Museums that prioritize art tend to disdain replicas and models while museums that prioritise stories embrace them eagerly. Indeed, the mantra of many history museums seems to be 'with this object we can tell that story.' Replicas, in this usage, aim to represent the originals in size, shape, material, function, etc., while models 'represent objects which are unattainable, or from their magnitude or minuteness, unavailable.'[1]

The Special Loan Collection held in London in 1876 was the first major display of historic scientific instruments, and when it closed, replicas of sixteen items were made for what would soon become the Science Museum, London.[2] One of these was an astronomical quadrant commissioned by Wilhelm IV, the Landgrave of Hesse, in the late sixteenth-century. Samuel Pierpont Langley, an astrophysicist with a passing interest in the history of science who was then serving as Secretary of the Smithsonian Institution, visited the Science Museum in 1893, admired this replica, and ordered a similar one for display in Washington (Fig. 1) [PH.181130]. At about the same time, the Smithsonian commissioned a half-sized replica of a Franklin-type electrostatic machine reliably associated with Franklin [EM.181501]. A charming diorama representing Otto von Guericke's dramatic vacuum experiment in Magdeburg in the 1650s, made for the Smithsonian display at the Sesquicentennial Exhibition of 1926, is a reminder of a continuing flirtation with the history of science [PH.308465.02]. These three pieces are still in the collections. The numbers in brackets indicate current museum identifications.

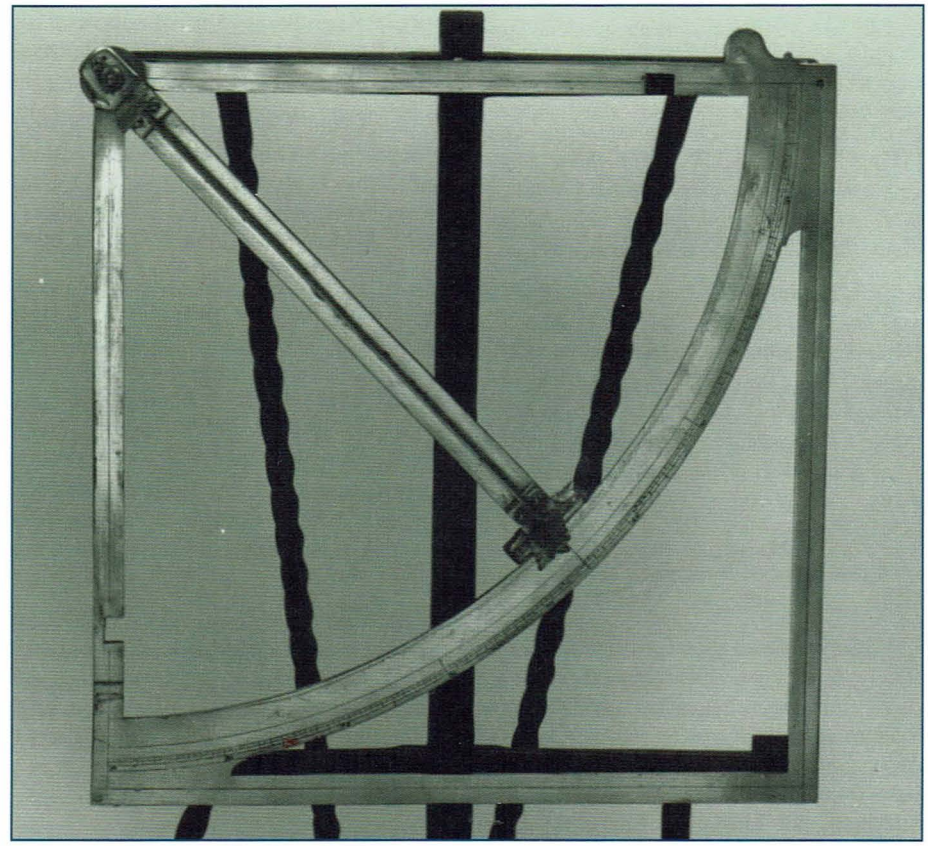

Fig. 1 *Wilhelm IV (1532–1592), Landgrave of Hesse, established an astronomical observatory with the aim of producing a new star catalogue. One instrument there was a brass and iron azimuth quadrant, associated in some way with the Danish astronomer, Tycho Brahe. The Royal Museum in Kassel sent that historic quadrant to the Special Loan Collection of Scientific Instruments held in London in 1876. At the close of the show, Elkington & Co., an important metal working firm in Birmingham, made a replica for the Science Museum. And it made this replica, presumably from the same moulds, for the Smithsonian in the early 18900 [PH.181130].*

