1999 Woodruff Distinguished Lecture
TRANSCRIPT

From POTS to PANS.com

Transitions in the World of Telecommunications for the Late 20th Century and Beyond

Given by
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The George W. Woodruff Annual Distinguished Lecture was established in 1990 to honor an engineer who has made an outstanding contribution to society and to provide a forum for that person to address the Georgia Tech community.

Support for the lecture is made possible by a generous endowment made to the School by the late George W. Woodruff: an alumnus, influential businessman, civic leader, and philanthropist. It is the mission of the Woodruff School to provide the finest education possible so that our graduates can be leaders in society.

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1996	Norman R. Augustine, Chairman and CEO, Lockheed Martin Corporation
1997	Charles M. Vest, President and Professor of Mechanical Engineering, Massachusetts Institute of Technology
1998	Robert A. Lutz, Vice Chairman, Chrysler Corporation
1999	George H. Heilmeier, Chairman Emeritus, Telcordia Technologies
2000	William A. Wulf, President, National Academy of Engineering

George H. Heilmeier is Chairman Emeritus of Telcordia Technologies (formerly Bellcore), a leading provider of communications software and professional services. Prior to announcing his retirement in November 1997, he was Chairman and Chief Executive Officer. Dr. Heilmeier joined Bellcore in March 1991 as President and CEO, and he transformed the company from a narrowly focused consortium to a global commercial business. Dr. Heilmeier, a native of Philadelphia, holds a B.S. in electrical engineering from the University of Pennsylvania, and M.A., M.S.E., and Ph.D. degrees in solid-state electronics from Princeton University. He has also been awarded honorary degrees by Stevens Institute and the Israel Institute of Technology (The Technion).

He joined RCA Laboratories in 1958, working on various electronic and electro-optic devices, and became Head of Solid State Device Research in 1966. His work with electro-optic effects in liquid crystals led to the first liquid-crystal displays for calculators, watches, computers, and instrumentation. In 1968, that effort earned him RCA's prestigious David Sarnoff Award, the IR-100 Award for the most outstanding technical product of the year, and the Eta Kappa Nu Award as the Outstanding Young Electrical Engineer in the United States.

In 1970, he was chosen as a White House Fellow to work on long-range research and development planning and technology assessment as a Special Assistant to the Secretary of Defense. He became Director of the Defense Advanced Research Projects Agency (DARPA) in 1975. He was twice awarded the Department of Defense Distinguished Civilian Service Medal, the highest civilian award given by the Department.

Heilmeier left government in late 1977 to join Texas Instruments as Vice President, responsible for R&D in petroleum exploration, systems technology, microelectronics, and software for TI's equipment businesses.

He has received numerous awards, including the prestigious Japanese Communications and Computers Prize (1990) and three major IEEE awards. In 1991, he was awarded the National Medal of Science by President Bush for contributions to national security and competitiveness. He received the National Academy of Engineering Founders Award in 1992. In 1996, he received the John Scott Award for Scientific Achievements from the City of Philadelphia for his pioneering work in the development of liquid-crystal displays. Previous winners of the Scott Award included Albert Einstein, G. Marconi, Madame Curie, the Wright Brothers, and Thomas Edison.

Dr. Heilmeier is a member of the Defense Science Board, the National Security Agency Scientific Advisory Board, the National Academy of Engineering, the General Motors Science Advisory Committee, the MIT Visiting Committee, and the Board of Overseers of the School of Engineering and Applied Science of the University of Pennsylvania, and he is a Fellow of the IEEE

and the American Academy of Arts and Sciences.

Introduction

[Editor's Note: Dr. Heilmeier used a series of slides to illustrate the points in his lecture. Due to production and space limitations, the slides are not included here. The text of the lecture has been adapted to compensate for the lack of visual references. However, the lecture may be seen in its entirety here on our web page by clicking on the George Woodruff Medallion to view the video.]

It is indeed a great pleasure for me to be here and to be the tenth Woodruff Lecturer.

I have the good fortune to know several of the previous Woodruff Lecturers, not least among them is Chuck Vest. I saw Chuck at an MIT Visitors' Committee meeting a week or so ago, and he offered his views on what I was going to find when I got down here to Georgia Tech. He said, "This is a place where Southern Hospitality is personified. You're just going to have a great day." Chuck was right, I have had a terrific day here. I've met some old friends like Jim Meindl, and I've met some people that I think are going to become new friends.

I can see how much Georgia Tech owes to George Woodruff. In a world in which many people feel compelled to be critics, George Woodruff was a builder, and Georgia Tech is very fortunate to have such a man as one of its benefactors.

Chuck Vest also told me something else about this day. He said, "whatever you do, George, remind those folks at Georgia Tech that George Woodruff was from MIT." I spent the better part of a day with Chuck, and almost at every break he would say, "you're going to have a great time; don't forget to tell those folks down there that George Woodruff came from MIT." I got a little irked about it after awhile, and I said, "okay, Chuck, what if they ask when was the last time the Red Sox were in the World Series?"

