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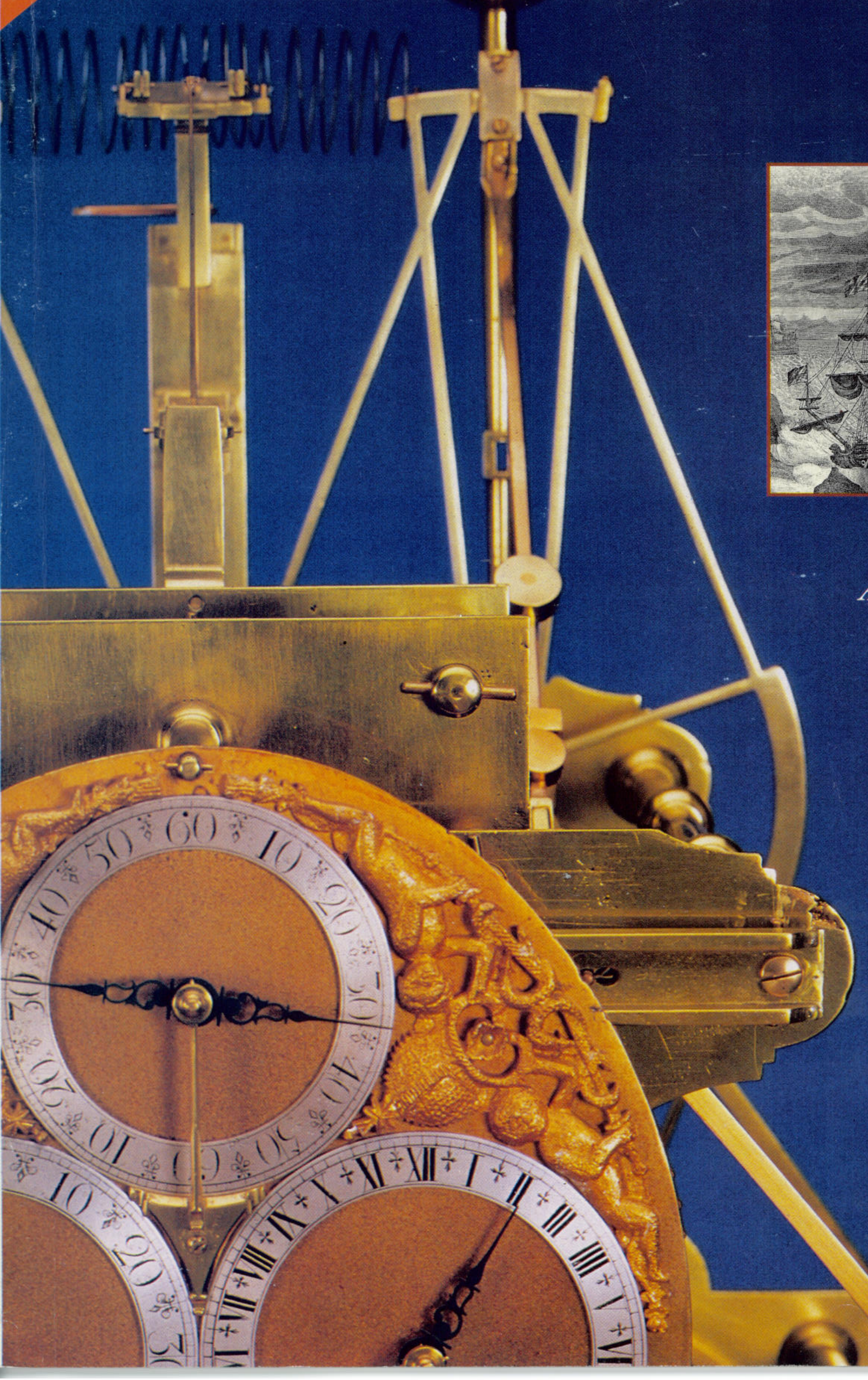
SPECIAL SECTION
Spring Events Guide

HARVARD
MAGAZINE



Seminal disaster: On October 22, 1707, Admiral Sir Clowdisley Shovell and two thousand of his men are lost at sea when the fleet runs aground off the Scillies. After the calamity, the British government offers large prizes for a solution to . . .

. . . the longitude problem

Left: the beginnings of an answer, John Harrison's first marine timekeeper.

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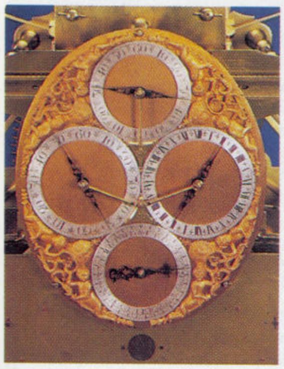

ON THE COVER

The first clock to keep accurate time at sea was a lifesaver for mariners and brought its maker fame and, belatedly, a fat reward. It's all part of the astonishingly rich story of longitude. The photograph appears courtesy of the National Maritime Museum, Greenwich, England.

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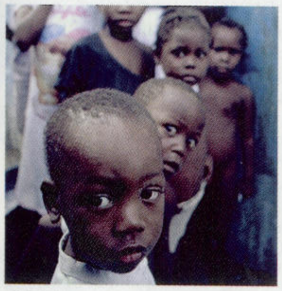

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Would you care to attend a three-day international symposium on . . .

