# Press Coverage



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## Rethinking Machines
**by Tom Standage**

## Danny Hillis, a computing pioneer and the inventor of the 10,000-Year Clock, has a distinctive perspective on the relationship between humanity and technology

THERE are probably a few dozen people alive today who can claim to have designed a machine that, for a few weeks or months, was the fastest computer in the world. But Danny Hillis is unique among them in also being able to claim to have designed the slowest. For he is the man behind both the blindingly fast "Connection Machine" computers and the "10,000-Year Clock", a binary-mechanical computer that ticks twice a day and chimes once a century. To describe Mr Hillis as an inventor, or a computer scientist, hardly does justice to his unusually philosophical attitude towards technology. Perhaps the best way to describe him is as a "metatechnologist"--someone who thinks about machines that change the way people think about machines.

Mr Hillis first came to prominence in the 1980s as a pioneer of a computing technique called "massively parallel" processing, the subject of his thesis at the Massachusetts Institute of Technology. At the time, computer scientists were struggling with the problem of getting computers to go faster, not by increasing the speed of their processing units, but by using two or more processors in parallel. The difficulty comes in dividing up the work between the processors in an efficient manner. Most researchers in the field believed that there was a limit to the speed increases possible through parallel processing, because there would always be parts of a problem that could not be divided up. A few parallel-processing computers existed, typically with between two and eight processors. So Mr Hillis was, to say the least, going out on a limb when he proposed the construction of a computer with 65,536 processors connected in a 12-dimensional "hypercube".

At first his suggestion was not taken seriously, but Mr Hillis and others showed that such a machine was, in fact, feasible. This involved devising an efficient way for thousands of processors to communicate with each other, along with new programming tricks that allowed common problems to be divided up between multiple processors--and solved more quickly as a result. In 1983, Mr Hillis established a company, Thinking Machines, to commercialise his idea, and in 1985 it built its first product: the Connection Machine Model 1, or CM-1. An imposing black cube, measuring five feet on each side and adorned with thousands of flashing red lights, this showed that Mr Hillis's apparently hare-brained idea--"massive" parallelism--actually worked.

The Connection Machine, with its thousands of simple processors, was explicitly modelled on the human brain, which consists of 100 billion or so very simple neurons. It was in marked contrast to other supercomputers, such as those built by Cray, the market leader, which had one or two extremely complex and powerful processors. Mr Hillis hoped his design would be better suited to those tasks, such as facial recognition, that humans find easy and computers find hard. But it turned out that the "killer app" for the Connection Machine was not artificial intelligence, but scientific modelling. Richard Feynman, a Nobel-prize winning physicist, worked at Thinking Machines in its early days and realised that massively parallel machines were ideal for modelling processes in areas such as fluid dynamics, particle physics and astronomy. This insight led to the CM-2, which had an extra 2,048 processors to handle floating-point arithmetic and could thus do complex scientific calculations better.

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Thinking Machines' customers included the Los Alamos National Laboratory, American Express and America's space agency, NASA. The hardware design was refined with the CM-5, and Mr Hillis even drew up plans for a Connection Machine with a mind-boggling 1m processors. His company also pioneered the idea of redundant disk storage arrays, in which a large number of hard disks are combined to form a huge storage system. But as the idea of massive parallelism took hold, the practice of building supercomputers by combining a large number of standard microprocessors became commonplace. Mr Hillis left Thinking Machines in 1994; the firm's hardware business was eventually bought by Sun Microsystems, and its software business, which specialised in data analysis, was acquired by Oracle. In a sense, by showing that massive parallelism was feasible, the company helped to put itself out of business. As if to prove Mr Hillis's point, IBM is now building a massively parallel supercomputer, Blue Gene, which will combine over 1m processors to form the most powerful computer ever built.

The experience of working with scientists in a diverse range of specialised fields had a strong impact on Mr Hillis. He saw that the trend towards increasing specialisation meant that researchers in different fields were often unaware of what others were doing. Or, as he characteristically puts it, "all of this getting smarter is making us dumber." And trying to stay ahead of the fast-changing computer industry, he found, resulted in a very short-term perspective on the future. Mr Hillis started to think about a deliberately long-term project he could work on--something that, like a medieval cathedral, would not be completed within the lifetime of anyone present at its start. Prompted by the pre-millennial euphoria of the 1990s, Mr Hillis had the idea of a clock that would run for 10,000 years.

