What Technology Can Contribute

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Note: this speech was given in the mid 1990s.

It is a great pleasure to be here and see so many people I have known and worked with over the years. This conference marks twenty-three years that I've been in this field, and it is remarkable to me how many of the people who have devoted their careers to this field have remained the same over the past couple of decades.

I'd like to talk to you today about the nature of information technology and the impact it is having on our world, particularly in creating opportunities for those with disabilities, especially visual disability. I would also like to comment on the proper role of technology—what it can contribute—but also what is outside its province.

Incidentally, I have always felt that there is a salient difference between the word "disabilities" and the word "handicaps." A disability does not necessarily need to result in a handicap. Through technology and the fostering of improved public attitudes, I believe most handicaps can be overcome.

Computer technology in general has been a very positive development in providing access to information for persons with visual impairments, and indeed the blind population is significantly more computer-literate than the rest of the population as a result. Information in computer form can be made readily accessible through screen readers, Braille displays, and the like although the graphical user interface (GUI) has been a bit of a setback. A GUI, such as Microsoft Windows, is a computer operating system which uses those little icons, a mouse, and bitmapped graphics. It is difficult to translate into speech because it places information on the screen in two dimensions.

If you recall the last U.S./Canada Conference on Technology for the Blind over two years ago, someone asked "What is Windows anyway?" Euclid Herie responded "it's a real pane."

I'll have more to say about technology for the visually impaired, but let me start with a little story that my parents liked to tell. They were from Vienna, so they liked to talk about Viennese pastries: Four pastry shops competed on the same street, eking out a living, but the market demand was not sufficient to support four shops. So one shop brought in a management expert, and the next morning there was a small sign in the window, "Best Pastries in Vienna," and they started to get a lot of curious pastry shoppers, and pretty soon they had a booming business.

So the second shop brought in their own turnaround consultant, and the next morning they had a bigger sign in their window, "Best Pastries in Austria," and they too attracted a lot of curious shoppers. The third shop soon followed suit with a really big, six-foot-high sign—"Best Pastries in Europe." So shoppers flocked to this shop.

Finally, the fourth shop owner decided that she needed to do something as well, so the next morning there was a really big sign that took up the entire window—"Best Pastries on this Block."

The moral of the story is that you don't have to be the best in the world; you only have to be the best in your neighborhood, and you have to be in the right field. In the Vienna of 1930, the right field was pastries. I grew up eating those Viennese pastries, but I don't eat them anymore, not since my nutrition book came out.

In 1996 the right field is software. But you don't have to be in the right neighborhood anymore. It doesn't matter whether you're in Vienna or Massachusetts or St. Louis because the Internet is the great leveler, the great equalizer. Everyone has ready access to the marketplace.

A couple of Yahoos in California can be as prominent as Microsoft. I was in Israel recently, where access to export markets used to be a big issue, but with the Internet high tech, and software in particular, is booming. So Israel today has a gross national product that is twice that of Saudi Arabia. Software and the intellectual content it represents exceed the value of oil.

Some of you remember the movie The Graduate; for some of you it may be before your time. Remember the enigmatic advice that Dustin Hoffman received? (I don't remember the name of his character.) I remember thinking at the time, "Plastics?" Even then I thought "computers" would have been better advice. Today, the advice would be "software." Some might say Internet, but in my view that is just another manifestation of software. After all, NetScape is a software company. You've no doubt noticed the extraordinary value of software companies. In my view this is not a passing trend; it is not a bubble that's going to burst, which is not to say that there will never be a correction or that none of today's high flyers will crash.

But what we are seeing today is a fundamental transformation of the nature of wealth away from commodities and towards knowledge, as embodied in intellectual property. In fact, you can draw a reverse exponential curve where the y axis is the percentage of value of a product represented by natural resources and the x axis is time, and the percentage of value represented by natural resources is asymptoting to zero as we go forward in time, and every product and service is on the curve. Some are closer to zero than others, and some categories of products are moving faster than others as they travel down the curve, but every product is on the curve, marching on down to nearly zero contribution from material resources and nearly 100 percent contribution from intellect.

