# The Global Scramble for Information Technology Leadership: Winners and Losers*

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I appreciate the opportunity to come here and spend some time talking with you about the Information Technology industry and what we see today, what we believe will happen as we go forward, and some of the challenges and issues that are out there ahead of us. These are issues that all of us involved in the industry are going to have to deal with whether we live in the US, Korea, Europe or Japan. It doesn't matter where we live -- we will all be facing these challenges. I think you will see as my discussion unfolds that the benefits of all the things we're doing in IT have broad and deep implications for everyone around the world.

I was the chairman of the board of directors of the Federal Reserve Bank of San Francisco for a number of years. In that capacity, I was involved in monetary policy and the issues driving monetary policy. Productivity was one of the very important matrices that we reviewed constantly. The IT industry is a very important contributor to the productivity improvements that have taken place for a number of years and will be more critical in the years ahead.

The title of my talk is *The Global Scramble for IT Leadership: Winners and Losers.* We are now in the early stages of a global scramble for leadership in information technology. While the US has been the undisputed leader in IT for the last 50 years, we're now in the beginning of a transition from silicon-based semiconductors that are the driving force for the IT world to a Nanoelectronics Era which will really begin to take hold some 10-15 years down the road. This transition will require the use of new materials, new device structures, and new manufacturing methods. A whole new area of activity will have to unfold. It will truly be a revolution in technology, and as we all know, periods of revolution offer opportunities for new leaders to emerge.

The CMOS scaling era that we've been in for the last 30-40 years is now coming to a close. Current technology will run up against the limits of physics in about 10-15 years, and the Nano Era will then take over. The Nanotechnology Era will present challenges and opportunities for the 50 years that follow.

Many countries around the world have recognized this opportunity and are now seeking leadership in IT. They are funding basic research, educating scientists and engineers, creating incentives for investment by high technology industries, and nurturing the development of domestic IT companies. The strategic importance of leadership in IT to countries' economic growth, productivity, standard of living, and national security has become readily evident to leaders of countries everywhere. IT makes enormous contributions to enhancing productivity of workers, enabling them to earn higher wages while producing goods and services that demand

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higher prices and provide greater value throughout the marketplace. IT is the most important contributor to productivity growth, not only in the US but also in countries around the world.

In the US, which has led the world in economic growth for many years, IT industries have accounted for 25 percent of all economic growth while making up only 3 percent of the GDP. Increasing worker productivity will be critically important for many of the world's industrialized nations in the years ahead. We'll soon feel the effects of aging populations. With fewer workers available to meet the needs of aging citizens, dramatically increased productivity is the only viable solution to deal with that issue.

It will be helpful to examine the evolution of the IT industry over the past century to provide context for examination of the coming transition. If we look at the evolution of the IT industry, starting with the advent of the vacuum tube, the subsequent inventions of the transistor and the integrated circuit, and going forward to new devices such as carbon tubes and nanotechnology, we can gain insights into the business models and policies that foster advances in innovation and technology.

The modern era of electronics can be traced to the vacuum tube in the early 1900s. The vacuum tube, which was essentially a switch, became the fundamental building block for all electronic systems for the first 50 years of the last century. But scientists soon realized that vacuum tube-based technology had practical limitations of size and power consumption. These limitations had to be overcome to capitalize on the opportunities lying ahead. So it was clear that we needed to do something different.

The first digital computer known as ENIAC for Electronic Numerical Integrator and Computer, graphically demonstrates why it was essential to find an alternative to the vacuum tube. This machine was unveiled in 1946, weighed 30 tons, took up 1,800 square feet of space, and consumed 150 kilowatts of power to operate 17,000 vacuum tubes. It was a marvel for its time, but it lacked the capability to provide computing power that was needed. The computing capability of that machine can now be purchased for about five dollars in one of the hand-held devices that are now commonplace.

Clearly, there was a need for a new switch that could operate on lower power and could be scaled to enable more practical electronic devices. The invention of the transistor at Bell Laboratories in 1947 launched the era of microelectronics. Bell Labs continued to serve as a source of innovation until the US Government ordered the breakup of AT&T in the 1980s. This was, in my view, one of the great mistakes made by the legal system in the US. We are now working to find new ways to replicate the contributions made by the Bell Labs to the advancement of Information Technology.

