1992

DATAQUEST CONFERENCE

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October 5-6

Semiconductor Conference

"Fueling the Engines for Growth"

Conference Transcription

Dataquest®

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Welcome & Semiconductor Industry Forecast

Gene Norrett
Principal Analyst
Director of Marketing, Semiconductor Group
Dataquest Incorporated

Mr. Norrett: Well, good morning, and welcome to Monterey. My name is Gene Norrett, and I'm Vice President and Director of the Semiconductor Group at Dataquest. On behalf of our forty-or-so people that are spread around the world, I'd like to welcome you to our 18th annual conference in semiconductors, and our most prestigious at Dataquest.

The theme of this conference is "*Fueling the Engines for Growth*," and I'm sure you're wondering why we picked that theme. Well, at Dataquest we believe that the relationships between the semiconductor vendors and their suppliers and customers are very interdependent. And as such, they depend upon each other saying it another way. These industries' success will depend upon how much value these industries provide to each other. We thought it was really important for us at Dataquest to have a conference and talk about the engines or high volume products these industries are manufacturing, and how these engines, in turn, become the fuel for their downstream customers' products and services. Because of the importance of the electronics manufacturing industry worldwide, we think it's also important that we spend time thinking about the issues affecting these critical manufacturing industries, and discuss these issues in depth.

As you walked in here this morning, I'm sure some of you saw on the screen here some of the semiconductor applications or engines for growth that are existing today in the marketplace. We also have included some really interesting ones, we think, will drive tomorrow's industries. And tomorrow morning, Joe Grenier, who is the director of our semiconductor applications and equipment and materials services, is going to talk to you about some really very unusual applications. The ones that you see here this morning are rather traditional applications, but I think it will be kind of humorous to hear some of the things Joe has been able to unearth about where semiconductors are going, and what are those applications doing.

To discuss all these applications and these engines for growth, we've assembled, we think, the finest group of industry speakers that Dataquest has ever had. They're going to share with you their perspectives, their real-world experiences, and hopefully their visions for tomorrow. That's really what it's all about. I think talking about history is interesting; but talking about the future is where it is at.

We have pulled together about 35 executives from the various industries to come to talk to you here about their thoughts on these very important topics and these very important times. I believe this will be an excellent opportunity for us all to sit back and give some thought to where we're going in the industry.

Attending the conference, we have approximately 315 outside attendees, and as you look around, you probably say to yourself, "Are there really 315 in this room?" The actual number is 350 including the personnel. The demographics for the attendees are as follows: We have 5 chairmen, 31 presidents and CEOs, 88 vice presidents, and 56 directors—a really senior group, and we thank you.

The attendees at this conference represent approximately 37 systems companies, 49 semiconductor companies, 44 equipment and materials, as well as assemblers, 10 financial companies, 3 distributors, and 11 members of the press. We believe this is also an excellent distribution of the attendees, and we like to have good intermingling between the industries that we're focusing on in this conference.

Let's take a few minutes and look at the agenda that we're going to have for this conference. We have arranged for fifteen 25-minute-or-so presentations covering the most critical factors in the electronics industry today. These are spread out over the next two days so that we didn't have a concentration all in one day

Secondly, we have planned for two interactive panels where we hope to see a lot of interaction from not only the panel members but from you folks in the audience. And we've picked what we think are two really important topics: The first is the future of the ASIC and ASSP industry. This panel will be moderated by Bryan Lewis, our senior industry analyst covering this very important industry. Tomorrow will be our second panel, moderated by our senior industry analyst, Ken Lowe. The topic of his panel is The Strategic Microprocessor Trends and Open Systems Computing Issues. We have assembled for these panels 10 very senior people in the industry.

The third portion of this conference is our four focus breakout sessions. You will be able to attend only two of these. We are showing these first four sessions at 1:30 on Tuesday afternoon, and then we'll repeat them again at 2:20 in the afternoon. But don't be alarmed—you'll be able to buy the transcripts from the other sessions that you missed, and all you need to do is speak to our staff and they'll be glad to arrange that for you. These topics are Manufacturing Trends, Personal Information and Communications Devices (PICDs), Procurement Issues, and of course Multimedia.

The fourth segment of this conference is our keynote speaker, David Packard. Dave is cofounder, as you know, and Chairman of the Board of Hewlett-Packard Corporation, and we are very, very pleased to have David with us. He is an outstanding individual, and I'm sure the points that he is going to make this evening will stick with you, as they have stuck with me in various meetings I have had with Dave. He will be speaking after our dinner this evening in the De Anza Ballroom.

Lastly, in our program we have planned for eight information R&D sessions. At these R&D sessions, we hope that you will be able to research out some mature friends, and develop some new ones here at the conference.

For this conference to be really successful, we need to have your interaction. We need to have you participating. What we'd like to see is you asking questions of the speakers after they have finished their presentations. Each of these speakers is an expert in his or her own field and welcomes your questions.

If you are uncomfortable speaking out in the audience and raising your hand to ask a question, we have put in your binders some paper to write down your questions, and we will have Dataquest folks available to pick up your questions and get them to the speakers.

Some other housekeeping items to point out: There is no smoking in the Steinbeck Forum or out in the lobby. You must leave and go out onto the verandah to smoke. Dress is informal. I think this makes for a much more interactive and relaxed conference. This evening we're going to ask you to dress up for our dinner in the De Anza Ballroom. And we would appreciate it if you would please return promptly to the Forum here when you hear our little bell. We're going to have a message board outside for you to get your important messages, and all of you can use your cellular phones for response rather than waiting for the telephone bank which is just out behind the lobby or downstairs where you came up from the main lobby. The restrooms are just as you go out of the Forum to your left. Lunch today will be a seated lunch, which means that you will need to get a table number. We have Dataquest people standing outside the De Anza Ballroom to help you get your table. For dinner tonight and for tomorrow's luncheon, we will have open seating.

Lastly, we have put a questionnaire into the binders that will help us with our planning of future conferences. It was your questionnaires from previous conferences that told us you'd like to dress down future conferences — that's why we have changed our tradition.

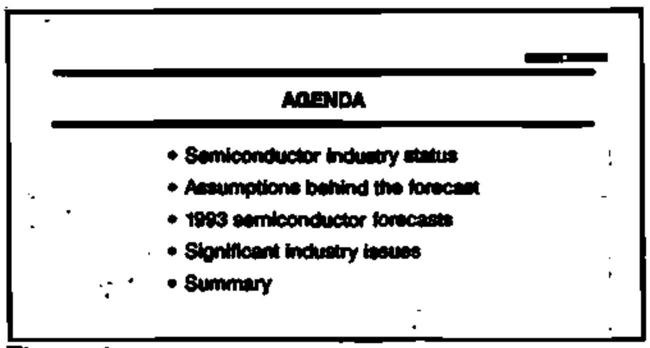

Figure 1

Okay, now let's get into the subject of the conference — my talk, the 1992-93 Semiconductor Industry Status and Outlook. At this time, I'd like to ask you to kind of sit back at your mission control centers, or disaster control centers, as some of you may think of them and get a picture of what is happening in this industry from 30,000 feet. My agenda will cover these five topics: status, assumptions behind our forecast (yes, we will tell you our secrets), a forecast for 1993, what we think are ten of the most significant industry issues, and then I'll try to leave you with some closing thoughts.

The industry just closed the books on a really outstanding third quarter, and as we get on into the presentation you'll see what I mean by really how outstanding it was. The normal trend for the industry is to have a slowdown in bookings and billings through the summer, but we didn't see it this year. I believe it was because of the strength of the personal computer and personal communications, and in general the broad communications industries We also saw strong trends in the distributor market, which tell us that the broad base of the industrial and computer markets is healthy in the United States, Europe, and very strong in the Asia-Pacific region.

Now let's take a look at where we are year-to-date in July, using the WSTS statistics. I have compared these with our own annual forecast for the industry. This slide shows that the July YTD for the industry is running at approximately 4.8%, versus our Dataquest forecast of 5.4% with the Japanese market down almost 10%, North America up 13.3, Europe 6, and Asia-Pacific up a whopping 25.2. You might be surprised at some of these really good statistics in the North America, Europe, and Asia-Pacific region end at the same time the worldwide is up 4.8%. Well, it turns out that Japan is the largest market, as most of us know, for semiconductor consumption. It represents about 33% of worldwide consumption, and as such has a large influence on the total number.

SEMICONDUCTOR INDUSTRY
1992 STATUS

	WSTS July YTD ($) Growth (%)	Dataquest Total 1992 ($) Forecast (%)
Japan	-9.8	-9.4
North America	13.3	15.1
Europe	6.0	7.2
Asia-Pacific/ROW	25.2	21.6
Worldwide	4.8	5.4

Source: Dataquest

Figure 2

The August numbers were just released on Friday, and I have an update of this table. Let me read the numbers to you. The Japanese market moved to only down 9.2%, so it is improving. North America jumped up to 14.9% — a very strong month of August. Europe is up to 7.8%, and Asia-Pacific keeps going up 26.1%. There is only one region there that we are in jeopardy of missing our forecast envelope of ±

3%, and that's Asia-Pacific. However, we do think that there is going to be an end to this boom out there, or at least an abating of this growth that we're seeing in Asia-Pacific. But, we still think that we'll probably miss the three percentage points ± on either side of our forecast in Asia-Pacific, and this is because of the high growth of networking products, PC products, and consumer products in Asia-Pacific.

One analysis that I do is take a look at how the total industry is doing throughout the year, versus our forecast of the industry. The horizontal line there is Dataquest forecast of 5.4 for the year, and the other curve is the YTD numbers. And as you can see, the July number is below our forecast, as you would think, since the industry is recovering. However, with the August data now, it turns out that our forecast is below the industry performance. Yes, this is really true. Dataquest forecasts will be under the industry average. Dataquest has often been called (and incorrectly) the industry's cheerleader, hoping that by giving high forecasts, you manufacturers will listen to us and produce more. I think that's rather silly, but that's what some journalists like to write about us. I wish I could invite you to some of our forecast meetings at Dataquest to see the heated discussions about the assumptions surrounding the forecast, as we challenge each other on various thought processes. The purpose of these forecast meetings, frankly, is to come up with the very best forecasts we can deliver to our clients, and second of all, give you the assumptions behind the forecasts so that you can see where we're coming from.

If you'd like to compare our forecast meetings with something that goes on in your company, you might want to compare it to the monthly P&L meetings, the annual budget meetings, or the negotiations on transfer costs with your international factory managers. Then you've got some kind of idea of how really exciting these meetings are.

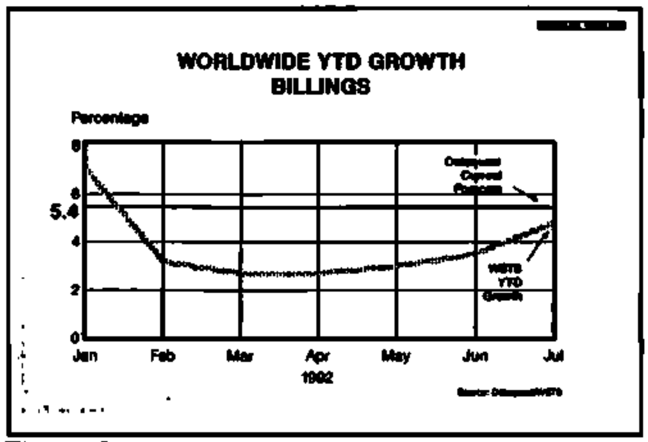

Figure 3

Now let's take a look at our scorecard. At our most famous of all Dataquest conferences, the Loma Prieta Conference in October of 1989, I told you that the 1990 industry was going to grow approximately 3%. The actual growth rate at the end of the year, we said, was 0.4%. So we were within our envelope of ±3 percentage points. In October of 1990, we told you that the industry was going to be 12.3%, and you did 9.4%. We just made it. In 1991, we told you 13.5%, and now, as you know, our estimate is 5.4%. For your information and comparison, I've also shown the August WSTS forecast for the industry for those two periods, and then their updated forecasts for April. For 1993, we're saying about 15.8 percent, and if you come back next year, I'll have the same slide and I'll show you how well we did.

OUR SCORECARD

Worldwide Semiconductor Industry

	Forecast CY+1 (%)	Actual CY+1 (%)
October 1989	3.0	0.4
October 1990	12.3	9.4
October 1991	13.5	5.4
WSTS (SIA)	14.5	6.8
October 1992	15.8	?

Figure 4

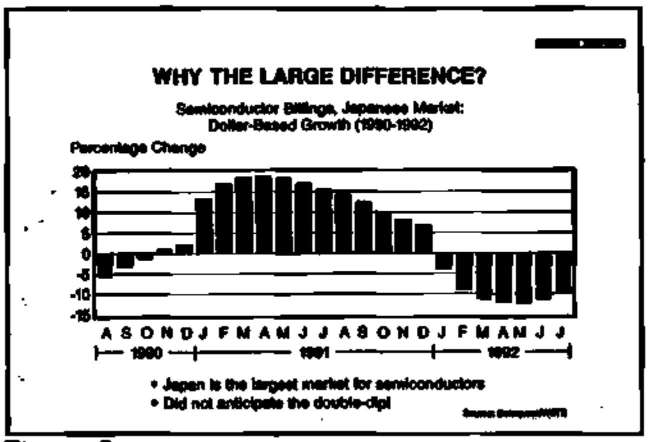

Figure 5

Now let's take a look at what went wrong with 1992 with not only Dataquest but also the WSTS, the two leading industry forecast groups. I'd like for you to focus your eyes on the scales. This is the Japanese market consumption, its YTD billings, and you can see that in October of 1991, the Japanese market was humming right along at 13% YTD. At that time, our forecast for the Japanese market for this year was mid-teens growth. This feud through October seemed to suggest that we were going to see a good 1992. But it didn't work out. Also at the time, there were many economist's forecasting Japan's GDP was that it was going to rise almost 3%; now they are saying roughly 1.5%. Certainly no one could have forecast that the Nikei index, in September of 91, when it was at 23,000 would drop to about 16,000 in July of this year. Also, no one forecasted that the largest market for semiconductor would take a double dip, as this slide here shows. As you can see here, the Japanese market has kept going south for the balance of 1991, and finally bottomed out in May of this year. Our forecasts for the other three regions (North America, Europe, and Asia-Pacific) are almost right on, so it really was this one region. But we missed the forecast.

Let's now move on and get into our assumptions associated with our 1993 forecasts. I've shown here our estimated GDP growth rates for seven of the most important countries to the electronics industry. And I don't plan to give you a macroeconomic presentation. I'll leave that up to the Paul Samuelsons and the Milton Friedmans of the world. But when I talk to you, what I hear mostly is the word *uncertainty* about the world conditions, and where is all this growth coming from.

ECONOMIC OUTLOOK 1993

Real GNP/GDP Growth, Local Currencies

	1992 GDP (%)	1993 GDP (%)
Japan	1.5	2.0
United States	1.7	2.3
United Kingdom	-0.3	1.4
France	1.5	2.0
Germany	1.3	2.4
South Korea	7.0	6.0
Taiwan	7.0	6.0

Figure 6

The industry, frankly, has been held hostage by three recessions: one in the United States, Japan, and then the United Kingdom. However, what I'm going to give you now are what I see as the risks associated with our forecasts, and also some things that I think are on the positive side.

First the risks. Many of the large companies that we all know and do business with are going through large restructurings. I'm sure you are sitting here and thinking about what is going on in your own company, and what effect that this restructuring is having on your suppliers and their suppliers. Also, the federal funds rate, although it is low, still needs to go substantially lower before this economy in the United States really gets going. In fact, it has to go negative, according to the economists, before we really get a health by recovery. Further, Europe is still wrestling with an inflated currency relative to the dollar, and making their goods very expensive. And finally, Japan's economic recovery is really just beginning, and it's going to take some time for them to pull out.

On the good news side we see that on September 4, the Federal Reserve dropped their interest rates for the 18th time since the recession started in July of 1990. U.S. households continued to reduce their debt and pay down their mortgages and reduce their spending. And in Japan, the government plans to spend $87 billion on infrastructure development and other economy-stimulating measures. So there is what I see on the positive side.

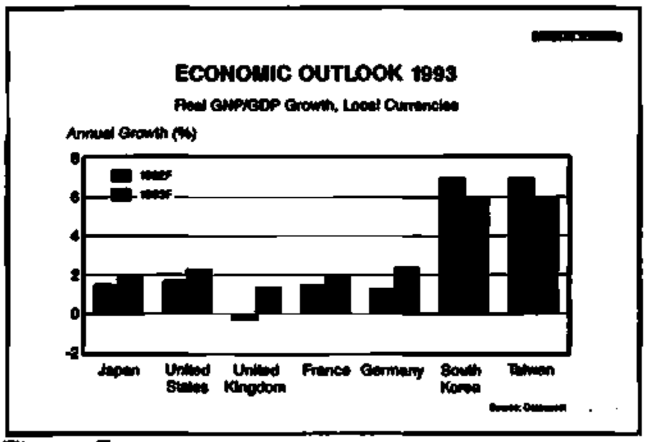

Figure 7

Like the two World Trade Towers in downtown Manhattan overlooking the smaller office buildings, the South Korea and Taiwan real GDP growth towers over the other countries in the G7. Though their GDPs are slowing from 7% all the way down to 6%, we are estimating that the growth out there will continue in 1993. And it is not only for those two countries, but also for Malaysia, Singapore, and Hong Kong. If you travel out there, as many of us do, you'll understand what I'm talking about. We are forecasting a better United Kingdom economy in 1993, and we also see a moderate growth for Germany and France, as their governments have sought to stimulate their economies. However, our forecasts are not aggressive. We still think that there is a lot of uncertainty in those regions, so we're being very cautious here with our forecasts.

Let's take a look now at our electronic equipment production estimates for 1993. In the '80s, the computer sales propelled the worldwide electronics growth, and the slump in the desktop sector of the PC industry in 1991 and earlier this year has created a ripple effect throughout many of the electronic companies that we do business with. Over the past 10 years, the U.S. and the European economies have been propelled by the large service sector, and this has created a large demand for computers throughout all of their companies.

1993 WORLDWIDE ELECTRONIC EQUIPMENT PRODUCTION FORECAST

	1992 ($B)	Growth (%)	1993 ($B)	Growth (%)
Data Processing	198.7	4.4	206.3	6.8
Communication	107.5	6.1	116.9	8.7
Industrial	104.9	2.3	113.1	7.8
Consumer	149.2	9.3	163.8	9.8
Mil/Civil-Aero	82.4	0.5	85.6	3.9
Transportation	23.3	6.9	25.7	10.2
Total	664.1	3.7	713.3	7.4

Figure 8

This demand for computers has propelled the semiconductor companies, the design tool companies, and the IC production equipment makers' businesses. However, I think today you will agree that we have far too much excess capacity throughout all of the U.S. economy, and, for that matter, the European and Japanese economies. So what is going to spur on the growth that we see here in the electronics industry? In other words, what will be the engines for growth?

Here is Dataquest's opinions. The first is what we call the small office/home office market. These are the millions of students, consultants (out of work, laid-off employees), and workaholics like many of us that take our work home on disks and work on those spreadsheets in the evenings. In this SOHO office market, as it is called, the PC consumption is up 22% this year, and we project strong growth in 1993.

Next, corporate America has downsized their staff, and are now looking to do more with less, and so networked workstations can do the work of many more expensive computers. Workstations are, in fact, the high growth segment in the Computer Industry this year. Overall, we expect data processing equipment, the largest market segment with electronics industry to grow about 6%. The second largest electronics market is the consumer market, and we expect it to grow approximately 10%.

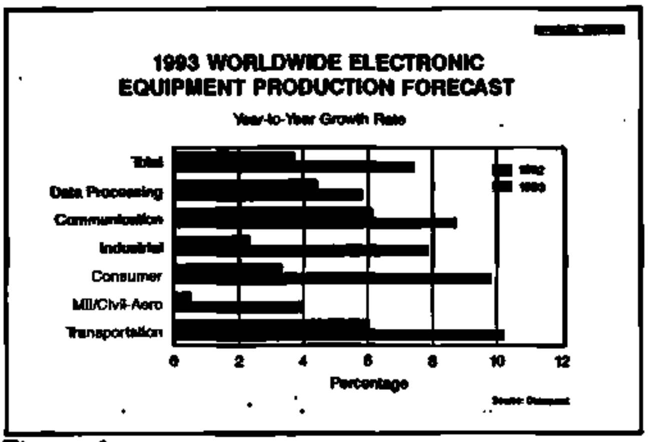

Figure 9

Today, audio and video equipment are on the mature side of the consumer industry average, but CD players, digital audio tapes, digital compact cassettes, large-screen TVs, and video games are expected to contribute significantly to the growth of the consumer market.

In looking at the transportation part of the industry, we're expecting only a 2-3% growth rate in worldwide production of vehicles. This translates, though, into a 10% increase in electronics. New automotive electronics systems that were designed five years ago have been increasing their content of silicon, as we all know. Some of the systems that we see coming on stream in 1993 and having a significant impact in semiconductor consumption are electronic steering, suspension, anti-lock braking, steering-wheel controls, navigation electronics, theft deterrent systems, and so forth. Ralph Wilhelm from Delco Electronics is going to talk to us a lot more about this area, and I'm really looking forward to his presentation. Overall, we're estimating the worldwide electronic industry growth to be up 7.4%.

Now let's take a look at the semiconductor forecast, first by the region of the world. We analyze it in three ways: by region, by product, and by application. In preparing this forecast for 1993, we all were reminded about the optimism we had in 1991 when we saw the first-half statistics from Japan, so we were cautious in our forecast.

WORLDWIDE SEMICONDUCTOR INDUSTRY FORECAST BY REGION

Percentage Growth*

	1992	1993
Japan	-9.4	12.8
North America	15.1	15.6
Europe	7.2	15.7
Asia-Pacific/ROW	21.6	20.0
Worldwide	5.4	15.5

Figure 10

We are forecasting a weak first half and a strong second half of 1993 in the Japanese market. We do expect it to continue its recovery, this year but we still expect it to be in the red, for the total year of '92. Overall we are forecasting a mid-teens growth rate for Japan for 1993. For North America and Europe, the growth rates here are just about at the industry average, so in fact it is not boom times. Asia-Pacific, we're looking for another 20%+ growth year, and over the last five years, Asia-Pacific has had an average compound growth rate of 23%, so comparing to the last five years' average, this is not also an aggressive forecast.

This is the second way of slicing our forecast, by product. The first category is the bipolar digital category. We're looking for this technology to continue its slide, declining about 8.6%, because of substitution and the new designs coming in the MOS area. With the recovery of the Japanese market and the strong workstation market that we see in the United States, we expect explosive growth in MOS memories next year. You probably are skeptical of the 28.9% growth rate for MOS memories, but let me cite you the growth rates over the last five years for MOS memories. 1987: up 34%. 1988: up 93% and 1989: up 32%. Of course 1990 and 1991 were less spectacular years for MOS memories, for all those people building those devices know quite well. In

DRAMs we believe that the market is beginning a cyclical upturn, and we are forecasting the acceleration of the bit-rate growth, which we hope will absorb existing capacity and slow the price-per-bit rate of decline. Overall we expect the improvement in all of your DRAM profits. We're also assuming the price crossover from 4 megabit to 16 megabit DRAMs will occur late in 1994, thus giving the 4 megabit a little bit longer life cycle.

WORLDWIDE SEMICONDUCTOR INDUSTRY FORECAST BY PRODUCT

Percentage Growth*

	1992	1993
Bipolar Digital	-9.8	-8.6
MOS Digital	8.7	20.7
MOS Memory	14.3	26.9
MOS Microcomponent	10.3	14.0
MOS Logic	-0.8	17.2
Analog	5.5	12.1
Discrete	1.1	7.4
Optoelectronic	-2.8	11.4
Total Semiconductor	5.4	15.5

Figure 11

Lane Mason, our principal analyst in the memory area, is going to talk to you tomorrow afternoon about what he sees as the important issues affecting this forecast. MOS microcomponents, which is the combination of the peripherals, the controllers, and the processors, we expect to be up 14% next year. The MOS microperipherals, the smallest of the two categories, we expect to grow at about 18%. This is due to some of the really exciting new devices that are being designed by many of the folks in the audience, such as the video compression chips, graphics and imaging chips, network controllers, and mass storage chips. For microprocessors and microcontrollers, we're looking for a low-teens growth rate for next year. We see lots of substitution of products going on in there markets. For the other categories of analog, discrete, and optoelectronic, we forecast more modest growth. And I will say that for the analog market, the most exciting products are the mixed-signal ones. We expect mixed-signal devices to grow at approximately 18%. MOS logic, which includes ASICs and standard logic, we estimate to grow 17%, and within that category, we see MOS PLDs having the highest growth at 29%, Gate Arrays and cell-based ICs will rise approximately 19%; for standard logic we forecast a flat growth and full-custom products will decline.

THE HOT AND NOT-SO-HOT IC DEVICES

	1993 Dollar Growth (%)	1993 Market Size ($M)
Hot		
4M DRAM	36	6,500
32-Bit MPU	19	4,100
Flash Memories	103	558
CPLDs and FPGAs	31	506
Not so Hot		
1M DRAMs	-26	1,395
STTL Logic	-14	1,065
≤ 1M EPROMs	-17	610
Bipolar PLDs	-16	228

Figure 12

THE HOT AND NOT-SO-HOT APPLICATIONS

	1993 Dollar Growth (%)	1993 Market Size ($M)
Hot		
Notebook PCs	153	4,369
Pen-Based PCs	700	1,900
Personal Information and Communications Devices	257	653
Multimedia Sound Boards	78	300
3.5-Inch Rewrite Optical Disk Drives	226	165
Not so Hot		
Mainframe Computers	-3.0	25,029
Dot Matrix Printers	-4.5	2,029
5.25-Inch Hard Disk Drives	-35.5	1,476
Modems	-10.1	790
Terminals (3270)	-14.7	789

Figure 13

I thought it might be interesting to point out some of the high-growth, large markets, as well as the large markets with low growth potential. Clearly 4 megabits DRAM have the highest growth and we're forecasting that the flash memories are going to grow substantially next year, up to almost $560 million, a growth of 103%. Complex PLDs and FPGAs will rise to over $500 million, a growth of 31%. On the not-so-hot side, we can see the older devices, older technologies, are being replaced by the newer technologies, such as 1Mb and the lower-density EPROMs.

This is the third and final slice we do of the industry, the applications slice. For your information, we at Dataquest look at the market, i.e. the systems market, and analyze 150 different market segments for their semiconductor content. We aggregate those into 21 categories, and then we multiply these by the semiconductor content estimated by our Dataquest industry analyst.

WORLDWIDE SEMICONDUCTOR INDUSTRY FORECAST BY APPLICATION

Percentage Growth*

	1992	1993
Data Processing	7.3	18.8
Communication	4.0	12.5
Industrial	3.5	14.1
Consumer	2.5	12.6
Mil/Aero	1.0	2.0
Transportation	6.3	16.1
Total Semiconductor Growth	5.4	16.5
Total Semiconductor ($B)	62.9	72.7

Figure 14

This, then, is our demand side forecast. We then compare these with our supply-side forecast.

As I've told you before, data processing is the largest application segment, and pretty much, as this segment goes, so goes our forecast. We're forecasting data processing semiconductors to grow about 19%. This is in part due to some of the really outstanding growth rates of some of the emerging products such as notebook PCs and pen-based PCs. And of course, as I said to you before, the workstation market will be the engine really driving the computer industry. For the workstation market, we're estimating it to reach $14 billion, and have a growth rate of about 42%. The second-largest market is the consumer market, and with the recovery of the Japanese and the European markets, which are dominant in the consumer market, we think that this industry will be up about 13%.

Next I'd like to share with you ten of the most significant issues facing you and Dataquest in the electronics industry. I'm not going to go through all ten in depth: I'm just going to try to hit the highlights.

SIGNIFICANT INDUSTRY ISSUES

- Asia-Pacific/ROW TAM ≈ Europe TAM in Q4 1992
- U.S.-based semiconductor companies gained market share in 1990, held in 1991, and will gain in 1992
- In 1991, Intel became No. 1 supplier to the U.S. market
- "Fabs will cost $2B by 2005" – Sematech
- IBM, Toshiba, and Siemens join forces in DRAMs

Figure 15

It has been a long time coming, but the time has finally arrived. In the fourth quarter of this year, total semiconductor consumption in Asia-Pacific will equal all of Europe, and next year we are forecasting that the Asia-Pacific will be larger, at least flat to slightly larger than all of Europe. So what that means now is that the ranking of the regions, in terms of where the semiconductors go, is now Japan, North America, Asia-Pacific, and Europe. There are some other significant facts associated with this occurrence here in Asia-Pacific, and I'd like to mention them to you. In 1991, North American companies' sales in Asia-Pacific surpassed the Japanese, and are now the largest group. Also, the Asia-Pacific companies themselves surpassed the European companies in Asia. So within Asia, the ranking is North American-, Japanese-, Asia-Pacific-, and European-based manufacturers. This of course means that companies such as Intel, Motorola, Texas Instruments, and National that have large shares of markets in Asia will see their 1992 revenues growing on average 23% to 26%. Further, in 1991, Taiwan passed Korea as the largest consuming country in Asia—another significant event.

What does this all mean? Well, to me it means that we're going to have more travel to the region, more Chinese staff being added to the region, more time spent strategizing about how to be successful there, and so forth. And we are not forecasting this trend to reverse itself; we expect it to continue.

If you look carefully at my regional projections this year, it says that the U.S. companies that have large revenues in the United States, in Europe, and Asia-Pacific on average will have their revenues growing about 15-16%. At the same time, the Japanese companies that have large revenues in their market that is declining anywhere between 5 and 10% won't fare very well in the Dataquest semiconductor ranking. I don't want to be specific at this time, because a lot could take place between now and the end of the year. But we do expect to see major shifts in the top five rankings. We look for the two microprocessor- and microcontroller-based companies located in Silicon Valley and the Valley of the Sun to be at the top of the ranking.

I am sure that Jim Norling, President of the Motorola Semiconductor Products Sector, and Craig Barrett, Executive Vice President of Intel, didn't miss the occurrence of this next event. Currently, the DRAM business is not for the weak at heart or for the paupers. It is for the patient, deep-pockets manufacturers, and clearly the ramifications to this forecast made, not by Dataquest but by Sematech are going to have a significant effect on the corporate strategies in DRAMs.. We expect to have people in our manufacturing trends breakout session talking about some of these issues shown here.

Here we have several deep-pockets manufacturers. In a drive to reorient their business model, IBM has elected to become an OEM PC manufacturer, and use multiple sources for their processors. I am sure that our third speaker of the morning here, Jim Picciano here from IBM, would be more than happy to answer questions on this topic. Right, Jim? Next PIDS these are really what we think is a major engine for growth in the years to come. Nick Samaras, our senior industry analyst in our group, is having a breakout session on the personal information and communications devices, and is going to be talking about these and many other portable PC opportunities.

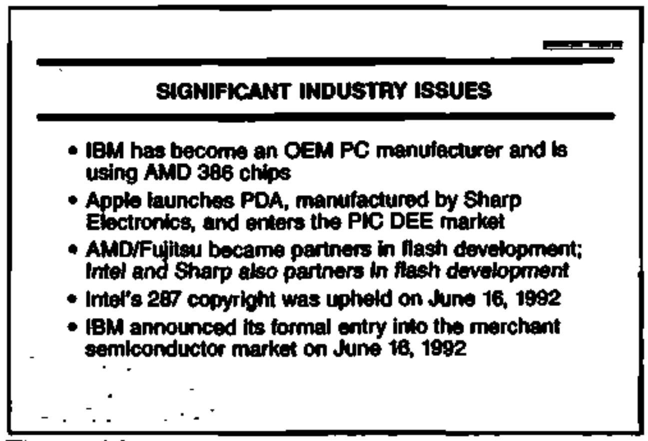

Figure 16

Also Wally Rhines' will talk on DSPs which are having a large impact on portable electronics. Next issue, AMD and Fujitsu, in flash development, as well as Intel and Sharp in flash development—we're forecasting this market, by 1996, will be at or above $2 billion. That's up from about $560 million in 1992. Currently we've seen the sum of the flash memory investment figures by the participant are in the business to be about $1.5 billion.

And now lastly, two very significant industry events happened on June 16, 1992. Anybody in the room have a birthday on June 16? I see one. I see two. I see three. Any others? Some rather significant other events besides your birthday. The Intel 287 copyright was upheld on that day, and IBM announced its formal entry, after contemplating this for probably ten years, into the semiconductor business. And we're very pleased to have the guy here that knows a lot about this activity. What a day, huh?

Okay, I'm going to leave you with a couple points here. First, we're looking for the electronic industry to be up approximately 7.4%. We're looking for the semiconductor industry to grow about 15.5%, ±3 percentage points. We'll tell you how we did with that forecast next year. Lastly, we're forecasting about two-and-a-half years of growth, in the semiconductor industry before the cycle finally turns back on us. By that time, the industry will have reached $90 billion, up from $63 billion this year

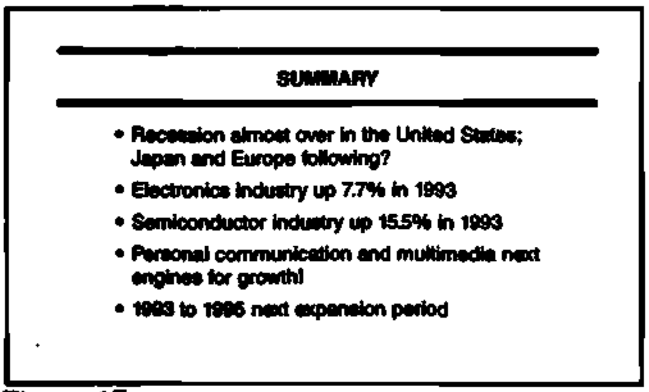

Figure 17

I want to thank you for your attention, and please have a great conference.

Emerging Markets: Advanced Processors

Craig Barrett
Corporate Vice President
Intel Corporation

Mr. Barrett: When you put the messages up on the board, you forgot to mention the most important one—that Stanford beat Notre Dame Saturday, 33-16.

I'm going to talk about where the processor family is going. The theme of my presentation will be what is happening in the realm of corporate computing, and what is going to have to happen in that world for, our business to continue to grow. The subset of the theme is really delivering computer-supported collaboration, or taking the computer and turning it from an individual productivity tool into a group productivity tool. At the end, we'll look at some of the future directions, with out a report card on how we're doing in some of these particular areas.

In way of illustration, consider the original PC, which was introduced in August of 1981. If you look at some of the characteristics of this machine, it was powered by rousing 4.7 megahertz 8088. It delivered something like .3 MIPS. It cost, I think, $2655 (the suggested retail price), and the cost-per-MIP was something like $9000. I wanted to compare that with what you can buy today, briefly, so last Friday at precisely 10:45 a.m. I priced an Intel 33 megahertz 486DX system, which delivered roughly 15 MIPS, and it cost $103 per MIPS. I want to tell you precisely the time that I priced that unit because it is relatively important not only for the year, and for the month and the day, but also the time to price PCs today, with many of them being introduced and having the price change before noon the date of introduction.

The real issue is; when the PC was introduced, it was introduced essentially targeted towards the home (or at least targeted towards personal productivity) as a replacement for personal productivity tools. When you consider some of the aspects of this, you find that it replaced the typewriter by bringing word processing to all of us. The spreadsheet replaced the things we did with manual calculators, and databases were a replacement for the things we did with Rolodexes or other data files. In each case, it increased individual productivity by bringing us these replacement technologies.

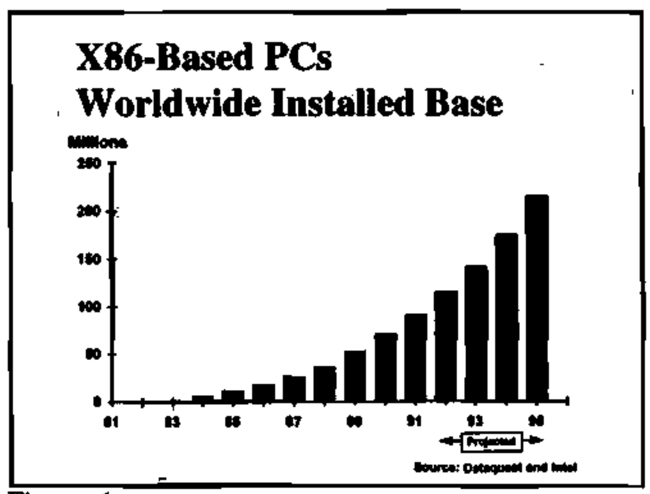

Figure 1

If you look at the number of installed PCs around the world today and what the forecasts are, at the end of 1992 (or at least today in early October in 1992) there will be somewhere in the range of 125,000,000 PCs installed worldwide—relatively smooth exponential growth. The bulk of these PCs have been used for increasing the volume of the things we do, rather than really the way that we do things, and again it's related to personal productivity. We see more word processing, we see more spreadsheets, we see more databases.

To really fuel the growth in this industry we're going to need to see is a change in the way we do business, and a change in the way people use PCs. And the aspect here will be really bringing different data types and different forms of communication to PC users. That will represent the rest of what I want to say today, moving from the individual aspect of PCs where we go from manual to a computer-supported form of work, to looking at the collaborative form of PCs, and in fact, how we can do computer-supported collaboration.

If you look at what happened around the world in the last decade in terms of those information technologies that have really been successful, you see fax machines which have been immensely successful and which have speeded up the delivery of information, and you see cellular telephones (probably all of us have our telephones with us today in our briefcases—I hate to admit mine is made by Motorola, but I have it with me today, and intend to use it at the coffee break). We see Federal Express, which was really a dream in someone's college thesis and turned into a viable business plan. And we see worldwide news, such as CNN, which brings you up-to-date information. All of this form of just-in-time business, or faster, better, cheaper information, allows us to make business decisions faster, and this is why I think we're really going to need to see computer-supported collaboration become the next main vehicle for computer growth.

Of the business functions that you want to play with, there are three keys ones: information access, anytime, anywhere; messages (be it mail or telephone) any time, anywhere; and conferencing. If we are successful in bringing these three business functions to the desktop and have them be computer supported, I suspect that we will see increasing pressure on the airline industry, as there will be less and less of us flying to meetings like this for conferencing.

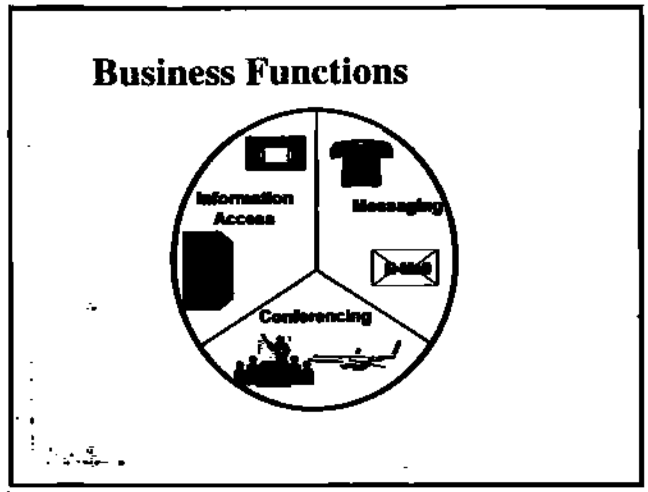

Figure 2

I know, sorry about that, Gene. I think the telephone companies will love it, because we'll be sending more stuff over the long-distance lines. But these aspects of just-in-time business are what is going to be necessary to be successful in the future.

Now, what does it take to make computer-supported collaboration at the desktop a viable reality? There are four key issues that we need to look at. One is performance of the CPU, or performance of the desktop machine. We'll talk about that. Another issue is bringing natural data types—voice, video, still images, handwriting recognition—routinely to the desktop. The third one is mobility—anytime, anywhere and the fourth one is connectivity of machines within your office environment, or the ability to connect from anytime, anywhere, into a network.

The growth of electronic mail in the U.S. suggests that at the end of this year that there will be 24 million or so separate mailboxes or people who have the ability to tie into a mail system. If you look at Intel as a typical Fortune 500 company: you have 25,000 employees, something more than 25,000 personal computers, and 25,000 separate people who have access to the same electronic mail system and can talk to anybody, anytime, anywhere, regardless of location.

Another aspect that suggests that this is going to be the wave of the future is at the pricing of PCs versus mainframes in terms of price per MIP—I mentioned to you earlier the PC that I priced last Friday in the morning was about $108 per MIP. That's really a little bit below the curve shown for PCs, but PCs are maintaining something like a 60- to 80-fold price decrement, or increasing in effectiveness in price per MIP over mainframes.

If you have this price advantage, and you have all these electronic mailboxes, then why isn't everybody charging forward and looking at computer-supported collaboration? Why isn't the business growing faster?

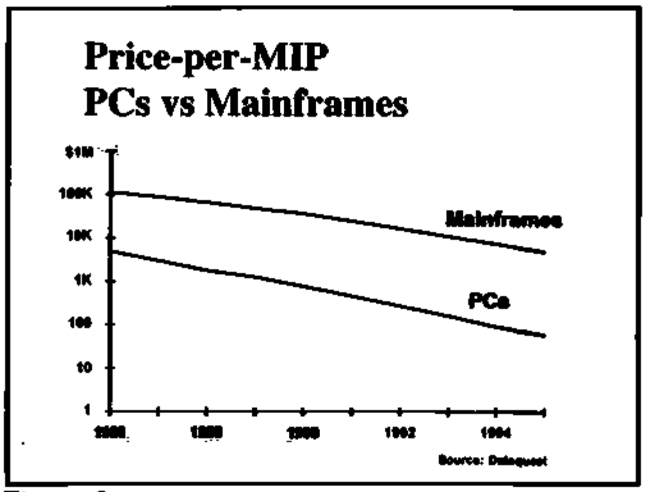

Figure 3

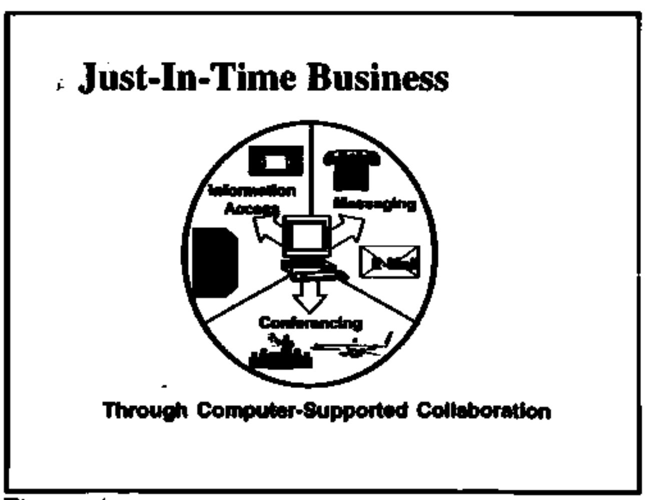

Figure 4

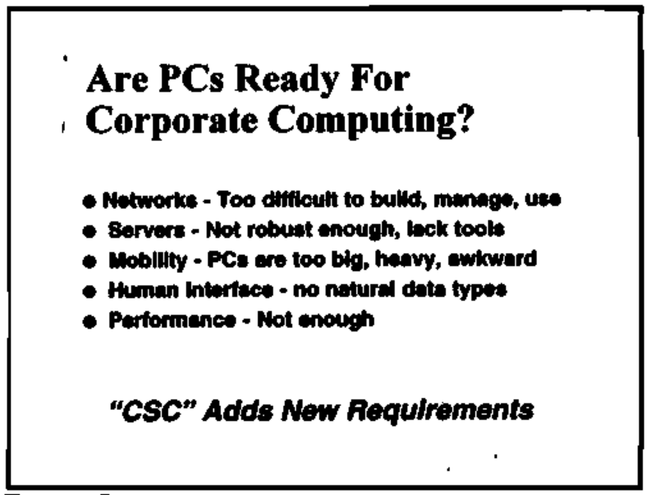

Figure 5

Let's look at the four main reasons (actually, I cheated—rather than having four, I have five, but the last two will be lumped together). We'll talk about performance, and we'll talk about not enough performance in the PC or the system or the CPU to do the sort of things we're talking about with natural data types. We'll look at the human interface (and the human interface here will be the ability for handwriting recognition or for audio recognition or for compression/decompression of video images). We'll look at mobility. Then we'll look at the issue of connectivity, which you can simply assume here combines the last two—servers and networks—both being critical to increase our local area network effectiveness.

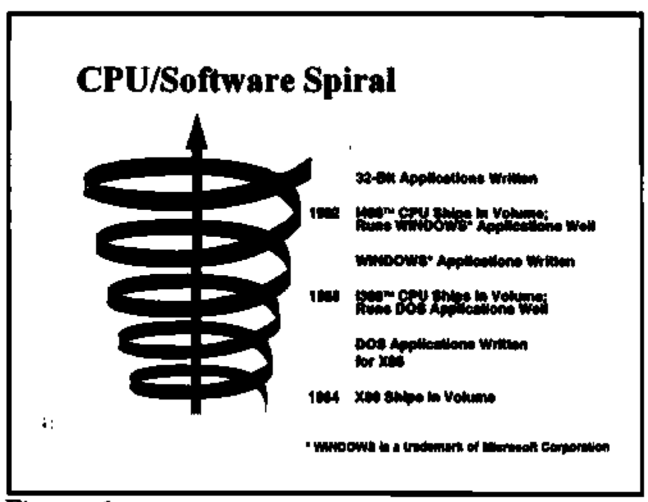

Figure 6

In terms of performance, what drives the performance requirement for CPUs and PCs? This is a representation of the CPU software spiral. It tells you why today 15 or 20 MIPS is not enough on your desktop, and next week 50 MIPS won't be enough, and next year 100 MIPS won't be enough. The PC was introduced in about 1981, and the 286 really got going in about 1984. People were writing applications for DOS-based applications, which ran reasonably well on the 286, but the 386 was introduced in about 1985, and by 1988 was shipping in reasonable volume, and was running DOS-based applications better than the 286. About that same time, Windows came out from Microsoft, and people started writing Windows-based applications, which would run on a 386, but not very efficiently. So by the early 1990s, when the 486 was shipping in volume, it was in fact running those Windows-based applications much better than any 386 would. Now, some seven years after the 386 was introduced in 1985, we're about to have some 32-bit application programs running on 32-bit operating systems, which will be designed to run on the 486. In fact, when the P5 comes out early next year, it will run those applications much better and much more efficiently than any 486 system. Then as we go on to the next twist of the spiral for the next set of application programs, you want more and more MIPS; to run more and more sophisticated application programs: which will, in turn, give you more and more data on your system. So this spiral is never going to slow down, but will continue to open up and require more and more processing power.

People today are buying applications and buying hardware to run those applications, Whereas in the 1988 time frame you might have been buying hardware to run your spreadsheet applications, in 1992 you're buying hardware to run your Windowing applications. Today you should be buying hardware to run the applications that are going to be present in the 1996 time frame, which will be natural data types on your PC, audio, video, etc.

Now, you get some benefits from this ever-escalating performance issue. The highest performance CPUs usually come out to run the departmental servers or the high-end servers when they are initially introduced, but they quickly fold down into the mainstream workstation, business workstation, for the desktop. The highest-end processors come out, run desktop servers or, even in the case of massively parallel computers, they quickly slide down this curve to the desktop and then quickly slide down even further to the laptop or sub-laptop or notebook-type framework.

This gives you a couple of advantages. One, you get compatibility across the entire spectrum, and second, you get upgradability. In fact you can buy a PC in the intermediate region with today's generation CPU, and be able to upgrade that CPU just by pulling it out or plugging another one in a year or two or three years after you buy it, and get some substantial increase in performance.

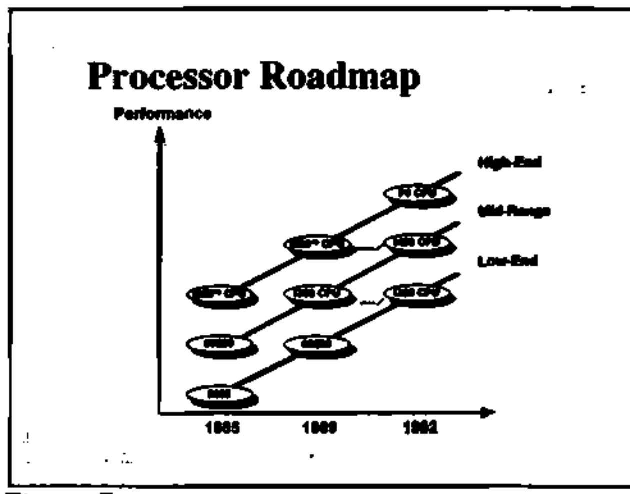

Figure 7

Another way to look at this is to look at the separate generations of CPUs as they come out. What I've tried to show here is the history of the 286, 386, 486, P5 generation. There are three separate curves. The low-end CPU at any given time, mid-range or entry-level desktop into the business environment; high-end (which would have been a server or high-end workstation environment). You can see in 1985 the low end was really the 8088, the original IBM PC CPU, the 286 would have been mid-range, and a 386 introduced that year would have been the high-end CPU for a server or high-end performance workstation. In 1989, when the 486 was introduced, it really shoved the 386 down one notch, which shoved the 286 down one notch. The P5 is about to be introduced, will shove the 486 down into the mid-range and the 386 at the low end. You can put price tags on these. A mid-range machine today is much like the one I mentioned earlier in the presentation: sub $2000, 10-, 15-, or 20-MIP machine. A low-end 386 CPU today goes into a sub-$1000 box, which is finding an advantage in the home or very entry-level student-type machine. The high end is the P5, which will be for the departmental server of high-end performance machines.

I don't see any slowing down in the need for performance. Let's look at natural data types: imaging, audio, handwriting recognition. Let me focus on imaging by way of example.

There are lots of ways to accelerate the video characteristics of CPUs by adding hardware.

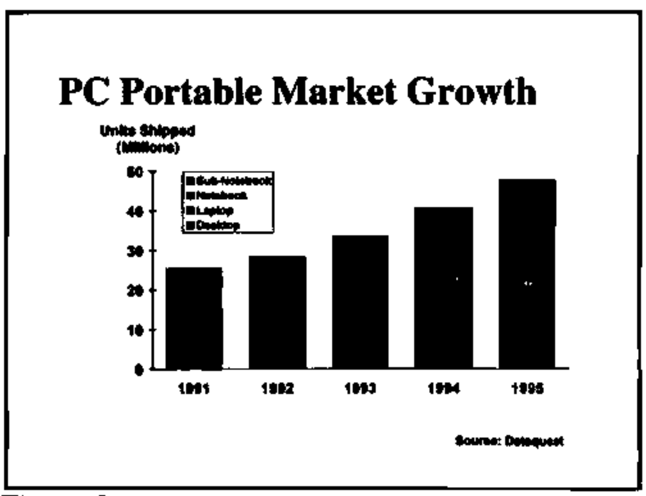

Figure 8

I've just shown you some examples from Intel, and there are equivalent examples from a number of other suppliers around the world. There is something called the 750, which is a video processor that takes care of some compression and decompression aspects for video. You can add AVKs (audiovisual kernels) into operating systems to allow these various bits of hardware to plug into a normal-operating PC, or you can have Action Media II boards, which are compression/decompression boards. The important aspect here in terms of video applications is really that if you count up the number of bits of information that you need for one minute of video in an uncompressed fashion, it's about something over a gigabyte for one minute of video on a PC. If you do a compression (and typically the compression is just throwing away unused bits of information—that stuff that doesn't change, or that stuff that you can interpolate), you can usually get about a factor of 100-to-1 compression ratio, which takes something over a gigabit of information for one minute of video down to something that is more manageable in the ten-megabyte category.

If you want to do full screen, high resolution in a normal, manageable memory bank, you really need to do compression, and most of the devices shown up here are those that allow you to do compression and decompression and get that video image on the screen.

If you look at the characteristics for video in terms of 30 frames per second and high resolution on a PC, what you need is something in the range of 100 to 1000 MOPS of computing, which is something like 10 times what your normal CPU will provide you. This is why you get all these hardware accelerators for very high-resolution video.

I think you're going to see a couple of things happen in the PC market, though. One has to do with business applications, for example—video conferencing (and just of interest here, how many of you have taken part in a video conference?) The typical video conference is not 30 frames per second, and is not really real time, but it is more than adequate for the typical business conferencing aspect of it. I think what we're going to see more and more in this industry is, in fact, some hardware acceleration. But as you get into the '93 and '94 time frame, when, in fact, your CPU performance will give you 100 MOPS or so of computational power, and you don't want full screen, but you're willing to settle for a quarter-screen image for video transmission, and the rest of the screen for data transmission, people are going to do software-only compression and decompression with the main CPU.

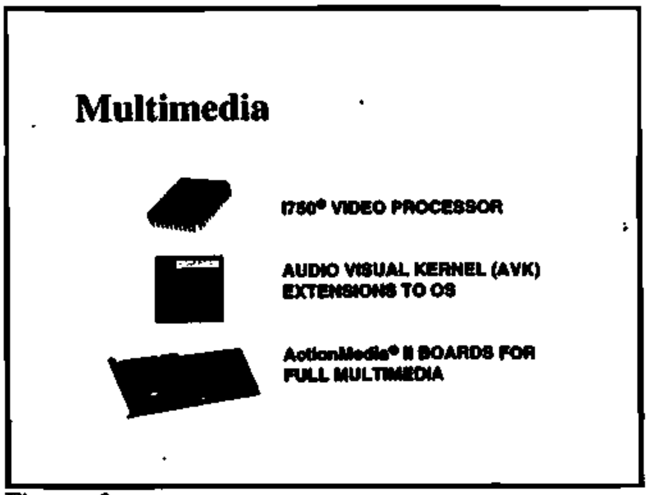

Figure 9

And, that will be satisfactory for the business needs. That will not take care of the installed based of the 125, 150 million or so CPUs with lesser power, where you can't do software only, so I think there will be a big business for hardware add-ins to meet that need, but I think we will see more and more software only with the resident CPU business communication for natural data types, some hardware acceleration for the older CPUs. But the thought of being able to sit at your desk with a $50 camera and do a video teleconference with anyone, anywhere in the world (for less than $500 or $1000 total add-in capability compared to the $20,000 or $30,000 or $40,000 video conferencing systems you have to use today), is a very attractive feature that will drive this business.

Another aspect of image types has more to do with the structure of the PC and less to do with the components that go in it *per se*. If you look at something called local buses or peripheral component interfaces (PCI), one new standard that has come up, and I've just listed this in the way of getting graphics really off of the I/O bus and onto a local bus.

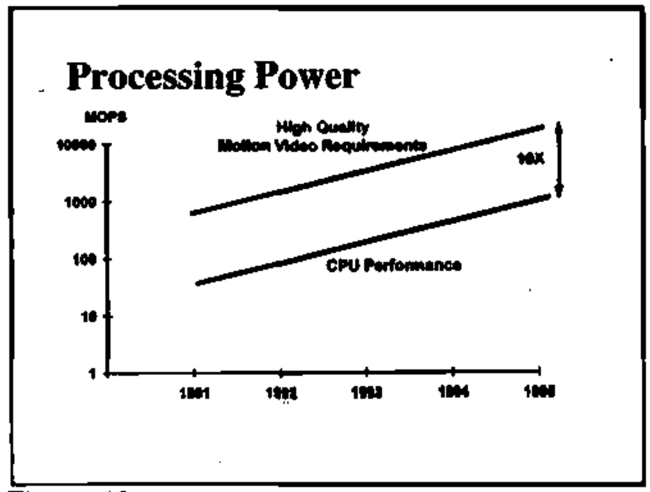

Figure 10

Then your frame buffers, which in fact can give you 100 megabytes or so, can provide much better engineering workstation graphics on a normal PC than you would have ever thought possible. This shows a PCI standard with the five companies that are driving it. There is just a sea of other people who are either involved in OEMing it or providing chip sets or capabilities to go behind it. This type of enhanced graphics on the normal PC, will drive its utility quite a bit further, as well as video or the other type of natural data.

Let's go on to portability. This is a huge area of growth. There are some neat things about portability in terms of driving acceptable performance and acceptable features to the end user. Lower power—it looks like we're really going to go to three volts. Lots and lots of three-volt microprocessors coming out, and the supporting chip sets and memory associated with that. Smaller form factors in terms of very low-cost, high-density plastic packaging. Increased integration, where we get two or three chips that will give you the entire PC in a very small, confined space. One aspect that is absolutely necessary for portability is, in fact, going to be wireless communication. I'm a firm believer in the personal companion computer, or the computer that you can take with you anywhere and dial into your local database or your local E-mail system without having to be connected by wire. For those of you who have crawled under beds and hotel rooms and tried to unscrew telephone jacks and connect wires in the middle of the night—it's really an exciting aspect. I would much rather have a cellular form of communication. And this will also drive some other interesting aspects of the business, in terms of PC cards, low-power cards for either communication, memory, or what have you. As Gene has pointed out earlier, flash memory as a replacement for the low-density hard disk drives will be a big business, There is a real low end to this business, which is kind of interesting and bandied about much in the press these days, and that's the PDA or PIA, the personal information appliance.

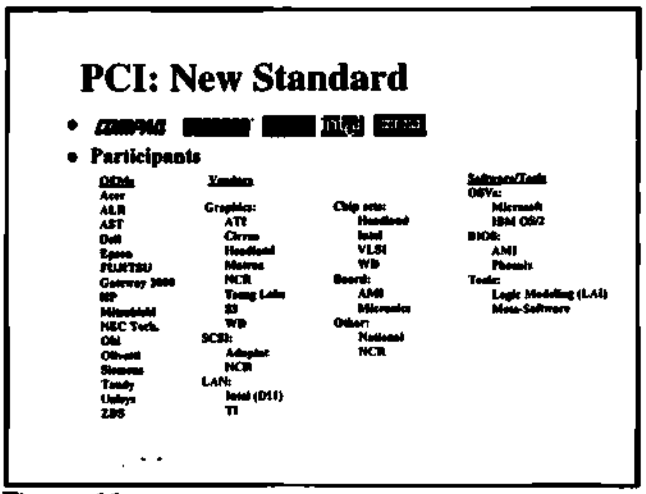

Figure 11

Some people think that this is going to be a big business; other people think it's going to be toys for us yuppies. This is an example of one which might be a combination of a personal organizer, a portable phone, a calculator, database, and besides giving you your portable stereo entertainment unit. If, in fact, PIAs turn out to be yuppie toys and they're consumer electronics, then I don't think compatibility with other PC systems is going to be terribly important. But, if PIAs or PDAs turn out to be commercial electronic devices—that is, extensions off of the desktop—then compatibility with other systems (both hardware and software) will become more and more important. I think you have to stay tuned for this as we go through the decade. There is lots and lots of work on these today, and there is certainly a strong emerging market. Whether it will be a useful commercial tool or something that the consumers will buy in mass, however, remains to be seen.

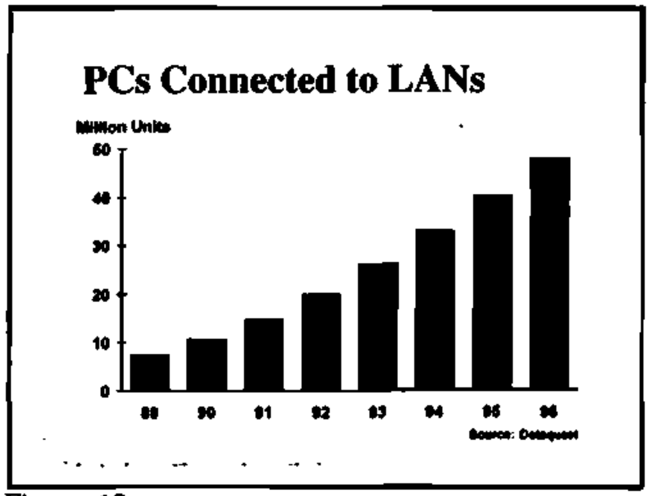

Figure 12

Connectivity also is important. At the end of last year, there were about 15 million PCs hooked up to local area networks in the United States. That represented about 40% of all the PCs in the industrial environment, and should rise substantially. By the middle of this decade, over 50% of the PCs ought to be hooked up on LANs, and there ought to be 50% more than there are today, so it's a big, big business. There are a couple of things that will drive this business: One will be shrink-wrapped servers, where products will provide the hardware and software capability to allow you to bring either an information server, an E-mail server, database server, whatever it might be, into your corporation. You just hook it up and walk away from it. Having (as most of us have to do today) to bring in the bits and pieces, and use our own staff to glue them together, makes it extremely difficult. The other aspect, or plug-and-play interface cards, printer cards, such that you can build your own local area network with a reasonable amount of skills that you learned in college 20 or 30 years ago and don't have to be a wonderchild to do it. Shrink-wrapped servers, plug-and-play network cards and server utility functions are going to drive the LAN capability and ease of use.

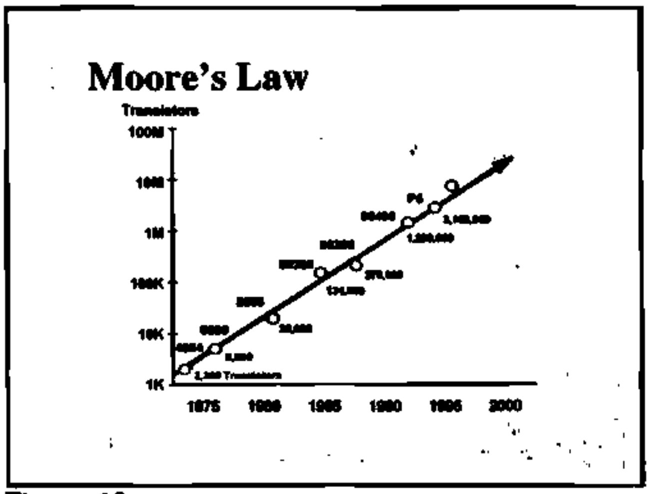

Figure 13

What you need for servers, and what you need for enhanced performance for natural data types, is more and more processing power. Let me just take a couple of minutes to give you the Intel advertisement here. This is Moore's Law—it works for processors, it works for memories. It really says that you double the number of transistors every 18 months or so on a memory chip or on a CPU chip. This shows that for the Intel roadmap, up through the follow-up device to the P5 (which will be called the P6 until we give it another name), and something like a 10-million transistor device due out in 18 months or so. It looks like there is nothing that is going to stay in the way of this trend, either for memories or for processors, at least for the next 10 years or so besides a few billion dollars to build the wafer fabs to make these. But that's a trivial issue for some of us! [Laughter.]

This is a picture of the P5, your standard 100-MIP processor with 3 million transistors or so. The reason I point this out is that I've talked a lot about natural data. Really what you're interested in doing is having enhanced graphics and video capability, and the P5 is certainly designed partially to do that with substantial graphic performance, upgraded floating-point performance over its predecessors. It is also targeted to run all of the advanced operating systems. But if you project out to about the year 2000 and see what your average processor will look like, it looks like what we refer to as Micro 2000, something like 100 million transistors, probably about 2 billion instructions per second worth of performance. In this case it would have essentially four CPUs operating in parallel, and each one of those four little CPUs at the bottom would be your standard four or five million transistor CPU. A couple of vector processors up at the top. That little square called test up in the upper left-hand corner, for

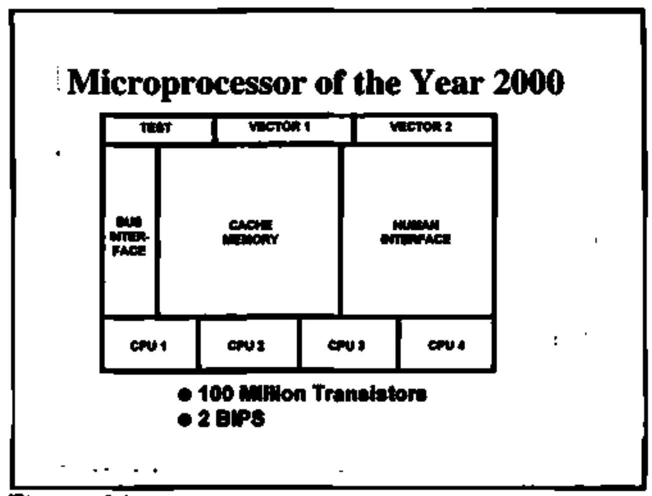

Figure 14

those of you who are familiar with the highest form of Trillium tester today, that's got more random logic up in that upper left-hand corner than the trillium tester has today. Also a bus interface and some human interface stuff. This will give you more than sufficient capability to do all the computer-supported collaboration I have talked about before, but you really don't have to wait that long to get that capability. This just shows where we'll be towards the end of the decade.

The last trend I want to show you is a combination performance indicator (comparing mainframes, minis and micros), and it really shows where micros are going relative to the other two. I haven't seen anything in recent time or any projections that suggest that this trend will not continue, which really says that the performance curve that micros are on is much, much steeper than that of either mainframes or minis.

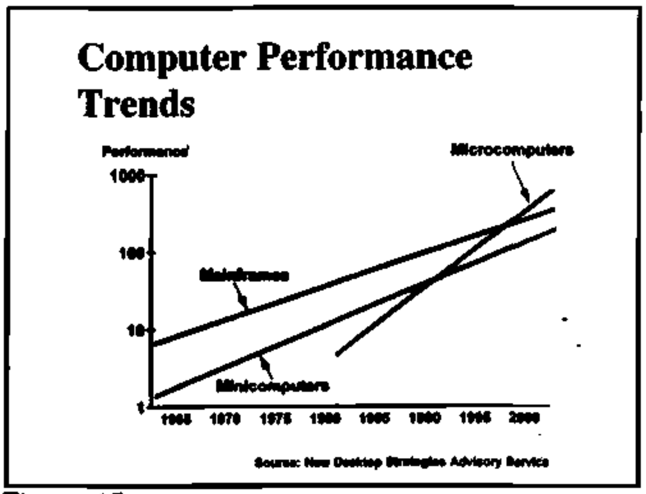

Figure 15

So let me conclude by suggesting that the issue of not enough performance for computer-supported collaboration, (getting what business needs on the desktop) is not a stumbling block. The class of processors and PCs that are coming out today are going to have sufficient performance for business needs. The human interface capability is coming, in terms of natural data types, be it in terms of handwriting recognition or video or audio on the desktop. We're going to see lots of product introductions in the next 12 to 18 months along those areas. The mobility area is hot. Adding cellular communication to your portable companion computer is going to make something that you will all be willing to stick in your briefcase—something in the range of a one-pound, rather than a six-pound portable, to lug around and allow you to tap into your database and your electronic-mail system at will. Then there is the issue of connectivity, in terms of shrink-wrapped servers and plug-and-play add-in devices. I don't think any of those are stumbling blocks. I think they're going to open up really a new era of growth, satisfying the needs of the corporate computer user. It should be an exciting time—looking forward in the next couple of years to these product introductions.

So hopefully the sluggish growth we've seen in the PC market (and it's not so sluggish compared to some others) will be substantially above its current five- to ten-percent compound annual growth rate, and get back up into the twenty-percent category. And, hopefully Stanford can continue their winning ways in football. With that, I'll take any questions you might have.

Questions & Answers:

Question: I have a question on your computer performance, microcomputer/mainframe comparison. In your view, what are the primary reasons why micros improve faster than mainframes and minis?

Mr. Barrett: I think it's really going to be the price benefit that the end user gets that drives that entire issue. I understand you clearly can look at whatever you call massively parallel computer, whether that's a mainframe or a mini or a micro. It's going to be built off of the individual microprocessors, and the cost-benefit driving the microprocessors is going to drive the cost-benefit to the user, which will continue their growth.

Question: A related question. Don't you suspect the mainframe will actually evolve into something more like a high performance data base I/O system?

Mr. Barrett: Well, for sure. I'm not really suggesting that mainframes or minis are going to go away. Every time I do that I sign another capital project authorization at Intel to buy another ten or fifteen million dollars worth of mainframes. They're not disappearing. But, we're taking our entire mail system off of mainframe and onto a local server, a local mailbox-distributed system. And that will be totally locally driven in terms of message transfers and transactions, and not off the mainframe.

Question: You indicated there will be 100 million transistors by the end of the decade. When do you see 64-bits CPUs?

Mr. Barrett: Well, it took seven years to get really 32-bit operating system for 32-bit microprocessors, and we're just about there. The concept of going to 64-bits for the desktop and for those applications, is many, many years away for any volume utilization. That doesn't mean that we won't be going to 64 bits by the second half of this decade, but in terms of applications and utility, I think it's going to be a 32-bit world for quite some time for the normal business computing, business workstation environment. If you want to go to the higher end and talk about what you need for massively parallel computers, 64 bits is going to come a lot sooner. But I think for the desktop, it's many, many years away.

Question: Could you clarify, on one of your slides regarding the video processing power, going from 1000 MOPS to even higher levels. I don't understand what that means. You sort of implied that the requirement is going up. Can you explain that curve?

Mr. Barrett: It just means that your expectation of high quality video is going to continue to go up, and you will require increased processing power to get that. What you consider to be high quality today, which might require 500 MOPS, you won't tolerate five years from now in terms of high quality. You'll want better definition for real high-quality video imaging. That's all that is meant to represent.

One more.

Question: Do you see the idea of the computer eventually evolving to be a chip? Could you comment a little bit more on high power consumption of these future chips?

Mr. Barrett: I'm not sure what you want me to comment on exactly.

Question: How are those functions handled in the future? How can you actually tolerate this power consumption in portable computers?

Mr. Barrett: I'm not suggesting that you're going to see 2 BIPs in your portable computer tomorrow. What I'm saying is you're going to have that capability on a microprocessor within the next ten years for a desktop. You handle power dissipation with design tricks and process tricks, or you put the processor to sleep between cycles, or you handle it by putting a local portable cooler on your CPU to help power dissipation. There are lots of ideas and possibilities in that area. Clearly as your processing power goes up, the power dissipation goes up. But we're going to take the operating voltages down, which we're starting to do rapidly now, to try to keep power dissipation in hand.

Mr. Barrett: Thank you very much.

Maintaining Technology Leadership in the '90s

James Picciano

General Manager, Applications and Solutions Development, Technology Products

IBM Corporation

Mr. Norrett: Jim is a 31-year veteran of IBM, and has been in management for most of his career. He started first as a Circuit Development Engineer at Poughkeepsie, and then moved to Essex Junction, and was in manufacturing and development. Then Jim became the Burlington plant manager, then moved on to Assistant General Manager for all semiconductor products at East Fishkill, and then moved on again to Burlington to become the General Manager. In 1988 he became a vice president in the General Technology Division, and was promoted to the Assistant General Manager for Technology Products at the Pyramids in the Sky, or Pyramids on the Hill, in Somers. If you haven't been there, you're in for a treat. In March of this year, he became a salesman, and he became the Assistant General Manager for Technology Sales, and he was promoted in June at the same time that Mike Attardo took over the top job when Paul Lowe resigned. Now his current position is General Manager of Applications and Solutions Development.

Jim is married and has three children, and spends a lot of time on Trillium—not the tester, but a boat. And he likes to spend time on his Harley-Davidson, or in his 300Z. Please give Jim a warm welcome.

Mr. Picciano: Thanks, Gene. Gene knows more about me than I suspected. Trillium happens to be a white lily-type wildflower that grows in Vermont, so it was an appropriate name for a white boat.

Being part of a large corporation, there are many times when people speak for the IBM Corporation, but on June 16 we raised that to a new high when I was surprised to find even our retired executives could speak for the IBM Corporation. That was the June 16 announcement was that Gene was referring to.

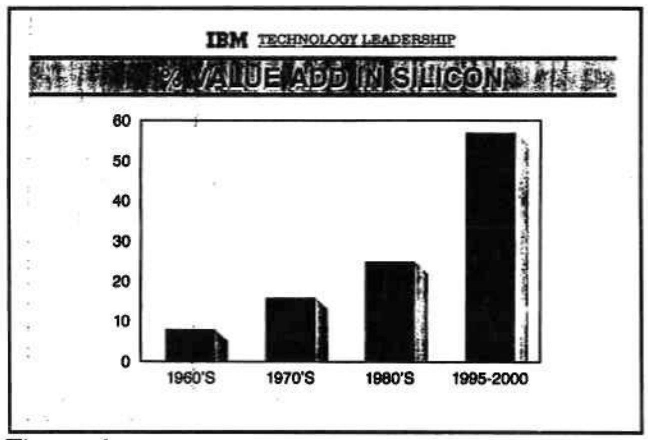

Figure 1

Now, in the next few minutes I want to talk about IBM's technology products business, and frankly, our strategy for maintaining technology leadership. Now, technology leadership is an issue that every player in our industry has dealt with in one way or another in recent years. And at IBM, we've always thought that maintaining technology leadership was strategically important and, in fact, provided tremendous opportunity. We continue to hold that view, and this chart shows fundamentally why we think it's important. More and more of the value of computers is in semiconductors. And more and more of the total circuits required for computers can be put on just a few chips. We're at the point where one chip can power the most sophisticated workstation, and soon we'll need only one thermal conduction module to operate a high-end mainframe. So it's clear, if you want to be in the hardware business, access to leading-edge silicon process, design, and architecture is absolutely vital.

We have these tools now. Our leading-edge semiconductor manufacturing package and design automation tools—in fact, the fabric that ties all those together—give us a unique leadership position. These attributes are a competitive plus, and maintaining them is really key to our taking advantage of future opportunities. We concluded that there was great motivation for finding ways to reduce our costs and risks so we could remain a leader. As all of you know, being a technology leader is not a free ride. There are challenges intrinsic to our industry that have to be overcome in order to remain successful.

In light of those challenges, five years ago, we adjusted our leadership strategy. We developed a strategy for building alliances and partnerships, which we continue to pursue.

As Gene pointed out, more recently, we've augmented it with an initiative for merchant sales. Before I explain our strategy in detail, I'd first like to discuss the challenges facing every technology leader.

Staying on the cutting edge of technology leadership in today's environment really means solving a bittersweet dilemma. If you're involved in developing and manufacturing successive generations of technology, you get tremendous productivity leverage—but at increasingly prohibitive costs. At the current pace of semiconductor development, for example, density is increasing by a factor of four every three years. The development and capital investments required to be a leader in this area are on a 19% compound growth rate tract.

Meanwhile, industry revenues over the past five years have gone up an average of 14 to 15 percent, and as Gene was projecting, would continue at about that pace in the future. Now clearly the disparity is not good for technology leaders. And it is likely to grow wider, rather than get closer.