Most of the people he mentioned it to thought it sounded crazy. His friends and colleagues wondered why such an obviously talented engineer should waste his time on such an apparently whimsical project. But Mr Hillis's idea struck a chord with some people. It made engineers start to think about how such a clock could be constructed; lawyers and financiers began to wonder how to establish an institution that could survive for such a long time (a religion, perhaps?); meteorologists tried to imagine the weather 10,000 years hence, far beyond even the centuries-long forecasts of global warming. In short, the idea of the clock made tangible the concept of the far future, of "deep time", and thus offered an antidote to technological short-termism.

As with the Connection Machine, Mr Hillis is really interested in the idea behind the clock, rather than the actual hardware. But, as with his massively parallel computers, he knew his clock idea would only be taken seriously if he actually built it. So, encouraged by a handful of like-minded friends, he set to work. He decided that the clock's design had to conform to a set of general principles: longevity, transparency, maintainability and scalability. Longevity goes without saying; transparency means workings that can be understood by inspection; maintainability means using nothing that would be beyond a bronze-age culture; scalability means a design that can work on scales from the table-top to the monumental. Longevity precludes the use of gears, which can wear, while maintainability and transparency rule out the use of electronics or atomic power. Tidal and geothermal power might work for a very large clock, but not for a small one.

Eventually Mr Hillis opted for a design that is both mechanical and, appropriately given his background, digital. Called the "bit serial mechanical adder", it uses sets of 28 movable levers, each of which can be in one of two positions, to store 28-digit binary numbers. Each set of levers is called an accumulator; the "year" accumulator stores the fraction of a year that has elapsed. Twice a day, when the clock "ticks", an ingenious mechanism adds a fixed value to each accumulator. After a year has passed, the value stored in the year accumulator overflows, the clock's display of concentric rotating rings is updated, and the left-over fraction is stored, so there are no rounding errors.

The first prototype of the clock, eight feet tall, was completed in 1999 and is now ticking in the Science Museum in London. Mr Hillis has since started work on a second, larger prototype. And last year the Long Now Foundation, a non-profit organisation established to promote projects with a 10,000-year perspective and funded by Silicon Valley millionaires, bought a mountain in Nevada where the full-scale clock will be installed. The mountain has a good deep-time pedigree, since it is home to some of the oldest living things on earth: 5,000-year-old bristlecone pine trees. Meanwhile, the foundation is working on other projects, including the Rosetta Disc, which will use semiconductor etching techniques to etch the same text in 1,000 languages on to a three-inch metal disc. The idea is to manufacture many such discs and sprinkle them around the world, to assist archaeologists of the far future in deciphering lost languages.

## THE HUMAN TOUCH

The common theme in all of Mr Hillis's activities is the relationship between humans and machines. The brain-like Connection Machine is an example of technology informed by humanity; the 10,000-Year Clock and the Rosetta Disc use technology to encourage the contemplation of humanity's far future. Between 1997 and 2000, Mr Hillis pursued these ideas alongside his day job as a research fellow at Walt Disney Imagineering, where his brief was essentially to have interesting ideas. He has recently parted company with Disney and is now setting up a new firm, called Applied Minds, in conjunction with Bran Ferren, his former boss at Disney, and Doug Carlston, the co-founder of Broderbund, an educational software firm. Mr Hillis is secretive about his new firm's activities, other than to hint that they may involve acting as an "idea factory" developing ideas for subsequent licensing to others, and might relate to educational computing. "We are educating people today in the same way as we did when there was 1% as much knowledge," he points out. Industrialisation extended humans' physical capabilities, he suggests, but computers have yet to extend their intellectual capabilities.

Evidently the new idea factory will not be short of raw material. But among Mr Hillis's many theories and speculations, perhaps the most provocative concerns the limits of engineering. He suggests that as technology becomes more complex, from operating systems to airliners, the pitfalls of engineering are becoming apparent. Engineered systems are brittle, frail, and liable to fail in
unexpected ways; Mr Hillis says he is surprised that the engineering approach still works. Some day, he speculates, complex systems, from artificial minds to spacecraft, may be constructed using self-organising components that are guided in ways like gardening. In which case all bets about future technology, which tend to be based on extrapolations of engineering, will be off. It sounds crazy. But, not so long ago, so did the idea of a computer with 1m processors.


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