The transistor radio is the most notable symbol of the transition from vacuum tube to the transistor. The next big breakthrough occurred about a decade later with the invention of the integrated circuit. That invention was jointly credited to Jack Kilby at Texas Instruments and Bob Noyce at Fairchild Semiconductor. In 1965, Gordon Moore, then a young engineer at Fairchild, and later one of the co-founders of Intel, observed the advances in integrated circuit technology had enabled a doubling of the number of transistors on a chip every year since the invention of the integrated circuit. That observation, as most of you know, has come to be known as "Moore's Law." The rate of doubling has continued ever since that time, and we believe we will keep pace with Moore's Law until we reach the limits of CMOS technology in 10 to 15 years.

For four decades the semiconductor industry has distinguished itself by the rapid pace of improvement in products. One metric that best describes the progress in semiconductors is the rapid growth in the density of memory chips. Two of the largest and most successful suppliers of memory chips are Samsung and Hynix, so many of you know a lot about the progress in memory technology.

The early DRAM -- the first one developed in 1970 -- had the capacity of 1,000 bits of memory. Today's DRAM can hold 32,000,000,000 bits on about that same piece of real estate. In the last ten years memory prices have decline by 98%. Today's most advanced microchips have about 1,000,000,000 transistors, on a sliver of silicon that is smaller than a thumbnail.

The applications for powerful circuits with ever-increasing functionality are limited only by the human imagination and creativity. We will be able to continue to make these devices smaller, faster, and at lower costs until we run up against the laws of physics with CMOS scaling. The challenge is to continue to reduce the cost per function by about 25 percent per year and to use those gains to drive productivity and enhance competitiveness of all of our industries around the world.

I read just a few weeks ago that Mr. Oh Sang-Rok of Korea's Ministry of Information and Communication announced a personal goal to put a robot in every home in Korea by 2010. South Korea is already the world's most wired country with 72 percent of all households having broadband service, so I really believe that Mr. Oh's goal will be achieved. He also hopes these robots will help children learn English, and sing and dance for them when they get bored. Imagine a babysitter that will entertain your children while teaching them proper English. I hope that Mr. Rak has plans to export these robots to the US so our children can learn Korean and together we will have better communication.

It is instructive to look at the business models that have evolved and helped drive information technology through the various transitions in the past 50 years. The business models have evolved very differently in the US, Europe, Japan, and Asia Pacific. I believe there is something to learn from these different evolutionary paths as we think about who will be the leaders going forward and what will it take to achieve leadership in the Nano Era.

In the US in the 1950s, six companies were the principal suppliers of vacuum tubes: GE, RCA, Raytheon, Sylvania, Philco, and Westinghouse. All of these companies were vertically integrated and had substantial internal demand for their vacuum tube products. By 1960, when transistors and integrated circuits began to proliferate, a number of new players entered the competitive arena, including Texas Instruments, Motorola, and Fairchild. Intel, which became the world's largest semiconductor manufacturer in 1992, was founded in 1968. Intel was one of many startups in the chip industry during that era, only a few of which survived. By 2004 a new group of players had emerged when the "fabless" business model came into being. The fabless model is exemplified by companies like Qualcomm, Broadcomm, Xilinx, Altera, and a host of others. These companies focused on innovative semiconductor designs while relying on independent manufacturing facilities known as foundries to do the actual silicon processing.

There was one exception to the pattern in the US, and that was IBM. IBM is notable in that the company has been a leader from the earliest days of the IT industry. IBM was a leader when the industry got started back in the 1950s and continues to be a leader today. The company doesn't show up on these tables only because IBM only recently began to sell ICs in the "merchant" semiconductor market. Up to that time, IBM had consumed all its microchip production internally.

With the exception of IBM, none of the leaders of 1950 are major factors in the IT industry today. The US business model in IT is based on excellent research universities, the availability of venture capital to fund startups, and the nimbleness and quickness of new highly focused companies. These characteristics resulted in major changes in both industry leadership and in the basic business model for the US IT industry.

In Europe, there was a very different pattern for the IT sector. Three companies dominated the vacuum tube business in Europe in the 1950s. The transition from tubes to transistors, and later to integrated circuits, did little to change the order of leading European companies. In the 1970s, the French and Italian governments began to recognize the growing strategic importance of microelectronics, and funded new ventures -- Thompson and SGS. In the 1990s, the Italian and French ventures merged to form ST, but Phillips and Siemens, the leaders in the vacuum tube era, were still among the top three European microelectronics manufacturers. The microelectronics business at Siemens has now been spun off into a company now known as Infineon. Otherwise, the order hasn't changed much from what it was in the 1950s.