I'm told that the title of my talk received a number of interesting comments. I need to tell you, I really was impressed because when I sent in the original title of the talk, one of the admin people called my office and said that we're going to have to make some corrections to that title. I said, "oh, you're going to make corrections?" "Yes," she said. "The way you have that written, it's a URL that's not executable." So, I got the impression that this was going be a tough group. I was impressed with the fact that I could get that kind of critique, but, believe me, I thought it looked prettier the way I had done it, but so be it.

In any event, I'm going to talk about transitions in the world of telecommunications, and the title of the talk is, *From POTS to PANS.com*. How many of you know what POTS means? (Show of hands.)

Good, we have a few Bell people here. POTS means Plain Old Telephone Service. Now, how about PANS. How many people know what PANS represents? PANS stands for Pretty Awesome New Services, and that's really about where we're headed these days.

Let me tell you a bit about the agenda for this talk. We're going to start out talking about transitions in the telecommunications industry. We're going to segment those transitions into three categories: industry structure, networks, and services from POTS to PANS.

Next, we're going to talk about the Internet. How can one give a talk in this day and age about telecommunications without mentioning the Internet? I thought about how I could go about doing this in a way that just isn't a repetition of what you've heard

many, many times about the Internet. So, I decided to focus on those of you out there who haven't made your fortunes yet on Internet stocks. That's why we're going to emphasize the business of the next Internet. Those of you who haven't yet made your fortunes based on the Internet stocks are going to get another shot. We're going to try to take a look at what those next Internet driven opportunities might be.

Finally, I want to talk about the transitions in the practice of engineering because there are many. I'd like to do that from the standpoint of what things are likely to remain the same in the practice of engineering, going forward, and what things are likely to change.

Transitions in the World of Telecommunications

There are three categories of forcing factors, which I believe are driving transitions in the field of telecommunications. One is technology related, a second is competition and regulatory related, and a third forcing factor is customer related. Now, these are not independent forcing factors. They interact with one another, and that makes life very interesting, indeed.

The first forcing factor is technological convergence. What do we mean by technological convergence? Well, we mean computer technology, telecommunications technology, and information and entertainment technology getting together to essentially lead us to a new kind of networked world. Computer technology has been driven by Moore's Law, progress in storage technology, and ease of use. In addition, progress in microelectronics has added the dimension of portability to computing.

Telecommunications technology brings to this party optical fiber, wireless technology, packet switching, Internet technology, new network architectures, Metcalf's Law, and, finally, new network economics.

The third element in technological convergence is information and entertainment technology. It has brought us digital audio, video and data, electronic games, video on demand and streaming video, and the Web and Web appliances.

The second forcing factor is competition and regulatory related. Technological convergence led to deregulation because the old view of the industry, started back when the Bell system was born, was no longer relevant. Regulation didn't make sense anymore, and after several years of fighting back and forth, the industry was pretty much deregulated. Deregulation led to competition, domestic as well as international. It led to some interesting partnerships and teaming between likely partners and unlikely partners. Finally, it made the major carriers, the major monopolies, act more like competitive enterprises with a premium on time to market and enterprise efficiency.

The third forcing factor is, of course, customer-related trends. We're going from POTS, Plain Old Telephone Service, to PANS, Pretty Awesome New Services. People want to behave in this arena just the way they behave with other products and services. They want to pick and choose, and they told us very clearly that they want work-at-home capabili- ties, and home-at-work capabilities. Home at work means the ability to remotely monitor what's going on in your home or your child's school. How many of you, for example, have experienced the same problems that I have: When you and your wife start out on a trip and your wife says, I don't know whether I turned the oven off. I've made many trips back to my house to check on that. For me, it's the garage door. I'm always thinking I forgot to put the garage door down. Home at work is also the world of online appliances that "talk" to each other as well as provide inputs to real people.

There's also personalization. People want things that they can personalize. People are beginning to become very interested in E-commerce, and joining E-commerce will be E-Services. Video and entertainment are also part of the new service portfolio. Finally, people will expect concierge-like customer care because the real differentiation going forward in this industry is going to

be on the customer-facing side, not the network-facing side of the business. There won't be captive customers anymore. People buy based on price, availability, and features just like they do in other competitive industries.

Let's turn to the industry itself and examine the changes that it is undergoing. First, this industry is undergoing a change from a de facto monopoly environment to a competitive, unbundled industry. It's going about doing it about fifteen years after the computer industry began to unbundle. People talk about the Bell system as being a monopoly, but I think you have to reflect on the fact that back in the early 1970s IBM still had about an eighty-five percent market share. So, let's face it, there was a de facto monopoly in the computer industry in those days.

Most of the companies were vertically integrated in the telecommunications industry as well as in the computer industry. Well, that's changing. The telecommunications industry is now becoming more horizontal in its structure. Network architecture is becoming more open. So, like the PC and computer industries earlier, we're now undergoing similar changes.

