DAVA SOBEL ON SUNDIALS ~ A FAB PREFAB HOUSE

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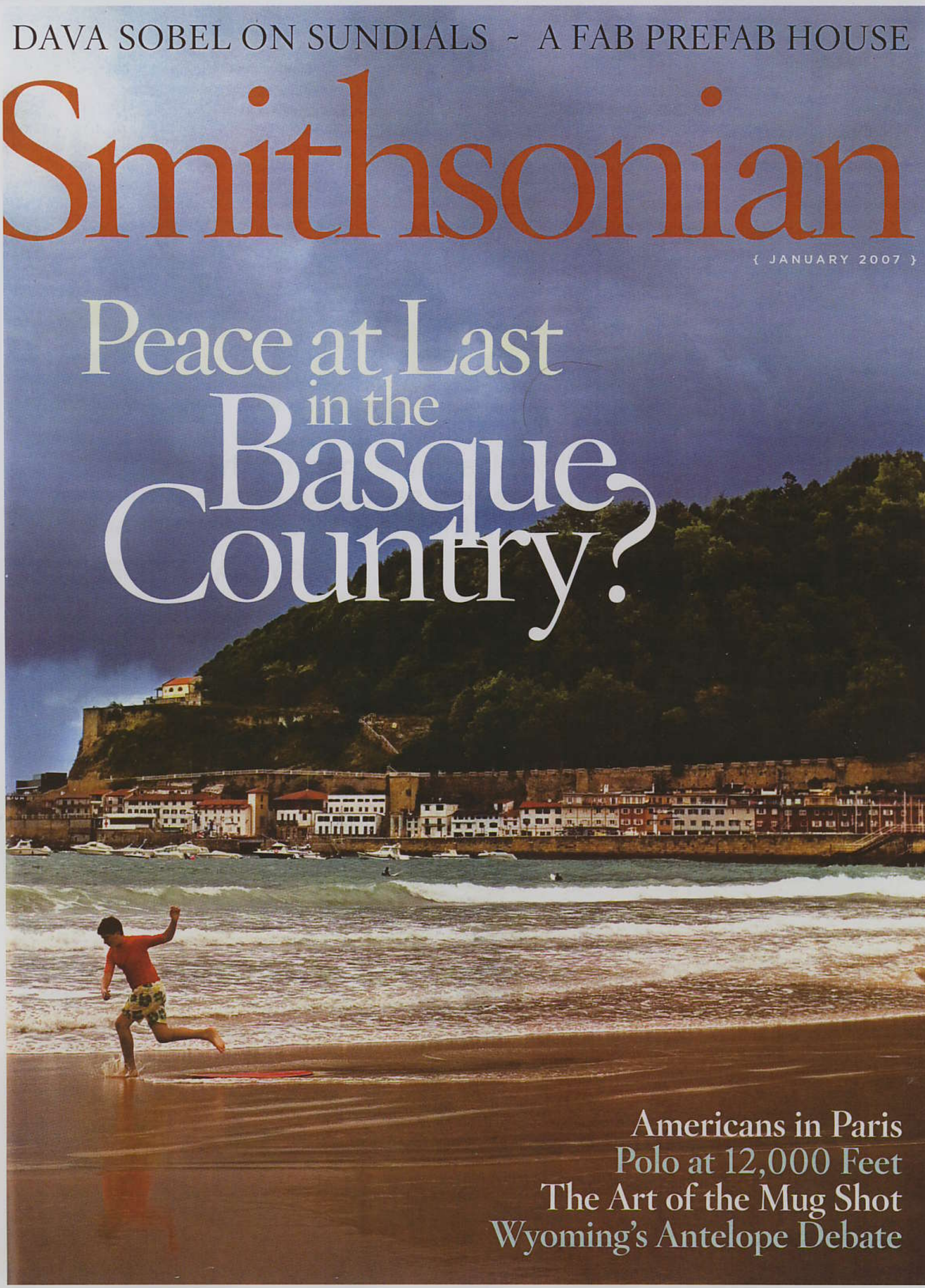