Indeed, over the past twenty years the value of commodity resources, as measured in constant dollars, has fallen substantially, about 40 percent, and this trend is accelerating. So sell short on your natural resource stocks. That is my only stock tip for today. Today the correct answer to the question of how to advance economic competitiveness is to foster the creation of intellectual property, which is information—that is, sequences of 1's and 0's that have economic value. And that has not always been the case in human history.

Now what is fueling this extraordinary and, in my view, permanent shift to knowledge, to intellectual property, to software as the foundation of wealth and power in this second industrial revolution? The answer in my view is Moore's Law. Moore's Law is the driving force behind a vast revolution. Okay, now what is Moore's Law? Moore's Law states that computing speeds and densities double every eighteen months. In other words, every eighteen months we can buy a computer that is twice as fast and has twice as much memory for the same cost. Now I won't subject you again to my chessboard analogy since I think that most of you have heard it before. If you recall, it concerns the reward that the inventor of chess receives from the Emperor of China. He gets one grain of rice for the first square, which is then doubled for each square of the chessboard. And we end up with a very big number of grains of rice—about eighteen million trillion as I recall, which would require rice paddies covering twice the surface area of the Earth, oceans included.

So actually I've ended up sharing the chessboard analogy with you anyway. That might remind you of the Presidential debates when Senator Dole said he was not going to bring up Whitewater and then went on to talk about it anyway. The chessboard analogy is meant to illustrate the power of exponential growth. What appears to start out in a subtle fashion ends up being rather overwhelming.

Now one might object to the notion of Moore's Law continuing for very much longer on the basis that exponential trends cannot continue indefinitely. For example, if a species happens upon a new habitat, its numbers will grow exponentially for a time until its needs outstrip the capacity of that habitat to provide for those needs. But it would be premature in my view to predict the demise of Moore's Law anytime soon.

First of all, Moore's Law is not a recent phenomenon. It has actually been going on for at least one hundred years from the mechanical card-based computing technology of the 1890 census, to the relay-based computers of the 1940's, to the vacuum tube-based computers of the 1950's, to the transistor-based machines of the 1960's, to all of the generations of integrated circuits that we've seen over the past thirty years.

If you put every calculator and computer for the past 100 years on a logarithmic chart, it makes an essentially straight line. Actually, it has been going on even longer than that. In my view, Moore's Law is a corollary of a broader law I modestly call Kurzweil's law on the exponentially quickening pace of technology that goes back to the dawn of human history—I mean, not much happened in, say, the tenth century, technologically speaking. In the eighteenth century quite a bit happened. Now we have major paradigm shifts in a few years' time, but that's another speech.

If you look at the computing technologies currently in development, we can have confidence in at least several more decades of the turning of Moore's screw. We have not even begun to explore the third dimension in chip design. Chips today are flat, whereas our brain is organized in three dimensions. We live in a three-dimensional world; why not use the third dimension?

Improvements in semiconductor materials, including the development of superconducting circuits that do not generate heat, will enable the development of chips (I should say cubes) with thousands of layers of circuitry, which when combined with far smaller component geometries, will improve computing power by a factor of many millions. There are more than enough new computing technologies being developed to assure a continuation of Moore's Law for a very long time.

Moore's Law is providing us the infrastructure in memory, computation, and communication to embody all of our knowledge and methodologies and to harness them on inexpensive platforms. It enables us to live in a world today in which all of our knowledge, all of our creations, all of our insights, all of our ideas, our cultural expressions: pictures, movies, art, sound, music, books, and the secret of life itself are all being digitized, captured, and understood in sequences of ones and zeroes.

Now I would like to examine some of the ways in which technology can contribute in the future, but before we do that, I think it would be worthwhile reflecting for a moment on the proper role of technology. The delegates to this conference hail from two great democratic nations, and perhaps the most important goal of a democracy is to provide equal opportunity for all of its citizens. To accomplish the goal of equal opportunity for people with physical and sensory disabilities, there are in my view three requirements.