From the standpoint of new capabilities, in the past you got what the carriers told you that you were going to get. In other words, the Bell companies were not like Burger King: You didn't get it your way, you got it their way, or you didn't get it at all. Well, that's changing because new capabilities now, just like the PC industry, are coming from start-ups, customers, and other third parties, in addition to the traditional service providers. When I reflect on the PC industry, I can't recall any major PC company that produced an application software program that was a big seller. Practically all came from third parties. The same thing is likely to happen in the telecommunications industry. The interesting thing is that you would have thought that the telecommunications industry would have learned from the PC industry that the best ideas are likely to come from people who are outside of their sphere of influence. They had the opportunity to do that. It was called the advanced intelligent network (AIN). Software that operates switches was "unbundled" from that which managed new services. We didn't learn the lesson. Instead of agreeing to a common service creation environment that could have had the power of DOS in the PC world, carriers decided that they really needed to "differentiate." This meant each company had its own service creation environment. This meant that a new service had to be done seven times to provide nationwide coverage. Of course, this extra difficulty seriously limited the number of really exciting new national services that emerged.

Networks are the second major area undergoing major transitions. We are going from a circuit switched network environment to a network that is mixed. Packet networks are growing rapidly, but there will also be a great deal of circuit switching around for some time. I don't think anyone should feel that the "hypemeisters" are right in saying that the next generation networks, which are just about upon us, are all going to be pure IP networks. Circuit switching will be around for a long time, coexisting with packet networks. I suspect that some people are going to have more difficulty than they are willing to admit in building a pure IP-based multipurpose, broadband network that handles voice as well as video, while meeting their very aggressive economic and quality of service projections.

It used to be that the control of the network was centralized. Well, now it's rapidly becoming more distributed. ATM and SONET are the technologies that essentially drive the current backbone network. The backbone network of the future is likely to be IP, ATM, and SONET based. It could very well be that ATM will drop out of that combination some time in the future as dense wavelength division multiplexing emerges. The networks in the past were servicespecific. The telephone network was a separate network as were data networks. In the future, we're going to see the advent of broadband multipurpose networks. One network carrying data, video, and voice, but they are unlikely to be pure IP networks

Access technologies. If you read the right telecommunications press these days, you think that picking "the" right access technology is the most difficult problem facing the industry today. By access technology, I mean the technology by which you get from the customer to a network access point Š the so-called "last mile" problem. In the past, one technology dominated Š twisted pair. Now there are at least six others. There's ADSL, cable modems, fiber to the home, fiber to the curb, hybrid fiber-coax, and various forms of wireless technology. Which one will win? They will all win after a fashion. There isn't one single

access technology that is going to sweep every single network. There are at least seven today, and there will be seven for the future.

Transmission technology today consists of optical fiber, wireless, and copper wires. The same technologies are going to play an important role in the future. The balance between them will certainly change. What we will have, in addition, will be dense wavelength division multiplexing. This is a technology that can support multiple optical wavelengths on a single fiber. It's a way of increasing the capacity of the network without essentially adding more fiber.

In customer premise equipment, the old "black telephone" will still be around. It is simple and "dumb." Customer premise equipment in the future will be highly functional. It will not only be PC-based, but will also include information appliances of various types.

Today, in spite of all the progress that is being made, operations are still technician intensive. In the future, they will be software intensive, and, indeed, excellence in software technology will be a core competency of the largest network operators. A large network operator will have to be, in large measure, a software company. Testing will also be software intensive. Testing in the future will be proactive and nonintrusive in contrast to the routine, intrusive testing that we do on networks today.

Finally, there's the issue of security and robustness. Today, we manage that reasonably well. The circuit switch networks really have set our expectations very high for network reliability, security, and robustness. If the network of the future becomes a network of networks heavily dependent on IP technology, the question is whether network security, at the same level we enjoy today, will be manageable. At this point I don't know the answer to that question.

In service activation, instead of calling and having an agent mediate your service activation, in the future service activation is likely to be self-service and software driven. It's kind of interesting to read about ADSL and its availability. But call up and try to order it.

Finally, one of the major problems is billing. Today billing systems are large, cumbersome, and inflexible. The typical billing system for a carrier might cost several hundred million dollars. In the future, billing is going to change. It's going to be one of the major differentiators. It's going to be merged with marketing and customer care. It's going to be in real time, featuring real-time rating and discounting and support for the flexible bundling of services.

Challenges and Predictions

In the tradition of David Letterman, let's examine the top challenges facing this industry. I've segmented them from the standpoint of their relative importance or impact on the industry versus the relative difficulty from a technology, cost, or cultural standpoint in implementation.

Number eight on my list would be the local loop, and that's the one that gets the most attention in the press. Are you going to bring fiber to the curb or fiber to the home? Will ADSL beat out cable modems? From a difficulty standpoint, I would say it's moderate, but it's only number eight on the list.

Another favorite of the trade press is voice-over IP or Internet telephony. That would be number five on my list. I think the technical difficulty has been underestimated. I think it's going to be a much tougher job than people think to deliver circuit switched network voice quality to meet customer expectations over an IP network.

So, what are the top challenges? Well, the top challenge in my view is network robustness. How do you make a network that is

as reliable and robust as the circuit switch network when it's going to be carrying primarily packets? You either have a robust network that's reliable, or you have nothing.