Why is it? Well, we're making finer and finer ground rules, larger and larger chip sizes. As wavelengths required to etch get smaller and smaller, we're pursuing more and more exotic technologies—technologies that, in many cases, are more expensive. To make the first increment of capacity, it takes more expensive tools. Since you're getting higher densities, the number of manufacturing steps increases. The upshot is you get higher manufacturing costs for the first increment of capacity.

Another challenge relates to product volume. As a result of your initial investment, you get a significant advantage in productivity. With the smallest increment in capacity, you would probably be able to make 25 percent more, whether it's bits or circuits or whatever, because of larger wafers, smaller dimensions, denser integration.

If you built a fab today, you'd use new tools. And those generally bring with them increases in throughout, in square inches of silicon, as well as basic engineered improvements in productivity.

Another way of looking at it: With your next generation of tools—assuming a similarly sized fab—you get a minimum of a factor of two output, compared to the previous three-year cycle. Now, the problem is that in order to justify those investments, you need to get a maximum economic return. You need to run that fab on an economy of scale where your costs per unit are as low as they can be. To do that, you've got to make a lot of product. In other words, you don't get the productivity advantage unless you use it.

To sum it up, you have to commit tremendous development and manufacturing costs. You have to maximize production to justify a return on assets. And you have to find ways to consume or sell all of your products.

Now, every technology leader has to find a way to compete successfully, given this reality. When we looked at those challenges five years ago, we also noted something else. In terms of technology development—especially in semiconductors—all of the leaders are in roughly parallel positions on the track. It's difficult to get a lead of more than six months. Those who are going it alone are duplicating the same set of costs as their competitors.

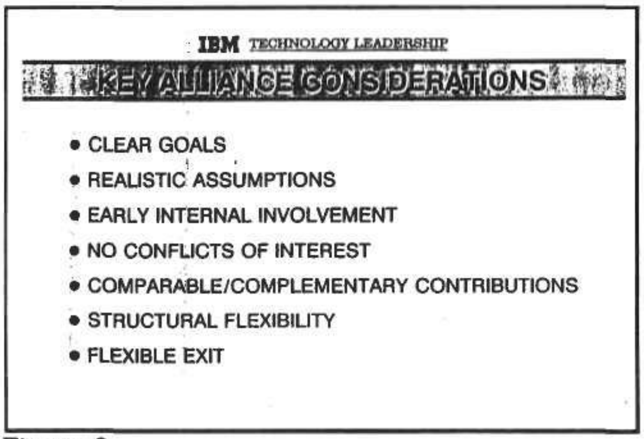

Figure 2

Now, we looked at this and we put together an alliance strategy. Its main guideline was that we wanted to ally ourselves with people in the industry who had the same goals, and who also wanted to be industry leaders. We identified several considerations that we recognized were key to our success.

Most important was clear identification of what we wanted out of the alliance. In other words, focused goals on each alliance. We realized that the more precise we could be in our objectives, the easier it would be to construct the agreement and to make it work. At the same time, we knew our assumptions, going in, had to be realistic. That meant we had to carefully examine how we would benefit in view of what the relationships would actually provide, and how our partner would benefit. We did that by involving our key people and organizations from the start. They were involved in the analysis of our objectives, and reviewed the feasibility of success. Their input helped keep us on track.

Now, another important consideration concerned potential conflicts of interest. We realized an improperly conceived alliance could do more damage than good. Accordingly, we took great pains to ensure that a potential alliance would serve both partners.

Another way we would go about increasing alliance success is to ensure that the agreement reflects complementary and comparable contributions. We also recognized the value of flexibility in structuring alliances, that each alliance is unique. So we sought to adjust the structural parameters on an individual basis. Flexibility in ending alliances was also a primary focus. Changing market conditions can change objective priorities, and there is no sense for either party to continue an alliance when the objectives do not maintain value.

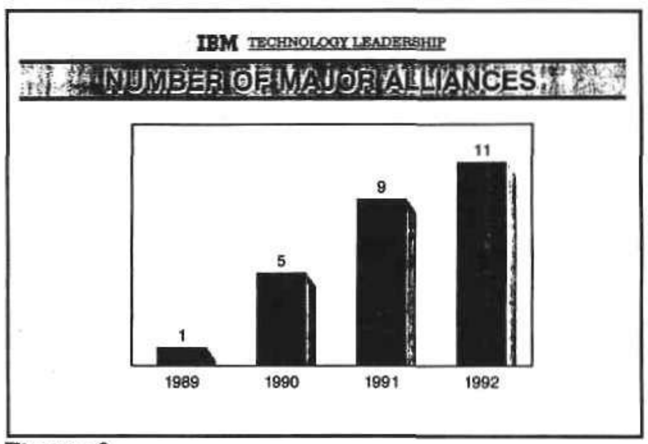

Figure 3

Over the past five years we've entered into numerous relationships using these guidelines, and as you can see, momentum is building.

While each arrangement has its own unique set of details, many share similar characteristics, and over time we distinguished five separate categories.

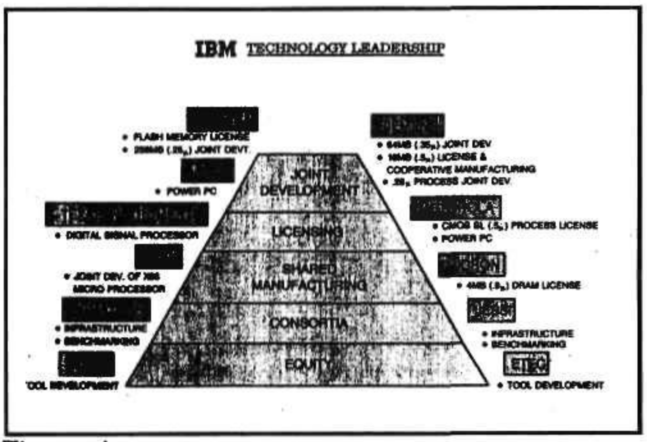

Figure 4

The first one is equity arrangements. Equity arrangements are basically financial linkages. Typically, we invest in a company which is engaged in developing a technology or a product we think is important. Such arrangements are notably appropriate with companies pursuing niche technologies and complementary tooling. Past examples of those alliances include alliances with SVG Lithography and ETEC.

Several consortia have been established in recent years to help support an industry-wide infrastructure. They also provide member companies significant opportunities to benchmark tools and processes. And Sematech and Jessi are two well-known consortia of which IBM is a member.

A couple of minutes ago I was talking about the high cost of manufacturing. Cooperative manufacturing alliances are a great way to defray those expenses. Last year we announced we would cooperatively manufacture our 16-megabit DRAM with Siemens in Corbeil-Essones, France. We haven't yet entered into agreements with anyone to manufacture our 64- or 256-megabit DRAMs, but we're evaluating whether that would be desirable.

In addition, licensing is another area in which we've picked up our rate of activity. And frankly, it's a win-win situation. The licenser gets a return on know-how and intellectual property, without giving up rights to it. The licensee, on the other hand, has the advantage of incorporating that know-how into leading-edge technology without having to develop it. We've been on both sides of license arrangements, and we will continue to be.

Recent well-known licensing agreements include process and design for our 4-megabit DRAM with Micron Technology, CMOS process technology and architecture with Motorola, flash memory technology with Toshiba, DSP licensing with Texas Instruments, and process and design for our 16-megabit DRAM with Siemens. As you know, one of our major efforts that I was involved in over the last year was licensing the power PC architecture to Motorola and Apple, and we're jointly designing parts with both companies.

The fifth category is joint development. Two well-known ventures have been our work with Siemens to develop the 64-megabit or .35 micron process technology, and our project with Intel to jointly develop microprocessor technology for the X86 series. Another agreement—our recent alliance with Toshiba and Siemens to develop technology for 256-megabit DRAMs—illustrates well the logic of sharing the development costs of technology leadership.

Individually, each company might be able to develop 256-megabit technology on its own, but probably at a prohibitive cost. In the alliance, each of us spends less than we would going it alone. We all maintain leadership. More importantly, we're poised to share the potential gains. A key gain, obviously, is becoming competent in .25 micron technology. Each DRAM cycle, as you know, is the basic driver and external benchmark for device technologies. Once you fine-tune the processes applied to a new DRAM cycle, you can use them to advance ASIC logic and microprocessor technologies. You are able to do this more efficiently than if each of you were pursuing such areas alone.

As you can see, there are powerful motivations for not abandoning a leadership position. But are the tradeoffs worth it? Frankly, we think so.

The advantages you gain by sharing costs, sharing risks and profits, provide a stronger competitive platform, and we think they'll be crucial tools for overcoming business challenges of development and manufacturing leading-edge products.

We think other technology leaders also determine these to be powerful motivations as well, and we see many other people in the industry forming alliances as well. As I said earlier, our alliance strategy was based on establishing common goals with other technology leaders. We think these arrangements have helped ourselves as well as our partners—and we're not done. We think there are a lot of opportunities remaining.

In the future, we're going to expand our alliance objectives toward maximizing benefits of complementary strengths. Among our strengths are leading-edge silicon and packaging technology, the know-how to design those into relatively large assemblies, and our manufacturing capability. We're looking for synergistic relationships. In other words, we want to ally ourselves with companies that can complement our strengths with leading-edge technology to a particular market focus. We're looking to turn those solutions not only to internal solutions, but also into external or merchant sales solutions.

This expansion of our strategy refers back to my earlier comments on productivity. Overcoming business challenges inherent in each cycle of technology development is like holding a tiger by the tail. At some point, help in holding that tiger is very welcome. One advantage we've had over the years is to have most of our products consumed internally. We never had to look to external markets to consume our product. Over time, however, it became increasingly clear that our productivity would eventually outpace our internal consumption. We looked at this, and we saw we had a real opportunity in merchant sales. It was an area brimming with potential, and one that we hadn't seriously pursued in the past. Others were involved in it, doing quite well. We looked at the success we were having in building alliances, and saw that we could develop similar relationships for external product distribution.

Accordingly, we've resolved over time to create a new business based on merchant sales. There has been much speculation in recent months about our merchant semiconductor effort, and I must say I am not prepared today to give you many details. We'll save that for a later day. However, I can tell you we're quite serious about the effort. And to underscore our commitment, we are hiring people from outside IBM who have knowledge that we don't have about the merchant industry to help us put together a world-class sales and marketing organization.

In the future, we'll be taking other steps to ensure that we pursue a winning strategy in the area of merchant sales. We know that the merchant market has its own terms and conditions—practices all of you are very familiar with. We also know that we have a lot to learn to be successful. But as I mentioned earlier, we think we have the necessary set of strengths to create a unique position for IBM in the merchant market—one that will enable us to meet our technology goals and will serve our customers very well.

We think we can do this work with others because it is what we have been doing with our IBM customers. That brings up another important point. In the future, we'll have alliances in the area of merchant sales where we ally ourselves with people to satisfy our customers. Of course, we'll also have alliances with external customers as well. And that means that we're going to do everything possible to delight them, to make high-quality products the way they want, and to deliver them when they want them.

Our involvement in the merchant market is not a short-term strategy—we're in it for keeps. We're going to draw upon our alliance experience to establish our merchant sales presence. We're going to work hard on developing merchant sales relationships with our alliance partners and our customers. And we're going to make whatever changes necessary to succeed.

I can't be certain of where I'll be in five years, but I hope to be able to return here and give you a very positive accounting of our merchant sales activity. I can, however, be certain of one thing. The microelectronics industry of tomorrow is going to become increasingly relentless as competition intensifies. But keep in mind that revenues most likely will continue to grow at a minimum of 10%, and that means plenty of opportunity for those who are nimble and quick to change to the shifting markets.

At IBM, we're making the necessary changes to be among the market winners. We're looking forward to an exciting future, and to sharing our successes with our partners and our customers. Frankly, I can't wait to be a part of it.

Now I will be happy to answer any of your questions.

Questions & Answers:

Question: What's the biggest difficulty in managing intellectual property in these many alliances?

Mr. Picciano: Basically, what we try to do is structure the alliance so that the alliance is creating intellectual property, and we have clear boundaries of what the alliance is supposed to be doing. These are not things where we join two companies together to do good. These are things for which we have very specific goals. We know what intellectual company each company brings into the alliance—that's defined at the time of the alliance. In general, the alliance is one which creates intellectual property; it is jointly owned by the partners.

Question: Do you still think that you can reach $500 million in the merchant market sales by 1995?

Mr. Picciano: Frankly, you have to take with a grain of salt targets that are set by retiring executives, right? [Laughter.] But let me say this. Really, our objectives are to create a merchant business. We look at it exactly that way. We're putting together investments in our marketing and sales, investments in development to serve the merchant market, investments in manufacturing capacity to serve that market. We think the only way to be successful is to treat that as a business. Where our goals really are to become a major player in three or four years, and frankly our long-term goal is to be one of the top ten suppliers, and our merchant sales business to be one of the top ten suppliers in the industry.

Question: Do you see your entry in the merchant sales market getting in the way of what could have been some potential alliances for the user side of IBM? Do you see getting into the merchant sales business getting in the way of what could have been some potential alliances?

Mr. Picciano: No, I don't. In fact, I think the opportunities will be greater. Most of the alliances we have are because we're both bringing value to the alliance. I don't think the merchant sales will hurt that. In fact, it will create new opportunities. Maybe different ones than we would have even thought of in the past.

Question: Are you going to sell the X86 processors?

Mr. Picciano: X86 processors? We're not going to sell X86 processors at the component level. By the way, we have made and sold X86 processors at higher levels of assembly for some time, and we expect to probably continue to do that.

Mr. Picciano: Thanks.

DSP — The Enabling Technology for Emerging Computer, Multimedia, and Consumer Applications

Wally Rhines
Corporate Vice President
Texas Instruments Inc.

Mr. Norrett: Our final speaker before we take a break will be Wally Rhines. Wally is in his 20th year at Texas Instruments, and has had many significant achievements there. He was responsible for the development of the TMS320 family of DSPs, their first speech-synthesis chips, the TMS340 family of graphics processors, and he has fathered several generations of DRAMs. Wally has a B.S., M.S., M.B.A., Ph.D.—just ran out of time on degrees here, Wally. His Ph.D. is also in Materials Science, just like Dr. Barrett, and also from the same university, Stanford. So I guess you were cheering for those guys on Saturday, right? He's married, has two daughters, and likes to jog and spend time with his family. Wally is going to talk to us about what he sees as the enabling technology for a lot of the hand-held and portable devices we heard a few minutes ago. Wally Rhines.

Mr. Rhines: Thank you, Gene. I don't know whether you did this on purpose. I find myself as the transition speaker between, on the one hand, Intel and IBM, and on the other hand following the lawyers and the economists. A strange position. It's no coincidence about this Materials Science thing at Stanford. One of my favorite professors there was Craig Barrett. As a matter of fact, he was teaching at Stanford about the same time Andy Grove was teaching across the Bay over there at Berkeley. Little did we know that later on these two would be generating more profit than the whole industry combined. We should have suspected, though, that they were architecting something here, because when I took Craig's course in Structure of Materials, he gave out the course notes and he charged us about five dollars! [Laughter.] By the time I left, the textbook was going for $30 and was required for you to take the course! [Laughter.] Oh well. Let me move on here.

We're going to talk about DSP, the enabling technology. It is one that ten or twelve years ago we thought was going to take over the world very fast, and it has taken more time. But it is inevitable, because most of what we want to process is in analog form, and most of our technology advance is in digital technology, so as we bring those signals into the digital world, we're able to grow applications at greater than 30% per year. The good news for the analog people is that it is actually increasing the market, particular for A to Ds and D to As. But the actual evolution of DSPs has come because, instead of just operating on signals that were already digital, we find ourselves in a position where smaller and smaller systems can do the conversion of analog to digital, and then process on the information.

I need a few fundamentals to talk about in DSP, so I've taken an analogy, an analogy everyone can identify with—stock prices—and plotted there (over on the left—Craig gave me his high-tech pointer here—no, no, he didn't charge anything!). Here on the left we have daily stock prices, so you might think the value of a company changes continuously with time, but we sample it every time we have a transaction, or issue a bid-and-ask price, and you can plot that against time here, about a 64-day period. If you think of that analogously, how you would get information out of that data, one way is why not do a five-day moving average, and smooth the data a little, and if you translated that into the DSP world, you would call that a finite impulse response filter.

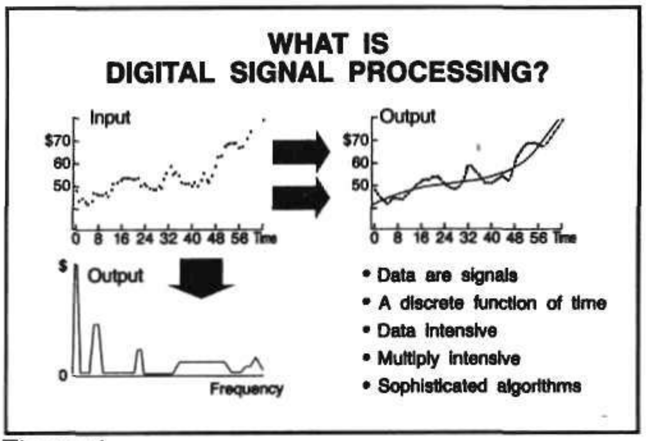

Figure 1

So in DSP terms, what you think of is, I'm going to take each piece of data, I'm going to multiply it by one-fifth, and then I'm going to accumulate the result over the last five samples. So multiply, accumulate—or MAC. When you talk DSP people talk about, how fast can you do a multiply/accumulate, or a MAC? That's because DSP operations are very intensive in that direction.

If you wanted to get further information out of that data, you'd do regression analysis, least mean square fits, all of which have analogous algorithms in DSP. Or you might want to look at trends, such as does the stock price increase before the dividend? If so, how much? Does it have cyclicality, and so on? And to do that, you'd transform it to the frequency domain, and look at the frequency distribution—how often does a certain price occur? So FFTs (Fast Fourier Transformations) are another typical example.

The other major example you see a lot of in DSP is correlation. So the analogous thing would be comparing this stock's price with a broad market average, or with other stocks in its industry, and look at correlation and look at the differences. Those are the kinds of things people do in DSP.

The analogy, though, breaks down in one important aspect. That is, when you're analyzing stock data, you're doing it at a very slow rate—minutes, hours, days. In DSP, we're typically looking at real-time processing, where it is not even interesting unless you're sampling data at about 5,000 samples per second or greater.

So why have people started this rapid move to DSP? One of the first reasons is reliability—just the issue that systems degrade with time. Mechanical systems wear out. You need temperature compensation because metals change their dimensions with time. DSP offers a way to compensate for those types of things and improve reliability. Reduced cost—because, in fact, as we move to more and more precise systems, precision components cost a great deal of money, and so by being able to avoid precision components, you can save cost at the total system level. Also (and this is the key one), it has made possible breakthrough products—things like voice recognizers and image processors that simply couldn't have been done before the days of DSP.

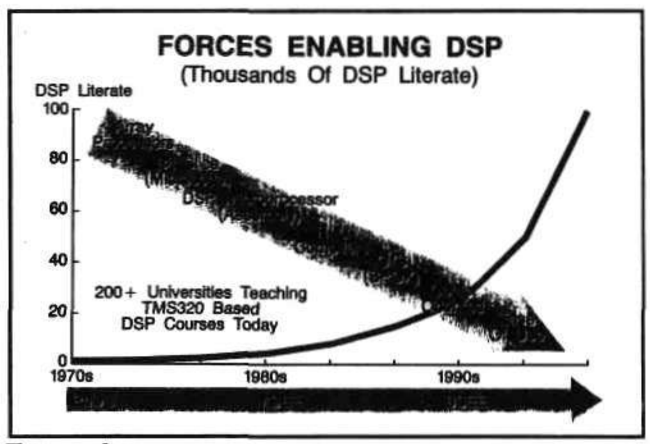

Figure 2

Now, there are a number of forces in the industry that have caused the change. One is the effect of price. When the first-generation DSPs were introduced, they tended to be over $100. They tended to see a lot of applications in military systems, and moving into telecommunications and computer in that $100 price range. But until you get down to the $20 point, the automotive industry isn't very interested; and until you get down to that under-$10 point, the consumer isn't either. So we have seen the evolution of prices coming down. Today you can buy a first-generation DSP for something around $3 for a unit, and all of a sudden all sorts of applications are possible. In fact, price is one of the forces with each generation that has been growing the market.

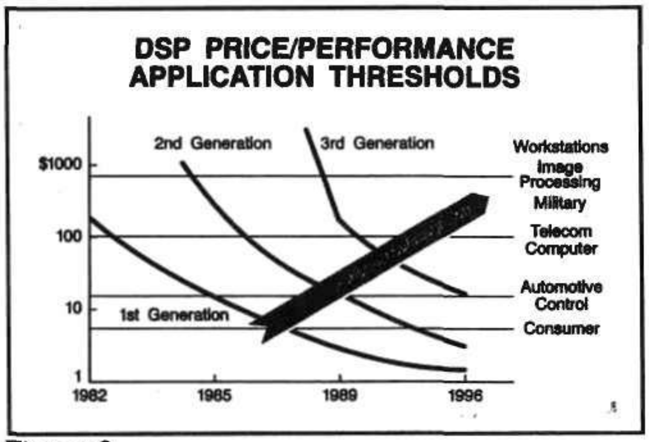

Figure 3

Another major force has been familiarity. The fact is that back in the 1970s only specialists and Ph.D's were worried about DSP and doing applications, and over the last 20 years or so, it has become a core part of the curriculum. In our case, for the TMS320 family that TI makes, we track over 200 universities that offer courses that use the TMS320. There are lots more that don't use the 320 because now it is not just a graduate course, it's part of the undergraduate curriculum, and we've now got over 100,000 DSP-literate engineers working in our companies, applying DSP. And once an engineer uses DSP for a solution, our experience has been that he doesn't go back. It's just so much more powerful in terms of what he can do that he takes advantage of it in his next design.

Another force is just the infrastructure for ease of use. DSPs, when they first came out, didn't have the development environment. They didn't have the emulation tools, simulation, and so on. What has happened over these last ten years is the evolution of tools comparable to what you'd expect with a high-volume host microprocessor. So today you don't have to just have an optimizing C-compiler. If you like ADA you can use ADA. If you want to do built-in self-tests you can get J-tag compatible scan designed in. If you want EPROM versions, you can get them. That sort of thing has allowed the industry to take off.

Now, what about the products themselves? Who is using DSP? Well, one of the first questions, you hear all the publicity about digital signal processors, but in fact the standard digital signal processors are really only about a third of the dollars. Two-thirds of the dollars go to dedicated hard-wired custom solutions, either ASIC-based, full custom, or some other hybrid, and what is interesting is that the ratio has stayed relatively constant through history. That's because first designs tend to be with a standard DSP, and then people tend to evolve.

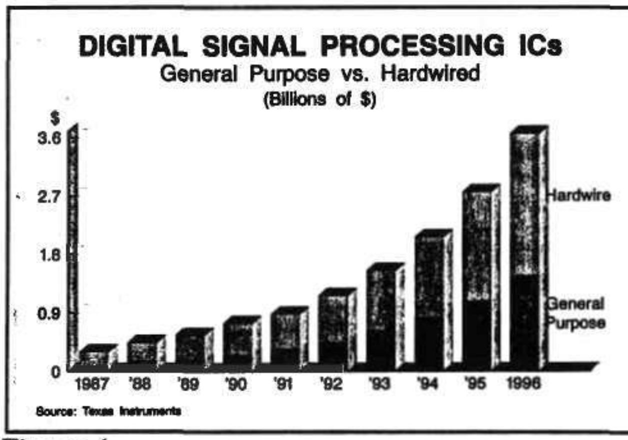

Figure 4

If you look among those standard DSPs, one of the first questions asked is, what about the floating point versus the fixed point? Floating-point DSPs tend to use more silicon area, so they're more expensive than a fixed-point DSP. But in fact, if time to market is your goal, development is easier, you can do it more quickly, save time, save cost, and be flexible and change things at the last minute. A fixed-point DSP is a little more restrictive, but still much better than a custom solution in that respect. So the engineer, of course, who is being held accountable for meeting the schedule wants to use a floating-point DSP.

DSP IMPLEMENTATION BENEFITS

	Floating Point DSP	Fixed Point DSP	Custom
Time-To-Market	Strong	Moderate	Weak
Development Cost	Strong	Strong	Weak
Performance	Moderate	Moderate	Strong
Cost/Unit	Weak	Moderate	Strong
Flexibility	Strong	Moderate	Weak

Figure 5

The product manager responsible for the cost of the unit looks at the difference and wants to use a fixed-point DSP. So usually people compromise and we work the engineers all night and design it with a fixed point. In fact, that is exactly what has happened. Still about three-fourths of the industry goes with a fixed point.

Now, custom solutions offer the best performance and the best cost per unit, but the least flexibility and the longest time to market. So typically people try to use a standard product early on, and then move to a custom product later in the cycle.

Let's talk about some examples of DSP applications. When we first introduced the TMS320 in 1982, we did a very thorough market analysis and determined that modems and speech processing would be the high-volume applications. In fact, for every DSP we have ever introduced, the highest-volume application for the first few years is always graphics. People who are in the graphics business seem to have an insatiable desire for more MIPS, and tend to use these. The RS6000, for example, is a very powerful workstation. In 1991 they introduced an add-on card that does 2D and 3D graphics acceleration. This uses 6 floating-point DSPs, and I'm sure if you asked the engineer why, he'd probably say, "Because we couldn't afford to use 10." Basically, it's because these graphics people have this shelf of algorithms that they've never been able to attack, and every time you give them a faster DSP, they reach up on the shelf and they pull down another algorithm, and they start implementing that in technology. And there seems to be no limit. So every generation, we move a step further in terms of the graphics enhancements. In fact, in 1991, at the time of this, four out of five of the leading workstation vendors in the world had floating-point DSPs as their graphics accelerator engine—320-based DSPs.

Another application for DSP is in modems. We first developed DSPs to penetrate the modem market for EXAR. Modems are an ideal application because there is a variety of signal processing going on in a modem. With each generation, the modem has been introduced at some number, hundreds of dollars, five-hundred dollars, or thereabouts. When it gets to $200, it takes off in big volume, and then it goes through a cycle, and eventually levels in the $50 range. So right now, the high volume today is still pretty much V22, V22 BIS actually, 2400 baud. The move now, of course, is most of the new systems ramping up are 9600-baud modems. Very quickly we'll be seeing V32 BIS systems, and those will up the MIP requirement to something like 15 to 30 MIPS. It'll take more MIPS, but actually the emphasis in this market is on getting lower power, lower cost, more compact, because the portables are driving the market more than ever.

Hard disk drives are a good market for DSP. It's an interesting market, because we didn't anticipate it when we originally developed our DSPs, and yet it is today the second-highest volume, could very well be the highest-volume user of DSPs. Essentially, every manufacturer of hard disk drives in the industry today uses DSPs. They use it, typically, for the spindle motor control and head positioning. Typically, they're not on the leading edge of MIPS. Today their volume products have 5-10 MIPS. This brings up a lot of issues of integration and now, with the move to portables, thin packaging and power dissipation. But hard disk drives are a good classic case, because they're really a classic DSP market. They use advanced filtering, they use adaptive control, and disk drive manufacturers (along with DRAM manufacturers) are the only truly crazy people left in the world today, dropping prices at the same time as they increase performance at a rate that guarantees no one will stay around long enough to make money. [Laughter.]

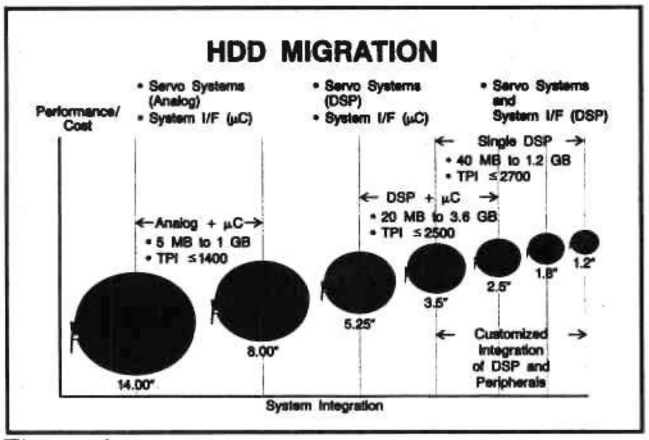

Figure 6

The classic evolution of hard disk drives has been from what I would call passive to active to adaptive. So the original systems were analog; they were passive. You would tell the head to go seek a point on the disk, and it goes and it does it, and if there is no thermal compensation, too bad—it's not on the track. In the active generation, typically microcontrollers stored a table lookup form of data, so that your disk drive, your disk head, could go look and get a specific position in a microprocessor, and you could even put in a little adaptive control there to correct for environmental effects. In the DSP-based systems that are going to market today, they are adaptive. So the head moves toward the track. It looks to see, "Am I on the track?" Before the first bit is through there, it can correct hundreds of times and adjust its position adaptively, depending upon where, or temperature, or whatever. It is those kinds of systems that are providing the density and reliability that are needed for disk drives of the future.

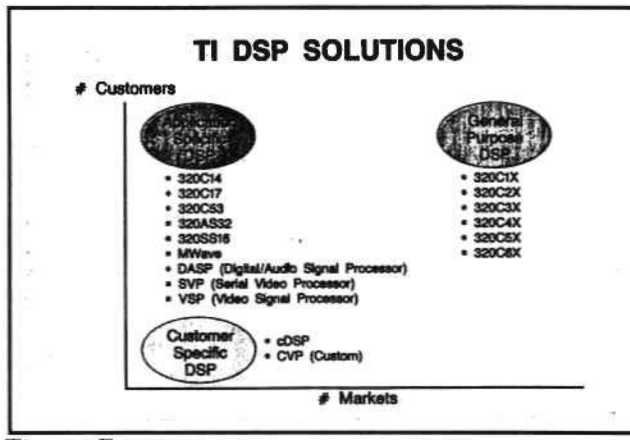

Figure 7

How do we serve this market? No differently than most others. We started with a family of general-purpose DSPs. They were typically integer DSPs, but soon we added floating-point DSPs, and then multi-processing DSPs, and so on. But it became apparent that you needed application-specific DSPs, that there were markets that required a special DSP architecture, like audio, like video, like multimedia (as I will talk about in a minute). So we have continued to spawn special-purpose DSPs to go along with the general-purpose ones.

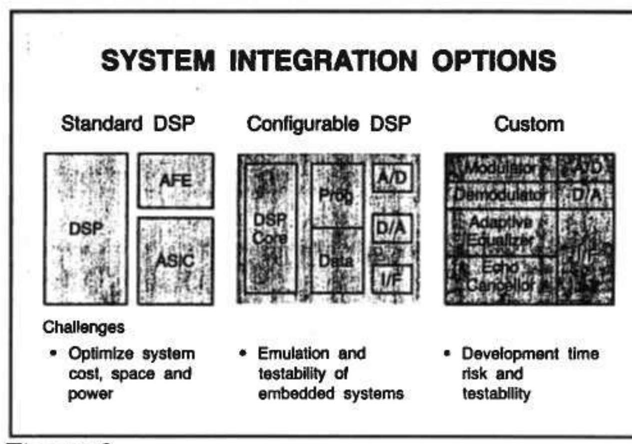

Figure 8

Then, more recently, customer-specific DSPs have become a large share of the total market. In fact, the typical design of six or seven years ago had a DSP with an analog front end and an ASIC, and you worried about optimizing system cost, base, and power. If you were successful, you could talk about integrating that onto a single chip. But, initially, it wasn't possible to do your first design that way. What has happened in the last few years is the introduction of configurable DSPs, supported with ASIC libraries, supported with emulation tools and embedded testability. This is so you can do your first design in integrated form with all the I/O and the DSP on the same chip, and then, if appropriate, migrate to a custom solution.

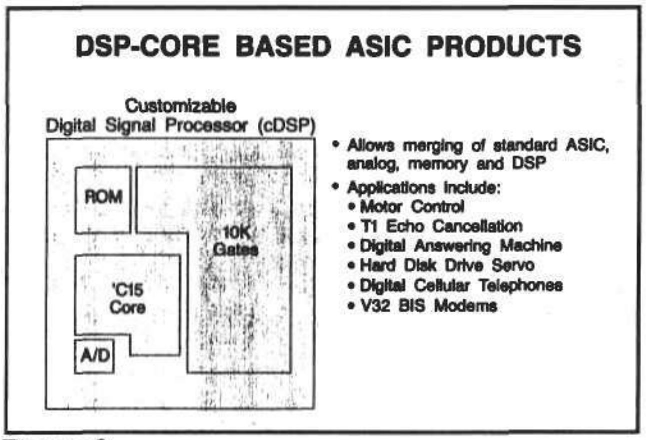

Figure 9

We used to show this as a real wonder. There's a 320C15 core. This is one that was originally done simply by taking the core and adding random logic around it. In fact, today we have dozens of designs where the design is done from the ground up with a core DSP, but you build the I/O and the random logic around it, and can use the development tools to debug the software in the design process, and that is certainly the wave of the future.

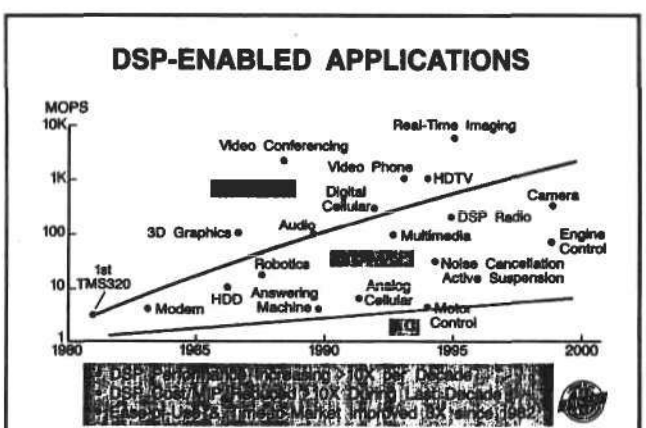

Figure 10

Now, a look at applications. We talked earlier about millions of operations per second, or MOPS. For a DSP, since they are really classic RISC machines, they are almost all one instruction per cycle, so MIPS equal MOPS. This goes on up to, I guess it is DOPS and GOPS, if you like billions of operations per second. In fact, we had some people in our labs who, when they were doing their BI CMOS processors, talked about B-BOPS as another possibility.

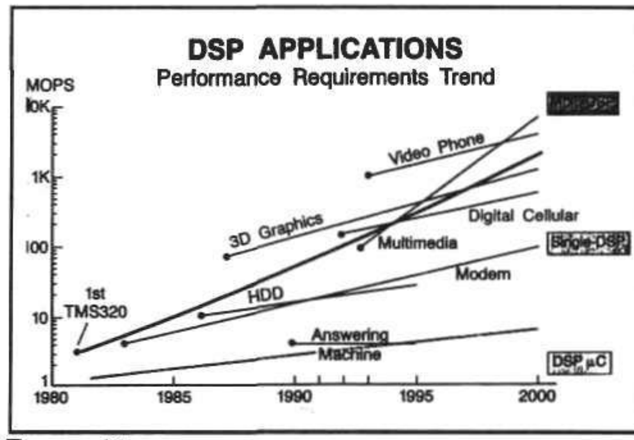

Figure 11

Here we have plotted those MOPS versus time, and the trend from our first DSP with time. You can see down in this range the low-performance people are doing microcontroller-type functions, like you would see in an answering machine or a motor controller. Most of the applications today are single-chip DSPs, typically used in things like the hard disk drive I talked about, or modems, robotics, that type of thing. Then at the high end, multiple DSPs, particularly for video applications. The record so far on the multi side is Fujitsu—they used 1024 TMS320C30 DSPs. They announced that product at the time the 320C30 still cost $500, and at 1024 per system it's enough to bring joy to the heart of a semiconductor manufacturer. Unfortunately, it has taken a while to get the product to market, and the price has come down.

If we look at the performance trends over time, we see these applications and their requirements and where they're going, and you can see that there is only so much you want out of your answering machine. Pretty soon it levels out down here and focuses on cost and feature integration. Modems and hard disk drives continuing to move up as new standards are introduced for modems or performance for disk drives, but staying below the performance-trend growth. Graphics—because graphics and video are limited by standards, they tend not to grow as fast. The application that really consumes MIPS without limit is image-processing multimedia, where there seems to be no limit.

Let's talk about multimedia. The first question is, what is it? No one seems to know. For some people, it is a sound blaster card so you can listen to audio on your PC. For others, you want to send Group 3 fax, or add voice annotation by compressing speech and putting it on a memo or add video or use your telephone while you send a fax, or whatever. Many different possibilities, and a lot of product definition going on.

And with that, the tradeoffs of DSPs versus microprocessors, because traditionally microprocessors have had the realm of large memory sizes and data management in non-real-time data processing applications, and DSPs have been used for signal processing in areas with relatively small memory, so they could do it in real time. What multimedia does for us is to move into that real-time block with large memory requirements, particularly for image processing, and that is why we are seeing more and more DSPs that are extending their memory address reach, and we're seeing RISC microprocessors moving into this realm, attacking the real-time market.

IBM has a good example of a multimedia card. It also happens to use a 320, but I mention it here because it was one of the earlier introductions of a multimedia card into a PC that you could plug in and add the features of audio compression playback and provide the basis for telephony and other functions, speech processing on an add-in card. Now, one thing that is apparent is that application writers all would like to use a DSP card, but in fact there is confusion in the industry. What they really need is a standard interface. They need some way to say, "Look, I've got to have the performance of a DSP, but I need to know it is there in some configuration." That's what this alliance that Jim referred to earlier with TI and IBM is aimed at. You want to have DSP functions. You want to know that this add-in card can send a fax or that it has a vocoder and so on. And, you want it to plug into a standard slot. But standardization and performance tend to be enemies. You don't want to eat up all your MIPS conforming to an interface that people write around. So the trick is to have a very efficient operating system and a standard interface, and let the application writers just call functions.

That is what the MWAVE DSP processor is. It is designed specifically for multimedia applications, and will be supported by IBM to drive that application standard so that DSP cards can be as common as modems in add-in slots, and eventually moving to motherboards.

It is in the area of consumer products where DSP really is being used. A classic example is telephone answering machines. At one time I counted 14 different companies designing telephone answering machines with our DSPs, and there were probably a lot of others. They have a very simple motivation. If you have ever used a telephone answering machine, you know that the tape that you record on is not very reliable. In fact, I was somewhat surprised to see data that indicate 11-16% of the returns within warranty were due to the tape mechanism. I figured it out when I read further and examined the "within warranty" part of that, since mine has been returned to the trash can at least twice, because of the reliability of that mechanical system. But, you can get rid of it. You can get rid of it by using a DSP to compress the speech so you can store it in a small amount of memory; in this case, 4 megabits of memory gives you 18 minutes. If you want to go to 16 megabits, you've got over an hour. You can also use the same DSP to scan the keyboard, drive the display, or do whatever else you want. To make it very cost effective for a consumer product, you'll notice at 4 megabit they've used the term ARAM (those of you who are not familiar with that, that's an audio RAM—that's a term we use in the industry to describe a DRAM that has a few bits missing). Normally, these go in the trash can also, but innovative marketers that our people are, they've figured out that in speech processing you really don't care if you miss a few bits, and so we make a deal and price these very aggressively, as do others. So, most of the answering machines use ARAMs at a very cost-effective rate to solve the problem.

Digital cellular is one of the most fascinating of DSP applications. Everyone is going to digital cellular, and this is a market that uses five to ten million units a year, and so it can be one of the largest DSP markets. Just to do today's IS54 standard takes somewhere between 40 and 60 MIPS of performance. The next generation will collapse the whole digital subsystem onto a DSP. The industry is moving rapidly in competition with multimode phones and other things that can use digital signal processing to reduce cost and integrate. In fact, it is necessary to go to digital for reasons of fraud or security, and only a case of how quickly companies can get their products to market and bring the cost down.

Another example that I find very interesting which is just now emerging and seeing a lot of competition, is noise cancellation. So if you take a signal that makes noise, and you realize with a DSP you can, in real time, sample that, do processing, and generate a new signal, then it becomes possible to generate a signal that is the exact inverse of the signal you detected, and therefore totally cancel it out. Now, you can't do that across the whole frequency spectrum, but for automobiles, for example, they can pick the resonant frequencies that cause objectionable noise, and they can cancel it out. In fact, the high-end cars that have super-quiet ride will be introducing it in the next year or two. I'm trying to tailor one for my one-year-old daughter to cancel out the noise as well! [Laughter.]

Television de-ghosting—another wonderful application, because this is one that certifiably requires 5 billion operations per second to perform. This is caused by the fact that television signals bounce off buildings, and so some of the signal gets there later or earlier than others, and if you live in a large city and don't have cable (or even if you do have cable the effect can show up), you see ghosting on the screen. But to process the information is an enormous amount of signal processing. To look at streams of data and decide what is a ghost, identify it, and cancel it, so it is one that can consume enormous amounts of processing power. The FCC is conducting tests now on inserting signals, during the retrace time on your TV, to aid in doing this. There are prototype systems now out in tests to perform this function.

Lastly, as you move beyond this, you are into the range of image processing. This area is where the exciting performance steps are being made, in particular, as we go to image compression. As Craig mentioned earlier, most of what you send in a picture is not really necessary. A JPEG-compatible photo, (JPEG is a standard - Joint Photographic Experts Group - one of the ISO standards for still pictures) is about a 14-to-1 compression, but in fact there are many that can do 24-to-1 very easily. You are not supposed to be able to tell the difference, though it is legitimately a compressed picture. The basic issue is to remove information that does not provide anything for you. So you use an algorithm called the discrete cosine transform and throw away information you do not want. This is an application where the products are just now coming to market, and where we are pretty much right at the edge of processing power.

If you take a step beyond that to video and real time, we are into MPEG and the associated standards for real-time video (MPEG being the Moving Picture Experts Group). MPEG 1 standard is barely set, and MPEG 2 is about to be released. There are lots of semiconductor companies out there doing chips to attack this market, because the applications are almost unlimited. Whereas you're stuck with still pictures here and putting them on CDs and things, in video just think of the additional opportunities when the first karaoke players hit the market in the U.S. (which they will in the next year or two). I know of at least three companies developing karaoke players based on an MPEG full-video standard so that you can see the real-time video and interact with it. CDI. A lot of effort from Phillips and other companies in driving standards. With the compression achievable today (there are systems operating up to 200-to-1-type compression that you would not be able to discern the difference), the issue is prediction and interpolation and how you can do motion estimation to guess what that next frame will be, and yet not throw away so much information that a single picture can't be used for freeze-frame or other type information. So it's a real challenge. But at 200-to-1, you get very recognizable pictures, and you don't have to be anywhere near that to replace a CD disk, replace the audio with audio plus video, so that MTV can go ahead and have single CDs that have the video encoded, and you can play it on your CDI player. So, there are lots of very high-volume markets.

Kodak's Photo CD that was just introduced uses a standard DSP with floating point. It lets you take your collection of 35mm photographs and store them on a CD and organize them and computerize the showing of them in any way you want. It uses a proprietary compression standard. The whole advantage of these other standards (JPEG and MPEG) is the idea of being able to exchange compressed data, which will come with time.

Lastly, looking at cable, we see one of the really wonderful types of applications from a semiconductor point of view. These people on cable are competing with Blockbuster. The way they look at it is—what is it going to take to keep you from driving down the street and paying a few dollars to rent a video? And the answer is, if you could just run the top 10 movies, start them every 10 minutes on a Friday night, then you wouldn't be tempted to go and rent that video. So all they have to do is a minor 100-to-1 compression or thereabouts, and they can give you 300 channels simultaneously so they can go and send whatever they want into your home. Of course, they've got competition from the people who want to do it over other means, over copper, over fiber, and so on, but the cable people have real products and are coming to market very, very quickly. And this is one where we can talk about tens or even hundreds of millions of units.

Whatever you talk about, it requires a lot of processing, and that's why DSPs are so important, and why it probably requires dedicated DSPs. Even when you get into these standards Craig mentioned in video conferencing, you're still up at half a billion operations per second. So you're demanding the maximum in performance capability.

If I look out in the future and consider where the past has been—where we started with hundreds or maybe thousands of mainframes and thousands of dollars of semiconductors per mainframe, and moved into a minicomputer era where there were hundreds of thousands of minicomputers and thousands of dollars per minicomputer—the great growth in the semiconductor industry in the last ten years came, to a very large extent, from the growth of the PC industry, where we could ship tens of millions of units with several hundred dollars of semiconductors per unit.

If I look out in time and say what is going to cause the next wave, it is the fact that this set of consumer products that are largely DSP based (for example a cable decoder) can now use $50-100 worth of semiconductors, and yet ship tens of millions per year, and hundreds of millions over their lifetime. That makes the PC market look like a very small one, and makes the semiconductor business look like a wonderful place to be, if we can just live that long.

Mr. Rhines: Thank you.

Questions & Answers:

Question: If you could do a single-chip telephone answering device, wouldn't that drive the conversion overnight we could get rid of those unreliable tapes?

Mr. Rhines: The answer is, with one qualification, yes. That qualification being, it will be a two-chip system, because ARAMs are such a cheap way to buy memory that you can hardly resist putting a second chip in, there is no reason to have more than two. The DSP can do all of that processing, and in fact I would anticipate that there are a lot of semiconductor companies here with exactly that product on the drawing board, maybe even with the memory integrated, because it is one where the market is cost-sensitive, and there is no reason why you can't.

Question: Why is TI in a leadership position in the DSP market?

Mr. Rhines: Hmmm. Thank you. Tell them I didn't submit it! Because we were so optimistic, we thought this market would take off overnight, so back in the late 1970s and early '80s, we developed DSPs thinking that we were going to sell hundreds of millions of dollars worth very, very quickly. When we didn't sell hundreds of millions of dollars worth, we didn't have anything else to do with the people, so they developed development tools and derivatives and kept making up excuses for why these things weren't selling, and pretty soon we got a pretty good base of support and products that people could use and a whole broad family. Then gradually the infrastructure built, and that gave us a position today that gives us, I guess, about two-thirds of the standard DSPs in the market. And it's something that we intend to hang onto.

Question: What will keep others from taking this distinction away?

Mr. Rhines: My goodness! I didn't read that first! Hmmm. It certainly is a market that is very attractive to a lot of people. To argue what can keep it, the answer is infrastructure, familiarity, these things I mentioned earlier—that you may have a DSP that will do the job, but do you have a version that has an EPROM on board. Or you may have the C compiler, but do you have an ADA compiler? Or you went to school somewhere where you learned to program with a 320 and it's just easier for you, so why not do it as long as they charge a reasonable price. Those are the things, the momentum, as well as some fairly large software libraries for standard functions, and some applications software. One of our most successful designs was a customer in the Far East who called up one of our application engineers in Japan and said, "Do you have a 320C10?" and the field sales guy pulled out the datasheet and said, "Yes, that will be $45," and he said, "Okay, I'll take two million of them." And we never knew, never had the design. We just knew that some applications engineer in Australia had designed a product and given out the application note, and so because we hadn't participated in it, we hadn't had a chance to bid down the price, and so ... [Laughter.] It had a very positive benefit. So that's what works for us. I think on the other side, Motorola, Analog Devices, AT&T, all have aggressive programs, all targeting areas of DSP, so we won't be alone. It'll be a hard fight, and the customers will benefit.

Mr. Rhines: Thank you.

Partnership, Policies, Profits, & Performance

James Norling
President, Semiconductor Products Sector
Motorola Incorporated

Mr. Norrett: Jim Norling has been President of the Semiconductor Products Sector of Motorola since 1986. He is Chairman of the Semiconductor Industry Association and a founding board member of Sematech. Jim has had a lot of jobs at Motorola—maybe not quite as many as Craig did, but he has had some very influential positions. Some of the positions are Operations Manager for Special Products. Yes, back in the early days of Motorola they were in the timepiece operation—he ran that business. I understand today that one of Jim's timepiece products is in the Smithsonian Institute, is that right? General Manager of the Cash Cow—I mean the Power Transistor business (sorry, Jim), and General Manager of the International Division. Then he jumped up to Assistant GM of the Sector, and now he's the President. A little-known secret about Jim: he likes speed, of the two-wheel variety. He rides a hog (if you don't know what that is, that's a Harley-Davidson motorcycle). Jim is also married and is active in his community.

Though the title of his presentation sounds a little philosophical (a lot of Ps there), knowing Jim as well as I do, it certainly won't be philosophical. Please help me in giving Jim a nice, warm round of applause.

Mr. Norling: Thanks, Gene.

Craig and I were trying to decide whether anybody out there knew who those two guys were from Silicon Valley and the Valley of the Sun. There's one of them, sitting right over there.

Thanks, Gene, and good morning to one and all. After two years of absence from the podium here, it's nice to be invited back. It is amazing what winning all five Dataquest awards can do for a company. I have to apologize to Gene Norrett for causing the demise of the Dataquest award—I guess we made it a no contest. I couldn't resist that. Since we took out the suspense, of course Dataquest has decided to adopt the Bush administration's view of industrial policy: they don't want to pick the winners or losers either. [Laughter.] Sorry, Gene. I guess the government doesn't want to accept the fact that the semiconductor industry *has* gone through a long, hard siege. As the epitaph on one tombstone read, "I *told* you I was sick!"

We've been in a saucer-shaped recession, though probably not a depression. Depression is a relatively new word created earlier this century to substitute for the previous term, panic. Fortunately, things are looking up this year, with growth expectations up over the past two years, which should have a positive impact on the industry's profit outlook. Unfortunately, that has encouraged the politicians to descend on our industry for donations. Someone should explain that high-tech touch isn't about political fundraising.

Today, in the middle of the U.S.'s quadrennial nervous breakdown, during which you've all conditioned yourselves not to believe anything that you hear from behind a podium, I'm going to try to attempt to define a winning formula for the "90's, based on, of course, Motorola's view of the industry. I'll throw in some of my own public policy views, mostly derived from a decade of battling to become a factor in the world's currently largest market, Japan.

If you have followed Motorola for awhile, the formula will sound deceptively familiar: Develop strategic worldwide partnerships with a few leaders in each major market segment. Then use the resulting core competencies and functionality to gain strategic advantage across a broader customer base. Partnering has been one of our leadership requirements since 1987, when we recognized that no one company could do it all alone anymore. We learned that the enabling competence for a successful partnership is applications functionality, increasingly exercised through software expertise. That is why you see so many customer/supplier component systems partnerships forming.

This requirement for success has been accelerating, and will continue to pervade our industry for a long time, driven by the increasing realization that technology by itself doesn't make money anymore. It takes a rich library of functionality mixed with combinational technologies often acquired through a partnership relationship. The electronics industry has been faster than many to weave a broad fabric of alliances for managing the entire value-added chain, in effect forming virtual enterprises. That's a fancy term, of course, for reshaping the basic nature and structure of the business enterprise, and challenging our old models for success. In essence, this model seeks to master complexity by disaggregating selected functions and building relationships throughout the value-added chain. Its goal is to deliver to the customer, in as timely a fashion as possible, the lowest-cost, highest-value product that the entire chain, not just a single company, can produce. The results are often better product design, higher quality, improved cycle time, and—if you manage it well—superior bottom-line performance.

Like runners on a finely tuned relay team, each member of the enterprise has his or her own talents, but no single runner has the strength to win the race alone. Constituent performers can focus on their own specific area of expertise. Example: Motorola's nearly six-year-old alliance with Toshiba continues strong and productive, because it was founded on the complementary capabilities of both partners. Here's a virtual enterprise that is far better at microprocessors and memories than either partner is alone. Recently, technology using microcontroller chips produced by both Motorola and Toshiba is spawning a number of design-ins to implement local operating networks produced by Echelon. Echelon is a small, California-based company that came to us with a great idea and somewhat subdued resources. We saw the huge opportunities in what they had come up with, so we came up with the resources to get them moving down a road that is sure to take their products—and ours—into offices, homes, and factories around the world. In fact, to paraphrase Victor Kiam of Remington Shaver fame, "We were so impressed with Echelon that we bought part of the company."

Last year's landmark Apple/IBM/Motorola partnership is another perfect example of a virtual enterprise. Here is the marriage of integrated circuit technology investment, systems engineering capability, and top-notch software competencies. Technology is key, but functionality will pay the bills. Without the systems and software proficiencies to extract its value, technology will be the equivalent of investing in raw land—a sobering analogy to many of us in the Western states.

Our alliance with Apple and IBM has all the right attributes. The world's two highest-volume computer manufacturers have chosen their next-generation architecture, and they chose to have it enabled by a silicon partner with a long, successful track record of giving their microprocessor customers their money's worth. Partnerships like this will take a lot of time and education. Nothing worth learning is learned quickly (except skydiving). If you saw last

Thursday's announcement of the first PowerPC chip—the 601—maybe I should consider that, in some ways, chip design can be a form of skydiving. We launched our first PowerPC design one year ago, and Thursday we introduced a processor with integer performance of 50 spec marks, floating-point performance of 80 spec marks, on a piece of silicon that is considerably smaller than any of its competition (read cost), and consumes about half the power. This chip is a technological *tour de force,* with the best MIPS per nano-acre-watt [laughter] of anything existing or due in the next twelve months, and this is just the first in the family. I'll bet you thought I made that up. It really is 6,000 MIPS per nano-acre-watt, if you want to do the calculation.

Again, here is the real-life example of systems and software expertise extracting the value from raw technology. In this case, technology consists of 6/10 micron feature sizes and four layers of metal. System and software developers are going to love this chip. Products like this are a perfect example of the kind of value-added blend that it takes to make money in this business. A winning formula, one that includes a healthy mix of growth and profits, also depends on the ability, through products like the PowerPC, to attract a robust mix of customers, themselves growing at a healthy pace. Growing faster than your systems partners is not a sustainable solution.

The financial requirements and risks of the traditional technology treadmill continue to escalate, driven by the obsession that today's technologies are never enough. Whether they've paid for themselves or not, they're jilted for tomorrow's tighter geometries. Not realizing it at the time, Yogi Berra articulated one of the fundamental axioms of our business. When talking about Yankee Stadium, he once said, "It gets late early out there." In our business, it also gets late early. Time to market is, along with unique functionality, one of the key drivers of profitability. And profitability remains one of the most accurate litmus tests of health. The epitaph I joked about earlier probably really said, "I *told* you I was losing money!" Even the Japanese participants, long considered immune from the financial viruses that affected the rest of us, have a serious case of the flu. Management is beginning to take unprecedented actions to bolster profitability and return on capital. Less variety of products, cutbacks in capital spending, longer intervals between new model introductions are being initiated to retrieve as much return as possible before obsolescence. Even employee cutbacks are not so subtly rumored. With industry in transition (and woe be to those who aren't in the right gear to keep up with the paradigm shift of the decade), the reality is, by the end of the decade, only a handful of major manufacturers will be able to afford this continual reinvestment game, and they'll have to be exceedingly good at what they do. There will be no margin for mediocrity.

I started this morning by poking fun at politicians. That qualifies me to offer opinions on policy as well. Speaking of qualifications, I was brought up thinking that anyone could be president. Now I believe it! [Laughter.] If you think the national political scene is crazy, you ought to live in Arizona, where the former impeached governor is now running for a Senate seat, and the current governor is under investigation by the RTC.

Fortunately, we do, as an industry, have a number of friends in Washington who understand the strategic importance of the semiconductor industry—that it drives an electronics industry with more economic impact and more employment than the auto industry in this country. There is no question our industry is transitioning from one that was treated by government with benign neglect to one that has been abruptly thrust into the national spotlight of strategic importance to our economic future. Politicians have just begun to comprehend what the Japanese have known for a long time—that the future conflicts of nations will be primarily economic, and some of the key combatants will be those of us in this room this morning.

The bursting of the Japanese stock bubble should not lull us into complacency about Japan's ability to invest in new technology. We can't afford to let our government or the press conclude that Japan has been neutralized by its problems. History tells us that Japan has a remarkable ability to face adversity and come out even tougher. It happened after the oil price shocks of the "70's, the high-yen period of the "80's. It is inevitable that they will recover again, and probably sooner than we think.

On the plus side, access to the Japanese market *is* getting better. U.S. semiconductors are being designed into Japanese autos, cameras, VCRs and computers. American-made pagers and cellular telephones are popular.

On the minus side, it's not good enough. Penetrating their market is like peeling layers off an onion with one hand.

As the Japanese economy slows, the pressure increases to return to the traditional keiretsu-bound network of suppliers and exclude outsiders. The access problem then will spill into the U.S. market, where Japanese transplants continue to rely on traditional suppliers and exclude U.S.-based companies. As Japan moves more of its production offshore, this could become a greater issue.

Yes, the center of gravity for our industry has shifted to Asia, as Gene indicated, with the U.S. dropping from 43% of the total market in 1981 to 28% ten years later in 1991. Japan consumes nearly 40% of the world's semiconductors, which has had the effect of putting 40 cents of every semiconductor dollar behind bars. Despite the energy spent on both sides of this issue, scant progress has been made during the past two years to ratchet up foreign share in Japan to approximately 16%, according to the latest estimate. It is difficult to compete when foreign rivals protect home markets, subsidize third-country markets, or dominate U.S. markets based on non-reciprocal access.

Our survival mandates that we assert our rights to fair access to foreign markets. The government has shown increasing resolve on this issue. They need our continued support and stimulus.

If industrial policy isn't a politically correct term, then let's call it something else. We've seen how business/government teamwork can make more progress on a market access issue than business could make by itself. In effect, what is needed is a national technology partnership among government, industry, and academia, with our government stepping forward with a pre-competitive R&D support, a policy that many other countries seem to sponsor so well. We need a government-advocated business environment that fosters investment as opposed to consumerism, through things like R&D tax credits. We need quicker capital depreciation, allowing depreciation of three years instead of five. And we need government encouragement of major new commercially focused technologies, such as smart streets and highways, HDTV, multimedia, nationwide fiber optics networks—things that leverage semiconductor expertise. It isn't, after all, much different from the national highway system that was sponsored in the "50's and "60's. And that national technology partnership must have enough vision to overcome the fear of picking winners and losers. No action means, of course, we get to pick the loser, and that's us.

But even if the government joins the team, we've still got a lot of work to do on our own. The industry really is in the midst of a transition. The old tools will have to be used differently, and new tools will have to be created. To get beyond survival to establish a degree of permanence, a different formula is required to win. Technologies—they're moving from monolithic to mixed, or combinational technologies, derived from a broad, diverse portfolio of devices and advanced systems on a chip that use everything from BiCMOS, to gallium arsenide, to things like power control and sensors on MCU chips. All of these and more are required to implement a more functionally rich and software-intensive set of products.

These have to be leadership products, developed with a robust set of systems partners and enabled by aggressive, well-funded research and advanced manufacturing programs. Global capability—wherein world-class suppliers must supply necessary and balanced design, manufacturing, sales, and marketing resources to keep pace with changing market dynamics and global customer demands. Regardless of where their plants are located, customers require the same level of service. Trying to serve Singapore or Tokyo from San Jose or Phoenix isn't good enough anymore.

Manufacturing excellence—because the most innovative technology in the world is useless if it can't be manufactured. Leadership companies will continue to leverage manufacturing capability to expand their positions. The top ten companies in the year 2000 will be those that have developed or maintained their world-class manufacturing capabilities.

Lastly, human resources and management style—the basics that never get the attention they deserve. I believe that the key to winning worldwide is a people-centered culture that promotes excellence as part of a winning team. An entrepreneurial mentality, superlative achievement, attention to detail, the correct level of discipline, and a means of participating and sharing fully in the business results are necessary to unleash the creative energies of company teams in a cost-effective, productive manner.

Well, the last couple of years in the semiconductor industry have been a little bit like sitting through a Woody Allen movie. You don't want to leave in the middle of it, but you sure don't want to see it again. [Laughter.] You can bet that this industry, with the vision, perseverance, and resources, combined with a winning combination of partners and leadership products, will author a continuing series of classic performances. Bring some popcorn—it's going to be a great show to watch.

Thank you.

Questions & Answers:

Question: What would be the impact on foreign market share of IBM entering the merchant market?

Mr. Norling: Well, okay, the smart-aleck answer is, I suppose, it depends on how well they do—but I think the intent of the question was a bit different. IBM sells a certain amount of product to itself in Japan. That has historically not been counted as part of foreign access. Obviously, whatever IBM sells to the Japanese market on a merchant market basis would immediately, obviously, be considered as part of foreign market access. I believe the government knows reasonably well what IBM's sales to itself in Japan are. If they choose, or if they decide with the Japanese government, to include that in the formula, then the goal would be raised accordingly. So I guess the sort of short answer, it may raise the number, but the target will go up with it, so it wouldn't make the achievement easier. I guess that would be the answer to what I think is the intent of that question.

Question: How soon do you think it will be before foreign market share will reach or go beyond 20%?

Mr. Norling: I think it will probably go up a bit in the fourth quarter, but I'm not sure. The quarter has just started. At this point, we're on a growth trajectory that will probably keep the U.S. and Japan governments a little bit from being totally at each others' throats, because at least there have been a couple of quarters here of improvement. I think that we'll achieve the 20% goal sometime in '93. I don't know, I guess I wouldn't presume to predict exactly when, but we seem to be seeing an increased realization on the part of the Japanese government that the industry is serious, the U.S. government is serious, and there are, in fact, some distasteful consequences of not paying some serious attention to this market access issue. So I think progress will continue to be made.

Question: how can your national technology partnership get better support than Sematech did?

Mr. Norling: Gee, I guess I'd first quarrel with the premise that Sematech didn't get good support. I certainly feel, as one of the founding board members, that it got tremendous support. It got all of the legal hurdles broken away, $100 million a year to match the industry for every year so far (now some talk of a slightly lower number). So I guess I would hate to use Sematech as an example of something that didn't work very well. On the contrary, I guess I think I'd like to be on the side of those that would declare it a victory of sorts. It was a good policy, and it was supported by industry and government, has had pretty good results, and I think we're seeing some benefit from it, both in the strength of the semiconductor equipment suppliers and in some regained market share for U.S.-based companies. So I think that the difference between this thing I dubbed Technology partnership and Sematech is that the thing that I propose is one that encourages, like the government did with the interstate highway system, or at least enabled it in the '50's and '60's. This would be an enablement of some technology, some large markets that would generate fallout for the semiconductor industry. Totally different concept than Sematech. I guess I'll argue at lunch, I suppose, with somebody who doesn't think that Sematech worked very well.

Thank you.

The Resurgence of American Electronics: Is it Real?

Michael Borrus
Co-Director
Berkeley Roundtable on the International Economy (BRIE)

Mr. Norrett: Our final speaker of the morning is Michael Borrus. Michael is Co-Director of the Berkeley Roundtable on The International Economy (BRIE), and teaches in the Management of Technology program, a joint engineering program with the business school at the University of California at Berkeley, who also did pretty good on Saturday—another one of the surprises. He has served as a consultant to the U.S. Congress Office of Technology Assessment, the President's Commission on Industrial Competitiveness, the U.S.-Japan Trade Advisory Commission, the U.S. Trade Representative Office, and many other very, very distinguished organizations. Michael is an attorney and a very well-published author and noted authority on U.S. trade with its partners. Please join me in welcoming Michael Borrus.

Mr. Borrus: Good morning. Thank you, Gene. Berkeley's football team is actually 23rd ranked in the country now, which is two years in a row in the top 25.

Like Jim Norling, I'm not going to use any slides, so I'd ask you to close your books, turn up the house lights if they come up higher, and focus up here. I'd like you to know that I'm not going to use slides because I can't afford to, because I come from a poor public university, which is getting poorer all the time. If only the resurgence of America would apply to the universities and the whole system of education.

My topic is The Resurgence of American Electronics: Is It Real? As the name implies, I want to start by taking on the notion of globalization. We're told that the electronics industry is globalizing. Maybe so. I'm not sure. My skepticism, I think, is perhaps best captured by a comment from a German friend of mine in the German Bundespost. The German telecommunications authority Standard Electric Lorenz (SEL) a few years ago, when you'll recall, the American firm ITT sold its German telecommunications subsidiary, to the French company Alcatel. Was my friend concerned about the change in ownership? "No," he said, "SEL was German when it was American, and it'll be German now that it's French." [Laughter.]

The idea that location still matters, and may in fact matter more than ownership, suggests to me a different slant on this idea of globalization. I don't view globalization as kind of the global homogenization of everything, or as that popular image of a borderless world with stateless and footloose multinational corporations. Of course, as Jim Norling and others have suggested, there are market opportunities all over the world. Customers have to be served all over the world. Given the costs and risks of technology development, one needs to operate all over the world. But there are, and will be, real differences from region to region—Asia, the U.S., and North America, Europe—in the skills, the distinctive competencies, the core technologies, the content of productive activities, not to mention government policies, that are relevant to competitive success in the electronics industry. In my view, no one region has all of the know-how, all of the technology, all of the competencies necessary for success. You've got to be global as much for access to the technology, to the competencies, to the know-how, that reside abroad as for access to the markets.

As much as the need to hedge against risk and cost, it's that mutual access to competencies lying elsewhere that lies behind all of the partnerships we've seen recently. Jim Norling suggested as much—Toshiba/Motorola—but I think one could say the same of IBM/Toshiba/Siemens, AMD/Fujitsu, as well as more broadly in the electronics industry—for example, Apple's deals with Sharp and Sony, etc. Now to caricature slightly: You can capture that sort of regional dispersal of know-how and of productive activities by suggesting that a lot of the hardware, a lot of the component technologies (more than simply the semiconductors, displays, power supplies, precision components, and the like) and a lot of the manufacturing and associated skills have migrated to Asia during the decade of the 1980s. They have moved to Asian producers, and not only to Japan, but increasingly to Korea, Taiwan, Singapore, even Malaysia, and will move progressively over the next decade to China (a topic I'll come back to toward the end of my remarks).

Meanwhile, the...I don't know what to call it...let's call it the soft stuff—design, architecture skills, product definition skills, software, networking, systems integration—in a word, all of that stuff that has been labeled computerlessness, is increasingly resident in the U.S., and to some extent in Europe. I'm not going to say a lot about Europe in my remarks, except to say now that I think there are increasingly some interesting electronics players in Europe, though not the traditional ones. Some of them, like Siemens, will obviously continue to be major players. But I see major electronics strength in Europe coming out of applications, particularly around a core competence like automotive systems, in which companies apply the electronics effectively, learn how to do electronics well, and then begin to apply it into other areas. Companies like Robert Bosch, the auto parts manufacturer, like ASEA, Brown Boveri, like the AEG division of Daimler-Benz, even like the Fiat subsidiary, COMAU, which does automation technology. I think some of these companies will come back and be major players, and that Europe, in areas like industrial control, will continue to have a significant role in electronics. But leaving that aside, the basic image is of hardware skills and manufacturing in Asia, soft stuff (along with some holdout manufacturers like Motorola and Intel, Hewlett-Packard and IBM) in the United States.

I've been saying for some time that I think there's a common dynamic driving that regional division, the emergence of a segment of electronics that cuts across the traditional categories—communications, computing, office, consumer, etc.—a segment I call "high-volume microsystems." It is what Apple means to capture with its notion of personal interactive electronics, and its personal digital assistant (PDA), that H-P tries to capture with its idea of information appliances, that Wally Rhines called DSP-based consumer products. But all of those products—notebooks and smaller PCs, portable telephony devices, portable office equipment (fax machines, copiers, and the like, and combinations of those things), controllers for automobiles and the various subsystems in machine tools and instruments, and the leading edge of consumer electronics products like hand-held digital combination VCR/TV kinds of things—all of those products share many characteristics. They're all essentially microsystems built around embedded processors, often with the software embedded. They're multifunctional, tending to combine communications with office or personal or consumer kinds of functionality. They're increasingly portable. They're increasingly networkable. And, they all use leading-edge component technologies, and again, not just semiconductors, but displays and power supplies, precision component and optics, and optoelectronic components etc. They're all manufactured in reasonably high volumes, consumer-like volumes, and sold at consumer-like prices. Those kinds of high-volume microsystems, will be supplemented soon by putting some of the mechanical functionality in silicon also, I believe, over the next decade or two—actuators and sensors and the like. The majority of those kinds of systems are manufactured, and a lot of the underlying component technologies are supplied out of Asia. What is surprising is that, despite that sort of threat of hardware dependency on Asian competitors, U.S. companies have shown remarkable strength in electronics broadly, and in fact in leading the development of many of those kinds of new products, indeed in leading those partnerships that I talked about before that cut across Asia and North America, rather than being victimized by the threat of competitive hardware dependence. So much so that we can talk about my topic today—resurgence of the American electronics industry. The question is, why? Why have U.S. companies been able to deal with the threat of hardware dependency so successfully? And that's really what I want to spend the rest of my time talking about.

I think there are three reasons. The first reason falls under the category of timing and good luck, or better, what Machiavelli called *fortuna*, which loosely translates as "good fortune."

A second reason actually has to do with that good fortune, and Machiavelli's sense of *fortuna* that you could mold and shape fortune to your own ends, and in fact U.S. companies have done a good job of that, choosing several clever strategies and several clever organizational forms, again to echo Jim Norling's comments, to exploit the opportunities that were available in the market. I want to talk about those strategies as well.

Third (and I will spend some time here), the current Japanese economic problems have also impacted the success of Japanese companies. I want to spend some time talking about that too.

So first, *fortuna*, good fortune. In my view, U.S. companies were fortunate that computerlessness was an effective strategy in the late 1980s and early 1990s. In a sense, the real issue is, under what set of circumstances will computerlessness continue to be an effective strategy? And under what set of circumstances does computerlessness become a real problem for the U.S. industry, become a decisive vulnerability in international competition?

Part of the answer depends upon the structure of existing markets for the hardware technology, and especially for the component technologies. To the extent those markets remain relatively open to trade and investment, to the extent they remain competitive rather than oligopolistic, to the extent they remain geographically dispersed (major players in the U.S., Asia, and Europe), to the extent the hardware side of the industry remains somewhat merchant (that is to say, to the extent there are independent players whose sole purpose is to sell the technology on the open market—players like TI, Motorola, and Intel who can keep vertically integrated electronics companies who also sell the technology honest in the market), then it is possible to get access to the hardware technologies you need in a reasonable time frame, and at a reasonable price. U.S. companies were fortunate that those markets remained open, that the Koreans busted the Japanese memory cartel, that the thrust of Taiwanese and Singaporean and Korean strategies in electronics were more to pressure Japanese companies in consumer electronics and at the low end of the electronics spectrum than they were to pressure U.S. companies, again generating great demand for the underlying component technologies. In key component technologies of the future (maybe displays—the plans of Motorola and AT&T to produce in the U.S. notwithstanding), those markets may reconcentrate. They may become less open in the trade and investment sense, less competitive, more oligopolistic, more concentrated in Asia, and less merchant in character. If that happens, then I think computerlessness will be a much less effective strategy.

The viability of computerlessness also depends, of course, on what you need. Intel and Motorola were not computerless in the sense of not having manufacturing. I would defy anyone to suggest that Intel and Motorola could have come up with the several billion dollars worth of foundry production capacity necessary for them to have been as successful over the last couple years as they have been. So, depending upon what you're doing, you may need to invest in hardware and manufacturing.

Finally, a lot of U.S. companies were lucky in the sense that the niches they were playing in—those computerless niches—were essentially uncontested. There wasn't a lot of competition. In that sense, Microsoft, which people point to as the archetypal computerless company, wasn't successful because it was computerless. It was successful because essentially it was a monopoly. And monopoly is the best business.

As companies have been successful and managed to maintain margins in those computerless niches, as those niches have grown, they've become increasingly contested, so it is not at all clear that the same financial success that companies experienced in the late '80s and early '90s in those areas is going to continue. It may well be that the cycle is shifting back, that you may need more control over hardware technologies; that is, to say it another way, it remains very hard to control what you don't produce, and it may be that those companies that have maintained a hand in hardware manufacturing will end up being in a better position as the industry changes over the next while.

But if good fortune played a role, clever U.S. strategies were also an important part of the story. After a decade, roughly during the late '70s through the late '80s, of being beaten up by Japanese manufacturing competencies, U.S. companies—either by accident or by intention—came upon a set of strategic responses. They were able to exploit a set of Japanese vulnerabilities which had always been there, but which were never so visible while Japanese companies were on a run competitively. I would include among those vulnerabilities a weakness in the same soft areas that U.S. companies are strong in; or, to put it slightly differently, it's a lot harder to predict the direction of change in the soft technologies than it is to predict the direction of change in hardware technologies. Because software markets have been less certain, Japanese companies (who are very good engineers when they've got a defined input and a clear output) find it much harder to track what is going on in software and to position themselves to be successful.

A second vulnerability is what I would call the "herd instinct," that very well-known fact that Japanese companies tend all to move into the same market opportunity simultaneously with the same level of investment. U.S. companies exploited that very well by getting Japanese companies to compete against each other on behalf of American partners.

A third vulnerability, a very significant one that American companies exploited, was a relative slowness in Japanese companies because of the organization, the consensual decision-making style—a slowness in reacting to abrupt market shifts and to new market opportunities.

Now, in exploiting those vulnerabilities, successful U.S. companies focused on significant opportunities for value-added product differentiation. They did so, in my view, with, on the one hand, the organizational innovations that Jim Norling talked about (and I won't), and on the other hand, by accomplishing three things in particular—the most important one of which is that they kept control over distribution and the link to the customer. Companies like Dell in PCs. That control over the customer link is, in some sense, the secret to their success. You'll recall that in consumer electronics, when the U.S. companies lost control of the industry, they lost control of the distribution chain, and really lost control of what the customer wanted. By and large, the successful U.S. electronics companies have managed to avoid that problem, and they've done so, secondly, while also retaining control over an equally critical technology to the hardware technologies they may have been purchasing abroad. A good example of that is U.S. workstation vendors who kept control of RISC architectures.

Third, U.S. companies also used their control over the alternative technology, over the soft stuff, to shape the evolution of the hardware technologies rather than permitting the vice versa to happen. They were able, in essence, to stay a step ahead of Japanese hardware producers. In my view, a company like Hewlett-Packard does all three of those things very well in an area like its printer business. It obviously controls links to its major customers and the distribution chain, and listens to its customers about what they want in future generations of laser printers. Although it is more or less dependent on Canon as the sole supplier of the laser printer engine, it does control the printer driver technology and has used that to bargain for leverage with Canon. H.P. also has used the operating system to shape the evolution of the hardware, rather than vice versa. Of course, you can also do those things badly, which is essentially what GE and RCA did in consumer electronics in the '70s, and lose control of the business. So hopefully some lessons have been learned since that time.

