artificial Intelligence," *Engaging Science, Technology, and Society* 6 (2020): 1-19.
[42] Mariana Mazzucato, *The Entrepreneurial State: Debunking Public vs. Private Sector Myths* (London: Anthem Press, 2013).
[43] Ibid.
[44] Tony Judt, *Ill Fares the Land* (New York: Penguin Press, 2010).
[45] Mazzucato, *The Entrepreneurial State*.

relations between startups, projects, and companies—are certainly engaged in the kind of "discursive battle" that Mazzucato has paid attention to. As consultancy companies they typically have a vested interest in both promoting technologies and emphasising the role of markets as well as promoting their role in facilitating markets. As Mazzucato has more recently argued, since the early 1990s consultancy companies have worked to situate themselves as both market actors as well objective experts advising governments and businesses on innovation strategies, funding and—typically— privatisation schemes.[46]

However, as we can see in the case of quantum projects, they too are engaged in a "discursive battle." Whilst the reliance on public funding is fundamental, their discourse is one of the needs to leave this dependency on the state and to *go to* the market. A recent article in *Nature* called for the need for quantum sensing to "get out of the laboratory."[47] The *way out* is demonstrated in the figure of the first author of the paper himself, who described himself in the following way:

> K.B. is co-inventor of US Patent 11,269,111, which relates to the gravity gradiometer mentioned in the article. He is also a shareholder in Delta-G, a spin-off company from the University of Birmingham exploiting this patent, and is on the advisory board for Quantum Exponential, an investment fund aimed at companies focused on quantum sensing.[48]

The main use of quantum sensors and the main contributors to patent holders to date is by the US military as communication signals detectors. The combination of state (in this case military) funding and the positioning of physicists as patentors and investors perfectly encapsulates the directionality of the quantum revolution: technologies need to get out of the laboratory, scientists need to be market actors and market investors. Or, to put it another way, if you don't have a market, build one, or *be one* yourself. This is the beating heart of quantum revolutionary leadership activity.

Considering the language of projects and the clear reliance of state funding and public scientific resources, in one sense it seems remarkable that reports and academic publications have not been more alert to take it seriously. This could be perhaps because it is a particularly European phenomenon (though work being developed analysing the development of quantum technologies in the USA and in China would suggest state involvement is not just a European phenomenon). However, it is more likely that the vagueness of the term "revolution" allows a range of potentially contradictory or even conflicting intentions and

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[46] Mariana Mazzucato, *The Big Con: How the Consulting Industry Weakens Our Businesses, Infantilizes Our Governments, and Warps Our Economies* (London: Allen Lane, 2024), 88-90.

[47] Kai Bongs, Simon Bennett, and Anke Lohmann, "Quantum Sensors Will Start a Revolution—If We Deploy Them Right," *Nature* 617 (2023): 672–75.

[48] Ibid.

experiences to operate, whilst maintaining some degree of rhetorical or political cohesion amongst the range of actors and institutions. "Quantum revolution" appears to have the ability to connect hoped for technological developments with market processes outputs at the expense of the inputs into its production that make it useful in a context when the point of such technologies is to create economic activity. The term revolution then, allows the state to be both called upon and written out; it is the market and market growth that is the prize, and the role of quantum technology is to bring it about. Major pillars of state funding and project coordination are converted into what can be made to look like market activity. Crucially, what also gets written out in the process is the work—both physical and analytical—of those physicists and technicians working day-to-day on quantum projects unless they are talking *as if they were the market*.

In his overview of the origin and meaning of the term "ideology," Raymond Williams has shown how the term has acquired three slightly different meanings, all of which are present in writings about the relationship between thought and one's place in society. Ideology, Williams suggests, may mean:[49]

1. a system of beliefs characteristic of a particular class or group
2. a system of illusory beliefs - false ideas or false consciousness - which can be contrasted with true or scientific knowledge
3. the general process of the production of meanings and ideas.

Based on the analysis presented above, it has been suggested that the quantum development discourse in Europe as being driven by "small" scientific start-ups and SMEs is extremely misleading. In this case, we might suggest that it falls within either first or second definitions of "ideology" described by Williams. If we are to be generous to those private consultancies—basing their data on outputs (patents, publications etc) rather inputs (funding and work done)—we might suggest that the assumption that startups are the basis of quantum markets and quantum inventions means it falls into category 1 or 2. However, for those scientists and technicians working in a predominantly publicly-funded structure of organisation, but who declare that innovation is coming from the private market, then placing that discourse into category 2—of a system of false consciousness—would be more appropriate.

This matters for our analysis of small science because it allows us to identify firstly that in twenty-first century Europe there are significant positive meanings of being "small" from an entrepreneurial/ideological point of view. It matters too, because in the case of quantum scientists, claims of being "small" works as a form of false consciousness. The effects of

[49] Raymond Williams, *Marxism and Literature* (Oxford: Oxford University Press, 1997), 55.

this false consciousness are not evenly distributed, and allow us to define and anticipate two broader areas of consequences that may arise in this discordance between ideological (discursive) and organisational reality.

The first is that in *acting small*, some scientific leaders/heads of SMEs intend to benefit substantially from investment and market gains. We might call this *acting small to be big*, and mirrors many of the entrepreneurial (false) narratives put forward by company directors, particular in the context of digital companies.[50] One clear effect of *acting small* is that it not only shifts the boons of profit from the state to private companies, but it also shifts the role of the state from that of a producer to that of a regulator.