LONGITU

by DAVA SOBEL

"The vast majority of the human race has absolutely no idea that your specialty even exists," Alistair Cooke chides the five hundred banquet guests assembled in Memorial Hall. In fact, confesses the widely loved author and television host, his own close friends had blinked incredulously and mocked his plans to attend tonight's engagement:

"You're speaking at a symposium on longitude?"

Cooke lets the word lunge off the end of his tongue with a soft *g*. LON-ji-tood. Then he holds it at the back of his throat with a hard *g*—LAWN-ga-tood—as though even the name of the discipline were fodder for intellectual dispute. He chuckles at the memory of his acquaintances' startled faces, and the audience laughs with him. Cooke has them all set up for his punch line:

"It was so ludicrous that of course I accepted the invitation."

Cooke pretends for a moment that the only thing he knows about longitude comes from having recently looked up the word in the *Encyclopedia Britannica*, and he quotes the full entry by heart:

"Longitude. See latitude."

Louder laughter greets what must be the ultimate in-joke for this crowd. Participants in the longitude symposium concern themselves only marginally with latitude—those concentric rings that girdle the globe from the equator to the poles. After all, any mariners worth their salt can gauge latitude readily enough by the length of the day, or the height of the sun, or stars above the horizon. For this reason certain parallel lines of latitude have served as worn pathways across the oceans since ancient times. Christopher Columbus "sailed the parallel" on his 1492 journey, and the technique would doubtless have carried him to the Indies had not the Americas intervened.

Longitude is by far the meatier subject. Longitude, measured in meridians and tempered by time, defied accurate determination throughout most of history. To find one's longitude

NATIONAL MARITIME MUSEUM, GREENWICH, LONDON

Right: Landfall. Before the invention of a reliable way for travelers to find their longitude at sea, they were in danger of reaching their destinations by running aground on them. This painting by Cornelis Claesz van Wieringen depicts the wreck of the Dutch ship *Amsterdam*.

DE?

Political intrigue, academic backbiting, scientific revolution, economic upheaval, and a mechanical genius who devotes his life to a quest. All these threads, and more, entwine in the lines of longitude.

at sea, one needs precise knowledge of the relative positions of the heavenly bodies, or a clock that can model the motions of the clockwork universe *and* keep on ticking through violent storms and temperature changes. Neither of these prerequisites existed until well into the eighteenth century. For lack of a practical method of determining longitude, untold thousands of sailors died when their destinations suddenly loomed out of the ocean and took them by surprise. It was just such an accident—on October 22, 1707, off the Scilly Isles, where four homebound British warships ran aground and nearly two thousand men were lost—that prompted Parliament to offer an enormous purse (roughly $12 million in today's currency) for a solution to the longitude problem.

English clockmaker John Harrison, the mechanical genius who devoted his life to this quest, ultimately claimed the prize money as his rightful reward—in a climate of political intrigue, academic backbiting, scientific revolution, and economic upheaval. All these threads, and more, entwine in the lines of longitude.

PETER WRENN

Alistair Cooke makes a point about longitude during the Memorial Hall banquet concluding the symposium. He told his audience that he had agreed to make formal remarks on the occasion because the topic was so ludicrous.

"The encyclopedia," Cooke continues to his enthralled audience, "says that John Harrison solved the problem promptly." He muses for a moment, chewing on the adverb. "He found the answer promptly after 45 years. The British government gave him the prize money promptly fourteen years later. And now we celebrate his birthday promptly three hundred years after the fact."

As Cooke's flip summary suggests, the cracking of the longitude mystery was a complex affair, and the tercentenary of John Harrison's birth (in 1693) provides the perfect occasion for reopening the case and reexamining the man.

Or so it seemed to William J. H. Andrewes, the dashing Wheatland curator of Harvard's collection of historical scientific instruments, who conceived and choreographed the longitude symposium, held at the University November 4-6, 1993, and who invited Alistair Cooke to be its guest of honor. The symposium continues the celebration that Andrewes began on John Harrison's actual three-hundredth birthday, last March 24, when he baked a cake in the shape and design of the prizewinning marine timekeeper and served it to the fifteen students in his history of science class, called "Instruments of Time and Space."

Andrewes—like John Harrison, his idol—is an Englishman with the soul of a clockmaker. Before coming to the United States in 1977, he looked after the clocks at the Old Royal Observatory and the National Maritime Museum in Greenwich. He then served as curator of the Time Museum in Rockford, Illinois, for ten years, until he accepted an appointment at Harvard in 1987 and subsequently became a preceptor in the history of science department.

Andrewes once won the honor of restoring an early John Harrison wooden clock and spent one day a week over a three-year period completing the task. He has a natural affinity for Harrison, a man described over the course of the symposium as brilliant, industrious, rough, dogged, possessed, passionate, argumentative, sober, modest, grossly puritanical, and an out-and-out workaholic—a man of simple birth and high intelligence who single-handedly revolutionized the science of timekeeping.

But unlike Harrison, who shunned people, Andrewes greets them on a forward tilt, eager to shake hands or grasp their shoulders and kiss them on both cheeks. His own internal clock appears to run a few minutes fast, as though a trifle overwound by energetic enthusiasm. The combination of his good looks and ready charm probably helps Andrewes effect plans that might be considered overambitious, or even harebrained—as when he began campaigning to bring together three or four hundred interested parties for an international conference on longitude.