Well, if U.S. companies were smart, they were also helped by the fact that Japanese companies were quite constrained by their own domestic economic problems, particularly over the last few years. Now, I want to make a quick caveat here: Interpreting Japan through the lens of U.S. experience is a very tricky proposition. It is not so easy to know exactly how to interpret their current economic problems. In my view, much of the current economic problem in Japan is cyclical; that is, essentially over-investment and under-consumption, a particularly bad business cycle, exacerbated by the bursting of the asset bubble—that is to say—by the collapse of stock market prices and land prices.

But some significant part of the current economic problems are also structural, and it's those I want to focus on. I think they amount to the possibility that we're going to see slower economic growth in Japan for some extended period of time.

There is some indication that the savings rate in Japan is falling on a secular basis and is going to continue to fall. As you know, Japan's rapid growth was fueled by high savings and the cheap and abundant capital those savings made available. That is changing for a variety of reasons that include demographic shifts, the aging of the population (the old tend to save less than the young, as well as the fact that the young tend to consume more in Japan than they used to), and the removal of incentives (there used to be incentives in place that essentially made the first $100,000 of interest income earned tax-free for each individual, and those incentives, because of policy reforms, have been removed over the past year or two). In addition, there has been an increasing use of consumer installment credit; it essentially doubled during the 1980s in Japan. If you add all those things together, there is the possibility of a significant fall over the long term in the savings rates. The Economic Planning Agency in Japan is projecting an 11% rate by the end of this decade, which would bring Japan much more in line with the European countries, although still several times higher than the pathetic U.S. savings rate (though hopefully that will change after the coming election).

In addition to the falling savings rate, it is likely, I think you can at least make the case, that labor in Japan is going to command a higher percentage of the returns than they historically have. The total labor force is declining in Japan, and there are significant shortages at the major skill positions, particularly in electronics, and more broadly in engineering. Moreover, Japanese consumers as workers are tired of deferring their consumption. That at least suggests the prospect that there will be higher returns to labor, less returns to capital, and therefore slower and more selective investment on the part of capital.

Finally, perhaps the most important, the bursting of the bubble and the accompanying financial deregulation that has taken place over the last few years in Japan has caused, as Jim Norling suggested, a real intense preoccupation with the quality of investment and with return on investment. The old system, particularly during the 1980s, essentially worked like this: Investment was stimulated by the run-up in asset prices and the consequent low cost of raising capital. The Bank of Japan estimates that the real cost of investment funds, of borrowing for investment in Japan in the 1980s, was essentially zero or even negative. Needless to say, as the economy slowed down, as the bubble burst, the dynamics of that situation have changed significantly. Return on all of the investment that was made in the mid- and late-1980s has fallen significantly, and Japanese companies are increasingly sensitive to market-determined borrowing rates, to the extent they can get capital to borrow, given the troubles of the banking system in Japan. In essence, the Bank of Japan has said that Japanese companies appear to be increasingly sensitive to return on investment differentials on fixed investment, maybe for the first time even foregoing investments that don't appear to have a sufficiently high payback.

All these factors—the falling savings rates, the higher returns to labor, the emphasis on return on investment—add up to slower growth, a more selective investment than in the past, a domestic market that won't be able to fuel the export surges that have been characteristic of Japanese industry to the same extent as they have been fueled in the past, and a slower turnover of technology in production. Indeed, many Japanese companies I know of are talking about producing a fourth generation of product in existing fabs, rather than moving on to a new fab after essentially three generations of production over twelve years.

In essence, product innovations that arise abroad, innovations on the soft side, may turn out to be a more powerful competitive weapon against a slower turnover of new technology in production than they have been in the past. Moreover, slower growth is exposing some other vulnerabilities of Japanese companies that have been hidden by rapid growth. In an environment of slower growth, that shift to high-volume microsystems I talked about leaves some Japanese firms much less well positioned than others. Sony and Matsushita have both recently announced either much lower profits or outright losses in some areas, partly because they are too heavily consumer oriented. They are finding it very hard to define successful new products in this new area of high-volume microsystems. Alternatively Fujitsu and Hitachi and even to some extent NEC have been living much as IBM has for a long time off the cash flow from mainframe computing revenues in Japan, and as the shift occurs towards high-volume microsystems, they are caught in the same kind of transition that IBM is. They are losing that cash flow sense, as well. Fujitsu, indeed, just announced unconsolidated losses for the first time in its history.

Thus, Japanese companies have become more vulnerable and are consequently more open to alliances than in the past. There are also some limits to the strategies—the rapid cycle times, the flexible manufacturing strategies—they've adopted over the past years. Maybe they've pushed cycle times too far. Product quality—there is a debate in Japan—product quality seems to be suffering because of it in some areas, and of course the faster you push cycle times the harder it is to recover investment, and so as they emphasize return on investment, there is a big debate about slowing down cycle times to compensate. In some Japanese fabs and more broadly assembly operations I know of, there is also a debate about whether they have become too flexible in the sense of introducing too much complexity to manage effectively. One company I know, a semiconductor producer, is operating over 90 different processes in its fab now, and is finding it very hard, as a result, to get high yields.

In addition to that, significant social problems in Japan are emerging. I mentioned the skilled labor shortages before. There is also significant urban congestion around the areas that used to characterize just-in-time production, like Toyota City. Indeed, MITI recently gave some administrative guidance to the companies to slow down on the implementation of just-in-time to deal with the congestion problems.

I see Japan moving—because of the labor shortages which require investment abroad to find the appropriate skills and because of the congestion and the like—from a homogeneous (that is, essentially Japanese) workforce and spatially concentrated production operation, to a much more heterogeneous (managing different people in different cultures) and geographically fragmented or spatially deconcentrated production structure. You know, it turns out it is much harder, or at least it's very different, to manage a heterogeneous and spatially deconcentrated production structure than it is to manage a homogeneous and concentrated one. Japanese companies are finding that it is taking a lot of change in organization and management tactics and the like to do so effectively. I don't know of many Japanese companies that are very happy with the investments they made in the United States, for example. They are finding it very hard to earn a sufficient return here.

Then there's China looming on the horizon. My time is running out, so let me just say this about China: I think China is the real story in Asia, though it is not apparent yet. China is currently the size of Germany as an economy, though obviously *per capita* it is much smaller. But it is growing four times faster than Germany, and is likely to sustain double-digit growth for at least the next decade, if not longer. While the political changes have focused our attention, underneath it the economic reforms have continued unabated, and those reforms have led , in many areas within China, to vibrant, innovative and quite entrepreneurial business activities. With China, you have the prospect of taking the best of Asian state-led development strategies and combining it with a very vibrant and entrepreneurial business culture to create a new model of economic development that could be very powerful. I expect that within a decade, China will turn out to be the most significant economic factor in Asia. It may well be that patterns of alliance with China, of how American companies operate in China and with Chinese business opportunities (versus how Japanese companies or European companies do that), may turn out to be the most important competitive factor in electronics competition over the next several decades.

Of course despite the fact that China is the story, Japan remains the political target, not only of the United States, but of European policy, of Korean policy, of policy throughout the rest of Asia. So put all that together, and there are a lot of constraints on the potential success of Japanese companies at a time when American companies have figured out some strategies that really work and have been the beneficiaries of good *fortuna*. What all of this says to me is that this window of opportunity for continued success of U.S.-based and U.S.-owned companies is likely to continue. The good news is the comeback of American electronics seems to me to be real and is likely to continue. The bad news, of course, is that competition—particularly from the rest of Asia, but in Europe as well—is going to be more nasty, more brutish, more brutal than ever.

Japanese companies recognize this. I just got back from Japan, and I think they're starting to develop a sense of humor about it. There was, making the rounds in Japan, a kind of bad news/good news joke about Asian competition, and it went something like this: The bad news is, the Koreans, the Taiwanese, the Chinese, all work a full seven days a week. The good news is, there are only seven days in the week. [Laughter.] Come to think of it, that's probably a joke we used to tell about the Japanese, and for all I know it may have originated in Europe about us 50 or 60 years ago.

Thank you for your attention.

Questions & Answers:

Question: During this decade, the Republican party has been committed to so-called free trade. Regardless of which party wins in November, what is the outlook on free trade after the election?

Mr. Borrus: Good question. In fact, over the last decade, the U.S. has become much more protectionist than previously. That is, I think, an obvious consequence of the fact that U.S. business has been much more troubled competitively, much more exposed to the world economy, than at any time in the recent past. In a sense, you have to ask yourself, what is more likely to preserve free trade and open markets abroad—aggressive U.S. policy or a lack of U.S. policy that ends up in crisis intervention and a dose of protectionism because we haven't been proactive ahead of time. I would argue it's much more important to be proactive, and in that way preserve the potential for open markets abroad, rather than reacting on a crisis basis, which is essentially what we've been doing for the past two decades. So I think the outcome in the November election does matter. I expect us to continue to be reactive if the Republicans win. I don't have the slightest idea what will happen if Ross Perot wins. If you look at Bill Clinton's economic policy, there is a strong emphasis on negotiating for market access abroad, while paying realistic attention to what needs to be done domestically, including developing domestic technology policies that have teeth in them. I suspect that that set of policies would permit the U.S. to be more open abroad. The best analogy is to arms trading. If the rest of the world is operating with aggressive industrial policies and we're not, we have nothing to bargain away with them in order to ensure that markets open abroad. It has essentially been the story of the past 20 years. We would never have negotiated for arms control with the Soviet Union that way, saying, "Please disarm, even though we don't have anything to trade away to compel you to disarm." Rather, we engaged in a huge arms build-up and used that as leverage and eventually, with the collapse of the Soviet Union, we can get rid of those things perhaps. I think the same applies in the trade area. The more aggressive domestic policies we have, the more likely we'll be in a position to bargain away for reciprocal concessions abroad to open markets and to create new opportunities around the world. I think the goal for everyone is the same; the difference is in how to achieve it. I would argue that the Clinton administration is likely to be more open and more positive and proactive on this matter than Bush has been over the past four years.

Question: Why will the U.S. savings rate increase after the election, and from an economist's viewpoint, who is the best choice—Bush, Clinton, or Perot?

Mr. Borrus: The savings rate will increase "naturally" if we get some economic growth, and unnaturally if we create incentives for better savings, which is what we need to do and which is a part of the Clinton economic program. Who is better—Bush, Clinton, or Perot? Well, I think my biases are rather obvious. [Laughter.] But they actually flow from having looked at the performance of the Bush administration over the past four years and the economic program that is available and quite detailed of the Clinton people. Again, I don't really have an opinion on Perot, since I didn't expect him to come back into the race. Since, as far as I know except for the deficit plan—which isn't a plan for economic growth except in the long term—I'm not sure where he stands. Clinton's program emphasizes domestic investment to get the economy moving again, in areas ranging from infrastructure to education to new technologies. It stands as something of an activist emblem, relative to the performance of the Bush administration over the past four years, which, as you all know (and I don't need to repeat the data) is the worst economic performance since Herbert Hoover in terms of job creation, economic growth, or almost any other index you want to look at. Whatever happens in the election, that's going to change somewhat—because it *can't* continue if Bush wins, and it *won't* continue if Clinton wins. The Bush people will come more toward the position that Clinton is currently advocating, because they have no choice—renewed investment and the like. In my view, the reason Clinton is, from an economist's standpoint (though I'm not an economist), a better choice in the end is the emphasis on health care. Look at the U.S. budget deficit numbers—if we get even modest economic growth of 2% over the next few years, the budget deficit really becomes much less of an issue. The deficit starts to go up again, however, in the late 1980s because of the impact of increasing health costs—Medicare, Medicaid, and the like—on the budget. Unless we get reasonable health cost control, not only will that hurt corporations (accelerating health costs are, in fact, a major reason that businesses fail and that labor disputes occur these days), but also we will be unable to deal with the budget deficit—completely unable to deal with it, unless we get health cost containment. That is a key and principal factor in Clinton's platform, something that is, by and large, missing from Bush's platform. So I think Clinton is the answer, but I'm obviously biased, and you can take that for what it's worth.

Thank you

Intellectual Property Strategy: A Necessity, Not an Option

Lois Abraham
Managing Partner
Brown & Bain

Mr. Norrett: Mrs. Abraham is Managing Partner of the Palo Alto office of Brown & Bain, and is a member of the firm's management team. She has been involved in technology litigation since 1973. I don't imagine there was too much at that time, certainly not as much as there is today, right, Lois? With leadership roles in cases that established the protection of the computer programs stored in ROM, the copyrightability of microcode, her clients range from Apple, Intel, Sun Microsystems, Intergraph, and Mike Dell's company down in Texas. Mrs. Abraham also counsels various technology companies in protection and licensing of intellectual property. She has a B.A. *cum laude* from Stanford University. I see you are well represented here—did you watch the football game too? Okay. And her law degree *magna cum laude* from Arizona Sports University—I mean Arizona State University. [Laughter.] That was back when I was in Phoenix—that was the state sports university. It has changed.

Lois's speech title is Intellectual Property Strategy: A Necessity, Not an Option. Please welcome Lois Abraham.

Ms. Abraham: I can't give you an intellectual property strategy, but I hope I can convince you that, whatever that is, you need one.

The intellectual property components generally are patent, trademark, copyright, and trade secret. But I'm going to concentrate today on the hot area—patent area. I don't need to tell many of you that things have changed enormously over the last ten years in the patent area. But what does that mean to you? And is it worth your time and attention to give some of the time that none of you have enough of to thinking about it? I think so.

Those of you in this room who have failed to craft an intellectual property strategy for your companies are fair game for people like me who can descend out of the heights of patent infallibility and present you with a letter that essentially says, "Your company's money, or your company's life." [Laughter.] Things have changed over the past ten years—although the change has gone on for a lot longer than that—most of us just didn't know it. The public and judicial regard for patents has changed them from ignorable nuisances to formidable weapons indeed, and the patent lawyer, who used to be kind of a harmless drudge, is now in the class of samurai warrior or technology terrorist, depending upon your point of view. And your point of view depends on whether you are one of the haves or have nots.

INTELLECTUAL PROPERTY COMPONENTS

- Patent
- Copyright
- Trade Secret
- Trademark

Figure 1

Do you have a big, fat patent portfolio that you can use offensively or defensively? Or are you on the upcoming edge of this, struggling to get one or maybe not even paying attention to getting one at all?
Many of you may be on the receiving end of a notice letter. I'd say, having read the list of attendants here, 70 to 80 percent of you are more likely to be a receiver than a sender of this kind of letter, and that can tell you whether you are a have or a have not, in a general sense. Many things come after the notice letter.

Dataquest has said that it prefers its speakers to keep the audiences awake, and that is a particular challenge after lunch—I know that. And Dataquest recommends humor, but I'm not particularly good at humor. I'm going to use horror instead. [Laughter.] The horror probably only applies to about 80 percent of you. For maybe 20 percent, what I'm going to tell you is a good news story, a sweet dreams story, and you can go to sleep anyway, because you already know what I'm going to say. But for the other 80 percent, if you are not having nightmares about the kind of story I am going to tell you—and it *is* a true (or almost true) story—you should be having nightmares, because you've got to protect your company from the kinds of things that can happen.

I want each of you to imagine that you are the CEO of a small, successful, growing company—and we'll call that SS&G—in a very competitive market, but doing well, good business plan, things going pretty well. Just to keep it from being an entirely true story, you sell cows. You're going along just fine with your business until one day you get a letter from BB&D (and that's Big But Declining) [laughter], and it's a little like this letter, but it says, "We'd like to call your attention to our patents that cover means for processing herbivorous blades." And you are careful; you send this off to your lawyer, your lawyer looks at it, comes back, and says, "Well, they must send out hundreds of these letters and these patents—look, they have pictures of horses all over 'em, and you sell cows. We'll write a letter. We've looked at the patents. We'll write a letter and say, 'We sell cows,' and maybe they'll go away." That little session probably cost you $10-15,000.

Worse yet, BB&D does not go away. In about six months, you are in a meeting. You're prepared for this meeting (that cost you quite a few more thousand dollars), and you're going to tell BB&D why you don't infringe their patents, and they're going to tell you why you do. So their patent attorney says, "Look, we cover technology for processing herbivorous blades. If it's got a tail, four feet, hair, and eats grass, our patents cover it." You say, "Oh, no, no, wait a minute. We're different—we're different! Sure, we have a tail and four feet and we eat grass and we have hair, but look at the differences: more than one stomach, horns, we give milk. Our products say moo!"

BB&D says, "Well, we've considered all that. We've got our expert here. Great expert, highly credentialed in this field. We pay him $400 an hour to testify for us. He tells us - he speaks excellent patentese he tells us that well, yes, there are pictures of horses all over our patents, but that's just the preferred embodiment. We still cover anything with a tail, hair, four legs, that eats grass. That's your product. And yes, your product gives milk and has horns, but it doesn't matter—extra features. That doesn't get you out. Sure, more than one stomach versus one stomach, obvious improvement, and easily known to anybody with skill in the prior art. And a moo and a whinny—clearly equivalent. Clearly equivalent. Let's talk licensing."

Out comes the standard license. You've thought about that. You've thought, "This is worth something just to get out of." So you have a number in your mind or a percentage in your mind, and you look at BB&D's. "Ten percent of my sales price? You've got to be kidding! This is a very competitive industry. I can't pay you 10% and have any reason to stay in business." Now, it might be worth one percent to get out of there, just to have this whole thing go away, but BB&D says, "Well, we've already had some people sign up at 10%, and there are most-favored-nation clauses in *their* licenses. If we let you sign up for 1%, their royalties drop to 1%. We can't afford it." So you can't afford to pay the royalty that is being asked; BB&D can't afford to take the royalty you want to pay, and you are on your road to the most obscenely expensive kind of litigation that you can find, because the patent defendant, aside from being under threat of an injunction (which puts you out of business if you lose) not only gets to prove that a cow is not a horse, but that the patents are invalid in the first place. Now you've got an army of lawyers out there, and the cheapest one is $115 an hour, and it goes up from there, and they are turning over every rock they can to find out who patented goats, who patented sheep, did BB&D tell the Patent Office all that they should during the course of the prosecution about the prior art, and you are spending money faster than you can believe—several hundred thousand dollars a month by the time you get near to trial. And you've tried to settle since then. There just doesn't seem to be any meeting ground.

But at least you're getting near to trial, the end is in sight. Two weeks before the trial, your lawyers are in a frenzy and you are paying for consultants, you are paying for experts, you are paying for graphics people, you are paying for lawyers whose names you don't even recognize, but the end is in sight—you're going to trial. You get to the pretrial conference and the judge looks at you and says, "Oh, you should see my calendar. My calendar is overflowing. Criminal matters. Come back and see me in six months." And the money keeps flowing out.

Are you awake? Some of you are awake!

I'll let you write your own ending, but I'll give you three possible scenarios. You sign up to the license. You may not be able to feed the cows after you sign, but you've decided no lawyer can tell you that your chances are 100% in a jury trial, the risk of an injunction is too great, and you just sign on.

Or, you're really lucky, you get to trial - the judge doesn't kick the patent case over to the newest judge on the docket - you get to trial, and there is some juror on there who says, "I don't know what these lawyers have been telling me for the past six weeks" (each week costing you about a quarter of a million dollars, by the way), "prior art, doctrine of equivalence, who knows what all that is, but I know a horse and a cow are not the same thing, and we're going to come in for the defendant." You are the lucky one. You go away, having spent a tremendous amount of your company's fortunes—and you are a capital-hungry company—on a case that you've finally won . . . until you get the next letter. And you're wondering how you can feed the cows and pay for the people to take care of the cows, but you've won.

Next scenario—you could be the loser. Another juror. Doesn't understand anything people have been telling him—and not through his own fault. He just doesn't speak very good patentese. But he remembers that the judge said, "There is a presumption of validity on these patents," and those papers with those blue ribbons, he remembers, looked very impressive. And you wouldn't have been there—I mean, BB&D wouldn't just drag everybody through this if there wasn't something really going on. So he's going to come in for the plaintiff. The damages could be trebled. The damages could be higher than a reasonable royalty.

This is not a level playing field, I guess, is the bottom line to this message. How did we get there?

We got there, in part, because the Court of Appeals for the Federal Circuit was established in 1982. Now, this was a very smart idea by the patent bar. They got their own court. The judges, the clerks, the lawyers, are all members of the same club. They all speak patentese. It was a very, very smart idea. The Court of Appeals for the Federal Circuit is here today, and going to stay. Patent litigation has increased more than 50% in the last ten years, and the number of patents that have been issued have increased almost that much. There is more fighting going on, more to fight about.

COURT OF APPEALS FOR
THE FEDERAL CIRCUIT

Before establishment of the CAFC -

- more than 50% of patents challenged in court were found invalid

After establishment of the CAFC -

- more than 75% of patents challenged in court have been found valid

Meaningful statistics?

Figure 2

Some interesting facts—before the establishment of the Court of Appeals for the Federal Circuit, more than 50% of patents challenged were found invalid. After establishment, more than 75% have been found valid. Is that a meaningful statistic? Well, as Everett Dirksen said, "A million here, a million there, and pretty soon we're talking about real money." We are talking about real money.

There are many headlines talking about million dollar settlements. $21 million. $127.5 million. $33 million. $100 million.

NEC and Toshiba will pay Wang a mere $8-12 million per year. Toshiba pays TI $1 billion over 10 years. Real numbers. $134 million. $70 million.

Since I collected these headlines in mid-September, we also have Honeywell, who now has signed up three more companies for a total of about $3 million for $50 million; Siemens settles with Medtronics for something estimated to be about $300 million over ten years. The federal circuit has had a dramatic effect on the fortunes of patent plaintiffs.

IN THE NEWS

- A hearing officer appointed by the United States District Court in Newark recommended that the Matsushita Electric Industrial Company be ordered to pay $21 MILLION for infringing patents held by Comair Rotron, a San Ysidro, Calif. company that makes fans used in personal computers.
- Minolta to Pay Honeywell $127.5 MILLION in Patent Infringement Settlement.
- A jury in Los Angeles ordered Sega Enterprises Ltd. to pay an American inventor, Jan R. Coyle, $33 MILLION for infringing a patent for an electronic circuit technique.
- A Patented Success: Lawyer Risks Long Hours for Huge Fees; Hosier's Latest Win is $100 MILLION Hot Wheels Case.

Figure 3

IN THE NEWS

- Wang Laboratories Inc. wins lawsuit against NEC Corp. and Toshiba Corp. that ultimately could result in patent royalties of $8 MILLION to $12 MILLION per year.
- Texas Instruments has won its first Japanese patent license settlement based in part on the Kilby patent upheld by Japan last year, and will receive an estimated sum of as much as $1 BILLION from Toshiba over the 10-year life of the deal.
- In Eli Lilly & Co. v. Medtronic, Inc., the jury awarded as patent infringement damages a reasonable royalty comprised of two components: an upfront payment of $26.5 MILLION and a running royalty per unit of 40% of sales.

Figure 4

POPA "GOALS"

Group	Relative Complexity	Average In Hours Per B/D
110	1.01	19.695
120	.93	18.135
140	.98	19.110
160	1.16	22.620
170	1.13	22.035
210	.97	18.915
220	.99	19.305
230	1.31	25.545
240	.88	17.160
250	1.08	21.060
310	.94	18.330
320	.88	17.160
330	.92	17.940
340	.94	18.330
350	.88	17.160

Figure 5

Another part of the how-did-we-get-here equation (and again, how we got there and where we are may be terrific for your company—in that case, you're going to want to keep this status quo, or at least keep a good watch on it while it is in its ascendancy here; it may be terrible for your company, and you're going to want to figure out, is there something we can do about it and how do we go about it?), so here's another part of the equation. It's the Patent and Trademark Office.

The Patent and Trademark Office is literally doing the best it can. Now, have you ever heard of anybody who is doing a terrific job when they tell you they're doing the best they can? This is pretty much the case with the Patent and Trademark Office. The examiners have tremendous pressures on them. It's a chronically under-funded area. Congressional pressure for reform always focuses on the backlog, the patents waiting to be processed, so reform pressure is pushing more and more patent applications through the same structure. It doesn't exactly improve quality when you do that, although you may get a little pickup in quantity. The examiners who work in high-activity areas (and right now those are patents for software and biotech) are in great demand from both law firms and industries, and they are hired away, so that less-skilled people must process more and more patents.

Working conditions explain some of the high turnover. The patent examiners work on what is almost a piecework basis. They are unionized. They negotiate a contract with the Patent and Trademark Office, and that contract establishes certain goals that the examiners must meet. They include average times of examination for various patents, and it includes a setting of relative complexity for various patents on a sliding scale. Here is the scale.

In the middle, group 230, you'll see the highest complexity of patent that is processed by the Patent Office. If any of you have ever read a Biotech patent, you will know that this is not easy stuff. *Any* patent is hard, but you get up in the high-complexity areas, the GS-12 average level of patent examiner is allowed 25.545 (that's a real figure) hours to process that patent application—highest degree of complexity—from start to finish. You can't even read one from start to finish in 25.545 hours! I've had one patent examiner tell me that his latest highest level of relative complexity patent was delivered to him in three grocery-store shopping carts. Now, how do you handle that in 25 hours? And what do you do when your bonuses, your raises, your promotions, depend on handling it within 25.5 hours? This is a system that can be played by people who know how to play it.

There are other working condition problems: The Patent and Trademark Office has, in active art areas, about 20% of what the examiners need, lost at any given time. Any of you who have ever requested 20 file histories will know that one of those is going to turn up lost. It simply cannot be found. So the tools of the trade are pretty obsolete as well.

What does that sometimes result in?

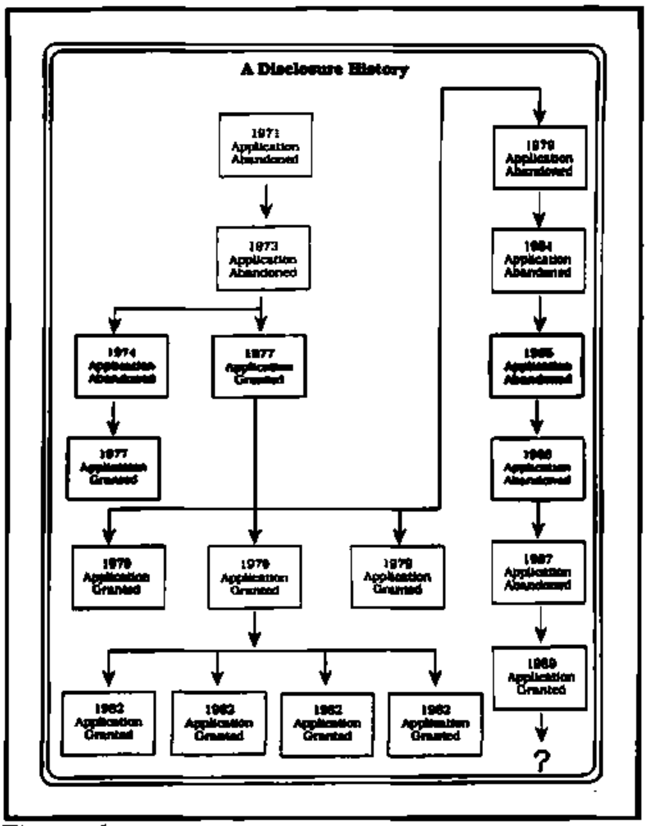

Figure 6

This is the actual history of one disclosure, one specification. The patent applications have come from one disclosure, starting in 1971, and they are still coming. We don't know what, because that's secret. But this comes off of one specification of an application filed in 1971. If you go down to that first juncture in 1973 (application abandoned), that application wasn't actually abandoned before it was allowed. That application was abandoned after notice of allowance by the Patent Office, then divided into two divisionals. All this is perfectly legal! There is nothing wrong with this. It's just that if you know how to play the system, you're better off than if you don't. The 1973 application divided into what are called divisionals—one pursued (on the left), one kept kind of awake but not real awake (on the right)—because you can keep these going for a long, long time. The left one was eventually abandoned. The claims of the right one were revised, were changed to cover technology that had emerged during the course of the application. Perfectly legitimate to write patents to cover technology as it emerges, and you've got a priority date of 1971. If you have overworked patent examiners, and you know what the deadlines are, and you know how the timing works, you can keep something alive for a long, long time, and do yourself a whole lot of good.

CURRENT PROPOSALS FOR REFORM

- **20 years termination**
- **18 month's publication**
- **First to file, not first to invent**

Figure 7

There are some proposals for reform that are current right now, in an effort to harmonize the patent laws of the United States with the laws of the rest of the world. One of the major features of these reform proposals is that a patent on a single specification would be expired 20 years after the priority date of the patent. So if you took my monster, it would be all over, no matter. You've seen recently that what we call submarine patents go under water for years and suddenly emerge in the middle of an industry that has been built up with no knowledge of the patent's pending grant.

A second part of the proposal for reform is that instead of secrecy from the day of filing to the date of grant, patent applications would be public in 18 months. There is varied practice throughout the world, but almost no place keeps them secret until the day they are granted. Eighteen months publication has been suggested; 24 months has been suggested; some countries, the patent applications are published as soon as they are filed. Then there is a first-to-file, not first-to-invent reform.

The patent bar is not giving these away for free. They are bargaining. They are protecting their positions well. If you are interested either way, if you are against reform or you're for reform, you should find out more about it. You should find out how you can become involved in this process.

IF YOU ARE PUT "ON NOTICE," WHAT IS AN APPROPRIATE RESPONSE?

- Ascertain whether you are, in fact, "on notice."
- Review the patents in-house under direction of an attorney
- Retain counsel to review the patents
- Consider a declaratory judgment action
- Obtain a non-infringement opinion

Figure 8

Now, what do you do if in fact you are the lucky recipient of one of these notice letters? Well again, there is nothing that I can tell you about what everybody should do, but there are certainly some things you can do to protect yourself, and one of them is to find out whether, in fact, you are on notice. Why does it make a difference? Well, if the notice has not been definite enough to tell you that you are an infringer, the clock on willfulness (or treble damages) doesn't start. But if you are raising cows in Santa Clara and you don't want to be sued in Boston, Massachusetts (which is a pretty likely thing to happen to you), you cannot yet file a suit for declaratory judgment.

The other things you might want to do are immediately investigate design-arounds, and immediately implement any design-arounds that you can (although the patentee might be able to hold that against you, come court, because why would you design around something if you didn't infringe it?—it's a two-edged sword). You may look for technology to buy so you will have patents that you will be able to trade, that you might be able to use in a defensive manner. You can find licensed vendors for the products that you're going to need to keep yourself in the market.

What you can't do is nothing—or you can, but that's not a great strategy.

STRATEGIES FOR "HAVE-NOTS"

- Promote proposed patent reforms
- Develop a portfolio

  or

- Publish
- Be unsuccessful

Figure 9

Strategies for have-nots—again, I can't tell you what your strategy should be, because it's going to depend upon your company's position. You can certainly promote those parts of the proposed patent reforms that fit with your business plan—but find out about them—and if there are things you think are worth pushing through, get in on the effort to push them through. You can develop a portfolio, and you may be able to do that more cheaply than you think. If you start out from zero, zero and up is a long way to get equal bargaining power. But it's better to have something than nothing, and you may be lucky and get one patent that is really worth something to the people who might be coming after you. If you don't want to develop a strategy of patenting, think about publishing. Get the statutory bars going, so that there isn't an argument about who was the first to invent. Have your people publish, present papers, get your technology out there, if that fits with your overall company strategy. It may not. That may not be the way you want to go. Another awfully good way is to simply be unsuccessful.

Nobody will come after you; nobody will be interested. But that's probably not the way you want to go. [Laughter.]

STRATEGIES FOR "HAVES"

- **Resist patent reform**
- **Mine patent portfolio**
  - **Develop comprehensive licensing plan**
- **Build portfolio**
- **Watch for pendulum swing**

Figure 10

Strategies for the haves. Maybe you want to resist patent reform; maybe you don't. Maybe there are parts of it that you'd like to have reformed. But find out about it, know what side you want to be on and know what issues you want to take a stand on. If it's part of your overall business plan, if you've got a patent portfolio, think about mining it. Think about what you can gain for your company on this rising wave. It's still going up, and you're going to continue to build your portfolio, but you might watch for the pendulum to swing, because one thing is for sure, and that is change. Just as the pendulum has swung on copyright protection for software, it is going to swing here. We just don't know what direction yet. But we do know that more patents, U.S. patents, are now issued to foreign countries than to U.S. countries. We know that in 1991, Toshiba got the most patents in the United States—more than any U.S. company. So a strategy that works very well today had better have a future strategy component, or indeed you may need someone like me.

Thank you very much.

Questions & Answers:

Question: You didn't mention anything about third-party suits, where, for example, you have some semiconductor equipment and it actually violates a patent or is claimed to, and use that equipment.

Ms. Abraham: The patentee can sue whoever is in that chain of buy, sell, or use. He will choose you if you have the deepest pockets. He may have a licensing arrangement with the company from whom you buy the equipment. It may not be a convenient company to sue, for reasons of relationships. But the patentee has a broad choice.

Question: How do you protect against that?

Ms. Abraham: This is an uneven playing field. I wish I had the secret of how you protect yourself against anything. You try to write indemnity clauses into your contracts. But the choice may be no equipment against having an indemnity clause, because the supplier of the equipment doesn't want to give you an indemnification clause either. So it depends upon clout. If someone wants to sell you something enough, you're going to be able to negotiate some protection in. Maybe not 100%, but some. But if you're on the weak side and you need whatever it is, this is not a fair world, and you're not going to be able to negotiate.

Question: Would you like to comment on the isolated inventor who has nothing to do with a corporation?

Ms. Abraham: In strategy, or in what he can do to you? He can turn you inside out if you're the defendant. He has fewer resources than some of the other plaintiffs, and to that degree, when you get into litigation, he may not demand every piece of paper in your company or to depose every engineer who has ever had anything to do with anything. Your expenses will be less. But you have to respond. You'll try to get out on motion, but most federal district courts now know that the Court of

Appeals for the Federal Circuit doesn't deal real kindly with judges who grant summary judgment motions against patentese, except on rare occasions.

Thanks a lot.

Advancing Video Communication & Computing

Curtis Crawford
Vice President
AT&T Microelectronics

Mr. Norrett: Curtis Crawford is Vice President of AT&T Microelectronics, and a Corporate Officer of AT&T. Prior to joining AT&T, he worked for 15 years at IBM where he held a number of challenging sales, marketing, and executive management positions. Curtis has a B.A. degree, an M.A. degree, and an M.B.A. degree, and like Jim Norling, likes to ride a hog. He is married with two children, and he is going to speak to us today about Advancing the Video Communications and Computing Industry. Please welcome Curtis Crawford.

Mr. Crawford: Thank you, Gene, and good afternoon. Most of the things you said were accurate but I think my staff got a couple of things out of line. I don't ride a hog. In fact, I ride a different type of motorcycle, but it is just as enjoyable. Personally, I never could afford a hog myself.

I'm really excited about being here. If I seem a little hoarse, it's because I just returned from Europe, and my last stop was in Munich, and my managing director there forced me to go to Oktoberfest again. For those of you that have experienced that, you know it leads you to believe that you can do things that you really aren't capable of doing, and so I'm paying for it, since I just arrived on Saturday. So if I seem a little lethargic, that's the reason for it.

Let me say that I really am very excited to be here in the company of so many industry leaders. It's an honor for me to participate in a program like this, and I think it's very important for our industry.

This afternoon, I want to share with you my personal perspective on visual communications, because I firmly believe that visual communications will certainly dominate the 1990's. In fact I think they'll influence the 1990's far more than the personal computer did in the 1980's. There's no question in my own mind that I think we're at a defining moment of our industry, and I think we all are quite fortunate to be at its present beginning.

Visual communications—including HDTV, videophone, desktop video conferencing, multimedia, and, in my view, the ultimate in visual communications called personal communications systems—will shape and influence our industry, our personal lives, and our businesses for years to come. I know that perhaps these forecasts may surprise some of you or even astonish some of you. However, those of you that have been tracking video will have no difficulty accepting them, and some of you might, in fact, believe that I am a bit conservative.

I've been a part of this industry for nearly two decades. I've watched it grow and I've watched it flourish, and during this time I've been across the entire spectrum of products and activities, from mainframes to microcomputers and microcomponents, and I've seen and participated in both the highs as well as the lows. Like some of you, I started out developing software. I've sold large machines that cost $8 million each, I've sold hundreds of machines that when you add them all up they total $8 million, and today, like many of you, my business develops, bills, and sells components by the tens of millions. What I've learned from this is that the most important element—and the most common element of everything that we do, really—is based on the customer. Customers truly are a very precious commodity for us to work with, and it is impossible for us to lavish enough attention on them. I've learned that if you look upon them as your partners, you really are in a much better position to prosper in business.

Well then, who are the customers for visual communications of the 1990's? The short answer is quite honestly, everyone. As you will see in a few minutes, I think the video products and services that we're talking about that are just around the corner are built for both businesses as well as consumer markets.

Now, I've been using the term *visual communications* and *video communications* interchangeably—but there truly is a difference. Visual communications really refers to the eye's ability to perceive and pass along to the brain for interpretation information from the outside world. Video communications, by contrast, is really a subset of visual communications, and typically refers to the electronic creation and transmission and reception and storage of moving images, usually accompanied by sound. As you can see, I did some research on my subject, and my questions really center around why there is so much interest in this area of visual communications. I was looking for some substantiating data that would provide me with facts and why there is a superiority view of visual communications over other types of communications, mainly written and speaking. One thing I wanted to know was whether visual communications boosted productivity, compared to other forms of communications. Does the eye take in more information for a given unit of time than the ear? And I learned from information scientists that that is exactly the case. Interestingly enough, the information capacity of the ear, for example, is 10^4 bits per second. The central area of the retina captures about 50 times that amount, and the visual system as a whole captures about 560 times the oral capacity. That's a technical way to say that we see a hell of a lot more than we hear. [Laughter.]

On the productivity question, however, I came up empty-handed. But, let me tell you what is intuitive to me about visual communications. For one thing, we get most of our information about the world through our eyes. So much information flows through our eyes that we often say, "I see," to mean, "I understand." No doubt about it—our powerful ability to extract data from visual images underlies the pervasive use of graphics that convey information in our society.

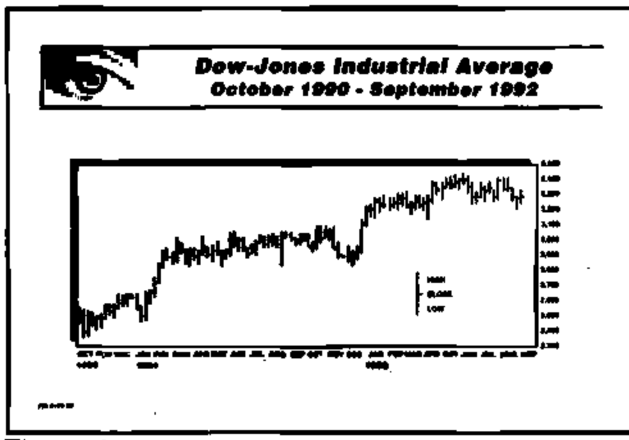

Figure 1

For example, imagine having to use words alone to describe the data encoded in the squiggly lines of past performance of the Dow Jones Index, or even trying to define what is happening to the market today.

In our own profession, the important information-bearing channel is the visual one. Circuit diagrams, circuit layouts, assembly drawings, blueprints, architectural drawings, maps—all of these are the hallmarks of the technical world that we created. Visual communications is also more rewarding psychologically than verbal or written communications. Being able to see someone, to make eye contact, to watch the subtle messages of the body language, all add a richness of experience in the communications process that is personally much more rewarding than simply hearing the disembodied voice on the telephone. From a purely business point of view, video communications provides a sizable portfolio improvement for all of us. For example, video communications boosts productivity through better use of company resources, such as building consensus faster for critical decisions, or delivering expertise to the right time, the right place. It reduces product cycle times through faster and more effective decision making. And it allows business people to converse and conduct meetings much more easily on short notice, with colleagues from around the world, without leaving the time zone or boarding a jet.

Like the computer did in the 1980's, video communications will bring on many new applications. One example certainly is high-definition television. The next generation of television will mean much more than just sharper pictures with bluer blues and redder reds. It will actually transport us to an electronic dimensions we have never experienced before with television. But even more, HDTV will be computerlike, with processing capabilities, storage capabilities, and bring all the possibilities of digital technology along with it.

Whatever the future applications of video communications products are, they do have one very common denominator— very exciting technology—and this technology is soaring, not just here in the United States, but around the world including Europe as well as the Far East and Japan. More importantly, the years of research and the millions of dollars our companies have invested are finally starting to pay off. As Wally Rhines mentioned this morning, we are certainly looking at stunning results from the digital signal processing capabilities based on new algorithms, especially in the area of data compression. Digital signal processing, long the driver for both enterprises and businesses, as well as military, is about to galvanize the video communications market in bringing a wealth of new products and new services available for the consumer, as well as business. I will have more to say on this topic a little later.

For now, I would like to zero in on some of the technology that will help make it happen. The hinge, on which video communications turns, is the video compression that is necessary because of the high cost of storing and transmitting the "band-width hungry" video images. Even a still color image with a resolution of 1000 x 1000 elements at 24 bits each is a colossal effort, and requires 3 megabytes of storage. To get past this hurdle, a variety of compression algorithms have been devised to shrink the amount of imaged data into a compact digital file. Compression algorithms, for example, for HDTV have managed to squeeze the enormous HDTV signal from 900 million bits per second to a much more manageable 17 million bits per second. The algorithm analyzes the HDTV frame in advance of transmission to determine which parts of the scene have changed, and then transmits primarily the changes. That's logical. Not so logical, however, is the algorithm's ability to fool the eye. The transmission is modified to take into account the properties of the human eye, which is less sensitive to variations in color and shade than it is to brightness. By mathematically smoothing out the details that the eye will not process, the image can be made to maintain or contain far less data than the slide shows. Now who said you can't fool Mother Nature?

Here is the same scene, compared with an uncompressed version. The application range of video compression technology is quite broad, and it extends from the 20 kilobits per second to about 20 megabits per second. The 20 kilobits-per-second figure compressed rate is used in AT&T's new video phone, which communicates over ordinary twisted pair. The 20 megabits-per-second rate is the compressed rate for HDTV that is intended to be transmitted over the standard 6 megahertz channel of terrestrial broadcast TV or cable television. So we have different bit rates for different applications that will satisfy different customers.

For now, I want to focus your attention on the bit span for two other technologies: stored interactive video and video telephony. The data range on these two realms extends from 40 kilobits per second to 4 megabits per second. This span is particularly interesting to us because there are some major breakthroughs that have occurred this year.

First, let's look at the problem. One of the biggest obstacles to proliferation of stored interactive video and video telephony technologies has been the lack of low-cost compression and decompression hardware.

Now, it is true that this hardware has been around for some time, but the silicon designs for implementing computer-intensive applications have left much to be desired, both in price as well as the amount of board space that it required. In addition to that, it didn't have the right levels of component integration, and it consumes much more power than was required. Technology that overcomes these obstacles was beginning to make appearances in 1992. For example, there is a three-chip codec that has been developed to perform full-motion video, and in fact handles the decompression as well as the compression (and that means up to 30 frames per second, for those of you that follow video). These codecs will allow the manufacturers to develop video telephony applications and multimedia applications for full-motion video as well as video conference, and bring it to the desktop, to workstations, as well as bringing it to conference rooms. The cost has to be key here, and it has to be in the range of $400-500 per system. This low cost is what will allow customers now to start building products and delivering them as add-on boards for the PC market and the workstation market. By comparison, most of the video codecs systems today are the size of microwave ovens, and cost as much as $50,000 each.

Where is this technology taking us? I want to show you a few roadmaps where I believe this market is headed, and where the growth opportunities lie over the next few years.

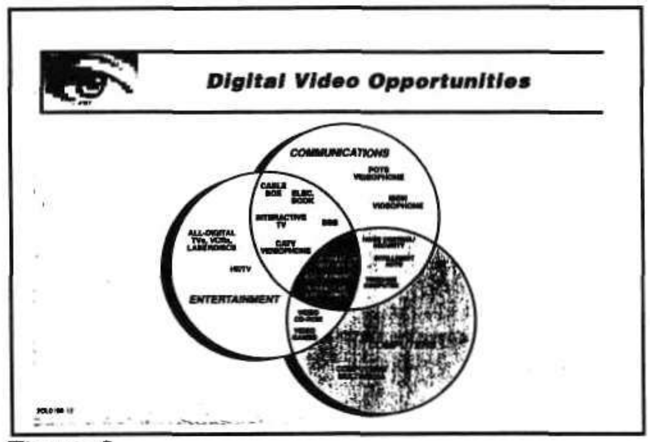

Figure 2

Here you can see the interlocking forces that will forge the new video opportunities. Underlying technologies in three industries that have been discussed earlier today: entertainment, computers, and communications, are converging. In fact, this fusion will happen in such a way that I believe by the year 2001 it will be very difficult to distinguish one from the other. This evolution is bound to influence everyone in this room in one fashion or another. The confluence of the three will do something wonderful for our industry, and it will spawn many new applications and many new products, many of which we can't even think of today, because we can't think how to apply all of the technology.

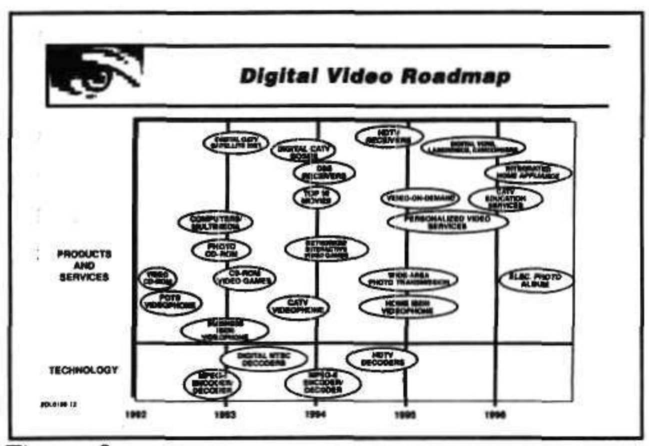

Figure 3

Two particular broad categories are digital video products as well as personal communicators. This is actually the same map but from a different timeline perspective. Let's look at the opportunities of digital video first.

For digital video in the near term, we see a wide customer base that, in the beginning, will consist of business users because, of course, it appears that they will be the largest consumer for video on the desktop, embedded either in PCs or workstations. Video communications in the form of desktop video conferencing (shown on this map as multimedia computers) promise to revolutionize the desktop and computer market. The primary driving applications here focus on people connecting with one another and collaborating over long distances. Applications will include teleconferencing, educating, buying, selling, and even just plain brainstorming, often by multiple parties, enabled by the video telephony, databases, E-mail, and integrated audio, still, full-motion, data, and text, which is primarily the definition for multimedia.

As a result, multimedia will be both PC and telecommunications intensive, fusing the two together as they have never been in the past. Multimedia will build on CD-ROMs and LANs. But CD-ROMs only involve the user and the machine, and since LANs as we know them today will not offer the guaranteed band width, they will not offer satisfying response times, they will not offer the widespread requirements for connectivity. The telephone network is needed for the rich human interaction in order to really fully implement multimedia as we define it.

So in summary, the computer itself will be transformed from today's passive, stand-alone mode that uses separate media to one that is interactive, one that is networked and incorporates integrated media.

There is another near-term trend. We think that plummeting technology costs will breed another base of customers—the mass market users of stand-alone videophones, such as the AT&T Videophone 2500. Around the same time, higher performance videophones in business will proliferate, as ISDN technology becomes much more widespread.

So for the near term, the video tidal wave is starting to swell, and it flows from the following:

- The readiness of the infrastructure that is in place today for telecommunications,
- The emergence of video compression in telecommunications standards,
- The advances in image compression and algorithms for VLSI technology,
- The need to cut high costs of travel.
- The ambitions of many, many companies in this audience for competing on the convergence of telecommunications, computing, and television.

Now, let's look out a little farther. Around 1994, we'll begin to see Top-50 Movies delivered to our living room, networked interactive video games as well as CATV videophones. All of this will be made possible based on compressed digital NTSC decoders with the full implementation of MPEG standards.

A year or two later, HDTV decoders will give us HDTV receivers and video on demand—not every ten minutes, but video when you want it. Toward the end of the decade, we will see real fruits of a revolution taking place with CATV education, integrated home appliances, as well as personalized video services.

Here are some of the estimates in terms of units for sale for a few of the new video products that really have the industry buzzing. These estimates are for five years from the time the product is introduced. So five years after they are launched, digital CATV boxes will be selling in the neighborhood of four million per year. For consumer videophones, our research tells us that they will be as popular as cordless telephones are today, so by the decade's end, videophones should see sales in the range of ten million units per year.

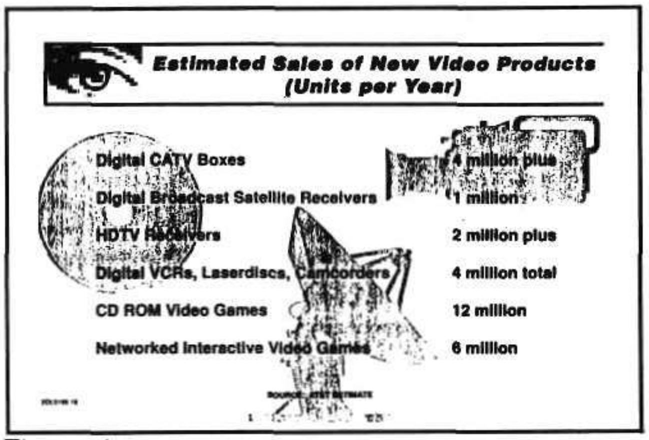

Figure 4

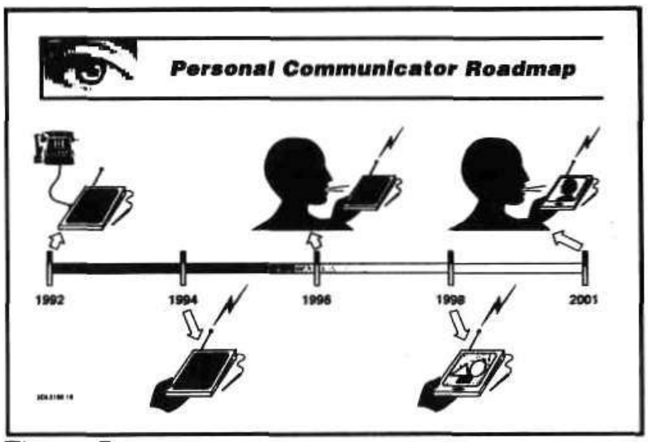

Figure 5

Turning now to personal communicators, here is another trajectory showing the ten-year evolution of these devices. The personal communicator will embody the ultimate in video communications. In full flower, it will deliver interactive, full-motion video in a device that you can slip inside of your pocket. You will notice that the communicator begins with a pen-based tablet cabled to a telephone providing data and voice over the current infrastructure, the telephone system. By mid-decade, the communicator, freed from its wire tether, has become wireless and also added speech recognition. Around the turn of the century, the defining feature of the personal communicator will be interactive, full-motion video.

Based on current products that share the communicator's underlying technology (and I'm thinking of laptops and cellular phones, for instance), we estimate that there will be some one billion personal communicators in the hands of users by the turn of the century. By any measure, that is one hell of a lot of microelectronics.

There is one final video market driver that deserves mention. Telephone companies were recently given permission by the FCC to transmit TV programs across their networks to the nation's living rooms. This subject has long been a very sensitive one in my business, and the major players in this arena are yet to be determined. However, the FCC's decision itself drives home the fact that communications companies will have a pivotal role in the new video age. One conclusion that you could draw from this decision is that video communications and communications in general, in all of their diversity, will rule the coming era. This existing communications could be in the form of satellites, cable, radio, terrestrial links, whatever the case may be—all of those will come into play during the 1990's.

I think these trends buttress my opening comments, that video will be a major, major focus for all of us in the 1990's. One fact that I believe is worth taking away from this is that the winning companies of the 1990's will be those that can provide products born from the merger of entertainment, computers, and communications.

That's the big picture of video communications for the rest of the decade. The question is, how will it happen?

Let's look at some of the market research that will reveal the true promise of video communications. The research points to opportunities in the video area for the semiconductor and electronics industries. The fact is, more of everything our industries produce will be needed: more ICs, more connectors, more power supplies, etc.

The statistics that I am about to show you were garnered from a variety of sources, notably Dataquest, Boston Consulting Group, and

Infocorp 100. The most salient fact here is that the global electronics business will be, for the five key industries, expected to grow to $1.2 trillion by the year 2001. That is more than doubled the $530 million or so at the beginning of 1990.

Second, when you consider of that $1.2-trillion pie, the lion's share (or about $260 billion of it) will come from electronic components. Electronic components will represent nearly 25% of the equipment and value-added, and the consumer market for components (that 25% that is highlighted on the chart) will get a big jolt from the HDTV discussion I had earlier. It will be a major, major contributor by the year 2001.

As the for individual components themselves, the picture is equally bright. Obviously, these are products that are not here yet, so we based our forecasts on figures for a variety of current applications and underlying technologies that we know and have available today, products that are designed to turn into new products into the 1990's, late 1990's.

The first eye-catching fact is that nearly six-fold jump in equipment demand for these technologies between 1990 and the year 2001, from $17.5 billion to nearly $100 billion in that time frame. As you would expect, laptops and notebooks consist of about $50 billion of that, or nearly half of it. Other components, though (printed circuit boards as well as connectors and power supplies) are also expected to increase in the future of video and wireless products. Taken together, their dollar value, as you can see here, will surge by a factor of five, representing about $1.6 in 1990 to $8.5 billion in 2001.

This chart shows the estimated value of end equipment in four targeted applications. Fully two-thirds of the demand will come from this beyond our borders—that is, in Europe as well as in the Far East and Japan. And here is a surprising figure. Visual and advanced computer electronics will represent over $30 billion of the $667 billion, and that is nearly as large as the wireless market that many of us are running after today.

It appears that we are blessed with many opportunities in video communications, and video opportunities are here to stay. Many of us will be around to savor the rewards, but unfortunately some of us in this room will not participate. The question is, who will be the survivors in the video communications arena, and what in fact are some of the hallmarks for their success?

Certainly I don't have a crystal ball, and there is no sure-fire formula, but in my opinion, a winning company must be able to deal with these facts:

- Fact: You must be able to provide strong technical leadership in areas such as digital, as well as analog, signal processing, and be based on very leading-edge algorithms.
- Fact: You must recognize and capitalize on the convergence of computer, communications, and entertainment technologies.
- Fact: You must provide the highest level of customer service and support—and by this, I mean working hand in hand with the customers, understanding their requirements and delivering solutions. The fact is, you must deliver solutions and applications—not chips—solutions and applications, because I believe in this regard we are where the PC business was ten years ago when they sold piece parts. Today's customers are looking for solutions, and they're demanding them.
- Fact: You must have access to great intellectual properties, have the vision, and the financial strength, and the daring to take advantage of this opportunity.

Now, we all know there are only a handful of companies that meet most or all of these requirements. Therefore, we must pick our battlefields. Selectivity is the key. We cannot be all things to all people.

Second, we must not try to reinvent the wheel. We have to form alliances with companies that are winners in their own right. Only companies who strike the right deals will have the edge in this challenging market. No longer can a single company develop, create, and implement technology and succeed in this marketplace alone. Today's economic and global realities are forcing us to form partnerships with our customers. We're being forced to compete with our partners. We're competing with our customers. And we're becoming customers and partners of our competitors. Quite complex.

As I looked at the list of speakers here, and the panel members for this meeting, several facts jumped out at me. Four are my direct competitors. Three are my customers. Four are simultaneously my customer and competitor. Two are my customers and partner. One company is only my partner, and one, Microsoft, is my supplier and undoubtedly the supplier to everyone in this room.

In closing, I would like to leave you with one of my very personal thoughts. "Preparation is the key to success. Without preparation you have no knowledge, and without knowledge you have no power, and without power you have no base from which to compete." Well, the video market opportunities are real, and they're here. The question is, are you prepared?

It has been a pleasure sharing my thoughts with you. I look forward to seeing some of you in the marketplace. Thank you.

Questions & Answers:

Question: We're often discouraged from using cellular phones, etc., for confidentiality reasons. We see a booming market, but are there real privacy issues.

Mr. Crawford: The question is over privacy using cellular phones. There is a big concern about using analog phones, and the security. As we move to digital cellular phones, that issue should be addressed quite effectively. That's why you see many, many firms moving very quickly to support the move to digital cellular phones.

Thank you.

The Changing Face of Displays

Jack Roberts

Analyst

Dataquest Incorporated

Mr. Norrett: Jack Roberts is Director and Principal Analyst of Dataquest's Graphics and Displays group. His responsibilities include directing the research and analysis relative to graphics processors, monitors, display terminals, and also network stations. Jack has a Bachelor of Science degree and an M.B.A. degree. Jack also is interested in speed, but he uses four wheels instead of two wheels—he races at Laguna Seca, not too far away from here. It seems this group of speaker are speed freaks.

Jack's presentation today is called The Changing Face of Displays. As we heard a few minutes ago, this is going to be a big part of the future of the visual or video communications markets. Please welcome Jack Roberts.

Mr. Roberts: Thank you, Gene. I'm not sure which is more intimidating—standing here in front of you or racing around at Laguna Seca at 100+ mph. Based on that, Gene, we'll try and start our engines here today.

I am often asked exactly what are graphics and displays, and my short answer is that it's anything that has a screen on it—the stuff that fits behind the screen and manipulates the picture.

This afternoon I'd like to talk to you about the traditional form of displays, which are CRT-based monitors, and then take a look at the future of displays and the growing flat-panel industry. Then we will take a look at what fits behind the picture—graphics and video processors—then briefly the long-overlooked (and often forgotten) area of display terminals.

Last year there were over 23 million monitors sold worldwide for revenues in excess of $10 billion. This compares to just over 20 million desktop PCs, so you can see there is a strong replacement market as well. 65% of all monitor production was based in Taiwan, and more than 98% outside of the United States. Average factory prices on 14-inch color displays, which constituted approximately 95% of the market, declined more than 15% from 1990. Yet, there has been a shortage of the replacement 15- and 17-inch CRTs—primarily as a result of CRT tube shortage.

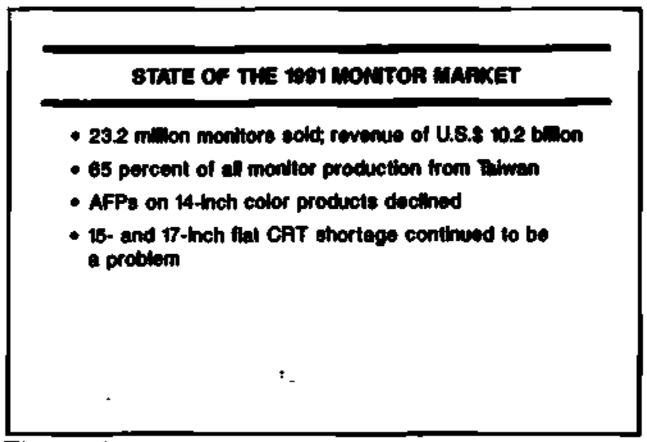

Figure 1

IBM's market share has been eroded because of clone penetration—not only clone PCs, but monitors as well. There is a growing movement among users to purchase monitors that are not manufactured by the computer manufacturer themselves (or whose name is different from the computer manufacturer). However, Apple was successful in increasing their market share along with their computer market share. NEC, who led the wave of larger-screen monitors, stumbled in terms of meeting the demand for these products. NeXT Computer had the highest growth rate in the workstation display market.

STATE OF THE 1991 MONITOR MARKET

- IBM's market share eroded because of clone penetration
- Apple Computer very successful in sales of low-end CPUs and monitors
- NEC stumbles in efforts to meet demand for new MultiSync FG displays
- NeXT Computer shows greatest growth in workstation display market

Figure 3

As we look at these shipments and Dataquest forecasts over time, you see that in spite of a gradually declining desktop PC market, we show a gradual increase, peaking in the 1993-1994 time frame for CRT monitors. The rationale for this is the growing demand for larger-screen monitors, based on graphical user interfaces (which we will talk about in a few moments), and also a growing replacement market in Europe—due to tightening ergonomic standard requirements.

Revenues, however, do not fare as well—but if you looked at this same chart based on personal computers and workstations, you would see much more rapid declines. While the monitor industry for PCs is moving from about $8 billion in 1991 to just under $6 million in 1996, you see increasing revenues (from just under $1 billion to approximately $5.5 billion dollars) for workstation products. The Macintosh monitor business continues to be very steady.

For average sale prices, you see an interesting chart that bucks a lot of trends in the computer business, for which many of you are suppliers, and that is increasing revenues and sales prices that are not decreasing nearly as rapidly as for computers themselves. The rationale for this is the move toward larger-screen monitors. Prices have not declined nearly as much for monitor products in the 1992 timeframe as they have for PCs. This is due to increasing numbers of larger screens, and as a result of some shortages in these areas that have kept prices up.

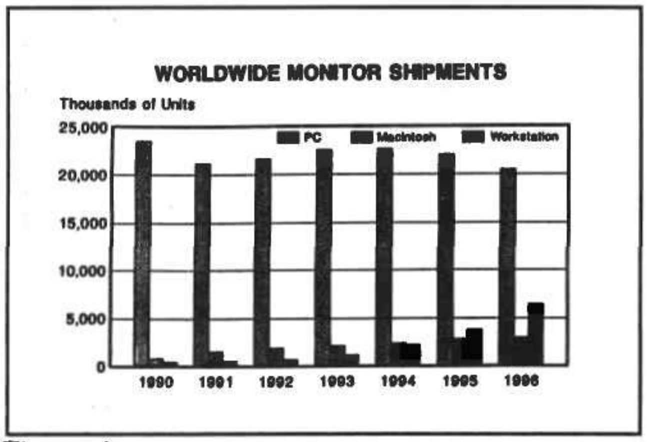

Figure 4

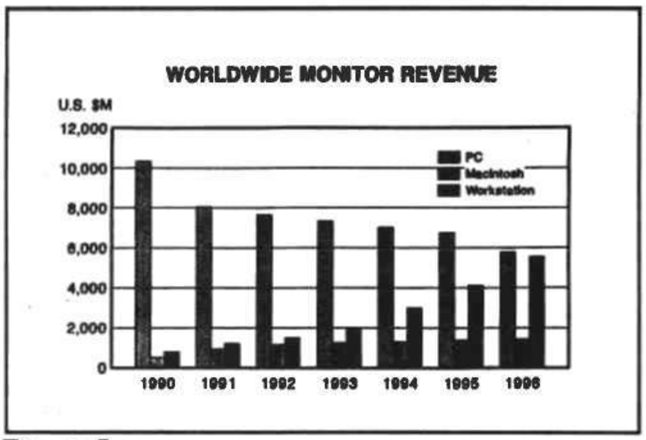

Figure 5

What are the opportunities for CRT-based monitors? They are primarily in workstation-type displays. In fact, we see a merging not only of desktop PCs and desktop workstations, but the monitors that are used for them.

While the largest growth area in PCs is in the 15- to 17-inch monitors, the largest growth area for workstations is also in those same size ranges—again reflected by the rapid demand for lower-end workstations.

Graphical user interfaces have pushed higher resolutions. Whereas the VGA 640 x 480 resolution was *the* standard only a year or two ago, that has rapidly changed to the 1024 x 768 resolution, typical of today's 15-inch monitor. Larger screen sizes will dominate. In fact, our projections in 1994 are that there will be equal quantities of 14-, 15-, and 17-inch displays sold. As I mentioned before, today the 14-inch display dominates.

The radiation issue will become more and more important in both product design and marketing. It is legislated in Europe as part of the EC-93 package, and will become not only mandatory for products purchased after that date, but the European Community will require the replacement of all nonconforming products within a three-year time frame.

The CRT is not dead. It continues to improve in terms of its technology.

As we get into our flat-panel discussion, I think this shifting paradigm will be more apparent.

As I mentioned before, we are looking for in excess of 55% compounded annual growth rate of 15- to 17-inch monitors over the next four-year forecast period. Workstation displays will gain as the 586 or P5 processors diminish the differences between personal computers and workstations. Upgrades of monitor products will play a major role in the market growth. There is opportunity for today's smaller-screen monitors—primarily in third-world markets.

I'm often asked when will flat panels replace CRTs? My standard answer to that is, "Not in the next five years." Of course I would have told you the same thing five years ago. The reason for that is because they are really different markets, and used in very different applications. Flat panels are utilized with portable computers in markets where CRTs are not possible. The Japanese investment in this technology has been astounding. Japan has invested between $1.5 and $2 billion over the past four years in TFT active-matrix LCD technology alone. The question of electromagnetic emissions—will this really drive the flat-panel market—I think has yet to be seen.

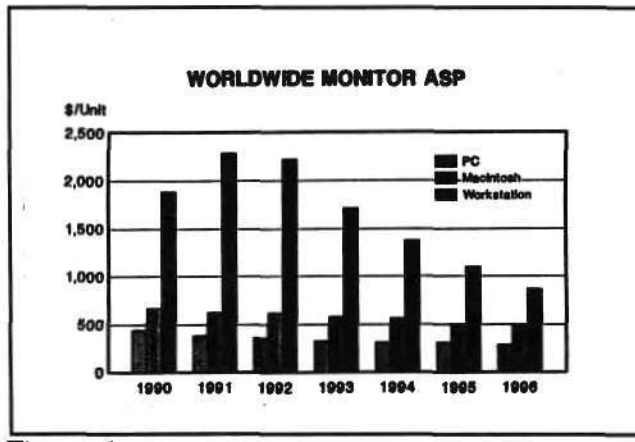

Figure 6

When we look at computers and Dataquest forecasts by packaging, you see that desktop computers are forecast as being very flat—with a slight decline—while the compound annual growth rate between 1992 and 1996 for portable units is approximately 47%. This differentiates CRT from flat-panel displays.

Flat panels have three things required for portable computer—compactness, battery power, and lower power consumption. We can all say in all honesty that there are two technologies that have not lived up to their expectations—particularly in regard to portable computers—one is battery technology, and the other is display technology.

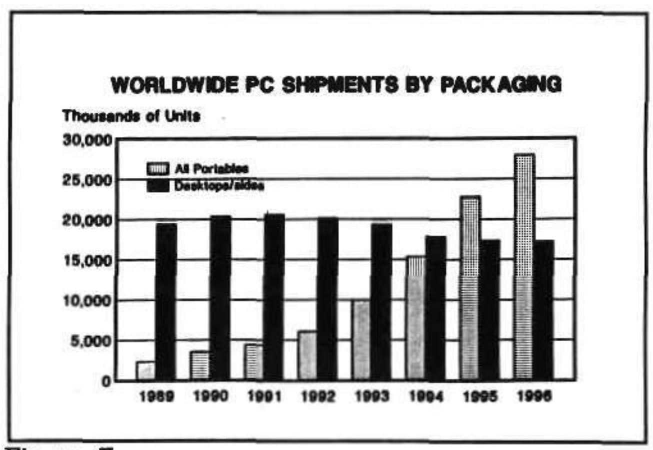

Figure 7

Japan owns this technology. If you look at the various companies inside Japan and their presence in all aspects of video technology, and then just for kicks look at their presence in systems and in the semiconductor technology—you can see the technology is pretty staggering. I think this is a real challenge for the industry as a whole, and the future of displays and graphics in particular.

Getting back to electromagnetic emissions, this is not only accelerated by end-user concerns, but is also driven by the Swedish recommendations, being legislated in the European communities. However, Dataquest believes that CRTs will comply within the next one to two years—in fact, some already do.

MARKET DRIVERS: JAPANESE PRESENCE IN ALL ASPECTS OF DISPLAY TECHNOLOGY

Company	CRT	LCD	AMLCD	EL	Plasma	Systems	IC
Citizen		x				x	
Fujitsu					x	x	x
Hitachi	x	x	x			x	x
Hoshiden		x	x				x
Kyocera		x	x			x	
Mitsubishi	x					x	x
Matsushita	x	x	x		x	x	x
NEC	x	x	x	x	x	x	x
Oki Electric		.			x		x
Optrex		x					
Sanyo Electric		x	x			x	x
Seiko-Epson		x	x			x	x
Sharp		x	x	x		x	x
Sony	x	x	x			x	x
Toshiba	x	x	x		x	x	x

Figure 8

In terms of the major market restraints for flat panels—it is really a manufacturing technology problem. Active matrix LCDs, which are those that can really compete with CRTs in terms of quality and performance, have gradually been increasing in terms of yields. While yields are only in the 20-40% range, some manufacturers have reported that their yields are approaching 60% (on a good day when all the stars are aligned correctly). As you can see, manufacturing costs are vastly different, as are the price to the end user.

Another limitation on the flat-panel market consists of screen size. I mentioned that my standard answer is flat panels may replace CRTs in five years. In fact, I was more optimistic a year ago than I am today, and that is because I see a tremendous paradigm shift in terms of screen size and resolutions. Whereas flat panels may have been ready to approach the typical monitor in last year's market, when I look at what the screen sizes and resolution requirements will be on typical desktops for the types of video processing that the previous speaker was just talking about, I think the flat panel has a long way to go. There is more room for increasing technology in that area.

FLAT PANEL MARKET RESTRAINTS

- Average yields
  - AMLCD 1990 = 5 - 10% (?)
  - AMLCD 1991 = 10 - 30% (?)
  - AMLCD 1992 = 20 - 40% (?)
- Manufacturing cost
  - 14-inch color CRT = \$40 - \$60
  - 10-inch color AMLCD = \$1,500 - \$2,000
- Price to end user
  - 14-inch 640 x 480 color monitor = \$295
  - 10-inch 640 x 480 color AMLCD = \$2,500 - \$3,000

Figure 9

This chart can be a little bit misleading until you look at the overall size of the pie. 87% of 28.5 million units is slightly under 25 million units for CRTs, versus a little under 4 million units (which is the 13% ratio) two years ago for flat panels. If we project that out into the future, we are looking at 54% of a 58 million unit market, which is in excess of 30 million units for CRTs. Flat panels are still under the 30 million unit number. You can see there is still tremendous growth for CRTs, but obviously flat-panel technology is where the future is.

CRTs will dominate where they can be used because of screen size advantages, continued low cost (of course), and dramatically improving display quality.

So, that "stuff" that fits behind the screen and manipulates the picture—what drives those markets? There were 25 million graphics and video processors sold in 1991 for revenues approaching \$1.5 billion. Again, this is for a PC market of just over 20 million units. More than 50% of this graphics consumption, however, was in the Asia-Pacific.

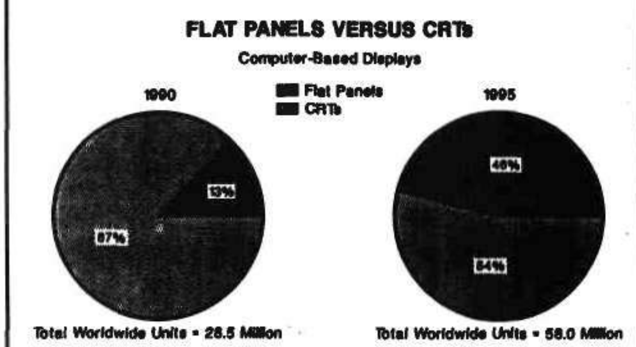

Figure 10

Unlike displays, average factory prices tumbled in the 27% range. We saw market declines in low-end PC graphics, high-end PC graphics, and (this may seem a little funny to you until a couple slides beyond where I am now) also in the Macintosh graphics arena, due primarily to increasing supply of graphics capability on board the Apple machines.

1991 GRAPHICS MARKET

- 25 million units sold; revenue of U.S. $1.4 billion
- More than 50 percent of graphics chip consumption in Asia/Pacific
- AFPs down 27.3 percent since 1990
- Low-end PC, high-end PC, and Macintosh graphics boards all show market decline

Figure 11

Graphical user interfaces (GUI's) are hot—the PC has discovered it. This mid-range or fixed-function graphics controller market, is forecast to be approximately 90% of add-on-board shipments in less than two years. ATI, which has traditionally been the market leader in low-end graphics boards, has grabbed the initial market leadership in this arena. S3, a spin-off of Chips and Technology, has become the market's chips leader.

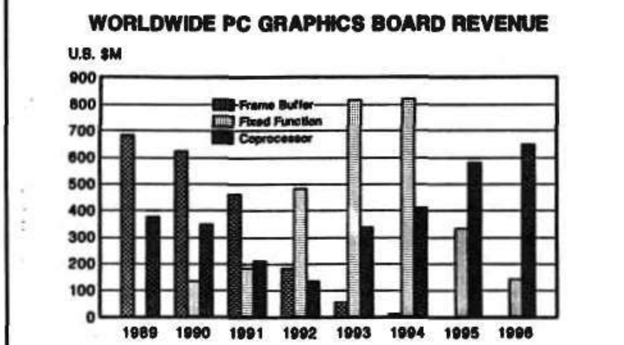

Figure 12

And a very interesting thing has happened in the marketplace—unlike VGA (which was the standard that dominated graphics for the last several years), XGA is seen as just another GUI accelerator. The reason for this is that a hardware standard no longer is required. The standard has moved to software, and the Microsoft Windows graphical device interface (GDI).

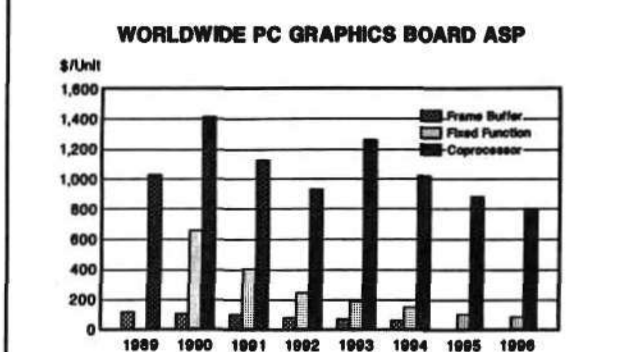

Figure 13

If you look at graphics board shipments—for which many of you are major suppliers—you will see that the frame buffer or low-end market has rapidly fallen off a cliff, and is being virtually replaced by fixed-function graphics accelerators. You may ask, what happens in 1995-96, when you show these products beginning to fall off of a cliff? The short answer is that this functionality will be embedded into PCs, and at that time the PC will literally transform itself from a character-based to a graphics-based machine.

