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The Magic Clock

By Sean Roberts, December 01998, The New Scientist Magazine

*Once upon a time there
was a great big clock that
had been ticking for thousands
and thousands of years.
One day . . . .*

"IT IS THE world's slowest computer. It's also the first computer that is year 10 000 compliant," quips Stewart Brand. He's not talking about a desktop PC -- nothing remotely electronic, in fact. As chairman of the Long Now Foundation, a non-profit organisation based in San Francisco, Brand is referring to the Millennium Clock -- a clockwork device as big as a good-sized building that will keep time for the next 10 000 years.

The clock is the brainchild of Danny Hillis, a computer scientist and engineer who invented the massively parallel architecture of today's supercomputers. As one of the founding members of the Long Now Foundation, Hillis talked about the clock at the Massachusetts Institute of Technology in Cambridge, last month. Hillis is designing the clock to survive not only the ravages of time but nuclear winters, earthquakes -- even the collapse of civilisation itself. It's a demanding brief. The clock must operate in a way that will allow anyone to decipher it, even if they know nothing about it and have never seen it before. It will have to be easy to maintain. And repairs must be possible with tools that are no more advanced than those in use during the Bronze Age. Hillis argues that these skills are more likely to survive into the distant future than those developed more recently. "Semiconductor technology could be a lost art in 100 years," he says.

The idea--and the reason behind the Long Now Foundation's existence -- is to promote the concept of long-term responsibility by encouraging people to think not in terms of hours, days or years but on a timescale of thousands of years. If all goes to plan, the foundation hopes to have the Millennium Clock complete by the end of 2001. A prototype should be completed early next year.

In essence, a clock is a simple device made up of four basic components. First, it needs something that performs a regular movement in a fixed time interval. This can be a swinging pendulum, a vibrating atom or simply the passage of the Sun across the sky.

Next, it must have a counting device that records the number of these movements -- teeth on a cog, the frequency of infrared light that excites an atom or even a human counting the number of times he or she turns an hourglass. This counting device is usually linked to a display such as the hands of a clock or figures on a computer screen. Finally, clocks need a source of power whether from mechanical winding, chemical battery power or some other source.

The Millennium Clock has all these components. The problem is to ensure they will be able to survive for the clock's projected hundred-century life span. The need for an open design means that dirt is certain to get into the works. Even small amounts of dust and grit can dramatically change friction in most mechanisms. However, there will be no lubrication. "We simply assumed the friction was going to be large and designed around it," says Hillis. Though the clock will be large, most of its components will move slowly over short distances. This will inevitably lead to some erosion, but again the clock's size comes to the rescue--it won't matter if friction erodes large parts by a millimetre or so over 10 000 years, says Hillis.

The timing device in this clock will be a torsion pendulum -- one that rotates rather than swings. Made of tungsten, a metal that is 70 per cent denser than lead, it will weigh 100 kilograms and hang from a 5-metre spring. The weight will rotate through 350 degrees and back again once every minute.

Ensuring that the pendulum has a highly consistent period is another challenge. Just as changes in the length of a swinging pendulum modify its period, changes in the elasticity of the spring in a torsion pendulum have a similar unwanted effect. The elasticity of most materials depends on their temperature, a factor that Hillis will not be able to control over the lifetime of the clock. So he will make the spring out of elinvar, an alloy of iron and nickel with an elasticity that is stable over a large temperature range.

But even elinvar cannot make a torsion pendulum consistent enough to keep time for 10 000 years. So Hillis plans to incorporate a mechanism for synchronising the clock with the Sun. The idea is to catch the Sun's rays at exactly midday every day and focus them onto a metallic plate that will expand and bend. The bending motion will adjust a cog inside the clock, rather like nudging the hands of a conventional clock towards noon.

Counting the cycles of the pendulum will be relatively straightforward. The device that links a pendulum to the rest of a clock, known as the escapement, serves two purposes. It converts the back-and-forth motion of the pendulum into a step-like motion in one direction. And it gives the pendulum the regular push it needs to keep going. In the Millennium Clock, the escapement will drive a series of cogs that convert the 1-minute period of the pendulum into a 12-hour cycle. The final 12-hour wheel is the one that will be nudged back into place by the solar synchroniser at noon each sunny day.

More difficult is converting the 12-hour period of the clock into an accurate display of months, years and seasons. The conversion is straightforward when one period is a whole-number ratio of another. For instance, when minutes have to be converted to hours, a simple arrangement of cogs does the trick. But a solar year is equal to 365·242189 days and designing a set of cogs that represent this ratio is impractical. "Clocks usually end up approximating but this won't work over 10 000 years," explains Hillis.

Digital design

So he is getting rid of cogs entirely and intends to calculate the time and date using a mechanical digital computer similar to the first mechanical computer designed by a mathematician called Charles Babbage more than 100 years ago. Known as the bit serial mechanical adder, the computer consists of a thousand levers that can be flipped back and forth to represent the 0s and 1s of a digital code. Every 12 hours, the clock will feed one bit of information to the computer, which will use it to update its calculations of the day, month, year, the season and the phases of the Moon. It will even take into account the precession of the Earth's axis: this has a period of 26 000 years and so is significant over a period of 10 000 years.

The final component of the clock is its power source. "It would have been very easy to make the clock automatic, by using temperature changes to wind it, for example," says Hillis. But instead, it will have to be wound every year. "Institutions don't survive without people," he explains. The clock will have to be cleaned, maintained and possibly even repaired. To this end, all the parts of the clock will be replaceable using skills that have been around for thousands of years -- sand casting with bronze and perhaps some hammering. "We will also leave some spare parts," he adds.

The next task for Hillis and his colleagues is to find a site for the Millennium Clock. "We have lots of ideas for places but we're still looking for suggestions." The foundation has already considered Egypt, Jerusalem and China as well as the peak of a 3000-metre mountain in Nevada. "That would make visiting the clock a kind of pilgrimage which is an interesting idea," Hillis says.

Will people want to make such a pilgrimage? "You never know until you do it," laughs Brand. "If it works, it becomes a kind of talisman for the long view, which means a responsible perspective on things." But above all, Brand believes the Millennium Clock will provide a source of inspiration for future generations. "It should give you a personal sense of: Wow! 10 000 years right there."