As it turns out, more than five hundred participants from 36 states and seventeen countries have shown up, including four foreign students (three Russian and one Czech), whose travel expenses are covered by a grant that Andrewes secured from friends and from the family of his Harvard predecessor and late benefactor, David Wheatland '22.

The conference attendees cannot be categorized. Many of them belong to the National Association of Watch and Clock Collectors, a 35,000-member body of hobbyists whose professional lives fill niches in medicine, business, education, and industry. Some number of symposium participants are bona fide horologists—professional or amateur specialists in the science of timekeeping. Others own sailboats and live a weekend life as navigators. Astronomers, mathematicians, materials scientists, geographers, and historians of science round out the roster, along with a few antiques dealers, museum curators, and rare-book sellers.

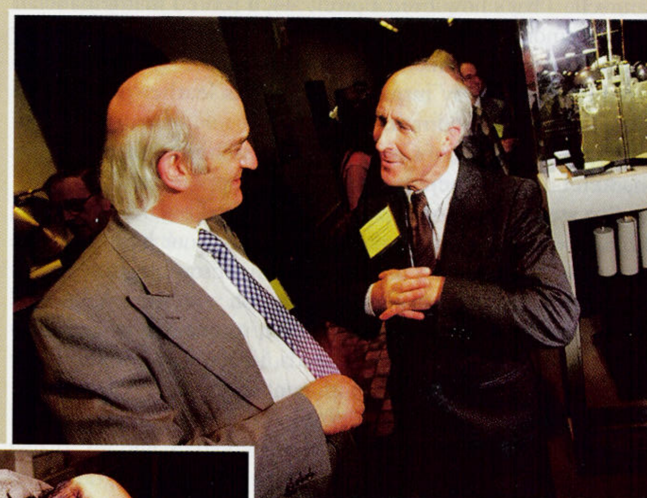
Walking among them, one sees a woman in dangling earrings composed of miniature watch parts talking to a man with a Salvador Dali clock melting down the front of his tie.

The longitude symposium, as Andrewes has laid it out, considers four major themes:

- the early history of navigation at sea, when great voyages of discovery got to some destination willy-nilly, in the absence of any means for ascertaining longitude, and when a landfall often took the form of a shipwreck;
- the early attempts to find longitude, including promising but painstaking efforts based on astronomy, as well as daft approaches involving the likes of wounded dogs, explosives, goats, and magic;
- the triumphs and tribulations of John Harrison himself, from the low-maintenance tower clock he built in the early 1720s that still keeps accurate time today, to the vindictive desecration of his prizewinning marine chronometers by jealous parties; and
- the perfection of marine timekeeping in the decades following Harrison's great advances.

The program lists the lecture offerings in military time, and every session starts precisely on the scheduled stroke of the hour. The strict punctuality has the quality of an ethnic joke about horologists, but no one laughs at it. Nor does anyone seem surprised or put out when the session chairs refuse to

Among symposium attendees are watch- and clockmakers and collectors, in heaven here at a Fogg Museum exhibition of clockwork from the University's treasure chest. Participants include, clockwise from top left: Andrew James, of Hampshire, England, center; George Daniels, Isle of Man, with watches of his construction; Anthony Turner, of Le Mesnil-Le Roy, France, left, with Joachim Schardin, of Dresden, Germany; Viscount Midleton, of Suffolk, England, who has borrowed the monocular of . . . Peter Schweitzer '51, of Cambridge, Massachusetts; and Will Andrewes, curator of the collection of historical scientific instruments.



PHOTOGRAPHS BY BROOKS KRAFT

wait for latecomers to straggle in. A lecture set for Thursday evening at 19:15 in the Charles Hotel begins with a pronouncement: "It is 7:15 by George Daniels's watch."

Forget Big Ben. People who know clocks know that George Daniels, former Master of the Worshipful Company of Clockmakers, sets a standard in long-term precision mechanical timekeeping. After writing half a dozen books about watches, and collecting as many gold medals for his efforts in watch restoration and design—including an M.B.E. awarded by Queen Elizabeth II—Daniels says the only things he likes as much as watches are vintage cars, fast motorcycles, opera, and Scotch whiskey.

Daniels's dapper three-piece suit serves as gray background for the gold watch chain festooned across his waistcoat. It holds the one-of-a-kind pocket watch that took him four thousand hours to build by hand, in honor of the Apollo landing on the moon. Working as he does at the furthest possible remove from mass production, Daniels has completed 25 timepieces in his 45 years as a watchmaker. A second of his singular creations is strapped around his left wrist.

Daniels will show you the pocket watch if you ask to see it. You can even hold it in your hands, the better to appreciate its exquisite detail, with separate dials for solar time, mean time, sidereal time, and phase of the moon, plus two subsidiary seconds dials (one for solar, one for sidereal) and center second chronograph. Telling time on such an instrument is no quick glance for keeping to schedule but a serious consideration of time as a universal dimension. Einstein should have had a watch like this. Only George Daniels, however, can really study his watch at leisure. Anyone else is conscious of being just three inches from his vest pocket, where he keeps it securely tethered. Beyond the gold chain, some invisible umbilical may attach it still more firmly to his person.

At a convention of watchmakers and watch collectors, the cognoscenti favor mechanical watches, pocket or wrist, and the older the better. Most collectors consider *quartz* a dirty word, since accuracy without artistry is nothing devoutly to be wished. The best watch is the one you purchase at a bargain because of pieces missing, then restore to accurate function by yourself. That's how Fred Powell '44, a retired mathematician from Vermont, came by his 1790 James Peto pocket chronometer. In contrast to Daniels, Powell unhooks the treasure from its lapel chain at every inquiry, slips off its leather pouch, and passes it around to admiring sighs.