Also interesting, is the co-processor area. Co-processors are those graphics add-on devices that really focus on the high end of the market—from different types of 3D, virtual reality, multimedia, to other types of video processing. Although this market today is taking a beating because of the fact that these fixed-function controllers are able to accelerate Windows and other graphical user interfaces, we believe that they will make a strong comeback. I think you will see this when the revenue of additional functionality, such as video compression, is added to these products.

With respect to the co-processor average sale prices—there is a somewhat similar situation. What you see in the beginning of the '93 time frame is that transition to additional types of graphics processing capabilities—video processing, for example.

We said that multimedia—whatever that is—is the future. Let me say one thing about multimedia—I think it is today, where office automation was ten or twelve years ago. How long has it been since you've heard that term? I do not mean that as a knock on multimedia. What I really mean is that multimedia will fraction into multiple markets—each significant in its own right—just as office automation became word processing, spreadsheets, LANs and everything else we know about in PCs. Multimedia will undergo the same transition.

Today, multimedia is mainly audio. Yamaha claims to be shipping between 300,00-400,000 of their audio chips per month. Over time, however, applications such as 3D will become more prominent on PC platforms. Virtual reality will appear first in the entertainment market. I read a very interesting quote in *Rolling Stone* magazine from none other than Jerry Garcia of the Grateful Dead who said about virtual reality, "They made LSD illegal—I wonder what they're going to do about this stuff?"

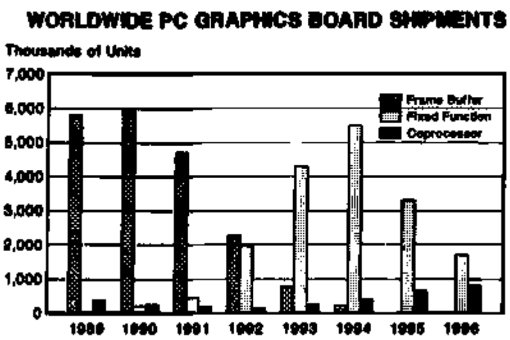

Figure 14

Display terminals are often thought of as a big yawn, but I think that it is an often-overlooked area. On a recent visit to Taiwan, I was amazed at the number of companies that had moved from display terminals to PCs in the last four and five years, and were now asking how they could get back into the display terminals market.

It may not be widely recognized, but the display terminal is still the second-most-popular desktop device, with approximately 5.5 million units sold in 1991 for about $3.75 billion. Dataquest follows this segment based around two IBM protocols, and the ASCII/ANSI/PC terminal-type protocol as well. The IBM mainframe segment is declining significantly. The 5250 (which is the nomenclature attached to the AS-400 series) continues to do well and rides on the back of the AS-400 product. Alpha Windows, which is a recent emerging standard that was developed by the Display Industry Association, will dominate the low-end PC ASCII and ANSI terminal segment.

This chart is not very exciting in terms of growth rates, but I think the most significant thing is that it shows a steady growth, particularly in the ASCII/ANSI and 5250 market arenas. The dip in 1991 (and some comeback in that area) account for two things: One is the

DISPLAY TERMINALS HAVE A FUTURE

- 5.5 million units shipped in 1991; revenue of U.S. $3.75 billion
- IBM 3270 segment continues in decline
- IBM 5250 segment continues to do well
- AlphaWindows to dominate ASCII/ANSI/PC segment

Figure 15

Alpha Windows standard, which will generate additional sales of replacement markets. The other is, PCs—because of some innovative software approaches—have all of a sudden become multi-user computers.

Looking at revenues, you see even slightly faster growth, which is amazing in this business. But if you look at the blue line, which is the bottom line associated with the major volumes, you will see slightly increasing average sale prices as terminals take on additional functionalities, such as windowing and graphics.

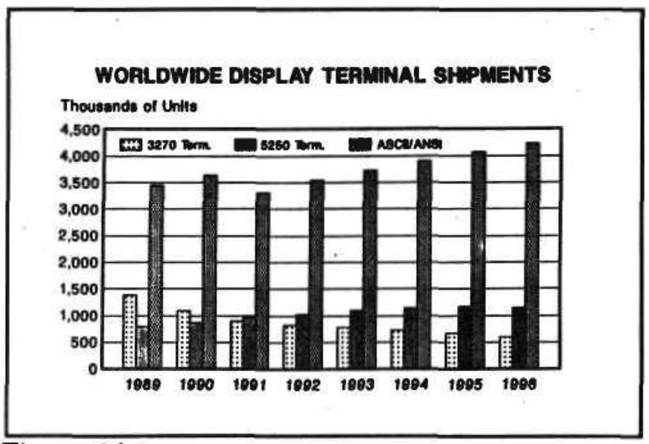

Figure 16

Let's also take a look at an interesting phenomenon called an X-terminal. An X-terminal is really a workstation that does not execute the application—in fact, it is the ultimate server. While the market reached only 111,000 units last year, that was up 61% over the 1990 time frame. Revenues exceeded $250 million— up almost 50%.

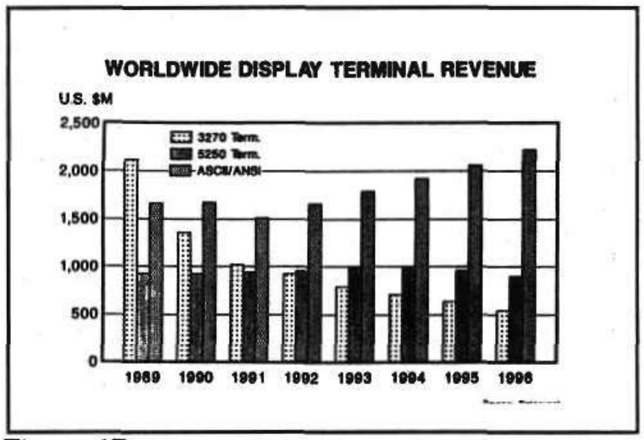

Figure 17

Network Computing Devices remains the market leader, with a 28% market share, while H-P is second, but rapidly closing, particularly in terms of revenue. H-P may actually meet or exceed NCD's revenue numbers this year.

We are looking for very steady growth in the X arena. X-terminals are not really terminals, as I mentioned before, but are sold primarily in conjunction with workstations. About 22% of the workstation desktops are now X-terminals, and we look for a slight increase in that over time.

DISPLAY TERMINALS HAVE A FUTURE

- X terminal shipments reached 111,000 units, up 61 percent over 1990
- X terminal revenue exceeded $266 million, up 48 percent from 1990
- NCD remains market leader with 28.3 percent share, HP is second with 17.9 percent of market

Source: Dataquest

Figure 18

As workstations are the fastest-growth area in the computing industry, X will surely benefit from this. Also, the X-server can utilize PCs as an adequate platform, particularly as PCs gain additional graphics-processing capability.

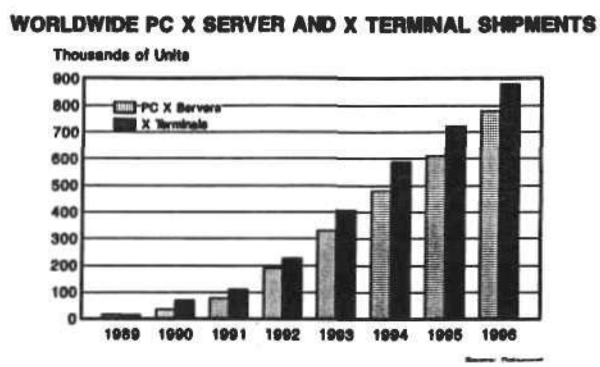

Figure 19

X terminals are the most exciting area showing growth rates slightly in excess of 40% with shipments expected to more than double this year over last. The present market is a highly technical one—being sold in conjunction with workstations—but as that technical market stagnates and becomes saturated, the future market will become increasingly commercial.

In summary, I would like to go back and re-emphasize some things that we have said in this presentation.

- Screens are getting larger. There is a tremendous demand by end users, driven primarily by the Microsoft Windows environment, for larger displays. In fact, some end-user surveys suggest that even 19-inch displays will become more popular, if and when their prices and bulk decline.
- The other thing to remember is that flat panels do not compete with CRT displays—at least not today.
- Japan is the technological leader in display advances, and is continuing to spend phenomenal sums of money in this direction.
- GUI accelerators are hot, at both the board and the chip level—the board level for the short term, chips for the foreseeable future.
- AlphaWindows and X Windows standards *can* coexist, and provide different levels of sophistication for end users.

In the future, demand for larger-screen and ergonomically correct CRTs will continue through the year 2000, so the CRT and its associated components are not dead.

Yields on active-matrix LCDs will improve significantly such that they become a viable desktop solution.

Displacement of CRTs on the desktop will begin prior to the year 2000—beginning about the 1998 time frame. These are numbers that are a long way off—but I think we can take some direction from them.

Japan will continue to be the display leader. In spite of the fact that their standard for HDTV probably does not stand a chance of being adopted in the U.S.—the fact that Japan has spent more than ten years investing not only in HDTV but the associated display technologies (which are, I believe, even more important), will make it very difficult for them to be unseated.

Flat panels will be the display of choice by the year 2020. Someone commented on this and said, "Wait a minute—aren't you getting a little beyond Dataquest's normal five-year projections with this timeframe?" But what I really want to say is that CRTs are not dead—and by the year 2020 will be almost 150 years old.

Multimedia will come of age in the late 1990s, and 3D and virtual reality will be mainstream after the year 2000—both areas being applications-driven. If I could say one thing to the people in this room, it is that you have to work very closely with the leading applications drivers in each of these areas.
At this point, I would like to open the floor for questions.

Questions & Answers:

Question: Could you comment on the flat-panel CRTs using a vacuum electronic source?

Mr. Roberts: I guess there is another thing happening in flat panels— it is this sort of a technology *du jour*—and I think rightly so. As the industry started to hone in on the fact that TFT was *the* dominant technology and would be the technology to concentrate on—now all of a sudden we see other technologies popping up. I'm certainly not in a position to stand here and say what technology will win out in the future—I don't know the answer.

Question: How do you distinguish between PCs and workstations in 1996?

Mr. Roberts: That is a very good question. The short answer is that in 1996 it will be very difficult. The answer today is that workstations have to have three things—graphics capability built in as a standard part of the unit, i.e., on the motherboard, a multi-tasking or "real" operating system, and third, built-in networking capability. I agree with you—I think it is going to be very difficult—in fact, that is one of the things that my group, which is part of the Computer Systems and Peripherals Group, is attempting to define. Particularly as far as desktop PCs are concerned, because they are rapidly migrating to the status of workstations.

Question: Can you comment at all on the U.S. display industry, is there any hope?

Mr. Roberts: I wrote an article about this last year—I think the title was "Commerce Fires a Shot at the Japanese Display Industry, But Unfortunately Hits the U.S. Computer Industry." [Laughter.] As a result, the commerce department was trying to protect what is maybe a $40 million U.S. Display Industry, at the expense of a $40 billion U.S. PC industry. And has helped by driving a little bit more of it offshore. The real question is investment—can you raise the kind of money that is being invested, primarily in Japan in the United States? It is a sad state of affairs, but if there was a government program that would assure that type of investment, then I think there are technologies out there that are still unexploited, and probably some that we haven't even thought of yet.

Question: What is the difference in resolution between PC monitors and workstation monitors?

Mr. Roberts: Well, resolution is very closely linked with screen size, and for comparable screen sizes, I think you will find very little difference in resolution. The 15-inch screens and 17-inch screens are predominantly 1024 x 768. I don't know if we've talked about RAM yet in the conference, but it is simply a matter of memory (and the cost of RAM in terms of the computer cost) and then the band width of the display device itself.

Panel Discussion: ASIC / ASSP

Bryan Lewis, Moderator
Senior Industry Analyst
Dataquest Incorporated

Panelists:

John East
President & CEO
Actel Corporation

Wes Patterson
Executive Vice President & COO
Xilinx

Allen Cox
Vice President, Technology Planning
Toshiba America Electronics Components, Inc.

Alfred Stein
Chairman & CEO
VLSI Technology

Wilfred Corrigan
Chairman & CEO
LSI Logic Corporation

Mr. Norrett: Bryan Lewis is going to lead the panel today. Bryan is our senior industry analyst, and has been following the industry now for about four years or five years, and is quite literate with the issues affecting the industry. I will turn the program and the microphone over to Bryan.

Mr. Lewis: Good afternoon, ladies and gentlemen. Welcome to the ASIC panel. Today we are going to take a journey into the future of the ASIC industry. To help us go on this journey, we have invited a group of ASIC visionaries from the leading ASIC companies in the industry. Not only are our panel members ASIC visionaries, they are fired up for this panel. As I called up one of our panel members to see if he wanted to use slides for his opening talk, he told me, "Absolutely not." He wanted to get the opening talk over as quickly as possible so he could get onto it and start to slug it out. Ladies and gentlemen, this should be interesting.

We're going to bring our panel members up one at a time from the audience. Please join me in welcome Mr. John East, President and CEO of Actel. Next up, we have Mr. Wes Patterson, Executive Vice President and Chief Operating Officer of Xilinx. Next, we have Mr. Allen Cox, Vice President of Technology Planning for

Toshiba America. Next, we have Mr. Al Stein, Chairman and CEO of VLSI Technology. Finally, we have Mr. Wilf Corrigan, Chairman and CEO of LSI Logic.

Welcome, gentlemen. Before we depart on our journey, I would like to take a few minutes to set the stage. Let's start by examining the characteristics of today's ASIC market. During the past ten years, the ASIC market has grown from $200 million to over $7 billion. The gate array market alone has grown from $137 million in 1981 to $3.9 billion in 1991. Cell-based ICs and PLDs have also experienced outstanding growth rates over the same time period, with compounded annual growth rates of 81% and 41% respectively. This is clearly a high-growth industry. While revenues have grown at a phenomenal rate, profits have been scarce. You might be asking yourself, why are profits scarce if revenues have grown at such a rapid rate? Dataquest is currently tracking 65 gate array suppliers, 60 cell-based suppliers, and 21 PLD suppliers. This many suppliers presents a problem to the industry. Management in all these companies believe that they can develop products that are far better than all their competitors, so therefore, guess what? They all will become rich! The reality is, there are far too many ASIC suppliers, all offering very comparable products, and very few are highly profitable. This leads me to my bottom line: The ASIC business can be considered a cut-throat business. In fact, it is one of the bloodiest battlefields in the entire semiconductor history. This even includes DRAMs. However, where there are large markets, there are opportunities for those suppliers who have the right business plans and who can execute on them. That is what we're going to talk about today.

Let's turn to the future of the ASIC industry and explore some of the issues that are challenging the ASIC suppliers. What will the future of the ASIC business look like? Where are the opportunities? What kinds of products will be most profitable? What kind of alliances are necessary or even mandatory to compete in this business in the future? These are the questions our panel members will be addressing in their opening talks.

Let's run through the agenda quickly. Each panel member will be coming up to the podium and will speak for about five minutes on the questions I just proposed. After the panel members have completed their opening talks, I will ask them a series of questions. After that, it's your turn. This is your panel, so ask as many questions as you can, and let's make them good, and let's keep this thing punchy.

It's time to explore the future of the ASIC industry. What will the ASIC market look like in five years? First up, we're going to have Mr. John East, President and CEO of Actel. For those of you who are not familiar with Actel, Actel is a hot Silicon Valley startup, and a leader in the FPGA (Field Programmable Gate Array) market. Please join me in welcoming Mr. John East.

Mr. East: Thank you, Bryan. I was just chatting briefly with Wes Patterson, and he and I were saying that it was really nice that you could invite a panel of visionaries. It is unfortunate that none could make it. [Laughter.] I guess the five of us will have to do the best we can.

If you look at the last five to seven years in the ASIC business, it has been characterized by rapid price declines. Of course when that happens it makes it tough to make a profit, and whenever *that* happens it becomes easy to ask the question, "Gee, what's happening? Is this business going to the dogs? Is it really possible to make a buck there?" In my five minutes, I'd like to take a little broader view, because I think the five- to seven-year view might be a little too myopic. So I'm going to go back about 15 years and then try to go forward about 5.

If you go back 15 years, you get into the late '70's, and there wasn't much ASIC business then. Oh, maybe a little bit—there have always been some customs done, but not many ASICs were done until LSI Logic popularized the CMOS gate array. That's when it really started to take off. Back then, the Japanese prophesied what they called the "3 Ms": memories, microprocessors, and master slices. (Master slice at the time is what they called the gate array.) But let's generalize now and say a master slice is really any ASIC. In retrospect, they were really right on the mark. If you look at what has happened so far and you look forward five years, I think you see a point—I definitely do—where all boards look the same. They have a micro, they have some memory, they have an ASIC. Sure, there are different kinds of micros, different kinds of memories, different kinds of ASICs, but basically every board is going to have one or more ASICs on it. I firmly believe that. In fact, if you look at most boards today, they're looking that way.

Given that I feel that every board will have an ASIC on it, and given that there are going to be lots and lots of boards made, it follows that I must believe in the dollar sales volume future of this business. And I do. I think it's going to be huge. I think the forecast now is 1996, $16 billion, so that is four years from now. Let's round off and say five years from now, round figures, $20 billion—so a huge market.

So then the only question is, what about the profitability? People who work for me will tell you that I am maybe the world's biggest pessimist. I see one out there, and he's nodding, so yeah ... But in this case, I'm not a pessimist. In this case I'm an optimist. I believe that there are three things coming together that are going to make the profitability turn around, gradually go back up, and have it be a nice place to be. Those things are differentiation, intellectual property protection, and (even though this may be an oxymoron) the maturing of the industry. Let's talk just one second about each of those.

Differentiation. It was tough to differentiate your basic CMOS gate array. People tried, but mostly they weren't successful, and mostly the products looked the same. I think if you look out at the business today where, as an example, people are out working on ASICs based on cores—(Wally Rhines told you today that he has a wonderful TMS 320 core, and he's using it in his ASIC offering), and I think by definition that will be differentiated. Other people won't be able to offer an ASIC with a TMS 320 on it. There are other examples. I could give you examples about FPGAs or other phases of the ASIC business—I think the generality is, it will be easier to differentiate, and of course that's the most important predictor of profitability.

Lois Abraham did a great job of talking today about intellectual property protection. Yes, Lois, sometimes that is horrifying, but by and large, I think it's the right thing for the industry, and I think it'll be applied at least as much in ASICs as anywhere else.

What do I mean when I say the industry is maturing? I mean ten or fifteen years ago, the normal way to do business was to watch, find someone who invented something that was good, and then second-source it pin for pin. So that's just the way we did things 10 or 15 years ago with TTL and with EPROMs and with DRAMs, and not quite in CMOS gate arrays, but close enough that I think you'd call it a first cousin of a pin for pin replacement. But you just see less of that going on. What you see today is the people that used to go after pin for pin replacements realize that's not good for them or the originator, and people are now going after their own version. The absence, or the decline, of that pin-for-pin competition on the buyer's desk, I think, gets you that last five percent of ASP that you really need to make money.

So my bottom line is, it is going to continue to be a rapidly growing industry, that the profitability will return to reasonable levels, and that we're really happy we're in it at Actel.

Thanks.

Mr. Lewis: Our next speaker is Mr. Wes Patterson. Wes is Vice President and Chief Operating Officer of Xilinx. Xilinx pioneered the FPGA market. Not only is Xilinx the largest FPGA supplier in the world, they are also the largest MOS PLD supplier in the world. Please join me in welcoming Mr. Wes Patterson.

Mr. Patterson: I always hate speaking after John—I have to pull the microphone down. Bryan suggested four questions that we use as an outline for these opening remarks, and as you might expect, as a representative of a programmable logic supplier, I'm going to give you the same answers to all four questions. [Laughter.]

His first question was, what is the future of the ASIC and ASSP industry? I think John covered a lot of the points that I wanted to make, that ASICs are the only technology that allow us to harness what is happening with the two Ms that John talked about—microprocessors and memories. This is what is takes. ASICs and software are what it takes to put those two technologies to work. So I think ASICs have a bright growth prospect. They should at least keep up, in unit shipments anyway, with what is going on in microprocessors and memories. There is the potential, I believe, for ASIC revenues and profits to grow faster than these other two markets if the industry can learn how to get value back for the value that they deliver to their customers. I think the challenge for the ASIC industry is to learn how to add more value to our customers' end product. If ASIC is going to be a business or an industry, rather than simply a technology, we're going to have to find better ways to add value and to differentiate our products from our competitors.

The second question that was posed by Bryan is, where are the ASIC opportunities? I chose about a five-year horizon for this—but I think whatever the horizon, the issue in ASICs is how to differentiate ourselves. Again, this is the subject that John talked about. If the differentiation comes along the dimension of technology, then the greatest areas of opportunity are those areas where the technology is changing most rapidly. In addition to that, if you look across the ASIC spectrum, there is an important service dimension to all the ASIC businesses. The opportunity really comes in adding value to these products. If you're delivering application-specific standard products, then you can differentiate yourself by having a superior understanding of your customers' problems. Sometimes that's tricky, because your customers are themselves often intense competitors. If you're in the custom ASIC business, you also have an important opportunity to differentiate your company by having a superior level of service to your identified key account. If you're in the programmable logic business, then you have some technology opportunities. This is a relatively immature technology; it's changing fairly rapidly, but we also have our dimension of customer service. So customer service, I think, is a common thread for success in the ASIC business, whichever section of it you choose to look at.

The third question is, which ASIC business will be the most profitable? And I think here again John has touched on these. The ones that will be most profitable are the ones that add the greatest value to our customers' end products—the enabling technologies that let our customers do something new, something innovative, that makes their products in turn more successful. Then behind that, another point that John already touched on, the profitable segments of this industry will be those that are well protected by intellectual property coverage.

The three forms of ASICs that I've talked about are significantly different when we get to the fourth question—and that is, what kinds of alliances will be key? If we look at applications-specific standard products, that form of ASIC requires very close alliances with customers. So the alliance between the supplier and the customer has to be very, very tight. For the custom ASIC suppliers—the customer alliance may not be quite as critical, because the customer is doing a lot of the design, but that is extended by having critical alliances with the CAE companies. Some of the panelists here have solved that by having their own CAE companies. Finally, for programmable logic suppliers like ours, the most critical alliances are probably those with our foundries, our manufacturers, since most of the programmable logic companies are fab-less.

Thank you.

Mr. Lewis: Our next speaker is Mr. Allen Cox. He is Vice President of Technology Planning for Toshiba America. Toshiba is the fourth largest gate array supplier in the world. Not only are they a large supplier in the world, they are also the largest Japanese supplier in North America. Please join me in welcoming Mr. Allen Cox.

Mr. Cox: Good afternoon. I don't know whether Wes and I had the same script writer, but maybe a lot of these thoughts will be reiterated again.

What's the future of the ASIC industry, or ASIC/ASSP—I wonder if anyone knows what it is anymore? Let's try and define it. What's the opportunity? What type of product is going to be more profitable? And what are the alliances necessary to make it work?

Well, that's a tall order covering five minutes, as my colleagues have said, but here are some thoughts.

First of all, what is the future of the ASIC/ASSP industry? Well, I think unquestionably the first answer to this question is that the industry is going to continue to be the enabler for added-value end products. Those of you who have had the pleasure of attending this conference over the years will remember not just the forecast but the actual results that Dataquest has shown about the huge advances made in ASIC capabilities. Let's not forget that fact—all the benefits that have enabled literally thousands of products to be brought to market with unique functionality and performance, and enabled those and were used to differentiate products. That has all been done with dramatic improvements in time, skill, and cost. In order to explore what is in store in the future, I think there are three key dimensions that characterize what we are choosing to call this ASIC/ASSP industry. Like Wes, I was interested in listening to Wally Rhines this morning. I think maybe he is in the same space. Perhaps you can think of this as a market domain with three axes. First, there is a set of methodologies for implementing ICs. Those include field programmable, metal, and all their programmable techniques (FPGAs, gate arrays, embedded arrays—there are a flavor of names), together with the EDA tools that have been put in place for techniques from synthesis right through design to test. Secondly, ICs that range from being specific to one customer through all customers. This could be a gate array design, for example, for a specific OEM done on a very close relationship basis, through to, say, a cell-based design based on our processor core, targeted for many potential users. I think that's what Wally Rhines was describing this morning. Thirdly, ICs that are specific to a series of distinct applications, and those that are reported on this morning by Gene—automotive, telecom, consumer, EDP, and the various other semiconductor markets.

What is in store, then, for the future, and what are the future opportunities? Clearly the opportunity is to continue to add that further value for manufacturers and users of end products. Specifically, let's look in the three dimensions and explore how they're going to be extended. First of all, the methodology. Manufacturing fabrication processes are in place for half micron, CMOS, and bipolar technologies that can generate half a million equivalent gate circuits. Most of the fundamental techniques and technologies for further device miniaturization in the next five to ten years already exist in the laboratory environment. The resulting huge available functional densities are going to be the fuel that will drive the future opportunity to bring complete system components to market quickly, via one of the techniques—FPGA, embedded array, or whatever you like to call it. Unfortunately, the ability to effectively utilize all of that available silicon is still lagging. There is a discrepancy between the available gates and the actual used gates, and it is continuing. I think if you look at the Dataquest numbers, you'll see that the peak is somewhere between 15,000-20,000 gates. It is still well below that which is available. The ability to effectively add value in this dimension hinges on advances being made in several areas. One area is high-level, top-down design methods. True behavioral synthesis is one of those—also re-usable design elements, system-level timing and power analysis, intelligent partitioning and layout of half a million elements. Also design for test and verification. In this sense, the future challenges and opportunities lie heavily in the area of design, verification, and custom support.

Returning to the second of our three dimensions—the degree to which the business is customer specific—here the pressure to bring electronic products to market on time is going to intensify, and it is that driving force that continues to bind OEM customers and vendors. I believe tightly coupled technology and service mix can be expected to continue, and maybe even extending to the classical co-destiny-type relationships. There also exists a more opportunistic sector where added-value design organizations can be expected to seed innovative solutions into the market. In fact, in preparation for this discussion today, I went back and looked at, I think it was a 1986 copy of the Dataquest manual—in fact it was one of the key thrusts in one of those discussions then. Although the longer-term prospect of that opportunity is less attractive, I believe it will continue to provide, high-potential growth based on the validity of the design element.

Finally, the third component—the degree to which the business is application specific—there has been a historical evolution of the various methodologies brought to market by these good gentlemen and many others to reach a point today where they are an integral part of systems design in almost all key application segments. The future opportunities are going to be satisfied increasingly by core functions (we've heard a lot of that today), capability of spanning application segment-specific solutions. This is already apparent in the areas of personal computing and workstations. But perhaps the most exciting opportunities—as we heard this morning—which I would like to reiterate, lie in the convergence of human communications with computing and broadcasting. The convergence of these three promises to provide a whole spectrum of opportunities that are going to be ASIC-intensive.

What type of products are going to be most profitable? Well, quite simply, those that create greatest value, where value is measured as the benefit to the user versus his cost. Product in that sense means the complete set of deliverables—not just silicon, but the design tools, access to applicable function blocks (either in hardware or software), design for test and verification, packaging, and a variety of support and services necessary for correct by-design programs. That's in addition to the delivery of high-quality, high-performance silicon. I believe the industry has shown and continues to deliver that increasing value.

While users can enjoy the benefits of high density that result from that continued investment in process development, there still is, as I said before, a wide gap in the design capability. As I said before, the opportunity here is, I think, to improve the benefits by improving the areas of design test and service.

This day-to-day battle for vendors to achieve a best-of-breed status in these areas of benefits is therefore the very same battle to maximize the value, and it's the very same battle to hence potentially maximize profitability.

Of course, unique benefits can give rise to unique returns, and there's a high potential in the technology hierarchy. This doesn't just cover process technology, which is the foundation, but increasingly favors innovation in circuit design, algorithmic development, and finally architecture.

While switching to vendors' cost considerations that ultimately are going to be passed to the customer, I believe vendors who are broad based and who can implement an overall strategy for manufacturability can develop a real advantage in that cost structure. The ability to effectively manage product loading and manufacturing sites is obviously one of the keys to success. By utilizing a process and design unified architecture in manufacturing, it is possible for a broad-based vendor to increase loading flexibility between product lines, and smooth out to some extent the effects of the perturbations of the market demand.

This unified process and design approach may, of course, create some design restrictions, but I think given the rapid advancement of the basic process development, the benefits gained in manufacturing efficiencies are going to outweigh the constraints.

Finally, what kind of alliances are necessary? There has been much debate and activity in the area of semiconductor alliances, some of which are being discussed here at this forum today. From a broad perspective, one can characterize the necessities in four areas of merit. Firstly, alliances of merit benefit from being global. They benefit from being competitive, they merit from being cooperative, and they merit from being complementary. Alliances which are well considered encompass all of these, and depending on the quality of the execution, they stand an excellent chance of being durable. It is becoming increasingly necessary, as we have heard, to share costs, engineering resources, and the risks in this increasingly expensive task of building advanced ASIC products, and indeed in semiconductors in general.

As an observation, though, there seem to be two areas of alliances that are emerging. One area is relatively large in scope, where sharing the burden of resource costs tends to be between large, internationally leading technology companies. The other area recognizes the need to quickly develop innovative products for fast-developing markets, and tends to be oriented towards innovative engineering-focused type companies.

In summary, if ASIC is the name that we're going to use to describe this business, which has the market domain and which has got the dimensions I have described, then the ASIC business is alive. It continues to be a critical enabler for increasing the value content of electronic products. I believe the cost of doing business, the diversity of the technology involved, the range of the applications, and the customer specifics favor a broad-based market-driven semiconductor vendor who can continue to invest in basic and applied research and development, and manufacturing capacity, while forming the necessary global alliances for success. Those who can continuously push the envelope of these benefits and optimize their costs will surely continue to add value to the electronics industry—and they'll do that throughout the 1990's, and continue to be the key enablers for a healthy, global electronics industry. Thank you.

Mr. Lewis: Our next speaker is Mr. Al Stein. Mr. Stein is Chairman and CEO of VLSI Technology. VLSI Technology is a leading supplier in both the gate array and cell-based IC market. VLSI has also leveraged their ASIC expertise to become the number one supplier of PC logic chip sets. Please join me in welcoming Mr. Al Stein.

Mr. Stein: John East, thank you for getting me off the hook. I feel a little better since I felt I was the only non-visionary on the panel up here. And Wes, I'm amazed. I would have jumped all over Bryan about this profitability bit—I don't understand what you're talking about. I think everybody is in a relatively similar position in this profitability area, but we can talk about that later.

However, I had to change my opening statement here. I was going to say, "A must for successful semiconductor companies ..." and I guess "must" or "successful" doesn't apply in terms of profitability. So I will start out by saying, the "musts" for *growth* of semiconductor companies tin the ASIC business over the past ten years boil down to three characteristics: You had to have software and libraries. You had to have advanced processing and packaging technology. Again, these programmable folks (who put products in inventory and then any customer can use them) don't need to have a fab. But for true ASICs, where we have to make individual devices for individual customers, we need our own fabs. You've got to have packaging technology—and these fabs must be flexible and provide a quick turn. The third point is that you have to have local design centers to add support to the customers in their home territory.

ASICs have been very successful in a lot of ways, and I thought I might elaborate on how they've been successful. If we look at personal computers in the early 1980's, we see they drove the ASIC business. The first computer that came out in 1983 (or the first clone computer that came out), had about 100 or so standard TTL products in it. Of course it had a microprocessor, and it had memory. By 1986, the chip count of these personal computers had gone down to about 20, thanks to the invention of chip sets. Three years later, this chip count went down to about five, and of course everybody is aware that today you can buy computers that have a single chip in them, in addition to the microprocessor and the memory. This reduction in chip count came about primarily because of the utilization of ASIC technology (and manufacturing technology, of course) to produce them. In our case, cell libraries of complex proprietary functions—or FSB (Functional System Block) cells as we call them)—played a very key part in integrating more and more onto an individual chip set.

If we look ahead, the future of the ASIC industry is a very positive one, and I think it's going to be very profitable one as well. The growth rate in ASICs is projected to be somewhere around twice that of the overall semiconductor marketplace, and I think there are tremendous opportunities in all of the market segments. At VLSI, the type of products that we feel will be most profitable are those that are FSB-based, and that offer some uniqueness and some distinctiveness in terms of the marketplace. These products will help us generate large, complex chips that will incorporate FSB cells to give us the uniqueness and differentiation.

Let me give you some examples of some of these proprietary FSBs: The Intel 386SL microprocessor; a fuzzy logic co-processor; an ARM RISC microprocessor; various communications: core devices such as SONET, DECT, CT2, and others—and, in addition, a host of other FSBs that are in our libraries.

Let me go back and talk a bit on the prior example that I mentioned in the PC area. In that example, the chip set, the single chip set, is made up of about 100,000 gates. Each of those standard products had about 1,000 gates on average. The 386 microprocessor has about half again that number of gates, and so the next natural extension is to go ahead and integrate the chip set with the microprocessor. Our agreement with Intel allows us precisely to do this. That integration is, of course, demanded by our customers in terms of the products that need portability, that lead to low power consumption, and that need cost reduction. The opportunities that we are going after with that solution are, I think, huge—it is the low-end, handheld personal computer marketplace.

If we can come out with those kinds of products, then I believe that the ASIC business indeed can be an extremely profitable one.

Let me summarize. To be successful in the ASIC world—the ASIC world of change—I think one must have, in addition to those three key elements I mentioned before (and perhaps maybe I just should repeat them: software tools, process and packaging technology, and local design centers). Anyway, the additional key things that I think one needs are first, a rich library of innovative and differentiated FSBs, of some proprietary nature. Second, access to microprocessor architectures, microprocessor FSBs, that are suitable for target markets. Third, one must have a system-level understanding of the desired end-equipment. The ASIC business is now becoming a system business. Finally, we must have alliances—alliances that provide needed attributes that we may not possess in-house. For example, these could be system architecture know-how, differentiated FSBs, processing technology, and so on. In our case, as you know, we have an alliance with Hitachi, and that is a very, very big plus for us in this area.

Finally, let me close by saying I believe very strongly that the ASIC business can be a very profitable one—and *will be* a very profitable one. The ASIC companies cannot be all things to all people. They must concentrate in a specific market area, and they must bring something that is very, very differentiated to that marketplace.

Mr. Lewis: Our next speaker needs little introduction. He is the Chairman and CEO of the largest merchant ASIC supplier in the world, LSI Logic, of course. LSI Logic pioneered the gate array market. Please join me in welcoming Mr. Wilf Corrigan.

Mr. Corrigan: You know, I think somebody has got to say a few words on behalf of the ASIC industry—which gets a little bit maligned at times from Dataquest and similar folks. You ask yourself, what was it that changed in the '80's where the ASIC industry was a tough place to make a lot of money? You might look around and say, what happened to the computer industry in that time period? I think that collectively, we misjudged—as the proprietary architecture or proprietary operating system computer industry misjudged—the rate at which the conversion to open systems would happen, and that ASICs *were* the architectural implementation for the minicomputer industry as such. Many of the mainframes were starting to move in that direction very rapidly. Then as the computer industry started to move much faster than anybody anticipated to open systems, we all found ourselves with excess capacity. The lead time on semiconductor capacity, as we all know, is several years. As we ran that vector out, and you put that capacity in place, collectively as an industry we were hung up with excess capacity. The reality is, if you look at the gross margin of the ASIC business, it is a very reasonable gross margin sort of business—for most of us who were major players in that industry. And all of us, in one way or another at this time, have figured out how to work off that excess capacity—that's what changes the picture fairly significantly in terms of what is the overall margin of the industry going forward.

Now, when we talk about the ASIC market—I hate the word ASIC, you know. Dataquest invented the word, I always thought Semi-Custom is a hell of a lot better word. But the ASIC covers a wide variety of things, and there's a tendency to pigeonhole them all under this one title of ASICs. PLDs are a significantly different piece of the market, even though there *is* overlap in application. As Al pointed out, it is quite possible to be in the PLD business without having to have an intimate relationship with your customer. The *CSIC* business, or the *custom-specific IC business*, is different. You really have to have a close relationship between the supplier and the customer. You can't do it too well at arm's length, or through third parties. Consequently, you can't really do it without having your own fabs, because customers invariably (the sort of guys that buy this sort of stuff that we call CSICs) want to see your fab. They want to see how it's qualified. They want to see what your statistical process control is. You can't say, "I've got some supplier way out here and most of the time he's pretty good." That is not how it works. So different elements in the industry behave differently.

The trends that I see—applications-specific standard products have been one significant trend in the last several years, and now we're starting to move into what I would call *semi-standards*. As we started out in the late '70's and early '80's with semi-custom, we now are dealing with semi-standards. If we look at what is the definition of an ASIC, it used to be, well, it's a computer-designed circuit. For a long time, we had the same argument that we had in the late days of the TV industry in the U.S. when Zenith used to advertise, "The hand-wired chassis is somehow better than a printed circuit board." You know—real men hand-wire their chassis. [Laughter.] Ten years ago, the argument used to be, "real men don't use computers to design circuits." That definition is now gone, because virtually all chips today *have* to be designed using what you would call ASIC design methodology. So the methodology is now pervasive and virtually everybody is using these same design techniques to design standard products as well.

The definition of what is an ASIC is becoming a little blurred, and if we look at custom, semi-custom, semi-standard, they're all variants on the same theme. I'd almost argue that today a microprocessor is what I would call a serial ASIC. It has many of the characteristics of an ASIC in the sense it has a relatively short life as a mask set. Frequent tweaks means many versions were the architectural life of the product. In one of my fabs, for example, I might be running 1,000 different codes at any point in time. In a microprocessor fab, you run fewer codes, but you start to run many different variants. So you're doing it serially rather than in parallel.

The hand-crafted design is no longer possible, because Moore's Law still applies, and there is no way (in a timely fashion) you can handcraft several million transistors (in any coherent fashion) on a chip of silicon. All chips have to be computer designed today.

The slow economic environment of the last couple of years—and some of the problems that the customers have had in the end marketplace—have masked a real step-function change in thinking in electronics systems companies. Many companies that, only two years ago, would think in terms as a policy or as a strategy—"Oh, we're only going to use ASICs up to about 10,000 gates"—suddenly those companies are not following what you used to think as an orderly progression. Many of them have said, "Jesus Christ, we better jump to 100,000 gates." Bang, just like that—a lot of the intermediate steps are being bypassed. That's not yet visible in too many end products. In '93, that will be visible.

Also, if you look at the *synthesis-driven* design (and it is being very widely used today)—I figure there are probably something in the range of 20,000 design seats now out there for synthesis-driven design, in a lot of ways it's not that good yet, but nevertheless there has been a large commitment to it . You're going to see that having a bit effect on these very large designs very quickly. That, combined with the very large building blocks (Al calls them FSBs—we call them cores—but they're the same thing really), this combination of synthesis for most of the peripheral logic; and the cores, which enable you to carry intellectual property through more than two generations, is really going to be the design style that the industry is going to use. This is an evolution, but it's a different sort of ASIC business.

Today, in hardware, the chip dominates both cost and performance. As we move forward, I think we're going to continue to see this trend. We all talk about the processor core, but the same sort of phenomenon is happening in sections of the industry that don't use microprocessor cores. The same move towards open systems and standardization means big chunks of intellectual property are going to be stitched together, and that is how you build the systems of the future. So this is high-level ASICs.

Fundamentally, everything we have been talking about today is what is going to make both the semiconductor industry and the ASIC industry a lot more profitable—it's *intellectual property*, it's *software tools*, it's *high-performance process technology*. I'd also like to emphasize today that DRAM technology, process technology, is very useful in an orthogonal sense to develop a layer and a given process.

But when you look at the architecture of an ASIC process, it's dramatically different—or a microprocessor process—it's dramatically different from a DRAM process. We're starting to see those very big differences—and that gives proprietary advantage.

As we move toward single-chip solutions (and whether you estimate that by the end of the decade we're going to be at 25 million, 30 million, or 100 million transistors on a chip), it's very clear that chips must be differentiated, or all systems will be the same. They *must* be differentiated. If you've only got one chip, you don't have much choice. Otherwise, the whole electronics industry will become one massive calculator business. [Laughter.] And I don't think we're going to let that happen.

Thank you.

Mr. Lewis: It's that time of the day—time to put the gloves on, gentlemen. I want no hitting below the belt, but I want to see you come out swinging. Okay, consider this: A state-of-the-art fab now costs in excess of $200 million, and it continues to rise with each new generation of product. These fabs require very large unit volumes to support them. Mr. Corrigan and Mr. Stein both talked about how fabs impacted profitability. My question to the panel members: Do real ASIC suppliers need to own fabs? If so, what kind of sales volumes are required to own these fabs? I know Mr. East has got some opinions on this. How about starting off with John?

Mr. East: Okay, Bryan. I think Charles Darwin had something to say about this. Actually there has been some Darwinian survival of the fittest out there. If you look at the larger ASIC suppliers who make the hard-wired ASICs, what you've pretty well seen is the fab-less people have gone away. There were a lot of them out there, but I think all the people that have succeeded so far have been the ones with their own fab, and I think it makes a lot of sense because with the custom ASIC, you want fast turnaround time, control of the fab, etc. So I don't think there's any doubt but that that's the case.

On the other end of the spectrum, with the field-programmable crowd, all of whom are quite a bit smaller, all the successes today are fab-less. So that's probably not just coincidence. That's probably a statement that that's the best way to do it at the two ends of the spectrum. The only question is, what happens when one of the little programmable guys gets big. My foundries are all out in the audience—maybe we should just ask them. Fred Schwettman of Hewlett-Packard and Wally Rhines of Texas Instruments but I'm not sure that either Fred or Wally will want to invest $2 billion so that I can grow to $1 billion in sales. As we start to get bigger, there will be more need for even the programmable people to have their own fabs.

Mr. Lewis: Can you put any kind of dollar limit on it, though? $100 million? $200 million?

Mr. East: Oh, if I were to put a number on it, I'd say $500 million today, but that is probably off by a factor of two. I don't know which direction. [Laughter.]

Mr. Lewis: Okay, Wes, how about you? You've got some opinions here, I'll bet.

Mr. Patterson: It seems like it's a matter of where you can add value. If you can add value by having a fab, either by quick turnaround or unique processes, then you should have a fab. But if manufacturing is not a point of value added, then I'm not sure there's any size at which a fab becomes mandatory. For a long time in the history of Xilinx, a fab was two years in the future, and we finally just gave up trying to predict when, if ever, we would need one.

Mr. Lewis: Okay, how about hearing from some of the other panel members? How large do you have to be to have a fab?

Mr. Stein: I think that in this programmable area, the time these folks are going to run into problems is when they cannot get the process technology that they need to have a leadership device. Unless they have differentiation they will run into some problems. But if they can continue to provide that differentiation without having a fab, then they're in great shape. As more and more people come into this end of the business, then there may be a time when they are going to be in trouble because they may not be able to get that advanced processing technology that will allow them to differentiate any further—I think that's really what's critical in the end.

Mr. Lewis: So there's really not a dollar limit, you think it's more just an issue of differentiation?

Mr. Stein: If I were them, I wouldn't have a fab. [Laughter.]

Mr. Corrigan: I think you've got to look at it in the different sectors—that the fab-less has worked well in ASSP. If I look at Chips and Technology, Cirrus, Adaptec, it works fine for them—because they could control the movement of the technology. The hard-wired ASIC business, arrays and cells, have much shorter cycles, than most other technologies. If a customer has a critical ASIC in his system—he wants to know, "What happens when I get to a million units a year? Can you guarantee supply?" I don't think they'll accept an answer that says, "I've got some guy in Taiwan," or "I've got some guy over here that has promised me a bunch of support." The strategy that seems to be emerging for the 90's is that fully-fab companies will start partially outplacing capacity, for a portion of the very *high-volume* requirements, and fab-less companies strategically will find ways in which to buy into existing fabs so they can at least claim that they've got some equity position. Remember, the rise of the fab-less companies has arisen during a period of vast excessive fab capacity. I'd be interested to see how the business model gets tested if there's a shortage of fab capacity. That hasn't happened yet.

Mr. Lewis: So you see multiple companies owning fabs together in the future?

Mr. Corrigan: Yes.

Mr. Stein: Bryan, I think that these guys are really not ASIC companies. [Laughter.] Well, think about it. They produce a standard product when it leaves their house, and then the customer takes it and makes it an ASIC. So they can build a lot of products and sell them to a very broad spectrum of customers—that's a really nice position to be in. As Wilf pointed out it's a lot different than what Wilf and I find every day.

Mr. East: We like it, Al. [Laughter.]

Mr. Cox: Wilf is absolutely right. Major U.S. customers absolutely demand long-term relationships, and fabrication capacity is fundamental to those relationships. They need to have visibility of control, delivery, quantity, price, and all those key issues. I don't think that's going to change. The size depends upon the business plan and the degree to which you're prepared to take risk. For example, someone this morning was questioning whether or not there was a successful fabrication plant built by a Japanese vendor, and they may or may not be happy with their investments. We certainly have had a very small, flexible, metalization test and assembly facility in the Bay Area, and that continues to add extremely good value for, in this case, hard-wired metal gate arrays. I think the other comment that I'll make is unfortunately the overlap is in the dimension of customer-specific—in the case of field-programmable devices—and that's where they overlap. As such, in that portion of the market domain, you can see them actually taking a portion of what otherwise would have been a hard-wired product. They offer distinct advantages, and should continue to do well.

Mr. Lewis: Okay, one more question from me, and then we're going to start getting some questions from the audience. What impact will the foundry business have on the ASIC market?

Will we expect to see it grow because of the increasing fab costs? Is this really an opportunity, or could it lead to further price erosion?

Mr. Corrigan: I think the foundry model works reasonably well when you have a pretty mature product. For example, the 386 was introduced in 1985—support chips for the 386, you've got seven years since then to figure out how to get a foundry in place. That is atypical—I suspect that Intel might be introducing their processors a little more rapidly in the future. But apart from that aberration, I think that generally you need access to leading-edge technology. Most customers want to get the leading-edge technology early in the design cycle, and the fact that two years later you might be able to foundry it is probably a little bit too late in our sort of business.

Mr. Stein: I don't think the model really works that well in the customer-specific business. It might in ASSP, and it does already in the PLD area.

Mr. East: Bryan, if I could take a shot at that. I'm not sure I understand the question, but it sounds like you're asking what changes do we see, and I don't think we see any. I think if you start with the little guys, it just plain is prohibitively expensive to buy a fab or build one. So I think that just won't happen. So the only other possible change would be that Toshiba would decide to go fab-less [laughter], and I don't think they have that in mind. So I think there are no changes coming.

Mr. Lewis: Okay, let's go ahead and get some questions from the audience. What would you folks like to know from our ASIC visionaries up here?

Question: With all these talk of strategic alliances, why wouldn't noncompeting vendors of various kinds of microcomponents get together and jointly own a fab?

Mr. East: I think that's going to happen. I think we all think it's going to happen.

Mr. Lewis: The question was, are multiple companies going to get together and start owning fabs, and I think clearly the answer is yes in the future, because of the rising cost of the fabs. Let's get some more questions here.

Mr. Stein: Well, let me expand on that. I think those things are already happening by some of the alliances where you have joint fabs in the marketplace already today.

Question: What happened to U.S. Memories?

Mr. Corrigan: Well, actually, that's a very good question. I had a little bit to do with that. [Laughter.] What happened with U.S. Memories was that very rationale that the gentleman just mentioned was, why couldn't the big users of memories in the U.S. (namely the mainframe computer companies, and some of the companies like Compaq and Sun and so on) get their heads together and essentially share a fab, if the fab was willing to produce at whatever the going market price was—which seemed like a fairly risk free sort of opportunity. The reality was, because of the things going on in the computer industry at that time, collectively they really couldn't decide to go do that. IBM and Digital Equipment were very willing to make that commitment, but it was impossible to get the other people to commit. Al reflected earlier, if you don't have a fab, maybe you don't want to get one if you can find some other folks to supply you. There wasn't enough communal will in the American computer industry to pool resources and put a critically sized wafer fab together. Also the shortage was beginning to abate at decision time.

Mr. Stein: I want to get back on the question about fabs. I don't want to make it sound as simple as I said, that it's already happening. Keep in mind that when you embark on a fab, you want to keep one basic process in that fab, so when companies get together, they have to have a common kind of product and a common goal. Otherwise, it becomes extremely difficult, because if you run many different products in a fab, you lose efficiency, and there are all kinds of problems when that happens.

Question: If that capacity dries up, does your business dry up?

Mr. East: The answer to the question is, I suppose, yes. It's harder if you have a custom process to line up foundries. There's no doubt about it— it's a factor.

Question: The fact is, what you people have been practicing isn't a foundry business—it's a strategic alliance. There's a big difference.

Mr. East: That's our particular answer to the approach. We have no pure foundries. We have a set of partners—and there is a big difference. Were we to use somebody for just straight foundry, I expect they might go away when the situation Wilf hypothesizes comes—namely, there's a boom in the business—if that ever does get here again. The straight foundries might go away. Wally Rhines and Fred Schwettman will not—they're with me for life. [Laughter.] See, he agreed.

Question: Over the next five years, do you see any consolidation in the ASIC foundry business? And the follow-up question is, what might be the impact if IBM enters the commercial foundry business?

Mr. Corrigan: I suggest Jim Picciano answer the second question. If you look at the foundry business as a business, it's probably at the wrong end of the business model. I mean, if you're going to take all of the capital risk, you've got the most asset-intensive part of the whole food chain. You're only going to get revenues from wafers. Ultimately, this is not a business model that is going to work too well over the long term, because you've got to look at it over a five-year cycle. Inevitably, customers generally are not willing to say, when there's a slowdown of business, "Why don't we kick in to cover some of your uncovered costs here?" [Laughter.] I mean, it doesn't happen. I think the foundry business, *per se*, is a little tough. Now, if I take my sort of business, to get a lot of the stuff foundried that my customers want and then say, "By the way, we'd like 1000 different assorted a week like that"—believe me, there's not too many takers.

Question: Regarding multiple companies setting up a fab line, it looks like that would be quite difficult. So sharing a fab line, it seems like you would lose differentiation and freedom of choice.

Mr. East: Tony Moroyan of Hitachi questions if can you have two or more companies sharing the same fab, and I think his point was, it'll be difficult. Tony, I agree, it'll be difficult. Necessity is the mother of invention. I think when we get to the time when we need to do it, we'll figure out ways—but it won't be easy. I haven't found an easy way to make a buck in this business.

Mr. Cox: Use a model where you'll ride the end of the food chain, which is, as I said in my brief explanation, the worst place you want to be after making an enormous investment. Probably one of the models that you should consider is typically the kind of model that Toshiba has used with Motorola where we've established a joint venture. There are some agreed working principles in that fabrication line, with a restricted set of products and with some kind of restriction in terms of the unified process and architecture that the two companies can use. I think that has been very successful—and I think that's a model that can be used again.

Mr. Corrigan: The question is, who is the partner that you have? I think from a business standpoint in the open market, you'd prefer a partnership with a guy that dominates the market on Mars, and that would make him very compatible to have a joint manufacturing strategy. From the standpoint of the actual manufacturing guy, the most compatible partner is probably your most violent competitor. I mean, I would suspect that Al and I could probably, in a manufacturing sense, share a fab a hell of a lot better than I could share a fab with Linear

Technology, because we've got the same objective, the same end market. The problem is, it gives you a hell of a problem in the end market—but it sure is a neat way to manufacture! [Laughter.] You might have a few minor antitrust problems, too.

Question: My question has two parts. Number one, does that imply maturity in the industry? And if it does, will the lowest cost producer dominate the market? The second part of the question is, what are some of the things that could be changed in the industry?

Mr. Lewis: The first question is, will the lowest cost producer win.

Mr. Cox: If I can take it first, I don't think necessarily someone who positions himself as a low-priced or as a low-cost manufacturer necessarily dominates the market. It's just one particular portion of the market that he has some kind of advantage that he can utilize for his own benefit. Traditional logic says that if you have a competitive advantage in terms of cost, you can utilize that sort of product range. We've been talking today about several key differentiators of products and markets that a reasonable cost structure should be able to support.

Mr. East: If I could take a shot at that. It was Vahi Sarkisian back there that asked that. So all my friends are turning against me. He's a former Board of Directors of Actel. Probably just checking to make sure my IQ is sufficient to pick that up. I think that was the old model. I talked in my five-minute shot about pin-for-pin competition, and no doubt when everybody made the same product it was pin-for pin and you could take his or his or his or mine and plug it in the same socket. The guy with the low cost won. I see less and less of that out there. I see very little as I look out five years. Once products are differentiated, I think that last five percent of manufacturing cost is a lot less important than it was. I think the intellectual property rights are a lot more important than they were. So I think those are the playing field's levelers, as I think Lois Abraham called it. Didn't she call it a level playing field or lack thereof? So I think it's intellectual property traded off against manufacturing cost—and the resultant field is really probably pretty level.

Mr. Corrigan: I think I'd add something to that. You seem to have the impression that several of us here said that it was going to be very predictable and evolutionary. Believe me, I don't think it's going to be very predictable and very evolutionary. As we get down to the half-micron level, the second-order effects make the design of this sort of stuff much more difficult. The ability for two other foundry people to come back a year later and take a net list and bang out a replica that is going to work right the first time is not very probable. We're into a different era of difficulty. When you're trying to arrange several million transistors on a chip, and you're trying to do it right the first time, no—I don't think this is going to be very predictable. The business issues are not very predictable in terms of what exactly is going to happen with the new architectures that are coming out. You know, represented in this room I'll bet there are ten different teams—alliances of people who are planning on working out how to screw the competitive standard at the next click of the architecture. A few key competitive moves and you could find yourself totally riding the wrong horse. So I believe it's a very unpredictable environment, but it's an environment where both the opportunity to build barriers around your position—and the possibility of abject failure—are going to rise significantly.

Mr. Lewis: Any last closing thoughts on this one? Unfortunately, we've run out of time here, ladies and gentlemen. We've explored a lot of different issues of this industry, including manufacturing fab strategies, alliances, product trends, and company strategies. I hope you all walk away with a better understanding of the issues facing the industry. I'd like to thank the audience for coming, and I'd like to thank our panel members—they did a fine job. A round of applause for our visionaries. Thank you for coming, and I'd like to turn it over to Gene Norrett for some quick closing comments.

Mr. Norrett: Okay, the next stop on the tour here at Disneyland is 6:00. We're going to be convening outside in the lobby outside of the De Anza Ballroom where we had lunch. We will have cocktails there for about an hour, and then we'll go inside the ballroom for our dinner, and to hear Dave Packard speak. We start tomorrow morning at 8:15, and, if you will, the same seat, if you'd like. If you don't like, you can change your seats. Lots of room. I'd really like to thank all the speakers that are still left here in the audience for an outstanding day. I've heard some really great comments from the attendees about your presentations. I really appreciate all the hard work that you've put into the preparation and presentation today. So have a good evening, and we'll see you tomorrow morning. And of course, dress up for dinner tonight, okay? Thanks.

Introduction

Joseph Grenier

Director, Semiconductor Equipment & Manufacturing

Dataquest Incorporated

Mr. Grenier: I am Joe Grenier. I am a Director in the Semiconductor Group and I'm going to be your host this morning.

The theme of this conference has been fueling the engines of growth. Mostly we've been talking about the big engines. Now I'd like to take a little bit of time and talk about the little engines of growth, or maybe some of the lesser known applications of semiconductors.

I have done some research in this area and this are what we've come up with at Dataquest. First, are electric carpets from Japan. These carpets have embedded heater wires which can be temperature-controlled via a panel on the wall. You set a temperature and it is displayed. It's nice if you like to walk on carpets in your bare feet or lay on the floor and watch T.V.

The second item, also from Japan, is microprocessor controlled paperless toilets. The heated toilet seat is temperature controlled. The temperature of the water is controllable, as is the temperature of the hot blast. No kidding—it really exists. Here is a block diagram to prove it. I would have made a slide of the block diagram but it is copyright protected, and at Dataquest we adhere strictly to law. The ecologists would probably love these items—it would probably save millions of trees annually.

The third is a group of applications which I have lumped together in a category called electronic herding and tracking. Sheep in Australia have passive RF transponders in their ears. These transponders have no batteries—they're activated by the energy of the pulse. I really didn't think shepherds made so much money that they'd be the target of such a labor-saving device. This will probably mean the demise of shepherds, and they will probably exist only in poetry from here on. Cattle and deer have also been tracked with IC's, and even salmon have had IC's attached to them. By the way, this is high technology. The sheep transponders are surface acoustical wave devices which, as you know, have very fine geometries. Perhaps the most bizarre application of all these is the tracking of killer bees by implanting some kind of IC on the back of the bees.

The next item is intelligent garbage cans in Europe. A chip on the side of the garbage can contains the owners ID and other important data, such as the weight of the garbage. When a garbage truck pulls up, the forklift picks up the garbage can, weighs it and records the ID number and weight in the truck system, and then updates the label on the garbage can. I think in the future, we're going to see some garbage can fraud as criminals try to alter the IDs. Imagine "charging" your garbage to your neighbor's account.

Another item is what we call customer-specific espresso machines from Italy. Each customer has his own special card with his own recipe just exactly how he likes espresso. He walks up to the machine, puts a card into the machine and it dispenses the espresso according to his formula.

How about chips in the caps of medicine bottles? The idea is to alert the patient when it's time to take his medicine. The bottles are programmed at the pharmacy, and they emit a little beep every three or four hours, or whatever. By the way, I think this chip was developed by Northern Telecom. This is all serious stuff. However, what does a hypochondriac do when he has a whole pocket full of bottles? I think it would be rather annoying to sit next to a guy in a plane and have all those beeps going off all the time.

That was all we were able to uncover. How about you out there? Does anybody have any unusual applications to disclose before we move on to the big engines? Dave Angel, I know you mentioned something about talking dog collars?

Let's get back on track to more serious business, and get on to the subject of the day.

Our first speaker is Dr. Myhrvold. He is vice president of advanced technology and business development at Microsoft, where he is responsible for research, advance development and identifying new technologies that may have commercial impact. He joined Microsoft in 1986. His previous position was director of special products, where he helped with the development and management efforts for a number of Microsoft products. Prior to joining Microsoft, Dr. Myhrvold was president and CEO of Dynamical Systems, a Berkeley software company. Before founding Dynamical Systems, he held a position at Cambridge University working with Professor Stephen Hawking on research in cosmology and quantum theories of gravitation. Dr. Myhrvold received a B.S. degree from the University of California and a PH.D. degree in theoretical mathematics physics from Princeton University. I'd also like to add that there are 12,000 employees at Microsoft and Dr. Myhrvold and another person are the only two people there with a cosmological background. Please welcome Dr. Myhrvold.

Software: The Invisible Enabler

Nathan Myhrvold
Vice President
Microsoft Corporation

Mr. Myhrvold: I'm going to talk about software and how software is changing in ways which will enable some new growth and new opportunities in semiconductors.

The world that we live in is increasing dominated by two remarkable technologies. One is VLSI and the second is software. Being a software guy, that's the one I focus on most. Our view is that software is the fundamental spirit, the thing that possesses your hardware, so to speak, and winds up giving it a personality, a usefulness to applications and end users.

If we look at where the 1980's have left us in the personal computing industry, we see that several waves of computing occurred. The first set, the interface was largely borrowed from character-oriented terminals—MS/DOS, and before that, Z80 systems were in that world.

The first machines were very chaotic. There were dozens of different standards. But soon the industry wound up focusing on just a small number of machines which became enormously successful. Perhaps it's my parochial view, but this success was driven largely by the existence of third-party software compatibility. You could go into any software store or any mail order house, and order potentially tens of thousands of different packages which would go and give this personal computer some use to you.

This created a hardware strategy which made an enormous amount of sense and money for people. The basic idea was to say all that software out there is the key asset. We have to make hardware that takes and runs that software very well. Better isn't different; better is able to run that existing installed base.

There's a number of problems with this approach. One is that as innovation occurs, you necessarily have to step outside that standard. Probably the most famous example is, for many years, the memory of personal computers, the IBM PC, was restricted to 640K. As an aside, that was Bill Gates' fault; he personally laid out the memory map. The good news is, it wasn't the 64K limit, which is what it might have been if we hadn't gone to 640.

Limitations like that were very natural, given the level of technology at that time. But unfortunately, for manufacturers, it meant that they had to wait for standards to settle down to a certain point before they could offer products. And it also wound up meaning that most personal computers were really a lot alike. Price became one of the primary areas in which people would compete.

One of the best examples of that was the Flight Simulator, a Microsoft product — one of our more popular products. The Flight Simulator became the acid test of whether you were PC compatible. You'd boot up Flight Simulator; if it flew, you were golden; and if it crashed, you crashed.

A number of manufacturers created machines that were much better than the original IBM-PC standard; better graphics; different set of support chips; actual genuine innovations. They were actually better from the point of the engineers who built them, but not the customers, because they couldn't run the software; they couldn't run Flight Simulator.

The fundamental reason for this, as we can see from our block diagram of MS/DOS—the key thing is this line going from application down to hardware. The only way to make competitive successful applications within that IBM-PC market, was to write directly to the hardware. So whether you were Flight Simulator or Lotus 1-2-3, or another application, you became intimately married with the details of the machine. That meant you couldn't change any of those hardware details without breaking the application, and therefore, without breaking the utility of the entire proposition to customers. There's a very funny situation here — millions of customers can't be wrong — you're wrong if you say you've got something better.

There's a solution to that, a solution which larger computers have had for a number of years, and which I'm happy to say personal computers have now. That solution is you have virtualize the hardware. You write a software interface, such that the application software that you might buy at Egghead isn't specific to a particular chip, to a particular register command that it gives. But instead you have device drivers and a variety of other layers of software that sit between the hardware in this application.

It's a great idea, but one the first PCs couldn't afford. They couldn't afford it in part because they weren't designed with that in mind. They also couldn't afford the performance and other features.

One of the ways I like to point this is out is to show a picture of a motherboard; this is a 486-PC. If you say how much of that motherboard was virtualized by MS/DOS, you'd say it's that area over there where you plug in cards, the I/O bus. So you could plug in a SCSI disk or an ESDI disk; it could be a CD-ROM, a variety of other peripherals. And MS/DOS device drivers would hide those from the end user—the file systems, and so forth, would work regardless of the device.

In the last couple of years, this graphical user interface has largely supplanted the world we've just talked about. The form I'm most familiar with is Microsoft Windows. Windows has a number of different features for the end user. It's easier to use, it provides graphics and many interesting features. We'll set those aside for now. The key thing, from the point of view of this block diagram, is that there's no longer a line between the Windows application on the hardware.

That's not just a rule; it's not a law we wrote. It's an important part of the functionality of Windows. Windows supports multiple applications at the same time. They can't use the hardware directly without conflicting with one another; they'll break. Also, we've gone to a fair amount of effort to provide virtual device drivers of VxD's which virtualize any of their remaining services that the software would need virtualized.

The key thing about this virtualization is that Windows sets the hardware free. Because applications are Windows applications, it doesn't matter nearly as much what the underlying hardware is. So whether you've got different communications or graphics, different sorts of printers, different ways of connecting printers—it might be serial ports or video ports—Windows fundamentally is the interface. I believe we're in an era where the next 10 years of computing will be dominated by machines that are specific to a particular application platform like Windows, or others. The end user will think of them as Windows machines. This has got a huge impact on the architecture.

If we flip back to our motherboard, in addition to covering all of the device drivers and plug-in boards the DOS would cover, in fact, video and variety of other I/O disk things are all covered by Windows. You might wonder why I didn't put floppy disk under DOS. It turns out floppy disk controllers were one of the most popular ways of doing copy protection. Even the floppy disk controllers got into the compatibility act in the DOS world. This offers a big opportunity for people to rethink the IBM-PC design.

That's not the last step. What I have shown you is the current version of Windows, Windows 3.1. If we look at Windows NT, our next generation system, we have even stronger goals for isolating hardware and software. Again, those goals are not just rules. It turns out if you make rules like this, if it's to their advantage, they wind up breaking those rules. The theory for the IBM-PC is people wouldn't write to the hardware. The trouble is you couldn't write applications that sold very well.

When you get to the era of NT, what you find is that people making sophisticated multi-tasking applications, multi-processing applications, client server applications, really cannot get the functionality they want if they do try to write to the hardware. There's a very strong force which is going to keep them writing only to software interfaces.

In order to support that kind of system, we have to go and replace the last remaining aspects of this PC motherboard. The ROMBIOS, which has been in since 1981, is no longer an issue with NT. In fact, the NT replaces it with something called the NT-HAL. You can still run this on a machine that has a ROMBIOS; the BIOS will boot and then bring HAL in. Fundamentally, this hardware abstraction layer for NT is the interface through which the operating system and then the applications see the hardware.

Here's a block diagram. The key issue here is there are several layers of software between any piece of hardware and an application. So when we go back to our motherboard, we now discover that there's essentially no aspect of it except the processor and DRAM. Everything else winds up being completely virtualized.

I believe this is going to offer unprecedented freedom for system designers. You no longer have to have the 8259 interrupt controller chip or the compatible equivalent. That's not just a commercial statement; it's not like I have something against the 8259 or the people who make it. It's more a question of where do we need to take personal computing architectures. If we want to make machines that are low power; if we want to make machines that are multi-processor enabled. We're not going to be able to keep doing that on 1981 architecture. The fortunate thing is that we don't have to. I think this also puts a large premium on innovation. It means that people are not required to only go and compete on the issues. There are also substantial functionality differences.

In general, what we're talking about is a variety of ways of accelerating Windows or creating hardware for Windows-optimized machines.

Mass storage is one of the most important areas. Mass storage is in some ways an old area, but we're increasingly seeing new varieties of mass storage—flash EPROM, PCMCIA cards, etc. The software virtualization is a very key feature for letting those become high volume quickly.

Peripherals are another important area. You don't have to have this software virtualization only in the machine. In fact, a wide variety of printers, scanners and other output devices are affected.

Networking is perhaps the biggest area for us to move us as a company and as an industry, to work for us in the next few years. Penetration of networking and personal computers is still rather low. It's only about 15 to 20%. I think that represents an enormous opportunity. To capture the rest of that doesn't mean that we're just going to create more miles of Ethernet cable and more Ethernet adapters. Many of those people are only going to be reached by wide area services, wireless services. Laptops might have docking stations but laptops and pen-computing and pocket machines all bring up new varieties of networking.

Servers are another important area. Servers are something that has traditionally been outside of the personal computing area. You can create PC servers. To a larger extent, a PC server, for the last several years has only been a machine with a little bit bigger disk drives, perhaps a bigger power supply. It wasn't possible to have a very large differentiating feature between a desktop and a server.

Symmetrical multi-processing changes that and changes it in a very fundamental way. Because we're now able to have a world of scalable computing that goes from single-processor machines that we might have on our desktop running a 486 and perhaps a P-5, to servers that will have up to very large numbers of processors. We have NT running today on 16 machines. We've talked to a number of people who are planning machines to go well beyond that. We've even talked to a couple of companies that are working on massively parallel machines where they would hope to make an NT machine that has on the order of thousands of processors.

The thing that's fascinating about that, for me as a software developer, is that it means that when we write a client-server application, that server piece can now handle problems of all sizes. The customers don't have to scrap one approach and start over with a different incompatible set of systems, but simply by a more powerful thing of the same basic architecture.

That architectural approach to the notion of scalabilities has been enormously important in the mainframe; that's largely what gave IBM its initial advantage with the 360. It was important in many computers; that's been DEC's advantage for many years. I think we're going to see this issue of scalability come to the PC arena where it's going to have a major impact.

This isn't just about traditional computing. The same sort of flexibility and virtualization is also allowing us to enter new areas. Pen-based computing is certainly one of those. The interesting thing about a pen machine isn't just the pen. It's that if you want to treat it as a notebook you also have to make it very lightweight, low power and robust because people are going to drop them. There's an enormous set of technical challenges. I think it will be several years before pen machines really catch on; just as it took a number of years for laptops and portable computers. I had one of the first Compaq portables; which is kind of a joke today. It was a great machine at the time. It was small, it would fit in the overhead compartment of an airplane.

The pen machines that we have today are about the same level as that initial Compaq. They're cool and you can proud be of them and show them off. I don't think that millions of people will start buying them tomorrow. Within the next few years, we will see millions of people buying them. It won't be a question of whether someone has a personal computer or access to one—it will be how many personal computers they have access to. You'll find that taking notes on a pen computer becomes important for large segment of society, particularly salesmen and people that have a need to be connected to the office and how they take their notes.

Pens aren't the only thing. There are an awful lot of pockets. We did an experiment in my group where we had everybody come and empty the stuff out of their pockets. It turns out most people have somewhere between 4 and 8 ounces of stuff they carry with them. I'm kind of at the upper end — I have got pagers and a variety of other things. One thing that is interesting is that almost all of the stuff in my pocket is either electronic already, such as this key—it's passive—a digital key to my room. All of this stuff could be put into a pocket computer. We think that they will be put into pocket computers over the course of the next few years.

Some people think that smart cards will be the approach to that. I think smart cards are interesting. I have 14 credit card-like things in my wallet. I don't seem much of a reason to carry 14 little computers when it would probably be easier to have one computer, a little bit thicker than a single credit card, that actually contains all of that information.

I think that the pocket and pen-top market is going to be another terrific area for growth as we put computers in every home and on every desktop. Clearly, pockets will be one of the next areas to take off.

This is not a market that I'm saying will be enormous in 1993. I think it will be something where many of the roots are planted in 1993. As people start experimenting and starting selling to gadget freaks like myself, these markets are going to start to shake out. All of this are things that you can't really accomplish well if you have a notion of application software binding directly to the hardware. We're not going to be able to make high volume pocket computers if we can't also let people buy software for them at Egghead or even at an airport.

Finally, there is home computing. There is an enormous set of opportunities here. Essentially, every form of human information is going digital. The first wave of that we've seen with things like CD audio, where they're digital but not very smart. It's simply a direct replacement for a record, only it sounds better because it uses digital technology.

I think that we're going to see, in the next couple of years, several waves of much more intelligent devices. One of the ones that's most exciting to us is Modular Windows, and the notion of having a combination of home PC and digital viewer—something that can be configured as a computer with a keyboard—or can be configured to play multi-media.

Within the next couple of years I expect to see those machines with cable TV inputs, because cable TV is going digital. If you don't have some intelligence and some user interface, it's going to be very hard for people to actually use systems that have—I think there's a system in New York that has 200 channels. Finding what you want to watch on that is pretty difficult. The people who are planning it are thinking of having 600 channels in the next generation system. There also are plans underway for a 1500 channel system.

That is pretty amazing if you think about it from the view of television. If you walk in a book store it's not quite so surprising. Book stores, in fact, offer thousands of different titles; thousands of different points of interest. I think that people want that. The only issue is going to be—how do you get that, how do you sort out what you want from that huge mess of things, and do it before the damn thing's over.

I am hopeful that software technology, combined with the right sort of hardware is going to be the answer, and that we're going to be able to evolve there from our current base of Windows computing.

Finally, if we look at an even broader scale, the real opportunity here is information appliances. Wherever there are people and there is information that they have to process, whether that's in their automobile, on an airplane, in their pocket of personal information and finances, or in the office—any form of human information needs appliances to manage it.

We've been familiar with a number of these—the telephone, the fax machine, the cellular telephone. Those have changed our lives; but within the next few years, we at Microsoft believe the pace of this is going to accelerate as these disparate areas merge. So that communications, computing and entertainment all wind up in one digital world. The key to that world, at least one key to that world, is having strong software standards and having sufficient virtualization and separation for application software that will be able to rapidly rev up the underlying technology base.

What I'm talking about here, fundamentally, is the notion of scalable computing. That a single standard, a single body of application software, a single body of end users, will stretch across a wider range than computing ever has. From machines that literally fit into your pocket or your pager, to machines that have hundreds or thousands of processors, dealing with airline reservations transactions and the larger scale computing problems. For all of these, I think that one of the key enablers is the system software and applications, which will allow that set of machines to give people utility.

Questions & Answers

Question: Would you compare Windows with the Macintosh.

Mr. Myhrvold: There are many ways to compare Windows with the Macintosh. From the perspective of this talk, I'd say that many of the fundamental directions that I have described, towards virtualization are ones which are inherent in any next generation software. So many of the things I have said would probably also hold for System 7. Apple hasn't announced multiprocessor plans; they haven't announced plans in an area similar to NT's, so I can't comment fully. Fundamentally, the notion of virtualizing the hardware certainly is present in the Macintosh.

Question: Do you see increasing use of the 486 to do traditionally hardware intensive applications like DSP done by the CPU?

Mr. Myhrvold: The answer is yes, but at what scale. I view this as an incredible opportunity for the ingenuity of software developers to come up with mass market, popular applications which are useful in point. Certainly, we've been looking at a variety of things along that line. Signal processing is one area. Unfortunately, floating point mathematics that is currently available in PCs isn't up to doing signal processing, and it's not clear that you won't do it with algorithms or something else. But, something in signal processing is a possibility. 3-D graphics and visualization is another possibility. This is one of the classic chicken and egg things. Because the floating point has been traditionally very expensive and hasn't been all that fast, people haven't actually used it.

Over the last couple of years, with the introduction of the 486, for example, it got faster and much more pervasive. It turns out it doesn't seem to have been enough faster that brand new very floating point intensive applications have come up. The primary reason is that the floating point is popular in the workstation world for technical and engineering applications. Of course, that will continue but it's not clear that those will be popular at Egghead, or the Nintendo world, or popular in the things that really generate volume.

So I have to say that yes, I think it will be used more. I'm personally betting that it will be used a great deal, but I can't really prove that today.

Question: How do you see protocol standards for networking evolving?

Mr. Myhrvold: There are really two issues with network protocols. For the existing jobs that the really standard protocols are used for, I don't think there's going to be an enormous amount of evolution. There won't be a lot of revolution—it will be business as usual. The interesting thing is when you come to really new kinds of networking. Wireless networking, for example; something that we call conversational networking where, as you bring machines into a room, you might set up what amounts to digital conversations, and you might walk out of those a few minutes later.

It's a very different model than traditional network, which assumes that more or less you have a fixed connection; the wire works, unless there are errors. In this new world, you have to rethink the protocol issues.

The same thing happens when you look at very high speed networking. These digital cable systems that have the hundreds or thousands of channels are typically going to bring in at least a gigabit, sometimes several gigabits for an average home. The protocols for those systems are certainly not well understood at present. People want to be able to tune into the middle of a show or in the middle of some piece of data and get into sync right away. That's not particularly easy to do. I think in those areas we'll find the traditional ways in which networking protocols have been developed. The committee standards have been around for several years. That same process probably isn't going to be the way these new standards are done because the technology underlying them is evolving at too rapid a pace.