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THE SHADOW KNOWS

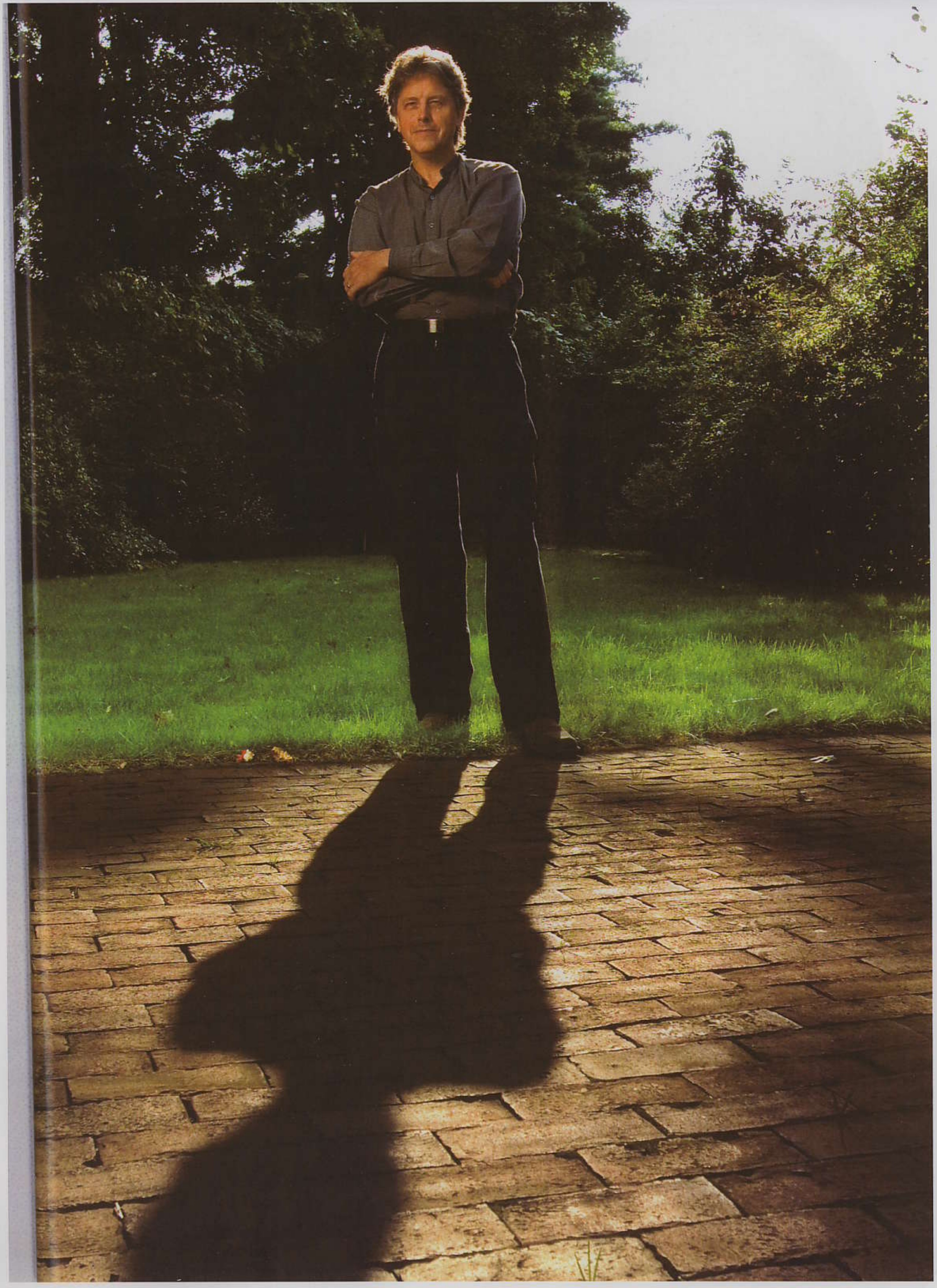
Why a leading expert on the history of timekeeping set out to create a sundial unlike anything the world has ever seen