Robert P. Multhauf, an historian sporting a recent Ph.D. from the University of California, joined the Smithsonian staff in 1954. His timing was good. In the face of Cold War concerns about Soviet achievements in science and technology, Americans were throwing money at science education and appreciation. For the Smithsonian, this meant a new National Museum of History and Technology (N.M.H.T.). As head curator of science and technology, Multhauf organised and oversaw exhibits that, in his words, would 'attempt to characterize through instruments (chiefly replicas) the scientific revolution of the seventeenth century, in which such instruments as

Opera, Race and Field Glasses, and other optical, philosophical, mathematical, surveying and standard meteorological instruments (London, 1873), 16. See also International Exhibition of 1862, *Official Illustrated Catalogue*, Vol. 2 (1862), Class 13, p. 33.

32. *The Intellectual Observer: Review of Natural History, Microscopic Research and Recreative Science*, **3** (1863), p. 66.

33. http://adb.anu.edu.au/biography/friend-matthew-curling-2069 - accessed 20 x 2020.

34. *Shipping & Mercantile Gazette*, 15, 18, 20 xi 1856. To their more general advertisement for nautical instruments - *Shipping & Mercantile Gazette*, 19 xi 1856 - Spencer, Browning & Co., added: 'NB. – Patentees of the PELORUS, an instrument for ascertaining the local attraction of a vessel on her compass, either in port or at sea. Invented by Lieut. FRIEND, R.N. F.R.S.'. There were wider sales through agents – see in *North & South Shields Gazette* frequently from 18 xii 1856 to 2 iv 1857: 'FRIEND'S PATENT PELORUS, a simple and efficient Instrument by which Captains of Ships can ascertain the amount of Local attraction and the Binnacle Compasses. To be had of JOHN TWIZZEL & SONS, Agents.'

35. International Exhibition of 1862, *The Illustrated Catalogue of the Industrial Department, British Division,* Vol. 2 (London 1862), class 13, p. 35- 'Telescopes, Crooke's spectroscopes, pocket and improved aneroid barometers, and nautical instruments.'

36. International Exhibition 1862, *Jurors' Reports* (London, 1862), class 13, p. 15.

37. For example – United States Hydrographic Office, *American Practical Navigator: an epitome of navigation and nautical astronomy* (Washington 1936), 23-4; R.K. Hubbard, *Boater's Bowditch: the small craft American Practical Navigator* (New York, 2000), p. 46.

38. S.T.S. Lecky, '*Wrinkles' in practical navigation* (London, 1884), p. 81.

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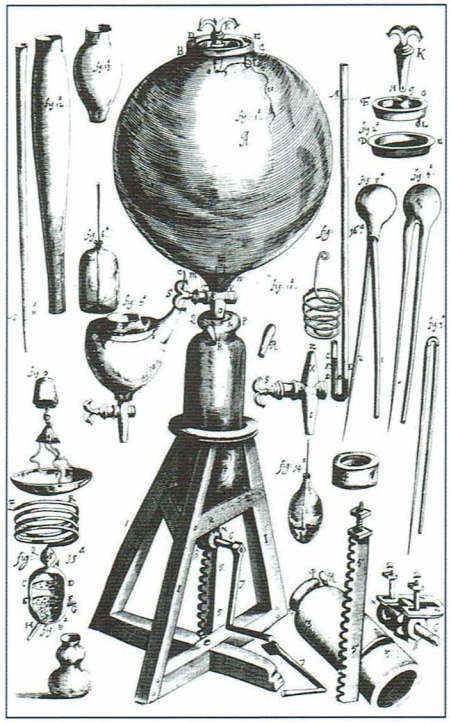

Fig. 2 (a) *The first functioning British air pump —produced by Robert Hooke, working with and for Robert Boyle, in Oxford in the late 1750s—no longer exists. This roughly half-sized replica was made from Boyle's published description and illustration. The picture was taken without the globe [PH.314816]; and* (b) *Engraving of the original air pump from Robert Boyle,* New experiments physico-mechanical, touching the air *(Oxford, 1660).*

the microscope, telescope, thermometer and air pump were very far from insignificant.'[3]