The second challenge is billing. We will have Pretty Awesome New Services (PANS), but if you can't bill for them, what does that mean from a commercial standpoint? You cannot take months to modify a major mainframe billing system that was built on software technology that's probably twenty years old. I've known companies who have paid several hundred million dollars for a billing system. And I know one company that paid close to three hundred and fifty million dollars for an internally developed billing system that would be flexible, and enable people to change and add new services quickly. Unfortunately, they paid three hundred and fifty million dollars for the development and didn't get it. This is really a very difficult problem.

My number three challenge is quality of service and fourth on my list of top challenges is customer care. There will be so many network service providers out there, so many alternatives for the customers that the way a customer is going to select will be driven by the quality of customer care that they receive from company A versus company B, or others.

Now for a few predictions. Prediction number one, the network of the future is going to be less robust than the circuit switched network of today. Second, I think network embedded services are going to become a major business opportunity. Third, I believe that concierge-like customer care and concierge-like directory services are a major "silver bullet" opportunity. My fourth prediction is that Internet telephony and Internet interactive video are never going to reach their full potential on a pure IP network. There are two major companies out there now whose stocks sell at very high multiples of revenue(!) and have "obscene" valuations, who would like Wall Street to believe that they are building all-IP networks. They get uncomfortable if you point out that they are building an IP network riding on ATM. They don't want to talk about the ATM part of it. In packet networks, there is a problem with predictable delays. To fix that problem, you have to do things that add cost. Of course, one of the big selling points with respect to packet networks is that they'll be less expensive to build and operate. I have a final prediction, and that is that you may be happier if you bought the stock of many of these new network operator entrants rather than their service.

I want to talk a little bit about what's happening in the computer industry. The computer industry, particularly the PC industry, has been operating on the premise that more sophisticated software requires more sophisticated hardware, and more sophisticated hardware essentially enables more sophisticated software. But that's going to change. There's another seat at the table. Sure, hardware is still there too, and software is still there, but now bandwidth is there. At Compaq, we don't build any computers these days without considering the issue of networking and bandwidth. We invest in cable companies to improve their networks so that they can support high-speed access because the big market going forward is for computers that have the ability to access the Net and other machines quickly and seamlessly, while supporting high-speed access. This has significant implications, in my view, for the PC industry.

The Business of the "Next" Internet

When we talk about transitions, as we just have, the Internet may be the biggest happening of all. I'd like to talk not about the current Internet, but the "next" Internet. Wayne Gretsky always said that he doesn't skate to where the puck is, he skates to where the puck is going to be. We are going to try a little bit of that this afternoon. We are going to try to look ahead and see what the business of the "next" Internet might be like. My problem is that I don't think about "one" Internet. When I think about the Internet, I think of at least five Internets that ride on a common platform. That platform has several things in common from network to network. It's a packet network, and, eventually, it's going to have to support bandwidth on demand, multiple levels of service quality, and audio, video, and voice-over IP.

The first Internet was a research and education Internet. When I was at DARPA in the mid-1970s, we were building the first IP

network, which eventually became the Internet. Everybody kept saying, we're building this network for research and education purposes. Well, we did a little study on the traffic. What we found was that some people were using it for research and education, but other people were using it for people-to-people communications or e-mail. That was the second Internet.

The third Internet was one that offered entertainment and games on one hand, but let's not fool ourselves, erotica on the other. People tell me that erotica represents roughly as much as twenty percent of the traffic in accessing Web sites today. Erotica really drove the early days of home video recording. Whether we like it or not, erotica seems to play a significant role in some new technology developments. The Internet and Worldwide Web are not exceptions.

The fourth Internet is the one that's featuring E-commerce and eventually E-service. This is a very hot area now, as you know. The interesting thing is that nobody seems to know how to make any money out of this. There are lots of start-up companies and a great deal of profitless prosperity at this time. Finally, I don't think it's going to be too long before we see a fifth Internet that is a machine-to-machine Internet, that is, "appliances" of one kind or another online "talking" to each other. Imagine having a Coke machine that automatically reports back when it needs to be serviced or when it needs to be refilled. That is one class of applications enabled by online machine-to-machine interaction.

I've always been interested in metaphors in my career because I found that metaphors are a great way to understand new things. They help me gain new insights, and they also help me to think "out of the box," so to speak. I think they help people understand new products and services. So, if you look at the Internet today, you ask yourself the question, if TV was radio with pictures, what is the metaphor for the Internet? My view is that we're going to be searching for a single metaphor for the Internet, but I'm not sure we're ever going to find it. It won't stop people from trying, however.