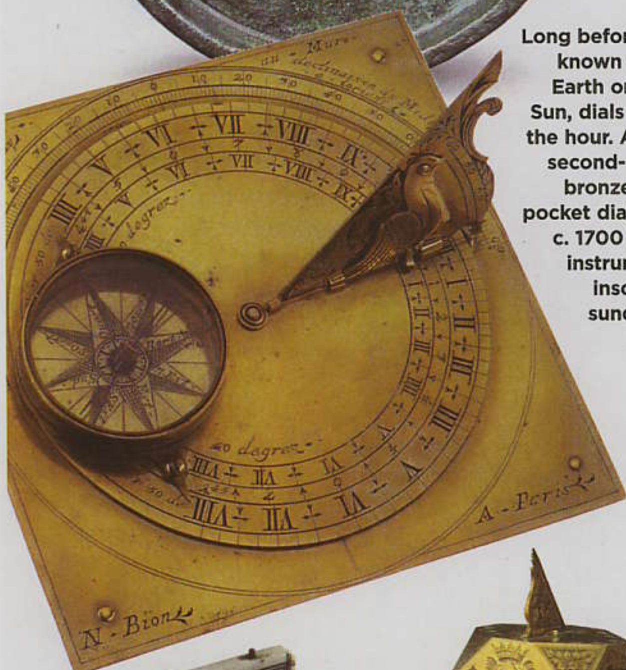
BY DAVA SOBEL

THE FIRST TIME I MET WILLIAM ANDREWES, several years ago, he was wearing an inexpensive wristwatch with the cartoon figures Tintin and Snowy running across the dial. Since Andrewes then served as curator of Harvard University's Collection of Historical Scientific Instruments, his whimsical watch cut a ridiculous contrast with the important timekeepers he maintained, exhibited and also used as teaching aids in his course, "Instruments of Time and Space."

Though sundials have been around 3,000 years (a model at St. Michael's Mount, Cornwall, England), William Andrewes (indicating the lateness of the hour in his garden in Concord, Massachusetts) is perhaps the first to build one showing the time in multiple places simultaneously.

MARK BOLTON / ALAMY; P. 89 JARED LEEDS





Long before it was known that the Earth orbits the Sun, dials showed the hour. Above, a second- century bronze Roman pocket dial. Left, a c. 1700 Parisian instrument for inscribing a sundial on a surface.

The dial's heyday was fanciful. Above, a 1661 polyhedral gilt bronze dial from Paris. Left, an ivory diptych dial, 1614, from Germany, has a lunar volvelle, allowing one to tell time by moonlight, and a compass.

Since leaving Harvard, in 1999, Andrewes, who is 56, has given up wearing a watch at all. At home, in Concord, Massachusetts, he can tell time well enough by a dozen or so antiques he keeps in good working order, and he says that while traveling he finds time "publicly available." When I saw him in October 2004 at Sotheby's in New York, for the seventh and final auction of the holdings of the now defunct Time Museum—the world's most comprehensive assemblage of timekeeping devices, dating from 3000 B.C. to the present—he was relying on his cellphone to keep appointments. "It allows you to tell time to the nearest minute," he assured me, "which is fine for civic purposes, though not sufficiently accurate for setting another clock."

Andrewes bid on several lots during that three-day auction, and almost everything he purchased, whether for himself or a client, he was buying for the second time; as the Time Museum's curator from 1977 to 1987, he had shopped the world to increase its collection from 1,300 to more than 3,500 items. Andrewes and his wife, Cathy, seated next to him that day at Sotheby's, could tie dozens of the museum's pieces to significant dates in their courtship and marriage and the births of their two children. They felt a special fondness for the clock Will had been restoring when they met—a 19th-century Christian Gebhard astronomical and automaton clock with 17 dials, 2 revolving globes, barometer, planetarium, date displays and figures performing each quarter and hour (including a religious procession every day at noon and a herald blowing a trumpet at midnight on New Year's Eve)—but it is nearly ten feet tall, more than eight feet long and far beyond their means. It sold for $142,400.

Despite Andrewes' long fascination with complex mechanical clockworks, he has recently taken what might seem a giant leap backward to become a "dialist," or maker of sundials. "My original goal in this," he said in response to my surprise, "was to produce an accurate timepiece with no moving parts—an original creation that combined art and science, drawing from the long traditions of both in its design, and incorporating the finest craftsmanship and latest technology in its construction." What really set his idea apart, however, was his intention to base the dial on an unusual type of map, and to center the map on the very spot where the dial would stand. The map's meridians of longitude would serve as the sundial's hour lines, creating a union of time and space for that particular location—something no dialist or clockmaker had ever before achieved.

