Press Coverage

Lessons from the Long Now

by Roger Smith January 02000, Software Development Magazine

Engineers today, especially software engineers battling entrenched millennium bugs, aren't known for their long-term planning. Computer scientist Daniel (Danny) Hillis, vice-president for research and design at the Walt Disney Co., may be the exception to this recent and unfortunate rule. Hillis, a pioneer in massively parallel computing in the 1980s, is part of a geographically dispersed consortium–the Long Now Foundation–that is building a unique clock designed to tick for 10,000 years.

"In my work on parallel computers," Hillis explains, "I met a lot of people who were obsessed with speed. My customers were always looking at 'faster, faster.' So I naturally began to think of 'slower' as the unnoticed frontier."

In 1993, Hillis conceived the idea of a three-story-tall clock that would run for 10,000 years in a remote desert location as "a long-term project to get people thinking past the mental barrier of the millennium."

An inventor, scientist and computer designer, Hillis is one of the few people nowadays looking beyond the average five- to 30-year technological cycle. But designers and builders haven't always been so shortsighted.

"When the oak beams of the hall at New College in Oxford had to be replaced last century," Hillis recounts, "wood from oak trees planted in 1386, when the hall was built, was used. The 14th-century builders had planted the trees in anticipation of the time, hundreds of years in the future, when the beams would need replacing."

Hillis's far-fetched Millennium Clock idea found support from a group of technologists that included, among others, futurist Paul Saffo, author Esther Dyson and British musician Brian Eno. Eno, who is composing the themes for the clock's chimes, coined the project's name, the "Long Now," to explain the group's conceptual goal of extending people's understanding of the present to encompass two directions–"making the present longer," as Eno puts it.

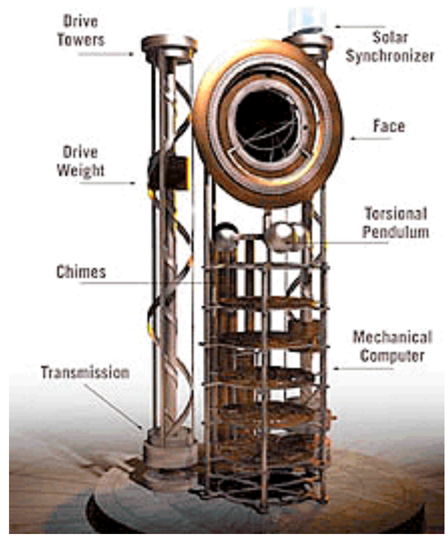
Another early adherent was author, inventor and visionary Stewart Brand, the man responsible for both the Whole Earth catalog and the early and influential online community The WELL (Whole Earth 'Lectronic Link). Alexander Rose, an industrial designer with a three-dimensional modeling and visualization background (and a family friend of the Sausalito, Calif.-based Brand), is executive director of the Long Now Foundation (www.longnow.org), which is raising money to build the clock.

Hillis, Brand, Rose and their cohorts also augur hope for a latter-day Library of Alexandria, built alongside the 10,000-year clock, that will hold books, music, cultural artifacts and lexicons or indexes into thousands of years of collected information. The remote location of the Long Now Clock and Library in the high desert of the U.S. Southwest may ensure that the library doesn't share the fate of the original Alexandria bibliotheca that Brand relates in his book, *The Clock of the Long Now* (Basic Books, 1999), when the books were ultimately burned to heat the public baths.

How it works

The 8-foot-high tungsten, monel, invar and elinvar prototype, being built at press time in a Sausalito machine shop, was scheduled to be completed by the end of 1999. Once an estimated $20 million has been raised, the roughly 60-foot-high clock will be deployed in the Nevada desert, on an 80-acre property dotted with ancient bristlecone pines and sheer limestone cliffs. The dry climate and geological stability of the high desert were chosen to ensure that the clock's materials last thousands of years–though the decision on whether to situate the clock in a mountain cave or on a valley floor has yet to be made.

Survivability of materials isn't the only engineering challenge in building a machine to last 10,000 years. Its meaning, function and maintenance features must be clear to anyone, even those from foreign (some might predict alien) cultures with only rudimentary understanding of late 20th-century Western technology. If, as with the Stonehenge megaliths, our civilization dies, the clock's meaning and function must still be understood transparently by future generations–unlike Stonehenge.



