Rory McEvoy and Jonathan Betts, eds. *Harrison Decoded: Towards a Perfect Pendulum Clock*. Oxford: Oxford University Press, 2020. 208pp (31 plates, 51 illustrations).

With the 1995 publication of Dava Sobel's best-seller, *Longitude*, the remarkable story of the self-taught, 18th-century English clockmaker John Harrison (1693–1776) became widely known. After forty-plus years of intense work, and despite lengthy battles to be awarded the British government's prize for accurately determining longitude at sea, Harrison proved that portable timekeeping accuracy was obtainable within the required seconds per month. Countless shipwrecks, overlong and/or disastrous voyages and mass drownings were avoided thanks to his groundbreaking efforts.

Far less well-known is his revolutionary work on land-based pendulum clocks – pitching and rolling ships precluded pendulums. These inherently had greater accuracy; but, until the early 20th century, they could not achieve the extremely high accuracy increasingly demanded by various scientific applications, especially astronomy. Issues of temperature, humidity, friction, barometric pressure, air density, metallurgy, lubricant decay and viscosity and cleanliness, fabrication deficiencies, vibrations, gradual wear, variations in force, etc. – all produced rate errors of seconds, if not minutes, per week, even with pendulum clocks produced by the finest makers in the 18th and 19th centuries. Until 1967, in fact, with the advent of atomic clocks and new time standards, everyone still needed to consult the stars to obtain absolute time readings, and it was from these observations, using sophisticated transit instruments, that all clocks were regulated. Harrison famously used the appearance of a star at the edge of his neighbor's brick chimney to gauge his own progress in accuracy.

As early as the 1720s in rural England, Harrison was developing innovative and counter-intuitive concepts even before he relocated to London and began interacting with the wider horological world. He attacked the principle enemies of accuracy and durability with frictionless escapements, movements requiring no oil, hardwood components, and pendulums that self-regulated against changes in temperature, air pressure and arc of swing.

A year before Harrison's death at age 83 in 1776, he produced a publication, extremely difficult to read and comprehend, that summarized his unique ideas on perfecting pendulum-clock timekeeping. His title alone is forty-three words and requires re-reading to absorb. Even with claims that other makers' solutions were wrong and that his could produce accuracy to one second in 100 days, his book was ignored or dismissed. Further scoffing was directed at his assertion that such a clock could run continuously, without maintenance, for one hundred years.

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Not until the 1970s did a small group of Harrison devotees begin studying his practical tested theories and eventually produced pendulum clocks based on Harrison's designs. Members of the "Harrison Research Group" also point to a wood-movement clock Harrison built around 1720 which still runs reliably, with no apparent wear, 300 years later. Nonetheless, his opponents' contrary insistence on oiling, heavy aerodynamic pendulum disks, minimal arcs of swing, deadbeat escapements, and other long-accepted dogmata of precision are still repeated today, even by this horologist reviewer prior to digesting the contents of *Decoded*.

The book tells these stories, leading up to solid proof, two and a half centuries later, that Harrison was mostly correct. Ten essays comprise the book's chapters, by Research Group members who document their history and achievements. Key to the tale is the multi-decade creation and completion of "Clock B," begun by the horological sculptor Martin Burgess and completed by the famed London shop of Charles Frodsham & Co.

In no way a replica of a Harrison timepiece, this contemporary masterpiece instead applies modern materials and methods to his basic principles. Over multi-month and then multi-year trials at the Greenwich Observatory, it demonstrated hardly a one-second gain or loss. Nor was it in some sealed and ultra-stabilized environment; it was simply wall-mounted in an area adjacent to areas regularly visited by crowds of tourists. In 2015, it qualified for a Guinness World Record of "Most Accurate Mechanical Clock with a Pendulum Swinging in Free Air."

The book's two editors, Rory McEvoy and Jonathan Betts, are both distinguished former curators at the Royal Observatory, Greenwich, and were instrumental in devising and running the extended testing of Clock B at that historic location on our planet's Prime Meridien. Each has a chapter in the book. (A weighty, related 743-page hardback tome by Betts was published by Oxford University Press in 2017; *Marine Chronometers at Greenwich* is a detailed exploration of the unparalleled marine timekeeping collection at the ROG.)

Fate intervened along the way, too. The artist, art historian and horological collector Donald Saff discovered a Martin Burgess clock in a fourth-floor clock repair shop in Manhattan, begged for three years to buy it, then had it fully restored when the seller finally relented. This introduced Saff to Burgess and to the Harrison group; he eventually financed the "rescue" of Clock B, as his essay title reveals, and its ongoing loan and display in the ROG's Longitude Gallery.

William Andrewes, lead organizer of the 1993 Longitude Symposium at Harvard University (which this reviewer attended and where Dava Sobel got her book idea), had early in his horological studies, between 1970 and 1972, worked with Martin Burgess. He included Burgess as a speaker at the international symposium, and writes the book's chapter about Burgess, whose own life could read like a Dickens novel. Sent after birth in 1931 to an orphanage because his father's banking family did not approve of his mother's lower-class origins, he was adopted at six months by a well-to-do spinster who ensured a privileged upbringing for the lad. Ironically, and a complete surprise, Burgess in 1959 was the sole heir to the sizable estate of his father, whom he had never met; he then could devote full time to his sculptural clockmaking endeavors. Burgess's 1993 lecture, aptly titled "The Scandalous Neglect of Harrison's Regulator Science," was expanded into a chapter of *The Quest for Longitude*, a 437-page hardcover report on the historic symposium that was published by Harvard in 1996.

While there is much technical material and data in *Decoded*, all relevant to the subtitle's theme "Towards a Perfect Pendulum Clock," there is plenty for the uninitiated to understand and enjoy learning. The art, not just craft, of Martin Burgess is well-worth appreciating. His clock movements are uncased objects of beauty; we see them operate with a full view of their mesmerizing oscillations and rotations. Color-plate illustrations include an image of his second commissioned clock, "Simon's Balls," built for the record producer Simon Napier-Bell who requested a timekeeping machine that would distract his clients from the fine print of their contracts. Another sculptural clock was completed in 1969 for the lobby of a London merchant bank and was the subject of Richard Gayer's documentary film, *Clockmaker*.

Burgess titled his chapter in the present book "Reflections on Making Clocks Harrison's Way," and he offers clear explanations of the necessary prerequisites. All of these spring from the principles of Harrison's "Late Regulator," which had been so obtusely described in the 1775 treatise. Had Harrison completed that clock, rather than putting it aside in frustration as he fell out of favor with the "experts," this book's contributors are convinced that it would have advanced horological science by 100 years, with commensurate growth in modern sciences dependent upon ultra-precision timekeeping.

We then could have thanked John Harrison not just for lifesaving advances in maritime navigation but also for other scientific progress delayed by more than a century. Slicing seconds into infinitesimally smaller units underpins the workings of GPS, computers, smart phones, space exploration, and so much more. Clock B can only hint at where we could be today if the 18th-century had listened even better to John Harrison.

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