A sundial is one of the oldest—it may be *the* oldest—of all scientific instruments. It depends on the Earth's rotation, although when it was first contrived, probably before 1500 B.C., its makers believed that the Sun revolved around

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DAVA SOBEL, *author of* Longitude *and* The Planets, *co-authored* The Illustrated Longitude *with William Andrewes.*

a stationary Earth. Either way one envisions the heavens, the practice is the same: the Sun shines on the dial, and a protruding "gnomon" (from the Greek for "one who knows"—presumably one who knows what time it is) casts a shadow among the hour lines marked on a dial plate, indicating the time. What could be simpler? Or rather, what could be more deceptive than the apparent simplicity of this device? For in order to make the fallen shadow even approximate the correct time, the dial must be laid out with regard to latitude north or south of the Equator where it is to be used, respecting the changing high point of the Sun in the sky from day to day over the course of the year and the variable speed of the Earth's annual motion. There is nothing obvious about the construction of a proper sundial. Anyone who buys a mass-produced sundial and sets it out among the flower beds as a decoration should not be surprised to find that it fails to work.

The great variety of dial designs through history, according to the late science historian Derek de Solla Price, attests to the "aesthetic or religious satisfaction" that dialists must have derived from trying to simulate the heavens. Vitruvius, architect of ancient Rome, counted at least 13 dial styles already in use in Greece by 30 B.C. Then as now, a dial could be mounted vertically on the side of a building or set horizontally on a pedestal or the ground, and take virtually any shape—flat, spherical, conical or cylindrical. Some sundials were stationary, others movable, and many, like a sundial George Washington carried, were meant to fit in a pocket. Although weight-driven mechanical clocks were introduced in England around 1280, and became fixtures of public and private life by the 1600s, their proliferation sparked a boom in sundials. In the 1700s, after the inventions of the pendulum clock in The Hague and the balance spring in Paris inaugurated the era of precision timekeeping, sundials achieved even greater importance than before. "Just as the computer increased the need for the paper that some people thought it would replace," Andrewes says, "clocks—and later watches—greatly increased the demand for sundials, because every timekeeper needs, at some point, to be set correctly." A clock or watch may keep time, but only a sundial can *find* time—a distinctly different function—by deriving the hour from the relative positions of the Earth and Sun.

Andrewes once worked with the biographer of John Harrison (above), the 18th-century clockmaker whose breakthrough chronometer solved the problem of finding longitude at sea.

Today the work of measuring precise time has been relegated to government agencies such as the U.S. Naval Observatory in Washington, D.C., the International Earth Rotation Service at the Paris Observatory and the Bureau International des Poids et Mesures in Sevres, France, all of which measure a second by the interval it takes a cesium atom to vibrate 9,192,631,770 times. Because the Earth goes its own way in space, however, heedless of atomic time, "leap seconds" are periodically added to our years to keep our clocks in sync with the turning of our planet. A sundial requires no such adjustment. "A sundial lets you see the Earth turn," Andrewes says. "Of course you know it's turning, but when you witness the shadow moving across the dial you feel something. Many people have no idea why the seasons occur—that the hemisphere tilted toward the Sun actually changes from winter to summer. Time has become separated from space, and I think that's a mistake."

ANDREWES' WORKSHOP, in the basement of his family's colonial-style home in Concord, accommodates a 3,000-volume reference library, banks of file cabinets, a desk with a computer and other office equipment, a conference table and his drafting table, lathe and workbench. Sundial parts lie everywhere, along with an accumulation of clocks he has bought, or built himself, or saved for sentimental reasons, such as a 19th-century cuckoo clock that belonged to his parents—the first clock he ever took apart.