Question: Why hasn't UNIX grown stronger or even replaced DOS?

Mr. Myhrvold: In terms of it being much better, you have to qualify that, certainly not from a volume perspective. The real issue is that people don't buy DOS to use DOS. It's not like people do that DIR command all day long and that's where they get their fun. The reason to buy DOS is to run something else. The fundamental reason DOS has held on as long as it has, is that it has the best application software base. Lotus 1-2-3 and Microsoft Word were the best applications you could buy. In fact, that trend has just continued.

There are funny economics involved here. If you write a piece of software for yourself, for every dollar that you spend, you get about a buck's worth of software if you do a good job. If you're in a mini-computer workstation sort of market, most of the companies there have somewhere between hundreds and a few thousand customers. More or less, their investment in the software is proportional to that. So if you spend a dollar on a piece of software from one of these companies, you get software that they probably spent between a hundred and a thousand dollars developing, per dollar. They can afford to because they have a much larger base.

You buy a piece of PC software, that ratio is between 50,000 to 1 and a million to 1. You can go and spend $100 and buy a piece of software that will cost the company $100 million to develop. That means it's chock-full of features. You might spend a lifetime finding them—but you don't care about that. If it has the stuff you want, you're happy. If I can put in the stuff that you and everybody else wants, it's successful. That's not just true of my company. If you look at Lotus or Borland, any of the major companies—this massive ratio—the software has been great.

That's not the only reason why Unix has caught on. There's a variety of industry and political factors. In terms of why people buy MS/DOS machines—it's the software. Same thing as driving Windows machines. We're selling over a million copies of Windows a month, right now. That's even before this Windows-For Workgroups was announced.
With that, it's not because Windows is so great intrinsically. You don't just sit there using Windows all day long, it's the applications that are on top of it—Excel, WordPerfect for Windows, and a variety of others.

Emerging Trends in the U.S. Telecommunications Market

Ken Landoline
Group Director, Telecommunications
Dataquest Incorporated

Mr. Grenier: Mr. Landoline is Group Director of Dataquest's Telecommunications group, and is responsible for managing all Dataquest research and consulting activities for the U.S. telecommunications markets. Before joining Dataquest, Mr. Landoline held management positions with Fujitsu America and AT&T, in marketing product planning and strategic product analysis for telecommunications equipment. Earlier, he worked in marketing at ITT Word Communications. He received a B.A. degree in economics from Rutgers College, New Brunswick, New Jersey, and an MBA degree in marketing from Seton Hall University. Ken has 22 years of experience in the telecommunications industry.

Mr. Landoline: When I was asked to give this talk by Gene Norrett a couple of weeks ago, he gave me three criteria to follow. Number one, I had to be done in 30 minutes, the second criterion was no numbers, and the third was no acronyms. I can do a lot in 30 minutes—I can even give a talk with no numbers—but I cannot give a telecommunications talk with no acronyms. So I am going to compromise. What I will do is at least explain my acronyms as I go through them. You will see some acronyms on the charts that we do not need to get into, but we can discuss those at the break. But I should give you a flavor of the acronyms to help understand the buzz words.

What I would like to do during the next 30 minutes is talk about the forces shaping the telecommunications industry. I cannot have a telecommunications talk without talking about mixed and multimedia—what it means to a telecommunications person, and what it means to a computer person.

I have to talk a bit about personal communications—obviously a high growth area for us—then we will talk about emerging network technologies that will enable some of the futuristic things we will discuss.

Finally, I did a little market research within my organization and asked the analysts that cover many facets of telecommunications, to pick out four or five companies in their area that they think are companies to watch—that are positioned properly for success through the year 2000. Some of these companies you're familiar with, and some of them are brand new start ups that you may not be familiar with.

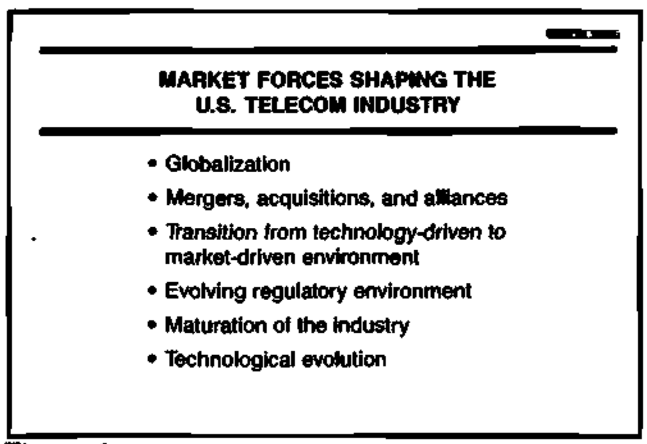

Figure 1

The U.S. communications market will grow from $184 billion in 1992 to approximately $229 billion in 1996. Services were the non-customer premise equipment piece of the market—about $160 billion in 1992—and equipment is about

$24 billion. I do not want to make equipment sound like it is a small piece—$24 billion is a lot of money.

The overall story is that this is a huge market. Even though the growth rates are somewhere in the 5 to 7% range, the market is still huge. So even a 5, 6 or 7% growth rate (which may not sound large by computer or other high technology standards), is certainly not a market to overlook.

As you know we are in a presidential election year. It has been a bad couple of years for the telecommunications industry in general. There are a lot of slow or negative growth areas, especially on the customer premise equipment side. Telecommunications spending has been very slow—we do not know what is going to happen. The recovery has been slow—what little recovery we had seems to be slipping back. Long term interest rates remain high, and people are not buying capital equipment even though shorter term interest rates have dropped significantly. New small business formations are dismally low compared to former years. Even through all this, our Dun & Bradstreet parent tells us we can expect somewhat of an economic recovery in late 1993, or mid-1993. I do not know if I agree with that wholeheartedly—what happens in the election is critical.

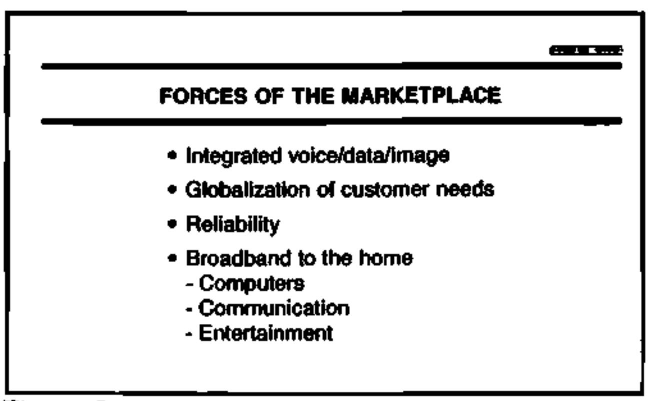

Figure 2

There are a number of forces shaping the telecommunications industry. First, is globalization. I don't think I need to go into a lot of detail, but certainly end users want global vendors and international products. Mergers and acquisitions and alliances have become commonplace in the telecommunications industry, just as they have in the computer industries.

There has been a transition over the years from a technology driven market to a market driven environment. There is an evolving regulatory environment, and a maturation of the industry in general. There are pockets of growth, however, and a technological evolution occurring in some product areas and technologies such as wireless telephony, personal communications, ISDN, broadband multimedia, etc.

There are many industry developments that are changing telecommunications. The direction I see for datacommunications—we are doing today what we have done for voice communications on the public network over the past 30 or 40 years. We have made it very usable and accessible.

First of all, digital communication is becoming more commonplace. Once digitized, the system and the network can certainly handle things like video, audio, data, etc. It does not even need to know the form of that information. Bandwidth has increased significantly, and will increase more into the future with technologies like fiberoptics. ISDN is providing international digital standards more slowly in the U.S. than other parts of the world, but certainly it will be here. Improved local area networks in the datacommunications arena are commonplace. Switch Multimegabit Data Services, (SMDS), a public tariff service to handle high speed multimegabit transmission will probably be here in 1994. The installed base of PC's, scanners, optical drives, high resolution monitors, and input/output devices are commonplace, and icon-based software provides a user-friendly interface.

The forces of the marketplace are molding new products—I am leading up to a pitch on multimedia. Integrated voice data image is becoming the standard mode for business applications, and will be even more so in the future. Movement of audio, video and data worldwide will be required. Reliability is ever more important. The computer and communications network products are no longer auxiliary apparatus—they are the factories and the highways of the information age. Broadband into the home will drive the completion of the infrastructure with fiber and broadband transmission.

As Ian Ross, the former president of Bell Labs, said last year at Telecom '91 "the home is the place where three major industries will meet—computers communications and entertainment"—I believe that wholeheartedly. Already PCs, faxes, and cable TV have joined us in the home with more to come.

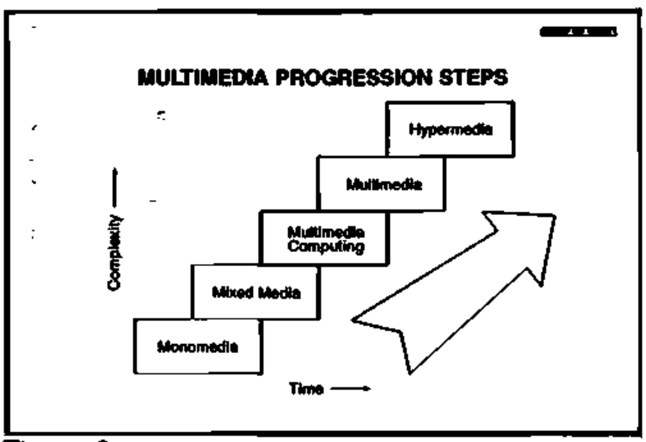

Figure 3

This is how I look at multimedia—the transition from what I call mono-media. You have the basics, such as plain old telephone service where a voice is transmitted, up through Hypermedia. Hypermedia—I was not really sure what that meant when I entered the floor of the show—was a word that was both used and over used. I know it had something to do with future applications.

Right now, I see us in the middle of this trend. we have gone through the mono-media phase. By mixed media, I mean the mixing of two mediums. In this example, I show facsimile and voice over the public network. In this example, the source is Kerygma Systems which implemented a central office-based product that allows calls to be automatically shifted, depending on the busy signal on the phone you're calling. Caller #1 calls gets through to a fax machine that is not busy. Caller #2 tries to send a fax, gets a busy signal, and his fax still goes to the central office and is stored for later. Caller #3 calls in and leaves a voice message in that same system—it is mixed media—it has facsimile and voice. These are the early stages of what is leading to multimedia.

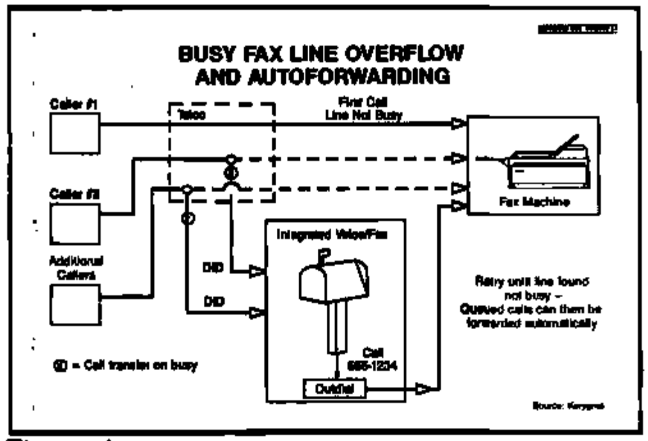

Figure 4

Multimedia computing is something I will define a little further. True multimedia, as I see it, is the merger of audio, video and data systems interactively exchanging information regardless of the location, the equipment or the databases.

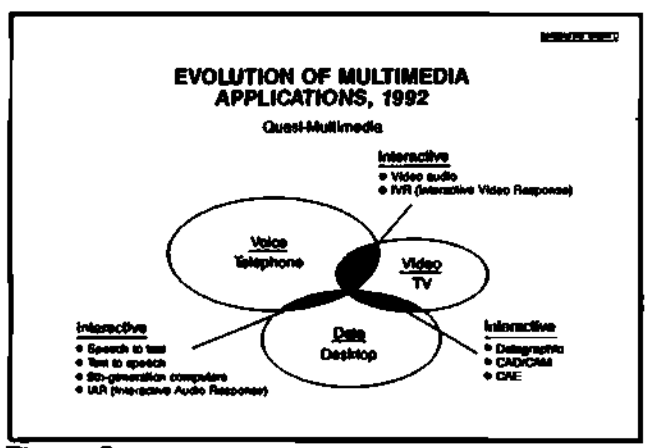

Figure 5

This is where I see multimedia in 1992. Basically, it is a cross-over of a couple of items—either voice or video, video and data,

data and voice, and some doing all three at one time. It is not really what we consider multimedia.

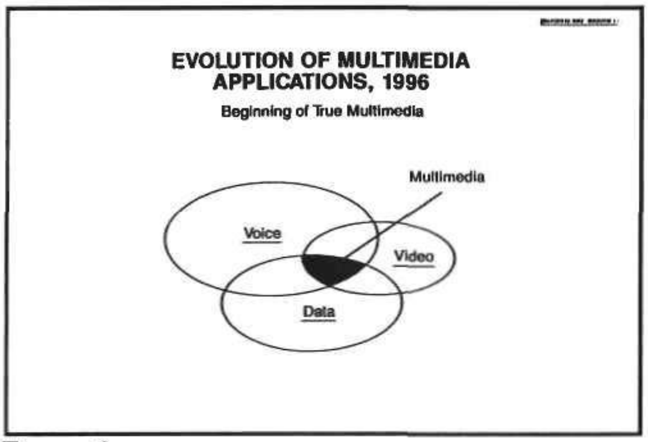

Figure 6

This shows the evolution of multimedia by 1996. I see this center area becoming larger — most industry followers agree that multimedia begins with the merger of voice, video and data.

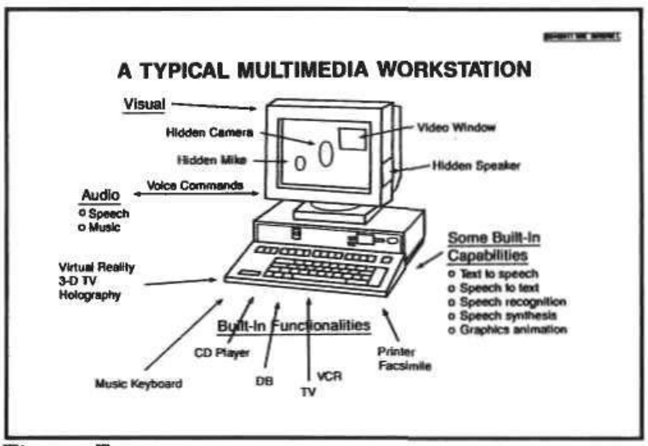

Figure 7

We have already seen computers that can record voice and bring it back on demand. This is what I call computer multimedia, and I think that is where we are today in the multimedia business.

True multimedia occurs when all three fundamental media can interactively exchange information regardless of the location of the databases and the equipment being used. It speaks to days in the future when bandwidth and storage will be perceived to be nearly free. Think about it as if making a local phone call, today. Even though local phone calls are not free—the perception is that they are. My daughter will stay on the phone for 5 hours with one of her girlfriends across town, and luckily it does not cost me any money. That is when multimedia will take off—when the infrastructure can handle calls when your database is in Europe, you are working in San Jose, California, while talking to someone else in Japan. When it all happens seamlessly—that is when true multimedia comes into play.

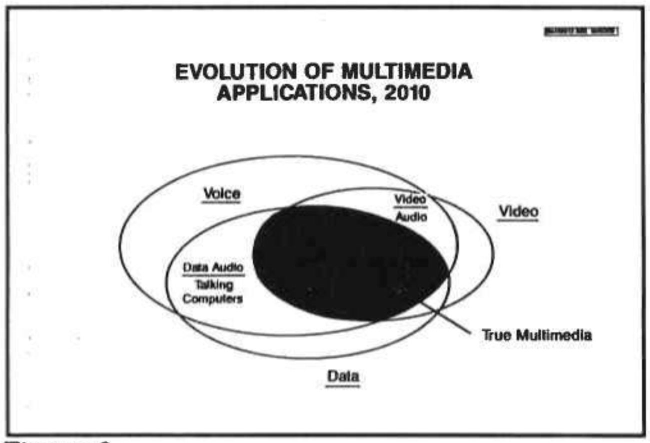

Figure 8

ADVANTAGES OF MIXED/MULTIMEDIA

- Economics
  - One system
  - Less user training and maintenance
- Flexibility
  - Switch between applications seamlessly
  - Add applications as modules
- Centralized network management

Figure 9

Here are some economic advantages of mixed and multimedia. When you have one system doing everything it is a bit more economical and requires less user training and maintenance. It is much more flexible. You can switch between an application seamlessly and add applications as modules. You have a centralized network management system that can manage the voice, the video, and the data.

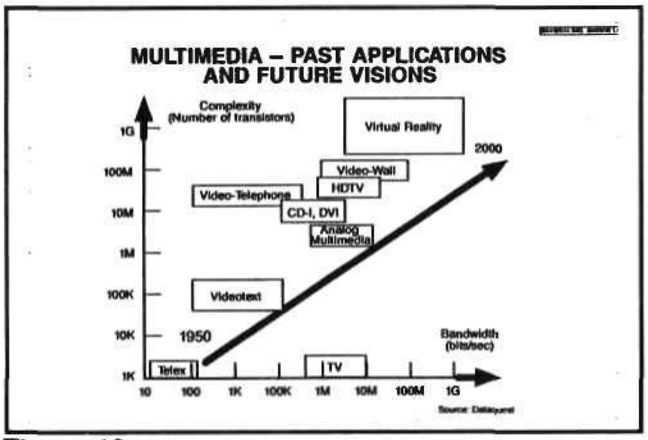

Figure 10

ago. 1996 revenues will be about $12.5 billion for all categories of multimedia.

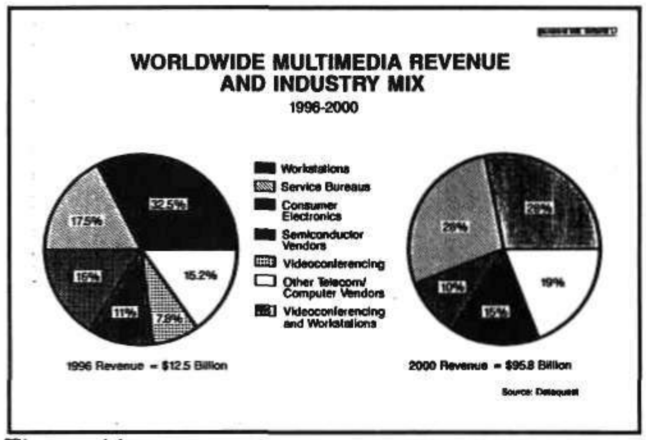

Figure 11

I borrowed this chart from our European office. It does a nice job of showing perspective, talking about multimedia, and indicating a trend comparing the complexity of a system—going up the vertical axis—and the bandwidth (bits per second) on the horizontal axis. This shows where we have gone from the telex days, up through virtual reality (one of those hypermedia things we talked about earlier).

What is the high technology industry structure? The thoughts on the next couple of slides are futuristic regarding what is going to happen to the high technology industry because of multimedia. I see six major players in this industry—(1) video conferencing vendors, (2) semiconductor vendors, (3) workstation, software protocol and value-added resellers group, (4) service bureaus, (5) consumer electronics vendors, and other telecommunications and (6) computer vendors with technologies such as CPE equipment, PBX telephone systems, etc.

Today, each of these vendors are developing their own standards. Although we are getting a little better coming together on some standards—we are in an interim period before our final structure is developed.

This shows Dataquest's estimates of worldwide multimedia revenues done six or eight months ago. 1996 revenues will be about $12.5 billion for all categories of multimedia.

All of this is not necessarily brand new revenue. Some comes from other areas. Obviously, video conferencing today may be moving to multimedia in the future—and in the year 2000 roughly growing to almost $100 billion worldwide.

One other thing you see is that we project the six wedges of the pie on the left will turn into the five wedges of the pie on the right. What I am predicting is an example of some consolidations and mergers coming together industry-wide—not just on a company basis. We are predicting that multimedia will lead to a restructure of the industry.

First, I show an example of workstation vendors merging with video conferencing vendors. I think that will be a reality in the next five or six years—two companies overlapping in certain areas.

Next, there will probably be some combinations with other telecommunications equipment manufacturers. Semiconductor manufacturers initially building subsystems, might move to building systems in the future. In addition, service bureaus and value-added resellers are being positioned for success.

What is Dataquest's perspective on multimedia? Certainly it has begun—although true multimedia is several years away. The effect on the industry will be evolutionary. *De facto* standards will evolve within industry segments. Technology is in transition—some standalone equipment markets will disappear. I think that is true because of the complexity of these systems. Much of this information will be transmitted so the service providers will make revenue on the transmission, and value-added resellers will be needed to move the data, mix and match it, put it together in different ways, and help people set up systems.

FUNCTIONAL COMPARISON OF PERSONAL COMMUNICATIONS DEVICES

	Telepoint	Paging	Cellular	PCN
Function	Originate	Receive	Originate/receive	Originate/receive
Communications Range	200m	Metro area	> 2 miles	200m
Mobility	Limited; no handoff	High	Automobile	Pedestrian
Terminal Cost	Low ($100)	Low ($100)	High ([illegible])	Low ($100)
Terminal Size	Small	Small	Medium/large	Small
Base Station Cost	Low	Medium	Very high	Low

Figure 12

Personal Communications is something we have been studying quite a bit at Dataquest. We did a fairly extensive wireless and personal communications study about a year ago, and we actually delivered it in May of this year. The theory of personal communications is the ability to communicate with anyone, anywhere at any time. That is the ultimate goal.

This is a scale that shows the personal communication service hierarchy going from the most simplistic of cordless telephony that you might have in your house, moving to paging and telepoint—a system that has caught on in Europe, prior to its introduction here. It is a replacement for the pay phone system—for making (but not receiving) calls. Enhanced telepoint, the two-way PCN (personal communications network) is a more advanced version of the poor man's cellular system. Then cellular telephony, both analog and digital, and moving up to satellite telephony (probably the most expensive and probably used most often for the hinterland areas).

We did a study, six or eight months ago, on what people were willing to spend for a telephone they could carry around with them to receive and send their phone messages on. We had three different bases of clients we talked to—business users, cellular users, and residential clients. As you can see, the willingness to pay is set by the expectations or experience of cellular phone users. The cellular user is willing to pay about $330 for such a telephone. Next, is the business user—on average, about $231—and the consumer about $218. Intuitively, these look like very realistic goals. Most often we hear from consumers, and what they want is a $100 telephone, with a 24-hour battery supply that weighs about 6 ounces.

In the business area, but still related to personal communications—I am talking about bringing a telephone from your office, using the same telephone at home, and then going on your boat for a weekend—again, with the same telephone. The system, the infrastructure, takes care of how you get billed for those different calls. When you're in your office your business calls will be charged through your PBX to your company—when you are on your boat it will be a cellular call—at home, it is a regular local call.

I think what is going to happen on the wireless PBX area, or CPE equipment, will be an adjunct kind of service. I do not see people pulling out their business systems and putting in wireless systems. Number one, it is too expensive, and really most people in an office do not need a wireless environment. Dataquest's projection shows the wireless business market in the office to be an adjunct kind of market. People will buy adjunct boxes to put next to their PBX, to make a certain portion of their business phones cordless—for those people that need it—such an office manager that walks around, a building maintenance man, or the president who wants to be wireless wherever he goes in the building.

We forecast that by 1996, about 6% of the actual PBX lines shipped will be of the wireless variety.

In personal communications, the market is changing rapidly. The cellular and paging systems are experiencing rapid market growth. They have enhanced the functionality and technological developments. There are merging opportunities that will create a new industry of personal communications in the U.S., and on a worldwide basis. Some interim markets will develop and then decline—telepoint will be one of those. It will be a cheap one-way kind of transmission, but it will certainly be superseded by Personal Communications Network (PCN).

PCN end service will not begin until the mid-1990's. The cellular market will continue to be strong throughout the 1990's, but at a higher price. The wireless PBX key market will be an adjunct market and the satellite base service will expand personal communication networks to less populated areas and demand premium prices.

One other interesting area is the switch computer integration application that we refer to as SCI. That is hooking up a telephone system with a computer—you may have, for example, a system at your local bank where you can call in, punch in some digits, recognize your account number and pull information off your computer database and either feed it through real time, or feed it to an agent you are dealing with. It is a rapidly growing market and we see a lot of growth in that area coming very shortly.

These are some of the emerging network technologies. Fast packet is a term that describes various emerging packet technologies such as some of the following—frame relay, cell relay, asynchronous transfer mode, and broadband ISDN. All technologies, or systems coming on-board, turn the private network into a public network—in some cases—so that data and voice can be transmitted on a broadband basis at very high speeds.

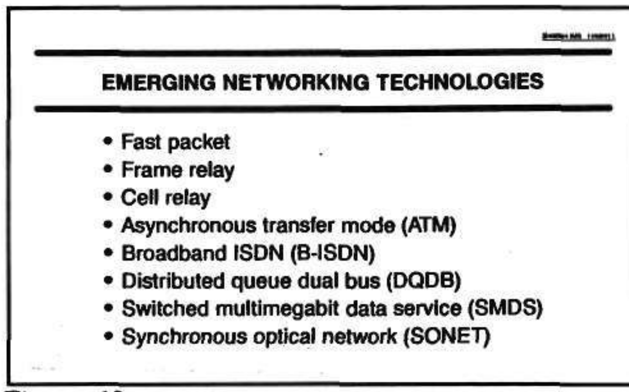

Figure 13

There are other technologies I have not mentioned—distributed queue, dual bus (DQDB) an emerging trend based on cells for metropolitan network. Also local area networks in a building or environment for passing information around from computer to computer, metropolitan area networks, and wide-area networks—which ultimately would be a global network.

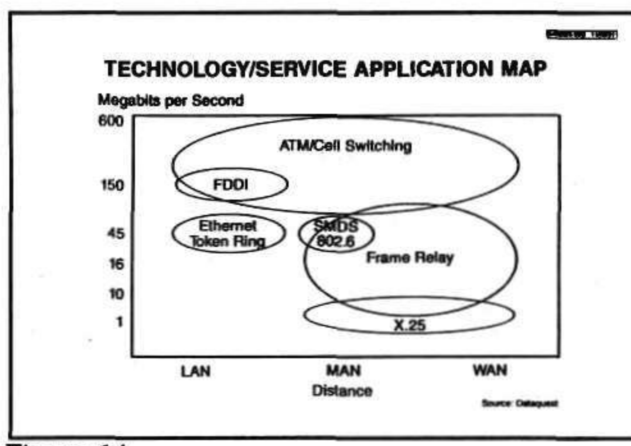

Figure 14

To put these in to perspective, let's look at how they fit together. We started out with X.25 on the MAN and WAN areas—to be replaced by frame relay at higher speeds—Ethernet Token Ring at the LAN area at 45 megabit speeds—FDDI, going at 100 to 150 megabits at the local area network and ultimately being replaced by ATM (asynchronous transfer mode, a cell switching environment) that will serve all the LAN, MAN and WAN areas—and ultimately tie locations together into a truly global network.

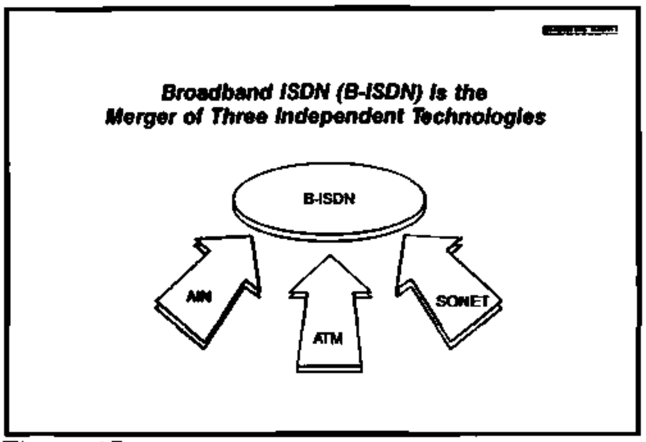

Figure 15

Broadband ISDN is not really a technology. It is the merger of three independent technologies—the advanced intelligent network, being implemented by Bellcore, the asynchronous transfer mode technology, and SONET, which is the optic fiber network standard being put in around the world.

I pulled some numbers from an FCC filing showing numbers that predict that by 1994, although 25% of those central offices will be ISDN capable in this country, only about 2% of the connections, or access lines, will really be ISDN. So even though the office is capable, only a small portion of those central offices will have ISDN. ISDN has been slower than we had hoped—it is certainly not ubiquitous throughout the country. We think that its success in Europe and the Far East ultimately will drive the United States to join in the ISDN game and truly have this international network.

Dataquest sees the initial commercialization of a number of technologies as we forecast various items—FDDI already out in 1990 timeframe, SONET coming in 1991-1992, SMDS cell relay in the '95 time frame, and ATM commercially available in '96-'97. Broadband ISDN available in '98-'99, general multimedia—in the telecommunications sense—available in '99-2000. Then later on—technologies like phototonic switching with tremendous bandwidth opportunities.

Always important to our market are the things that are hardest to predict, and one of those is the regulatory environment. We think, ultimately, that somewhere by the end of this decade, the regional bell operating companies will be totally deregulated. We see that in the 1998-99 timeframe. That will mean many things. It will mean mergers with some kind of cable TV activities—lifting of the long-distance ban, both internationally and domestically. Long distance companies getting into local will change the complexion of the communications market place—and probably will be better in the long run for the consumer.

The last area is the companies that my analysts have identified as companies to watch—voice, data networking and public and multimedia companies. Octel, a neighbor of ours in Milpitas, made their name in voice messaging. We think they are a company to watch because they have gotten into multiple application platforms with a product called PowerCall which has voice messaging, IVR, fax, audiotext and E-Mail applications available on one equipment platform.

Centigram is a very early innovator in applications of text and speech—and Edify, which was previously called Reach, consists of some ex-ROLM people with new ideas in call center technologies. Active Voice and Applied Voice Technology are two voice messaging IVR companies. Active Voice is going after the simpler low end client; where Applied Voice is going after the more complex lower end systems. ROLM, who is a leader (and has been a leader in switch computer-interface applications) is a company to watch, and Aristicom—if and when ISDN takes off—is in Alameda doing some things with IBM and AT&T on ISDN software, BRI and PRI.

A company to watch in multimedia and public networking is Compression Labs, for its dominant position in video conferencing. Now that there is a standard in video conferencing, we think it is in the era that facsimile was when they went from Group 2 to Group 3. Group 3 allowed unlike machines to talk to one another. Now we are getting to that point with video conferencing equipment, and we expect that market to grow at the same percentage growth rate that the fax did. Watch Tandem because they are a computer vendor delivering computers into the public network and doing very well there—Sun, Apple and Hewlett-Packard because of their obvious entrees into multimedia. Also, telephone companies like Centex who is a value-added reseller for telecommunications services and has showed some success in the past, and LSI Logic for semiconductor content of multimedia applications.

Finally, data networking companies to watch. Cisco, the market leader in routers. I'm sure you are familiar with router technology, it has a solid position in the high and low end. Cisco has some good strategic alliances. Network Equipment Technology, active in local area network interconnection and the wide area network area, has strategical alliances with IBM.

Tandem, again, and their Ungerman-Bass division, is in a good position on the high end. Remedy, in Sunnyvale, a small start-up network management support company for Unix and PC-LANs—Ascend, in Oakland, a software house working with bandwidth on demand for front processor applications—Netronics, who is the number two supplier of Token Ring transport and bridging behind IBM—Synoptics, who is a leader in wiring centers and very aggressive price leaders—and, lastly, Veriphone, a fairly new start up credit card verification company.

In summary, the economy is uncertain and will drive, to some extent, what happens in the telecommunications industry—but we do see slow, sustained growth. There are pockets of opportunity in many areas in multimedia and personal communications. We see increased globalization, new freedom for the regional Bell operating companies, and lots of niche growth areas. Mergers and alliances will continue—many companies have seen this as a way to success.

I was recently at a luncheon with a company called EO who is coming out with something called a personal communicator—their new paradigm in personal communications. The interesting thing about this company is not so much the product, but who's backing it. They're backed financially by some venture capitalist at AT&T, by Marubeni and by Matsushita—some very large forces in the market place. I think we should watch that company go forward.

Certainly, it will be a multi-vendor environment. No one company is going to provide all these services in multimedia to the end user. It will be a very diverse field with many opportunities for new vendors.

Questions & Answers:

Question: How will synchronous and asynchronous applications come together?

Mr. Landoline: There are asynchronous and synchronous opportunities. I have a general philosophy about telecommunications that touches this area, as well as many others. Most technologies are never totally going to go away. For example, we will have analog for a long time in some areas—we will have digital—and we will have a mixture of the two. We will have private networks existing along side with public applications—both capable of doing the same job, but for different reasons. Just like today, over the past 10 years we have had customer premise equipment solutions for problems—and we have central office solutions for telecommunications situations.

To answer your question, I really do not know, long term, how synchronous and asynchronous technology will come together—I am not a technologist in that sense. I can get you in touch with some people in my organization that can better answer that question. I think for the short term—the rest of this decade—we are going to have systems working in parallel—working side by side. For a while, we are going to have people manufacturing cellular handsets that can either be analog or digital. There will be a transition period until we are all digital in the cellular area.

Question: Where do we put Microsoft on the list of the six groupings of multimedia participants?

Mr. Landoline: I think I would have them in the workstation, software protocol, value-added reseller area. I do not have Microsoft as an item that I have plugged in there, but if I was pressed to put one in there, that is where it would go.

Applications As a Process Driver

Shigeki Matsue

Vice President, Semiconductor Group

NEC Corporation

Mr. Grenier: Mr. Matsue is Vice President of NEC. He joined NEC in 1964 and has led NEC semiconductor memory sales from 0 to nearly $1 billion. The last two positions Mr. Matsue has been responsible for are general manager of the memory products division, and general manager of the semiconductor applications division. Mr. Matsue received his MS degree in electronics engineering from Keio University. He has 5 boys, the oldest in the university and the youngest in Kindergarten. He says he still plans to have a daughter.

Mr. Matsue: I am very glad to have a chance to talk to all of you. Yesterday morning Gene Norrett told us that the Japanese semiconductor market declined 10% this year. And also, Mr. Jim Norling told us that the semiconductor share was increased this year. The market declined and foreigners' share increased. What a miserable situation for Japanese semiconductors.

At first we would like to understand the environment in the 1990s. Micro economics–The age of seeking new stability. The electronic equipment market, an age of selective consumption.

Age of seeking new stability

Up to the 1990s there was high growth. But in the 1990s, there was an establishment of new order in world economics and frequent occurrences of unexpected events. We did not expect the fall of the Soviet Union; we did not expect the Japanese decline of this year. We cannot predict the next president. I only understand that the rate of economic growth has slowed.

The general situation of the world real GNP trend–average annual growth was, Asia was high and Japan gradually went into a decline.

The electronic equipment market up to 1980. New products attracted consumers. Timely introduction to the market, and creation of fresh markets.

The semiconductor industry in the 1980s, in the days of VLSI. We experienced large ups and downs. The presence of specific products such as process drivers, which stimulated the semiconductor business, the VCR and PC, for example. There was an advance in internationalization of the industry.

The history of the Japanese GNP shows the growth of electronic equipment in Japan. In the last 30 or 35 years, the Japanese GNP became 30 times bigger. In the last 20 years, electronics equipment increased in the Japanese market. The slope shows how attractive the products; color TV increased from 0 to 100% share in 10 years. Radio cassettes take a long time to increase, but the VCR market is very sharp.

But before color TV, there was black and white TV in Japan. Japan is quite a unique society. More than 90% feel that I am middle class. But at that stage, there were two types of people–people who had TV, and who didn't. There was no question whether to buy. The only one problem was could we buy or not?

The electronic equipment market in the 1990s had a negative effect from high growth in the 1980s-saturated customer satisfaction from "over buying." No outstanding new products which are attractive to customers. Excess functions were difficult to use. Price competition let customers wait and see.

The semiconductor industry in the 1990s was the age of selective consumption–the days of ULSI, expansion of market and linkage with micro-economic growth. Moderate silicon cycle, further progress in high integration and customization. Huge resources that restrict business growth.

Promotion of international corporations—This chart shows the perspective for the 1990s semiconductor market. This chart is used for the student. The real meaning shows that we can know what already occurred, but we cannot know the future.

In terms of trends in world economic equipment production—we experienced several booms and peaks. First was PCs and also VCRs. Big demand. Second, the office automation boom, 32-bit PC, portable PC, and facsimile.

This year, we are in a very bad situation. The newspaper asked me "why is the Japanese semiconductor market so bad, this year." My answer is "when the electronic equipment market is bad, ours cannot be good." They also asked me what, when and how can we improve the situation? The answer is; the only way to improve the semiconductor market in Japan is to improve the market of equipment. This is the only way to solve our situation.

Let me reconsider the history of NEC Semiconductor. Fortunately, we have grown very rapidly. But in this stage, color TV and calculator equipment is supported a lot. In this stage, more than 10 calculator manufacturers existed. And they bought more than they needed. In this stage, the VCR, is a very big market and, also, the memory market increased very rapidly. In this stage, suddenly the alpha particle story occurred. And fortunately, our die was so big and no influence from Alpha Particle. And NEC became the number one supplier for memory. This high growth was a combination of PCs and VCRs. To support future growth, the only way is to find the new equipment and support.

To summarize this growth; the contribution to the market growth. There are three major reasons. Category one is the realization of higher performance and advanced functions through development of new technologies, like advanced DRAM and high speed logic. The second; cooperation of the system designers, calculator chip, video RAM, FDD devices, hard disk drives, and chips for games. The third is the expansion of existing markets through cost reduction devices for the TV, VCR, and PC. High technology, system engineering and value engineering. These are the major three items that grow our business.

System manufacturers want system side–better standing against competitors, differentiation, and cost reduction. This is our job, our mission is to support these requests; state-of-the-art technology, short development TAT, and local manufacturers. We really want to support system manufacturers.

One example is multimedia.

Today, we need more than 100 pieces of LSI to support it. But even if the performance becomes 10 times faster, we can decrease to 30 pieces. And soon we can decrease less than 10. One example is a cellular phone, in the past, it was 400 cubic centimeters, but now, the newest one is 150 cubic centimeters. But we intend to be as large as this.

Famous high-definition TV; in the past, it was a very huge one. But this year, in Japan, the newest system is $10,000 in the market. But we expect in the coming two years, it will become less than $5000.

The basic philosophy to support this high integration, we call system-on-silicon. We intend to realize various kinds of function in one chip. This is one example. This is a famous 64-

megabit DRAM. Even in DRAM we are now going to diversify application-specific design. For the mainframe, we continue to develop a standard one. But for graphic, TV, we are going to support many kinds of variations, and also, workstations, PCs, notebook PCs, and even the silicon file. Now, many people are talking about Flash memory. I think we can realize it by 1996.

The relationship between system and device–In the past we get an order from the equipment manufacturer after they finished the design. But now, we need cooperative development from the beginning of system design. So a semiconductor company is now becoming a system development partner.

Key technologies of the ASIC system LSI–I think one is the process: high density low voltage; another one is package; and the third one is design environment. Of course, this is a very popular trend. We are now using a .6 micron, but soon we can realize .4, .5, even .3 micron is on the schedule.

Concerning the support of the die package, it is now 250 to 300 pins. But next year, we will realize 500 pins. Even 1000 pins already in the plan. The third is what we call "open CAD." Because so many CAD vendors exist, and each customer uses different kinds of systems, so we cannot force our original system. We are going to adapt to many kinds of CAD system.

I talk a lot, but basically, I'm very optimistic because the general trend of electronics market is bright. The computer market, telecommunication market, consumer market, and automotive market–all these markets are expected to grow.

When you look at the estimated worldwide semiconductor demand by application, I hesitate to violate Dataquest–but the biggest market we expect is the PC. Of course the growth rate will decrease, but still the number one is the PC and communication market.

But our home market, Japan, is a little different. Last year and this year, in Japan, the PC market was minus growth. But we expect it to recover.

One of the unique situations in Japan is games. Even today, games are a very big market. Not only the CPU for games, but cassettes are a huge market. Last year, 150 million cassettes were produced. Each cassette selling price is $20 or $100. So even by the cassette market, it is almost more than $1- or $2 billion. Our newest game cassettes include 2 million byte memory a decompression circuit for graphics, and graphic accelerator in one cassette, not in a CPU.

The VCR market is also a very big market in Japan, including the camcorder. It's about $3 billion. One of the reason why it's so bad this year–they declined 30%–that means almost 800 million markets disappeared this year. But gradually, electronic car components, color TVs, and these markets are going to recover and increase.

This is another aspect, especially in the Asian market. This slope shows the history of the Japanese GNP–and we added the U.S. and Japan, Europe. This is Singapore and Hong Kong. This is Korea and Taiwan. As I have told you, there is some relationship between this GNP and electronic equipment which we buy. In these areas, already they can buy any electronic equipment–VCR, CD or cellular. In this area they just started to buy VCRs. In this area, about 70 million people exist. And in this area, about 300 million people exist. They just started to buy TVs, VCRs or something. I can't say when, but more than 1 billion people are waiting to buy telephones and color TVs. This is very important. When we talk about these areas, we say "high technology." But in these areas, still popular equipment has a huge market.

Market expansion–I expect in two areas. One is the cultivation of new markets–of course, supported by new technologies. We do the best in this market. But also, there is another market. Expansion of the market of existing equipment, cooperation with systems designers, cost reduction and improvement. More than 1 billion people are waiting for the telephone and color TV.

Automotive Electronics: Achievement of the Next Frontiers

Ralph Wilhelm
Director, Advanced Development Systems Integration
Delco Electronics Corporation

Mr. Grenier: Our next speaker is Dr. Wilhelm, the director of advanced development and systems integration at Delco Electronics Corporation, a subsidiary of General Motors. He is responsible for developing advanced electronic products, processes and systems that will be in production for the next 4 to 10 years. Dr. Wilhelm joined General Motors in 1971 in the research laboratory.

Mr. Wilhelm: Your choice of a conference theme, "Fueling the Engines for Growth," seems hand-picked for the automotive electronics industry. The automotive electronics market has doubled in the last decade. It will only take half as long to double again.

Our engines for growth are turbo charged, and the fuel propelling the automotive electronics industry headlong into the future is the work, the research, the development and the unflagging support of those of you in the semiconductor business. That's why I'm so glad to be here today. Your efforts are vital to help the automobile reach its ultimate form. Our engines are revved. We're ready to go. So climb aboard for the next few minutes, and ride along as we explore the future frontiers of the automotive electronics industry.

Mapping our trip along the automotive frontier won't be easy. The rapid and often cataclysmic changes taking place in the world today dramatically illustrates man's inability to accurately chart the future. Who among us could have predicted the demise of the Soviet Union or the reunification of Germany? The best efforts of our most learned consistently fall short in the area prognostication.

Despite this difficulty, we in the electronics business are not only called upon the predict the future, but to build upon it. As inexact a science as forecasting is, we nonetheless find it an integral part of our business.

This accelerating rate of change is producing new frontiers of technology that greatly affect our business. Tomorrow's winners will be those who can best anticipate, explore, and conquer these frontiers.

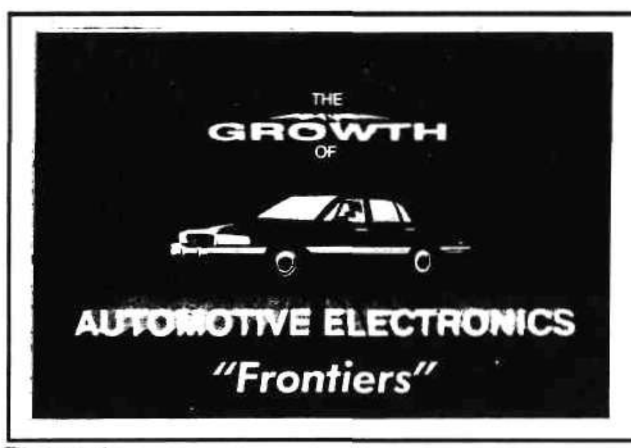

Figure 1

But, before we explore the future of automotive electronics, we need to first explore the past. So, if you don't mind, I'm going to shift the car into reverse and back up all the way to the 1970's to gain a bit of perspective on the scope and magnitude of change, our industry has been through.

The frontiers of the 70s grew out of customer demands for better radio receivers and demands for warranty reductions in automotive components. Engineers turned to electronics to provide the solutions. And the solutions were good ones–radios without mechanical tuners, ignition systems without quick wearing distributor points, and vibrating voltage regulators.

Figure 2

The solutions also enhanced performance. By achieving precise timing and long burn time, electronic ignition enabled automotive companies to meet the first round the U.S's clean air requirements.

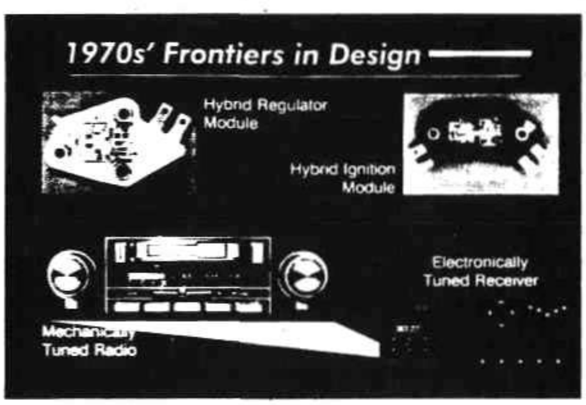

Figure 3

The solutions also enhanced manufacturing techniques. The 1970s produced hybrid electronic modules, which were built to withstand the harsh environment of the engine compartment, an environment with extreme heat ranges, constant vibration, and disrupting electrical noise. Hybrids which can operate 125°C, combined I/C and ceramic substrate technology in our industry.

The frontiers of the '70s appear tame by today's standards, but for those pioneers who contributed to the success of these ventures, it was no Sunday cruise through the park.

The electronic radio and ignition system helped shift the automotive electronics vehicle out of park and into drive. And it didn't take long for it to get up to cruising speed. The developments of the 1970s gave us the momentum that resulted in the tremendous automotive electronics explosion of the 1980s. The average electronic content per vehicle tripled in the United States during this period. This explosion was led by electronic engine controls for fuel, spark, air and many other engine functions. The impetus for these developments was the original Clean Air Act requiring tight emissions and continuous improvement in the miles per gallon rating by the Corporate Average Fuel Economy, or CAFE rating.

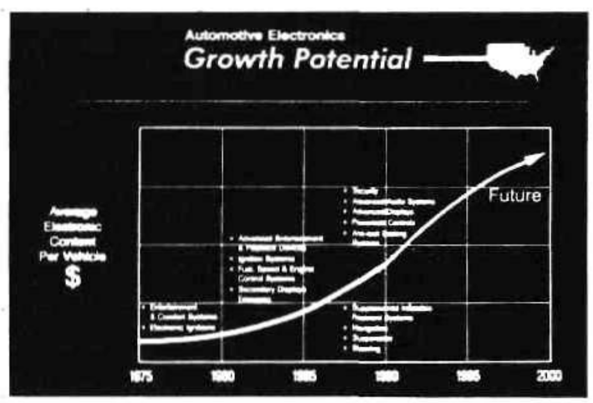

Figure 4

These electronic engine control modules (ECMs) rapidly expanded the use of microcomputers in cars. In the 1980s programmable memories were introduced in the engine controls during this period, as were high density circuit boards.

Every automotive system became the target of electrical engineers. So much so, that controlling runaway expansion on automotive electronics became a major issue. Electronic system functional up-integration offered a way to reduce product cost and improve reliability.

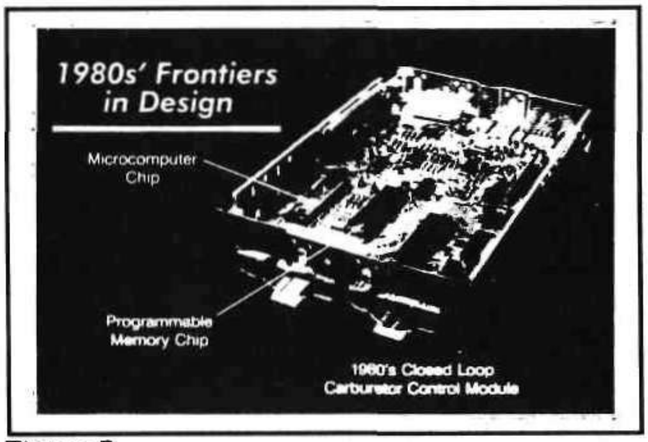

Figure 5

Up-integration was made possible by manufacturing improvements and printed circuit board assemblies in smaller dimensions in integrated circuits.

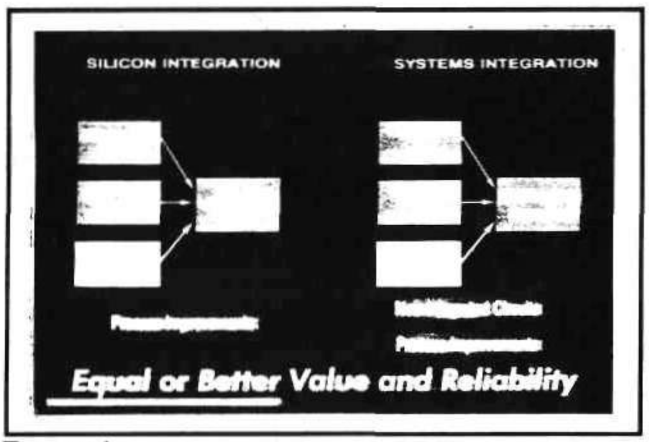

Figure 6

Its affect on automotive electronics has been impressive. Today, up-integration is a rapid technology growth phenomenon. And we continue to look for new and innovative ways to combine multiple components into a single unit while achieving exponential gains in cost and reliability.

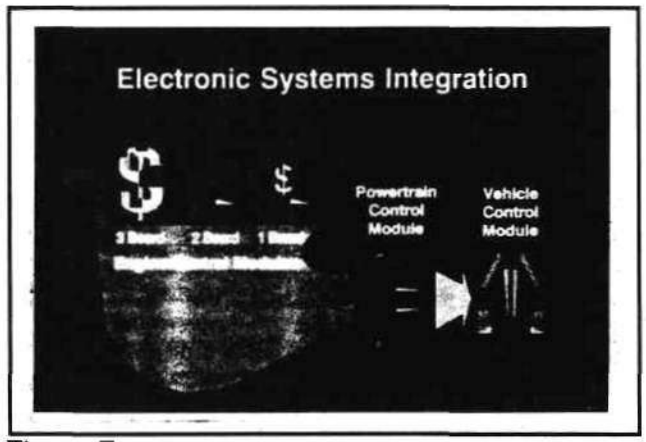

Figure 7

In one example, we've combined transmission controls and engine controls into a single Powertrain Control Module, which in turn will someday be replaced by a Vehicle Control Module that integrates even more functions.

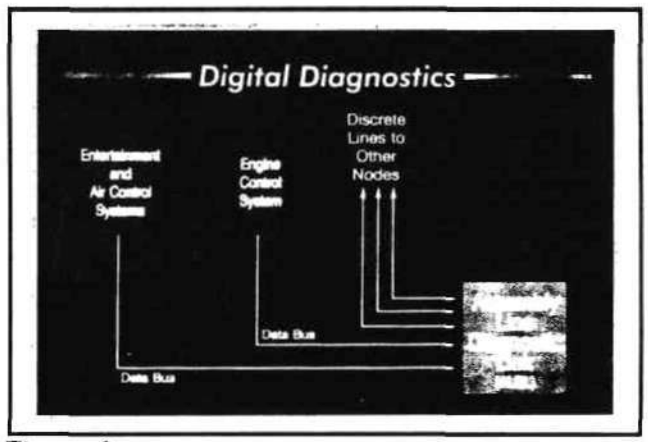

Figure 8

Another major trend in electronics systems integration occurred during this time period—digital diagnostics. Its importance continues to grow.

Automotive electronics frontiers in the entertainment area also were traversed during this important era. Typified by such developments as the Delco/Bose audio system, this frontier grew out of the consumer's desire to duplicate or, exceed the quality of their home entertainment systems in their vehicles.

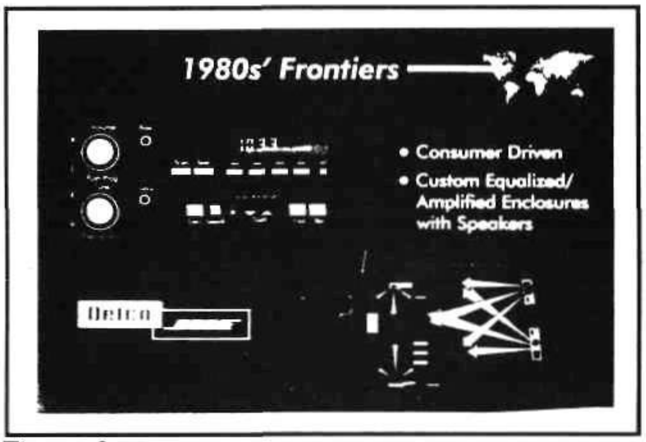

Figure 9

Today, many automotive audio systems include carefully tailored amplified audio enclosures customized to match the acoustical characteristics of the vehicle interior, characteristics such as driver placement, seat shape, or even the fabric used on the seats.

The application of electronics in vehicle safety saw its beginnings during the 1980s. Key developments were steering wheel controls and head-up displays. Along with the emerging airbag and anti-lock brake technology, these products became the forerunners of our current strong and sharp focus on safety.

Placing controls for radios and airflow systems in the steering wheel required the use of data buses, a forerunner in the development of multiplex vehicle control.

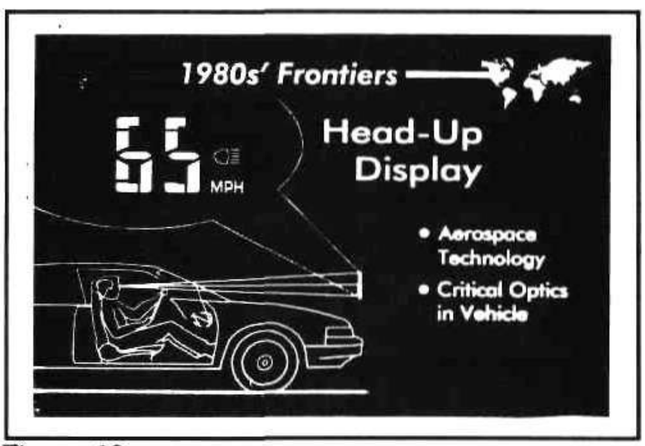

Figure 10

Head-up display for vehicles was in its infancy in the late 1980s. Still it has turned into a significant driver's aid. The enabler for HUD was the availability of aerospace technology, for us, brought about by General Motors' purchase of Hughes Aircraft. This aerospace technology introduced critical optical design techniques into traditional electronic and vehicle manufacturing.

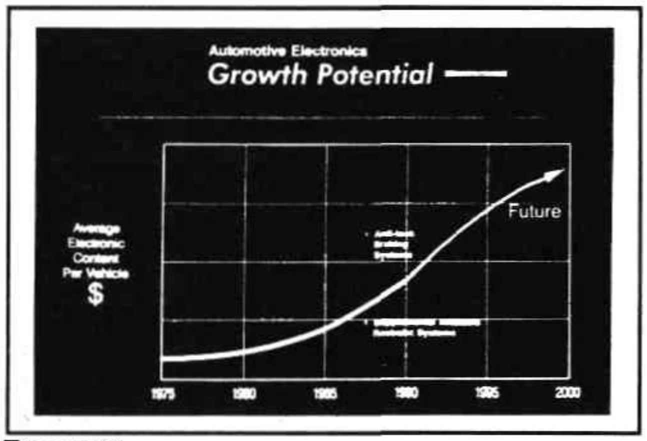

Figure 11

The developments in the 1980's were dramatic, but the frontier spawned by those developments, promise to be even more dramatic. By 1995, experts say we could see automotive electronics industry sales double from where they were at the end of the last decade. The increase primarily will come from vehicle body and chassis functions such as anti-lock brakes and airbags. The mid 90s will see these products grow into a mature, well-defined product line that will be standard equipment demanded by the safety conscious public and government.

The automotive electronics frontiers of today and the near future have expanded well beyond technology and product. Today and tomorrow's frontiers now include ultra quality and high reliability. Today's consumers demand trouble-free operation of their vehicle, a requirement that is often taken for granted but not by those of us in the automotive electronics business. For example, in the area of supplied material discrepancies, we no longer use percentages; we use parts per million. And we've seen the parts per million acceptable rates decrease from tens of thousands to hundreds to single ppm.

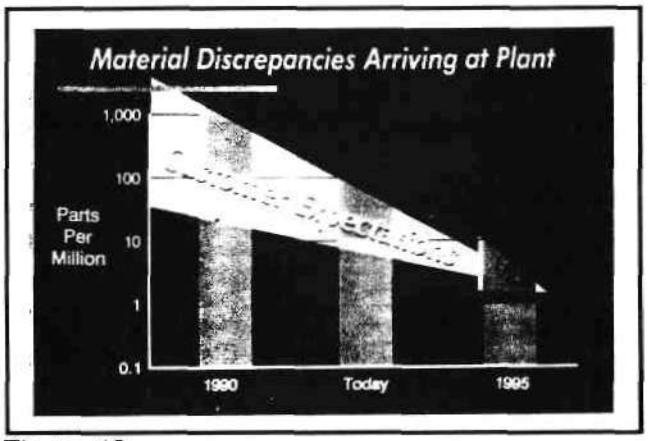

Figure 12

Dominating a major portion of today's frontier is work on complex power training control electronics. This control is needed to meet the high reliability warranty requirements, as required by the California Clean Air Act for 1994 through '96, commonly referred to as "CARB" OBD-II or California Air Resource Board-On Board Diagnostics II. Also driving the development of this complex PCM is new legislation in U.S. clean air regulation and corporate average fuel economy ratings. At the same time we're doing all this, the consumer is demanding a higher performing vehicle.

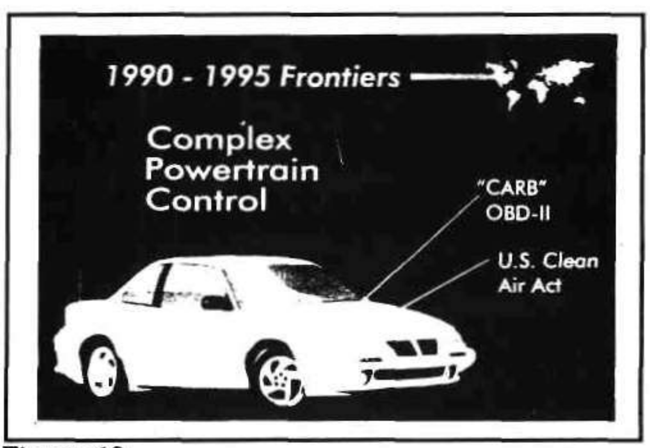

Figure 13

Tough U.S. legislation is having a worldwide effect. During the 90s, some form of U.S.-style emission standards will be required in Europe and parts of South America, which portends good things for the U.S. automotive electronics industry.

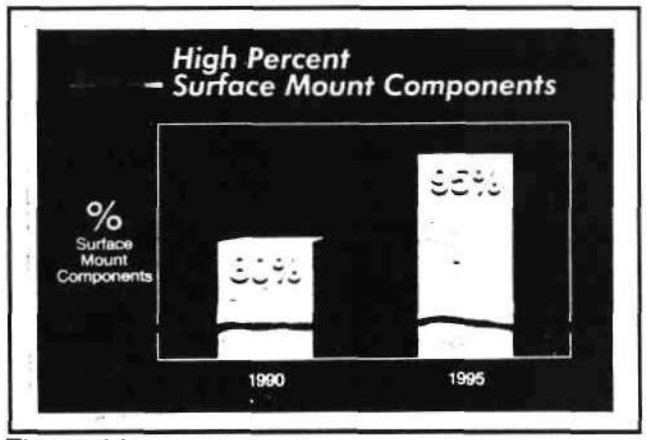

Figure 14

Production of these complex powertrain controls reasonable cost and size requires a high percentage of surface mounted circuit board components. By 1995, it may reach 95%.

The use of surface-mounted electronic components is exploding. By 1996 our consumption should climb from today's 1.5 billion a year to nearly 5 billion. This trend towards surface mounted components is typical of what is occurring across all our product lines. The boards these surface mount components are being placed upon are undergoing dramatic change as well.

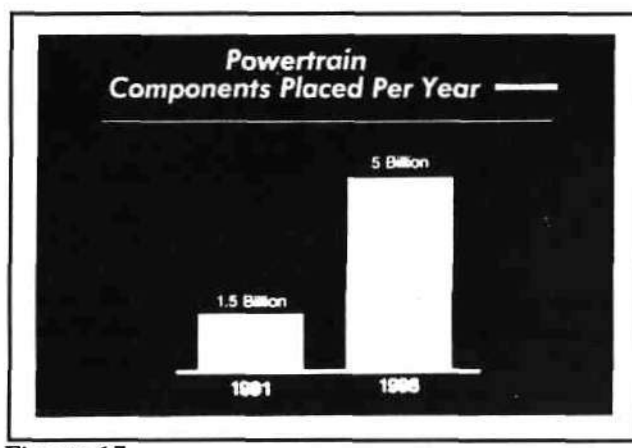

Figure 15

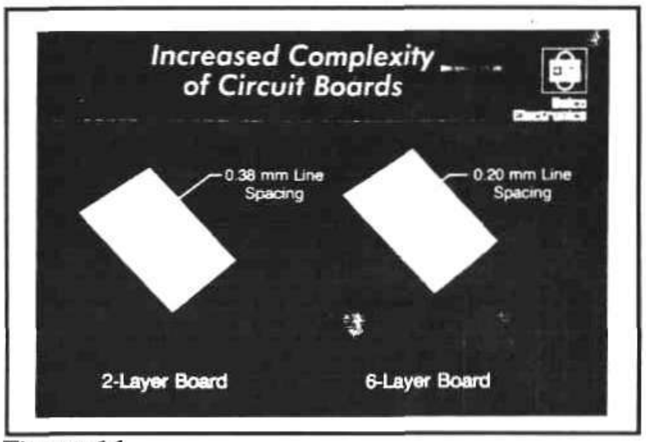

Figure 16

The use of four-layer and six-layer circuit boards will be commonplace in manufacturing along with narrow-line spacing. Today's two-layer boards use 0.38 millimeter line spacing. The six-layer boards will use 0.2 millimeter line spacing.

Another significant factor in powertrain development is the automotive company requirement that controllers be placed in the engine compartment, which means they'll have to meet 125°C application requirements.

Innovative product design requires equally innovative process design. Automated manufacturing techniques will be essential to meet reliability and cost, goals... Manufacturing techniques that, in addition to surface-mounted components, include X-ray inspection of electronic circuit board assemblies.

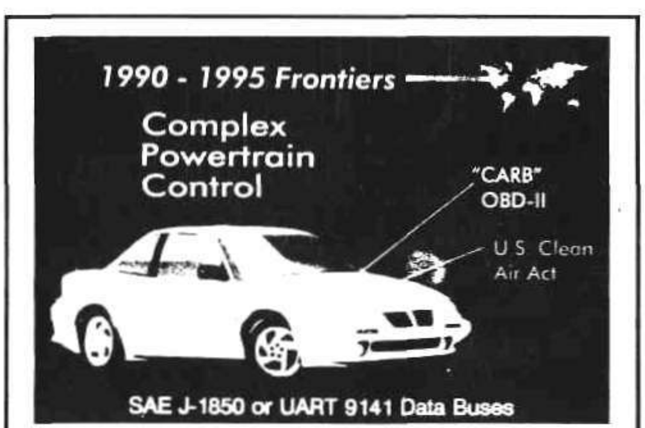

Figure 17

New vehicle applications techniques will also be required. I mentioned earlier the development of the Common Vehicle On-Board Diagnostics driven by CARB, in California.

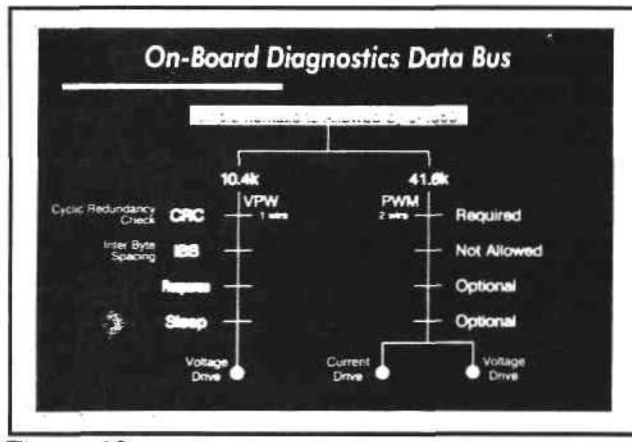

Figure 18

CARB demands have given rise to the SAE (Society of Automotive Engineer) controlled, common diagnostic tool specifications and standardized data buses, data buses such as the SAE J-1850 and the European URAT-9141. The near future will bring the adoption of even higher performance data buses, such as the CAN bus.

Use of data buses, perhaps, points to the most striking innovation in this era, which is conversion of virtual all systems from analog electronics to high capability digital electronics. The ratio of analog to digital was approximately 80/20 in the 1970s; we are currently at a 20/80 ratio. Digital electronics is made increasingly practical by technological advances that bring about much greater computational power, information storage, and precision. All hardware features and software behind the instrument panel and under the hood will eventually function digitally, possibly as early as the year 2000.

Digital technology represents a quantum leap for audio and communication systems. You have to look no further than the information storage comparison of an analog phonograph record to that of the digital compact disc. Digital signal processing already has had a significant effect on audio equalization and sound enhancement, and has made possible the development of the digital cellular phone. This ongoing conversion of new products to digital electronics will continue to take place in vehicles throughout the 1990s.

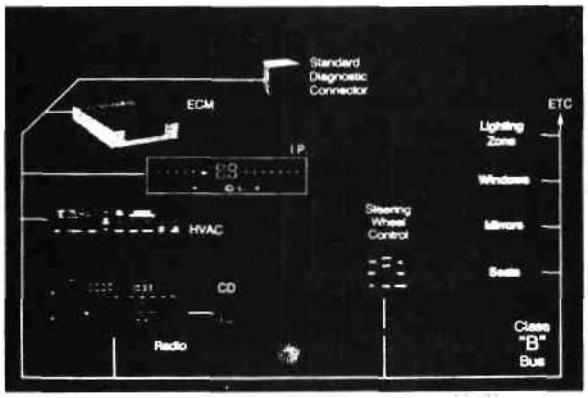

Figure 19

One more related benefit in the digital arena is improved service driven by the need for quick dealer repair capability and single-visit problem diagnostics.

An emerging I/C technology, that you know well, is being tapped for this use. "Flash memory" allows for complete recalibration or reprogramming of even the control algorithm in the plant or at the dealership level. These smart proms will make their debut around the '93-'94 time frame, and we expect their use to expand dramatically.

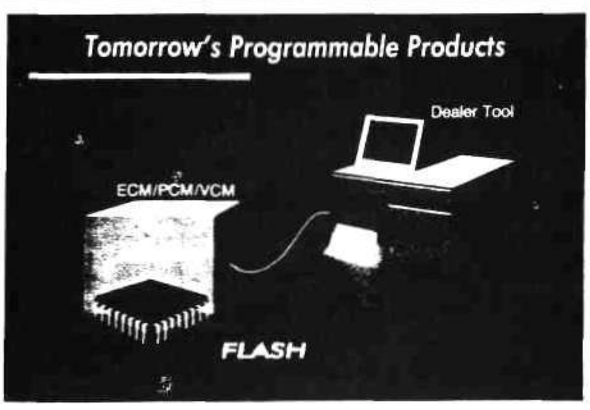

Figure 20

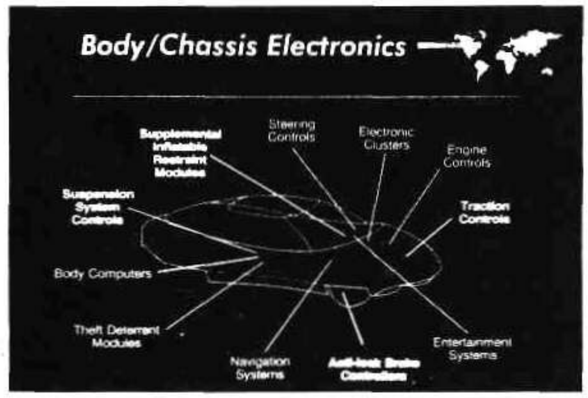

Figure 21

The body and chassis electronic frontiers are typified by supplemental inflatable restraint, ABS, traction control, and ride control. These are driven by safety legislation and also by consumer pull perhaps giving the vehicle manufacturers one of the best methods to meet consumer expectations, and also increase the product offerings.

The design and manufacturing technical advances previously mentioned applies equally to these products. If there is one item that captures the flavor of tomorrow's frontiers today, it is the electrical vehicle. Delco Electronics is heavily involved in meeting the desire to have zero emissions vehicles to help meet clean air requirements. As you may know, our GM prototype electric vehicle goes from 0 to 60 miles per hour in 8 seconds, has a fully discharge range of 120 miles, and can be completely recharged in two to three hours, using 220 volts. Many new digital electronic controls, such as induction motor speed controls, regenerative braking, and battery monitor are needed. One key development in electric vehicle controls will be a hybrid power switching module that can control more than 500 amps for each phase of the induction motor.

The last major development to be mentioned in the mid-90s time frame is what we call a Vehicle Communication Key. This key is used for communications from the person to the vehicle. Acting as a key for everything from entry to ignition, this application is driven by vehicle personalization, security, and safety desires; all appealing safety features.

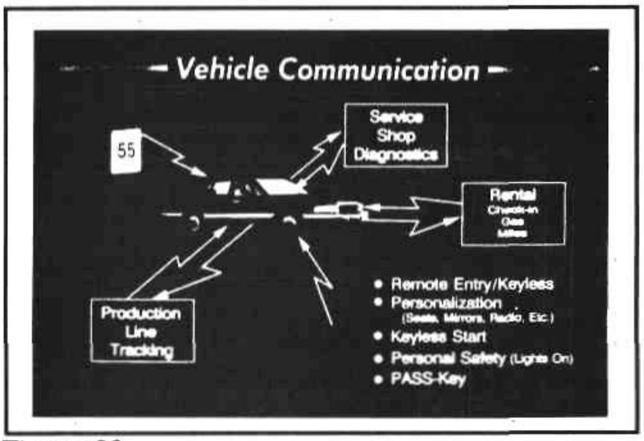

Figure 22

The technology employs a remote transmitter on a key fob to communicate between the person and the vehicle with a range of up to 200 meters. The key fob behaves as a data bus and transmits the digital data, including encryption for security and vehicle/user identification. The same link could be used for a vehicle-to-toll booth communication, or more elaborate Intelligent Vehicle Highway System (IVHS) related functions.

These are just a few of the items under development today with near-term application. Also under development is navigation, including route guidance, and global position satellite system or GPS. This technology has become very popular in Japan, but has not caught in volume in other parts of the world.

But for now, let's take the tomorrow exit and explore the frontiers we anticipate for the end of this decade and beyond.

To begin with, we see more growth—maybe not as dramatic, but certainly significant. The growth will come from enhanced body and chassis electronics led by chassis controllers, multiplex vehicle wiring, and the need for more, yet highly improved, human interfaces.

This growth will demand ultra-reliable components driven by the very high number of automotive electronic assemblies. We talked earlier about impressive material discrepancies in the single digit parts per million range. Tomorrow's semiconductors will require a parts per billion performance level in material discrepancy. The electronic boxes themselves will be asked to perform in the 0.1 to 20 PPM range. . . certainly "a must-meet goal" for the year 2000 and beyond.

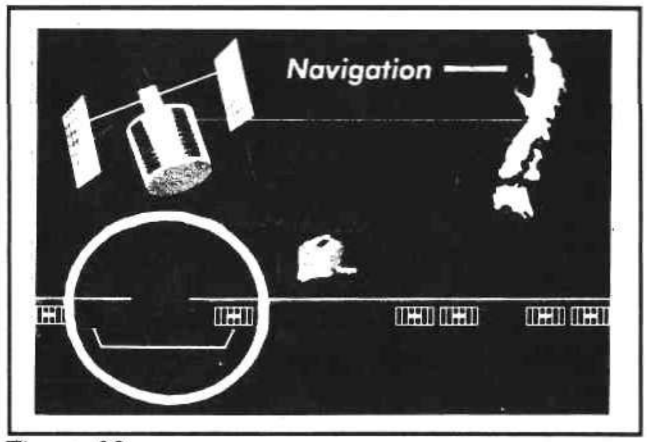

Figure 23

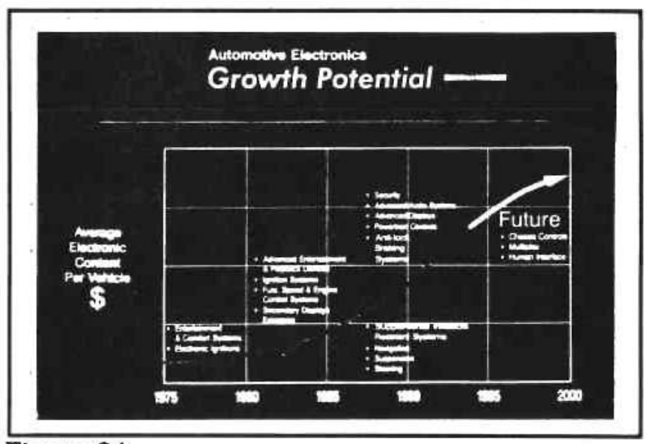

Figure 24

This reliability improvement is paced by novel and new techniques. For example, integrated circuit development will require 100% designed-in protection for latch-up of every IC element, 100% designed-in protection for electrostatic discharge of every element, plus a guarantee that every IC circuit element meets all the inherent physical capabilities of such a circuit section.

Tomorrow's vehicle content explosion will be driven by customer demands and expectations, increased safety demands, and new, large-scale program efforts led by governments and industries; efforts such as Prometheus in Europe, IVHS in North America, and AMTICS in Japan.