Multhauf had little experience with museums or collections before arriving at the Smithsonian, but he learned quickly. Derek Price, a British historian of science who had recently gained fame with his reconstruction of a medieval astronomical instrument, served as a consultant to the Smithsonian before landing a professorship at Yale.[4] Laurits C. Eichner, a Danish-American craftsman and history buff, was also influential,[5] as was Frank Taylor, the technological enthusiast who served as the founding director of the N.M.H.T. And so too were the Deutsches Museum displays of the history of science and technology, that relied on replicas when the originals could not be had.[6]

The most attractive scientific display in the N.M.H.T.—in the sense that it attracted the most attention from visitors—was a Foucault pendulum swinging in the centre hall, knocking over a circle of pegs, and demonstrating the earth's daily rotation on its axis. This pendulum was not a replica, but rather a re-creation of a remarkable experiment.

Replicas can be quite good, especially when replicator had talent as well as access to the original. One such is the large mural quadrant that was made by the Dutch artisan, Willem Janszoon Blaeu; that was used by Willebrord Snell, a Dutch scientist famous for having obtained the first modern estimate of the size of the earth; and that resembled one described by the Danish astronomer, Tycho Brahe. Multhauf saw the original in the Leiden Observatory—he was tagging along as his librarian wife Lettie was touring astronomical libraries—and commissioned the Observatory instrument makers to make a copy for the Smithsonian [PH.326989].

Equally reliable is the replica of a small balance that was used by the eighteenth-century Scottish chemist, Joseph Black, and that ended up in the National Museum of Scotland (now the Royal Scottish Museum). Curators responsible for this balance informed Multhauf that they made a 'scrupulous' comparison of the original and the replica, and found a few small problems that were quickly fixed; adding, however, that the replica did not show the evidence of wear and tear of the original [CH.316202]. The Smithsonian's replica of the Fleming diode of 1904—invented by the British physicist, John Ambrose Fleming, and now seen as an early example of a vacuum tube—was copied from an original in the Science Museum, London. The deputy keeper of that collection described the two items as indistinguishable from one another [EM.318014]. The same might be said of the several replicas of physics apparatus from the Cavendish Laboratory at Cambridge University, produced by the Laboratory instrument makers [EM.318205 et al]. And also, the replica of Justus Liebig's chemical apparatus constructed by instrument makers affiliated with the Deutsches Museum [CH.316710 and CH.316711].

Eichner's mate to a Joseph Priestley burning mirror in the Smithsonian collection appears true to form [CH.316959]. So too does his replica of a eudiometer that was designed by Robert Hare, professor in the Medical Department of the University of Pennsylvania. In this instance, Multhauf arranged for Eichner to have access to an actual example in the collections of Transylvania College, as well as the description and illustration in Hare's *Compendium of the Course of Chemical Instruction* (Philadelphia, 1840) [CH.316886].

Some replicas were produced by their original makers, or their successors. One such represents the cash register devised by the Ritty brothers in Dayton, Ohio; the successor firm, the National Cash Register Co., showed the replica at the St. Louis World's Fair of 1904 [MA.316700]. Another represents the Comptometer, a key-driven adding machine devised by Dorr E. Felt in the 1880s. The replica was made by the Felt & Tarrant Co., apparently for display at the Chicago World's Fair of 1933. In both instances, the replicas closely resemble the originals [MA.311192 and MA.323646].

When the original item no longer exists, replicators rely on texts and perhaps impressionistic images as well. And here, as with Albrecht Durer's image of a rhinoceros, errors are inevitable. A good example is a half-size replica of Robert Boyle's first air pump. After Eichner let it be known that the illustration in Abraham Wolf's *History of Science, Technology, and Philosophy in the 16th and 17th Centuries* (New York, 1935) was 'not too accurate in its perspective', Multhauf obtained a copy of the illustration and description from Boyle's *New Experiments Physico-Mechanicall* (1699) in the Library of Congress. And as to size, he found that the cavity of the glass was 'large enough to contain about 60 lb. of water, allowing XVI [ounces] to each pound'. Eichner then worried about what wood was suitable for the stand and was there a foundry that could make 'old fashioned' yellow brass. And, presuming that American glassmakers could not produce a suitable globe, he sought out Danish craftsmen who could make 'the inferior glass which was used in that day'. Multhauf was pleased with the result (Fig. 2), deeming it much more authentic looking than the full-sized replica he had recently seen in Oxford, and expecting it to 'attract much favourable attention from students of the history of science'[7] [PH.314816].