Though clocks surround him, Andrewes says he doesn't pay that much attention to time. "Clockmakers are the least time-conscious people," he says, "because in the end it does not matter how much time it takes to build a timepiece, but only that it turn out beautifully and show none of the angst that went into it. Engineers are happy if they make something that works, and many tend not to care what the inside bits look like, but clockmakers attend to all the hidden details, even on parts that will never be seen unless the clock is dismantled. To be a clockmaker is to work not just for yourself or your client, but also for someone else far in the future, someone who knows enough to judge your work, and who will look at something you've made someday and—you hope—say, 'That was done right.'"

As a teenager in North London, where Andrewes spent school vacations assisting a local clockmaker, his hero was John Harrison, the 18th-century clockmaker who solved the problem of finding longitude at sea by creating the first accurate marine chronometer. By age 19, Andrewes

Beyond Time

A unique sundial marks places as well as hours

William Andrewes' Longitude Dial tells time—assuming the Sun is shining—but it also does something no other dial can do: it tells place. As the daylight hours pass, the telltale shadow cast by the wire, or gnomon, moves across a laser-etched map; wherever that longitudinal shadow falls, it's noon. Part of what makes this feat possible is that the dial is custom-built for its location, with that very spot serving as the center of a computer-generated map on the dial face. In this dial, customized for a client in New York State, the gnomon's shadow indicates it's 11:45 a.m. at the dial's home base. Wherever the gnomon's shadow falls on the map, it's noon, and where it crosses, the degree scale marks the longitude of those places. The spherical shadow in South America, cast by the round bead on the gnomon, indicates where the Sun is precisely overhead.

ROMAN NUMERALS
Indicate the hour, when the gnomon's shadow falls on them. Minutes are marked by Arabic numerals.

CALENDAR CIRCLE
This ring is encircled with the number of minutes added or subtracted to convert solar time (as shown on a sundial) to so-called mean time (as kept by clocks and watches).

SUMMER SOLSTICE
The shadow of the gnomon's bead traces the Tropic of Cancer on this day, June 21. The time of the day's sunrise and sunset are also indicated on the ring encircling the hours and minutes.

DEGREE SCALE
Marks the longitude of those locations under the gnomon's shadow.

GNOMON

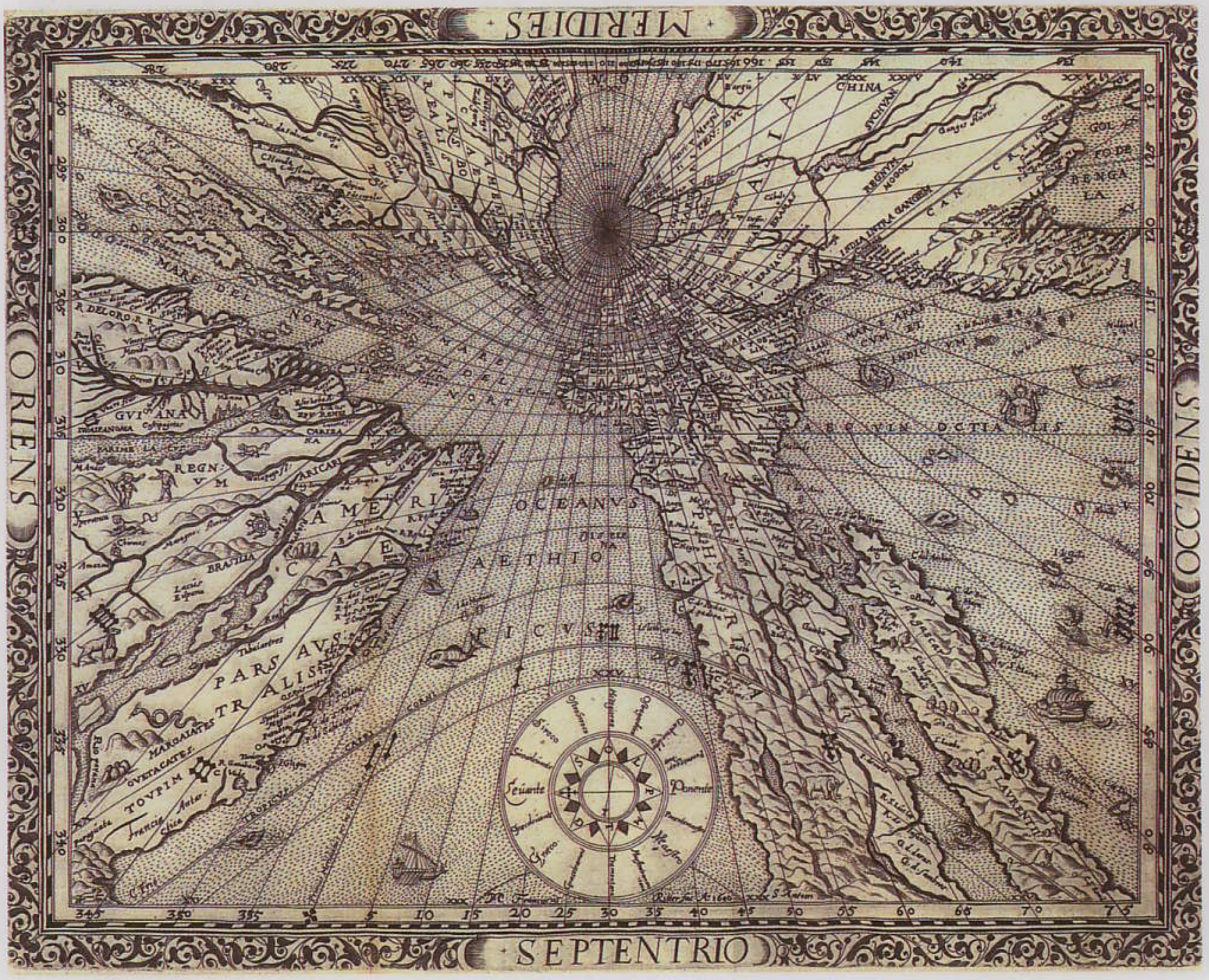
STEVEN PITKIN STUDIO / (SOME IDENTIFYING INFORMATION ON THE DIAL HAS BEEN BLURRED TO PROTECT THE OWNER'S PRIVACY.)