Unlike the evolution of the US microchip industry, startups haven't played a major role in Europe. Whether this is due to cultural differences, a lack of readily available private venture capital, or attitudes toward entrepreneurial efforts, the pattern is vastly different and offers room for discussion and speculation.

The evolution of the Japanese business model reflects the unique culture of Japan. All the leaders of 1950 were vertically integrated. By the 1960s, a rare startup -- Sony -- emerged on the scene as a major player. Sony built its business around consumer electronics, and unlike most of its competitors, the company was never a member of a *keiretsu*. Major changes to industry structure in Japan are relatively recent phenomenon. Elpida Memory resulted from the combination of the DRAM business of NEC and Hitachi in 1999, while semiconductor operations of Hitachi and Mitsubishi merged to create Renesas in 2003. Japanese industrial policy and the *keiretsu* system tended to favor and nurture existing companies as opposed to entrepreneurial startups. As a result, startups have been rare in Japan, although we do see some change taking place there today.

The microelectronics industry in rest of Asia-Pacific -- Taiwan, South Korea, Singapore primarily, and now, with China coming on the scene -- emerged a bit later. Samsung, Goldstar, and Hyundai were the largest IC suppliers in the 1990s. These companies got started in the late 1980s and became major players in the 1990s. An important development in the 1980s was the fabless model that became the driving force for the semiconductor foundry industry in Taiwan. In Korea, the major players have been integrated companies. In the Asia-Pacific region, TSMC and UMC in Taiwan, and Chartered Semiconductor in Singapore, are leaders in the foundry business. These are very good technology companies, and provide an excellent service to the fabless design companies. We now see in China, the first phases of that same model evolving, with SMIC, Grace, Wahong, and others establishing foundries, and we're beginning to see the emergence of fabless companies based in China. For Korea, the prevailing model is vertical integration, with companies achieving great success.

The Asian IT industry seems to have borrowed from the experiences of all of the other regions. Clearly, entrepreneurial energy has played a role in some segments of the Asian market, while the vertically integrated companies played a part in others. A combination of the business models of the US, Japan, and to a lesser degree, Europe has fostered what has taken place thus far in the Asia-Pacific market. Industrial policy has also played a role in shaping the microelectronics industry of this region.

The fabless business model now accounts for about 20 percent of the world's semiconductor market and is growing all the time. I do think there is a limitation that it will bump up against at some stage. I'm not sure exactly where, but if I had to guess, I would say somewhere in the vicinity of 40 percent of the overall market.

There are several other evolutionary changes and trends in the industry that are worth noting.

First, in the earliest days of the IC industry, chip companies of necessity were horizontally integrated and they did everything. Over time, specialized firms emerged to supply a vast array of equipment, materials, and other products, forming an infrastructure for the industry. This infrastructure is very strong and important today, and again is resident around the world. Some of the companies were spin-offs; some were new; and some were divisions of old companies, but nonetheless, the infrastructure built out and made the industry what it is today.

A second phenomenon is the unparalleled globalization of the semiconductor industry. Globalization resulted in a degree of interdependence that is unmatched in any other industry in the world today. I think that is very important as we look at the Nanoelectronics Era in the years ahead. The innovation ecosystem is by necessity a regional system. But it also has as a part of it, a global context. The semiconductor industry's innovation ecosystem is the driving force for the IT progress that has taken place for many years. I cannot stress enough how important that ecosystem is. This innovation ecosystem begins with basic research at our universities, and includes precompetitive research at our companies along with the commercialization, and manufacturing of new products. In the absence of this innovation ecosystem, the continuous progress and advances we've achieved would not take place.

The worldwide web has accelerated the globalization of the industry. Engineers trained in Korea, Japan, Europe or the US may find themselves working in a design lab or a manufacturing facility on a different continent because today they are no longer relegated to any one geography. There are opportunities around the world for them. Virtually every company that is a major player in the industry, has major manufacturing capability around the world. Samsung just announced in the last few days a manufacturing facility in Austin, Texas that eventually will be an investment of some $3,000,000,000. Assembly and test operations are largely concentrated here in Asia. In fact, I came to Korea the first time in 1967 to set up an assembly and test operation here for Motorola. At that stage, one could see there was a lot of promise here, but there was still a long way to go. Now, some 40 years later, it is wonderful for me to come back here and see the progress that has been made in those four decades.