David B. Searles, of Cambridge, Massachusetts, a worldwide marketer of fine timepieces as well as a supporter and exhibitor at the symposium, wears what he calls "a garden-variety Rolex," with sapphire crystal and jumping hour hand that lets jet-setters adjust to new time zones without stopping the watch.

Will Andrewes sports a character watch with the French cartoon hero Tintin and his dog, Snowy, running across its face. Quartz! But then, Andrewes spends his days among the ivory diptych sundials and nineteenth-century regulators that grace his basement exhibit hall in the Science Center, and can afford such a departure from form.

The illustrations at the bottom of this and the following pages mark significant events in the finding of longitude at sea, culminating in the work of John Harrison.

Now, as he prepares to open the Friday morning sessions with Jeremy Knowles, dean of the Faculty of Arts and Sciences, Andrewes thanks his good fortune that all the people he admires most in the fields relating to longitude have responded so positively to his invitations to teach and learn at the symposium. The cast includes eighteen of the world's leading historians of navigation, astronomy, cartography, and horology. First up is David Landes, the Coolidge professor of history and professor of economics at Harvard.

Landes looks around the packed auditorium, pleasantly surprised to find so many people ready to listen to lectures at 8

"By the mid-sixteenth century, scientists knew the nature of the longitude problem; they just lacked the means to solve it."

A.M. University classes scheduled at the same hour, he says, suffer from "severely limited attendance." Turning to his prepared remarks, Landes offers the group his historic-economic perspective on the costs of being literally "at sea" in the fifteenth, sixteenth, and seventeenth centuries, with no practical means for determining longitude.

"Too many were the ships that thrashed aimlessly and fruitlessly about," Landes laments, "too far this way, too near that, until scurvy and thirst killed off or incapacitated so many hands that the crew could no longer man the rigging and direct the vessel. And then the ship would float helpless, with its populations of skeletons and ghosts—another Flying Dutchman, to fetch up one day on reef or sand and provide the stuff of legend."

As naval and merchant fleets grew in size and burgeoning trade spawned international competition, Landes explains, war ships and trade ships fell easy prey to pirate ships, since all ships were confined to conventional lanes by limited navigational skills. Seafaring nations panted after a way to find their bearings on the open ocean.

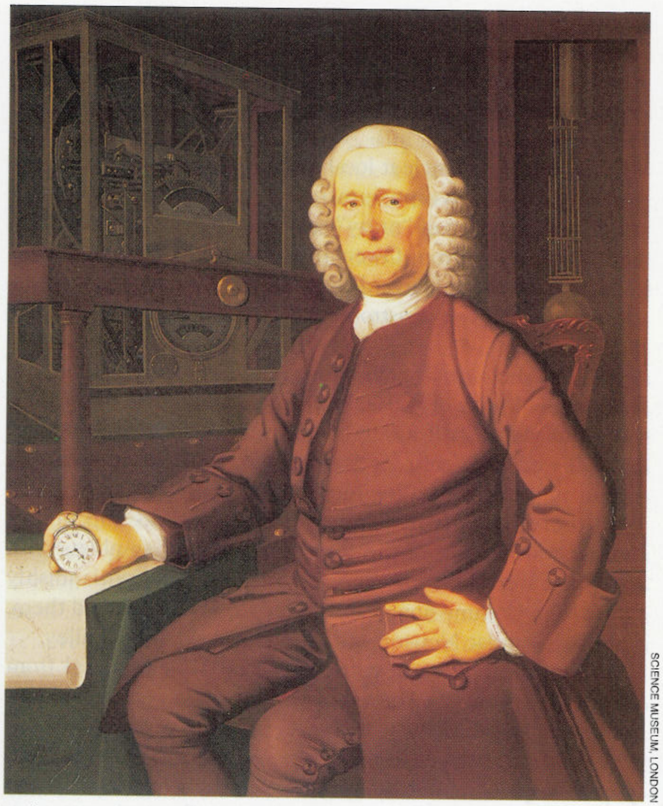
"So much for the demand side," Landes continues. "On the supply side, scientific knowledge and capabilities were coming together to render possible what had long been visionary. By the mid-sixteenth century, scientists knew the nature of the longitude problem; they just lacked the means to solve it. The essence of the problem was to find a way to learn the time in the place


HOUGHTON LIBRARY, HARVARD UNIVERSITY

1514: Johannes Werner proposes a (time-consuming) lunar-distance method for finding longitude.

1530: Gemma Frisius has the idea of using a timekeeper.


ASHMOLEAN MUSEUM, OXFORD



SCIENCE MUSEUM, LONDON

John Harrison, circa 1767, in a portrait by Thomas King. Harrison holds his fourth marine timekeeper. Behind him is the very much larger number two.

where you were—in situ—and the simultaneous time at some other place of known longitude. And then you could convert the difference in time into the distance in between." (A complete 360-degree revolution of the earth takes 24 hours. Thus, a time difference of one hour between two locations equals a change in longitude of fifteen degrees.)