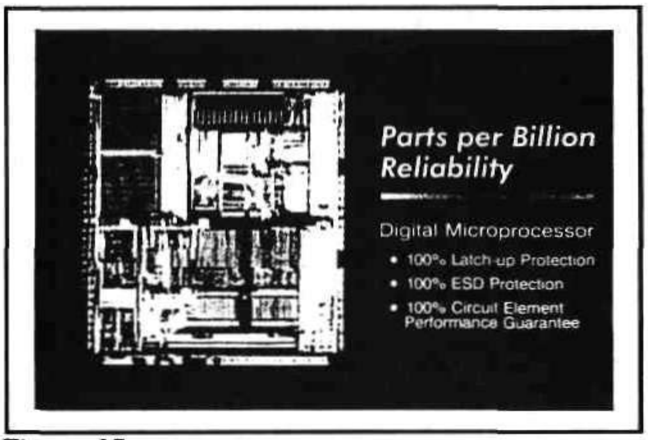

Figure 25

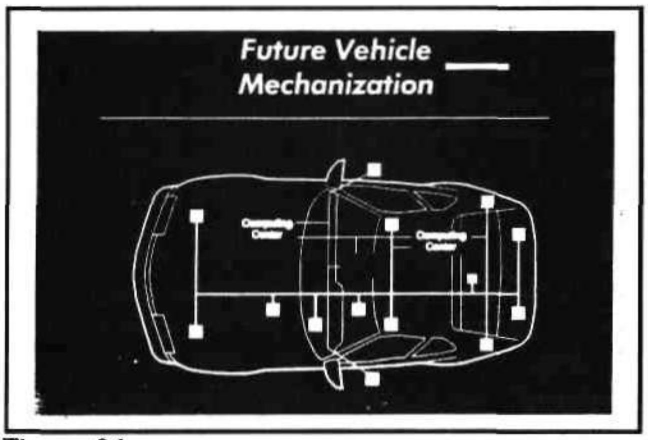

Figure 26

This content explosion will require several major computational centers and various distributed boxes interconnected by at least two types of data buses. The electronics will stay distributed to accommodate various options at reasonable cost. We don't see just one large computing center in the vehicle's future, but rather a close parallel to distributed computing idea that is evolving in business and education. Better human interfaces and human factors will be driven by new customer demands for safe driving and crash avoidance capability.

Advanced, high content head-up displays will present new data beyond vehicle speed. Without looking down, the driver will receive traffic information, radio data system messages, roadside warnings, and speed limit indications, as well as performance against speed limits.

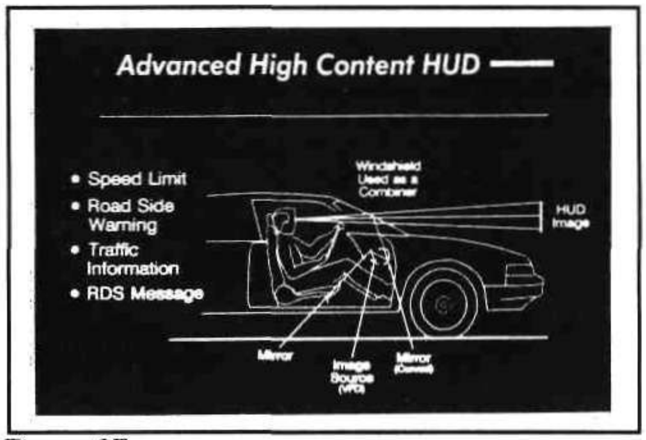

Figure 27

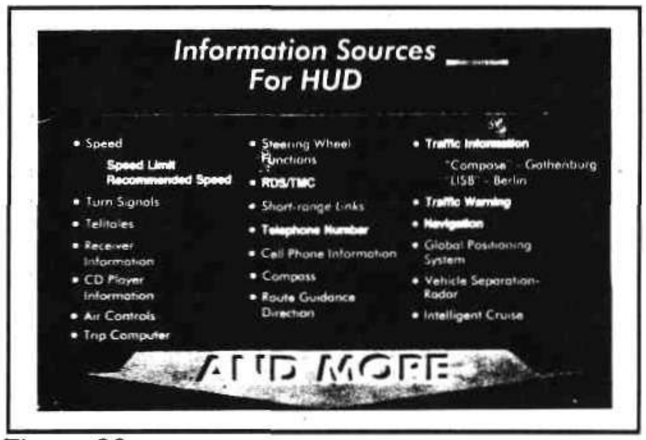

Figure 28

Other sources of display information will involve navigation and cellular phone number dialed. Today, the sources for better driver information are growing. The technical challenge here is not only finding the appropriate reconfigurable HUD, but making the instrument cluster user-friendly without being over-whelming to the driver.

A related frontier will be microwave or radar-based products, which also is driven by strong consumer voices for safety, and increases in occupant protection legislation. The applications will span from object detection in various directions from the car, to intelligent or possibly autonomous cruise control, to road surface condition detection, and true road speed measurement to aid ABS and traction control.

Radar-based products will present a considerable challenge in manufacturing. To produce affordable designs, we will go from discrete microwave assemblies to gallium arsenide integrated circuit-based units.

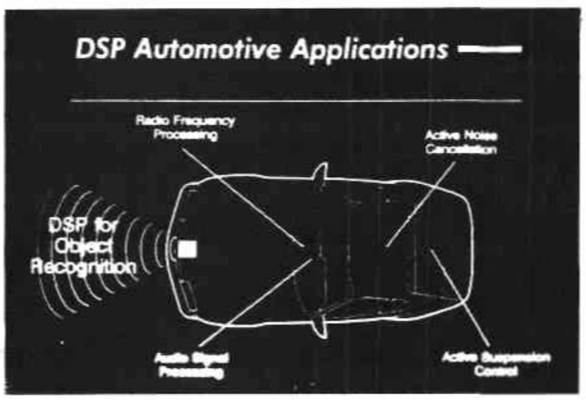

Figure 29

Digital signal processing has often been mentioned for the areas of audio signal processing, active suspension control, active noise cancellation, and radio frequency processing. However, digital signal processing will be an absolute must for the development of various radar or even optical object detection schemes. Here digital technology will be used to recognize whether an object is a car, a motorcycle, or merely a traffic sign at the edge of the road by using its reflected radar cross-section.

Additional and expanded chassis controls will be part of the turn-of-the-century vehicle. These controls will provide improved ABS, traction, suspension, steering, and vehicle stability in a growing, highly competitive, high-end car market. The difficulty of predicting functional grouping and needs, hardware requirements, and software packaging grouping, plus the need for quick product cycle time will lead us to modular designs of many in the above areas.

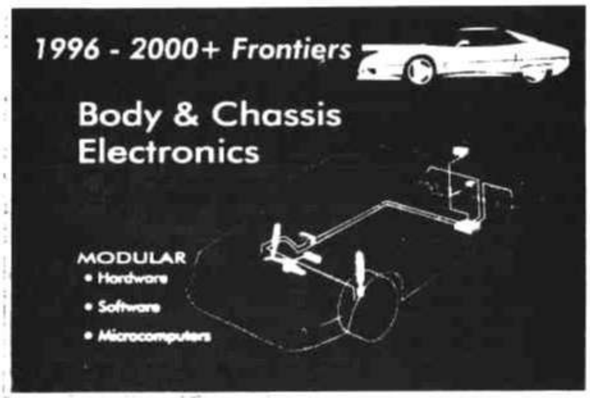

Figure 30

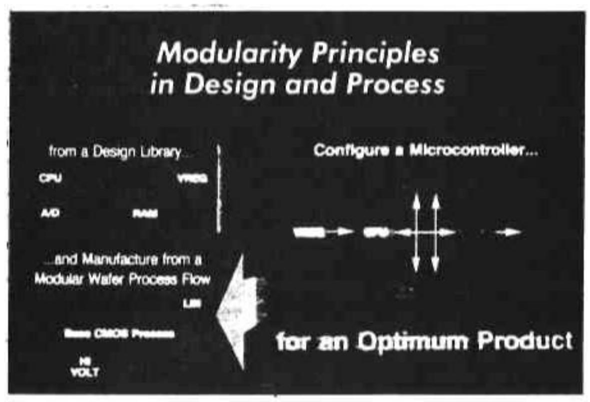

Figure 31

For example, the future automotive microcomputers will be completely modular to allow the designers to "pick and choose" functional modules as the application dictates. For example, using a digital signal processing CPU, a CAN bus interface, and several memory units create a radar controlled cruise that interacts with ABS.

Modular electronics will make critical the need for multiplex vehicle wiring to reduce wire weight and provide the production capability of installing wiring for tomorrow's sophisticated high electronic content vehicle. Without multiplex, we will rapidly reach a "no-build" situation from a wire complexity viewpoint . . . Not only will multiplex simplify wire cable installations, but it will actually save money by using single wires to send multiple signals around the vehicle.

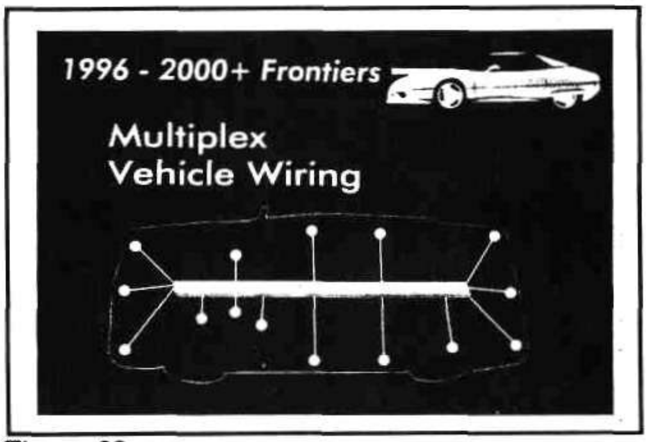

Figure 32

An idea similar to multiplexing is the expansion of smart sensors. Smart sensors also are driven by a need to simplify vehicle wiring. A simple example might be the airbag accelerometer that detects "g" levels continuously and deploys airbags in a more controlled manner. Another example would be the "percent" methanol in-gas-tank sensor that sends a digital signal on a single wire to the engine controller, which adjusts the engine performance.

The list of potential smart sensors includes items such as the yaw sensor, oil quality sensor, various fluid pressure sensors, and the conversion of today's sensors to smart ones such as temperature, manifold pressure, linear position, and so on.

Another major frontier in this era will be digital communications to the vehicle driven both by consumer pull and technology push.

This will be largely driven by the World-Application Radio Conferences recent selection of digital audio broadcast in the L-Band at 1.5 gigahertz.

Compact disc grade audio will be broadcast to the vehicle without the usual multipath interference found in FM frequencies. This broadcast method could provide digital transmitted information in the case of IVHS (intelligent vehicle highway systems). Digital Audio-Broadcast will complement the work in digital transmission for cellular phones. The expectation is that digital cellular phones will become dominant over analog ones in the 1995 to '97 time frame.

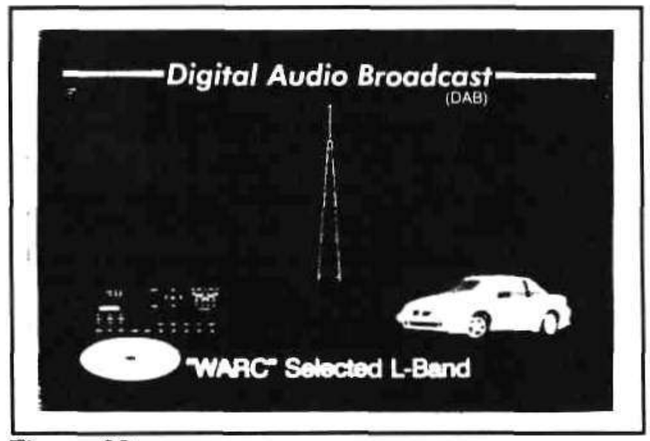

Figure 33

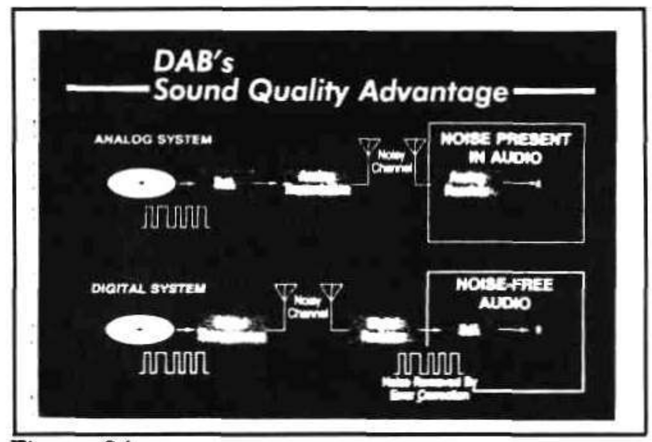

Figure 34

Figure 35

Finally, another significant frontier we will approach in our automotive electronics vehicle involves the requirement to recycle 100% of all electronic assemblies. This will not be a simple task considering that today we only reuse the aluminum cases that protect the electronics. We also extract the gold wires from the IC package, but this is just the beginning. The future will see the complete recycling of the electronics hardware, which in many cases will long outlive the vehicles that carry them. Here may be the frontier that offers the greatest potential for exploration and profit because recycling will be a very strong customer voice in the year 2000 and beyond.

As the automotive electronics industry approaches its next frontier, it will continue to rely on a semiconductor industry to fuel its engines for growth. . . the achievement for parts per billion in ultra reliability . . . cycle time from custom design to silicon in a few months . . . merged processes that will allow power and logic integration unheard of today . . . microprocessors with speeds above 100 megahertz . . . gallium arsenide devices that begin to approach silicon in cost . . . power devices for electric vehicles that switch more 1,000 amps . . . All of you are much more familiar with these frontiers than I am, I trust that you'll agree that these are worthy challenges when these frontiers are closely examined and the ultimate customer benefit is weighed. Together we'll be able to provide an unprecedented new round of functions, products, and capabilities for each vehicle and each customer. It's a win-win-win situation—a win for the semiconductor industry, a win for the automotive electronics industry, and most importantly, a win for the customer.

Questions & Answers:

Question: What's the design cycle today from inception of design to start of production, and what do we see in the next 5 plus years?

Mr. Wilhelm: There's a real confusing answer. There are some things that we've put in production *in* six months, however most things take much longer. We worked on anti-skid brakes for 20 years before they became a real market. More traditional now would be a 3 to 6 year time frame, and it's unacceptable. Our goal is to cut that in half. In my opinion, at the year 2000 if we take longer than 4 years to design products, we're going to die, because you want cars turning around faster, therefore our products have to turnaround faster.

Question: What's the outlook for night vision? We've been working on a program for 3 years, spending considerable development money. In developing room temperature infrared, that is based on a $100,000 cooled system (that none of you would buy for your vehicle). Our goal would be to sell it to you in the range of $500 to $1000; it would look forward of your vehicle and be able to look beyond your headlights. We're still working on it. We've got this IR device from the size of a small refrigerator, down to two packs of cigarettes. Even better news, we're getting flat panel displays, integrated instrument clusters and that's all coming along. The cost still needs to improve more, as does the performance. So we're not there yet.

Question: What other technologies besides head-up displays are you working with Hughes Aircraft on?

Mr. Wilhelm: We are working on radar-based object detection systems, digital broadcast, a fully digital receiver, manufacturing technologies, quite a bit.

Question: What would be the estimated band width needed in 5 years on a car?

Mr. Wilhelm: I'm a bit unclear regarding your question. All I know is if we don't get a wide band fiberoptic system for some vehicle control systems, we're going to crash and burn in 5 to 10 years in many high level cars, because we're loading them down with costly, complex electronics, and the electronic boxes have all got to talk to one another and be compatible. We've gone to open architectures in the last two years, both in medium speeds and high speeds buses. Now third parties will be able to sell many products that are compatible—however the last thing you want in your car, is to have your car stop in the middle of the road because you bought a really neat radio. We'd like to make this fool-proof just like you would, because we're designing for 100,000 miles and beyond.

Question: What is the value of electronics, in particular the semiconductor content per vehicle today?

Mr. Wilhelm: Automotive electronics is in the range of $750 to $850 per vehicle. Semiconductors, I'd estimate to be between $100 to $200. There's pressure to up-integrate, so that keeps costs from growing too rapidly.

Question: Are we prepared to support software for complex systems like navigation for future vehicles that will be very functional, and will add more value to your vehicle?

Mr. Wilhelm: Yes. The complex answer is how do you get the industry to all agree. I only represent a small part of the industry. We sell to 40 different customers and everyone of them is right. Toyota is just as right as General Motors, just as right as Ford. But we haven't yet found, other than through the SAE, a way to help all of us to standardize. It's being done in Japan to some degree, but they're a different society. They look at life very differently and do a very good job with third-party software being used for navigation, for example. I think the infrastructure views are going to be very tough.

Question: How much electronics design is done outside of GM and manufacturing?

Mr. Wilhelm: There's quite a bit of design being done by other people besides the company I work for. I'm not quite sure where you're going with the question.

Question: Is all manufacturing done in house?

Mr. Wilhelm: **Right** now in Delco Electronics—85% of our business is with General Motors. That is declining. 40 of our customers are not GM; our intent is to grow the non-GM, as well as keep GM totally happy. Not all of our manufacturing is done inside Delco Electronics. Some of it is done by third parties for us. I don't have a percentage for that.

Question: How popular are GPS systems in Japan?

Mr. Wilhelm: Last year in Japan, 250,000 navigation systems were sold. All you have to do is go over there and spend a little time. The irony is that they've been on that market since 1984-85 with dead reckoning systems that didn't work well. You sat in somebody's car in Tokyo and watched some "vehicle" on the electronic map eventually going to Tokyo Bay due to system error. Because of the foresight of our government, we now have a GPS system that is going up around the world. Japan was one of the first countries to be covered in December of last year. It's making their navigation systems bullet-proof. It is wonderful to sit in a car and drive through Tokyo and you never get lost, because they don't have any road signs. It's terrific.

Revitalizing American Competitiveness

Ko Nishimura
President and CEO
Solectron Corporation

Mr. Grenier: Dr. Nishimura, President and Chief Executive Officer, joined Solectron Corporation in 1988. Prior to joining the company, he had 24 years experience in disk file design technology and manufacturing management with IBM. Dr. Nishimura holds a B.S. and M.S. degree from San Jose State University, in Electrical Engineering, and a Ph.D. in Materials Science from Stanford. Incidentally, this is the third Ph.D. in material science from Stanford that we've had speaking at the conference, plus Dataquest has one, Dr. Charles Boucher, in the semiconductor group.

During Dr. Nishimura's four years with Solectron, revenues have quadrupled and Solectron has won the coveted Malcom Baldrige Award. In addition he has overseen the expansion of Solectron from one location in San Jose to four, including Bordeaux, France and Panang, Malaysia. Dr. Nishimura is considered an agent of change and a visionary.

Mr. Nishimura: A little break from your normal semiconductor talk. We're not in the semiconductor industry, but we're users of semiconductors. We happen to be the second largest contract manufacturer in the United States.

What I'm going to talk to you about is the Baldrige Award. We did not go out to win the Baldrige Award. Winning wasn't important to us. What was important when we looked at the Baldrige application; it was a key business process on how to build a quality company, not just building quality products. So we looked at it and said, this is a great idea.

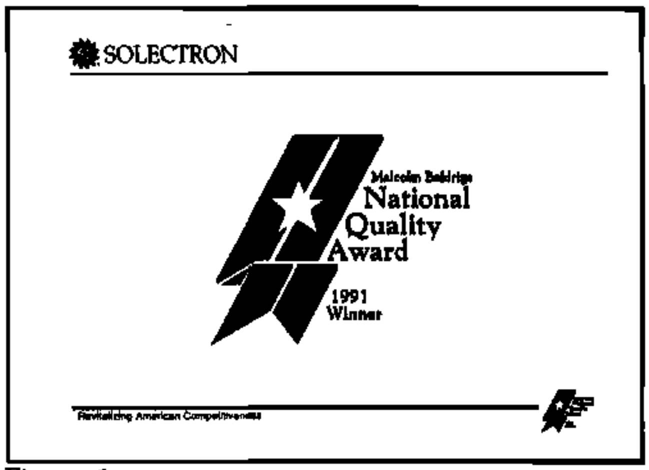

Figure 1

You read a lot of things in the paper, especially by academics, who write about how bad the Baldrige Award is. As soon as you win the Baldrige Award, you go in the tank. Let me tell you what happened to us. Our revenues, this year, after we won the Baldrige Award, increased 53%. Let's put that to bed. One of the things I don't like about academics is they like to write papers, but obviously they don't know how to make money. We're all in the business of making money. That is why we went through the Baldrige process. It is not a perfect process—but if you recognize that, you can implement your own processes in the areas you feel that you need to have better processes. We're talking about key business processes.

You can see the categories that we have.

The important thing is to satisfy your customers. Dave Packard talked about it last night. He said the most important thing is not to satisfy your shareholders—it's to satisfy your customers, keep your employees happy, help your suppliers out, and be a good member of the community. If you're all of these you are going to satisfy your shareholders because you'll make money.

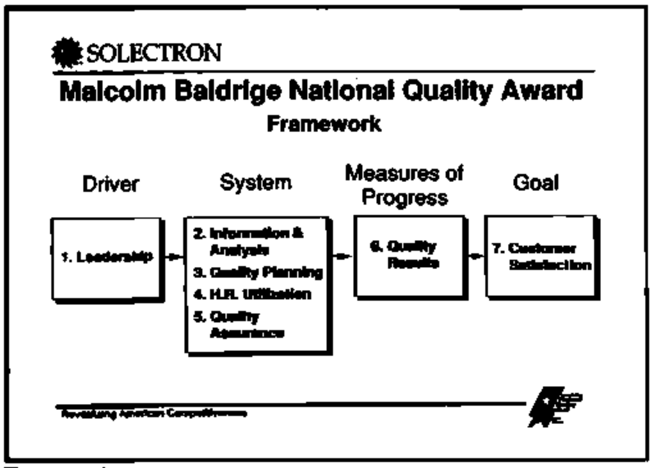

Figure 2

The first year we applied for the Baldrige Award, we finished in the top 40%. Our company is dedicated to continuous improvement. That's all we do.

The next year, they raised the criteria, and we still finished in the same category but we were in the top 20%.

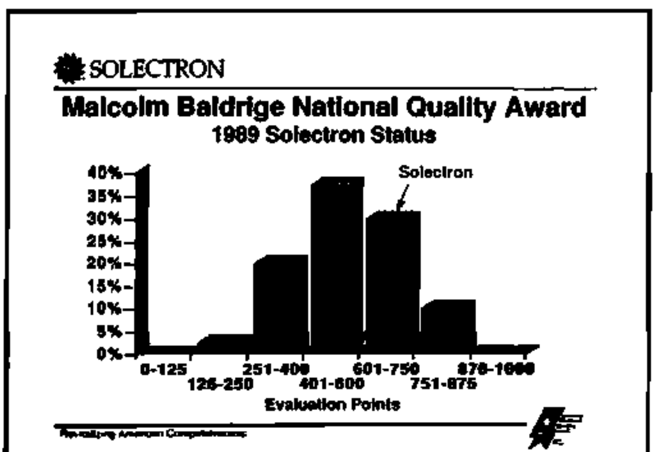

Figure 3

One of the good things about this process is you get two things out of it. One, is you go out and benchmark other people so you find out how good you are. Nobody cares how good you think you are. What's important is how good you really are.

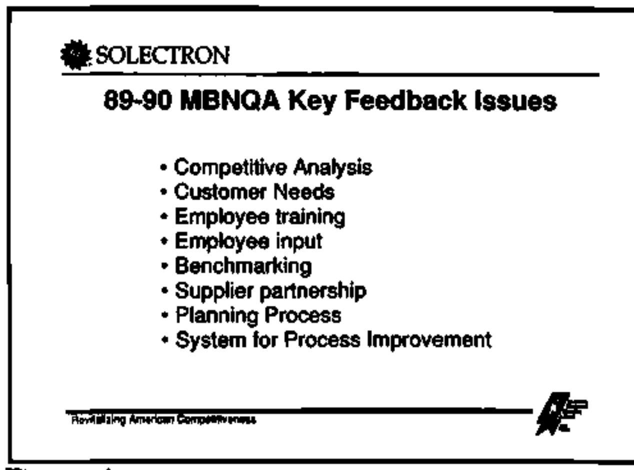

Figure 4

The other thing is being a tax payer—I finally got something for free from the government that was useful. They came back and told us—we didn't do enough competitive analysis—who are our competitors, direct and indirect, what are our customers true needs, and how are we training our employees?

One of the things we didn't do very well is to ask our employees for input. Those guys are pretty smart people. So we started asking our employees and our efficiency went up—our profitability went up.

We did some benchmarking and we also started recognizing that our suppliers were a very important part of our value-added chain. What happens when your supplier comes in at 6000 parts per million defect rate? You can't make six sigma, that's including your raw materials. So your supplier is very important. The Japanese figured that out a long time ago—it's nothing earth-shaking when you think about it.

The planning process—we found out we can do a better job of planning, and that you need a system for the process of improvement. It doesn't happen by itself.

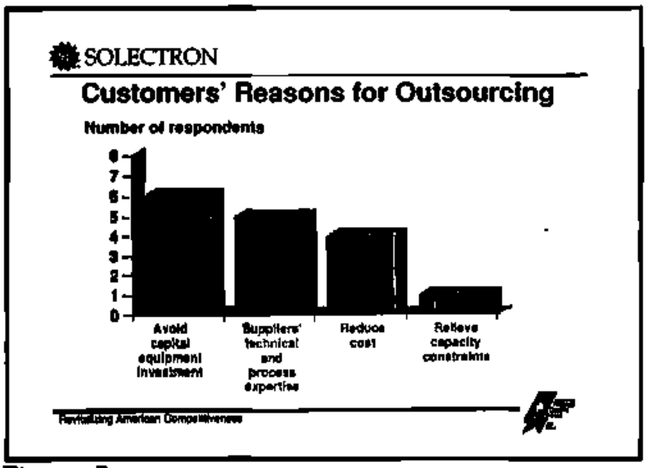

Figure 5

Here are some of the reasons that our customers told us we are their source.

This is a chart that shows that the more you out-source and the less vertically integrated you are, the better financial performance you get. If you have people who do things equal to or better than you do, then let them do that. Do the things that are proprietary to you and are important to you.

Here is how customers felt about us. We survey our customers once a week. We ask them for grades on delivery, quality, serviceability and communication.

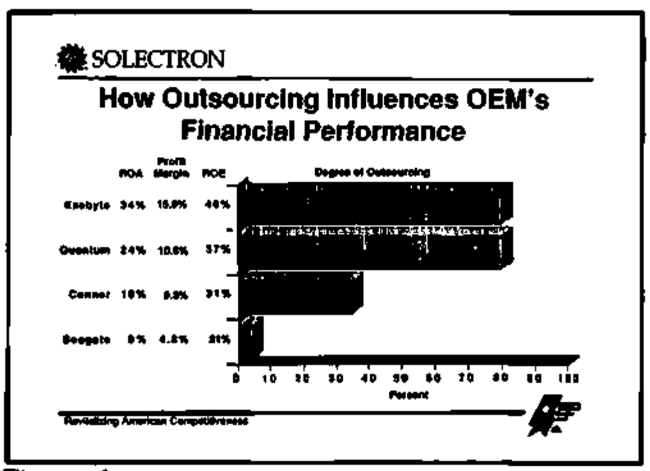

Figure 6

An A is 100; a B is an 80; and a C is a 0. We don't tolerate C's. We don't want to be mediocre. It's important that you send that message. D is a -100. Our divisions are about 92%, average.

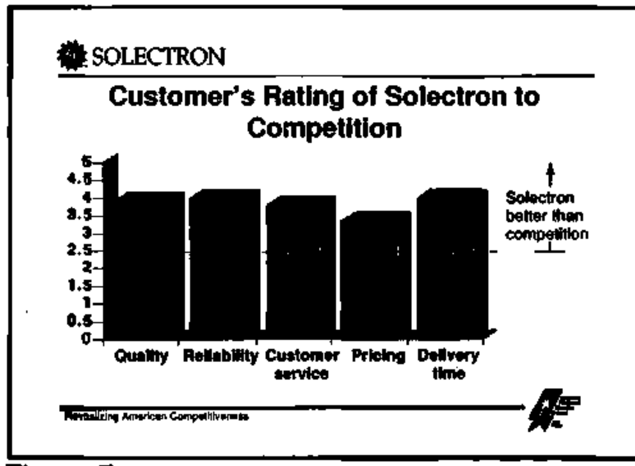

Figure 7

Last year we trained each of our people 85 hours. Five percent of our working day was spent training. The more we trained, the more we found out that our operations got more and more efficient. As time goes on, we all recognize that what we're doing today, five years from now we will not be doing. I really believe this is the most important thing we can be doing for our employee besides paying them, because it gives them longevity in the industry that they're participating in.

We benchmark a lot. We benchmark, not only our technical processes, but our financial processes, even our delivery process. A good example of this is, when I first came to Solectron, it took us 9 days to close our books every month. So I called in my controller, a Stanford MBA and asked what would it take for us to close the books in one day. You know what the answer was? He said "you can't do that." You see, I take "can't do that" means "I don't want to do it." So I asked him the question again. Again he said "you can't do that". He said "the problem with you is you're a rocket scientist." (He couldn't tell the difference between a materials scientist and a rocket scientist.)

And the next thing he said, is "You don't understand finances." I said "I understand finance, I don't understand bookkeeping." So we had this conversation for about 15 minutes, and finally he said, "Okay, wise guy; show me one outfit that closes their books in one day." I said, "That's easy; the banks do it everyday. They can't go home." He said, "That's different." I said, "We have a conversation now." He says, "I got it." He came back about 7 months later and said, "I haven't got it down to one day, but I'm doing it in two days." That's pretty good, I said, that's great. What are you doing differently ?" He said, "We were reworking the books to try to close them." You see, it's rework. You don't only rework products but you rework things all over. Payroll does it—we're doing it. So he was very happy. So I said, "Now that you can close the books in two days, we've got a lot of computers in our company; how do we leverage them?" He said, "what do you mean by that?" I said, "We should be able to close the books after every transaction." That's what we're working on now.

What are all our financial people doing with all these MBAs? The 7 or 8 days they were taking to close the books, they're now taking this time to figure out what the cost structure of every division is, where the places of opportunities are to reduce costs, and they're helping the division managers. This is what the Baldrige process helped with.

Improve Through Benchmarking

Solectron Benchmarking Process

Process	Phases: Planning	Analysis	Integration	Action	Maturity
Products and services					
Test strategy	●	●	●		
Cycle time	●	●	●		
SMT processes	●	●	●	●	●
Customers					
Customer satisfaction monitoring	●	●	●	●	●
Suppliers					
Supplier training	●	●	●	●	●
Employees					
Employee involvement	●	●	●	●	●
Suggestion program	●	●	●	●	
Internal operations					
Baldrige compliance	●	●	●	●	●
Benchmarking	●	●	●	●	●
CAP	●	●	●	●	●
Housekeeping, safety	●	●	●	●	●
Shop-floor	●	●			
Order processing, accts. pay., credit collection	●	●	●	●	●
QIP	●	●	●	●	●
Root-cause failure analysis	●	●	●	●	●
Employee training	●				
Cost analysis	●				

Figure 8

Supplier relationships—the important message here is our company is process oriented. This is how we run our business operation. We do a market analysis, based on our corporate strategy, we look at our customers' requirements, and you can see what we're doing here. The reason that we're able to manage our revenues is that we're not interested in being the biggest revenue company in the world—we want to be the *best*..

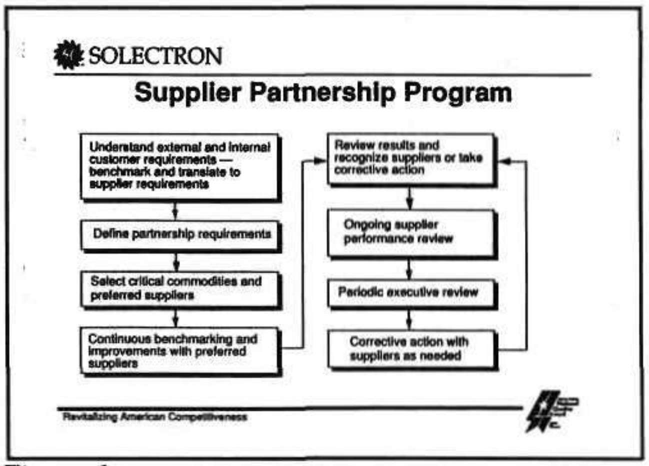

Figure 9

When you look at it in that sense, we manage our customer set like a portfolio. Some are grown up, some are coming up—on the average, we're doing very well.

Figure 10

The worst year we had was last year, 1991, during the recession; and we increased our revenue 30%. The other years were running about 50% increase in revenue. That's not easy because in order to do a good job when you grow your revenue in your company, you have to also grow your infrastructure. So we spent a lot of time training. We do a lot of succession planning. From succession plans come individual employee development plans. You can see how we deploy our quality. Our most important block is the employee involvement. Everything supports that.

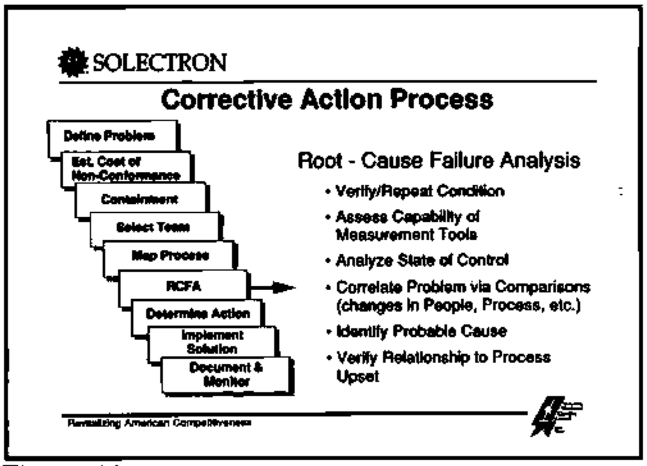

Figure 11

We have a corrective action process and a quality improvement process—who does what, when.

If you look at shipment linearity, we look at shipments everyday by division. We look at quality everyday. Three times we review our quality first; secondly, we measure our shipments. We look at P&L (profit and loss) by division and then customer, once a week. The important thing here is cycle time, velocity. You can correct things when you look at them that fast.

We don't look at it monthly; we look at it weekly. We also do activity-based accounting. We've been doing that for the past five years and it really helps. We work closely with Stanford University to do this. George Foster and his students in the Stanford Graduate Business School have written papers on us.

If you look at the CSI (customer satisfaction index)—we do that once a week. The guys that aren't doing well on Thursday morning with these customers get an opportunity to stand up and tell what they're doing to fix it.

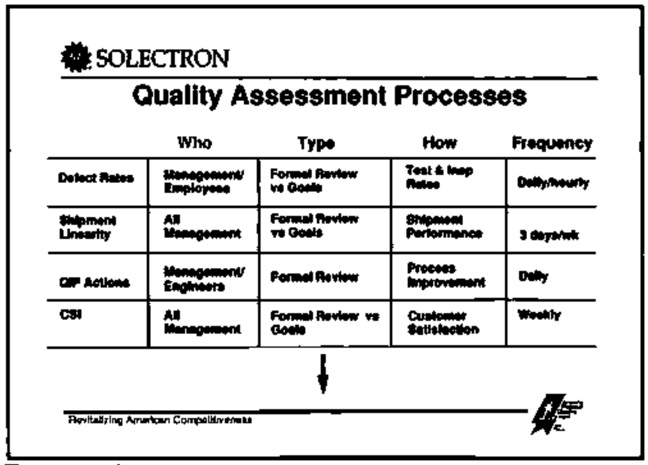

Figure 12

It's a very powerful tool. Our people are empowered—they're empowered to do good things and they're empowered to make mistakes. And when they do, they know they own it. That's the important thing.

One of the areas that is important to us is accidents. Our accident rate has dropped dramatically. The best part is, our employees are healthy but also, our Workman's Compensation rate is very low. We only pay 30% what other people pay. That's non-productive money.

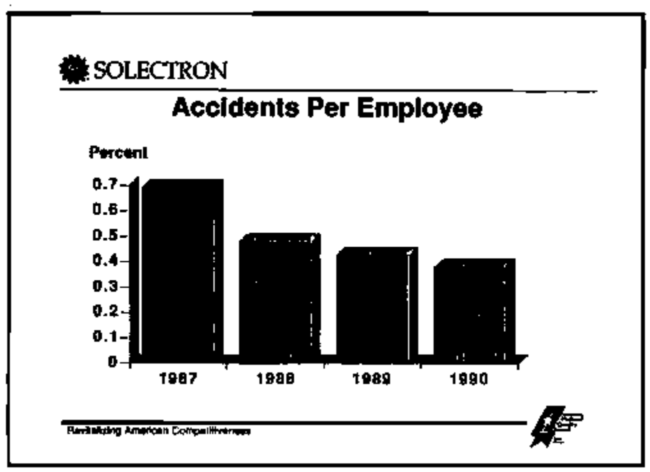

Figure 13

The first pass yield is about 97-98% right now. You notice as a percentage of labor revenue, the rework rate has gone down—that's money in our pocket. That's also money that we can return to our customers because we charge them less. That's what the competitive world is doing, and that's what we're doing. This all came from the Baldrige. Rework has decreased 4X while revenue has tripled.

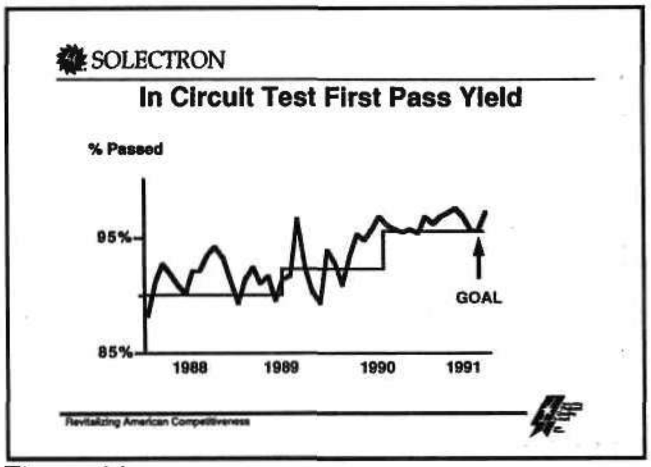

Figure 14

Our suppliers on-time delivery currently is about 95%. We can't build unless we have all the parts for carrying inventory. Which means, we're paying for this stuff, paying interest for the money we're using to collect all this inventory. One of the other bad things that can happen is shrinkage on the floor—you'll lose things, which cause people to go out and get parts. You can move them around, you can damage these things. On-time delivery by our suppliers is a very important part of our success.

Currently our inventory turns are about 8—in our industry our inventory turns are typically about 3 or 4.

Day sales outstanding—this tells you how fast we collect. When I joined the company, we were around 45-50 days; we're down to about 38 this year. Everyday that we don't collect it means over $1.5 million a day to us. It's very important.

This is a chart that one of our customers gave us. That customer was willing to pay us more for that. You can charge a premium. We didn't ask for it—they paid us because they were fooling around with that inventory. As a customer, they had some very unhappy customers, too.

This is our return rate. We're down to about a tenth of 1%. (See that spike up there.) One of our customers happened to be an American subsidiary of a Japanese company, decided it was more efficient to return defective parts once a year. That didn't help anybody.

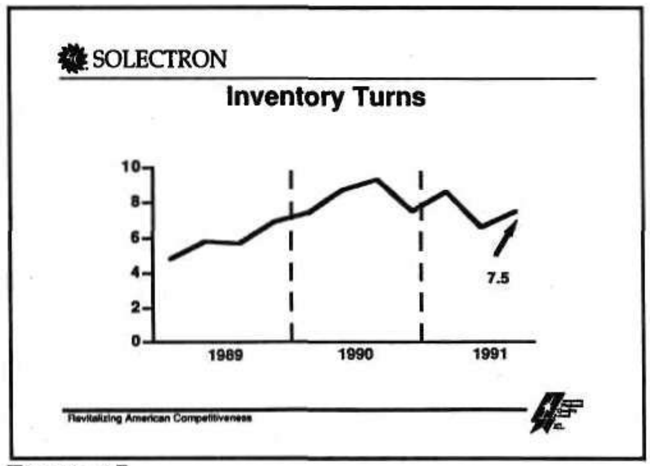

Figure 15

They carried all that inventory and we didn't find out what the problem was for a long time.

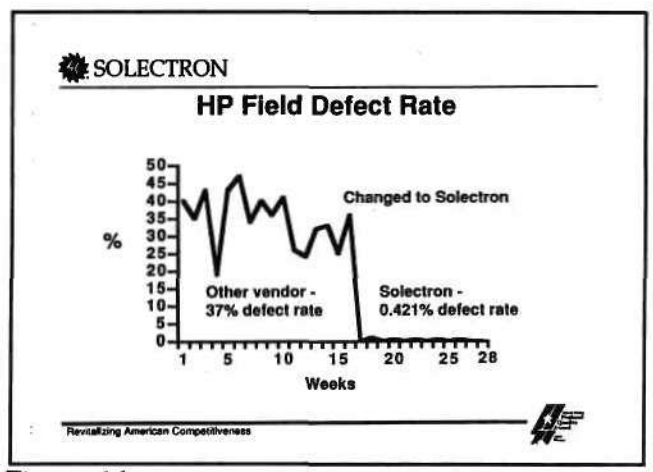

Figure 16

Our customer satisfaction has continued to improve. We're at about 93% now, based on 100, and the standards are always going up.

We've been recognized by our customers. I think the most important recognition is not so much the Baldrige Award, but the recognition by our customers, because that's what brings in our business. The government doesn't bring us business—but they have given us a very nice process to improve our company.

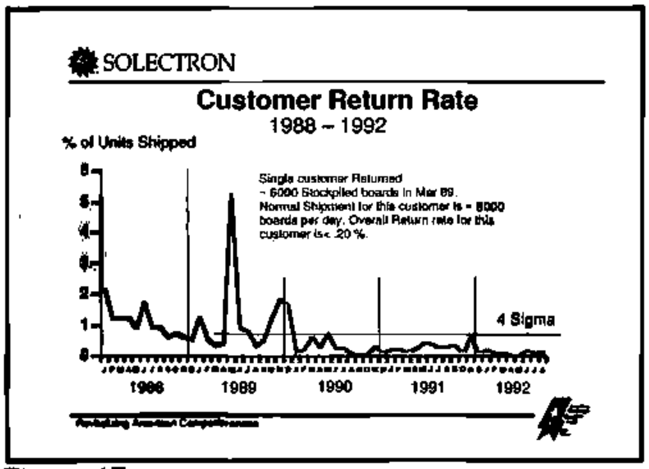

Figure 17

You can see what happened to our gross margin. That's steadily dropping, over the years it has dropped 30%. But during those three years, if you look at profit before tax, that is why we participated in the Baldrige Award process.

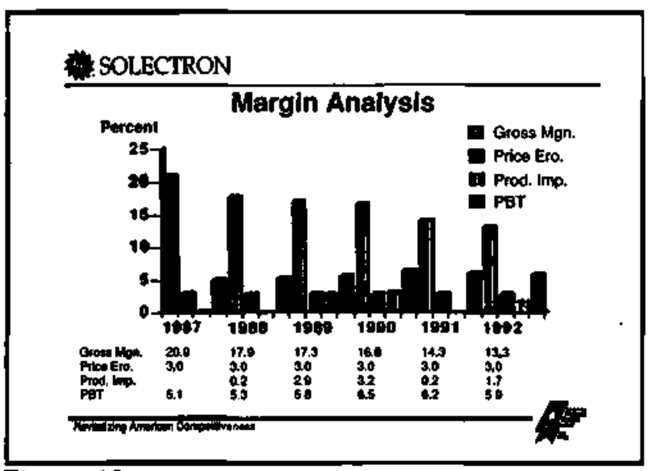

Figure 18

We did not participate just to win the award—we decided this was what would help us improve the quality of our company. And it has. We also did it to make money.

In closing, every company needs a goal and these are our goals for the next five years.

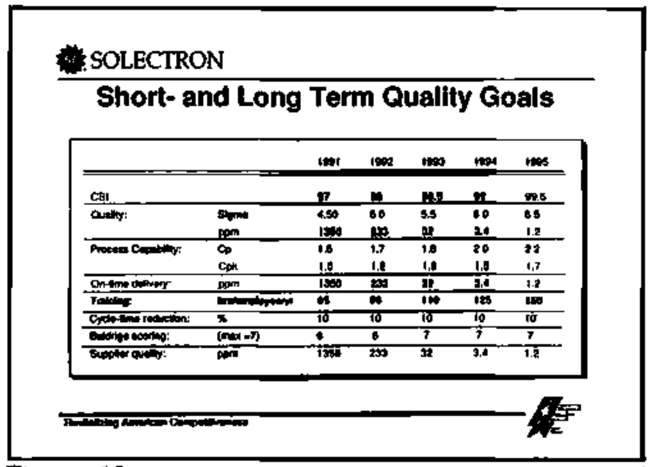

Figure 19

Questions & Answers:

Question: Compare the Baldrige versus the ISO 9000. Secondly, how important is it for you to have your semiconductor suppliers be qualified on ISO 9000?

Mr. Nishimura: We did the Baldrige Award process to make sure everybody had a process. That's what Baldrige did for us. Depending on the personality of the division managers, they implemented the processes differently to get the same objectives. We looked at the ISO 9000 to help us become uniform, across the company. So that's what ISO is doing for us. I think it's important for us suppliers to be qualified ISO 9000. Our customers are asking us to be qualified ISO 9000.

Question: How do you insure consistency in the value of custom grades they give you?

Mr. Nishimura: The customer satisfaction index is what the customer feels. Every customer has different needs, so it's however they feel like grading us. The important thing for our people to find out if they get a bad grade is find out why they got a bad grade. It's a communication tool to understand what the customer's needs are.

Question: How do you respond to price reduction pressure?

Mr. Nishimura: The important thing is to continue how you do business. What we do is to look at two things. We have a pricing model and a cost model. If they don't match then we have to look at different ways of doing things. One of the things our people are very good at doing is shifting paradigms—there is some pressure, though.

Question : How do you define training?

Mr. Nishimura: We ask what does it take to keep our employees successful, and also be employed, either at Solectron or some place? That's the question we ask. Let me tell you the kind of training we've done. As an example, we have contracted the local community college to give us English as a second language. Many of our people are foreign-born. In order to be able to interact with our customers they have to be able to communicate. We do it on company time, on company premises. When we found out that we were going to pay for this and let them go to the local community college, because many of our lower level car-pooled they couldn't get there. So we also teach it in-house. We also teach employees American culture. Some of these people are very well skilled. So it's not a skills problem as far being able to do engineering work or financial work—hey just can't communicate in English. As an example, we gave our opinion survey in four different languages. We provided interpreters for three more languages.

Those of you in California know that by the year 2000 the demographics of California will be that only 1 out of every 5 people entering the work force will be a white male. At the University of California and UCLA—last year's freshman class was 60% minorities. That's the nature of our country. I look at this as very positive. Many of you may not have thought about it, but this country was founded by immigrants. The industrial revolution was supported by immigrants. The Chinese built the railroad across the west. The strength of America is its immigrants.

Today, if you look at the semiconductor business, many of the people here are immigrants supporting the process.

Question: Is size a factor in your quality?

Mr. Nishimura: We may look like a large company, but we have business units. I think some of the most important people in the company are the top people who understand quality. How many CEOs understand the quality process—how many have done it? I have. As an example, I was one of the few guys at IBM, when I was there, who looked at the Deming tapes. I knew somebody was succeeding with it. How many CEOs go out and study quality in this country?

If you look at the top executives in the company and look at their pay scale, where do you think the manufacturing executive sits, compared to the marketing guy and engineering guy. America deserves what they're getting because they're looking at manufacturing as a backwater of somebody's career. What do the Japanese do? We, at Solectron pay our manufacturing executives. We know what's going to happen to them.

Question: Are all your divisions lean production models?

Mr. Nishimura: Some of the groups are and some aren't. We're not perfect—we have wars. Some of the guys are pretty lean in their structures, others aren't. The surprising thing about this is, you look at the number of levels of management and you think they have inefficiencies in it. Yet they seem to be able to get the gross operating margins. I don't tell them how to structure—I tell them to return the profits and they do it their way. That's the important piece.

Question: How do you get the customers you want?

Mr. Nishimura: My philosophy is if business exists, and we happen to be the best, we will get

the business we want. Secondly, a company like Sun Microsystems says the way we reward you for doing a great job is to give you more business, and that's what's been happening. You also have to know what business your customer is in. Who are the top guys, and who are the emerging guys. We do a lot of marketing studies. We can't take on everybody. The important thing is we select our customers. When we select him, that customer, we treat him the way we would treat our biggest customer. We have to support our customers.

Thank you.

Memory Outlook: The Future Isn't What It Used to Be

Lane Mason

Director and Principal Analyst

Dataquest Incorporated

Mr. Grenier: Mr. Mason joined Dataquest in January 1992. He is responsible for analyzing and forecasting trends in the DRAM and video RAM market. Having helped start Dataquest's memory research in 1978, he served as Senior Memory Analyst from 1981 to 1986. His early efforts established a database that formed the basis of Dataquest current memory research. Prior to rejoining Dataquest, Lane was founder of Viking Research, which is a market research company specializing in strategic alliances and DRAM market research. Lane has 14 years market research in the semiconductor industry. He received a B.S. degree in physics from California Institute of Technology and has done graduate work in economics at UCLA.

Mr. Mason: Let me describe the issues I propose to address. The principal theme is to look at the forward costs that memory makers, specifically dynamic RAM manufacturers face through the end of the decade, and at some of the tools that we have at our disposal to meet those costs within the limits of available resources.

First, I will back up and discuss the early part of the dynamic RAM market from the '70's to the mid-80's, the rather cataclysmic occurrences from 1985 through 1989, and how we emerged from that with a new picture of what the considerations would be for dealing with the investment issues and return on investment issues that we face in the coming years.

Finally, I will close with some of the views of what may take place in the industry as we move out into the end of the decade — with specific regard to new, innovative industry structures.

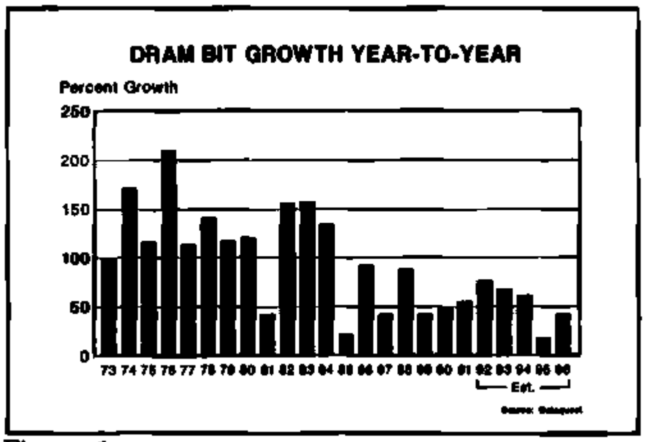

Figure 1

I'd like to discuss the annual bit growth rate from 1973 through 1991 with a look forward to 1996. From 1971 to 1984, 13 out of the 14 years, bit growth exceeded 100% over the previous year. The only exception to that was the downturn in 1981, when bit growth slowed markedly. 100% bit growth means that more bits were shipped in that given year than in all previous years before that time. The average bit growth was 110% per year during that period.

The downturn in 1985 was a real watershed event in the industry — bit growth slowed markedly, and since that time, has only exceeded 75% twice, averaging about 60%, from 1985 to 1991, or half its former level.

The years 1985 to 1989 mark a transition to an old era of homogeneous products, selling to the same users, through the same channels, (at about $2 a piece, per unit) into a new era of differentiated, rapidly evolving product line, equally tough competitively, with a much improved appreciation of the return on investment considerations.

Some say that the downturn in 1985 was precipitated by Micron Technology's price announcement of September 1984, of sub-$2.00 levels for 64K RAMS, but the industry was on a collision course with excessive capacity expansion in '83 and '84, ending in '85, running into dozens of PC makers, each of whom expected to get 20% of the market.

During the 1985 and 1986 time frame, memory producers lost about $4 or $5 billion dollars. The repercussions from that rippled through all the companies with changes in personnel, and changes in strategy by the Board of Directors who controlled the resource allocation into the memory group. During that time, six U.S. memory suppliers left the market.

The recovery of 1988 and 1989 brought profits back to the industry, but more importantly, it brought a far more sophisticated view of the issues that were at stake in evaluating an investment in the memory future. Such things as "return on investment" were given much more serious consideration — the magnitudes of the investment were far larger than they were before. There was a lot of discussion during that time, as people tried to understand exactly how they could evaluate a long term investment required to participate in the memory business, and still get a return on investment for the program. The profits of 1988-89 were far less important than the increased awareness that the memory producers gained in how to evaluate the problem.

Right at the height of the shortage in 1988, companies were trying to understand what their forward price and cost structure might look like. This slide highlights an estimate that a 4Mb DRAM would cost ten times as much to make as a 256K DRAM in its mature phases, and the increasing complexity that the industry would face as it went from a 256K to a 1Mb, to a 4Mb when a 10 mask NMOS process moved to a 17 or 19 CMOS process, and up to a 20 masks for a 4Mb DRAM. In addition, "everything sells for $2.00," that people said before this time, was replaced by something called the "bi-rule," which attempted to explain that each successive generation would sell for twice as much than the previous generation.

COMPARISON TABLE OF DRAM PRODUCTION FACTORS

Factors	256K	1M	4M
Type	NMOS	CMOS	CMOS-(Trench or Stack)
No. of Masks	9~10	17~19	20~25
Total Process Steps	200	350	450
Test Time (Sec.)	60	120	240
Chip Size (Ratio)	1	2	3
Logical No. of Chips/ Wafer (Ratio)	3	2	1
Good Dies/Lot (Ratio)	6	2	1
Clean Room Class	100	10	1
Cost Ratio (on a Mature Production)	1	4	10

Source: Mitsubishi Electric Corporation, April 198[illegible]

Figure 2

Subsequently, it's been refined to the "pi rule," where each generation will ultimately sell for pi (3.14) times the previous generation.

So there was a major attempt to try to understand what the future cost structure would be. The memory producers were trying to understand this and trying to break the mind-set, — both of themselves, collectively of other players in the market, and of their user base which said you get 30% improvement per year, year after year, and the mind-set that said $2.00 is the ultimate floor price. I think they were very effective in achieving that, in trying to understand exactly what the cost structure would look like. As we stand here in 1992, everyone on both sides of the table has a much greater appreciation of what to expect for the future.

The new view we faced as we emerged into the 1990's included a number of very important issues that were made more real by the remarkable sums that had to be spent to develop process technology and to build new facilities—the long investment lead times that required expenditure of hundreds of millions of dollars over many years before you got your first return. The uncertainties out there in the future as to what the market would be and what the price points would be, what would be the make up of the market.

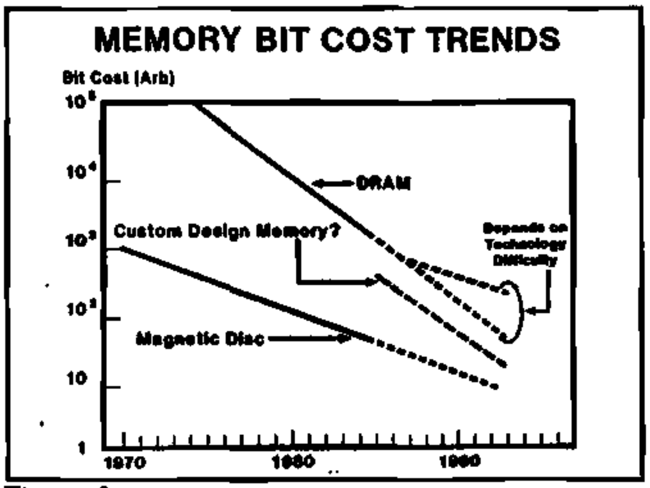

Figure 3

An additional factor that emerged in 1987, was the intellectual property burden, which was primarily instituted by Texas Instruments and their round of licensing agreements in 1987. What had been a friendly gentlemen's game became real and expensive, and it continues to boil on the front burner right now, as an important consideration for every company that will participate in the market.

In addition, increasingly with the long balance that we've seen in the market over the last three years (really since the summer of 1989), people are asking whether there can be profits in the market if there is no shortage. Every time a price quote was held back in the last three years to try to stabilize pricing, there was someone in there to undercut and take the business. This has created a situation which could not go on indefinitely because producers would never generate enough profits to fund the next generation of product development.

Let's talk about what a few of the industry participants were to face in terms of their own cost structure. For example Texas Instruments estimated a 64Mb, fully-automated line, 25,000 wafer starts, in 1995, would cost about $1 billion, compared with a 256K line 10 years earlier at about $150 million. So there was a seven-fold increase in facilities cost in a decade.

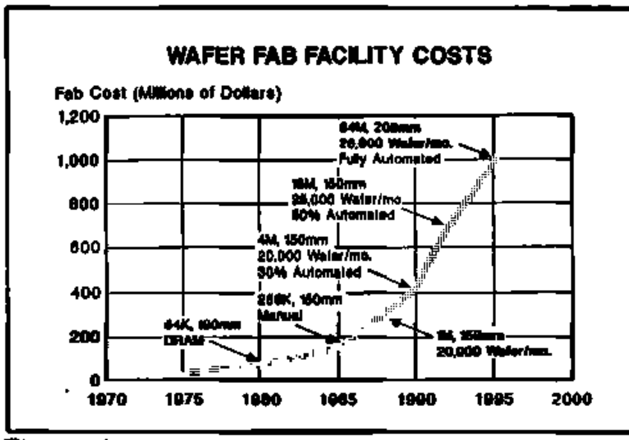

Figure 4

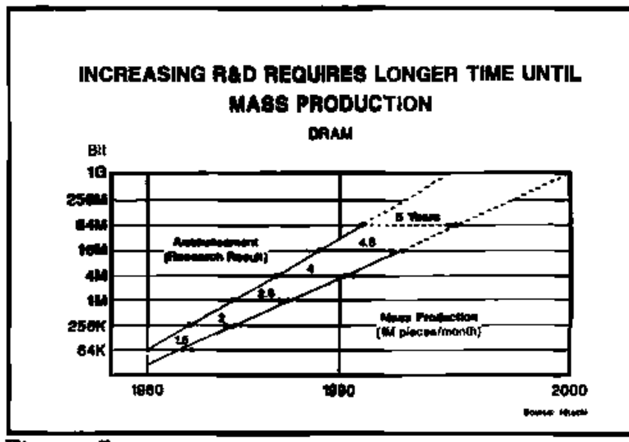

Figure 5

When you consider the lengthening time it takes over which you must invest, this is an added complication in your return on investment equation. The lag time between R&D, prototype and production is lengthening dramatically from generation to generation, and at the 64Mb generation, we now have been able to define the product nearly a decade ahead of when it will be in its peak production. So you have to invest a lot money early on, and wait a long time before it starts to show up on the other side of your balance sheet.

The lengthening lead time introduces a significant element of risk and uncertainty, as well, and impacts the ROI equation through the action of the cost of capital, which has changed dramatically in the U.S. and in Japan (in opposite directions) over the past couple of years.

Another issue is the equipment that is going to be required at the 64Mb transition. For a single stepper, you're looking at a cost of $2- to $3 million dollars per unit, and perhaps up to tens of millions of dollars for the transition of 256Mb to 1Gb, unless the life of optical lithography can be extended further than people anticipate.

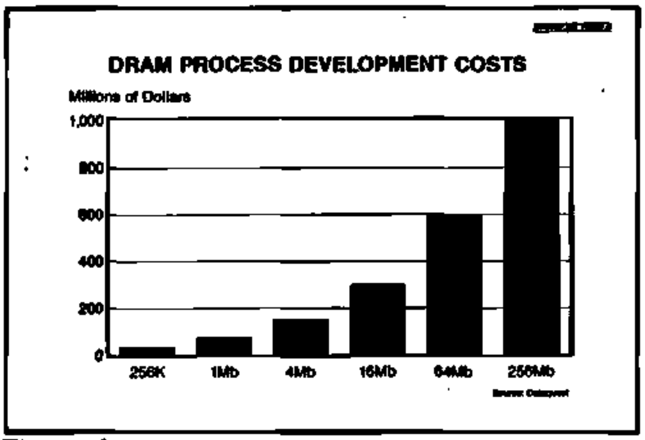

Figure 6

Next, is the process development cost. These are estimated to be increasing by about 60% per year. The 256Mb program, if you read the press release of IBM and Toshiba, or NEC, can be expected to cost $800 million to one billion dollars spread out to over 7 years, before you finally go into production and start generating some income.

These are some formidable future costs that all the members of the industry look to face, and the important thing is to understand how they reacted to this and some of the methods that they got for trying to keep these costs under control.

There is one final issue, that of the intellectual property. I estimate that about half of the industry royalty and licensing fees paid this year are paid specifically for memory technology. There are some (primarily new) entrants without their own strong product or patent portfolio that are paying about 10% of revenues to a host of intellectual property holders, including TI, SGS Thompson Microelectronics, and some of the other DRAM patent portfolio holders in Japan.

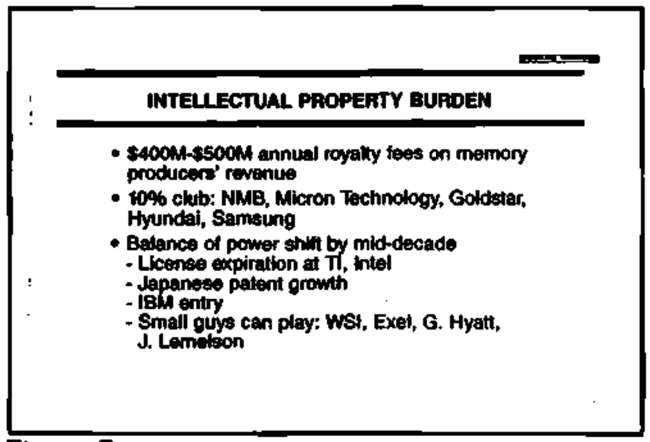

Figure 7

TI's aggressive licensing strategy — viewed by many as extortionate — is viewed by others as valuable and necessary to the industry. In their view, the industry is finally finding the right value for intellectual property, and, accompanied by changes in the law, will ultimately result in a more stable relationship in the industry in the latter part of the decade and the early part of the next century.

There are many ways that the industry is already accommodating the change in the playing field in intellectual property, primarily through cross-licensing through joint ventures, where the intellectual property becomes community property of the joint venture.

One issue of extreme importance in determining what future pricing in the market is likely to be, is of how fast the bit growth will be in the future. In mid-1988 in the midst of the shortage period, I pulled together five bit shipment forecasts by different manufacturers, and Dataquest, and these forecasts ran out to 1991 and 1992.

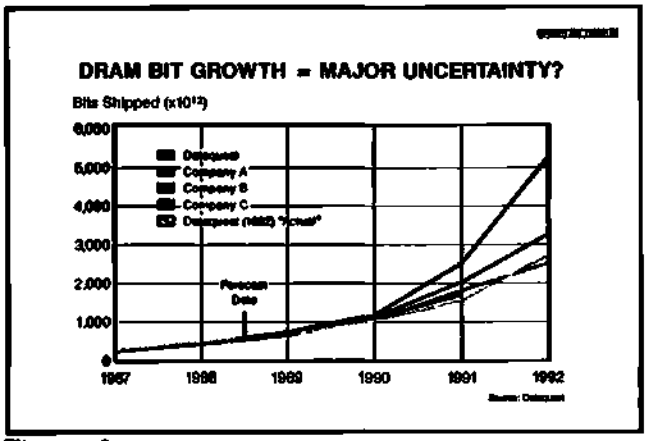

Figure 8

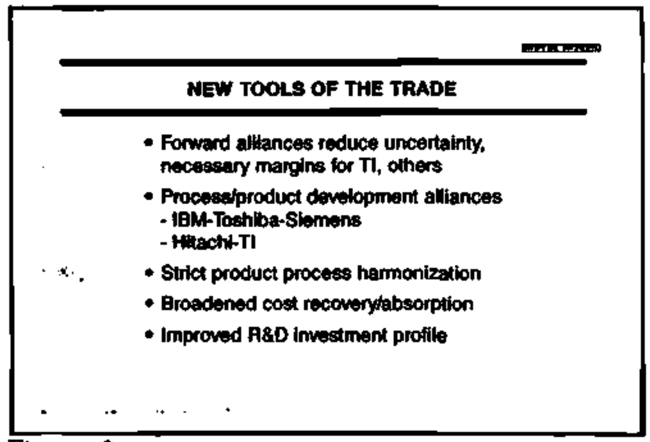

Figure 9

The bit growth rate had slowed down remarkably just before that, and we were trying to get a new reading on how fast the new bit growth rate would be. Manufacturers were selling into demand that was poorly defined, and we did not understand where all the bits were going. In spite of that, most of the forecasts for 1992 came within about 30% of what we think the actual number will be for 1992.

Depending on how strongly you embrace the learning curve as a predictor of forward costs or prices, you could argue that forward prices in the market would be predictable within about 10% if we could foresee the future bit growth rate as well as we did from the middle of the last shortage.

Moving on, to address some of the new issues manufacturers face, let's look at some of the means they have developed or that have evolved, in the last several years.

The first issue is forward alliances — relationships between a manufacturer and his customer that are established to short-circuit the market and reduce the cost of using the market to allocate the product. In the case of Texas Instruments, they got cash equity investments from many of their major customers, which allowed TI to accelerate building of their own facilities. At the same time, the customers got a guarantee of output from TI, and TI was guaranteed a certain high level of capacity utilization in the facility.

The under-capacity utilization in 1985 and 1986 was the primary cause of all the financial losses. Facilities were built and then boarded up because there was so much over-capacity. Forward alliances solved one problems and was a response to what happened in '85 and '86.

Other companies have similar programs — but the best contract has yet to be written in the future. I think this is a real exciting area for reducing the overall cost and risk of continuing to invest in the DRAM market.

The second item that has gained a lot of momentum in the last several years is joint process development. The companies that participate in these programs get a full unit's worth of technical knowledge for half a unit's worth of participation or cash outlay—or, in the case of the IBM, Toshiba and Siemens relationship, each company gets about a billion dollars worth of technology development to use, however they choose, for about one-third the price. This is a very important way of controlling the forward cost of technology development.

Another practice that TI uses is strict process harmonization to reduce the diversity of processes that you have to develop and support in enforcing that policy throughout their product line. This is also an effective, cost-saving tool.

Broadened cost recovery is another strategy. It should be true that broadline suppliers are able to have a better memory cost structure than those who are narrow producers, because they can absorb the cost across their entire product line.

That is a short list of new developments over the last several years that will be brought increasingly into play as we move out into the latter part of the decade.

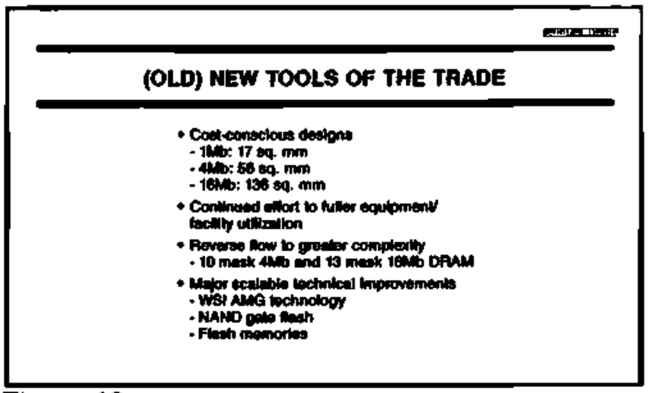

Figure 10

Traditional ways of getting the costs down are exemplified in a couple of ways. Cost-conscious designs — such as Micron Technology's die sizes — are an example. In the 1Mb, they are way ahead of the game. They have the smallest die in the industry. It yields about 800 gross die per wafer for a 6-inch wafer, and is a very competitive, cost-effective die. For the 4Mb — they are about even with the industry with the 4Mb with the 56-square millimeter die. In successive generations, they will bring this down to about 40 to 42 square millimeters. They are behind in the 16Mb arena — they are technology laggards, because their die size is bigger. I suspect when the final chapter is written they'll have the smallest die size there too just as they have at the 256K and 1Mb level.

There are always opportunities for improved capacity utilization—a faster ramp up to high volume—and that will continue in the future.

Another aspect of technology development where Micron Technology has done a good job is in keeping control of the complexity of the process. Currently, Micron Technology runs a 12 mask 4Mb DRAM, and you can compare that with what Mitsubishi expected the 4Mb to be at the 20 to 25-mask level. In the early part of next year that 12-mask process will be reduced to a 10-mask process. Their 16Mb is a 13-mask process, and although I'm not sure where they'll take it from there, that is substantially less than anyone in the industry right now.

Given that each mask costs about $10 to $15 million worth of capital equipment budget, this becomes a critical consideration if you can do it without cutting too many corners. Micron Technology is able to produce many more units out of their capital budget than other manufacturers who, as they moved from generation to generation, let complexity get out of hand.

Finally, there is the traditional way of doing things — the traditional technical innovations we see throughout the industry since the beginning of new cell structures and innovative ways of laying out the chips, that conserve silicon or are more cost-effective.

I have taken an example out to the end of the decade for illustrative purposes — to show you what the impact of a number of these innovations can have on a 64Mb produced in 1999 or the year 2000. The "business as usual" column is as if one manufacturer continues to go it alone, develops his technology along the path that he has for the last couple of generations and does not have any alliances or partnerships. His cost structure might be twice that of a manufacturer who took advantage of all of the existing tools of the trade during that time.

In the late 1990's, the most important consideration for a memory manufacturer or a technology leader is to invent the wheel just once. We have seen a lot of examples of this — mainly in alliances where there is co-development and sharing of the process and product development costs — and there is a substantial reduction in how much money you have to recover through the sale of chips. The 3-way sharing of the process development costs lowers the price that you have to charge for a 64Mb DRAM by about $4.00.

COST WORKSHEET: 64Mb DRAM -- LATE 1900s

	Business as Usual	Best Idea in Class	
Facility Cost ($M)	800	600	Mask count reduction
Process Development ($M)	600	200	3-way shared cost
Variable Costs ($M)	300	330	More wafers throughput, more A&T
Total ($M)	1,700	1,130	
Net Die Out (M Units)	100	120	Small die, fast ramp
Cost/Die	$17.00	$9.42	
Markup	x2.0	x1.75	Lower markup/guaranteed sale/broad cost recovery
Total ($)	34.00	16.48	

20K-200mm wafers/month
0.30-0.35μm process
Four-year depreciation schedule

Figure 11

Given that we now have about 3 or 4 alliances at the 64Mb level and just one at the 256Mb level, I think it will be almost impossible for other manufacturers who insist on going it alone, to remain competitive against the cost advantage that participants in those alliances will have

There are additional strategies for the late 1990s, I think sharing the cost is extremely important and that means when you develop a process, you want to proliferate throughout your product line as rapidly as possible and recover the cost either from your own product line, or from products run on your process on a foundry
basis.

An interesting aspect of the IBM-Toshiba-Siemens venture, is that the three parties each have a right to sell the technology outside the three principals. I think that this is another way that the industry collectively can invent the wheel just once, by selling the technology outside the joint venture, in order to recover some of the cost.

More traditional means involve looking across the entire industry to see who is doing what and try to adapt those techniques to your own business strategy. The history in the dynamic RAM business shows that no one has a monopoly on the truth, and a lot of benefit can be gained by looking at the way other people are doing it, both from a business point of view or a technical point of view, and then adopting some of those practices or techniques for your own business.

SCENARIOS 2000

- Common process development with alliances
  plus
  private process development for competitive differentiation
  So
- Fewer independent processes developed, with greater feeding from each process
- Value in design decommoditizes memories

Figure 12

If we look out 8 or 10 years, one thing that we will see as a result of process co-development in joint venture situations, is likely to be fewer standalone-ventures. "Enterprises" will develop collective common processes, and more of the industry output will feed off those few processes, either as a foundry user, as a purchaser of technology, or one of the principals who participated in developing the process from the beginning.

In the year 2000, companies are likely to have access to one of these common core processes, and then develop some of their own differentiated processes to create the high value-added specific to their product and strategy.

The same scenario applies to intellectual property. I remind you of what Mr. Picciano said about IBM and the fact that IBM and Toshiba and Siemens, before they went into the joint venture, defined the technology that they were each bringing in. They first defined their own intellectual property — then the technology that the venture develops becomes the common property of each of the participating companies. In the future, I think you'll find more intellectual property held jointly. This will spawn a whole new direction in the board rooms of companies, as they decide which intellectual property they want to have exclusive rights to, which they will want to hold in common with their joint venture partners, and which they want to license from others.

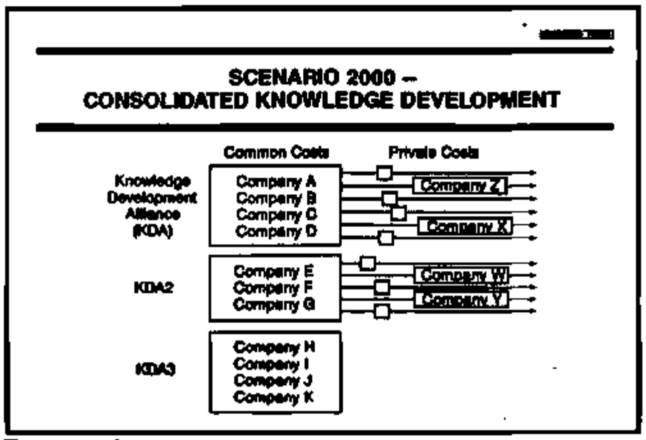

Figure 13

An industry structure that I can imagine unfolding in the next 8 or 10 years would be to have the process technology and the manufacturer dominated by consortia of 2, 3 or 4 companies each, with the rest of the industry feeding off these processes and manufacturers. It is not necessary that all of the common costs are undertaken by semiconductor manufacturers. There may be an opportunity for steel companies, or petrochemical companies or other companies in the process (or process development area), that want to participate in the semiconductor industry to become involved in the industry at that point. This manufacturing capability or process would still be accessible to other people who are design-intensive and pay much more attention to the marketing, as opposed the manufacturing aspects.