If false consciousness may result in some people/groups "acting small," it may also have the effect on others of "feeling small," in the sense of having little agency over the character and direction of the knowledge/goods/services being produced. In 2023 a researcher based at Barcelona Supercomputing Centre (BSC)—one of the institutes tasked with installing and developing the capabilities for a quantum computer and for the Quantum Spain project—said that one of the most frustrating challenges for them is "coming up with problems that a quantum computer could solve" and that this was hampered by the fact that the "computing power on hand was not sufficient" and there was a lack of "quantum error correction." Despite this, researchers felt the pressure to make such technologies ready for the market, particular with the pressure of short timeframes provided by the projects that fund them (Author Interview, 2023). A physicist working at the BSC put it more bluntly, complaining that the work they were doing was "to create demand to use a computer that doesn't yet work" (Author Interview, 2024).

The feeling of being trapped between expectations of "enchanted technologies" and the expectations of the market is not something reserved for quantum technologies, nor necessarily for the kind of organisation of technological production outlined in this article. Indeed there is evidence that across the world of tech and data, a form of leadership discourse operates to shut down alternative narratives of the potential impact of a technology or system. As Elish and boyd have shown, Big Data and AI have also been subject to "the manufacturing of hype and promise."[51] Under Elish and boyd's analysis, this hype has come from the business community with two types of effects: "Not only does it trigger innovation and bolster economies, but it also provides cover for nascent technologies to potentially create fundamentally unsound truth claims about the world, which has troubling implications for

[50] Leonardo Mazzoni, Wim Naudé, and Niccolò Innocenti, "The Myth of Entrepreneurship as a Tool: Reorienting Business Venturing as a Goal in Itself in a Post-Growth Society," *Journal of Business Venturing Insights* 23 (2025): e00512.
[51] M. C. Elish and danah boyd, "Situating Methods in the Magic of Big Data and AI," *Communication Monographs* 85, no. 1 (2017): 57–80.

established forms of accountability." Issues surrounding discourse, accountability and a lack of space to intervene have also been expressed by data scientists:

> I found that the people who ascribe the most power to statistics and data are not people who do statistics and data science. They are executives who give the vision talks about the power of data. . .I've seen so many cringe-inducing assertions. . .In my head, I'm listening to all these things and am like, I remember that conversation, and the data on which that is based is so utterly flawed and unlikely to be true. But it supports the mythos of this particular executive. So let's just repeat it until it is true.[52]

Environments in which claims are repeated, yet their audiences know or feeling them to be false, does not only align with our category of "feeling small," but it mirrors what political economists refer to as alienation or estrangement: the feeling (or fact) of being removed from the products and processes, the making of which the subject is a part. As such smallness is created by a lack of control. Such *negative* forms of smallness contrast with those more *positive* forms of smallness, in which the false consciousness may create financial and/or status gains, as in the case of start-up group leaders or tech moguls.[53]

Despite quantum computing being dominated by narratives of *being small*, this section has tried to show how: i. this is not satisfactory evidence for being considered as small, but should be considered a form of false consciousness; ii. comparing ideology and narratives with organisational structure offers some insight into the aims and consequences of *acting small* or *feeling small* in twenty-first century European quantum development. Acting small may well be a result of false consciousness but can lead to positive or negative forms of smallness depending on the position of power within the organisation of scientific production of which the actor is part.

Conclusion: Spitalfields and the Transformation of the Artisan

In the two case studies above, the piece has identified four kinds of "smallness" in relation to the organisation of techno-scientific production in two different stages of the history of computation. The first case study identified two kinds of "smallness" that unsettled the big. From this, the concepts of "being small *in itself*" was contrasted against "being small *for itself*." Whilst the organisation of human computers and clockmakers were eventually subsumed, the processes through they were was determined by the degree to which they were being and acting small (clockmakers), or simply were being and feeling small (computers). The

52 Ibid.

53 Mazzucato, *Entrepreneurial State*.

second case study attempted to show how "smallness" may be used as an ideological or discursive category to obscure the larger forms of financial and institutional organisation upon which its work directly relies. In other words, in "big" systems, "smallness" can exist as the handmaiden of the big. It has been argued that two related forms of "smallness" may result from this false consciousness smallness: *acting small* and *feeling small*, where the first may have positive effects, but the second typically will not.

On 2 October 1813, when Joseph Steevens presented the Spitalfields Mathematical Society *Receptacle,* he dedicated it to a former computer at the Royal Observatory at Greenwich, the SMS's president John Crosley. As a computer, and former comparer, he experienced first-hand the forms of alienation and lack of autonomy that could be created by the Greenwich system of organisation. Yet, through his association with the SMS, he found ways to imagine a different form of organisation that made a virtue of being small without compromising to the big.

It is the overall argument of this article that meaning of "small" is far from a stable category. By placing the meanings of smallness and artisanal in relation to the organisation of work in the computational sciences, we see how their meaning is defined by the specific social relations that make up that organisation, which in turn is hard to separate from the broader political and economic context. Where the eighteenth century artisan saw power in being small because it was unmonitorable, being small *for itself* has through the twentieth and twenty-first centuries been transformed into a highly marketable performance: *acting small* has replaced *being small*. It is presumed that in this transformation, the process of alienation and *feeling small* has only increased.

As this piece has tried to show, the politics of the Spitalfields artisans and London clock and watchmakers was unsettling precisely because they were small *for themselves* not just *in themselves.* It has also tried to show how *acting small* has become much more valuable in the computational sciences than *being small*. This does not mean that being small in contemporary sciences is impossible, rather, it suggests that its position is almost by definition unsettling. It is this feeling of unsettling or uncanniness that makes "small science" so hard to pin down. It is also precisely this feeling that makes it a worthwhile pursuit.

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