"The key to the conundrum lay in this matter of simultaneity," Landes reminds the gathering. "You have to know your local time and the time at some distant place at the same moment." There were two ways to calculate the time at that reference point—the clock method and the astronomical method. However, no clock of the day was up to the task of putting the clock method into practice. While it was possible to keep accurate local time with sundials, no clock could beat true to the home-port time for the duration of an ocean voyage. A simple matter of a change in temperature would make the clock run faster or slower.

The astronomical method made heavy demands, too—not the least of which were clear skies and a reasonably steady deck for taking observations. The navigator had to determine local time by the Sun—watching its apparent motion to establish the exact moment of noon—and keep track of time from day to day; then he had to observe some predicted celestial event and compare the local time of its occurrence with the time that this same event was to appear in the sky over a place of known longitude. Intermittent heavenly events such as lunar and solar eclipses were too infrequent to fill the bill. Navigators needed predictable events that happened often enough for them to use at will for taking longitude readings. And so they pressed the moon into service as a longitude indicator. By measuring the position of the moon vis-à-vis certain fixed stars, a good astronomer could make the necessary longitude calculations in about four hours. (The Royal Observatory was founded at Greenwich in 1675 to make the detailed observations of the night sky that navigators needed as a basis of comparison for their shipboard observations.) By the 1760s, says Landes, the lunar technique yielded fairly accurate results, but it remained so complex and time-consuming that only a small elite of specialists, armed with the sextant, employed it.

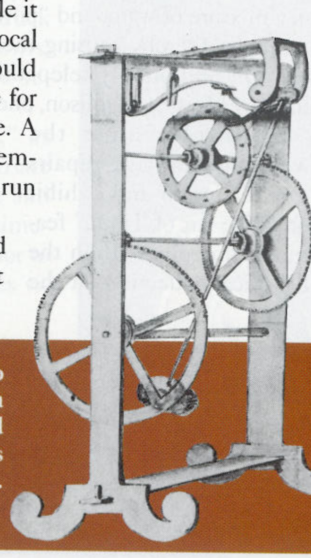
"Royal navies could train such people," Landes concedes, "but you couldn't expect an ordinary merchant ship to have them on board." Thus the technique, though taught and used, was obsolete from the outset.

"It gave way eventually to sea clocks, because these were bargains in performance and time-saving," he points out, hinting at subjects to be covered by others in greater detail. "So it is the invention of these clocks that we are celebrating here.

"Today," he concludes, "thanks to satellite signals and triangulation, a properly equipped ship can know its location within a matter of yards, or even feet. Many more marine chronometers exist in museums and collections than on the high seas. Science, which has a way of junking the things it no longer uses, has long since left these clocks behind. But that is why we need history—to remind us of our debt."

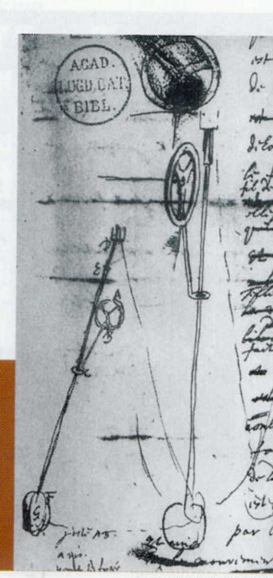
More debt service follows quickly, in talks that flesh out Landes's overview. Historian Albert van Helden, of Rice University, for one, explores the use of Jupiter's moons as a device for finding longitude. Galileo discovered these Jovian satellites in 1610 and noted how their regular circuits of the planet made them disappear and then reappear according to a precise and predictable schedule. Galileo was well aware of the longitude problem, too, and had more than a passing interest in claiming Spanish and Portuguese prize money being offered, in his day, for a solution.

By 1611 Galileo had codified the eclipses of Jupiter's moons, which occurred hundreds of times a year, and provided what



1641: Galileo discusses the concept of a pendulum-controlled timekeeper with his son Vincenzio.

1656-57: Christiaan Huygens develops the first pendulum clock.



UNIVERSITY OF LEIDEN

one contemporary called "the hands of a clock" for mariners. Galileo even constructed a special sea-going telescope that consisted of a spyglass attached to a helmet, but, unfortunately for him, the decks of ships proved too unstable for accurate observations. (Galileo himself conceded that, even on land, the beat of one's arteries could cause the whole of Jupiter to jump out of the telescope's field of view.)

After Galileo, Jean-Dominique Cassini, the Italian-born director of the Paris Observatory, continued the tracking of Jupiter's moons and published more reliable time tables in 1668. Improvements in telescope design at that same time made the Jovian satellites the accepted standard for determining longitude—but only on land. Mason and Dixon used the technique, Van Helden says, and it spurred a revolution in cartography by improving the accuracy of maps. Indeed, Louis XIV, confronted with a revised map of his domain based on longitude measurements, reportedly complained that he was losing more territory to his astronomers than to his enemies. At sea, however, the method of determining longitude by the satellites of Jupiter remained useless.

John Leopold, assistant keeper of the British Museum, tells how Dutch astronomer Christiaan Huygens developed a clock

Cranks and opportunists swarmed out of the woodwork, filling pamphlets with ideas that were by turns impractical, naive, and outlandishly funny.

in 1662 that he hoped would help to measure longitude. Even though Huygens made many great astronomical discoveries, including the largest satellite of Saturn, he found nightly observing to be drudgery and pursued other interests. Certainly he preferred clocks to the heavens for the purpose of marine timekeeping. His own shipboard clock failed to work because its pendulum stretched out in the heat of the equator, so that it couldn't keep the same time it kept in cold weather. But at least it showed that longitude by timekeeping was not entirely out of reach.