The largest scientific replica in the Museum

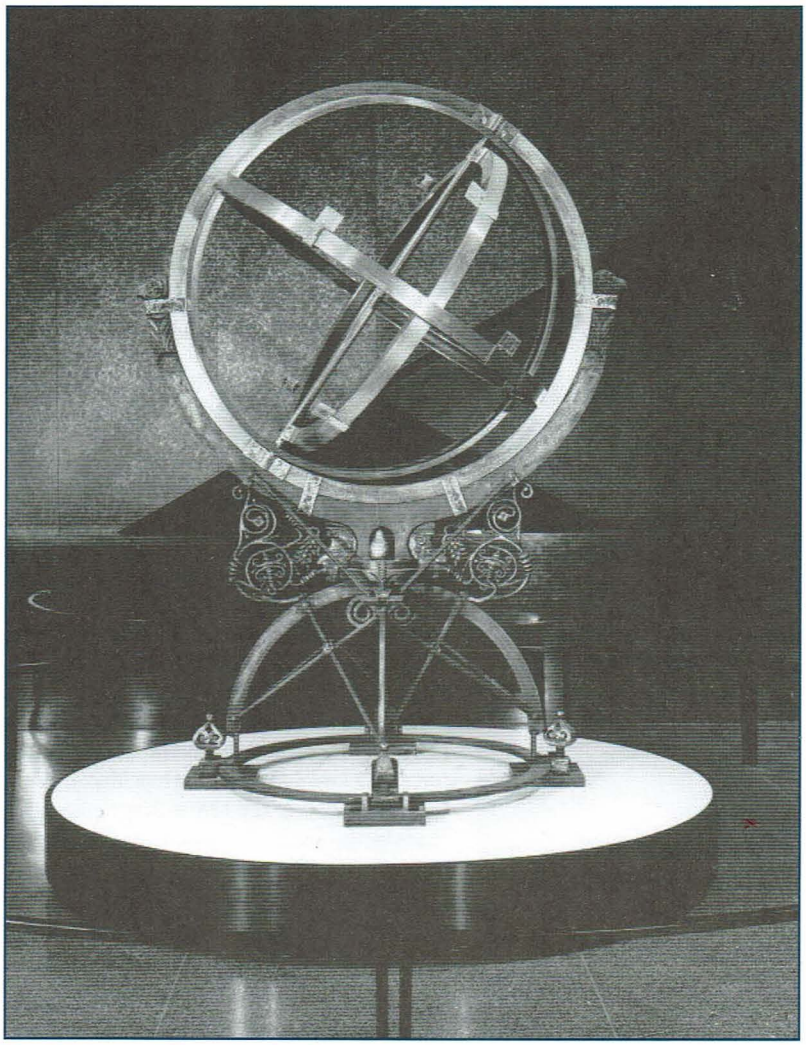

Fig. 3 *Replica of Tycho Brahe's large equatorial armillary sphere made by the talented Danish-American artisan and instrument maker, Laurits Christian Eichner, and sold to the Smithsonian. [PH.321830].*

represents Tycho Brahe's great armillary sphere (Fig. 3). Eichner reported having obtained his information for this from Tycho's *Astronomiae instauratae mechanica* (1598), a copy of which he found in the New York Public Library. He said nothing, however, about his decisions as to size, material, or other details.[8] Eichner had become fascinated with Tycho during his student days at the Odense Technical School. And later, having learned of plans to restore Tycho's observatory on the island of Hven, he decided to replicate some of his instruments. Military contracts took priority during the War, but by 1946 Eichner was able to send several replicas to Copenhagen, for an exhibit celebrating Tycho's 400th birthday. The armillary sphere came to the Smithsonian in the early 1960s. Eichner's replica of Tycho's smaller astronomical quadrant came later [PH.321830 and PH.333622].

Another amazing replica represents the astrarium that was designed by Giovanni di' Dondi, a fourteenth-century Italian physician/astronomer/engineer, and that was deemed the 'earliest clockwork of which an almost complete description and incontestable documentation have survived.' With seven faces displaying the motions of the sun, moon, and five inner planets, it was also 'one of the most complicated clockworks known to have been produced until recent times'[9] [ME.319999].