A three-dimensional rendering of the clock prototype.

"Stonehenge is evocative," says Brand, "but it's only evocative."

Clock-Design Principles

Starting with an observation and idea for the clock project, Hillis soon was able to articulate a set of design principles in discussion with other founding board members.

- ***Longevity.*** With occasional maintenance, the clock should reasonably be expected to display the correct time for the next 10,000 years.
- ***Maintainability.*** The clock should be maintainable with bronze-age technology.
- ***Transparency.*** It should be possible to determine operational principles of the clock by close inspection.
- ***Evolvability.*** It should be possible to improve the clock with time.
- ***Scalability.*** It should be possible to build working models of the clock from table-top to monumental size using the same design.

More specific rules also followed from these general design principles. To promote longevity, designers shied away from sliding friction (gears). To encourage maintainability and transparency, they decided to use familiar materials, to make it easy to build spare parts, and (most importantly) to include a manual of instructions. For scalability and evolvability, they proposed to similarly size all the parts, to separate functions and to make interfaces as simple as possible.

"We wanted the users to be able to access all the key parts. It's a skeleton clock: no case, no louvers or covers," says Rose.

Hillis' timepiece design has been described variously as a fusion of Renaissance design, space-age engineering and Bronze Age technology with the world's slowest computer. It's a mechanical computer that would make Charles Babbage, the 19th-century inventor, proud. Suspended on six columns, the prototype is driven by a torsional pendulum, a whirligig of three rotating 22-pound tungsten bobs suspended from a 1/4-inch wide double ribbon of flexible elinvar.

"Elinvar, as its name implies, has an elastic coefficient that is invariable over normal temperature changes," Rose explains. "That's ideal, since we're using this as a spring."

The pendulum signals when five circular, binary tracks (the adders that are the "chips" of the clock's computer) should turn. As the adders complete their allotted one revolution per hour, they reset moveable pins that can be programmed as ones and zeros. Each adder tracks a specific measure of time corresponding to one of the dials on the clockface. The clock's face displays the Gregorian calendar, the sun's position, moon phase (with the current star field in the middle) and the precession of the equinox (the axial wobble of the earth that occurs every 25,792 years).

The clock design has more than a passing resemblance to one of those glass-domed anniversary clocks popular as wedding gifts, because they can be wound once a year on the wedding anniversary. Originally designed to be powered by seasonal temperature changes, the current design calls for human winding, Brand writes, "because it fosters responsibility ... and invites people's involvement."

Once wound, power is delivered to the mechanical "bit-adder" computer via a pair of weights corkscrewing their way down matching drive towers that hug both sides of the clock. An innovative clock section called an escapement–adapted from a marine chronometer design but using a torsional pendulum instead of a balance wheel like a watch–impulses or feeds energy to the pendulum.

The clock is projected to be accurate to within one day every 20,000 years, but just in case it isn't, a solar synchronizer will correct the time shown on the clockface. A lens on top of the clock will advance or retard the display by phase-locking to the local noontime sun. The digital mechanical design also allows the clock to adjust for leap days, leap years, leap centuries–even for the precession of the equinox. (See sidebar: The Equation of Time.)

The Long Now Library

In 1995, the foundation's effort to build the clock grew to encompass a library project when board members decided to expand storage of clock-specific media into a repository for all kinds of information that would be useful over millennia, such as scientific studies or records of policy decisions with long-term envi-ronmental consequences.

Not surprisingly, library archivists soon ran into a series of problems that ought to be familiar to software developers. Any computer user who has tried to find software to translate WordPerfect 4.0 or MS Word 3.0 files already will be familiar with problems caused by the increasingly fast cycle of obsolescence in hardware and software. Incompatible file formats are just the tip of the iceberg of difficulties in both government and industry caused by electronic data proliferating across various platforms. Dectape and UNIVAC drives, which for years recorded huge amounts of government data, have vanished, as have software programs such as FORTRAN II.