had befriended Harrison's biographer, Humphrey Quill, a past master in the Worshipful Company of Clockmakers, a guild. Quill, by then elderly, placed Andrewes under the guidance of world-renowned watchmaker George Daniels, and also entrusted the youth with an unfinished Harrison clock—an early wooden regulator abandoned around 1720—for him to complete as his formal initiation into horology, the science of precision timekeeping. After Andrewes graduated from the Kingston College of Art in 1972, he taught design, clockmaking and metalwork at Eton College. The commission he won from the Royal Mint to create three medals commemorating the 300th anniversary, in 1975, of the Royal Observatory, in Greenwich, led to his taking charge of the observatory's historical collection of chronometers and precision clocks.

In 1977, Andrewes moved to the United States to head the Time Museum, in Rockford, Illinois, at the invitation of its founder, Seth G. Atwood, a manufacturer of hardware and automobile parts. At the museum, housed in a hotel Atwood owned then called the Clock Tower Inn, Andrewes looked after hourglasses, water clocks, fire clocks, incense clocks, oil lamp clocks, electric clocks and atomic clocks, in addition to many marvelous mechanical clocks, 65 of which were kept running abreast of time, meaning they had to be set forward an hour every spring and turned back an hour in the fall.

The museum contained about 100 sundials. They ranged from a fifth-century Greco-Byzantine vertical dial to a brass and silvered-brass mechanical equinoctial standing ring dial, made by Richard Glynne about 1720 for Archibald Campbell, the Earl of Ilay, whose arms and initials were elaborately incorporated into its shining design, and which told the time with a focused pinhole of light instead of a shadow.

Andrewes modeled his business card on a sundial devised by 15-century astronomer Johannes Müller, or Re-



An inspiration for Andrewes' Longitude Dial was a 1610 map by Nuremberg mathematician Franz Ritter. It placed his city at the center, so that the meridians of longitude emanating from the North Pole could also serve as the hour lines of a Nuremberg sundial.

giomontanus. Andrewes' folded card, which exceeded the usual business-card dimensions even before it was opened, allowed recipients to convert it into a working sundial with the addition of a needle and thread according to directions printed on the back. Later, when Atwood's daughter announced her engagement, Andrewes designed a toast-rack sundial as a wedding present. "It was a square dial of the horizontal type," he recalls. "Instead of numbers, it was inlaid with different woods that helped you count the hours, and its triangular gnomon was cut with vertical slots, to hold your toast."

