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THE THIRD CULTURE

"SPECIAL RELATIVITY: WHY CANT YOU GO FASTER THAN LIGHT?"
W. Daniel Hillis

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EDGE IN THE NEWS

Wired News, ABCNEWS.COM, FEED, Salon, Newsweek, Wall Street Journal, Daily Telegraph, DaveNet on "What Is The Most Important Invention In The Past Two Thousand Years"

(4,644 words)

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THE THIRD CULTURE

"SPECIAL RELATIVITY: WHY CANT YOU GO FASTER THAN LIGHT?"
W. Daniel Hillis

Introduction by
John Brockman

Danny Hillis is one of the most inventive people I've ever met, and one of the deepest thinkers. He's contributed many important ideas to computer science ‹ especially, but not exclusively, in the domain of parallel computation. He's taken many algorithms that people believed could run only on serial machines and found new ways to make them run in parallel ‹ and therefore much faster. Whenever he gets a new idea, he soon sees ways to test it, to build machines that exploit it, and to discover new mathematical ways to prove things about it. After doing wonderful things in computer science, he got interested in evolution, and I think he's now on the road to becoming one of our major evolutionary theorists.

— Marvin Minsky

Danny Hillis, physicist and computer scientist, brings together, in full circle, many of the ideas circulating among third culture thinkers: Marvin Minsky's society of mind; Christopher G. Langton's artificial life; Richard Dawkins' gene's-eye view; the plectics practiced at Santa Fe. Hillis developed the algorithms that made possible the massively parallel computer. He began in physics and then went into computer science — where he revolutionized the field — and he brought his algorithms to bear on the study of evolution. He sees the autocatalytic effect of fast computers, which lets us design better and faster computers faster, as analogous to the evolution of intelligence. At MIT in the late seventies, Hillis built his "connection machine," a computer that makes use of integrated circuits and, in its parallel operations, closely reflects the workings of the human mind. In 1983, he spun off a computer company called Thinking Machines, which set out to build the world's fastest supercomputer by utilizing parallel architecture.

The massively parallel computational model is critical to an understanding of today's revolution in human communication. Hillis's computers, which are fast enough to simulate the process of evolution itself, have shown that programs of random instructions can, by competing, produce new generations of programs — an approach that may well lead to the first machine that truly "thinks." Hillis's work demonstrates that when systems are not engineered but instead allowed to evolve — to build themselves — then the resultant whole is greater than the sum of its parts. Simple entities working together produce some complex thing that transcends them; the implications for biology, engineering, and physics are enormous. following introduction:

So why is Danny Hillis working for Disney today? Well, the founder of Thinking Machines Corporation and the innovative designer of the massively parallel "connection machine," used to drive to work in a fire engine and was once a toy designer for Milton Bradley. In college, he became interested in building a computer out of anything. As a demonstration, he and some friends built the Tinkertoy computer, which was comprised of 10,000 Tinkertoys and could play tick-tack-toe. His interest in building gadgets and games was, to some degree, influenced by his friend, the late physicist Richard Feynman, who would leave Caltech in the summer to go to Cambridge to work for Danny at Thinking Machines.

Part of Danny's charm is his childlike curiosity and demeanor. The first time we talked was on the telephone one Sunday morning in 1988 when he was at his home in Cambridge. We got into a serious discussion about the relationship of physics to computation. "This is interesting," he said. "I'd like to come to New York and continue the conversation face-to-face." Three hours later, my doorbell rang, and there stood a young man, looking like a clean-cut hippie. He had long hair, wore a plain white T-shirt and jeans, and carried nothing. We talked for hours.

I later returned the visit. This was a different side of Danny. He lived with his family in a huge old house off Brattle Street. The domestic scene I encountered included a bunch of babies, two au pairs (a blonde from France and a brunette from Argentina), a dog, and a houseful of interesting guests — all presided over by Danny and his wife, Patty. I sat in the living room with Danny and evolutionary biologist Stephen Jay Gould as they discussed the effect of massively parallel computers on evolutionary theory; meanwhile, Danny's mentor, computer scientist Marvin Minsky, played Mozart sonatas on the grand piano in the adjacent room.