The first is education. Consider the issue of mobility for the blind. A blind person can travel across town and across the globe as the participation at this conference attests and as Euclid Herie's travels over the past four days particularly attest. Despite efforts at creating effective mobility aids, it can be said that technology has not yet made a contribution to this issue, nor does it need to. The requirement is education—in this case mobility training. The state of the art is a low-tech device—the modern, lightweight cane, together with modern mobility training. An effective means of reading and writing literacy for blind persons is Braille. But Braille needs to be learned, so again education is the critical requirement.

The second requirement is the fostering of positive attitudes, specifically the attitude that a disability, such as blindness, is a characteristic—a characteristic which does not impart limitations on what a person can accomplish. The positive attitudes needed are both social and personal. Society needs to understand what its citizens, blind or sighted, can accomplish and contribute. And an individual needs to appreciate her own capabilities and reject the negative stereotypes that the deeply ingrained prejudices of society may attempt to impose.

I won't belabor this issue. One could examine it engagingly at great length. It is an issue in which we have made great progress, in large part because of the devoted efforts of people in this room, such as Dr. Jernigan, Dr. Herie, and all of the organizations represented at this conference.

As just one small example, if you remember, at the last U.S./Canada Technology Conference almost three years ago, we watched a video of a then current TV show in which the basic premise was how hilarious it was that the show's blind star was apparently unable to walk across the room without knocking over numerous lamps, vases, and other breakable objects. That was considered funny, at least by the show's producers. That was the entire premise of the show. The show was quickly canceled, in large part, apparently, because of the strong reaction of people in this room. Today such a show would be unthinkable, at least on mainstream TV. But that was not the case three years ago. There's certainly a lot left to do, but progress is being made.

And finally there is technology, which also has a part to play. Technology can also provide a means for independence, particularly in the area of access to information and knowledge. Blindness is a sensory disability and therefore involves access to information. Human intelligence has a great deal of redundancy, and there are many routes to access information. Technology can provide a bridge to supply visual information through our other senses. An obvious example is a reading machine, which provides the information from printed documents through either spoken words or Braille displays.

So, using Moore's Law as our road map, let's consider where we are headed in the area of technology for the disabled. Reading machines for the blind have certainly benefited from Moore's Law. I examined this issue recently with regard to reading machines. I have incidentally started a new company, Kurzweil Educational Systems, Inc. which is devoted to creating the next generation of reading technology. I've gathered up some of the best people that I've worked with in this field over the past twenty-three years, and we have created a new type of reading machine for the blind, for persons with low vision, and for persons with learning disabilities and dyslexia.

I recently did a comparison of the first reading machine, the Kurzweil Reading Machine, which I introduced in 1976, to OMNI 1000, which is my new reading machine. Without tracking through all the details, the 1996 product provides about 256 times the performance of the 1976 product, at about one forty-second of the price, which is a price-performance improvement of 10,752. Interestingly, that's just about what you'd expect from Moore's Law in twenty years.

Now reading machines constitute an area of technology with which I have some familiarity, so let's consider the future of reading machines. Moore's Law will continue to improve all aspects of reading machine price and performance in the years ahead. Recently two-dimensional scanning chips have emerged which can scan a full page of text with 300-spot-per-inch resolution without any moving parts. These two-dimensional scanning arrays, which have over 5 million pixels, are prototypes and are, therefore, expensive. But within a few years these chips will permit the development of pocket-sized scanners the size of a small camera that can snap a full page instantly.

Thus, within a few years a full print-to-speech reading machine will fit in your pocket. You'll hold it over the page to be scanned and snap a picture of the page. All of the electronics and computation will be inside this small camera-sized device. You'll then listen to the text being read from a small speaker or earphone. You will also be able to snap a picture and read a poster on a wall or a street sign or a soup can or someone's ID badge or an appliance LCD display and many other examples of real-world text.

This reading machine will cost less than a thousand dollars and will ultimately come down to hundreds of dollars. Algorithmic improvements will also provide capabilities to describe non-textual material such as graphs and diagrams and page layouts. These devices will also provide on-line access to knowledge bases and libraries through wireless connection to the World Wide Web. By the end of the first decade of the next century, the intelligence of these devices will be sufficient to provide reasonable descriptions of pictures and real-world scenes. These devices will also be capable of translating from one language to another.