Toward the end of 1986, Atwood curtailed the museum's collecting and publishing activities. "Seth Atwood is the only person I know who was infected by the horological virus and later recovered," Andrewes says. "For most collectors, death is the only cure." The next year, Andrewes was appointed curator of Harvard's historic scientific instrument collection. The wealth of sundials there—more than 700—exceeded anything he had previously overseen. In 1992, Andrewes supervised the publication of a catalog covering a small subset of these: *Ivory Diptych Sundials 1570-1750*, with text by Steven Lloyd and hundreds of photographs, describing 82 tiny folding contrivances gathered from Germany, France, Italy and other countries, each bearing its own time design in blue, red, green and brown, with a string for a gnomon and a built-in compass to point it north. The following year, Andrewes organized a Longitude Symposium that drew 500 participants from 17 countries to celebrate the tercentenary of John Harrison's birth, and later he published an annotated edition of the proceedings, *The Quest for Longitude*.

His delving into that subject helped revive Andrewes' own sundial idea, what he calls the Longitude Dial. His original inspiration came from a 1610 map that University of Wisconsin cartographer David Woodward had once shown him. That map and others by the mathematician Franz Ritter are the oldest known examples of a gnomonic projection. They appear in Ritter's how-to book on sundials, *Speculum Solis (Mirror of the Sun)*, published in Nuremberg, Germany. Ritter's map placed Nuremberg at the

JARED LEEDS

"To be a clockmaker is to work not just for yourself or your client," says Andrewes (in his workshop), "but also for someone else far in the future, someone who knows enough to judge your work." His smallest Longitude Dial (opposite) costs at least $15,500.

center of the Western Hemisphere. The farthest reaches of the map's landmasses look grossly distorted as a result, but the novel perspective causes the meridians of longitude to radiate out from the North Pole in straight lines, so they can double as the hour lines of a sundial. Ritter's innovative pairing of time and place might well have impressed any dialist, but it struck Andrewes with the force of a revelation. And although Ritter intended his gnomonic projection as the basis for a novel sundial, he seems never to have built one. Andrewes knew of no such dial anywhere. But he determined to make one.

It's a measure of the astonishing recent progress in computing that the first gnomonic projection that Andrewes commissioned—in 1979—was such an onerous undertaking that it was created on the University of Wisconsin's supercomputer, by Woodward. By the time Andrewes returned to dialing in earnest more than 20 years later, a gnomonic projection map could be drafted at home on a laptop in just minutes, thanks to Geocart, a cartography program developed by Daniel Strebe of Mapthematics in Renton, Washington. (Today, the gnomonic projection finds its most common application in aviation.) With Geocart, Andrewes realized he could design a dial plate for any location in the world. As a test, he created a paper-and-cardboard prototype for the coordinates of the hotel in which he and his family planned to vacation in Crete. "Everyone else was sunbathing," Cathy Andrewes recalled of that 2002 summer vacation. "William was balancing paper sundials on trash cans at the beach, trying to keep them from blowing away." Even after sunset he busied himself with the dial, since he had fitted it with an attachment, called a lunar volvelle, for telling time by moonlight. By August, he had convinced himself that the basic design was sound.

Inspired by the look of his favorite historical instruments, Andrewes arrayed the Roman numerals for the hours in a ring around the map, by hand, drawing their vertical strokes so they all pointed to the North Pole, and rendering their serifs concentric with the center of the dial. He wanted the small Arabic numerals that counted off ten-minute intervals to bow and tilt according to their longitude, and likewise the tiers of tiny tick marks subdividing the larger intervals into individual minutes. Decorative flourishes shaped like tridents or fleurs-de-lis, inserted at the half-hour points, would change their orientation and shape according to their distance from the pole. Andrewes appealed to Strebe, who, with his colleague Paul Messmer, created a "sundial plug-in" for Adobe Illustrator that lets Andrewes automatically adapt his hour-ring artwork to any number of locations with only minor adjustments.