Danny's energies have concentrated on getting processors to work together so that computation takes place with communicating processors, as happens with the Internet. The Net's potential to become an organism of intelligent agents interacting with each other, with an intelligence of its own that goes beyond the intelligence of the individual agents fires Danny up. "In a sense," he says, "the Net can become smarter than any of the individual people on the Net or sites on the Net. Parallel processing is the way that kind of emergent phenomenon can happen.

The Net right now is only a glimmer of that." Danny describes the Internet of today simply as a huge document that is stored in a lot of different places and that can be modified by many people at once, but essentially a document in the old sense of the word. In principle, the Internet could be done on paper, but the logistics are much better handled with the computer. "I am interested in the step beyond that," he says, "where what is going on is not just a passive document, but an active computation, where people are using the Net to think of new things that they couldn't think of as individuals, where the Net thinks of new things that the individuals on the Net couldn't think of."

Danny asks questions like What are the limits to what computers can do? Can they think? Do they learn? His intellectual range is startling. Unlike many other people engaged in the world of computing, he does not limit himself to any particular group of colleagues. Some of his biggest fans are among the brightest people on the planet. Marvin Minsky says "Danny Hillis is one of the most inventive people I've ever met, and one of the deepest thinkers." Philosopher Daniel C. Dennett says, "what Danny did was to create if not the first then one of the first really practical, really massive, parallel computers. It precipitated a gold rush."

Physicist and Nobel laureate Murray Gell-Mann notes that "he's not only a daring person, which we know, but also a deep thinker — and a very effective one.

JB

W. DANIEL (DANNY) HILLIS, a physicist and computer scientist, was named the first Disney Fellow becoming vice president of research and development at The Walt Disney Company in early 1996. He is also an Adjunct Professor of MIT at the Media Laboratory, and co-chairman of the board of directors of The Long Now Foundation which seeks to promote "slower/better" thinking and to focus our collective creativity on the next 10,000 years. He is the author of a new book, *The Pattern on the Stone: The Simple Ideas That Make Computers Work* (Science Masters Series).

See EDGE: "The Clock of the Long Now — a Talk with Stewart Brand"; *The Third Culture*, Chapter 23; *Digerati*, Chapter 11.

The Essay...

"SPECIAL RELATIVITY: WHY CANT YOU GO FASTER THAN LIGHT?"
W. Daniel Hillis

You've probably heard that nothing can go faster than the speed of light, but have you ever wondered how this rule gets enforced? What happens when you're cruising along in your spaceship and you go faster and faster and faster until you hit the light barrier? Do the dilithium crystals that power your engine suddenly melt down? Do you vanish from the known universe? Do you go backward in time? The correct answer is none of the above. Don't feel bad if you don't know it; no one in the world knew it until Albert Einstein worked it out.

The easiest way to understand Einstein's explanation understand the simple equation that you have probably seen before: $e = mc^2$. In order to understand this equation, let's consider a similar equation, one for converting between square inches and square feet. If i is the number of square inches and f is the number of square feet, then we can write the equation: $I = 144 f$. The 144 comes from squaring the number of inches per foot ($12^2 = 144$). writing the same equation would be $i = c^2 f$, where c in this case is equal to 12 inches per foot. Depending on what units we use, this equation can be used to convert any measure of area to any other measure of area; just the constant c will be different. For example, the same equation can be used for converting square yards to square meters, where c is 0.9144, the number of yards per meter. The c^2 is just the conversion constant.