A few examples of metaphors for the Internet include the Internet as a dialtone for data, or how about a dialtone for information, or maybe even a dialtone for knowledge. Maybe it's a dialtone for machine-to-machine calls. Perhaps it's an "information mall." Maybe for some people it's electronic catalogue shopping, for others it's the electronic printing press for publishing and distribution. Some people will look at it as a customized community; the real "friends and family." My favorite metaphor for the Internet, however, is an "information utility." Now, why an information utility? Well, all utilities have certain functions which are common to them: generation, transformation, storage, transmission, distribution and access. You can fit the functions of an information utility into this class. For example, with generation, we can talk about publishing, commerce, education and research, and entertainment. Those are the kinds of things that essentially, "generate" information. How about transformation? We tailor our transmissions and distributions to the media that's available to us. We work with a variety of formats, depending on the media. So, as you look at the functions of a generic utility, you see them repeated in the information utility context. We are not likely to find just one metaphor for the Internet, but, from my standpoint, an information utility probably comes as close to a single metaphor as anything.

One of the major players in the Internet/Web revolution today is the Internet service providers, the ISPs. These folks really represent the gateways to the Internet, and a very interesting business to be in. The network subscribers are doubling roughly each year. The capacity of the network is quadrupling. There are roughly four thousand ISPs out there trying to get your business as a gateway to the net. The largest ISPs in the country last year grew several hundred percent. But there is a problem, and the problem is that these folks do not scale efficiently to accommodate increased demand. If you want to stay in this business, you must invest big dollars. Help desk costs are cannibalizing the business from the standpoint that as less and less experienced users get online, they essentially need more help, and the ISPs are the first people they call. A good service desk is expensive to operate and one that most ISPs are really not prepared to handle very well. There are also quality of service issues, which many really haven't dealt with very well. If you put all this together, not just the opportunities, but the problems, there's a word that comes to mind, and that word is shakeout. Shakeout, consolidation, and survival are the watchwords of today's four thousand ISPs.

Today's ISPs provide access. Oh, a few of them do some other things. For example, a few of them will do Web site hosting, a few are capable of Web site design and implementation, and some of them will offer server operations and maintenance. But for survival, they are going to have to "morph" themselves into what I'll call ESPs, enhanced service providers.

ESPs are the folks who are going to offer value-added network services; services that are essentially embedded in the network. From the standpoint of data, they might offer local caching of high-hit sites. That's one of the things that @HOME does. They might manage security for you and your local network. They could handle authentication, data compression, provide you with a virtual private network, remote access, data warehousing, and a whole raft of things that today are essentially done at the edges of the network by users. Tomorrow they could be offered in the network, by network operators providing a network centric solution.

It is my view that all four thousand ISPs are certainly not going to survive. The ones that do survive are going to be the ones that "morph" themselves into ESPs. Those that remain will be large, and they'll be profitable because the profit is not going to be in just providing access. The profit is going to be in the network embedded services.

As we look at corporate networks today, we can ask ourselves if the ESPs could support a major paradigm shift. For the most part, corporate networks today are owned, operated, and maintained by corporations. Almost every CIO (chief information officer) that I've talked to would like to get that burden off his or her back. They'd like to think of the corporate network as a rentable resource. Who might provide that? The ESPs might have a shot at doing that, but to do it, they are going to have to be able to provide the customer with oversight capabilities for that rentable resource regardless of where the routers reside. They're going to have to provide the customer with voice-like data quality and reliability; not an easy task at all. They're going to have to provide you with network monitoring and billing systems that can support guaranteed levels of service. In other words, the network operator who's providing you with that rentable resource has to provide tools so that you can make sure that you're getting what you pay for. And, once again, if the network is a rentable resource, the network has got to offer solutions that are embedded in the network, not solutions that the CIO and his staff have to build and maintain.

These are some very, very difficult problems. Are the ESPs of the future going to be up to working them? Some will, but the ESPs will be more than just small businesses. The ESPs will be larger companies, and they will have the sophistication to offer a corporate network as a rentable resource.

I would now like to discuss some business opportunities built on some very sophisticated technology. The theme is turning necessities into differentiators. In my view, the elements of the network, for example, switches and routers, are essentially necessities. Network operators are unlikely to be differentiated by their routers or switches. In a similar manner, no one is going to be differentiated based on software systems that operate the network. Such systems will be widely available, as they are for circuit switched networks today, and anybody that can afford them can certainly buy them from companies like my old company, Bellcore.

The real differentiation going forward is in the two higher levels of the TMN model of the network, and they are service management and enterprise management. The things that I think are going to lead to major business opportunities down stream are in the areas of concierge-like customer care, concierge-like real-time billing, and concierge-like directory services. This is where differentiation is going to be found in the future.

As you may recall, customer care was my number four challenge. Today, customer service is viewed by most companies as an expense. It's order taking. It's questions. It's the complaint department. The metrics are all inward focused. For example, How many calls were handled per day? How long did the customer stay on the phone? Those are internal metrics, essentially indicating that this function is being treated as a necessary evil of the times. Then along came call centers, and businesses think that this is a great way for customers to connect with their company and save some money. For example, you are

presented with a list of fourteen items, and you have to remember all fourteen. Then you are asked what service you want to select. This is an abomination. When you do get through, you have never talked to a real person. I can't tell you how many times I've heard my wife say, "is there anyway that I can talk to a real person? I keep getting voice mail or voice messages from the call center." What's happening now is that businesses are becoming so conscious of this that they outsource it. Many don't even do it in-house anymore. It is very expensive to have real people on a hot line because sometimes customers can get very nasty when they get frustrated, and it's not the kind of job that people want.