China has become the electronics-manufacturing powerhouse of the world, with about 30 percent of all the semiconductors made today being put into systems made in China. China is clearly the largest market and will continue to be for the foreseeable future. China is also becoming a very large consumer of electronic products, including the world's number one purchaser of cell phones today, and number two or three in PCs, and moving up in consumer products like TV and digital cameras. An important question today is whether China will try to establish standards that will make it more difficult for the rest of the industry around the world to participate in those markets as they unfold. One of the great strengths of this industry has been the evolution of standards that are very broadly based and have allowed many players to become important contributors to the industry.

All of these developments have allowed a very large community around the world to be players in the global IT arena. It's very important that this innovation and competition continues in the future. If you think about it, it's easy to see how an engineer here in Korea could conceive of a device needed for a PDA and send the design concept to a company in Europe, which in turn would design a product to be fabricated by a foundry in Taiwan or Singapore. The silicon chip would then travel to an assembly facility in Malaysia, and be inserted into a circuit board in China, and ultimately sent to a customer in New York. This is the kind of interdependent globalization that is taking place in this industry and one of the things that has made it so strong.

One of the factors that have allowed the IT industry to become so global was the near-universal agreement to eliminate barriers to international commerce in information technology products. Clearly, free fair trade is good for consumers and manufacturers of IT products. The World Trade Organization has long recognized the strategic importance and economic benefits of IT products and sought to eliminate all tariffs on them. Governments around the world have sought to attract investment in IT. The speed at which technology transfers across borders promotes collaboration between companies in different countries. The process that I'm talking about here drives technology transfer. As all of you know well, technology transfers through people, not paper. Access to world-class engineering schools in the US, Europe, Japan, and now Korea and other parts of the world are increasingly an important part of the global ecosystem.

Effective intellectual property protection laws and rigorous enforcement of IP rights is another essential element for this industry to continue to expand and innovate.

Various forms of industrial policies, such as tax holidays, tax breaks, and subsidies will influence site location and investment decisions. However, it is my view that such "constructed" comparative advantage will have limited success if the companies involved do not emerge as important players, or if the rest of the competitors around the world take countermeasures to neutralize industrial policies put in place to distort free-market investment patterns.

The globalization of the semiconductor industry is likely to continue as other nations become players, but it will also help drive other trends in the industry. Research and development is moving outside of manufacturing companies. There's a growing demand for a closer relationship of design and manufacturing as we continue to shrink dimensions and encounter less predictable material performance. That is becoming increasingly important as we go down from the 65-nanometer node to the 45-nanometer node. The predictability that has been a part of the CMOS scaling is far less the case at smaller dimensions. The cost of designing and bringing a product to market is becoming more expensive. New designs today are costing upwards of $50,000,000, so you have to be right the first time.

Centers of excellence located around major research universities will take over the role of Bell Labs. This is an important paradigm shift, and the way we're driving technology in the US.

IP royalty is going to be a much more important part of this business as we move forward. Pure-play IP companies are popping up all over the place. As a consequence, companies that need this technology, will contract with IP companies which will result in a whole new method for implementing new technology.

I believe that as we go down to the 45- nanometer node, we'll see the first indications of how nanotechnology is going to play in this business over the next 10 years. At that stage we'll have some problems that will need the capability that nanotechnology offers.

Going forward it is also clear that we're going to have some problems with power consumption, and that we will have to overcome by utilizing nanotechnology.

Cross-border relationships will be increasingly important. New types of relationships will emerge involving design support, foundry services, and process technology packages. One of the issues we need to keep in mind as we go through this process, is the likelihood that foundries will decide that they want to capture more of the added value that their fabless companies are now getting, by integrating backwards and becoming a part of the fabless foundry business from both sides. If you talk to the foundry companies, they will now say that this is not in their plans.

Manufacturing is going to be the easiest problem to solve for the rest of the CMOS scaling era because it's very tightly aligned with the process technology. The design part is going to be more difficult because the way we are doing the design tools, they're very independent of what the process technology involves. If you look at the capability of the equipment and process technology, it is growing rapidly. The EDA tools are progressing a much slower rate, so the delta between the two is getting larger and is providing opportunities for more companies to become players in the EDA world.