The reason why these area equations work is that square feet and square inches are different ways of measuring the same thing, namely area. What Einstein realized, to everyone one's surprise, was that energy and mass are also just two different ways of measuring the same thing. It turns out that just a little bit of mass is equal to a whole lot of energy, so in the equation, the conversion constant is very large. For example, if we measure mass in kilograms and energy in joules, the equation can be written like this: $e = 90{,}000{,}000{,}000{,}000{,}000\ m$. This means, for example, that a charged-up battery (which contains about one million joules of energy) weighs about 0.0000000001 grams more than a battery that has been discharged.

If we work with different units, the conversion constant will be different. For instance, if we measure mass in tons, and energy in BTUs, then c will be 93,856,000,000,000,000. (It happens to work out that the conversion constant in a particular set of units is always the speed of light in those units, but that is another story.) If we measure both energy and mass in what physicists call "the natural units" (in which $c = 1$), we would write the equation: $e = m$, which makes it easier to understand; it just means that energy and mass are the same thing.

It doesn't matter whether the energy is electrical energy, chemical energy, or even atomic energy. It all weighs the same amount per unit of energy. In fact, the equation even works with something physicists called "kinetic" energy, that is, the energy something has when it is moving. For example, when I throw a baseball, I put energy into the baseball by pushing it with my arm. According to Einstein's equation, the baseball actually gets heavier when I throw it. (A physicist might get picky here and distinguish between something getting heavier and something gaining mass, but I'm not going to try. The point is that the ball becomes harder to throw.) The faster I throw the baseball, the heavier it gets. Using Einstein's equation, $e = mc^2$, I calculate that if I could throw a baseball one hundred miles an hour (which I can't, but a good pitcher can), then the baseball actually gets heavier by 0.000000000002 grams — which is not much.

Now, let's go back to your starship. Let's assume that your engines are powered by tapping into some external energy source, so you don't have to worry about carrying fuel. As you get going faster and faster in your starship, you are putting more and more energy into the ship by speeding it up, so the ship keeps getting heavier. (Again, I should really be saying "massier" not "heavier" since there is no gravity in space.) By the time you reach 90 percent of the speed of light, the ship has so much energy in it that it actually has about twice the mass as the ship has at rest. It gets harder and harder to propel with the engines, because it's so heavy. As you get closer to the speed of light, you begin to get diminishing returns — the more energy the ship has, the heavier it gets, so the more energy that must be put into it to speed it up just a little bit, the heavier it gets, and so on.

The effect is even worse than you might think because of what is going on inside the ship. After all, everything inside the ship, including you, is speeding up, getting more and more energy, and getting heavier and heavier. In fact, you and all the machines on the ship are getting pretty sluggish. Your watch, for instance, which used to weigh about half an ounce, now weighs about forty tons. And the spring inside your watch really hasn't gotten any stronger, so the watch has slowed way down so that it only ticks once an hour. Not only has your watch slowed down, but the biological clock inside your head has also slowed down. You don't notice this because your neurons are getting heavier, and your thoughts are slowed down by exactly the same amount as the watch. As far as you are concerned, your watch is just ticking along at the same rate as before. (Physicists call this "relativistic time contraction.") The other thing that is slowed down is all of the machinery that is powering your engines (the dilithium crystals are getting heavier and slower, too). So your ship is getting heavier, your engines are getting sluggish, and the closer you get to the speed of light, the worse it gets. It just gets harder and harder and harder, and no matter how hard you try, you just can't quite get over the light barrier. And that's why you can't go faster than the speed of light.

(Excerpted from *How Things Are: A Science Tool-Kit for the Mind*, edited by John Brockman & Katinka Matson. William Morrow, 1996).

"WHAT IS THE MOST IMPORTANT INVENTION IN THE PAST TWO THOUSAND YEARS? "

John Barrow, Todd Siler, Peter Tallack, Brian Goodwin

John Barrow:

John, The most important invention is the Indo-Arab counting system with 0,1,2,3,4,5,6,7,8,9 with its positional information content (so 111 means one hundred plus one ten plus one unit), zero symbol, and operator property that by adding a zero to the righthand end of a string multiplies the number by the base value of 10. This system of counting and enumeration is completely universal and lies at the foundation of all quantitative science, economics, and mathematics.