What is the edge for concierge-like customer care? Well, of course, there's the opportunity to provide exceptional handling of customer problems by harmonizing voice, e-mail, fax, and web-based engagements with a customer. The customer reflects the mode or modes of interaction. But one can also anticipate customer needs, and problems, and learn from his or her customers. For example, build lists of customer care-abouts and proactively offer ways to improve satisfaction. One can increase customer loyalty, which is a huge problem for the telecommunication industry today. People shop for different services every day. Prices change, and then they jump to another carrier. This "churn" drives a signifi- cant amount of expense. One can also segment his or her customer base and chart attitudes and customer-specific needs. One can target products and services to specific customers based on usage patterns and offer them incentives, like bundling services. For example, we call Dallas a great deal because our kids and our grandkids are there. If there were such a thing as a company that offered concierge-like customer service, we would have a service provider note our many telephone calls to Dallas and offer to make calls to Dallas made on Sundays free if we buy their cable TV or cellular phone service. That's what I mean by bundling services. Studies have shown that if a customer buys more than one service from a carrier, he or she is twenty percent less likely to churn. Churn is a signifi- cant expense that network operators would like to minimize or avoid.

Billing was the number two challenge in our "Letterman List." Today, billing systems are large, inflexible software systems. They enter orders, calculate and print bills, but they are a static function of price, billing method, etc. To introduce a new service requires modification of the billing system and this takes time. Looking forward, we can see the billing system that is client-server based, rather than mainframe based. We can see it operating on real-time information and real-time conditions. If successful in offering a concierge-like real-time billing system, the opportunity to harmonize customer care, marketing, and billing presents itself. This would be a very flexible enabler of rapid response to market conditions. One could change service bundles and immediately bill for them. The ability to dynamically change rates and service bundles is a powerful tool to attract customers and retain them. Customized billing services would also be possible. The customer could determine the billing mode and how the service is budgeted. The customer may want to spend no more than a hundred dollars a month on long distance calls, and it would be possible to keep the customer informed of how well he or she is doing against that budget. Personalized discounts would also be possible, as I mentioned earlier. Service providers could also cross-market products.

You may have heard that when MCI introduced "Friends and Family," it took several months before AT&T had a competitive offering. Why? Billing system problems. So, you can see how important real-time concierge-like billing services really can be in a world where there are lots of network operators out there, and they are all very competitive.

The third opportunity for differentiation is concierge-like directory services, or as I like to call it, one-on-one marketing. Today, we have printed directories, or we have something like Big Yellow, which is online. Big Yellow is little more, in my view, than electronic page turning. These are dedicated systems, and they provide basic information. Information systems technology is enabling exciting, new on-line opportunities here. You could build constraint-based search systems. For example, if I'm having a transmission problem in my car, I go to the Yellow Pages. Normally, I would ask for transmission repair shops. In a concierge-like constraint-based search, I could say, "I've got a transmission problem. I need to be referred to a transmission shop that can fix it in two days, is open till 8:30 at night, and has a loaner car for me. I don't want it to be any more than five miles from my home, and, oh, by the way, I don't want to go to any transmission shop that has had more than three or four Better Business complaints against it." Now, in some areas, it might be pretty tough to satisfy the latter constraint, but the interesting thing here is that a constraint-based search offers a new spectrum of business opportunities. My model of this business is based on a

sophisticated data warehouse, data mining, and data farming capability. As a business, one gets paid two ways. Businesses who want to be part of your service will pay to be part of the service. On the other hand, users of that service will also pay to use the service. Over the next several years we're going to see the emergence of concierge-like directory services and one-on-one marketing. Those, along with flexible, real-time rating and discounting billing systems and concierge-like customer care are going to represent major opportunities.

I can't leave the topic of the "next Internet" without talking about search, because in the Internet world, search is a core capability. Today, it's like a bus that gets you within a mile of your destination. Most of the search techniques are based on one kind of word-matching scheme or another. For the most part, it's document retrieval, and some of the documents are not even relevant. We're going to see search engines based on concept- or context-based search that support inference and deduction. Instead of mere document retrieval, we're going to have systems based on a query/response paradigm.

There's a site on the Web called, "Ask Jeeves." This is a query/response type of system. It may ask you some further questions in order to narrow the possible answers. This is a very primitive next- generation search engine, in my view. Go look at it (AJ. com). I think you'll find it kind of interesting. It may not have quite the right technology yet, but I think you can begin to see the power of the query/response paradigm, rather than a keyword retrieval system.

There's several other aspects of this. Today, we do text-based search. It won't be too long before we'll not only be able to do text search, but audio-based and image-based search. Show me all the pictures of bomb damage in Yugoslavia, for example; hum a song, and have the system respond by telling you what the name of the song is. That's what I mean by a search that goes beyond just text.