In the panel discussion that ends the morning's talks, one question is addressed to the audience at large: "How many people here have determined their position at sea?" About one hundred hands go up, suggesting that 20 to 25 percent of the group has a visceral appreciation of longitude.

After lunch at local restaurants in Harvard Square, the symposium reconvenes to hear a baker's dozen of "nutty" solutions to the longitude problem from Owen J. Gingerich, senior astronomer at the Harvard-Smithsonian Astrophysical Observatory and professor of astronomy and the history of science at the University.

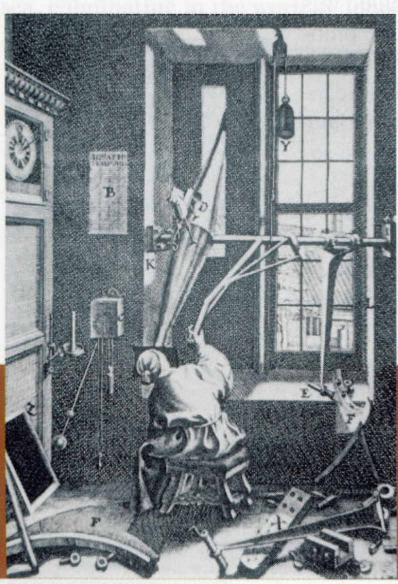
In 1714 the British government, by act of Parliament, offered a grand prize of £20,000 for a method of determining longitude to within half a degree. Lesser prizes of £15,000 and £10,000 were proffered for methods that could claim accuracy within two thirds of a degree and one degree, respectively. With these incentives, Gingerich notes, cranks and opportunists swarmed out of the woodwork, filling pamphlets with ideas that were by turns impractical, naive, and outlandishly funny. The Commissioners of Longitude, who reviewed them, included Sir Isaac Newton and astronomer Edmond Halley.

Among the first earnest tries was the 1714 proposal from William Whiston and Humphrey Ditton, who wanted stationary gunships, called hulls, to be staggered at roughly six-hundred-mile intervals across the oceans. These were to be securely fixed in place, if not by anchors, then by weights, let down from the hulls through the upper currents of very deep oceans into the still waters below. At local midnight each night, each ship would fire a rocket that could be seen and heard over great distances, enabling ships within a hundred-mile radius to determine their positions.

Critics of the Whiston and Ditton approach, Gingerich notes, raised many objections, including the impossibility of fixing the hulls at sea because of the action of swells upon the cables; the hard life of the sailors aboard the hulls, who could face starvation or pirates; and, of course, the problem of keeping the sailors sober.

Although Gingerich restricts his comments to ideas based on physics, the discussion raises questions about several "biological methods" for determining longitude, such as taking wounded dogs along on ocean voyages. The injured animal's bandage was to be left with a trusted person on shore, who would dip it in a mixture of water and "powder of sympathy" every hour on the hour, thereby causing the dog to yelp the correct time at sea. Or, purportedly telepathic goats could be urged to beat time by bleating in unison, one on shore and one on shipboard.

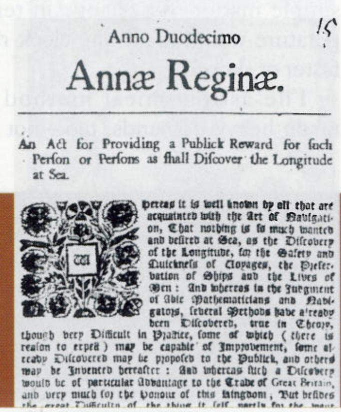
On Friday night the whole assemblage repairs to a reception and exhibit on "The Art of Time," featuring timepieces from the historical collection, at the



THE BRITISH LIBRARY, LONDON

1675: Using the eclipses of Jupiter's satellites, Ole Roemer discovers the finite velocity of light.

1714: An act of Queen Anne offers a £20,000 reward for the solution to finding longitude at sea.



Anno Duodecimo 15

Annæ Reginæ.

An Act for Providing a Publick Reward for ſuch Perſon or Perſons as ſhall Diſcover the Longitude at Sea.

Whereas it is well known by all that are acquainted with the Art of Navigation, That nothing is so much wanted and desired at Sea, as the Discovery of the Longitude, for the Safety and Quickness of Voyages, the Preservation of Ships and the Lives of Men: And whereas in the Judgment of Able Mathematicians and Navigators, several Methods have already been Discovered, true in Theory, though very Difficult in Practice, some of which (there is reason to expect) may be capable of Improvement, some already Discovered may be proposed to the Publick, and others may be Invented hereafter: And whereas such a Discovery would be of particular Advantage to the Trade of Great Britain, and very much for the Honour of this Kingdom; But besides

SPECIAL COLLECTIONS DEPARTMENT, HARVARD LAW SCHOOL LIBRARY

Fogg Museum. Here, in a gesture of supreme thoughtfulness for people who love to take things apart, all the clocks have been gutted. Their ornate wood and metal cases stand empty, like lifeless pieces of furniture, while their extracted works whir and tick for all to see in specially made protective plexiglass boxes. The thankful audience closes in around the see-through walls, scrutinizing the mechanisms, squinting to peer more deeply, squatting for a different view. If only they could osmose themselves through the barriers. One aficionado is all but lying on top of a display case, with a small telescope aimed at the open pocket watch inside it, a scant six inches away.

