George Group is already working with Hill's Pet Nutrition to begin mass deployment of micro-produced dog food in Europe.

If mass customization is the future, why aren't more people doing it yet?

Two reasons. The first is technical. Only in the last five years have chips become powerful enough, small enough and cheap enough to do many of the tasks demanded by mass customization. You don't want to put a $500 Pentium in a lightbulb to help it conserve power. But the same Pentium five years from now will cost about 10 bucks, and five years after that, 10 cents. And when the brain of the most powerful PC becomes less expensive than shoestrings, imagine the possibilities. Conversely, the new $500 microprocessor of a decade from now will have all the power of today's Cray supercomputer: animation, modeling, speech recognition, pattern recognition, etc. Just imagine what you can do with one of those wired into one of your factory robots.

Indeed, use your imagination. Failing to do so is the second reason limiting the general acceptance of mass customization. Despite Wilkie's dictum, few manufacturers or service providers can yet imagine the reality of mass customization and how quickly the little chip will get us there. But it will. And some of those companies may be your current or (dropping in seemingly from nowhere) your future competitors. Often, the first *to* market will quickly *own* that market, leaving room for perhaps one more competitor. So the real question to ask yourself is: Will my company be one of those two that survive?

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RULE NO. 3: RIDE THE SILICON LEARNING CURVE

This third and final rule is embodied in the first two. If you fully understand the power of the semiconductor chip, then you know the chip is not a one-time implementation, but a process that must become a continuous part of running your business. The bad news is that since the ENIAC computer of 1946, the efficiency of information technology, especially at the chip level, has jumped by 32 orders of magnitude—that's 100,000,000,000,000,000,000,000,000,000,000, or about 100 octillion times—not only the greatest single improvement in productivity in human history, but a leap to the very limits of human experience with the universe. And that is how big of an opportunity you've already missed.

But the good news is that most estimates put us only halfway through the advances of the chip. The greatest are yet to come. So, though you may have missed one universe of opportunities, it is not too late to get on board for the next one. The Chip Revolution has only just begun.

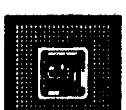
JUST WHAT IS A CHIP? AT THE CORE is a switch, an idea that stretches back to the first wooden gates on corrals and herding pens. A gate has a binary function: Open it and animals pass through; close it and they cannot. Translate this to a mechanical system—say a lock or a railroad track—and you have a mechanism that was known to the Romans: a mechanical switch. Run electricity through it and you have that ubiquitous mechanism of modern life, the wall light switch.

PENTIUM AT A GLANCE

❑ Estimated total cost to produce the Pentium: roughly $1.5 billion.

❑ Approximate cost for design and development: $200 million.
Time spent: three years.

❑ Cost to build fabrication plants used to manufacture the Pentium: $1 billion to $1.5 billion each; 75% of the cost is for equipment.



❑ Average cost to produce a Pentium processor: approximately $50. Average price of the Pentium: $300.

❑ Number of Pentium chips produced in 1995: 32 million.
The Pentium was developed more quickly than any other generation of Intel microprocessor. Also, it took less time to reach a million units shipped than any other generation—it happened within the first year. (It usually takes at least a year and a half or longer.)

❑ Fab plants designed to produce the Pentium can be used in that capacity for only about two years. By that time, the equipment is outdated and the fab has been completely amortized. To get its money's worth, Intel has to run the plant 24 hours a day, seven days a week. Employees work shifts of four days on, three days off, which switches every other week to three days on, four days off. Older fab plants are used to manufacture less-complicated chips such as flash memory or 16-bit microprocessors.

An estimated $20 of the $50 spent to produce each chip goes into engineering and design; $20 goes into capital-equipment expense and depreciation; $10 goes into chemicals and materials.

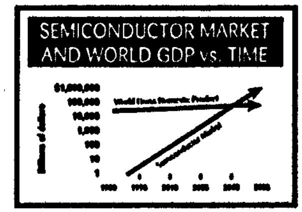
❑ A 100-megahertz Pentium costs $118 to manufacture and sells for $300. The faster Pentiums cost the same to build but are sold for more. Chips are manufactured, tested and then stamped according to their evaluated performance speed.

❑ A 120-megahertz Pentium sells for $357; a 133-megahertz for $520.

❑ Estimated salaries of design team:
Key architects: $150,000 (for senior people maybe $200,000 maximum; with stock options, can make over $500,000)
Software programmers: $60,000
Circuit designers: $80,000 to $120,000
Testers: $60,000 to $100,000
Manufacturing workers: $30,000 to $60,000

Sources: Dataquest, Hambrecht & Quist, Intel, Microprocessor Report, VLSI Research

But you've still got a problem. The mechanical switch is a powerful tool, but it has real limitations. For one thing, you need someone on hand to throw it. Somebody has to lock the gate or the cows get out; and some yardmaster had better run down the tracks and swing the big switch arm or two trains will collide.