"When you look at the first 20 years–from the '50s to the early '70s–of remote sensing data from NASA, we no longer have that information," says foundation director Rose. "They recorded data on giant mag tapes and used purpose-built readers that eventually got cycled out. When archaeologists asked to see the data, NASA ultimately rebuilt a reader, but they have no idea of what the data means, no organizational structure, no notes on organizational structure." Among the missing remote sensing data are some of the first photographs of Earth from space that helped energize a generation of environmental activists.

For this reason, Brand enumerates a set of emerging "best practices" in a chapter entitled "Ending the Digital Dark Age." To ensure digital continuity in long-term repositories such as the Long Now Library, Brand recommends that computer users use the most common file formats, avoid compression, keep a log of changes to a file, employ standard metadata and make multiple copies where possible.

The Long Now Library will store data using a technology called HD-Rosetta, developed at Lawrence Livermore Laboratories and commercialized by Norsam Technologies (www.norsam.com). HD-Rosetta preserves texts and images by microscopically etching them on two-inch nickel disks with an ion beam. Depending on location, the nickel disks have a shelf life of between 2,000 and 10,000 years. To call attention to the fact that a miniaturization process is going on, the etched text starts out at an eye-readable size and rapidly shrinks to nano scale, which future readers will be able to read with a microscope.

"The aim is to do more than flat storage; one of our goals is to create a cross-language translation key similar to the original Rosetta stone," says Jim Mason, Long Now staffer and Rosetta Disk Project Manager.

Who will Maintain It?

Even if the parts and mechanisms function as predicted and survive environmental and cultural onslaughts for centuries, who will maintain the clock and the library for the next 10 millennia? Both Rose and Brand point to the Shinto Shrine at Ise, Japan, which was originally built around A.D. 4 and reconstructed every 20 years or so, as an example of what historian Daniel Boorstin calls "an unbroken lineage of structure, records, and tradition." Likewise, Brand admires Big Ben as a state-of-the-art timepiece that is accurate to the second and "that, refitted every 250 years or so, should endure indefinitely as a symbol of British civilization." So far, the foundation has a hare-and-tortoise strategy of building the clock quickly and the library incrementally.

The library idea is still taking shape, primarily in the form of gatherings such as the 1999 Time and Bits conference, sponsored by The Long Now Foundation and the Getty Conservation and Information Institutes (www.ahip.getty.edu/timeandbits). The meeting focused on future uses of digital technologies and problems caused by the obsolescence of data formats and platforms. Another 10,000-year library conference is scheduled to be held at Stanford University on June 30, 2000.

The overall goal of the Long Now Clock and Library project is to transform our idea of time–to shift our view from next week or next year and immediate profit or short-term goals toward the perspective of tens of thousands of years.

"It's not a business model," says Brand. "It's a long-term (cultural) success model. The project is intended to serve as an antidote to Millennium Fever, an antidote to the short-sightedness of thinking that lead to the Y2K crisis."

Hillis and the others are as concerned about the Y10K problem as they are about Y2K. In some of his original design work, Hillis used a Microsoft Excel spreadsheet to predict which clock dials would get indexed at what times. He soon found that Excel wasn't Y10K-compliant–he was not able to format the date function past the year 9,999. Although he eventually solved his problem by rewriting the equations in LISP, Hillis, Rose, Brand and the others have made a conscious decision to write the date as 02000 as a way of getting the jump on the Y10K problem inherent in their endeavor.

Visiting the Monument

Rose's successful petition to the U.S. Internal Revenue Service to get 501(c)-3 public education nonprofit status for the Long Now Foundation includes a version of the following story–describing what a visitor to the desert clock and library would see and experience.