Another thing that will emerge as we go forward is the need for a lot of data warehousing and the movement of that data around the world rapidly and effectively. That will be a huge challenge.

I'd like to close by putting forth some questions for you to think about.

First, of the business models I've described -- the industrial policy model of Japan, the entrepreneurial model of the US, or something in between like the model of Europe – which is most likely to be successful in the scramble for leadership in the nanotechnology era?

Is the entrepreneurial model of the US transplantable? I can't tell you how many people have come to see me from around the world and asked how to start a Silicon Valley in their own country. I don't think you start a Silicon Valley; I think it starts on its own because of the universities, entrepreneurs, venture capital, and other factors. It's not something you can just create.

What is China's role going forward?

Does it matter if the EU resolves its governance issues in some of the areas that are unfolding?

What are the essential elements of an innovation ecosystem that will contribute to a successful IT industry?

Can an innovation ecosystem be global and not just regional?

When will India, Brazil, and Eastern European countries become important factors and what roles will they play in the global IT industry?

Does it matter how the Middle East issues are resolved, and who will benefit and who will be burdened? Will energy policy play a role in the outcome?

How important are cultural differences in contributing to a climate for innovation?

For as long as I've been involved in this industry -- almost 50 years now -- we've tracked global sales of semiconductors and the US has been fortunate to have led this parade for all but a few years in the late 1980s when Japan took over. However, Asia-Pacific is becoming a bigger factor and the question is, who will give ground to Asia-Pacific as their market share continues to grow?

Major innovations in semiconductors such as the DRAM and the microprocessor played a major role in ensuring that US market share leadership continued. The creation of the Internet was a logical consequence of the proliferation of all these technological innovations that came together in the 1990s. But in addition to that, the advances in the life sciences couldn't have occurred without the advances in information technology driven by semiconductors, and as a result, people are living much longer and healthier today.

As Professor Dale Jorgenson, one of Harvard University's foremost economists, has observed, the economics of information technology begins with a precipitous and continuous fall in semiconductor prices. He credits the rapid adoption of IT in the US for driving substantial economic growth in the US and, as a consequence, the productivity enhancements I alluded to earlier. Professor Jorgenson goes on to say that since 1995, IT has accounted for 25 percent of overall economic growth while only 3 percent of GDP. The resulting benefits of that technology have been calculated by the Bureau of Economic Affairs in the US Government. They looked at local, state, and federal government purchases of computing capability over the last 10 years. If the 1995 prices had been in effect the entire time, the cost would have been about $260,000,000,000. As a result of advances in technology and reduced prices they paid about $80,000,000,000, so there's a $180,000,000,000 in savings because of the productivity enhancements and greater functionality that comes with faster and more cost-effective computers.

Further advances are on the horizon. For example, I expect that when the cost of 10 gigabytes of flash memory falls below $50 for rotating memory applications, flash will replace rotating memory. Within five years, we'll have computers that are just flash driven.

Over the next 30 years, there will be a dramatic increases the percentage of the population over 65 years of age in China, and North and South America. South Korea and Japan face the most serious challenges of all. By 2050, nearly 40 percent of Korea's population will be over 65. With fewer workers actively producing goods and services to support larger numbers of retired workers who will consume a high proportion of costly services such as health care, the only practical solution is to drive dramatic increase of productivity among active workers, while applying technology to control the cost of services.

Historically, there's been a lag of about 15 years from the beginning of basic research until the first commercial applications of a new technology. 2020 is less than 15 years away, and by then, nanotechnology must be a mainstream technology if we are to continue progress in IT at the historical rate.

The global scramble is now underway. As a consequence, there is an opportunity for dramatic changes in the world order. Obviously we in the US have a strong desire to maintain the leadership we have enjoyed, but the outcome of this scramble is by no means certain. For our part, we are working to strengthen our innovation ecosystem on a number of fronts. We're seeking a significant increase in the funding of basic research in the physical sciences in American universities to keep them at the forefront of basic research. We're working to improve the K-12 education systems so we will become less dependent on international students to become America's scientists and engineers of tomorrow. Three quarters of the graduate students in the physical sciences of US universities today are foreign born.

