

The Journey InsideSM: Technology and Society Student Handout: To Infinity and Beyond

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by Michael S. Malone, courtesy of *One Digital Day* (1998)

In the Spring of 1965, Dr. Gordon Moore pulled out a sheet of logarithmic graph paper and began to plot the complexity of the circuits that had recently been integrated onto slivers of silicon. He noticed that during each of the first few years of the integrated circuit revolution, the number of transistors and resistors that fit onto a chip had nearly doubled, to the point where the newest circuit contained a total of about 60 components. Making the bold extrapolation that this rate of progress would continue in a predictable pattern, he projected that by 1975 microchip complexity would increase a thousand-fold, to some 60,000 components in a single circuit, a prediction that was realized with surprising accuracy.

But Moore's prediction did more than just stun his audience. Moore's Law, as it has been called ever since, had detected the hidden metronome driving the technology age: that the number of transistors on a chip doubles every two years.

If, in 1965, you had known nothing about the forces propelling our civilization except Moore's Law, your predictions about life at the century's end would likely have proven more accurate than with any other combination of indicators. Moore's Law has given us an extraordinary gift: We know how and when the future will arrive.

This remarkably accurate cycle tests existing companies to see if they still have the mettle, and in the process keeps the good ones perpetually young. It revives entrepreneurship, creating openings for new companies led by people with innovative ideas. It instills in the market a willingness to try anything new, and thus creates a demand for the fruits of this biannual revolution.

This cycle has become so refined, so enmeshed in our daily lives, that it has become as omnipresent and as deeply felt as the seasons. Now, the unveiling of a new generation of microprocessor is treated like a royal birth, with press conferences serving as the public christening for thrilled onlookers around the world. We now grow impatient if a new application—an operating system, a consumer product, a computer—slips a few months beyond its appointed date.

In September 1997, during an extraordinary week in electronic history, Intel announced that it had found a way to double chip capacity, and IBM proclaimed that it had found a way to plate chips with copper, further increasing their capacity and speed. Within 24 hours, Moore's Law had taken a huge leap. At the semiconductor level, we had just gone from the Sopwith Camel to the P-51 Mustang, and the reaction was: "But, of course."

And perhaps nonchalance is the proper reaction to the rate of change we live with today. For all we know, it's quite possible that everything that has happened since Dr. Moore drew his graph could be merely a prelude before the real symphony begins.

But what a prelude it has been. Today you can buy greeting cards containing processors with more computing power than the world's largest computers in 1971. Microprocessors are so ubiquitous and inexpensive that we now embed them under the skin of our pets, sew them into clothing and attach them to lightbulbs, running shoes, ski bindings, and jewelry.

That's one side of Moore's Law: hold performance steady and the price falls, so that the most powerful chip of 10 years ago costs a fraction of what it once did. But the other side of Moore's Law is equally profound: hold the price steady and performance skyrockets. In 1975, the Intel 8080 microprocessor cost about \$300. It was powerful enough to run the Altair, the first personal computer. In 1998 that same price bought a sixth-generation descendant of that chip, a Pentium® II processor, with enough power to direct the Pathfinder on its exploration of Mars, generate scenes for a computer-animated motion picture, or manage a Web site receiving 10 million hits per day.

Many futurists predict that seven generations from now, the descendants of these chips—for the same price—will construct software agent "avatars" with human characteristics that will act as our personal assistants, helping us shop, planning our days, and organizing our lives. These chips will also bring speech recognition to word processors and order-entry systems. They will generate 3-D wall-sized graphics for television, teleconferencing, even custom-made movies. They will direct our vehicles for maximum safety and create virtual worlds we will walk through. They will instruct our children, monitor our health, replace lost body parts and, through a grid of billions of sensors, connect us to the world in ways that we can only dimly imagine.

Will Moore's Law ever tire of its relentless change? Engineers and physicists have often expressed doubts about how long the miracle of Moore's Law can last. And yet, each time we approach a technical wall, it miraculously crumbles. Today the concern is over the basic laws of physics themselves: as the alleyways and gates on the surface of the microprocessor shrink to atomic levels, what happens then? Is the atom the final, unsurpassable barrier?

Perhaps, but only to the world of the silicon microprocessor. Already, scientists are making critical breakthroughs in new processor technologies involving everything from quantum switches to growing human neurons on silicon sheets to computers made entirely of DNA strands. These last are, metaphysically at least, the most compelling of all.

Finally, if the optimists' predictions about Moore's Law are correct and we are still only at the beginning of the Microprocessor Age, what does that portend about humankind a century from now? Will our descendants even think like us? Will they view time and space and the world around them in a manner so completely different that they won't even be able to imagine our lives? The one thing we can be sure of is that the world of our children will be as different from today as our world is from that of our grandparents.