There remains the key question about browsers and operating systems. Microsoft says that browsers should be integrated with the operating system. Others contend that they ought to be harmonized with the operating system. Who wins? Only time will tell. But in the future, I think it's inevitable that browsers and operating systems are going to be integrated, and the thing that's going to be harmonized is latent semantic indexing technology. Latent semantic indexing technology is a key component, in my view, of the search systems of the future with all the attributes that we have just discussed.

What about the Internet stocks? They remind me of the Great Oklahoma Land Rush. It used to be the companies that had more than fifty percent market share made a lot of money. It is a principle taught to everyone in business school that market share drives profitability. If you look at AOL, they have more than fifty percent market share and just started making a few pennies, and yet its value is over two hundred times revenues!

There's Yahoo. At this time, it is, perhaps, the premium portal on the Web, and it is selling for more than a hundred times last year's sales! Amazon.com has a market cap that is way above two billion dollars. That means that it has a market cap which is over fifty percent for the total of all the book sellers in the U.S. It operates at a loss, and nobody knows exactly when they will make any money.

In my view, what's happening in the market for Internet stocks is similar to the Great Oklahoma Land Rush. The interesting thing is that people do just what they did back in 1889. You stake a claim, and then you worry later about what you're going to grow.

Amidst all of the exitement, there may be nontechnical things that could represent "speed bumps" in the world of the Internet. Basically people like to own "stuff," and people like to touch and smell and taste "stuff." People like simple "stuff," social "stuff," and getting "stuff." I get on Amazon.com and buy books, but I would much rather go to Barnes & Noble and browse around. I meet some interesting people, I get a feeling for things that I probably wouldn't have stumbled on. I go to book stores for

different reasons, even though Amazon.com might be a better deal. There may be some aspects here that I don't think we have really fully understood. The predictions today are of continued explosive growth in the Internet and the Web. I wonder whether the "speed bumps" will have something to say about this.

Transitions and the Practice of Engineering

Just as there are transitions in the world of telecommunications that are enabling new businesses and new business models and changing the way we live, w ork, and relate to each other, there will be transitions in the practice of engineering. I'd like to look at these from the standpoint of things that I think are going to change in the practice of engineering and things that are going to remain pretty much the same.

You know, as much as some of our friends in Silicon Valley would like to repeal it, I don't think there's any sunset clause for the scientific method. I'm old fashioned. I think we ought to collect data and then draw conclusions. If you reflect on some of the things that are coming out of some start-ups these days, that's not the way it is. You draw conclusions, you make claims, and once somebody's interested, you try to go out and get some data. That is not the scientific method, ladies and gentlemen, and that borders on questionable ethics and integrity. Selling people something that you know doesn't have all the features that you've advertised, is a question of ethics and integrity. The need for ethics and integrity in the profession simply isn't going to change.

The "catechism" isn't going to change. It is a series of questions that I've used in trying to lead research and development activities in the business world. The first question is: What are you trying to do? The second question is: How is it done today, and what are the limitations of current practice? The third question is: What's new in your approach, and why do you think it can succeed? The fourth question is: Let's assume that you're successful beyond your wildest dreams. Who cares? What difference does it make to a customer? The fifth question is: What are the risks, and what are your risk-reduction plans? And the sixth question is the old "blocking-and-tackling" question, meaning: How long is it going to take, how much is it going to cost, what are the mid-term and final exams? The "catechism" is not going to change. Those questions are too fundamental.

I think another thing that isn't going to change is the need for a fundamental, physical feel for systems. Amidst all the computer modeling, and simulation that we do these days, we've got to have some basic, physical feel for what the simulations and models are telling us.

There's also the whole issue of interpersonal relationships. There are many people in our profession these days who sit at a workstation all day. The workstation becomes a kind of idiot savant and substitute for interpersonal relations. We forget that there really are personal interactions that have to take place. If we really want to gain acceptance for our ideas, designs, products, and services, we must recognize the continued importance of interpersonal relationships.

The fundamental importance of cost, schedule, and features/performance in running an engineering program is not going to change. You are always going to manage all three, but you can only constrain two of the three. The trick is to find out which two of the three the customer really cares about and will agree to constrain. I can't tell you how many times I've had clients tell me that they wanted to constrain cost and schedule, when what they really wanted to constrain was schedule and the features or performance. So, here again, you can manage all three, but you can only constrain two of the three, and you've got to figure out which two of the three are the things that are the most important to constrain.

Another characteristic of a successful engineer, that's not going to change is the ability to sense the coupling between seemingly disparate issues and ideas. That's one of the characteristics of a creative engineer. It's not going to change. It's still a very important aspect of this business.

Finally, innovation isn't going to change. There are some who feel that any invention or significant change is an innovation. The real definition of innovation is to take an idea and make it a business success. Liquid crystal displays were an invention in the 1960s. They didn't becomean innovation until the late 1970s when they became a business.

Just as there are things that are not likely to change, there are things that will, indeed, change. We are likely to see even heavier emphasis on modeling and simulation; heavier emphasis from the standpoint of incorporating heuristics and nonlinear models. I think object-oriented methodology is going to be extremely important, especially in the context of modular software designs. We might reuse modules and assemble software systems instead of starting from scratch with every system. We can do that if we have the right kind of object libraries.