Finally, we're working to improve the investment climate for IT Industries in America while opposing measures that would direct or control the free-flow of capital between nations and open markets around the world. Our view is that investment decisions ought to be based on what makes good business sense, not on government industrial policy.

The global scramble for leadership is good. Competition is the greatest driver of progress. While there will be a winner in this scramble for leadership, there will be no losers. We will all benefit from the progress of IT, and people everywhere will enjoy a better quality of life as a result of the continuous process that IT brings to world economy.

Questions & Answers

**[Q]** Throughout the process of this device technology breakthrough, we saw the 1K becoming 4K, 16K, etc., it became increasingly capital-intensive, and many companies could not keep up with it, and as a result, companies had to collaborate together to keep up. During that process, two factors were in play. These two are innovative power of the smaller companies versus the resource and power of the larger companies. And during that process, Samsung benefited in that it had both the resource of the large companies combined with innovative capability of small companies. But we have now reached the stage where it is no longer a question of whether you have one or the other, but you acquire both because of the magnitude of the capital requirements.

So to address your question, can the companies do this, or do you need the industrial policies in back up of the government? I think the question there has to be answered in various ways. First of all as the scale of the next stage of development and the capital requirements become huge, can the economy adjust to specialized sectors so the risk can be managed? If free enterprise can do this effectively, then the market economy will triumph.

**[A]** I think basically that the key question is whether the investment necessary to establish a manufacturing capability in the industry, which is now at $3,000,000,000, will go much higher as we go forward? I don't think it will go much above $5,000,000,000 because we'll run out of time.

If we get to an 18-20 inch wafer, that's going to be the last step just because by that time we'll be down to roughly 10-nanometer technology which will be about the ultimate limit of scaling with CMOS technology. Is it going to be possible for the industries to fund this investment, or will it take government funding for that to happen? I think I agree with the idea that industry can fund this, and I hope it can fund it. And it will do it in three different ways. The large integrated device manufacturers -- Samsung, Hynix, Intel, TI, ST and perhaps a few others -- these companies will be able to afford the investment. They're big enough, have enough product and demand, and they can do it. We then have the fabless foundry model, and the foundries are getting very large, and they'll be able to fund and afford making that investment. I think there is a third one that is going to emerge: there's a very strong likelihood that a number of the large fabless companies will band together and decide that they have enough commonality in their need for technology and manufacturing that they will then establish a manufacturing capability of their own. So I don't think we need the government to get involved in that investment process. The only reason they will be involved is to make sure that investment comes to country "A" versus country "B".

**[Q]** In the Clinton administration, there was a national information infrastructure. You mentioned that with the decline of computing prices, it allows the government to do less with the money, do you think that some kind of selective control with the Federal Reserve to force the IT or biotechnology? Since the first of February, the FTA preliminary negotiations have been going on between the US and Korea, do you think that so far as the IT industry, what is the merit and demerit for both sides of the FTA?

**[A]** On the FTA, I think it's a great idea. We've been very strong supporters of eliminating tariffs on IT products for 25 years. When we first went to the US Government in the 1980s we said we would like to have the tariffs taken off because it just adds to cost, and it doesn't help create a market at all. The government was stunned, but they did so. Then we went around to several other countries and did the same with their governments, and finally got them to agree that it was only a cost that didn't benefit anyone. So I think the FTA is just the next step in that process, and we strongly endorse them. We want to make certain that we eliminate all barriers to the flow of commerce, investment, product, ideas, technology, licenses, and so on. The more FTAs the more that the competition will decide what the costs will be and will continue to drive them down and create that additional productivity we talked about that we're going to have to have as the population gets older.

Now in regard to the Federal Reserve, keep in mind, it has two basic responsibilities. First, to keep inflation under control, and second, to maintain a steady growth in the economy with full employment. I don't expect that that will ever change and consequently I don't think they will ever get involved with the industry or technology.

[Q] How would you evaluate Korea's IT leadership? What is Korea's rank or market share in the world, and prospect for maintaining this position in general, and Samsung, LG and KT in particular? Is Korea considered a big winner or small loser in IT leadership in your view?