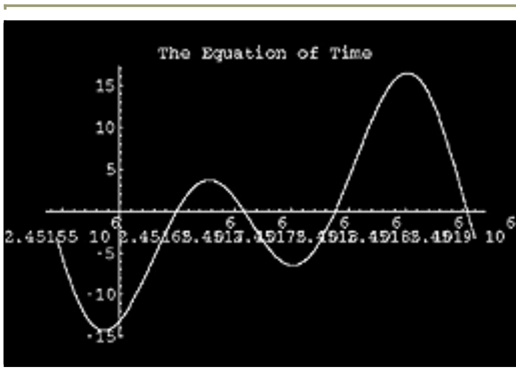
"You arrive at a flat knoll where you see a cave ahead," Rose writes. "Peering into the cave, you gradually make out a giant pendulum swinging back and forth, one pass every 10 seconds. You proceed into the cave and realize you are actually within the clock mechanism itself. Climbing up a spiral staircase, you come to the fastest of the mechanical calculation devices, which ticks once per day. You climb up flight after flight through slower and slower mechanisms until you arrive at the last one, which records the procession of the equinoxes with a 25,784-year cycle. When you reach the top of the stairs you are in a huge dimly lit room several stories high that, at midday, is brightly lit by the sun coming directly in line with a slit in the wall."

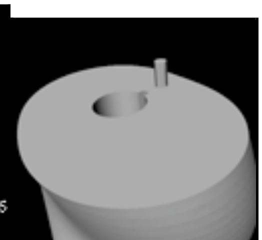
"Emerging from the cave," Rose adds, "you will be able to reflect on your underground experience among the sheer limestone cliffs and bristlecone pines that have been part of the high desert site since time immemorial."

"The clock began for me as a story, and gradually it became real," says Hillis, describing his inspiration for building a millennial clock. "In some sense, we've run out our story, which was the story of taking power over nature. It's not that we've finished that, but we've gotten ahead of ourselves, and we don't know the next story after that."

"The clock is a way of bridging between stories, embodying respect for the full span of the old story and confidence in the gradual emergence of a new story," Brand explains. "It is a transition-managing device. In a world of hurry, the clock is a patience machine."

The Equation of Time





Cylindrical Mathematica plot of equation of time, converted into a CAD object.
< Equation of Time plotted past the year 2000.

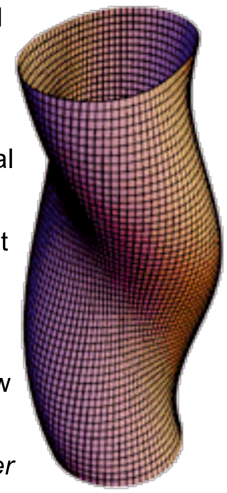
Slow down and take a long look at a far, far-reaching future. That's the message brought to you by the Clock of the Long Now. It's true. We are moving far too fast.

Communications, machines, vehicles, our heart rates–everything is in hypermotion. As a result, we're living more and more in the short term, not taking the time to gaze upon the far-reaching expanses of a much larger picture: The planet we will leave our children and their descendants centuries from now.

In an age when computers can process billions of decisions in split seconds, the Clock of the Long Now may be the slowest-moving computer ever made. It uses precise mathematical models to keep local, absolute and astronomical time over a span of 10,000 years. Danny Hillis's original design called for a clock that ticked once a year, bonged once a century–and a cuckoo that would come out once a millennium. Any slower than that, and you're in permanent suspended animation.

The clock uses an ingenious binary digital-mechanical system that is precise to one day in 20,000 years. It uses the equation of time to convert local solar time into absolute time, and it accounts precisely for the elliptical eccentricities in the orbit of the Earth.

When the equation of time is plotted past the year 2000, the graph looks like the one at the top left. The local maxima and minima are aspects of the graph that shift with the precession of the equinox over a period of about 26,000 years.



The graphic to the right shows the equation of time as computed in Mathematica and wrapped onto a cylinder. The rotational range is one year; the axial range is Gregorian year 1500 through 12,500.

In the top right graphic, the cylindrical Mathematica plot of the equation of time is converted into a CAD object (by Stewart Dickson) for output using a three-dimensional Rapid Prototyping printer.

The CAD output is the model for a mechanical cam that will resynchronize the clock at local solar noon via a thermal trigger. The beautifully formed part was cast at the Crucible, a company in Oakland, Calif. specializing in out-of-the-ordinary casting jobs.

The Clock of the Long Now is an ingenious idea. But more than anything else, it is a reminder for civilization to step back and take a much longer, more contemplative view of life on Planet Earth.

–Chris Preimesberger

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