The history of the industry, over long periods of time is the history of knowledge, the creation of knowledge, and the diffusion of knowledge, throughout the industry. What we are seeing right now in the leading-edge technology development areas is a more refined, more formal handling of knowledge, both with the litigation of suing for royalties and limiting access to intellectual property, and through alliances which co-develop common intellectual property. I think these trends will continue throughout the decade and will be driven by the memory producers themselves.

Questions & Answers:

Question: For more specialized memories, will it be possible for them to get investment in their businesses as facility and process costs rise?

Mr. Mason: Definitely, yes. If those manufacturers can have access to a first rate process technology without investing the billion dollars themselves, then they are in the part of the high value-added part of the market and they should be able to get investments. That would be like Company Z or Company X, in figure 13 not the initial provider of the core process technology, but as the supplier of a differentiated capability.

Breakout Sessions

Presented by Dataquest Analysts

Procurement Issues 1993: Is the Law of Supply and Demand Subject to Appeal?

Ronald Bohn
Senior Industry Analyst
Dataquest Corporation

Mark Giudici
Director, Principal Analyst
Dataquest, Inc.

Mr. Giudici: Today, I'd like to talk about some issues taken from a 1993 poll of procurement clients. But first, some background.

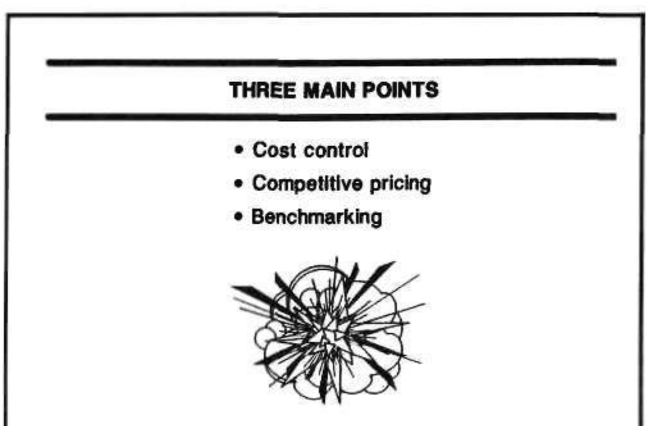

Figure 1

In procurement —these three factors: cost control, competitive pricing, and benchmarking currently are the main focus—and will remain so through 1993.

In the area of cost control, it is often a tops-down mandate from finance to procurement to continue their cost control efforts. This is not a new phenomenon for most procurement managers—it is getting a lot more attention in the board rooms these days.

Competitive pricing is a large portion of the cost control equation. As the system price wars continue, there will be continual pressure, at the component level, for competitive pricing. It is not that many procurement managers would need to hammer on their supply base—but they're getting forced to because of the price wars.

Benchmarking is a result of the global market place. As companies compete in the regions of the world, looking for ways to compare themselves with their competitors—on price, quality, and delivery—many companies are looking for ways of benchmarking their cost structure against the regional markets of the world class companies.

HISTORICAL PROCUREMENT ISSUES

	1993	1992	1991	1990	1989	1988
Cost Control	1	6	3	3	7	4
Lead Times	2	-	-	-	-	-
Availability/Allocation	3	4	2	4	1	1
Pricing	4	1	1	2	2	2
Developing Supplier Relations	5	10	-	-	-	-
Quality/Reliability	6	2	5	6	4	6
JIT/Inventory Control	7	7	4	5	6	9
Memory Products	8	-	-	-	5	5
On-Time Delivery	9	3	6	1	3	3
Packaging Standards	10	-	-	-	-	-

Source: Dataquest

Figure 2

This is the historical viewpoint relative to the current poll of top issues, as voted by our recent survey. Normally, cost control and availability or allocation have not been historical front burner issues, but they are this year. It's interesting to see that cost control, which embodies many of the issues that you see as less important, makes the number one rank. I think it is partially the view that there's a tops-down mandate that will be achieved. There is also a higher level of sophistication in procurement groups these days, noting that cost control embodies many of the individual issues that in the past have been highlighted as getting the price down or the quality up. Without a combination of these issues, cost control is going to fail to meet the total levels of achievement.

The development of supplier relations which, up until last year, was not even an issue, this year ranks number 5 and ties with the cost control function. This is a large area that is being explored by many of the procurement managers and procurement groups.

Tying in with the lead time and availability is the issue of memory products. The last time we had this as an issue was in the 1989-1990 time frame. This is a phenomenon that many users are looking at as posing possible problems down the road.

Packaging standards have become the number 10 issue. This is due to the high pin count ASIC world where standards are many. If you go with a certain package, will your supplier be around in 5 or so years, and will that standard be around.

From what environment did these responses come? In 1992, the electronics growth is not that hot—semiconductors are expected to grow about 5.4% this year—modest at best. We estimate 1993's electronic market growth rate to be a bit under 8%—7.7%. The capacity issue may come to the forefront because, although the growth rate of electronics is not that spectacular, the level of capacity being put into place over the past two years is very low.

There has been an incremental increase in demand that has held steady for the past two years, that has received adequate supplies in most areas. As this incremental growth rate continues on through the 1993 time frame, we see potential for some memory supply issues that may cause some companies to go on allocation—or result in a stretch in some key strategic parts that they may want to look at right now to secure capacity.

One issue that is flavoring the overall environment is portability. It is not just laptops or portable notebooks—it involves ASICs, integration, large pin-counts, fine pitch packages, and 3-volt products. Anything that runs on batteries is causing some concern on the user level because, although the supply base is getting there, it is not happening as fast as some folks would like. In addition, the design standards are not yet fully set.

The survey we conducted was primarily the result of 20 semiconductor procurement clients. These companies reflected over $170 billion in electronic sales in 1991, and about $1.7 billion in semiconductor purchases. For a relatively small sample, it represents a large portion of semiconductor buys.

PROCUREMENT ISSUES

Methodology/Demographics

- Telephone survey of top 20 U.S. semiconductor procurement service clients
- Represents:
  - Estimated electronic sales -- $170.4 billion
  - Estimated semiconductor purchases -- $1.7 billion
- Respondents:
  - Purchasing manager/senior buyer -- 50%
  - Procurement manager/component engineer -- 35%
  - Buyer -- 15%
- Industry representation:
  - Data processing/communications -- 50%
  - Industrial/consumer -- 43%
  - Military/transportation -- 7%

Figure 3

The respondents were about 50% from the purchasing manager or senior buyer rank, 35% from the procurement manager in engineering groups, and 15% from the buyer ranks—folks dealing with suppliers on a daily basis.

The industry representation closely matches the mix in the U.S.—data processing and telecommunication companies coming in at about 50% of the responses, 43% coming from the industrial/consumer groups, and military and transportation companies accounting for 7%.

PROCUREMENT ISSUES

Ranking -- Total Cost Variables

1992	Issue	1991
1	Quality	1
2	On-Time Delivery	2
3	Overall Price	3
4	Technical Support	4
5	Customer Service	4

Figure 4

Last year we asked our customers, of the total cost, how would you rank the variables that go into total cost? There is not much of a difference between last year's response and this year's—quality and on-time delivery are #1 and #2—followed by price, technical support and customer service. We continue to see that quality and on-time delivery are the prerequisites for cost control. Without these two functions, you are pretty much doomed, as far as getting costs under control is concerned. Quality is the key issue.

The differentiators as to who gets the business often comes down to price, technical support and customer service. How well you support your client, how amenable you are to changing price structures or whether people come in after hours to support customer's needs. These things are what is differentiating the supply base these days.

As the capacity bucket fills, the on-time delivery variable will also become a differentiator. Companies that can deliver on time, in volume, will be the ones that get the business.

PROCUREMENT ISSUES

Three Top Unmet Technical Needs

1.	Specialty/next-generation memories	30%
2.	ASICs	25%
3.	Standard logic alternatives	20%

Figure 5

We also asked what is not being done in the market place these days. These were the top three areas—33% of those respondents noted that specialty memories, VRAMS, next generations parts were not being adequately met in either quantity or in the type of speed that is needed. Related to that is that a quarter of the respondents noted that in terms of ASICs from a supplier, the ASIC solution and road map scenario is not clear, and continues to be an issue with the buyer. Besides the product issues, the supply base concerns (Will the ASIC supplier be in business in 5 years? Will the process that I choose be upgradable?) are important. Many companies are in the ASIC camp, but the road map is not clear.

Standard logic alternatives are an additional un-met technical need. Many companies that still have standard logic designs, are looking at a supply base that is down to half a dozen companies. They are asking if the next generation will tie them into a sole source situation—do they want to go that way. Not a clear picture. To 45% of the respondents the two issues of ASIC's STD Logic alternatives were a big concern.

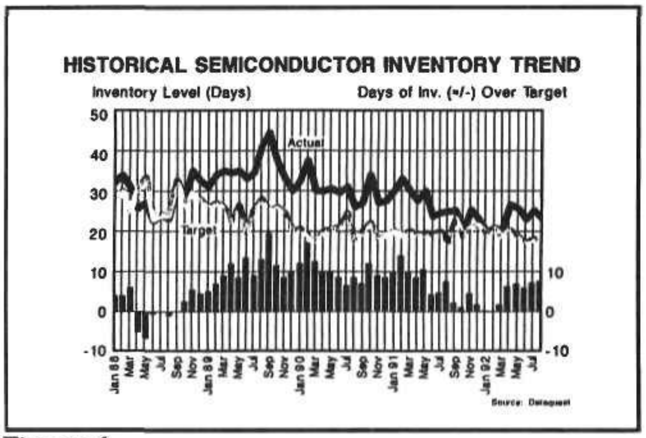

Figure 6

There has been fairly good inventory control over the past year, with no more than 7 days over target per our monthly Procurement Survey. The overall average target is about 18 days and the actual is about 23 to 24 days. That's the average. There are some companies with targets of 5 days and actuals of 10. The survey here had an average target of 17—with the actual in the 31 day area. This was due to the high industrial, consumer input. Next year, the target is expected to be around 14 days, and the actual should come down too.

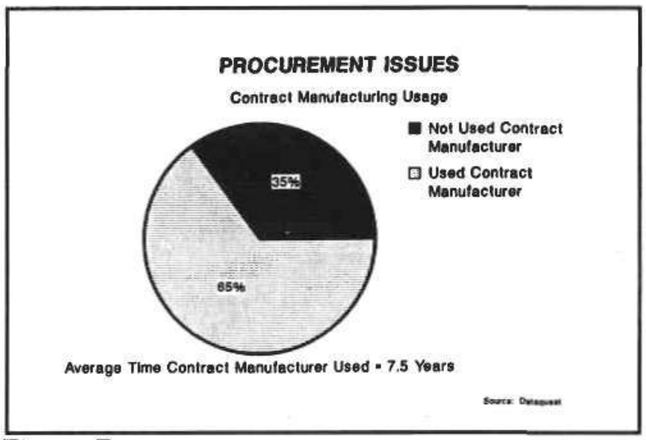

Figure 7

Contract manufacturing—65% of our respondents had used contract manufacturers. For those that had used one, the average length of time was around 7-1/2 years. For these respondents, contract manufacturing is not a new trend or fad. Many of the issues mentioned, lower price, equal or higher quality and lower inventory costs, among others, were why people used contract manufacturers. Where you can outsource—it is a viable option. If you have a proprietary product or process, or something that is strategic to your company's welfare—it does not make sense to go outside.

Cost control hinges on three areas: forecast discipline, quality, and price and delivery reviews. Without a regimented forecasting cycle—quarterly, semi-annually, or whatever (as long as it's steady)—cost control can be destructive. Quality is a prerequisite—not an option. To have less than top quality will doom your cost control efforts from the start. You may have the best price, on-time delivery, etc., but if you have in-field failures, it can throw all those savings out the window. So to start up with a good quality base is mandatory. Within the forecast framework, make sure the market dynamics do not get out of hand, and that regular communication is done regularly. That allows the flexibility of the forecast framework to occur.

RON BOHN

Mr. Bohn: Benchmarking—which directly relates to the cost containment issue—will serve as one backdrop to our discussion of the microprocessor and memory IC pricing trends.

The title of our session "Is the law of supply and demand subject to appeal?" – was chosen to highlight the conflict and interplay between market economics and the legal system. Legal developments that have affected IC procurement, will serve as a second backdrop of our discussion.

Intellectual property has moved to the forefront among issues for users of the 486 devices. In that area, there are two series of key cases involving the 486 and X86 processors. First, there is the 287 microcode case. This includes Intel's stunning victory over AMD during June of this year, and also AMD's victory prior before the California arbitrator regarding X86 rights. AMD's loss in the 287 case snapped closed AMD's window of opportunity for entering the 486 market this year to a large extent.

The second series of cases pit Intel against a couple of cross-licensees who would like to serve as foundries for would-be suppliers of the X86. This would include Intel against VLSI systems—via Hewlett Packard—against Cyrix and SGS Thomson (where Intel lost in a Texas federal court), and also against Chips and Technology and TI.

Intel views its legal actions as protection against patent laundering—the other parties view their actions as simple and legitimate foundry activity. The federal courts have issued conflicting decisions in this series of cases. Ultimately, the U.S. Supreme Court will get involved. The U.S. Supreme Court will make its decision in the next several years.

Let's focus on the critical 33 megahertz 486DX device. For the fourth quarter this year, our forecast came in at about $325 dollars, and Intel's list price for a thousand piece order is now $328. The real question is whether there will be a step function down in pricing for that part. The 486X took a step down in price in the second quarter of this year. Dataquest believes there will be a slashing of the 486DX price next year.

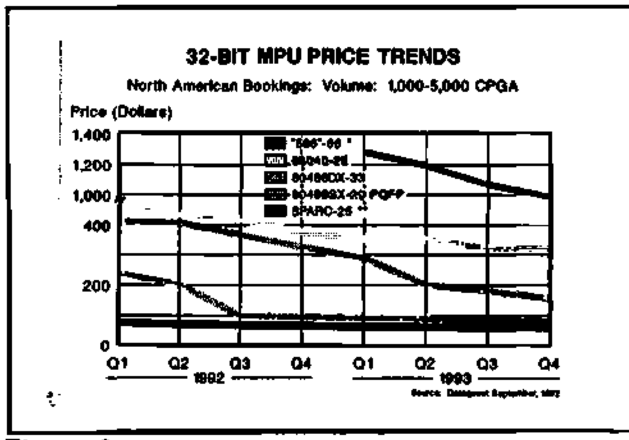

Figure 8

There are two factors that guide our assessment. The 586 device will be introduced the first quarter of next year (after the conference Intel named this device the "Pentium"). We do not really expect Intel to bring down the 486DX price curve until about that time. We notice that the spot market 486DX price has recently skyrocketed. Another factor that would affect the slashing of the pricing is the issue of second sources. We expect, during the first half of next year that AMD and Cyrix will enter this market place which will mean some kind of step down in pricing.

Regarding the Motorola 6804—Motorola is reporting quite impressive shipments of that part, including the embedded control version during this year. Over time we expect the pricing for it to be parallel—in terms of a price curve—with the 486DX, but lagging the 486DX price curve by 6 months to a year.

There are many more choices for 32-bit MPU suppliers. Today, the interesting category on this slide "Other"—which includes the IBM/Apple-Motorola alliance on the RISC power PC. In just a one-year time frame, they've announced a sample of that device. You can also put in there HP's Precision Architecture, and for 64-bit devices Digital Equipment's Alpha architecture.

Benchmarking is the corporate effort to learn and then surpass the performance parameters of the so called worldwide best of class, regarding any organizational process or function. Price benchmarking, based upon inquiries from Dataquest's SPS clients, boils down to the search for the "best price" being the lowest price. We do not believe that price benchmarking will be a problem-free exercise. We know that for some companies, price benchmarking may be more of a short term fad, as opposed to a long term trend.

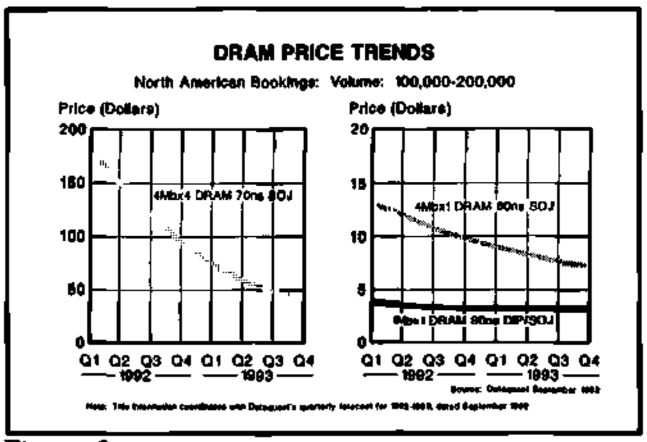

Figure 9

For 4Mb DRAM—What is the price benchmark at the North American contract volume for Q4-1992? If any buyers get $9.00 or less during this quarter, they have probably gotten the best price. Our quarterly price survey for the fourth quarter showed a price range from, on the low side $9.50—to a high of $10.50 from major buyers and suppliers. Even allowing for some discount for a higher volume—a half million piece part—you're still not going to get that close to the $9 level. By contrast, the pricing for the standard 1Mb and 1-DRAM is in the trough. Our price on the low end of the survey—4th quarter—is about $3.00. I saw some other regions under $3.00. So allowing for a volume discount, we would say the price benchmark for the 1Mb is about $2.85. In other regions, this year that price has been busted in Europe, Taiwan, Singapore.

For 16Mb DRAM—next year we expect the supply and demand for that part to go up and price to drop about 9 or 10% per quarter. The main point is, we don't see the pricing for it collapsing. That leads into the question of when there will be a crossover. Dataquest expects the "4 to 1" price crossover to the 16Mb device will happen during the second half of 1994.

The assumptions behind our forecasts are critical and allow us to capture the dynamics of changing market realities—such as the recent imposition of the European community of a 10% anti-dumping duty on the Korean suppliers. We thought the Micron decision in the U.S. would be last week. Recently I heard it's been delayed for about 3 weeks. We expect non-Japanese suppliers (Koreans) to increase their market share—but legal jurisdiction, trade laws, will serve as a barrier or balance to the expansion of any supplier network in the globe.

For 1Mb VRAMs—you should expect higher prices, more flat price curves, and periodic spot shortages. We don't see a price much below $6.50, $7.00 range. This contrasts with the sub-$3.00 price of the standard 1Mb DRAM. The lead times for 1Mb VRAMS are as long as 20 weeks, whereas the standard 1Mb DRAM are still under 10 weeks. We should expect users of specialized DRAM, over time, to experience periodic market shortages, shifts in the supply base, and a more narrow supply base— meaning somewhat higher pricing.

While the DRAM market is moving from the standard market to a more specialized market, the static RAM market seems to be heading the opposite way. The market during the past 5 to 10 years ago has been a series of fragmented specialty micromarkets, and now is moving towards more of a commodity market. Pricing for the 64-K fast static RAM devices is about $1.75. In other world regions, that pricing has fallen even lower. There is strong competition in Asia and Europe. In addition, for the 256K fast SRAM, the price benchmark is sub-$5.00 pricing.

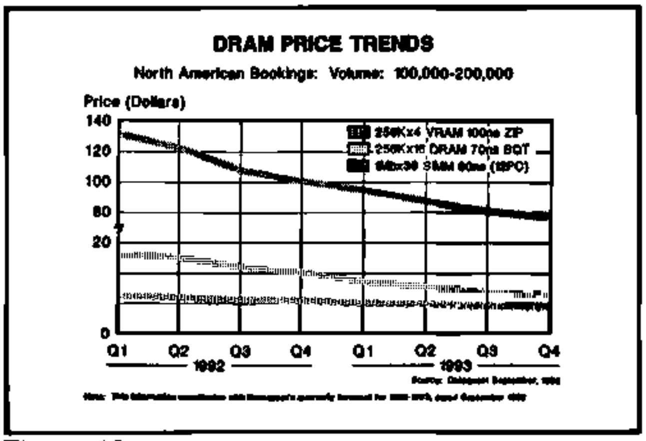

Figure 10

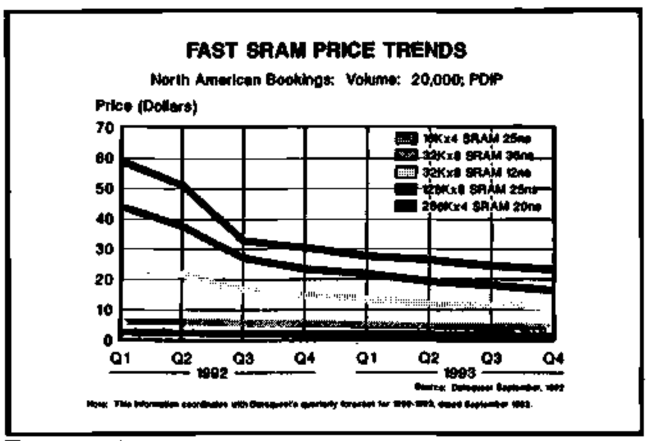

Figure 11

As we get above that, to the 12ns device, you have just several suppliers and much higher pricing. Until the supplier base widens more, you are not going to see intensely competitive pricing for that device. For the 25ns 1Mb static RAM the price benchmark is about $25. For the 20ns device – pricing is about $30. The supplier base for the 20ns and faster 1Mb SRAMS is still young.

For the 4th quarter, pricing has been quite brutal this year around the world. The user base that has been under tremendous corporate pressure to get better pricing. There are market exceptions—the 1Mb VRAM, the 486DX, and the bipolar standard market.

There is a transition from EPROM to flash memory. This will result in EPROM s firming up pricing and longer lead times.

The real critical point is regarding the 1993 DRAM capacity outlook. The basic 1991-1992 scenario—ample supply for the 4Mb device—or more than ample capacity. Suppliers like Toshiba have sent signals that they're not going to tolerate living in a role of excess DRAM capacity. Last year, Toshiba forecasted a 4Mb DRAM shortage for the middle of this year, and moderated their capacity build up. They still stand by that forecast.

IBM is going through tremendous changes. They are studying and evaluating entry to merchant market for IC business, including DRAM.

Flash memory was one of those technologies of tomorrow. Toshiba invented the technology in 1986, and ceded the market development and power to Intel. Before this year, the question was flash memory versus EPROM in terms of system displacement and hard disk drives applications.

This year, Intel made a strategic stroke of genius. They started positioning flash memory as being price competitive against DRAM. They positioned it in the user's mind and started benchmarking flash in terms of cost, *vis a vis* DRAM. They are gunning for the '94-'95 time frame of pricing parity between the DRAM and flash memory. The DRAM supply base is still large and expansive, so you are not going to see that scenario in '93.

Intel did this positioning so well that they have accelerated demand for flash memory, such that now there is a supply/demand imbalance. Intel got caught off-guard. We see prices still edging downward somewhat. The other players are still forging their strategies—those include Mitsubishi, Hitachi, TI, SGS-Thompson and AMD. The AMD 3-volt technology may be a real market winner in terms of 3-volt flash applications.

RISC/CISK is an emerging technology. A couple of years ago the strategy of RISC suppliers was to license their technology and drive their RISC technologies into PC's or other systems. Intel has turned that around. Their goal is to drive CISC technology into the workstations. System manufacturers look at systems performance, software compatibility and price. If you look at the performance at the Pentium (aka 586 or P5), that is going to be a competitive device for the workstation market place.

System manufacturers—including IBM, Digital, Hewlett-Packard and Sun— are leery of remaining dependent on anyone for a critical technology like MPU's—and that includes Intel. That's why at ISSCC, the new 1992 architectures were put out by systems houses.

IBM's role is a potential wildcard in this arena. Under their alliance with Intel (on the 486) IBM cannot sell these chips—they can only modify them. IBM is selling board level products and test marketing the market place. If you pull the 486 off that board and examine the price—it would be quite competitive.

MARK GIUDICI

Mr. Giudici: The 3-volt trend is currently in transition. The majority of 3-volt devices are screened parts built to 5-volt process parameters. For most applications, these parts are adequate. There are a few exceptions where you have fast, high speed or extreme temperatures.

Where you do need ultra high speed or low voltage, you will have to go with 3-volt speeds. These are parts that will be in the 80ns range and have fairly quick megahertz clock rates. The supply base for these parts is not that large. It is increasing, but as more folks come out in the ASIC arena, it will increase over time by about half a dozen suppliers.

The current price premiums for the rescreened parts ranges from about 25 to 30% for 3.3-volt designed parts, an additional 20 to 25% needs to be added, totaling 45 to 55% above a standard 5.0-volt device. As the supply base increases, the competition will increase, and the price premium should decrease to 10 to 15% by the end of next year.

One of the factors driving 3-volt technology is systems miniaturization. Smaller and smaller systems—whether on desks, laptops, or notebooks—are forcing more integration and more use of ASICs. With portability (anything that uses batteries) you need lower voltage. As you design circuits with less than a 0.5 micron gate width, voltages above 3.5-volts will short out the circuit. So you hit a physics wall. With the 16Mb DRAM and a lot of the advanced microprocessors, those products are being built under half a micron, and those products will need 3 volt supply voltages.

As these processors get up in speed—40 megahertz, 50 megahertz, and the nanosecond speeds are down to 60ns—there's no way to get those kinds of speeds with 3-volt rescreened 5-volt parts. You have to go to true 3-volt devices.

Is the 3-volt process going to be a short-lived item? As gate widths go down to .2 or .3 microns, are they going to be needing two volts? Right now, and for the foreseeable future, we expect to see the 3.3 volt standard to be with us. After 5 years—we are not sure. It's not going to change over night. The 5-volt standard has been with us for over 15 years now, so when it does change, there will be a lot of notice.

As the consistent price declines continue, cost control is going to remain the top issue that procurement managers and finance people will be looking at the in the upcoming year. As long as the semiconductor capacity is available and the price erosion continues at the system level, there is only more pressure for procurement groups to go for low prices at the component level. Then benchmarking is going to be looked at more and more for those companies trying to compare themselves in world markets to ensure that they stay competitive. How far that can be maintained is a good question, because if you take it to the logical extreme—if everybody gets the best price where does it leave the supplier?

Currently there is a quality improvement group called the Computer Industry Quality Consortium. This group consists of many large U.S. computer companies. They are defining quality in business practices specifications for the computer industry. This consortium will deal with quality and how the supply base deals on businesses practices. This idea ties in with the overall cost control function.

Semiconductor Outlook: Manufacturing and Equipment Trends

Charles Boucher, Ph.D.
Senior Industry Analyst
Dataquest Corporation

Mark FitzGerald
Semiconductor Equipment, Manufacturing, and, Materials Service
Dataquest Corporation

Mr. Boucher: Good afternoon, and welcome to this session on manufacturing tends. My name is Charles Boucher, and I am a senior industry analyst in Dataquest's semiconductor manufacturing and applications group. Mark FitzGerald, who is also a senior analyst in the group, and I will examine the outlook for semiconductor manufacturing, worldwide, and see what is in store for the next ten years. In particular, Mark will address the mechanics of the Japanese semiconductor slump, what caused it, and what the prospects are for recovery.

My talk is entitled "Semiconductor Outlook and Manufacturing Equipment Trends."

At least part of the Japanese semiconductor industry recession can be traced to the massive investment in 4-megabit DRAM manufacturing capacity. It will difficult for them to recover much of that investment, given the delayed ramp of 4-megabit DRAM demand, coupled with very rapid price erosion.

To begin, I would like to start by establishing what the ground rules will be for future IC production. The financial constraints the IC companies will face in the coming years have forced new methods to deal with spiraling costs of technology development and manufacturing capacity. I will also look at some possible configurations for future Fabs which are driven by the changing face of the semiconductor market. This will lead to a discussion of the way in which Fab changes will trickle down to the equipment suppliers—as they inevitably do. I'll wrap up with a few conclusions.

GROUND RULES

- R&D, fab, and manufacturing costs escalating
- Thin margins on commodity products
- Return on R&D, fab investment takes longer
- Pure technology no longer enough to differentiate products

→ Industry is maturing

Figure 1

Let's start by defining what the ground rules are in which future Fabs will operate. Very clearly, the cost of technology development and manufacturing capacity are growing at a very high rate. The standard cycle in the industry has been to use DRAMs as a technology development and manufacturing development vehicle. The earnings from the DRAM operation would then fund the subsequent DRAM generation. This is no longer necessarily true due to the declining profit margins in DRAM and commodity products, in general.

Another observation is that the length of time that's required to introduce a product into manufacturing (from the time of its initial development cycle), is increasing with each new generation of technology. As the advances become costlier and take longer to implement, it is really not clear that technology alone is a sufficient product differentiator. What that says, is that industry has undergone a fundamental shift from being technology driven to being market driven. That is a theme that has become clear during the talks of the past few days.

What this points to is that the industry is going to start maturing. It is maturing—and we have to treat it as a mature industry when we look at the future in R&D and manufacturing development investment.

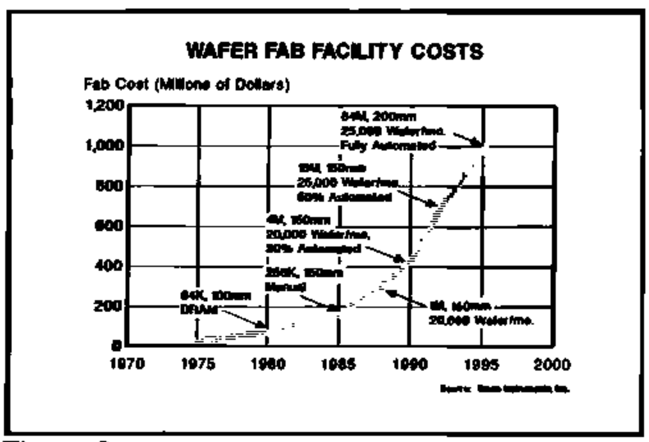

Figure 2

Let's take a closer look at what I mean by high Fab costs—the escalating cost of DRAM Fab construction. The vertical axis shows the cost, in millions of dollars, to construct a DRAM factory of a given generation and wafer size. These are 20,000, 25,000 wafer per month type of facilities. The horizontal axis shows the approximate date that the given DRAM has entered volume production.

What is clear is that as the line geometries shrink, and contamination control requirements become more demanding, the costs of building a state-of-the-art facility are increasing at an exponential rate. In fact, the expected cost for a 64-megabit DRAM facility will be in the neighborhood of a billion dollars. If we extrapolate the graph further, the expected cost of a 256-megabit facility will push $2 billion. Many people are starting to question whether these levels of investment are justified.

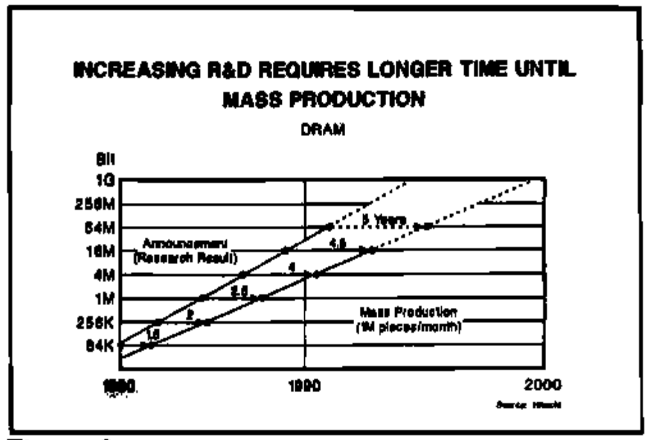

Figure 3

Another source of pressure on the IC companies is the increasing length of time from the beginning of the development phase to the point at which the DRAM actually goes into mass production. This graph shows how the length of time is increasing with each technology generation. The development has to begin earlier as the process complexity increases. As an example, the 256-megabit DRAM has been in development for over a year, but it's not really expected to generate any significant revenue until close to the end of the decade. It is no wonder, faced with these types of uncertain markets, that I see manufacturers losing sleep when deciding how to commit their development dollars.

This chart shows the cost of new Fab construction, broken down into facility costs (including land building and utilities) and Fab equipment costs in the years 1991, 1995 and 2000. As you can see, the cost of equipping the Fab is rising at a much higher rate than the cost required to build the clean room. The reason for this is that the equipment is being asked to do more, to include more functionality, to handle larger wafer sizes, reduce defect levels, and to increase wafer throughput Many stringent demands are being made on equipment manufacturers.

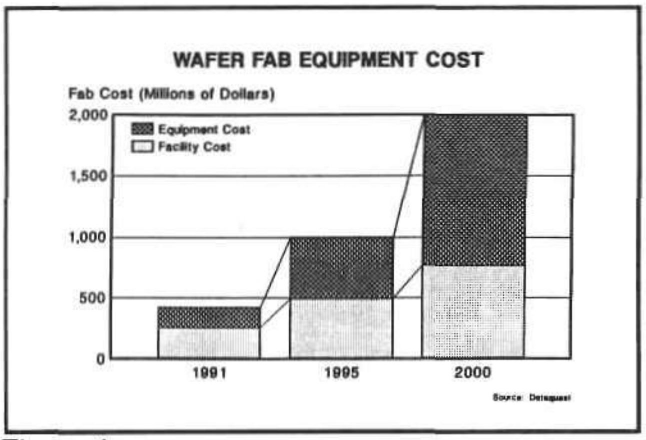

Figure 4

As the advanced Fabs shift from batch processing to single wafer processing, more equipment is required as the average wafer throughput begins to go down.

What this means, is the wafer Fab equipment suppliers are going to be the center of any strategy to control escalating Fab costs. One report that was issued by Professor Ohmi's group at Tohoku University, suggests that to control rising equipment costs, all equipment suppliers would need to manufacturer equipment with a common process chamber and common internal and external architecture. Given the competitive nature of most Fab equipment suppliers in this industry, this doesn't seem very likely. We're having a lot of trouble just getting them all to sign up for a common external interface, let alone, sign up for the same internal chamber.

What this means is that when you pay more to build your Fab, and your market pressures do not allow you to sell your product for a higher price, the time it takes to recover the costs of that Fab goes up. This graph shows the time to recover the cost of the Fab and equipment for different DRAM generations. This includes facility costs, but does not take into account technology development costs. What you can see is the pay-back time increases rather dramatically. According to this calculation it will take nearly twice as long to recover the investment in a 256 megabit DRAM factory than to recover the initial investment in a 4Mb factory.

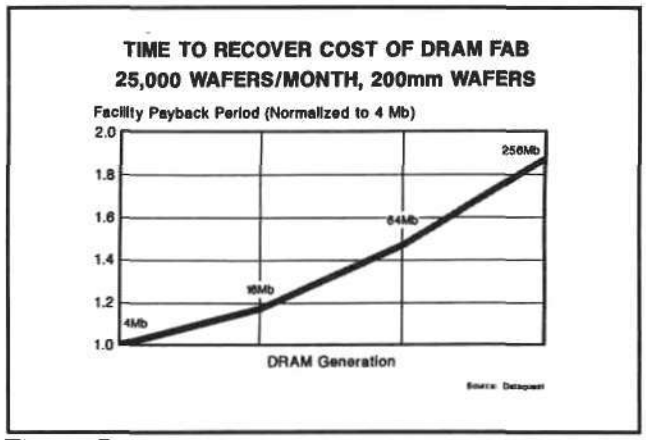

Figure 5

This is our best case scenario because it does not include the cost of research and development, or the burden of carrying that cost over a very long time period.

You either must have extremely patient investors or you have to look to other means to accelerate your return on investment for the factory. This is the total cost of equipment, clean room and land.

ADAPTATION TO ENVIRONMENT

- Development of technology, products, and manufacturing resources strongly driven by cost
  - Greater sharing of process/equipment across product lines ("harmonious" technology development)
  - Longer life cycle for plant and equipment
  - Standardization
- Multinational alliances
- Value added through design, rather than process

Figure 6

How will IC companies deal with this type of environment? They have decided on several approaches which will be implemented pretty rapidly. One way is to amortize the cost of technology and manufacturing over many different product types and over a longer time period—to extend the lifecycles of plant and equipment. TI coined a term called process harmonization that has been used to describe this approach.

Another approach is to standardize things like gas interfaces, the interface between the equipment and the Fab, and Fab subsystems such as ultra pure water. That is one way to contain the cost of putting together a facility. That will require a tremendous cooperation between all the parties involved—the Fab, suppliers, equipment manufacturers—everyone must work together in order to make this approach work.

Alliances with other companies are becoming a solution which more and more companies are participating in. I think you have seen that in some of the talks given by IBM and Intel. There is a very strong interest now in setting up strategic partnerships.

Another more sweeping strategy is to target higher value-added product markets. There is a shift in emphasis away from standard commodity products, and toward more highly integrated value-added products with proprietary architectures or high proprietary content.

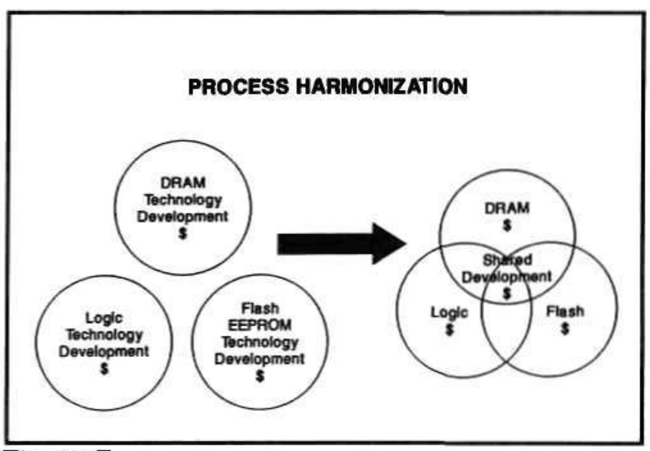

Figure 7

Let us take a look a some of these responses. This is a schematic illustration of what I mean by process harmonization. In the past, people have used disparate groups to develop their own technologies with very little overlap. There is a high degree of redundancy, and you pay more for the technology than you need to. If you can do this in an integrated fashion, you can minimize the degree of redundancy and save your technology development costs. If you have a more cohesive process, it is easier to mix different products in a factory. It is also easier to move a different product into a factory as it moves down its life cycle.

What is a realistic target for process harmonization? The goals that TI set up are to maintain about 2/3 of the recipe steps in common to each type of product flow. Obviously, DRAMs and EPROMs are not going to be 100% compatible because they have specific modules—but, 2/3 overlap would be a very good number.

The other thing is to maintain commonality on tooling and equipment to get a higher degree of overlap in the equipment mix. What this does for you is to save equipment evaluation expense because you are looking at one equipment set rather than several different equipment sets. It also lets you to utilize your equipment more heavily and reduce your overall equipment capital budget.

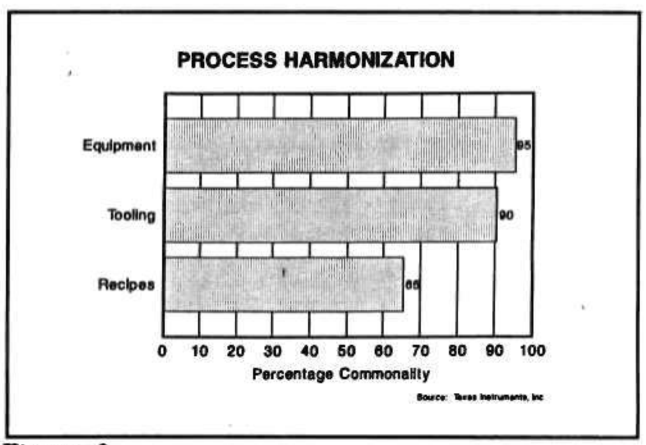

Figure 8

Partnerships, particularly development partnerships, are becoming —in the '90's—what mergers and acquisitions were in the '80s This table shows a partial list of some of the recent alliances that have been announced. If you look at the number of 64 megabit, 256-megabit DRAM alliances, it is clear that this concept of sharing costs and risks has become popular.

GLOBAL ALLIANCES

Alliance	Product/Technology
IBM/Toshiba/Siemens	256Mb DRAM
IBM/Siemens	16Mb/64Mb DRAM
AT&T/NEC	64Mb/256Mb DRAM
TI/Acer	4Mb/16Mb DRAM
TI/Kobe	4Mb/16Mb DRAM
TI/Hitachi	16Mb/64Mb DRAM
Intel/Sharp	Flash EEPROM
AMD/Fujitsu	Flash EEPROM
IBM/Toshiba	Flash EEPROM
IBM/Toshiba	Flat Panel Displays
Apple/Sharp	PDA
Apple/Toshiba	Multimedia PDA

Figure 9

The DRAM joint development teams have not yet addressed the issue of expanding Fab costs. They still have not gotten together on how they are going to pay the enormous capital investment to build tomorrow's DRAMs. The reluctance of the end users to pay a very heavy premium for high density memories makes it difficult to realize much of a return—unless you make changes to accelerate that pay-back.

The future DRAM Fab is going to base most of its supplier decisions on cost per good die out. This is going to outweigh almost all other considerations. Raw technology is no longer a differentiator—you need to look at it from a cost basis.

An alternative approach for the IC company is to shift to more profitable products and produce multiple products within a factory. What this Figure 4ows is some of the advantages that can be realized by running the correct product mix. The point is to demonstrate how slim the profit margin is for DRAM. I want to emphasize that the assumed yields for this calculation are hypothetical, and do not in any way represent proprietary company data. An 80% probable target for a 4Mb DRAM is not that far off—and you are looking at $2600 a wafer. That is not much money, considering the amount of technology that goes into it.

VALUE ADDED THROUGH ARCHITECTURE

	386DX	486SX	Ethernet LAN Chip	4Mb DRAM
Process Technology	1.0 Micron Double Metal	0.8 Micron Triple Metal	0.8 Micron Double Metal	0.8 Micron Single Metal
Die Size (mm^2)	42.6	72.0	38.7	90.0
Gross Die per 200mm Wafer	657	365	729	310
ASP ($)	90	119	30	10.5
Assumed Final Yield (%)	50	40	50	80
Revenue/200mm Wafer ($)	29,563	18,329	10,935	2,604

Source: Dataquest

Figure 10

If you look at the amount of profit per wafer—even running at a 40% yield level from an Intel 486 chip—it is clear why Intel can joke about paying billions of dollars for a new Fab to build tomorrow's products. That is the kind of market that companies need to move toward.

As the Fab evolves in response to the changing business environment, the governing principles are going to be cost-control and efficiency. This means that anybody who provides equipment, materials or services to the factory, is going to be held accountable for extremely high quality and absolute minimum cost per function.

FAB EVOLUTION

- Dominant characteristics of new fab facilities:
  - Cost control
  - Efficiency
- Fab architecture will be product-dependent
- Commodity product fabs will be large, optimized for high yield on standard products
- Emergence of highly integrated ASICs/ASSPs will generate unique fab requirements

Figure 11

The architecture of the Fab will be dependent on the product, or product mix, being run and commodity products (large conventional Fabs that follow that trend) are going to place an extremely premium on high yield and very low cost per function. Companies that concentrate on ASICs and application specific standard products (ASSPs) will build Fabs with the capability of running many different products. The emphasis will be more heavily placed on flexibility and adaptability rather than sheer cost per function reductions.

FAB TYPE A: COMMODITY PRODUCTS

- DRAMs and SRAMs will continue to drive process and manufacturing technology:
  - Smallest geometries
  - Largest wafer size
- Law of nature: DRAM fabs must turn a profit
- Emphasis will be on minimizing operating costs:
  - Very high, reproducible yields
  - High degree of automation

Figure 12

If we continue to follow the evolution of the commodity product Fab, it will continue to be a large Fab and will run the most aggressive process technology. It will be the first facility to move to larger wafer sizes, and the quest to achieve lower costs per die out. Every decision made by the Fab planners and the manufacturing teams will be driven by one overriding concern—cost and cost control. This kind of optimization will be done at the expense of flexibility, and is geared toward very large numbers of wafer outs.

FAB TYPE B: APPLICATION-SPECIFIC PRODUCTS

- ASSPs place heavier demands on flexibility
- Level of integration increases with shrinking feature size:
  - Microprocessors now have CPU/FPU, RAM, DMA, cache control, interrupt, bus control logic on board
  - ASIC fabs now offer microprocessor cores in cell library
  - Interconnect-intensive processes
- Capability of running many products, more than one process:
  - Advanced factory control software
- Short cycle times
- Heavier use of process tool clusters and microenvironments

Figure 13

The other type of Fab that will emerge is the facility designed for production of more specialized high function, high value-added products. This poses a special set of problems to the Fab designer. Since many products are going to be running concurrently, flexibility is very important. These products will leverage shrinking feature sizes by pulling more function from the PC board back onto the silicon. Examples of that trend can already be seen. If you look at the increasing levels of integration on standard microprocessors, and you see many ASIC suppliers adding microprocessor cores to their ASIC libraries. As an example, IBM recently announced their power PC 601 RISC chip is going to use 4 levels of metal, plus 1 metal local interconnect layer. These will be very interconnect-intensive products. The mix of equipment in the Fabs is going to be heavily slanted toward that back end process module.

The need to run the various types of products is going to place a heavy demand on very sophisticated factory control software. The tendency of such products to have short life cycles will make cycle time on the Fab a very strong criteria. This is likely to promote the use of process tool micro clusters and micro environments for cost control (in terms of constructing the Fab) and user configurability (when you move to different processes or different products). This is the sort of Fab architecture that is being promoted very heavily by Sematech, in the "Fab of the future" plan.

Our considerations, so far, have centered around problems facing the IC manufacturers. Let's turn now to what this means for equipment suppliers if they want to continue to keep their Fab customers happy.

Cluster tools will clearly be an important part of future Fabs, especially the type of Fab just mentioned. But cluster tools have to add value where needed. Nobody is going to buy a cluster tool just because it is a cluster tool. The days where people sold products based on sexy new technology are gone. Everybody is now looking at cost of ownership.

MEETING THE CHANGING EQUIPMENT NEEDS: CLUSTER TOOLS

- Transition to cluster tools driven by:
  - Economics
  - Enabling technology
- Economics:
  - Reduced capital investment
  - Decrease in number of process steps
  - Reduced cleanroom footprint
  - Short cycle times for quick-turn fabs
  - Reliability
- Cluster tools will be used for production when they confer an economic or technical advantage

Figure 14

The tool must offer one of two fundamental benefits—that is either to reduce cost or provide enabling technology. If the tool does not offer an improvement in one of those areas, it will not be widely successful.

That functionality does come at a cost, however, and that is a higher selling price for equipment. This represents a win-win opportunity for both sides. The equipment vendor must keep in mind that the clustered system will be a viable production tool only when it confers some sort of a technical or economic advantage.

The evolution of IC community alliances and partnerships changes the market structure. Alliances formed with several companies really appear as one company to the equipment vendor of the future. If development partnerships bloom into production partnerships there will be less redundant capacity built because they will plan more efficiently. That means the total available market for semiconductor equipment units will be reduced. The end result is that the relationship between the equipment supplier and IC supplier is especially critical. The IC company is likely to ask the equipment supplier to become a partner with him while he works toward an optimum cost effective process solution. In fact, this movement is already under way.

Increasingly, the decision to buy equipment is being driven by cost of ownership issues. The customers will decide to deal with the equipment vendors who offer the best total package of hardware, software process capability, low cost of ownership, and the very best applications and service support.

MEETING THE CHANGING EQUIPMENT NEEDS: MARKET STRUCTURE

- IC alliances changing the market structure:
  - Reduced number of customers
  - Better worldwide fab capacity utilization -- reduced TAM
    - Relationship with IC manufacturer critical
- Role of large IC companies and Sematech in fab equipment development
- Equipment selections based on "total package":
  - Hardware and software
  - Process
  - Cost of ownership
  - Applications and service support

Figure 15

MEETING THE CHANGING EQUIPMENT NEEDS: COST OF OWNERSHIP

- Equipment "must haves":
  - Higher wafer throughput
  - Reduction in defects added
  - Greater uptime
  - Reduced consumables
  - Smaller footprint
  - Flexible configuration: standalone, cluster, or microenvironment-compatible

If "yes" to all of the above, equipment can also have a higher ASP

Figure 16

In order to be a successful equipment supplier, it is important to meet the changing needs of the Fab. The sector that historically has driven the process and has the equipment technology, is also the one that is under the most pressure right now— commodity memories. These products are going to continue to drive the baseline technology and to be a supplier to those Fabs, new equipment must continue to drive down the cost of ownership. That is a phrase you hear over and over. It means continuous improvement in wafer throughput, fatal defects added, tool reliability, etc.

The equipment must be configurable, either as a stand-alone unit as part of a cluster tool, or compatible with micro environments. In other words, you must be able to meet many different customer needs. Of course, if the equipment has the right set of attributes it can also have the most important one—a high selling price.

CONCLUSIONS

- The IC industry is maturing, and can no longer pursue a headlong, technology-driven growth strategy
- The guiding disciplines for the industry will be cost control and ROI
- Fab companies will resort to alliances, changing product mixes, and extending the fab and technology life cycles
- Suppliers must adapt their strategies to recognize the needs of IC manufacturers
- In order to realize acceptable ROI, equipment suppliers must:
  - Partner with IC makers, with each other
  - Become truly multinational companies
  - Add value where it's needed: low COO, high flexibility

Figure 17

The industry is showing the characteristics of a mature business. Future business growth must be planned very carefully, and future investments analyzed properly. Return on investment analysis is gong to be a central decision making point, and new product and technology development will be subject to those criteria.

In order to moderate the cost and risk of advanced development, companies will be partnered together. They will amortize their investments over longer time periods, thereby extending their plant and equipment life cycles.

Suppliers of equipment and materials to the IC companies must recognize that shift and modify their strategies accordingly. In many ways, Fab suppliers are facing the same problems as the IC companies themselves. Some of the same solutions may be appropriate. The equipment companies must become part of the Fab development team—working toward a common goal.

The equipment company that wants to succeed in the remainder of the decade, clearly has to be a global company. Your customers are going that way, so you have to be there for them. The value has to be added where it is needed. Fabs are no longer swayed by exotic technologies or novel techniques that simply do not offer a real tangible benefit—they cannot afford to be.

Questions & Answers

Question: What is the definition of a cluster tool?

Mr. Boucher: Dataquest defines a cluster tool as a tool that combines more than one process function on a common mechanical chassis. There are different types of cluster tools. There are some that are simple parallel processors with several CVD chambers sharing a common mechanical chassis with a central wafer loader.

When we talk about cluster tools in reference to the type of cluster island, micro-environment Fab I referred to, you are talking about clustering together several operations—a CVD with an etch step, a custom lithography track system, a stepper where you are putting disparate systems into one.

Question: What is the actual pay back time in Figure 4 The Figure 4ly showed the payback time relative to the 4Mb DRAM.

Mr. Boucher: The pay-back for a 4Mb Fab is about 18 months at current price.

Question: What do you mean by process harmonization—will you be able to run several types of devices through a common process, and will that offer an advantage to the companies who are able to do that?

Mr. Boucher: You can achieve a high degree of commonalty. I have seen companies that have product groups doing their own process development, and they use subtly different processes. They may change a gate oxide thickness by 10 angstroms, or change the temperature by 10°. But they require different recipes in the Fab—you have to maintain those recipes. If you look at the whole process with an eye toward minimizing unnecessary redundancy, it is easy to keep isolation modules, gate oxidation modules, standard. The only things you tend to change are the capacitor module in the DRAM, which is going to be different and unique to the product. In many of the standard steps you can maintain high commonalty which offers a big advantage in terms of cost savings.

Question: Is there a standard Fab cost of ownership model available?

Mr. Boucher: Sematech has issued their attempt at a standard cost of ownership model—I think it is very well done. The model is for equipment cost of ownership. They are now working on a Fab cost of ownership model that takes into account many of the economic factors that come into play in determining the Fab cost. I think their cost of ownership model for equipment is very well done and I think they'll probably generate a similarly good model for the Fab. The U.S. industry has adopted it, and I'm seeing more companies overseas use that model to do a comparison for equipment evaluation.

Question: Can manufacturing alliances really work?

Mr. Boucher: I think it can work. I think there are some manufacturing alliances going on right now, TI-Acer for instance, with their DRAM alliance. I am sure there will always be some fine tuning in terms of who gets the last penny when you split up the pile. That seems to be working pretty well.

MARK FITZGERALD

Mr. FitzGerald: My presentation will focus on the Japanese market and what the downturn means for Japan. The title of my talk is "Japan Stumbles."

Here are a few of our 1991 statistics to give you a feel for the importance of the Japanese market when it comes to manufacturing.

A SECULAR SHIFT IN SPENDING

Semiconductor Capital Spending, Compound Annual Growth Rates

	CAGR (%) 1991-1996	CAGR (%) 1986-1991
North America	8.1	13.1
Japan	**9.3**	**25.0**
Europe	7.9	10.0
Asia/Pacfic	12.0	39.1
	6.9	20.4

Figure 1

In 1991, according to Dataquest, Japan accounted for 47% of the worldwide IC production, 43% of the worldwide capital spending, 49% of the wafer Fab equipment purchases, and 50% of the silicon wafer starts. So the downturn in Japan is going to ripple through the entire global market, especially when you consider the investments in overseas facilities that Japanese companies have made in the last 10 years.

I will spend most of my time talking about capital spending, because capital spending is the best leading indicator of the health of the industry.

I did a comparison of our forecasts for the previous six years. I chose 1986 as the base year for the comparison because that's the year we were coming out of the last major recession for the industry. As you can see, our view of the world today is quite different than it was 5 or 6 years ago, when we were experiencing the recession. There are several reasons for that. At the forefront of these is the deceleration in growth of capital spending by Japanese companies. This deceleration is going to have a big impact on the global market.

Take into consideration that the Japanese firms have invested heavily in two of the major foreign markets—North America and Europe. The major Japanese device manufacturers facilities now include Fujitsu, Hitachi, Matsushita, Mitsubishi, NEC, Sharp, Sony and TDK. In Europe, we're talking about a smaller investment on the part of the Japanese, but still very important when you consider the size of the European market.

The facilities in Europe include Fujitsu, Hitachi, and NEC. Mitsubishi is half-way through a facility that they have not quite equipped at this point. When the Japanese companies pull back over 1992, and decelerate the growth levels of investment in front-end facilities, North America and Europe are two markets that will be hit hard. In fact, in our view, North America would be down more heavily if it were not for the microprocessor franchise of many of the North American market companies (mainly Intel and Motorola).

Asia Pacific will be less impacted by the Japanese deceleration in capital spending just because there are no Fabs (or not the level of investment in this area by Japanese companies) though we certainly expect this to change over the next 5 years.

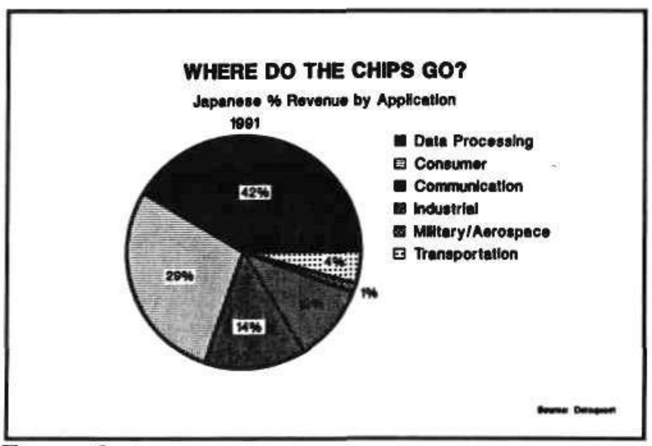

Figure 2

There are two markets that account for the lion share of the Japanese process revenues—data processing (computer systems and the peripheral equipment associated with data processing), and the consumer market which Japan is recognized for worldwide. Those two markets account for 71% of the total IC's consumed in Japan. The changes that are occurring in those markets in Japan today, represent some of the reasons that the Japanese semiconductor industry is slowing the pace of investment.

This is our global forecast for the systems business—As you can see it is the PC and workstation market that is growing, and the mid-range market and the mainframe market that are flat and decreasing. In fact, this forecast was done at the beginning of 1991 and the mainframe market looks like it will be down even further in 1992 than our original forecast. You are seeing companies like Amdahl with a new product that has really fizzled, and some of the problems that IBM and DEC have experienced.

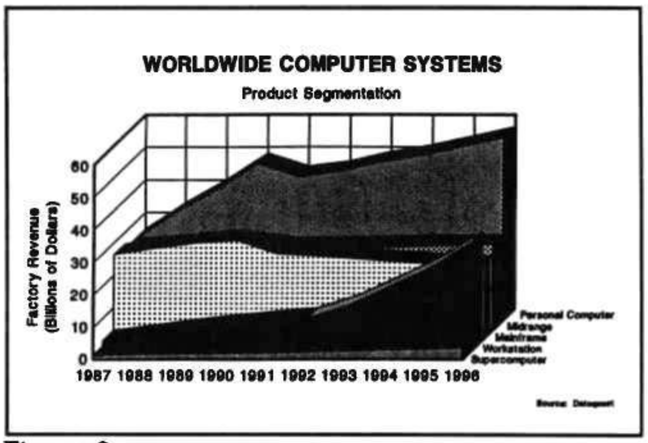

Figure 3

This is a worldwide forecast. Keep in the back of your mind what is happening in the personal computer and workstation market, versus the mid-range and mainframe market.

I want to focus on the Japanese market and the major systems manufacturers. These are the top four systems manufacturers—Fujitsu, Hitachi, NEC and Toshiba. I have taken their 1991 sales and broken them out in percentages and total revenues for their systems business. This includes the boxes and service contracts. The major companies are highly leveraged in the mainframe and mid-range market. Fujitsu and Hitachi have the lion-share of their businesses in these markets. If we look at NEC, we see just under 50% of their systems market is in mainframes and mid-range products. You can see how these companies are into the wrong products.

WRONG PRODUCTS

1991 Computer System Sales Revenues in Millions of Dollars

	Fujitsu	Hitachi	NEC	Toshiba
Supercomputer	5.1	1.9	1.9	N/A
Mainframe	46.1	84.4	23.5	6.4
Midrange	37.0	6.3	23.5	18.5
Workstation	3.7	4.7	3.1	2.0
Personal Computer	8.1	2.6	48.0	73.1
Total Revenues	4,735.5	2,366.1	6,257.6	1,846.4

NA = Not applicable

Source: Dataquest

Figure 4

I want to address Toshiba's and NEC's strong PC business. At first glance, this might seem like an advantage for these companies, but when you consider some of the dynamics in this marketplace, we think that these companies will face problems even in their PC business.

NEC has the largest share of its PC business in Japan with 45% of the PC market in Japan. That is unheard of when you compare it to any other region of the world—Europe, Asia Pacific and the U.S. For instance, in the U.S., the leading PC manufacturer might have a 12-15% market share.

We expect that to change over the next five years because NEC's prices are very high. They have their own operating system. As DOS-based systems penetrate more of the marketplace, as Windows penetrates, this will open the opportunity for foreign competitors to enter the marketplace. Specifically, I would point out the U.S. companies—in the midst of a PC war, and looking to Japan as a major market for expansion because of the price differentials.

Toshiba has come further down the learning curve in the PC business. They have a large notebook business overseas—and a lion's share of that business here in the U.S. They have already experienced the downturn. Some of the problems at Toshiba, this year, are associated with weak sales in the overseas notebook market.

These companies are either in products that are low growth markets over the long term (over 5 years), or they are in a market place where they do not have the cost position or cost structure to compete. In fact, these companies have chased the IBM model for years. For the past 20 years Japanese companies have been catching up and modeling themselves after IBM. Just as they are arriving, the whole IBM model is collapsing. Long term, these companies are going to have many structural changes, just as IBM has had in the last couple of years.

WRONG MARKETS

1991 Computer System Sales

	Worldwide Revenue ($M)	Percentage by Region			
		Japan	United States	Europe	Asia/Pacific-ROW
Fujitsu	4,735.5	83.5	0.4	15.3	0.8
Hitachi	2,366.1	71.2	22.6	6.2	0
NEC	6,257.7	74.7	7.4	4.6	13.3
Toshiba	1,846.3	47.4	19.0	27.0	6.6

Source: Dataquest

Figure 5

They have focused in the wrong markets and are heavily leveraged in the Japanese market. These are systems sales. Three of the companies have over 70% of their systems sales in Japan. With the current downturn, japan is the market that has been hit the hardest. With capital spending budgets being cut throughout the Japanese industry, it is a difficult time for the Japanese systems vendors. When you look at what is happening with the financial markets in Japan—in particular, security firms and banks and some insurance firms, (the biggest buyers of big mainframe systems), you can understand why these companies are currently having difficult times in 1992. They do not have any geographic diversification to soften the downturn.

The computer systems market is changing. We do not think that Japanese companies have adopted a global point of view to compete aggressively in these market places. We expect the competition and their own domestic markets to intensify, as well.

Just as we have seen in the U.S. market for computer systems—from mainframes to PC's—the price margins enjoyed in Japan, at this point, look in jeopardy.

What does this mean for the Japanese IC business? By no coincidence, the top four systems manufacturers in Japan are also the top four semiconductor manufacturers. An important point is that anywhere from 15 to 29% of their IC sales end up in their own products. So if their systems business is really going to hell in a hand basket—which it has over the past year—then you can expect that to filter down into the semiconductor operations. The semiconductor operation is tied very closely to the opportunities offered by the systems business.

JAPAN'S TOP FOUR

1991 Semiconductor Sales

	Worldwide Revenue ($M)	Percentage Captive	Percentage DRAM	Percentage Japan
Fujitsu	2,705	29.0	18.6	73.0
Hitachi	3,765	20.0	17.6	68.2
NEC	4,774	26.0	15.6	72.9
Toshiba	4,202	15.0	22.8	58.0

Source: Dataquest

Figure 6

The systems business is such a large consumer of DRAMs—PCs alone account for 50% of the worldwide DRAM consumption. I f you throw in the rest of the data processing equipment, such as printers and media storage devices, then you would probably end up with 75% of the DRAMs and data processing markets. This has a big impact on the Japanese DRAM business, as well.

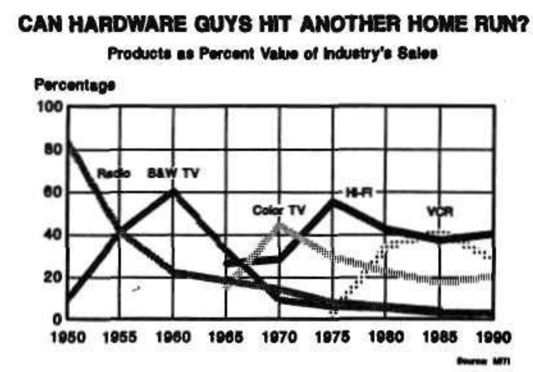

Figure 7

As we look back over the last 30 years, electronic components going into the consumer business have been driven by a what I call a homerun product—every 5 to 10 years. When we look out today— what products are out in the future. The question is, from a timing point of view, when will they happen? We have talked about multimedia, HDTV and personal communication devices. We do not expect these technologies to have a large impact on semiconductor demand until the middle or latter half of the next decade. So if you are a consumer electronics executive at one of these vertically-integrated consumer electronic firms—you sit back and wonder about investing further in semiconductor operations to support the products that are so far into the future.

The other major trend that has the Japanese scrambling to adjust, is the collision course between consumer electronics and computer-based technology companies. If you followed the press over the last year, you saw the host of joint ventures going on between companies like Apple and some of the larger consumer electronic companies in Japan. That is a function of the future that we're talking about—whether it is personal communication devices, HDTV or multimedia—we are going to have a host of technologies required to make these products successful. Three leading edge technologies that will be required for these products are: software, memory chips and MPU's. If you are a Japanese company looking at your strengths, it is really in the memory chips area. Software skills and MPUs are areas in which these companies are most weak.

When Japanese executives think about investing in their vertically integrated operations (where they have semiconductors at the bottom of the food chain feeding their consumer electronic operations), they have to wonder what benefits they can bring to the ball game in the U.S. An excellent example of this is the recent announcement by IO, Inc. about a joint venture between itself, Matsushita, Marubeni, and AT&T, to produce a personal communicator. When we looked at it more closely, we found out that AT&T is the supplier of the RISC processor, the DSP chips, (the value-added chips) going into that communicator.

You can see the divergence where the skill base in the United States in MPU's is helping out the semiconductor industry, and working against the Japanese companies in the consumer electronics area.

NEC, Fujitsu and Toshiba all announced in 1991 they were cutting capital spending even further than they had previously announced at the beginning of the fiscal year. We now expect Japanese spending in 1992 to decline 35-40%.

With the investment growing at 25% over the last 5 years, we have ended up with capital spending trend that is not sustainable in Japan at current levels. Even with a 30% drop in capital spending in Japan, it will still be one of the largest regions in the world—neck-in-neck with the United States. My point is not to de-emphasize the Japanese market—but the trend that we have seen over the last five years of Japan investing at this level, is not going to continue over the next 5 years.

Other items to fall out from this is the over capacity situation and some of the Fab closures and delays that we have heard about Also, the level of foundry activity has gone up noticeably. With all this excess capacity, there are a lot of Japanese companies looking to fill that capacity.

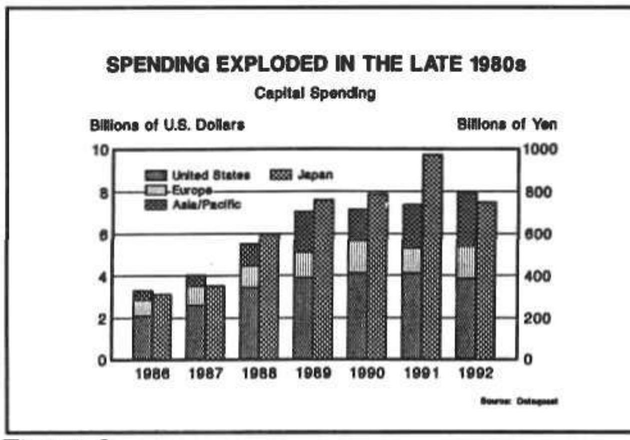

Figure 8

This shows the capital spending of the top 15 companies for semiconductor operations—both front end and back end. It compares 1991 to 1992—and you can see Japanese companies still dominate. Do not de-emphasize Japan—just expect them to be a lot slower growing than we historically have expected or seen.

We keep a list of Fabs—and these are several announced delays in 200mm programs by Japanese companies. Our point of view is that the capital spending cuts are so steep in Japan, that some of these Fabs will not happen. Although they currently are classified as delayed, I do not believe that some of these will happen.

Sharp just announced a few weeks ago that they are not going to continue operating or being in the DRAM business. That raises questions about their 4Mb production facility that was going to be a 200mm facility.

The other companies in jeopardy of canceling their 200 mil programs—Oki, Sanyo and Toshiba—should move ahead, but not at the level of three production facilities for their 4Mb and 16Mb. In fact, our analyst in Japan who follows the manufacturing market for us, believes that, long term, Japanese companies will maintain investments in leading edge technology, but that for future DRAM generations—it will be one major facility per company, rather than multi-facilities.

It is certainly a changed climate in Japan. I think the major losers in the slower growth market, (as far as capital spending goes), will be the European and U.S. markets who have already seen the lion's share of their investment. Japan will continue to be a leader the manufacturing segment. If they're going to invest overseas, it certainly will be in the Asian market.

Multimedia: Oasis or Mirage?

Gregory Sheppard
Principal Analyst
Dataquest Corporation

Bill Kesselring
Industry Analyst
Dataquest Corporation

Mr. Sheppard: My name is Greg Sheppard. I am an analyst at Dataquest in the semiconductor group and I spend my days looking at applications. One thing that has become clear over the last year is that multimedia is either the world's biggest buzz word—or it's a good opportunity. Perhaps it is a little bit of both. Today, I'm going to try to peel back the layers of the onion to examine where we believe some of the opportunities lie, and also what some of the hazards are as we try to further develop the market.

DEFINITIONS

- Multimedia technologies enable:
  - The interactive mixing of text, graphics, animation, images, video, and sound
- Multimedia technologies effect:
  - The creation, manipulation, transmission, display, and storage of the above types of information

Figure 1

First, some definitions. What we're talking about is taking the usual way of computing with text and graphics (also the way of communicating with voice and data), and adding more functionality. In particular, animation, sound in the form of music and voice, and video images are being added. We could extend even further to including speech recognition, speech synthesis and beyond. These are the ones on the horizon.

Multimedia technologies affect many other technologies. They affect not only computing, but the type of communication systems needed, the type of storage required, and the transmission in between.

WHY INVEST IN MULTIMEDIA?

- Saturating PC market, consumer electronics market
- Need to provide value-added/productive products
- Untapped information technologies home market
- Insatiable entertainment market
- Productivity enhancement:
  - Engineering/design/manufacturing
  - Business
- Availability of key enablers – standards, communications bandwidth

Figure 2

Why invest in multimedia? If you're a PC or electronics company, I think the answer is becoming clear. It is the search for a margin product; a search for a profitable set of technologies. Without a doubt, almost every major PC and consumer electronics company in the world is sinking millions into this technology. They're obviously out to add margin to their bottom lines. It's well known in Japan, that almost all the major companies (from Sony on down) are recording record drops in profits, and they're looking at multimedia and other personal and portable technologies to help them become more profitable.

The other reason to invest in multimedia is the untapped home information technologies market. Right now, there are approximately 250 million households in the G7 countries alone. Of those, we estimate that 8% are penetrated with PC's, 25% with video games, and approximately 50% with either cable or satellite terminals. There is a lot of room for growth.

In the business world, one of the problems with understanding multimedia is it has come from the consumer PC side, and now is moving into the business world. The big question is what does it do for business? The bottom line is productivity enhancement in all facets of the company— design and production of products, video conferencing, design of an IC's around the globe, and manufacturing tied to testing. All these factors leading the time to market.

We also have the availability of key enablers— the VLSI world is responsible for a lot of that. Multimedia technology is memory-intensive in some cases, so the drop in price per bit, has enabled that. In addition, we have the emergence of standards, particularly on the software side.

Communication bandwidth is becoming more available, but that is still a big stumbling block to achieving a wide area of multimedia communications.

These are some of the hardware markets that are candidates for multimedia. Multimedia isn't a single market—instead it is a whole array of product features that will affect many markets.

The POS (point of sale) Kiosk systems are a market. Perhaps you've seen (at the airport or in hotel lobbies) machines you can query to get interactive information on the location of sites around the city. Just imagine going into a hardware store that has a Kiosk with an embedded PC in it, and there is the face of Bob Villa. You touch the screen, enter in plumbing, and learn how to do that home plumbing project. That's the reach of this technology.

HARDWARE MARKETS

- Video capture boards/compression/display
- Sound capture boards/compression/playback
- CD-ROM drives (and derivatives)
- Image capture (scanners, still cameras)
- General-purpose platforms (PC/WS/servers)
- Upgrade kits (for example, MPC)
- Kiosks/POS systems

Figure 3

HARDWARE MARKETS

- Video networking/phones
- LAN/WAN/internetworking equipment
- Switches/multiplexers/transmission (ISDN, SDH/ATM)
- Satellite/cable terminals and transmission
- Home interactive terminals
- Consumer multimedia players (Nintendo, CD-I...)

Figure 4

Potentially we can have every retail outlet in the world equipped with these systems—certainly home improvement stores. For example, the Blockbuster Video chain is already installing these systems with miniature video clips so you can preview a movie before you rent it.

Now we're going to give you a quick demonstration of multimedia.

BILL KESSELRING

MULTIMEDIA COMPUTER SEGMENTATION (TWO LAYERS)

First Layer
- Intel-based clones
- Macintosh/PowerPCs
- Workstations
- Others (Commodore, Atari ...)

Second Layer
- Complete multimedia systems (CMS)
- Upgrade kits

Figure 5

Mr. Kesselring: Dataquest has segmented the multimedia computer market into two layers. The first layer describes the platform that consists of four basic platforms—Intel based clones, Macintosh/Power PC's, workstations and other platforms. The second layer indicates the origin of the machine's multimedia capabilities. These capabilities can either be inherent in the design of the machine and sold as a complete multimedia system, or it can be added to an existing machine in the form of an upgrade kit.

OPPORTUNITIES TO SUCCESS

- Digital video
- Networking
- Multimedia specific distributors/ need specific design

Figure 6

In any emerging market, there are opportunities for the success of that market that must be addressed by the participants. Dataquest has identified the following areas as opportunities that will facilitate the success of multimedia enabled computers.

Audio is one of the two most compelling elements in multimedia—digital video is the second. Digital video capabilities will be the next sound board of the future. Once the digital video market is expanded, the multimedia market will have another leg to stand on.

Man does not live alone. The ability to network computers and people is integral to today's business environment. Systems with multimedia capabilities are no exception. One of the most anticipated uses of multimedia computing is video mail. Video mail initially will be used much the same way as E-mail, except a video/audio recorded message will be sent to the chosen address.

Another application on the horizon is video teleconferencing through the desktop. Imagine never having to leave your office to attend this conference. Imagine having an entire virtual conference that offers an interactive question and answering period. Another more practical use would be to involve CAD programs. Having the ability to interactively design and implement changes of an IC simultaneously, with all involved work groups, could reduce time to market, and at the same time, improve inter-group communications and the design of the IC itself.

As with any new product or market segment, the problem with getting the product to the people who want it must be faced. Dataquest believes there is an opportunity for multimedia distributors or integrators. Today, multimedia integrated machines, for the most part, are kludged machines. That is, these machines have been taken off on existing assembly lines and been given multimedia capabilities. They have not been designed from the ground up for a specific task. An exception would be NCR's Model 3331, which is designed specifically for the computer-based training market.

It is human nature to be reluctant to change, and it is this reluctance to accept multimedia as a viable contributing environment that multimedia hardware vendors will have to take into consideration when marketing their products. As a new technology, it will take time for the market to accept and become comfortable with multimedia computing.

BARRIERS TO SUCCESS

- Lack of acceptance of new technology
- Lack of multimedia applications
- Production capacity of CD-ROM drives
- Lack of perceived need
- Cost
- Budget cuts in education

Figure 7

The multitude of features can be confusing and intimidating to users. To ease the transition, most of the hardware vendors are providing on-line tutorials to familiarize their users. But as the market grows, and corporations begin implementing these systems, formal classroom training sessions may be necessary to speed the learning curve.

History has illustrated that a major factor in the relative success or failure of the hardware product is the availability of software. Multimedia hardware vendors are definitely aware of this and have been working with independent software developers to insure that the variety of multimedia solutions will be developed. Despite their efforts, there is a lack of multimedia applications at the present time—especially for business use. Although Dataquest expects the growth of multimedia applications for business to occur within the next 12 to 18 month time frame. The current lack of applications are preventing corporations from investing in multimedia hardware.