**[A]** I think in a word, Korea is doing very well. In terms of market share, Korean semiconductor manufacturers have gone from 6 percent a few years ago to over 10 percent and their market share is continuing to grow. The companies here are very strong from a technology standpoint. In the areas they've concentrated on whether it's DRAMs or flash memory, they're doing just fine. I think Korea has an important role to play in the rest of the CMOS era over the next 10-15 years, but I would guess that they're also doing the things necessary to develop the nanotechnology capability that will allow them to be a major player then as well. That is a tougher problem. I will address that now during this discussion as I wanted some feedback. I think we'll have to spend the next three to five years just looking over the horizon of all the ideas that are out there that would define nanotechnology/biotechnology and how they're going to be cross-functional and how to go about that. And then having thought that through, what are the various ways we can deal with that issue? What materials would be involved, and what device structures look like, and how would they be manufactured? It is going to be a very complex set of issues that need to be dealt with to get started on how to start solving those problems.

One great thing about the semiconductor industry is that we started the technology road map a long time ago, and later enlisted the involvement of the industry around the world. There are about 400 of the best technologists around the world who get together every year and look at this roadmap to see what issues lay out ahead of us. We have to do something like this in nanotechnology as well, but it will be far more complicated and harder to define the first steps of that roadmap, let alone 15 years out as we can do with CMOS scaling today.

So that is going to be the challenge, but I hope it will bring the industries and countries of the world together to work on this important technology because it is going to be so critical to so many aspects of our daily lives. Again, I'll go back to my original point that driving productivity is so critical to our economies and welfare of all our elderly people as we go on.

[Q] As you mentioned, our telecommunications infrastructure is quite mature, and almost 80 percent of Korean households are connected with high-speed Internet access capabilities. Coming from KT, our economy in Korea is quite dependent on the telecom infrastructure and the IT industry. But the next decades have to become dependent on the combination of IT and other industries, but the problem is that the other industries are reluctant to merge with IT industries in some respects. Eventually, we need some convergence, so what are your ideas for the good relationship between these industries, and what do you think the government's role should be in it?

**[A]** I think it's going to start at the universities. I know in the US, the best research universities have interdisciplinary programs that deal with the various technology initiatives, but they also bring into play the business schools. So when you look at how they're structuring the physical and academic programs for these disciplines, they're locating them in the same general area. There is a lot of cross-pollination because of the physical location, but then the course requirements will demand that they have an interdisciplinary approach to their learning process. I think much of this will occur naturally as these areas play off each other, and we will involve everyone essential as we do the work. Again I go back to our roadmap. We'll figure it out as we go along.

The thing that hasn't happened that I've been pushing for about five years is that we haven't yet figured out how to get the consortia from around the world to come together. There is still a hesitancy that is getting in the way of real cooperation and the elimination of duplication that's out there today. Now duplication in the early stages is ok because we don't know the best solution. I think there is a way for it to come together, and it's a complicated problem, but I think we're beginning to move in that direction, and I think we'll get there.

[Q] What would you say occupies you the most as the president of the Semiconductor Industry Association? How important is your work in relation to government affairs, for example? And how much time do you spend with the research communities and universities?

**[A]** That's a good question. Our number one priority where I spend most of my time is on the basic research issue, making certain that we're doing everything we need to do to make sure we get the funding for the basic research. Our view is that this is the responsibility of the Federal

Government, to fund basic research at our universities. But as you know, all governments have many demands on them, and if we don't stay close with that issue and make certain it happens, there's always someone else with a priority that gets in the way. As some of you may know, in the President's State of the Union Address, he made a couple months ago, one of the commitments he made was to address and fund the American Competitiveness Initiative. We were very strong advocates for that being put in the address so that we could get the appropriations and legislation moving this year to get the funding.

The second issue on which we spend a lot of time on is making sure the environmental safety and health that's associated with our manufacturing operations and the materials we have to handle is being done in a way that ensures every worker in the industry is working in a safe and clean environment. This is an international effort. There is an international symposium every year to make certain that the workplaces around the world will be safe and that we are doing the right thing for the environment.

[Q] How do you advise the President of the US and do you have any policy recommendations to give to our President?

**[A]** I just mentioned the American Competitiveness Initiative, but one of my responsibilities on the President's Council of Advisors on Science and Technology was to head up a study dealing with IT and innovation. I presented that report to the President about two years ago and we made it clear that it was something that we had to address. And he did include it in his address which we are very pleased with. I'm now heading up a study dealing with the high-end computing and what we must do to maintain our leadership in that area.