The scanning sensors of the future reading machine will ultimately become very small and could be built into a pair of eyeglasses. The advantage of doing this is that it would allow the user to control the direction of scanning through motion of the head in the same way that a sighted person does. Once these devices can provide reasonably intelligent descriptions of real-world scenes, they will evolve into navigation aids.

I will point out that access to the world of print has been a more important issue than navigation. Braille, of course, is a vitally important technology in that it provides access to the world of literacy for both reading and writing. It does, however, have the limitation that only a small percentage of books and topical literature is available in this alternative medium. Recorded material has the same limitation. Thus reading machines have provided the opportunity to overcome a principal handicap associated with the disability of blindness: access to ordinary print.

Until a navigation device can provide a level of intelligence sufficient to be truly helpful, the most useful navigational technology will, as I pointed out earlier, continue to be the modern lightweight cane. Electronic navigation devices have already been developed, but they have not yet proved useful. Unless such a device incorporates a level of intelligence at least comparable to a guide dog, it is not of much value.

Systems have been demonstrated which use satellite positioning systems to determine a person's location. Arkenstone, for example, has demonstrated systems of this type. These systems, using an on-line map of the community, will be able to inform a blind traveler of the location of nearby buildings, mail boxes, phone booths, and other permanent fixtures. It will sound like the buildings are talking to you, saying something like "I'm the library, and I'm over here." I think such a system will be useful for people, sighted or visually impaired. I'd like to have buildings talk to me as I walk by.

General purpose artificial vision is now being developed for robots and is in an early stage, although progress is being rapidly made. Today robotic factory inspectors can outperform human inspectors in many visually demanding tasks. Vision has lagged behind other developments in artificial intelligence because of the enormous flows of data required to process visual information intelligently. With the advent of massively parallel computing and the continuing progress made through Moore's Law, this difficulty is gradually being overcome.

Such a combination reading machine-navigation aid will be an assistant that will describe what is going on in the visible world. The blind user could ask the device (verbally or using appropriate manual commands) to elaborate on a description, or he could ask it questions. These artificial visual sensors need not only look forward; they may as well look in all directions. And they will ultimately have better visual acuity than human eyes. Everyone—visually impaired or not—may want to use them.

Persons with other disabilities will benefit from the continuing advance of computer technology as well. Another company I founded, Kurzweil Applied Intelligence, Inc., has developed speaker-independent, large-vocabulary speech-recognition, and one of our primary goals is to develop a speech-to-text sensory aid for the deaf, which I believe will be introduced within the next several years. We expect to introduce a device next year which will be able to understand fully continuous speech with a large vocabulary. Its primary limitation will be that you will need to restrict your topic of conversation to a particular domain, such as medicine or law. It will take several more years before our large-vocabulary, continuous speech-recognition technology is capable of understanding human speech without a domain restriction. I do believe, however, that a speech-to-text sensory aid for the deaf will become a popular device by early in the next decade.

A principal physical handicap is paraplegia, the loss of control over the legs. The most common prosthetic aid for this disability is the wheelchair, which has changed only in subtle ways over the past two decades. It continues to suffer from its principal drawback, which is the inability to negotiate doorways and stairs. Although federal law now requires most public buildings to accommodate wheelchair access, the reality is that access to persons in wheelchairs is still severely restricted. By the end of this decade we will see the first generation of effective exoskeletal robotic devices, called powered orthotic devices, which will restore the ability of paraplegic (and in some cases quadriplegic) persons to walk and climb stairs.

Overcoming the handicaps associated with disabilities is an ideal application of artificial-intelligence technology. In the development of intelligent computers, the threshold that we are on now is not the creation of cybernetic geniuses. That will come later. Instead we are today providing computers with narrowly focused intelligent skills, such as the ability to make decisions in such areas as finance and medicine, and in recognizing patterns such as printed letters, human speech, blood cells, and land terrain maps. Most computers today are still idiot savants, capable of processing enormous amounts of information at very high speed and with great accuracy, but with relatively little intelligence. When one considers the enormous impact that these idiot savants have had on society, the addition of even sharply focused intelligence will be a formidable combination.