Distracted by a Degas sculpture and several Monet paintings hung in an adjoining, less crowded gallery, two members of the British Horological Institute contingent, Joyce Bolton and N. Geoffrey Bolton, await the right moment to view the exhibit. Geoffrey Bolton, a Yorkshire native like the great John Harrison before him, now owns the clock shop where he apprenticed as a young man.

"I've spent 55 years working in the same room," he says without a trace of remorse. His wife, who handles "the business side" of the enterprise, appears equally proud of his tenure and urges him to talk about unusual clocks he has known.

"Someone once brought me a watch that had been dug up around the concentration camp at Bergen-Belsen," he recalls. "Its face was cracked and heat-damaged, and of course it didn't run. I learned that watches were routinely taken from the prisoners by the guards, who buried them in a box. At the end of the war, the liberating forces found these watches and kept them. I restored the watch to working order," he adds, "but I left the dial cracked—to show that it had a history of suffering."

Saturday's sessions convene in a student-vacated lecture hall in the Science Center, where speakers address the heart of the longitude matter, namely, the inner workings of John Harrison's clocks.

Most members of this audience know intimately the intricacies of clocks' interlocking wheels within wheels. Others have only a vague feeling for the challenge of precision timekeeping and couldn't tell the interior of a Timex from a Rolex on a bet. Yet this day's sessions still manage to speak to everyone, in part because the expert presenters remain absolutely awestruck by John Harrison's achievements. There is nothing dry about their reportage.

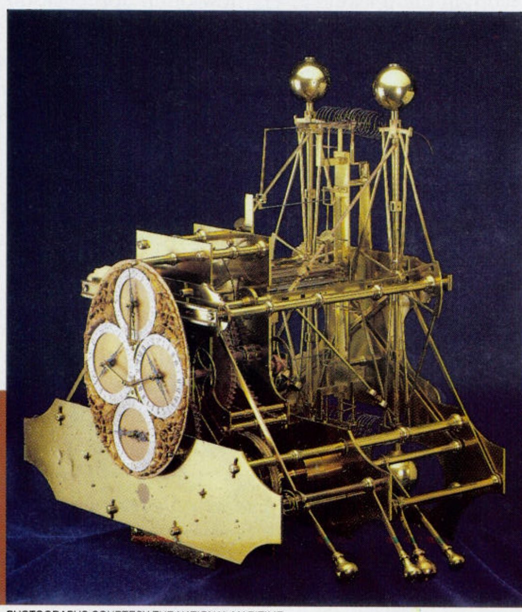
Not only did "the master," as some call him, have to compensate for the changes in temperature and barometric pressure that his timekeeper was sure to encounter (not to mention the constant, sometimes violent motion of a ship at sea), but he also had to allow for the troublesome effects of high humidity, the corrosive salty air, and even the variations in the earth's gravity at different latitudes that would normally cause a clock to gain or lose time. Harrison met these challenges by devising virtually friction-free clocks that required no lubrication and no cleaning, that were made from materials that would not rust, and that kept their moving parts perfectly balanced in relation to one another, regardless of how the world pitched or tossed about them. He did away with the pendulum, and he combined different metals inside his works—in such a way that when one component expanded or contracted with changes in temperature, the other counteracted the change and kept the clock's rate constant.

Animations of clever clock mechanisms, created by John Redfern, of Scotland, do more than illustrate several of these talks. They mesmerize the audience with their cartoon-bright colors and comforting noises (not just "tick-tock" but "bong-da-dum, bong-da-dum" and other technically accurate facsimiles). The viewers seem to sway and breathe in rhythm with the animated movement, and then momentarily lose their breaths when each segment stops.

Andrew King, a clockmaker from the United Kingdom and an acknowledged expert on the life of John Harrison, describes his hero as "a unique and individual character, free from the shackles of contemporary thought." This condition was no doubt aided by the fact that Harrison had no formal education. He had, instead, an endless fascination for his favorite fields—music, carpentry, and clockmaking.

By some accounts, Harrison did not take on the challenge of the longitude prize until 1726, some twelve years after it was announced. By then he had conquered most of the problems of timekeeping on land and so turned his efforts to keeping time at sea. Here he enjoyed a head start because of his early endeavors on some of the intrinsic problems. For exam-

1735: John Harrison unveils the world's first practical marine timekeeper, called H-1. The dials, clockwise from the top, are for seconds, hours, calendar, and minutes. A detail appears on the cover.



PHOTOGRAPHS COURTESY THE NATIONAL MARITIME MUSEUM, GREENWICH, LONDON

1761: Harrison's fourth timekeeper (above) begins tests on a voyage to the West Indies. H-1 weighed 75 pounds and stood 25 inches tall; H-4 was five inches in diameter and weighed just over three pounds.

ple, he and his younger brother, James, had long since timed pocket watches in various positions to observe how gravity affected their accuracy. He had also timed his clocks by observing the stars through a homemade transit instrument he fashioned from his window frame, noting to within a fraction of a second when they disappeared behind his neighbor's chimney.

A man who tried and tried again, Harrison built four marine timekeepers, or chronometers, over the course of 35 years. He put at least three years of thought and five years of labor into his first contender for the prize, now called H-1. When it was finished, he accompanied it to Lisbon on a voyage that made the inventor quite seasick but affected his clock not one whit. H-1 worked so well, in fact, that Harrison was able to use it to contradict the ship's officers on the way home, correcting their estimate of the ship's position by sixty miles and handily winning their admiration.