Then he cast about for the right stone. "I thought it had to be bright stone," he recalled. "Most sundials are made of light-colored materials because those show off a shadow to best advantage. I'd gone down to see this wonderful chap in Newport, one of the great monument stonecutters in America. I wanted him to cut a dial for me by hand in granite. He took one look at the design—the map, the numerals, the precision constraints for the minute ticks—and said, 'You must be mad.'" Andrewes turned to establishments where stonecutting had been mechanized and modernized, namely the manufacturers of cemetery memorials. On a visit to Rock of Ages in Methuen, New Hampshire, he learned that black gabbro stone could be etched by laser. What's more, it displayed the unusual property of turning white where laser-etched, so that every incision appeared both cut-in and painted-on. "That was the turning point," Andrewes said. The map's white continents would stand out from dark seas, and decorations too delicate to be chiseled in stone could be transferred to it from pen-and-ink drawings by a carbon-dioxide laser's white light. The finished dial plate, polished to a mirror-like luster and water-sealed, would show off a gnomon shadow as well as any pale-colored stone could do. Gary Hahn, a stone artisan in New Hampshire, has since become Andrewes' collaborator. Together they found a source of superior gabbro from China. Andrewes' friend and colleague Linn Hobbs, a materials scientist and nuclear engineer at MIT, advised him on how best to attach metal parts to the dial and pedestal.

Andrewes has built ten Longitude Dials in the past two years and delivered these to clients in England, Spain, Connecticut, Maryland, New York State and California. Each is a precision timepiece without hands—a wheel of polished black stone bearing a laser-etched map that centers its intended location inside a private time universe, where the hours pass visibly minute by minute on a ring of Roman numerals reminiscent of an elegant 18th-century watch face. In addition to giving the correct time, each dial acknowledges an important moment in its owner's life—a wedding anniversary, a birthday—by casting an annual commemorative shadow along a customized date line. "It's a magnificent thing, a unique type of instrument that does not seem to have been built ever before," says Bruce Chandler, a mathematician at the City University of New York.

Andrewes builds his signature dial in three sizes, the largest of which is nearly four feet across and costs at least $50,000 with its pedestal and base. The smaller, garden dial also stands on a permanent pedestal and base, and starts at about $30,000. The petite terrace dial, only a foot in diameter, has adjustable brass feet, along with a tiny spirit level tucked in a drawer underneath, that help it accommodate to a slanting tabletop or a sloping porch. In its handmade wooden presentation box, it starts at $15,500.

A LONGITUDE DIAL sits in my backyard atop a granite pedestal centered on a patio Andrewes designed in the style of a compass rose. Andrewes typically visits the site of any proposed garden or monument dial, paces around to pick the most Sun-favored spot and fixes its position with a hand-held GPS. But he downloaded my latitude and longitude from a computer database of ordinance survey maps. The coordinates became the raw data for the gnomonic projection centered on the house where I've lived for the past 20 years—and now may never leave, since its location is set in stone on my dial, with the latitude and longitude expressed in degrees, minutes and seconds of arc. It was plotted to work just here and nowhere else. In this sense it is a far more personal possession than the wristwatch I wear every day. And lovelier too. Early in the morning, I find the dew has collected on the continents, clouds floating overhead are reflected in the dial, and I can read the wind's direction by their passage. The gold-plated bead on the gnomon wire throws a small round shadow on the part of the map where the Sun is precisely overhead. The bead's shadow will cross the map along the straight line of the Equator each year on the days of the vernal and autumnal equinox, and on June 21, the summer solstice, it will trace out the curved Tropic of Cancer. Because I consult my dial most in warm-weather months, when daylight saving time is usually in effect, I chose to have it constructed to that system.

"With each dial I discover some new technique that makes me want to redo the earlier ones," Andrewes says. "But of course I can't do that." He can, however, incorporate innovations in the next dials, such as the monument-size one that has just been commissioned for an English country house. "The joy for me—and one of the most exciting things about a good sundial—is that once it's leveled and oriented correctly, it will never fail you when the Sun is shining. If anything goes wrong with the Earth, this dial will show it. You could be among the first to know. But if that suddenly happens, don't call me. Pray." ○