It will be particularly beneficial for the disabled population. A disabled person is typically missing a specific skill or capability but is otherwise a normally intelligent and capable human being. There is a fortuitous matching of the narrowly focused intelligence of today's intelligent machines with the narrowly focused deficit of most disabled persons. Our primary strategy in developing intelligent computer-based technology for sensory and physical aids is for the focused intelligence of the machine to work in close concert with the much more flexible intelligence of the disabled person himself.

There are an estimated twenty million disabled persons in North America. Many are not able to learn or work up to their capacity because of technology that is not yet available or technology that is available but not yet affordable or pervasive and because of negative public attitudes toward disabled persons. As the reality changes, the perceptions will also change, particularly as formerly handicapped persons learn and work successfully alongside their non disabled peers. By the end of the first decade of the next century, I believe that we will come to herald the effective end of handicaps.

Finally, let's consider the long-term impact of Moore's Law. I made a rough estimate of the computational ability of the human brain, which comes to about twenty million billion calculations per second, give or take a couple of orders of magnitude. When does Moore's Law predict that your standard personal computer will be capable of that capacity—twenty million billion calculations per second? Without taking you through the details of this prediction, it turns out to be around the year 2020.

Now matching the raw computing speed and memory capacity of the human brain, even if implemented in massively parallel neural nets, will not automatically result in human-level intelligence. The architecture and organization of these resources—that is, the software—will be at least as important as the capacity itself.

There is, however, a source of knowledge that we can tap to accelerate greatly our understanding of how to design intelligence in a machine, and that is the human brain itself. By probing the brain's circuits, we can essentially copy, that is to say, reverse engineer, a proven design, one that took its original designer several billion years to develop. And it's not even copyrighted.

Just as the Human Genome Project, in which the entire human genetic code will very soon be fully scanned, recorded and analyzed, to enable our understanding of the human biogenetic system, a similar effort to scan and record the neural organization of the human brain can help provide the templates of intelligence. Now I won't track you through these details either, but I do believe that this will be accomplished as well by around the year 2020. And when that does happen, I think we will finally realize just how revolutionary Moore's Law really is.

So I'll leave with a final thought to underscore the revolutionary nature of Moore's Law. Another revolutionary, Mao Tse Tung, said that power comes from the barrel of a gun. That statement was true when he said it. But he said it in the last possible decade that one could make that statement because through physical coercion you could control natural resources. If you could control natural resources and compel people to labor, you could control wealth. And while not providing the happiest or most productive workers, it worked well enough.

The second industrial revolution, however, the one that is now in progress, is based on machines that extend, multiply, and leverage, not our physical, but our mental abilities. A remarkable aspect of this new technology is that it uses almost no natural resources. Silicon chips use infinitesimal amounts of sand and other readily available materials. They use insignificant amounts of electricity. It's a fortunate truth of human nature that, whereas labor can be forced, creativity and innovation cannot be.

But there's something else Mao said that is true today, although not in the sense he meant it, that is, the reality of permanent revolution. The exponential progress being created through Moore's Law and the move towards an economy based on knowledge and intellectual property is a permanent revolution. It's not just that densities of memory double and that computing speeds double; Moore's Law constantly changes everything—the means of education, the needs of the market, the methods of development, the channels of distribution.

It is a continual paradigm shift, and to understand how to create a product or an educational program or a program of social change, one needs to understand how our ideas will fit into, not just the world of today, but the world one year from now and two years from now, which will be very different. History is full of missed paradigm shifts. When the telephone was first invented, the chief engineer of the British post office said, "This is no big deal; we have plenty of messenger boys." But the mayor of Philadelphia had considerably more insight into the importance of this new development. He saw the paradigm shift. "This is of great significance," he said, "Someday every city will have one."

Why Doesn't Technology For Blind People Cost Less And What Can We Do About It?

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