This demonstrated success occasioned the first-ever full meeting of the Board of Longitude, in 1737. No other effort until that time had been serious enough to merit such a convention. But John Harrison was not yet satisfied with his efforts. Instead of appealing for the prize money, he petitioned the commissioners for funding to subsidize work on a new model. They gave him £250 as a grant, promising an equal sum when he delivered on his promise.

Four years later he had finished the big brass H-2, but he never bothered to test it. He had grown disenchanted because of a deficiency he detected in it, and he wanted nothing so much as to plunge ahead with H-3. The commissioners gave him another £500 to help him do so. And they kept on awarding him sums of money through the nearly twenty years that Harrison struggled to perfect H-3. At length, although he applied some of his most creative and lasting inventions to what he called "my curious third machine," Harrison abandoned it.

Meanwhile, he had designed a pocket watch for himself—one that he could use to test his other equipment—and had given the plans to a London watchmaker to make up for him. The timepiece far surpassed his expectations, since other pocket watches of that day did not approach the accuracy of large clocks. H-1, H-2, and H-3 all weighed in the neighborhood of seventy pounds and stood at least two feet high. Harrison realized, much to his surprise, that with a few improvements, a watch "of such a size as may be worn in the pocket . . . may be render'd capable of being of great service with respect to the Longitude at Sea."

The fourth timekeeper, H-4, looked like a lovely silver pocket watch for a giant, as the diameter of its face measured five inches across and the object weighed three pounds. A series of contentious trials proved the watch to be even more accurate than the terms of the Longitude Act required, but the board refused to pay up. The commissioners, many of whom were astronomers wedded to the lunar-distance method, considered H-4 an irreproducible fluke and therefore not "practical and useful" as the act demanded. Before the commissioners would yield the prize money to Harrison, they insisted that he yield the watch to them. The board assembled a panel of experts to dismantle and study it. They further required Harrison to make two copies of H-4 after he had handed the original over to them. They later claimed possession of all the marine timekeepers and sent Nevil Maskelyne, the Astronomer Royal, to Harrison's shop to collect them with a rude cart. En route from the building to the street, porters dropped H-1.

Although Harrison finished H-4 in 1759, he did not receive any prize money until 1765, at which time he collected only half of it, or £10,000. Even after continued appeals, Harrison could not recover the remaining half of the reward. Finally, to prove himself, he completed a fifth marine timekeeper in 1770, H-5, which was tested two years later by none other than King George III in his private observatory. When this timekeeper proved itself accurate to within four seconds over ten weeks, the king is reputed to have said, "By God, Harrison, I will see you righted!" Harrison was eighty years old when he at last received an additional £8,750 in 1773.

The timekeepers themselves remained at the Royal Observatory, in sensational neglect. When horologist Rupert Gould exhumed them from a cellar in the 1920s, he found them in poor condition. Gould said of H-1, "The brass now offered to the eye a superb bluish-green patina, rivaling any Etruscan bronze in the British Museum. Had it sunk with the *Royal George* and been recovered from Spithead after the war, it could scarcely have achieved a more perfect degree of corrosion."

Today the care of Harrison's marine timekeepers rests with Jonathan Betts, the curator of horology at the National Maritime Museum and one of the last to speak at the symposium. The tall, slender Betts, who has written several books and pamphlets about clocks in general and Harrison's clocks in particular, shoulders his awesome responsibility with equanimity. But to a man who uses clock words such as *fusee, remontoire,* and *escapement* in ordinary conversation, as Betts does, the Harrison timekeepers probably have the feel of sacred relics.

At the closing ceremonies in Memorial Hall, Philip Morrison, Institute Professor emeritus at MIT, stands up with his wife and partner in science explication, Phylis Morrison, and right before the eyes of the participants uses portable electronic equipment smaller than a Sony Walkman to pick up radio beacons from satellites eleven thousand miles above the earth. The Morrisons give the precise position of the longitude symposium as north 42 degrees, 22 minutes, 34 seconds; west 71 degrees, 6 minutes, 56 seconds.

The participants delight in this reassuring announcement. Some, like Andrew Hunter, a representative of Bernard Quaritch Ltd., antiquarian book dealers in London, take it in with a newfound appreciation of its significance. Hunter quietly tells his dinner partner that he now has for sale in his holdings an original 1767 copy of *The Principles of Mr. Harrison's Timekeeper,* in which John Harrison described the building of H-4. The forty-page book, with fold-out engravings of Harrison's drawings, is valued at £8,000 (about $12,000).

The catalogue blurb that Hunter wrote before leaving London, he says somewhat sheepishly, notes the text's condition and physical characteristics in coded abbreviations, along with a perfunctory description of its contents. He simply must go home and revise that write-up now, he says . . . now that he's vicariously circumnavigated the globe without a means for finding longitude. Now that he's been a fly on the wall in John Harrison's workshop for four decades. Now that he understands what it takes to wrest one's whereabouts from the stars and lock the secret in a pocket watch.

Dava Sobel writes frequently about science for several magazines. She is co-author with Frank Drake of Is Anyone Out There: The Scientific Search for Extraterrestrial Intelligence. *For more about longitudinal celebrations, please see page 4.*