In one of his first forays into the history of scientific instruments, Multhauf called attention to the oceanic depth sounder (Fig. 4) that Robert Hooke presented to the Royal Society in 1663. Since England's defence and prosperity depended heavily on mastery of the seas, it is not surprising that an organisation recently established by royal charter promoted projects pertaining to navigation. Nor is it surprising that the Royal Society's first Curator of Experiments understood that to know the depth of the sea may be 'of good use, both Naval and Philosophical.' For Multhauf, however, the sounder and its improvements 'exemplify the curiously incidental way in which scientific instruments emerged out of the preoccupation of the scientist at that time with experience (observation) and measurement'[10] PH.316644].

In order to represent items that no longer exist, and for which there are no reliable descriptions or images, one might use replicas of contemporary and presumably similar things. Such is the case with a 'replica' of the standard rain gauge (Fig. 5) designed for the Smithsonian meteorological network in the 1850s [PH.315898].

Some replicas are essentially generic. One such is a porcelain alchemical furnace of unknown form and date, made by the Coors Porcelain Co. [CH.320316]. Another is a copper alembic and a moor's head, made by Eichner and based on seventeenth-century illustrations [CH.323661 and CH.323662]. Yet another is a bunch of glass receivers, alembics and aludels made by the Kimble Glass Company and based on sixteenth-century illustrations. For this project, Kimble chemists analysed some old glass of unknown provenance, provided by Multhauf, and made a new batch of similar composition[11] [CH.323343 and CH.323344 and CH.323345].

Some replicas provide, at best, a rough sense of the original. The seismoscope devised by Zhang Heng, a remarkable Chinese scientist/statesman, c. 132 C.E., was apparently massive, complex, and ornate. Our replica—though here model is probably the better term—was copied from a small and very much simplified example devised in Tokyo in modern times[12] [PH.321329]. Some replicas are the right form but the wrong stuff. Such is the case with two water current meters made of aluminium, a substance not widely available when the originals were designed and described[13] [PH.317670 and PH.317671]. And some replicas, such as that representing an early photographic barograph, are largely fantasy. Here, in the absence of clear instructions, Eichner 'aimed at making an instrument such as might be made in a university laboratory shop; designed by the professor and made by him and his mechanic. In other words: with a somewhat 'home-made' look[14] [PH.319425].

Most of the questions that curators ask about replicas concern appearance, which is appropriate if replicas are made primarily for exhibition. But should we not sometimes be somewhat concerned with function? We know, for instance, that Robert Boyle worried more about the quality of the seals of his air pump than about the form of the legs.[15] Likewise, the tubes and mounts of early optical instruments are replicated with relative ease, but the optical elements are more problematic. Eichner's copy of the small reflecting telescope that Isaac Newton sent to the Royal Society in 1671 closely resembles the one believed to be the original. But what about the eyepiece and objective mirror?[16] [PH.314610] Similar questions might be asked of the many Leeuwenhoek microscope replicas in museums

Fig. 4 *Robert Hooke presented his first depth finder to the Royal Society in September 1663, at a time when several founding fellows were discussing ways to improve oceanic navigation. Correspondence in the accession file indicates that Eichner made this replica to look 'weather beaten and aged.' [PH.316644].*

Fig. 5 *Museums sometimes represent items that no longer exist, and for which there are no reliable descriptions or images, with replicas of presumably similar things from the period in question. Such is the case with this 'replica' of the standard rain gauge designed for the Smithsonian meteorological network in the 1850s. [PH.315898].*

and in circulation [MG.M-09840 and MG.M-12187]. A replica of the Charles Babbage Difference Engine No. 1, a gift from I.B.M., looks great but has no innards [MA.323584].

Multhauf was not heavily invested in the aura associated with (or attributed to) authenticity.[17] Nor was he, in museum parlance, a good looker. That is, he never got much from looking at objects, or even expect to do so. He did, however, believe that objects, either real or replica, could stimulate interest in what they did or were supposed to do, how well they operated, and the people involved in their design, manufacture, and use. And, while Multhauf may never have claimed that objects 'tell' a story, he often said that objects provide hooks on which curators and other historians can hang the stories they wish to tell. To put it another way, museum visitors will gravitate towards attractive objects and perhaps linger long enough to read the accompanying label.

The National Museum of History and Technology became the National Museum of American History in 1980, the new name indicating an intention to pay more attention to social and cultural history, especially of the United States, and less to science and technology and the European antecedents thereof. In connection with this transformation, most of the scientific replicas were put into storage, out of sight and largely out of mind.