JOHN BARROW is is Professor of Astronomy at the University of Sussex, England. He is the author of *The World Within the World*, *Pi in the Sky*, *Theories of Everything*, *The Origins of the Universe* (Science Masters Series), *The Left Hand of Creation*, *The Artful Universe*, and *Impossibility: The Limits of Science and the Science of Limits.*

Todd Siler:

To avoid incurring the wrath of some scholars, I wanted to add this parenthetical note (see asterisk below) to my statement about language. Hopefully, it clarifies my point a little; or, at least, focuses it.

My first candidate is "language"; specifically, our initial realization* of its creative potential, building on the intuitions of the ancient Greeks and Romans. Language is the life-force and body of communica- tion. It comprises all forms of symbolic creations, expressions and systems which we use to communicate: from the mathematical to the vernacular. Without language, every other invention and innovation may never have existed -- including humor!

My close-second candidate is E = mc2. When we learn to tap the full meaning of that piece of symbolic language, we'll create more than a Nuclear Age. "Matter is frozen energy," Einstein said, relating the essence of his insight into the mass-energy relationship. Similarly, language is frozen meaning. When we discover how to unleash the enormous energy in meaning by continually transforming information (data, ideas, knowledge, experience) in new contexts, we'll make a quantum leap in applying the power of language to achieve our boldest dreams.

* Note: Some people may choose to date our first deep realization of language's potential around the late 1700's. That's when the first scientific study of the nature and origins of language began to unfold through the systematic, comparative studies of the German scholars Friedrich Schlegel, Jakob Grimm, and Franz Bopp. Others may focus on the work of Ferdinand de Saussure whose general, descriptive method led to some basic laws that relate to all languages (about 3,000 or more now). My broad statement is meant to embrace the "makeup" of language: its symbolic nature, structures, semantics, and boundless usages. I'm not simply referring to the inventive act of classifying spoken and written languages into families, or categorizing the growth patterns of language, or charting the evolution of grammar.

TODD SILER is the founder and director of Psi-Phi Communications, a company that provides catalysts for breakthroughs & innovation in business and education. He is the author of *Breaking the Mind Barrier* and *Think Like A Genius*.

Peter Tallack:

The horse collar as the most important high-tech invention.

Developed around 1000 AD in northern Europe, it allowed the region to be farmed efficiently and so, it could be argued, was responsible for the rise of civilization there. It also gave its possessors great war-making potential — think of knights in armour, for example.

PETER TALLACK, former book editor of *Nature*, is science editor of Weidenfeld & Nicholson, London.

Brian Goodwin:

The most important invention in the past two thousand years is the printing press. When William Caxton published 'The Canterbury Tales' in the 15th Century with his newly invented printing machine, he dramatically accelerated the separation of human culture from nature, eclipsing the direct experience of natural processes that continues in the oral tradition and replacing it by words on a page. This cut in two directions. (1) The power of nature diminished so that science and technology could start the systematic program of gaining knowledge for control of nature, liberating people from drudgery and freeing the imagination. (2) At the same time, nature was degraded to a set of mechanisms that humans could manipulate for their own purposes, and the 'rape of nature' began in earnest. We are now reaping twin harvests: vastly expanded potential for written communication through the internet, as in this exchange of views at the Edge web site; and a vastly degraded planet that won't support us much longer, as things are going. Can we use one to save us from the other? We can now connect with each other as never before; but what about nature?

BRIAN GOODWIN Brian Goodwin is a professor of biology at the Schumacher College, Milton Keynes, and the author of *Temporal Organization in Cells and Analytical Physiology, How The Leopard Changed Its Spots: The Evolution of Complexity*, and (with Gerry Webster) *Form and Transformation: Generative and Relational Principles in Biology*. Dr. Goodwin is a member of the Board of Directors of the Sante Fe Institute. See EDGE: A New Science of Qualities; The Third Culture, Chapter 4.

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