Moore Spoofing *In an effort to poke fun at the more optimistic chip visionaries, Intel's Gordon Moore comically points out that by the optimists' own projections, the chip business will overtake the global GDP by 2040.*

So now take that mechanical switch, the one with electricity flowing through it, and add a second electrical line, this one passing through a coil of wire that is wrapped around the metal arm of the switch itself. If you send a current through this second line, it will create a magnet and throw the switch—from afar. Thus, you have an electromechanical switch, a key invention of the 19th century and the heart of telegraphy (and, until recently, telephony).

So far so good. What followed was the idea of using one flow of electricity to control another. No moving parts—a real breakthrough!—but the feat could be done only in a vacuum tube. Then, in the late 1940s, two physicists at Bell Labs in New Jersey, Walter Brattain and John Bardeen, experimenting with a crystalline structure called a semiconductor, came up with this idea: *Why not build an electronic switch out of solid materials without the need for fragile glass vacuum tubes?* Bardeen and Brattain took their idea to another scientist at Bell Labs who happened to have one of the greatest minds of the century: William Shockley. Intrigued, Shockley offered some critical suggestions ... and in 1947, two days before Christmas, the team built the first working *transistor*.

The transistor, eventually sold in the billions and stuffed in everything from jet fighters to cheap radios, revolutionized electronics. It was very fast, small and used little power. By the end of the 1950s, the solid-state revolution was well under way. Transistors and other semiconductor devices quickly supplanted traditional tubes in almost every application, from radios to computers, and enabled even the rockets of the space age itself.

All of this presented a terrific opportunity for clever entrepreneurs willing to dive into the semiconductor market. One such player was William Shockley himself, fresh from earning a Nobel Prize for the transistor. Moving back home to Palo Alto, Calif., he gathered the brightest young men in electronics and solid-state physics and set out to take the transistor market by storm.

Shockley, however, was a miserable businessman, and his young engineers, henceforth known as the Traitorous Eight, soon grew disenchanted and quit to found their own company, Fairchild Semiconductor, the mother firm of Silicon Valley.

AT FAIRCHILD, A TEAM LED by the Eight's leader, Robert Noyce, set out to find a new, more effective way to manufacture semiconductors. Noyce had the idea (coincidentally also being pursued by a scientist at Texas Instruments, Jack Kilby) that the transistor could be created using a lithographic process as a series of etched and plated regions on a tiny sheet of silicon. Moreover, he thought this process, like printing, would be almost infinitely repeatable. And that in turn meant a semiconductor manufacturer could replace a bank of transistors soldered to a printed circuit

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GLOSSARY

ASIC
(application-specific integrated circuit)
Devices that perform a specific task using a custom blueprint of logic circuits, which can be mass-produced at low cost. Used in everything from video cameras to microwave ovens.

Clock speed
The number of cycles of operation, measured in hertz (cycles per second). The 8088 microprocessor used in the first IBM PC had a clock speed of 4 megahertz. Today's Pentiums run in the range of 75 to 160 megahertz.

CPU
(central processing unit)
The microprocessor governing the operation of PCs, servers and workstations.

DRAM
(dynamic random-access memory)
The primary type of RAM used in PCs. It is dynamic because its contents can be changed at will by applications running on the system.

Embedded processor
A cheap microprocessor built into products like greeting cards and toys.

Fuzzy logic
The application of vagueness and approximation to computer logic, allowing computers to respond to less clearly defined input.

Instruction set
A set of binary codes that directly manipulate the registers, memory locations and other devices of the microprocessor. These codes are also referred to as microcode.

Microcontroller
A stripped-down microprocessor, designed to perform a specific function such as controlling an automotive fuel-injection system or a laser printer. Generally has fewer memory-management capabilities and a smaller instruction set than general-purpose microprocessors.

Microprocessor
A CPU on a single chip. Contains the logical elements for performing calculations carrying out stored instructions.

Microprocessor learning curve
As more companies employ microprocessors at the heart of their products and services, they will have to improve their products and services at the rate of chip evolution.

MIPS
(millions of instructions per second)
Measures performance of microprocessors.

Neural networks
The application of microprocessors and other integrated circuits simulating the architecture of the brain. Neural nets are used for pattern and voice recognition, and other applications requiring cognitive skills.

Transistor
An electronic device capable of amplifying electronic signals similar to the vacuum tube but made from a semiconductor material such as silicon or germanium. Today's Intel Pentium contains more than 3 million transistors.

Source: The Microprocessor: A Biography by Michael S. Malone