We generally don't teach programming in the schools today. When we hired programmers at Bellcore, we had to put them through a "software boot camp" because, in too many cases, what comes out of the universities today are people who are, more or less, schooled in the "hacker" way of doing software. You can't be in the business of building large, highly reliable software systems using that methodology. Coupled with that comes the philosophy of "late binding" systems, as well as the concept of software architecture. A software system architecture should be the first deliverable in a software system.

I think that, in many cases, technology transfer is a misunderstood concept. When some people think of technology transfer, they think of giving a presentation or writing a final report and letting somebody take it from there. Well, someone once said to me that technology transfer is a contact sport among consenting adults, and it really is. In the future when we talk about technology transfer, it's going to suggest that perhaps you did the work in the wrong place in the first place. The best way to "transfer" technology is through technology harmonization and multidisciplinary teams, and more and more, that's exactly what is happening in industry today.

In many cases, I think we're going to see some changes in the way that we design. We are likely to be more willing to trade off performance and efficiency for our ability to manage complexity. We've never done very much of that, but I think it's going to become more important as we go forward. Finally, as we discussed at lunch, this profession is a profession like many others that are going to require lifelong learning skills. You're not going to be able to succeed in this world with an education that isn't constantly being upgraded.

Without a doubt, engineering education will see some changes as well as some things that will remain the same. Certainly, the Internet has made it much easier to store and deliver information. There are, however, aspects of formal education that students find most valuable that have little to do with the delivery of information. They have everything to do with direct personal contact with professors ... someone who has opened your mind, changed how you viewed the world, or guided you in testing a hypothesis. Those are the priceless aspects of education. You can't get them over the Internet, and you can't get them over the Web. To be sure, the Web and Internet are important in lifelong learning, but universities can't substitute them for direct contact between students and faculty. At MIT, a little over a week ago, the administration talked about the investment they are going to make in their own Intranet to supply the students with more access to teaching materials. The administration was very excited about this. Do you know what the students said? They said, why don't you save your money and hire more teaching assistants. The students understood what's really important to them, and it wasn't getting better Web sites and better information delivered over the Intranet at MIT. The bottom line for formal engineering education, in my view, is that we must figure out what aspects the virtual university can't deliver and focus on them. Those will be the things that the more successful engineering schools of the future will do well.

A Final Thought

This lecture has been an attempt to look forward. As such, it included a heavy dose of predictions. I'd like to leave you with a

final thought: Niels Bohr once said that predictions are always difficult, especially about the future. I'd like to observe that it's much easier to predict the future than it is to change the past.

This has really been an exciting day for me. I very much enjoyed having lunch with the students. Ward, you've been a terrific host, and Georgia Tech certainly has opened my eyes. I'll always have fond memories of this day. Thank you all very much.

Question and Answer Session

Q: I'd like to pick up on two of your ideas and challenge a third, to piece it together and suggest that engineers need to become information hunters. The two ideas, one is that there's a vast wealth of information coming with the tools to get at it. Second, you said it's important to be a coupling center to see how things connect, but I'd like to challenge the NIH syndrome idea. I think it's going to be vital for engineers to know how to get beyond the immediate information within their company or their discipline, and make the links with the high value end.

A: You're quite right that we have a raft of means to get information almost on demand. I don't think that changes the NIH factor. People don't change all that easily. Some are very proud, and the NIH factor, in my view, has corrupted the meaning of the term innovation. As I said in my presentation, some people do not think of innovation as an idea that becomes a business success. They think about changing something. They think about modifying something, not necessarily in the context of trying to create a business success. That comes under the NIH banner, as well. When I was at Texas Instruments, semiconductor manufacturing process development was one of the activities that reported to me. At that time, TI Japan had much better yields than our factories in the United States. I can remember we developed a process for the 256K d-ram in the United States, and we sent that process to our factories in Japan. It didn't yield worth a darn. What we found when we finally got to the bottom of this, was that our colleagues in TI Japan had changed the process to "improve" it. The process in the pilot line was yielding just great. The process in the fabs in Japan wasn't yielding worth a darn. We finally found that they had changed the process but didn't tell us about it. At that time, the Japanese were just essentially sweeping the industry. I thought, aha, we have found their Achilles Heel. They've contracted the American disease; it's NIH.

Q: With the recent release of the Pentium III and the ID numbers that Intel placed on their net, there's been a lot of discussion about privacy and security in networks and information technology. I was surprised that nothing like privacy or security seemed to make your top ten list. Could you comment on that and where you see that direction going?

A: I think it did make the top ten list, but it did not make the top five. I think there are straightforward ways of handling information security by encryption. I think the real security issue is network security. This is a more complex issue.

ANNOUNCEMENT

The George W. Woodruff School of Mechanical Engineering
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2000 George W. Woodruff Distinguished Lecture

Will Be Given By

Dr. William A. Wulf

President
National Academy of Engineering

Tuesday, April 25, 2000
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