Some instruments and replicas, however, have been lent to museums still interested in the history of science. Some point to social and cultural diversity: my 'Women in Science' exhibit, from many years ago, was an early example of the genre. And some, as this essay suggests, help remind us of where we have been, and consider the value of our collection objects, real and replica.

Keywords: *instrument replicas, models, astronomical quadrant, Elkington & Co., Boyle, air pump, Tycho Brahe, Robert Hooke's depth finder.*

Notes and References

1. George Brown Good, *The Principles of Museum Administration*, (New York, 1895), p. 45. Here, however, the words replica and model are often used interchangeably. For an account of a museum that contains only replicas and models, see Yakup Betkas and Roger Sherman, 'A Bold New Enterprise: The Istanbul Museum of the History of Science and Technology in Islam', *Technology and Culture*, **54** (2013), pp. 619-639.

2. South Kensington Museum, *Handbook to the Special Loan Collection of Scientific Apparatus* (London, 1876). Robert Bud, 'Responding to Stories: The 1876 Loan Collection of Scientific Apparatus and the Science Museum', *Science Museum Group Journal*, Issue 1 (Spring 2014). http://dx.doi.org/10.15180/140104/

3. Robert P. Multhauf, 'A Museum Case History: The Department of Science and Technology of the National Museum of History and Technology', *Technology and Culture*, **6** (1965), pp. 47-58.

4. Seb Falk, 'The Scholar as Craftsman: Derek de Solla Price and the Reconstruction of a Medieval Instrument', *Notes and Records of the Royal Society of London*, **68** (2014), pp. 111-124.

5. Robert P. Multhauf, *Laurits Christian Eichner Craftsman, 1894–1967* (Washington, D.C., 1971).

6. Robert P. Multhauf, 'European Science Museums', *Science*, **128**-3323 (Sept. 5, 1958), pp. 512-519. Wolf Peter Felhammer and Wilhelm Fuessl, 'The Deutsches Museum. Idea, Realization and Objectives', *Technology and Culture*, **41** (2000), pp. 517-520.

7. See correspondence in N.M.A.H. accession file 210759.

8. George H. Waltz, Jr., 'Star Studded Hobby', *Los Angeles Times* (Sept. 1, 1946), p. E7. *Tycho Brahe's Description of His Instruments and Scientific Work as Given in Astronomiae Instauratae Mechanica* (Wandesburge, 1598); translated and edited by Hans Raeder, Elis Strömgren and Bengt Strömgren (Kobenhaven, 1946). See also correspondence in N.M.A.H. accession files 215541 and 210759.

9. Silvio A. Bedini and Francis R. Maddison, 'Mechanical Universe: The Astrarium of Giovanni di' Dondi', *Transactions of the American Philosophical Society*, **56** (1966), pp. 1-69.

10. Robert P. Multhauf, 'The Line-less Sounder: An Episode in the History of Scientific Instruments', *Journal of the History of Medicine and Allied Sciences*, **15** (1960), pp. 390-398.

11. '17th Century Glassware Copied', *New York Times* (Aug. 20, 1962), pp. 33-34.

12. Toshio Asanuma and Iwao Sensui, 'Ancient Chinese Seismoscope Made by Chang Heng', *Natural Science and Museums* (1960), pp. 13-19. André Wegener Sleeswyk and Nathan Sivin, 'Dragons and Toads: The Chinese Seismoscope of A.D. 132', *Chinese Science*, **6** (Nov. 1983), pp. 1-19.

13. Arthur Frazier, *William Gunn Price and the Price Water Current Meter* (Washington, D.C., 1967). Frazier, *Water Current Meters in the Smithsonian Collections of the National Museum of History and Technology* (Washington, D.C., 1974).

14. Robert P. Multhauf, 'The Introduction of Self-Registering Meteorological Instruments', *Contributions from the Museum of History and Technology* (Washington, D.C., 1961).

15. Steven Shapin and Simon Shaffer, *Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, 1985).

16. A. Rupert Hall and A. D. C. Simpson, 'An Account of the Royal Society's Newton Telescope', *Notes and Records of the Royal Society of London*, **50** (1996), pp. 1-11.

17. Walter Benjamin, *The Work of Art in the Age of Mechanical Reproduction* (1936).

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