Just as a lack of multimedia applications has tempered market growth, the availability of CD-ROM drives will play a major role in determining multimedia's market potential. The demand for CD-ROM drives has increased tremendously, and the CD-ROM manufacturers have been hard-pressed to meet these demand requirements. With the multimedia market poised to take off, as more applications become available, even more pressure will be placed on these manufacturers. If the demand requirements cannot be met, it will be detrimental to both the multimedia hardware and upgrade manufacturers. That is why we have designated production as a barrier—this may be an opportunity for new CD-ROM drive manufacturers to enter the market.

The dramatic new technologies offered through multimedia should appeal to a majority of the market—though a certain percentage will question the need for such an environment. Some will argue that the business environment has progressed nicely without multimedia.

The features are exotic, but are they necessary? And why invest in a technology that exceeds the computing requirements of your company? The only way to combat these issues is to demonstrate the value-added features that multimedia can bring to the desktop. This lack of perceived need relates back to the acceptance of new technology. Once users are properly trained and have reached a comfort level with multimedia, then the system may be perceived as a need.

Much attention has been focused on the cost of multimedia systems due to the price wars in the PC industry. While traditional PC and workstation vendors have engaged in price cutting, some anticipate the same to occur with multimedia systems. This simply will not happen at the present time. From a basic economic standpoint, multimedia vendors are bound by the component vendors' costs, especially CD-ROM drive manufacturers.

The price premium that the multimedia system vendors must charge may be an initial barrier. But if they can communicate the value added message to the corporate, home and education environments, they can effectively differentiate their products from the traditional PC, which has essentially become a commodity item.

Over the past decade we have already witnessed the benefits of traditional computers in education—especially in the K-12 grade levels. Imagine the impact that interactive multisensory multimedia computers can make in the classroom. This vision, though, may never be fully realized due to budget cuts that have plagued the educational system in the past few years.

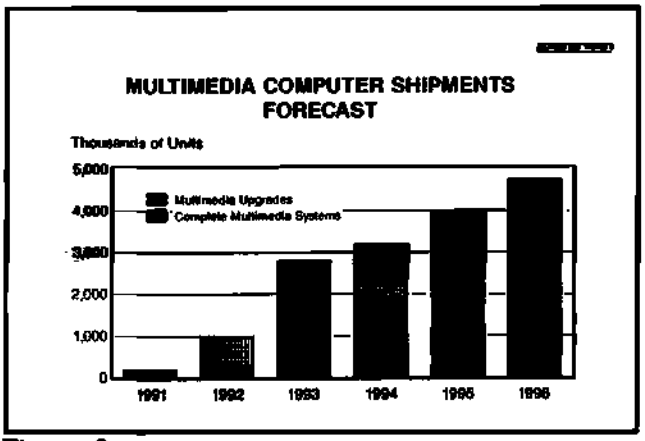

Figure 8

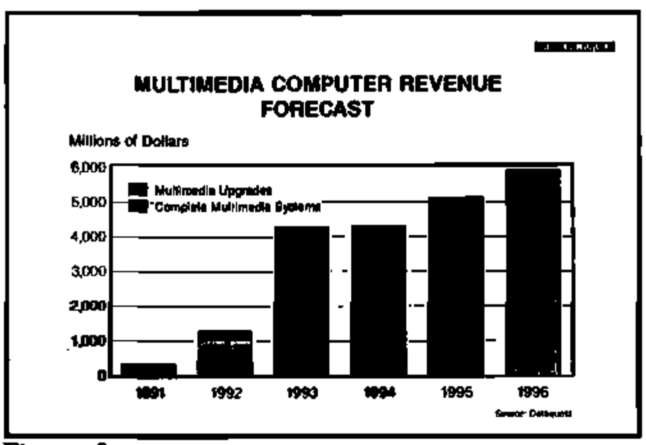

Figure 9

Dataquest views the multimedia computer market as a summation of upgrade kits sold, plus the number of complete multimedia systems sold. Upgrade kits are expected to peak in shipments by 1994, shipping nearly 1.3 million units, while complete multimedia systems are expected to post a 121% compounded annual growth rate, reaching nearly 4.8 million shipments in 1996.

GREG SHEPPARD

Mr. Sheppard: Now we're going to talk about the software, which for the computer world, is the most crucial thing to expanding multimedia.

SOFTWARE SEGMENTATION

- Authoring software
  - Personal authoring software
  - Professional authoring software
- Multimedia applications and titles
  - Custom applications
  - Commercial titles

Figure 10

There are two types of software. One is what we call authoring software. This is what we used for this presentation. This software represents the various off-the-shelf packages, as well as the professional packages that are used to develop multimedia material. They're much like using a presentation package—they provide templates and storyboarding, and you can import sizing. There are various specific editing features you can use to overlay sound and do sound editing for more polished presentations.

The other aspect of software is the applications themselves, such as Lotus (which is embedding multimedia into its package). Several of the major packages are incorporating multimedia into their releases over the next year. They will need to tap into hardware features present in the machine to be fully utilized—so we see, on the sound side, some good growth for hardware ahead.

Shrink-wrap software is what we refer to as commercial titles. Custom applications are those that would be developed by a publisher, printed on a CD-ROM, and shipped that way. That is certainly where much of the market is now, in terms of the game and entertainment side.

OPPORTUNITIES (TODAY)

- Training and education
- Advertising and presentations
- Information publishing
- Consumer/entertainment

Figure 11

These are some of the opportunities today. The biggest opportunity is the training area where corporate training programs already are using multimedia. One of the areas that training is most effective with multimedia, is in languages. Having an interactive session with a system that's been set up to repeat and do the things you need for effective language learning, is something that's available today. We're starting to see every language in the world come out in multimedia titles.

Advertising has been in multimedia for some time. There's hardly any print advertising that isn't scanned in and digitally manipulated somehow before it's finalized.

In the presentation area we are starting to see more demonstrations pop up around the world.

Information publishing—this is the area of the CD-ROM titles. Definitely a hot area.

In the consumer and Entertainment area, what has been extremely viable over the last year, is sound—particularly sound boards. We're projecting some new exciting things, in terms of dedicated consumer multimedia players.

Many of these markets can be addressed vertically, with targeted hardware and software combinations. In an area like medicine, a doctor can interact with his or her colleagues, look at an X-ray or image of a patient, and globally come to a prognosis and treatment for the patient.

In the Real Estate field, Realtors are already capturing video images of properties, compressing them down onto CD-ROM libraries, and shipping them to their counterparts. They can play these back and prospective buyers can actually see the property. It is computer and networked-based—and it is timely.

BARRIERS

- Lack of applications
- Platforms
- Standards
- User understanding and evangelism

Figure 12

What are the barriers to acceptance? Currently, there is a dirth of applications in the business world. This is, however, being alleviated,. We spent a lot of time talking to the upgrade kit providers, the Multimedia PC counsel people (which is one of the labels being promoted for multimedia PCs), as well as Microsoft. We asked them about who is developing what, and just about everyone in the world is working on it. For '93 and '94, we expect much more to be released.

One barrier is the need for a performance platform. The Multimedia PC counsel people recommend a 386 system or greater, but if you add video, it's more than likely that a 486 system would be preferred.

Although standards are an issue, this will be alleviated by the end of this year as a couple of key software standards come into place.

User understanding and evangelism are important. There has to be the comfort level with users of this technology, and there must be the zealots that promote the technology. We are starting to see that happen.

In terms of authoring software, you have to look at what has to be shipped before multimedia can happen. You have to get the creation of multimedia material going before the end users can use the technology. This projection shows that in '92 there is going to be 700,000 authoring software packages shipped. The bulk of those are going to end users for presentation purposes. This will grow to 2.8 million packages by 1996. It is an attractive market from a software standpoint if you track the revenues.

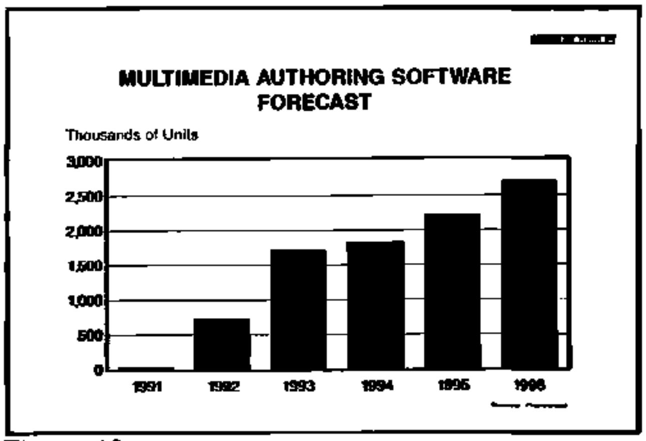

Figure 13

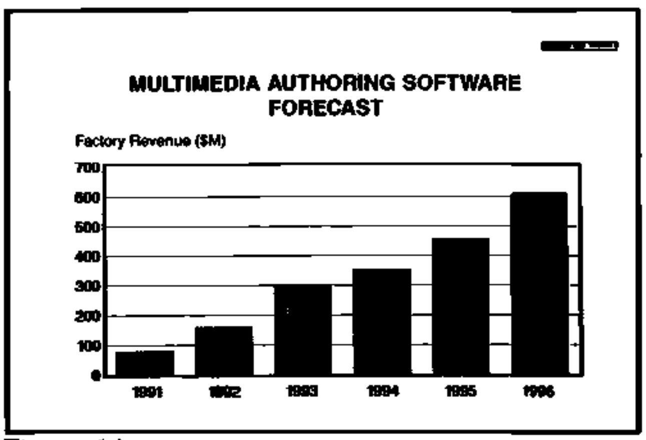

Figure 14

We take the capabilities of multimedia and break them down to video, images and sound. What goes on with computer digital video is the ability to capture video, import it into the system, manipulate it, and edit and store it. There is a variety of hardware boards available now.—they range in the high $400 range up to several thousand dollars, all with varying capability.

The key tradeoff with video, to date, remains bandwidth versus resolution. You can get 30 frames per second full motion video, but the tradeoff is you have to put that in a tiny part of your screen, or go to a rate of a few frames per second at full screen. The other dimension of this is color coding with 16 or 24-bit color.

At the heart of this is where compression technology falls. Compression obviously allows you to squash down the information and get it to the bandwidth necessary to transmit. The most commonly used number in the industry right now 1-1/2 megabits range, which is also the T1 transmission rate—an ISDN rate. It's also the rate at which CD-ROM accesses data.

There are some developments in CD-ROM technology that will double that. We will see the bandwidths go up—that is generally what people are trying to target with cost- effective hardware.

Some key semiconductor functions are—data conversion (analog to digital, digital to analog), new types of RAMDAC technology, TV signal and decoding. There are half a dozen TV standards around the world, the most popular being the NTSC standard (used in the US and Japan), and the PAL standard (used in Europe). There are circuits out now that address this area. There also is a need for integration of some of the other functions. There is also a need for dedicated compression chips. Perhaps the most famous of these standards are JPEG and MPEG for still and motion compression.

With respect to memory, if you look at the bill of materials of a digital video board, it's easily half DRAM or VRAM. This will definitely be a shot in the arm to the memory market.

In terms of compression standards, if you had asked me six months to a year ago, I would have said MPEG would be the market to look at. Now it's taken on a different twist. It all started in the Apple world with Quick Time (the multimedia extension to the Apple operating system). The success they have had with software-based compression has been tremendous. You can buy a video board to go on that—SuperMac is benefiting the most from that. About 20,000 units a month are being shipped with these types of boards to people interested in doing Quick Time movies on a Macintosh.

The Microsoft DOS and IBM OS 2.0 world is now catching up with this. Microsoft is going to release, later on this year, their technology like Quick Time. It's called Audio/Video Interleaved (AVI), and will also involve software compression. There is a market on the high end for accelerating full motion, full screen, too.

COMPUTER DIGITAL VIDEO

- Capture, digital processing, and display of images and video
- Key trade-off: resolution versus bandwidth
- Key functions: data conversion, TV signal encode/decode, compression ...
- Compression standards – software driven
- Fragmented market: Truevision, SuperMac, Video Logic, New Media Graphics early leaders

Figure 15

The computer digital video market is a broad market—and very fragmented. Truvision on the IBM side, and Super Mac on the Apple, are the volume leaders. There are about 30 of them. We see graphic board vendors—companies like ATI—becoming big players. Naturally, these functions will end up integrating with graphics features as they become more cost effective.

This is our forecast for digital video boards and subsystems—in 1992, the market is estimated at 450,000 units. Many of those will go into vertical applications —such as the Kiosk and arcade games. It is through the middle part of the decade that we see units moving more into mainstream business applications. In 1996, the market will grow to approximately 3 million units.

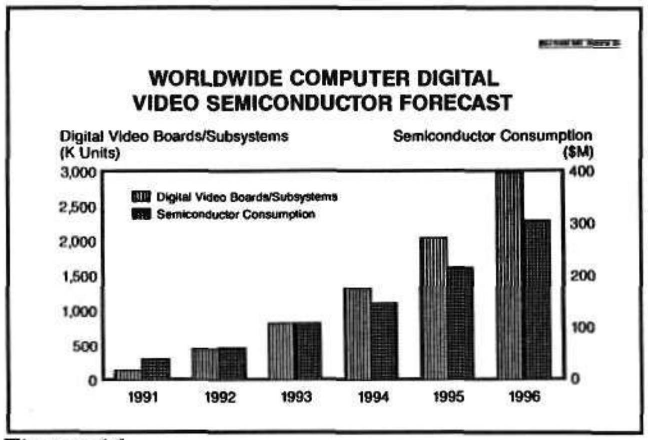

Figure 16

We estimate the corresponding chip market from digital video to be about $60 million growing to $300 million by 1996. Not a huge market, but if you're one of half a dozen players, it's a very tidy business.

Computer sound is the most readily adopted multimedia feature. Like video, it involves the capture of sound, processing—the playback of voice and music and other sounds. What you just heard was actually played back via a 16-bit sound board. We used an FM synthesis approach.

The real race the sound board people are in, is to reduce costs and to incorporate (from the OEM's perspective) the sound's subsystem onto the motherboard. One of the key enablers for this is digital signal processing technology (DSP). We foresee many of the high end computers—starting next year—having a DSP processor on board. You can look at IBM and Apple as examples of that technology. It started in the workstation arena with companies like Next.

This DSP processor will be multifunctional. It won't just address sound, but will have the ability to fax and modem and crunch data. We also see the use of third-party algorithms, or as new algorithms for speech recognition come out they will have general purpose single processing capability on the motherboard to handle that. These new technologies will set up a situation where, in the future, we can incorporate new features rather quickly on PC platforms.

COMPUTER SOUND

- Capture, processing, and playback of voice, music, and other sounds
- Cost reduction race
- Key functions: DSP, synthesis, mixing
- Concentrated market fragmenting: Creative Labs, Media Vision, Roland, AdLib ...

Figure 17

Computer sound is now using FM synthesis. Think of the synthesizers that you heard in the '60's for rock music—that type of approach but a little more sophisticated—it is all on a couple of IC's. We're moving to the use of sampled sounds—where you record a little of a piano, a little of a horn, a little of a sound of nature, etc. and put these sounds in a ROM library. On can then use a DSP to access the sounds and play them back. In terms of fidelity, that seems to be the ultimate incarnation of sound. We're waiting for the price to come down before we see that in the mainstream.

This market is a little more concentrated than the digital video market. Creative Labs, through late '91 and early '92, dominated the market with their sound Blaster Card. It is hard to go into one of these electronic super stores these days and not see a huge stack of Sound Blaster Cards. Up and coming is a company called MediaVision. Between the two companies, they control about 80% of the market. There are, however, some other companies that have come in—Roland, Turtle Beach, and IBM.

Our projection for the sound market—both the boards and subsystems— is that by the middle of the decade, 1997, 1998, essentially every PC will be sound enabled. By our definition, it will be able to accept sounds as a minimum. The sound board will continue to be a good opportunity in the near run, and also work as a way to modify the installed base.

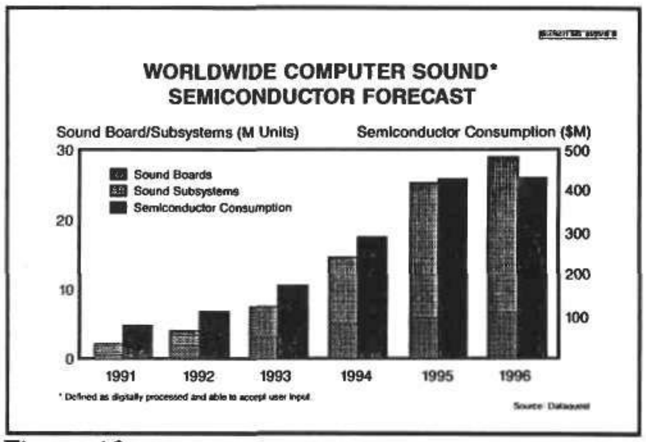

Figure 18

The corresponding chip market is estimated at about $110 million in 1992—going to $435 million in 1996.

PERIPHERALS

- CD-ROM (and variants) burst on the scene in 1991, add-on and upgrade kit opportunity; over 3,000 titles
- CD-ROM, CD-ROM/XA, CD-I, Photo CD ...
- VCR, digitally controlled VCR (NEC, Toshiba-GI) laserdisk
- Scanners

Figure 19

There are several peripherals that go along with these computer systems— particularly CD-ROM. CD-ROM, as a market, lulled around for years in reference library sorts of situations, or as a way to store corporate records. It looks like it's finally found a home with multimedia. It is growing so quickly that Dataquest keeps revising their estimates of this market, quarterly. We expect in 1992, that a million CD-ROM drives will ship worldwide, and that will grow to 4.8 million in 1996.

The core CD-ROM is still the largest market, as it remains the cheapest. We project OEM prices on CD-ROM drives could drop as low as $60, 3 or 4 years hence. The CD-ROM/XA refers to a standard that will allow for the interweaving of audio. That market is really getting started and being pioneered by Sony as the initial entrant.

One technology that's used a lot in multimedia today is the good old VCR. There are a lot of professional service bureaus and consultants who are capturing video on a VCR and spooling it into a computer to develop a presentation. What has been created is the need to have a better VCR, particularly one that is based on digital technology and can be controlled frame by frame in order to edit. NEC has a box out now that does this. Toshiba and General Instruments has announced a deal to do this, as well. There is a digital motivation to this beyond multimedia.

Scanners will be important—the ability to capture an image and import it. We project that by 1996, the scanner market could be a million units—both the hand-held variety tabletop units. We'll also see a transition over to full color scanning, and a doubling of the resolution that can be handled.

Another barrier to multimedia is the intellectual property issue—having to do with, for example, the photographers' ownership of the photo, or musicians' ownership of the music. These are issues that companies like Microsoft are wrestling with because they are out-licensing as much as they can get their hands on and putting it into CD-ROM libraries. As a matter of fact, the music you just heard was a sound clip that we pulled out of a library.

On the photo or imaging side, companies like Kodak are buying up libraries of photographs and the photographers want a cut of the take. It is the same situation that Hollywood is in with recording and going digital. So, property awareness is needed.

Communications—I have been looking at ISDN for years, and it's always been an ideal, particularly here in the U.S. But with multimedia, and the desire to beam it around, we finally have something that can take advantage of ISDN and, as near as we can tell, will be a stimulant. The other market is that ISDN is a wide area network.

COMMUNICATION

- The need for bandwidth is catching up with the desire to provide it
- ISDN and FDDI
- The promise of asynchronous transfer mode (ATM) for WAN/broadband (1 Gbps) transfer is great; existing networks cannot handle traffic
- Regional Bells cleared for "video" dial tone

Figure 20

Within the building, FDDI, the high speed upgrade token ring (think of it as a LAN'S LAN) multimedia is stimulating the need. FDDI has some limitations, and that is where asynchronous transfer mode (ATM) comes in.

The main thing about ATM is that it provides bandwidth on demand. Imagine a video conferencing situation where you turn the system on and you need the bandwidth to communicate back and forth. You need a point to point connection. Local area networks are sending packets of data around, and you don't have a deterministic way of measuring exactly when that packet will reach another point. That's intolerable in a video conferencing situation. Thus, ATM is needed. Not only are the public networks looking at it, but the premise people are as well. There is a group called the ATM forum—a group of implementers as opposed to a standards body—that are looking to roll out some hardware as early as first quarter '93.

The regional Bells have been cleared in the U.S. market to deliver a video dial tone. Essentially, they can deliver images and services (involving more than just voice and data) to the home.

This is going to be a stimulant for them to invest in the technology.

Video conferencing—the high-end is based on proprietary compression like the conference room type video conference—and the low end consists of add-in cards that go into every workstation and PC. These are based on CCITT standards, an international standards body. Basically, it's a prescription for a low end conferencing system that can handle 15 frames per second. There are several companies working on chip sets and boards. Video conferencing has expanded from 4 or 5 companies, to as many as 30 predicted over the next year.

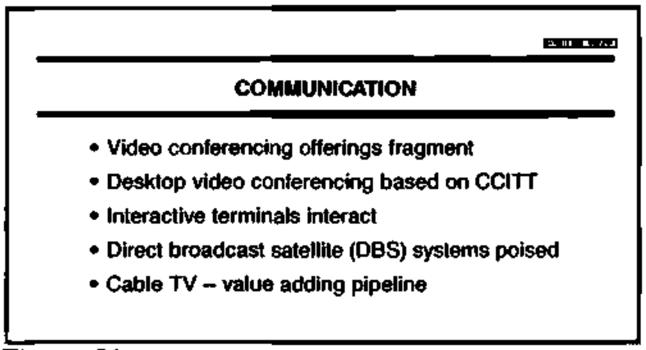

Figure 21

There is also the idea of a new type of interactive terminal for the home that can interact with the outside world for services.

Direct broadcast satellite systems are being rolled out aggressively,—especially in Japan.

Direct broadcasting satellites and cable TV are big users of compression technology. In both cases, we see them turning to a solution like MPEG more readily than the computer world, because of work the that has been done there. At least one of the HDTV proposals in front of the FCC is based on MPEG.

On the consumer side, I think it is important to point out that everybody is fighting for the home. The PC people want to get into the TV business via digital video, and vice versa. What will happen is that the living room, wherever the TV is, will still be used for entertainment purposes. A majority of PC's actually do not go into that situation—they go into an extra room for, perhaps, home office applications or computer games.

We believe there's roughly a thousand dollar budget for these sorts of things. There is about $80 per month, per household , that goes towards information-type products like newspapers, magazines, and cable TV fees. We have to fit the technology within that paradigm, as well.

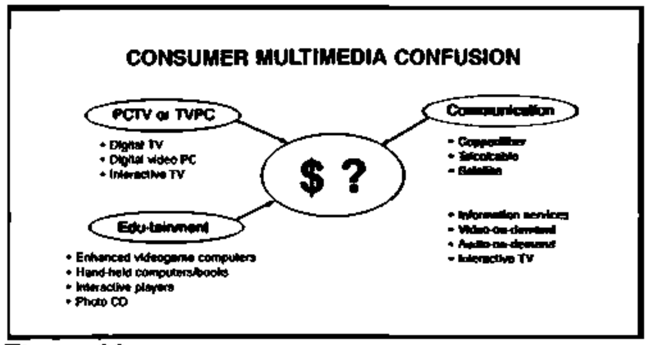

Figure 22

On the communications side, the telephone companies and cable companies all want to be hooked up the house to deliver these services.

There will be audio on demand—this is the idea of picking your favorite '60's or '70's hit and having it delivered to your home over the cable.

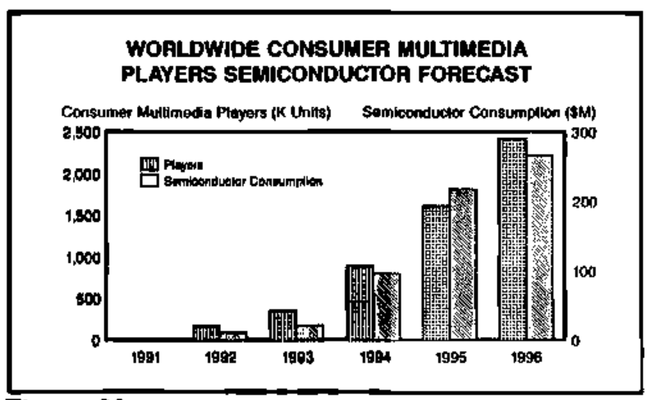

Figure 23

One of the major aspects that is emerging is the multimedia players who are exemplified by the CDI technologies from Philips. Philips has several partners among the Japanese electronics companies—including Nintendo. The next generation of video games would be this type of technology. We have put together a conservative forecast. We project these players will account for to be 2-1/2 million units by 1996. The corresponding chip forecast will grow to be 250 million units by 1996.

We feel there are definite and immediate opportunities in the sound area. Sound is here and so is optical disk. Digital video will emerge modestly— it still remains an expensive technology. We will see software compression roll on for a while, but it will be more towards the middle of this decade before the digital video market settles down.

Video conferencing is beginning to roll out in a big way.

Consumer interactivity is ramping up quite nicely. Between Philips and Commodore, there are 250 titles planned for release by Christmas.

What is important in this market is relationships—whether co-development or alliances—all need to be flexible. If you are flexible, you can be successful.

Questions & Answers

Question: Can you tell us how your presentation was put together?

Mr. Sheppard: We had five different slides that had sound. We took almost 16 megabytes of memory to store roughly 8 minutes of music and voice. The sound part was about 95% of the storage. We used wave files—uncompressed files. It took us about 12 hours to put this together, and the package we used was Micromedia Action. This was a little overkill but this is the system we had available. We used a $30 microphone. That's it.

Question: How much is the projector?

Mr. Sheppard: About $10,000.

What Multimedia products are shipping today?

Mr. Sheppard: Primarily on the boxes and upgrade kits. A third of those are going towards the consumer; the other two-thirds are a split between corporate training, education and the college level. We also included all the vertical applications for Kiosk and point of sales systems, as well.

Personal Information and Communication Devices

Jerry Banks
Director and Principal Analyst Semiconductor Group
Dataquest Corporation

Nicolas C. Samaras
Director and Principal Analyst, Semiconductor Applications Market
Dataquest Corporation

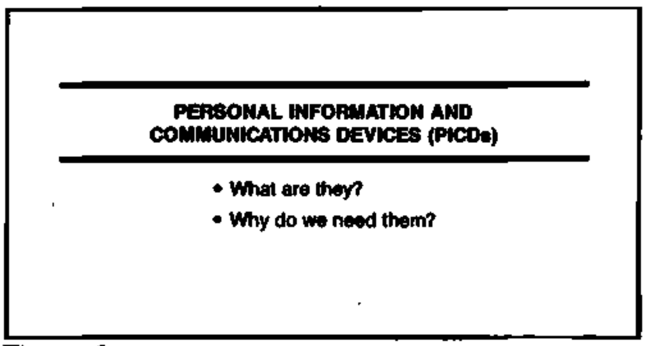

Figure 1

Mr. Samaras: What is the definition of a personal information and communication devices? When we talk about PicDees we're talking about describing a range of devices. PicDees describe a small form factor personal computer that relies heavily on communication, uses a pen centric operating system, with a pen as the main input device. PicDees are meant to be highly mobile; they're small and should be self-sufficient for long periods of time—about 20 to 100 hours.

The key point is we're talking about a range of devices, in terms of price, size weight and capabilities. Even though PicDees are meant to eventually become consumer items, they will not begin that way. They'll cost more money, up front. We expect that the range that we're going to see PicDees is $900 to about $3000 right now—that should move down to about $250 to $1500.

What we have is the merging of two different form factors. From the bottom up, we have the organizers, the Casio, moving up. From the top we have the pen base computers and the notebook computers that are shrunk down and wrapped around good software and operating systems, and these become PicDees.

We have talked about what they are—why do we need them? We need them because what we have now is not useful enough. Portable PCs are too heavy and they run out of batteries two or three hours after we turn them on. Even though we're told they should last longer, they don't last very long, and therefore are not very useful. What we do need is useful devices.

Beyond the range of operating power, in time, usefulness is the issue. How good are those machines? The software and hardware are not well integrated, so we have to use a variety of skills to deal with these tools, and tools are meant to help us. We're looking for something better.

From a size standpoint, one size that appears to be optimum is about 6" x 4" x 1". So far, the most useful computer device that we use is the Daytimer. What we need to do is emulate our Daytimer by means of electronic ink and organizers, and devices that can actually use a spreadsheet.

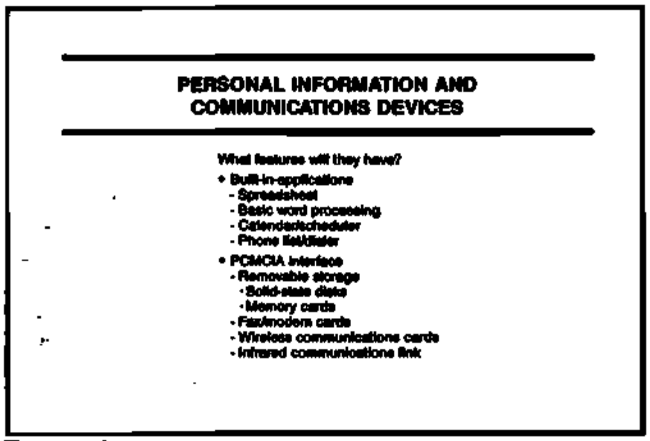

Figure 2

Features they're expected to have—they will include built-in applications, spreadsheets, word processor, calendar, scheduler, phone dialer. These are described as personal information management tools. I think this list is going to look very unimaginative in five years, or maybe sooner than that.

The interface for adding storage devices and communication capabilities to the PicDees—PCMCIA—has strong support from both system and semiconductor manufacturers. Intel, Apple, IBM, AMD, all the Japanese companies are behind that standard. So what we've seen in addition to new form factors is the emergence of this new interface that has helped along the form factor. All the card interfaces that Casio or Sharp are using today, will go away.

We expect to have removable mass storage both in terms of memory cards and solid state storage, using flash memory devices. These are going to be the floppies of the future—SRAM with battery backup is another alternative. Then we're going to have fax/modem combination or separate cards. A number of people have such devices right now and they're really small.

Wireless communication—that's a bit farther out. For the time being we're going to use cellular technology. Something that's here today and underutilized is the infrared capability to communicate with our desktop PC. Today, if you have a notebook and you need to attach it to your desktop you need a cable—it's a mess. You don't know who is talking to whom. Most people get lost after an hour or two of usage.

What we're looking at is a new environment where a user can pick up one of those devices, point it at his desktop PC and be able to transfer upload/download files. That's all that's needed—it should be very easy. People know how to use a remote control and infrared communications. There are some semiconductor opportunities in that area that have not been exploited to date, both telecommunication capabilities and semiconductor.

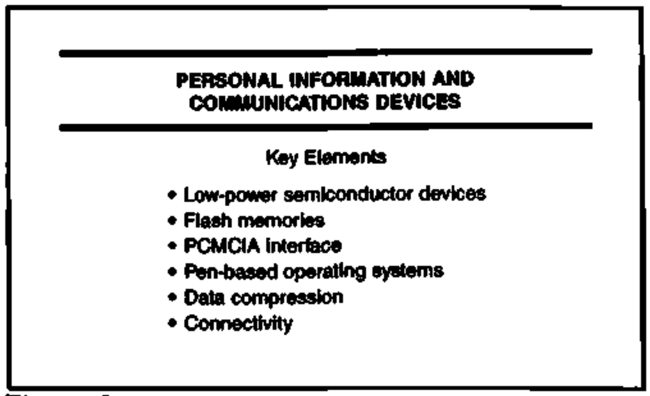

Figure 3

Low power consumption is a key for PicDees.

There are many things that need to happen for PicDees to take off. You need good operating systems, you need small form factors, they have to be light, and they have to last long. If any of those doesn't play, then the whole scenario for market development is going to slow up for a while.

The PCMCIA is definitely a key interface and we expect its position will be solidified. The pen-base operating systems are an absolute must. People are familiar with pens; that's what most of us use to write notes all the time. I'm not saying that the keyboard is not an efficient device—it is a very efficient device for writing large amounts of text. On the other hand, in the past, it has imposed form factor limitations and has affected the structure of the PCs. If you have to shrink a PC down to the size you can put into your pocket, then the keyboard is useless. If you do have a useful keyboard, then you don't have a PicDee. You have a laptop.

What we're suggesting is that perhaps there's a solution in between. You could have a pen-based operating system in a PicDee and a pen, and you can use that most of the time. If you need a keyboard you can have it in your briefcase, take it out and use it. They don't need to be connected. You can have IR communication between the two. If you need a keyboard, take it on the plane, then put it away. But most of us don't use a keyboard for the majority of our writing.

We have to get back to the basics to learn to emulate what we always have known how to do (pen and paper metaphor).

Data compression—we're talking about a lot of storage, not enough space, memory cards—and solid state storage is expensive. So how do you make it less expensive? You compress it. It doesn't take a brain scientist to figure that out. We haven't really taken advantage of that to date. We just have floppies—but most of them are empty.

If a memory card is expensive, what you do is take all of that storage space and you compress it. Data compression is the key technology for semiconductor opportunities in that area.

In a loss-less compression method, which are the data files, the compression ratio that you're going to have is probably 2 to 1, depending on the type of the file. If you start storing faxes or images of files, then your compression ratio can become significant—up to 64 to 1.

Connectivity has to be nice and easy to use. If someone hands you two cables, it's irrelevant—that's not good enough. For these things to become consumer items, they have to be easy, like a remote control that sits on the table. I pick it up and I do something with it and I walk away. I don't need to know how to connect the two things. The connectivity is very important. It needs to be addressed properly—both from the software and hardware standpoint.

Who's going to use the stuff? We know the first group of people are the ones who always buy stuff that comes out—but they're not a big market. The mobile professionals are most likely going to be the ones who are going to use them as the next step. We've seen the first element of that—some insurance companies went out and bought some organizers. Someone wrote some software for them, and they went out and did some work with them. There are some vertical markets we can see developing right away, and those can support the higher price point.

PERSONAL INFORMATION AND
COMMUNICATIONS DEVICES

- Who is the customer?
  - Gee whiz, I gotta have it!
  - Mobile professionals
  - Less mobile professionals
  - Consumer market

Figure 4

Then as time goes on, the less mobile professionals will start using them, and finally the consumer market will take off—perhaps in 3 to 5 years. As we move on, the devices will become more capable, less expensive and the margins will drop—on the other hand, the volume will be significant.

PERSONAL INFORMATION AND
COMMUNICATIONS DEVICES

- Standard operating system?
  - DOS
  - System 7
  - PenPoint
  - PenDOS
  - GEOS
  - PenWindows

Figure 5

Do we need standard operating systems? I'm not sure we actually need one. Again, those devices are not meant to be your PC. They're not meant to replace your desktop. I'm using a

Casio organizer. and I don't think it has an operating system—but I don't really care. I think that should be the attitude of the consumer. If it does what you need it to do, the operating system becomes less of an issue. There will not be floppies to stick in, or new programs. Those things will come preconfigured from the factory—at least at the low end.

We might see DOS in devices like the HP95 LX derivatives or the sort. The field is open for other operating systems. One that is a good contender right now is the pen point. Microsoft now has Pen DOS, and other companies are moving along trying to take advantage of this new opening of operating systems environment. The key is it's not clear that you do need a standard operating system—or Microsoft behind it.

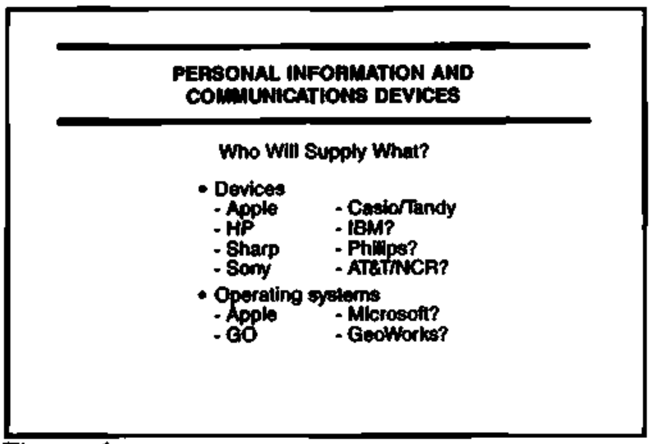

Figure 6

When I talk about devices, I'm talking about things—boxes—things we take along with us. Apple—has announced Newton. I hope that Apple is successful with Newton because it will take good implementation of devices for this market to develop. HP was very successful with their implementation of the HP95 LX, and it will take good examples like that to move this industry.

Sharp and Sony both have had pen-based organizers that have been available in Japan, and these companies have no problem in bringing those from the bottom up to meet the demand. Casio and Tandy have a joint venture. IBM should be involved, and so should Philips—after all, these things are going to be consumer devices in the future. We know about AT&T and Matshushita and Marubeni just announced a new venture called EO—and that's a hardware company. They're going to use the GO operating system along with hardware microprocessor from AT&T to build PicDees.

From an operating system standpoint, the two major contenders for a set of different devices—Apple will have their own operating system for Newton, and Go is envisioning their operating system becoming the operating system for pen-based applications. Potentially, Go wants to become the Microsoft of the 21st century—and there's a good chance they might be able to do it if they execute well. Microsoft is there, and so is Geoworks, and these companies are going to have products for this market.

There are a lot of people out there that have a lot of toys but don't have a computer. They don't have a computer because they're not useful enough—they're not entertaining. Perhaps Apple will bring in some of that entertainment element.

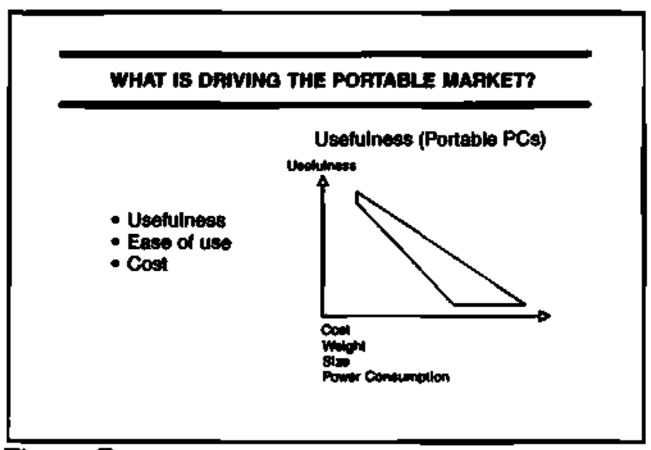

Figure 7

As the cost increases, or weight or size or power consumption, the usefulness goes down the tubes. It is meant to show what we need to do to have devices that people will want to buy.

ENABLING TECHNOLOGIES
Semiconductors
• Highly integrated low-power microprocessors
• Flash memories - 8Mb today → 64Mb by 1995
• Data compression ICs - Key technology for solid-state storage
Software
• Pen-based operating systems
• Connectivity/communications software

Figure 8

PORTABILITY NEEDS
• Improved man-machine interface - Pen input - Voice input/output - Video
• Pen-based operating systems (O/S)
• Nonvolatile memories and mass storage - High-density Flash memories - Solid-state disks (Flash)
• Communications hardware - Fax, modem, voice ICs - Wireless (RF, IR)

Figure 9

Enabling technologies from a semiconductor standpoint—we don't have much power to spare.

Flash memories are good because they are non-volatile memories and because they don't need batteries. Today, we're at about 8Mb. We expect the market place will start growing and exploding at 16 and 64-megabit level by '95.

Data compression—is a key development—not too many devices now—we need more devices for solid state storage and for communication.

Software—pen-based operating systems, connectivity, and communication software. Implementation of these is critical for the success of the PicDees.

We need to have improvement in the interface. What we have today is good enough for the people that use it, but if we expect the market to explode, then that must be improved. The next step is to have pen input.

Pen input—I didn't say handwriting recognition. I said pen input and digital ink. What I'm trying to emulate is the ability to write with a pen in the same way I do with a Daytimer. I store notes—I just write on something and it's stored away as an image file. After all, the Daytimer doesn't really know what we write down. The first step is to emulate what we have today.

Another point about handwritten text—there's a lot of information that is contained in the way we write. If you take a page of information scan it and use handwriting recognition and transfer it to a page of text, you lose a lot of information—a lot of visual cues go away.

The technology is not here today because it brings PCs down to their knees. Most people don't need handwriting recognition, so why talk about that. Let's do what's doable today. Write something on a PicDee and then store it away. When you need it, you go back and get it by date or by a few key words that you store it with.

Voice input and output are functions that will come up in the near future. We don't expect them right away in video. It's a function that has to wait for a number of years—maybe by the year 2000—but it's going to be integrated.

We need the ability to send and receive faxes and to connect to a mainframe or a system at work, and wireless. Infrared is what's here today—let's use it. Cellular is the next step in truly wireless communications.

In summary, the opportunities are in memories, both flash and static, mass storage (the larger size tablets will have space for a 1.3" hard disk). In solid state storage—the form factor is a PCMCIA card—which will be both the floppy and hard disk in the future. It is removable and easy to carry along. It's your storage—everything you have. Today we're at about 20 to 40 megbytes of solid state storage. We should be at 1 gigabyte by 1999, and that's a conservative estimate.

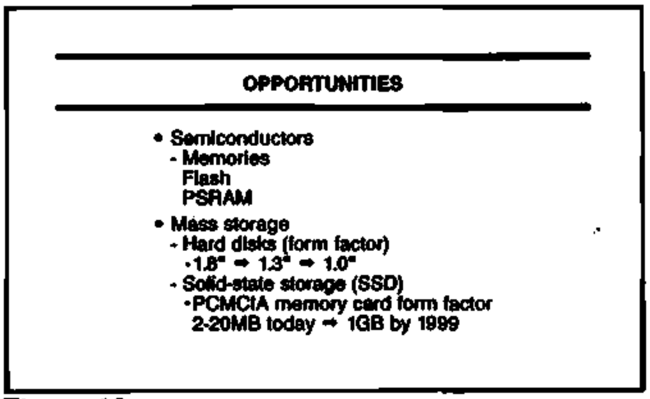

Figure 10

A lot of things must come into play for PicDees to become successful. The software has to be good and easy to use and the hardware should be user friendly. The pen—the box—should be light and should last long. They should be able to communicate with each other, and you should be able to send and receive a fax. If the value is there and people will buy them.

The opportunities are significant, but it will take a number of developments—both in terms of software and hardware—for that to happen.

JERRY BANKS

Mr. Banks: For the last couple of years we've heard a lot of talk, and read articles about the different markets. Some people wanted to play in markets and stay away from others, for example, many semiconductor companies have a policy to stay away from the consumer market place. Robert Lucky said, "you can sit inside one of these industries and think you're immune, but these industries are coming at you." You have to be able to participate in all three categories or you're not going to be a player.

If people stick to their safe positions and stay in their data processing niche or industrial niche, they're going to find out there's going to be ever-shrinking niches, and you can't grow a company like that. To play in PicDees, you have to broaden your outlook on markets.

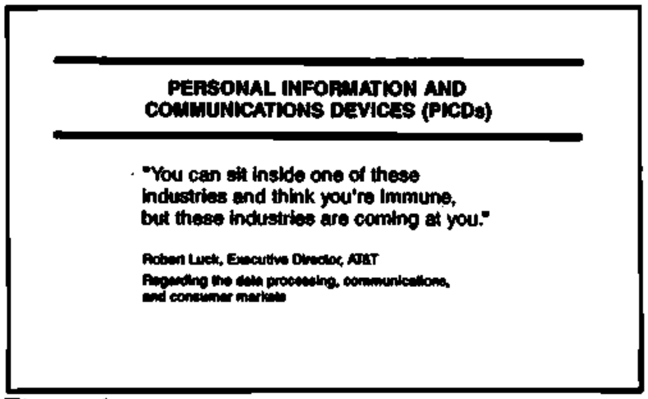

Figure 1

We're talking about new levels of system integration. We can't afford to think of having a stand-alone microprocessor and a standard product chip, and an ASIC chip, and discrete analog functions. We're talking about functional integration, not just a more powerful microprocessor—more cache on board, and a wider CPU path. We're talking about bringing those functions on board the microprocessor — logic functions, analog functions, etc.

Integration is a must in this form factor. It will allow the manufacturers of PicDees the possibility of differentiating themselves. Wouldn't that be a nice change. In today's world of clone PCs, there is no room for differentiation. Some of the PC board manufacturers today are no longer targeting a percentage profit margin. They don't care if it's a 386, 486 or P5—there's a dollar figure they want to make on each board they sell.

To differentiate themselves, the IC manufacturer can provide the means to allow equipment companies to offer feature differentiation on their end equipment. It allows them a whole new level of differentiation.

Offering this differentiation requires the use of the "A" word—ASIC. Although pure play ASIC companies still having a problem making a profit, ASIC still has a very valuable role in the market place, and that's in the role of differentiating quickly. So ASIC tools are an absolute must to bring the product to market quickly. What had been missing in the ASIC world before was cells that could be protected, specific architectures that you can do that others can't do. Everybody now can bring things to market quickly or build a gate array. But if you want to do things quickly and maintain a competitive advantage you must have functions in there that you can protect intellectually.

By the latter half of this decade we will be talking about systems that cost $250 to the end customer. We will not be talking about hundred dollar microprocessors, we're talking about a $20 or $25 microprocessor, at most, even with all these functions. So we have to provide all this capability at a competitive price.

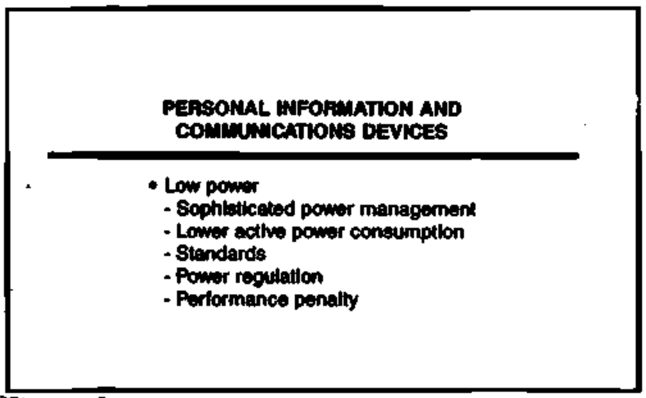

Figure 2

One key area here is low power CMOS. These devices have to last a bit longer tomorrow than today's notebooks. Our belief is that PicDees, when they start out, will have to be 20 to 100 hours before they'll be a usable product. In order to do that, we have to have whole new levels of power management on board. We see it beginning now. AMD and Intel both offer products that talk about system power management. We'll be talking about ever higher levels of system management.

One thing we have to address is active power consumption. When the device is actually running and is turned on, it has to consume less power. By the way, we want it to have the same performance we had before. One way to do this is to take your current 5-volt devices, test them at 3 volts, and ship them. However, going down to a lower voltage opens up a whole new can of worms.

One example of this is standards. About a year ago I was running around the country talking to people about the issues of low voltage, and I asked them what standards are you adhering to. Everyone said JEDEC I asked what do you mean by JEDEC standards? They said 3.3 volts plus or minus 10%. There was no thought given to maximum voltage levels allowed, and minor issues like I/O threshold levels. A high in one device wouldn't necessarily be registered as a high on another manufacturer's device. If you took the worse case parameters of different companies that claim they had 3-volt parts, they wouldn't talk to each other—but they're all "adhering to a JEDEC."

Well, the JEDEC committee has recently voted on a JEDEC standard for regulated 3.3 volt supplies. The council was suppose to have ruled on this last month. So in that regulated arena we think we're close to a standard, but not on the unregulated side—which PicDees will probably end up being.

One more thing on low voltage-- FLASH. If the devices themselves are to be able to program flash memory on board, the flash devices that are out there now have to be able to be programmed and read at the low voltages.

One thing that we do when we lower the voltage from 5 to 3, is we get a tremendous decrease in power consumption. Power and voltage are a square relationship—3^2 or 5^2 is 9/25—gives you a greater than 50% power savings. It also cuts your performance down dramatically. We can't afford to have the performance cut down, so you just can't take today's 5-volt product, test it at 3 volts, run it out there and think you've got a good part. You have to make sure the I/O thresholds match some sort of a standard. You also have to go back in and re-tweak the design and device itself to try and recapture that lost performance.

Now we're talking about whole new design methodologies and new simulation models. It's not a simple matter to go from 5 to 3 volts, but it's an absolute necessity.

Analog. When we talk about not affording microprocessors to stand alone and ASIC to standalone, and analog is a required function—we have to be able to bring it on board.

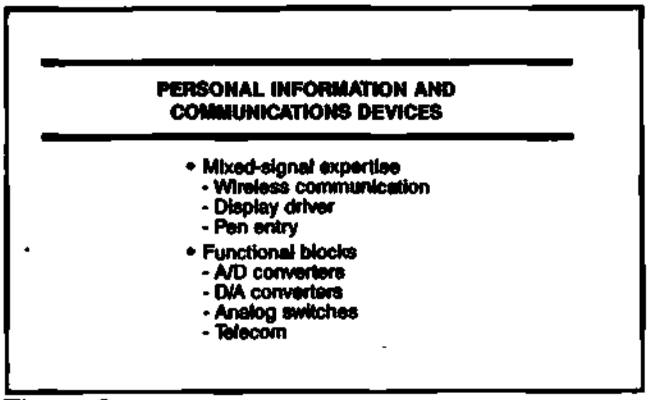

Figure 3

Mixed signal expertise is not a trivial matter. There are a few real good players out there and people who dabble in it—but it's an absolute requirement in the world of PicDees. So if you plan on getting into this game, and start thinking about the consumer market, the data processing market, and communications market—you also have to start thinking about whole new technologies and bringing mixed signal on board, and trying to separate the clock signals from your analog where it can foul up your analog.

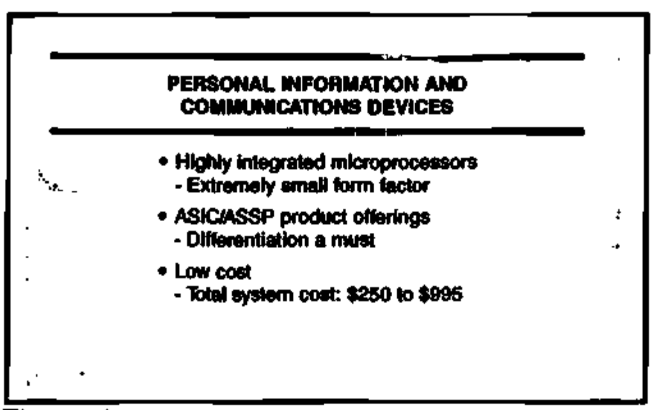

Figure 4

Such a small device that does so many applications. That's quite a lot for one company to come up with by themselves. Alliances are an absolute necessity—I don't think one company will become an expert in all of these in the time frame required. Market windows will continue to shrink, and product lifecycles will continue to shrink—so you've got to be on top of these technologies from day one.

One alliance involves AT&T and Go, for example. AT&T is probably one of the few companies in the world that has everything. They have the processor architecture in the Hobbit. They've got ASIC expertise, logic design, mixed signal, communications, and digital signal processing. There's only one thing AT&T lacks —the ability to take all of this to market.

Another example of an alliance is Intel and VLSI technology. Intel has an industry standard architecture—well understood—pervasive in the industry. They've got a knowledge of notebook computing, and power management capabilities. They have a partnership with VLSI (the leading supplier of PC logic chip sets today), a proven capability in designing logic chips, world class ASIC tools and the ability to bring a product to market quickly. It's a good foundation—good enough to start—but they're still going to have to bring in people with signal expertise and communications and signal processing capabilities.

These are a couple of partnerships that look like they'll have a good chance to succeed, but involve some pretty big companies. When you talk about Intel with its $2.9 billion treasure chest, making more money all the time, and with a stake in VLSI. Even Intel didn't want to go out and develop its own capabilities. AT&T is still partnering with other people. These are huge companies with a lot of R&D capability. I think everyone has to partner—it's a necessity in this market place. You have to be world class, you can't be mediocre in any of these capabilities.

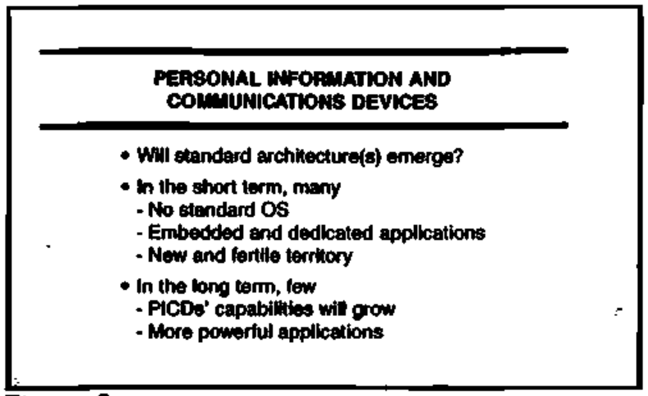

Figure 5

Will standard architectures emerge? No time soon. There's room for several different architectures. Already we've seen several companies offer processor architectures. We've got Newton, we've got the Hobbit going into EO, and we've got X86 products with HP as a derivative of a V series. We've also got different 386 products coming out—and we expect even more architectures. We think there's room for it right now—but we're in the experimental stage.

There's a big market out there that thinks they want these things, but everybody had their own mind-set. So we'll have people trying to differentiate their products—trying to find the right market—a whole brand new set of marketing.

In the beginning there's going to be a lot of room. People will buy—the mobile professionals will buy. As the market starts to mature (and the feature sets become more common, more standard and more well known), the manufacturers are going to try to make the devices more powerful and more capable. They'll add more hardware capability and make them last longer, but they're going to need more software features as well—more powerful tools. To provide those, they're going to have to find some third-party software manufacturers—Microsoft, Borland, Lotus, etc.

If we have 8 different architectures out there, not all 8 are going to get supported. Mr. Gates at Microsoft isn't going to say he'll support all of them—I'm sure he'll pick those that he thinks are the best and standards will start to form after that. It's kind of a dangerous position to be in if you're a vendor of a PicDee. As a consequence, I wouldn't sit around waiting for one of those pick me—I'd start some conversations with them and make the choice for them, that you are the one. Down the road, software will play a major role in PicDees.

Mr. Samaras: There are some front runners right now—Apple and AT&T.

The pocket PC was one of the first PicDees. It was a nice, small device, had a nice keyboard, and it used AA batteries and lasted for a while. One of the significant advances in PicDees was HP95LX, because basically HP took that IBM PC, shrank it down to size and gave us nicely integrated software. That was a major advance.

If we look back at this 5 or 10 years from now, perhaps we'll think this was a significant development. Even though the keyboard is small, I think we'll have better devices as time moves on.

Newton is a small pen-based device–you just use a pen and write on it. We hope that the Apple implementations is useful; that will do more for the market place than anything else. We have the software and hardware—it's just the implementation that's a problem.

Poqet computer, a Fujitsu subsidiary, also has a pen-based unit. By the way, I personally don't like the term pen-based. It might be a term that we use to describe PCs, but that term will go away. After all, we don't refer to our PCs as keyboard-based PCs. The pen is just an input device that we use.

Small form factors; memory cards from Sundisk—I think that's an IBM PC using a memory card for solid state storage. You can use those things with HP type of devices— but the programming voltage has to come down.

Communications—Motorola is doing some good work in that area.

Form factor—that's a PCMCIA modem. Now AT&T has a modem and fax in the same form factor. These are small devices that are very capable, and we'll see a lot more coming along the way.

There's a space for the small disk drive—like the 1.3" from HP. We're going to see 1" soon.

A 20 memory storage space is like a credit card—a bit thicker.

What's to come in the future? We're approaching PicDees from two areas—one is the organizer and the other is the communicator. AT&T calls these devices personal communicators because they say it is the telephone that's important to us because we use it all the time. So what if you have micros in there and you actually make it an organizer, too? Overgrown calculators are less useful to us than our need to communicate. AT&T is approaching this whole area from a communications standpoint.

Apple is approaching it from a different standpoint—perhaps they will bring in some of the entertainment value and element that is missing from our desktop PCs.

The tablet communicator is something you take along with you. By the way, AT&T has no illusions. They say today you're going to take that along with you and once or twice a day plug in your RJ-11 plug on the wall, and transmit and receive faxes. That's a very down to earth approach. You don't need wireless communication for that, but then you can use a cellular phone. I think that's what they mean by the cell pad.

The travel companion will be able to use the cellular phone and have the ability to access maps, databases, airline information schedules, etc. The note form is actually a pen-based system that you could use in the future. By the year 2000, perhaps we will have a video capability to take along with us.

So that's our vision for the future.

Panel Discussion
Strategic Processor Issues

Ken Lowe
Senior Industry Analyst
Dataquest Incorporated

Andy Bechtolsheim
Vice President and Co-Founder
Sun Microsystems Inc.

Phil Hester
Vice President and Director,
Advanced Workstation Division
IBM Corporation

John Mashey
Director, Systems Technology
Silicon Graphics Inc.

Duane Dickhut
Semiconductor Business Group Manager
Digital Equipment Corporation

Michael Mahon
Principal Architect, Computer Systems
Hewlett-Packard Company

Mr. Lowe: Our goal is to highlight the realities involved in penetrating the mainstream computer market with microprocessors. Since our theme is RISC processors in open system computing, I have been asked why Intel is not one of the members on the panel. The X86 architecture currently owns the mainstream computer market, taking in over 80% of the available revenues. Each of the RISC vendors, on the other hand, is making a bid to take away a significant portion of the business at hand. Furthermore, beyond their common use of RISC technology, each one has a different mix of technical and marketing advantages that they're going to use to stake their claim.

As a backdrop for today's discussion, I want to briefly review the opportunity at hand, the industry status, and some of the key issues that we feel are critical to developing insight as to who may dominate in the next 5 years.

First, Dataquest has predicted that the market opportunity for microprocessors into computer applications will grow from approximately $3 billion this year to over $6 billion by the end of a significant portion of the business at hand. Furthermore, beyond their common use of RISC technology, each one has a different mix of technical and marketing advantages that they're going to use to stake their claim.

As a backdrop for today's discussion, I want to briefly review the opportunity at hand, the industry status, and some of the key issues that we feel are critical to developing insight as to who may dominate in the next 5 years.

First, Dataquest has predicted that the market opportunity for microprocessors into computer applications will grow from approximately $3 billion this year to over $6 billion by the end of 1996. The challengers have a different set of advantages and disadvantages from the starting point; different set of silicon vendors, systems support, and they're all starting from a different base volume level.

Some of the key issues that each will try to address—technical performance, is the CPU performance really an issue? As the X86 family introduces the P5 early next year, pushing performance up to the 100 mips level, is this going to present an issue? Does the RISC processing approach really offer any cost advantages?

In terms of dominating the complete computer market place, can a vendor focus on one area, whether it's portables, desktops or servers; or do you have to dominate in each of the three areas in order to be a significant factor.

The new operating systems—Windows NT and the like will create a different scene but will that really create a complete level playing field for all the processors to sell volume into.

The X86 architecture has been cloned by at least 3 vendors, to date, and more are waiting in the wings. Is this really creating an open standard—multiple vendors producing multiple architectures and different price performance levels.

Can all five of the architectures survive and prosper as we look out into the future?

Mr. Bechtolshwim: We at Sun believe that the future of microprocessors is highly related to software instead of hardware.

This year—1992—software is a key industry. This is the first time Unix workstations and services will exceed $10 billion in revenue. I think most people don't realize that this is roughly 20% of the size of the entire PC DOS Windows market, in terms of revenue. Units shipped—the total is about 600,000 this year. If we look at the RISC units, the data looks different. The trend is to the RISC environment. Some of our analysts are projecting what's going to happen in 4 or 5 years. If you assume a 25% annual growth, you're looking at about 1.7 million units, 5 years from now.

The unit projection seems to be healthy. Assuming that the units hold true, the workstation industry will go to roughly half of the current PC DOS Windows environment (in revenues) in the next 5 years.

Where's all this growth coming from? This calendar year, Unix is roughly 50% technical and 50% commercial, even though the workstations are largely the technical side and the servers are more on the commercial side. This is in terms of revenue. If we add up the total number of Unix licenses shipped this year, all the SCO interactive licenses, this is the first year we'll pass the 1 million unit mark, in terms of licenses shipped. Breaking that down by operating systems vendor, most of the volume will be 5.4 based. We don't expect too many changes on that.

Where's the real opportunity for Unix? This is 50% of the entire computing market today, in terms of dollars, still proprietary systems, meaning not PCs and Unix systems. Five years from 1997, the projection is that Unix will grow its shipment about 22%. The PC market will gain as well.

In five years we see about $25 billion in the traditional Unix workstation service space, and another $50 million on all other platforms and implementations. In terms of units, this breaks down to 2.5 million workstations and 1.5 million other PCs. Assuming the total is true, Unix looks like the single, largest growth opportunity in the computer industry, growing by about $20+ billion dollars in the next 5 years. We don't know any other market segment that comes remotely close.

You have to have watch Unix, since that's what's driving these workstations. The Unix industry has really grown up and matured quite a bit. If you look at any single vendor, it might not be as large—but the industry as a whole is very healthy and has grown about 20% in dollars over the last year. We do see these growth rates continuing.

Mr. Mashey: MIPS architecture always faces the following interesting problem. It's gotten used and spread around among so many people, that it's much harder to count than any of the other architectures. That's either good or bad, depending on what you think. We think there's about 200,000 chips last year, and we think it's going to be between 300,000 and 400,000 this year.

MIPS chips have been used in PC-like devices, various commercial systems.

The part that surprises many people is MIPS chips usage in embedded control. For the economics of the semiconductor business, it's wonderful to be able to crank out chips over many years to keep our FABs busy and make the economics work. MIPS chips are in airplanes, printers, copiers, color copiers, terminals, automobiles, graphics boards, and telephone switches. Most Tandem computers in their product line use MIPS chips. They didn't tell people until they were shipping them. Tandem is a $2 billion a year company, but those numbers don't show up when you take the top 5 workstation companies. It's hard for us tell. I have no idea how to count some of these other things. Do I count $25 million for an F16 just because it has a MIPS board?

People wonder how a company like Silicon Graphics can keep up with this. Architectural design and VLSI design is a small piece of what you do. Where you really spend a lot of money is in FABs, in all the rest of the support, and in production. We get a free ride that many companies do not. We generally build our chips on processes that build SRAMS, very good semiconductor process drivers. Modern microprocessors have a lot of SRAMs on them. So what happens is some of our semiconductor partners think R4000's are easy, compared to building SRAMs.

The model that we like to use is like this It takes very aggressive machines built to very demanding problems, on things like image processing and visual simulation. Every generation squeezes these down to smaller machines that get into desktops, eventually.

It's only been a year that SGI started shipping desktop machines. Everything before that was desk side. I think you'll see that our volumes are going up, as well as the revenues.

This shows spec integer in years. What it shows is the chips that bother them—MIPS chips, Sparc chips, and then Intel chips with 486 getting very fast. What this says is that P5's will be out about 4 months later than R4000's. R4000's would be about 50 SPECs, and P5's would be about 70 SPECs.

If you look at this business, we're all getting 50 to 60% per year. I would bet that when P5s get out and you can buy them, it will get back on this line. I just remind people to be careful to calibrate what is real.

This is the strangest business. In the systems business, if you see a machine with a benchmark and you like it, you buy it. In the chip business, it's who can sell more futures faster.

These have been out in systems at 100 megahertz internal since March. Our 4000A's are about to come out—they get about a 50% boost. It gets another tune up to get about 200 megahertz internal, some time next year. This is one design team. The second team is working on the successor, which is another integer floating point balanced, single chip micro. This is a low power version, less than 2 watts; less than $50.

The first MIPS chips in systems came in 1987. We've got many where you don't see them. We get a free ride on SRAM. You should check on which vendors do SRAM and which don't. That will tell you some interesting things about what it will cost to do micros. When you see vague logarithmic charts, keep a hand on your wallet.

Mr. Mahon: Is CPU performance an issue? I say yes. If we look at clients, the continuing demands of GUI's and emerging demand of multimedia are a couple of good examples of why we're going to need more and more performance on the desktop. More performance than people think, not for recalculating spreadsheets, but for providing all of the "warm fuzzies" that people are coming to expect.

In the server domain, people are using ever bigger databases and bigger shared file systems, and they need them because their administrative expenses go up as the number of file systems they have to maintain. Large databases, large file systems and many clients guarantee that there is an unlimited appetite for performance at the high end. So performance is an issue.

Does RISC have any cost advantages? Can we get this performance by using X86 machines? I think there are some cost advantages for RISC machines, and I think the best example is the P5, which is coming out about around the performance of the R4000. It has three times the transistor complexity of the R4000, and it's just about the same performance. A significant penalty in complexity is paid for sticking with an architecture which has seen better days.

Let's look at the performance aspects. You're giving up about two or three times the performance, relative to the hotter, leading edge microprocessor implementations. If I take a design completed sooner than the P5, and is going to ship in volume a few months before the P5, the PA7100, there we see about a 2 to 3 times performance advantage.

The question is whether two or three times is a significant difference, given the marketing muscle, the established leadership in the market, the tendency to do the same thing year after year. Maybe people will just leave the 2 to 3 times performance difference on the table.

How important are the various realms in which microprocessors are used? We have portables, desktops and data centers. All of those are important areas. If we look at volume, clearly the lower we go on that pyramid, the more volume we see. On the other hand, volume isn't everything. How many people want to change their word processor every year? So far a lot of people don't want to do that; every 5 years if they're forced.

The situation we have now where there's a tremendous nucleation of software around a given architecture, is actually a transient situation. They're all important and they'll have their separate niches that develop as a result of that.

What about the OS? If we have a common, new OS that's common across multiple architectures, will that level the playing field? It would be nice to say yes, but I think the best we can hope for is that it will make the playing fields simply hilly and not mountainous. There's going to be some slant in that operating system towards certain kinds of environments.

What we're really seeing here is that the differentiation in systems is moving above the processor architecture and operating system levels to higher levels of system architecture. APIs are being implemented in places you'd never expect. We're seeing standard distributed computer interfaces develop, and that allows machines to interact and operate in network environments.

This is actually going to lead us to a distributed computing utility-like environment, and there will be a lot of opportunities for specialized optimized servers and for clients that are optimized in various ways.

There's a question about whether the X86 is becoming an open standard. I think if you were to ask the people who stand accused of making it open, like AMD and Cyrix, they would say no! I think there are extremely unequal participants in this, so it's very difficult to consider the X86 an open standard.

If you go down to the low end, or if you get "nichey" into low power chips or embedded versions, there are some interesting possibilities. In terms of who's driving the X86, there's no question about who's doing that. If you look at the P5, you'll see that the X86 architecture is evolving with considerable velocity toward a RISC design, although it still has one foot nailed to the floor, in terms of instructions referencing memory, a small register file, and variable-length instruction.

Can all RISC families survive? Maybe not. It would not surprise me to see the players change. On the other hand there are going to be lot of opportunities for servers and clients optimized around various price and performance points, and a platform which can do all of its graphics in the processor without requiring an external accelerator, or do all of its multimedia processing in the processor without requiring DSPs, has a competitive edge in terms of cost and power consumption. So I think there are a lot of possibilities for non-X86 architectures to survive.

In looking at the size of shipments, one of the things I call to your attention is that in the case of PA-RISC, shipments leverage over $5 billion worth of systems shipments per year. Theta is a substantial revenue flow which will maintain PA-RISC in a very competitive position.

An interesting question to look at is what we can expect in processor performance throughout the decade. In a way, the way we've tackled this topic is focused a little too closely on X86s and RISC processors. I think you can expect uniprocessor performance, which has been going along at 60-80% per year, and has been sustained now for several years, is going to taper off. Around the middle of this decade, we're going to realize that a good part of that compound growth was derived from mining the low level parallelism in single-threaded programs. We're going to exhaust this kind of parallelism. So around the middle of this decade, I would expect us to get back to something more like 20 to 30% per year growth rate in uniprocessor performance.

Why is that important? I think that means we have to be a lot more interested in multiprocessing. We are already exploiting a lot of "embarrassing" parallelism in things like transaction processing, various kinds of services on networks, even places inside graphics. However, there is much more to learn about this. We have a great deal to learn about how to apply general purpose multiprocessing.

Symmetric multiprocessing is fairly straightforward. We're going to see SMP for every value of between 2-way and 16- way. The sweet spot in system design is probably around 4-way. That brings up the question—what do you do after 4 (which gives you an improvement of about pi, in terms of performance)? You start looking at things that are not so tightly coupled. You look at loosely coupled systems. We've got a lot of those; a lot of processors plugged into networks. You can have thousands of machines on networks cranking away on problems, as long as they're sufficiently coarse-grained parallel problems. Unfortunately they're so loosely coupled, that if there's much interaction between the parts, the whole thing dies in communication.

We should also consider multicomputer systems I refer to as "Closely coupled"—that means that we're not sharing memory; we're not sharing an operating system. But we can communicate with high bandwidth and low latency. I think that kind of clustered system will give us scalability from a handful to several dozen on a lot of problems interesting to customers. I think this will be a very important area to watch during the next decade.

The final thing that's going on is that we're seeing tremendously increased levels of system integration. The reason is the nonstop progress in integrated circuit technology that's been fueling a great deal of what we're talking about here.

By the time we get to 64-megabit chips, somewhere around the latter part of this decade, we'll also be able to build a system on a chip which has everything—processor, cache, cache controller, video processing, ATM interface—everything but the DRAM. And that will mean we can build something about the size of a credit card that is about a 64-megabyte, 500 MIP processor with a selling price of about $200. You slip that into a display, attach a tuner and it's an HDTV. That will cause qualitative changes in the computer marketplace. Because if you thought the personal computer revolution snuck up on mini and mainframe manufacturers, what do you think an entertainment revolution would do to the current computer industry?

M. Hester: On a worldwide basis, we see the market split about equally, 50% in the commercial, and about 50% in the technical market . On the vertical scale it's continuum, from very low cost systems on the low end—notebooks, laptops—to some high end systems, commercial machines and scientific machines.

If you think of the market place a series of concentric circles in terms of technical versus commercial, that's what we're up to. We clearly believe there's a high volume base on the low end that we have to drive. We believe that is going to be commodity driven in terms of the things you've heard and in terms of the silicon technologies underneath that. As you scale up above that level, there's going to be some system effects that start to show up, such as data integrity checking, and scalable issues addressed by mainframes in the past that will need to be addressed.

Our strategy is twofold. What I'm showing on this (chart) is some very high volume microprocessor technology. And (above that) is some technology which would leverage that base but not restrict in terms of some of the packaging constraints that you would have assuming high volume under line technology.

In terms of what's been delivered to the market, there are two areas—the commercial side. Performance is doubling about every 12 to 18 months. Since the RS6000 was introduced in the commercial market place, using a TPC-A benchmark, the performance has doubled about every 10 months. If you look at the technical side of the market place, the performance is doubled about every 17 months. So if you take that 12 to 18 month generic doubling of performance, what's been delivered to the market place falls within that window. As we get into the true semi micron technologies, we may see an accelerating rate of improvement, as opposed to decelerating rate of improvement. We expect the performance to increase at a continuing rate of doubling every 12 to 18 months in the technical and commercial environment.

If you cluster some of these machines together—the RISC technology base machines—our experience has been that you can already run a large portion of the super computer job loads. If you keep in mind the price performance on the RISC technology as a factor from 3 to 10, the mini super and super computer business— you can buy the RISC technology in increments of 50-$100,000, as opposed to increments of a million to $10 million. It's a really good deal.

If you think about taking some of the super computer jobs today and distribute them on clusters of high performance workstations, we tell you that 60-80% of all the jobs today run very efficiently in the cluster technology with the amount of real memory and floating point capability that you've got.

What's interesting is what's going to happen in the future. Microprocessor technology is going to continue to evolve. That will mean the node performance in each one of these cluster scenarios goes up so you're able to run more of the jobs. Just as importantly, is what's happening in the area of high speed interconnect. If you look at what's actually happened, the top rate of change is microprocessor performance. I have applied it on MIPs, etc. If you apply it on megaflops or spec marks it would look the same. It's doubling about every 12 to 18 months, and it has been since the introduction of the first RISC technology in the mid-1970s. Below this is the intertechnology—the local area network regardless of whether it's Ethernets or token rings, has been stuck in 10's of megabits per second since that same time frame.

What's happening right now, over the next 3-4 year period is a transition towards magnitude improvement and more than 2 orders in magnitude improvement in latency between the local area network technology and the fiber interconnect. The FDDI technology at 100 megabits per second is in volume production, this year. Within the next 12 months, the gigabit level fiber channel standards should be in production. What that means is now that the bandwidth ratio of MIPS is improving in these clusters, you can think about doing finer grain parallelism than you could in the past, both for commercial and scientific applications.

In terms of the ability to do parallel processing, what you need to do beyond multiprocessors is answered by some of the key things that the fiber channel standard technology brings to the market place.

This is how we see that playing out. The uniprocessors will continue on doubling their performance about every 12 to 18 months. On top of that there will be a family of symmetrical multiprocessor products developed.

What do you beyond that, both for performance with hundreds of transactions per second, which is a large business. In addition to the price performance attributes of these systems and scalability, we also think the attribute of availability will become more important and we think is a key enabler in solving most of these problems. It allows you to build loosely coupled clusters for individual nodes. It can be either uniprocessors or symmetric multiprocessors in anywhere from 16 to 128-way FCS connections we think are reasonable with individual nodes being in the hundred of MIPS and transactions per second. So you're talking very large systems.

The fact that you can have physical separations, power boundaries and distribution of applications over the fiber channel standards also allows us, with the appropriate software to address the issue of availability.

The range of systems you need to develop are clearly built on a foundation of uniprocessor performance. Then for both performance capability and availability, closely coupled fiber interconnected systems.

At Motorola, in order to drive volume business, we are developing a family of microprocessors. Approximately 12 months ago we put a roadmap together; we described the 601, which was designed for use in entry and mid-range systems, followed by a family of 3 products that would span the general high volume range from the notebooks and laptops on the 603, to some mid-range commercial and scientific systems on the 604. The high end to be held by the 620 utilizing 64-bit architecture implementations of power PC for the high-end commercial and numerically intensive market place.

Approximately 12 months ago we put these road maps together. Since then, we've put a family of design teams together that have been working on all of these parts since then. At the time that we put this schedule together, we had a goal of taping out the 601 on July 15 of this year. We met that objective. We had some aggressive objectives for this design, in terms of die size. We clearly think the RISC technology brings either price performance or time to market advantages of technologies.

One of the things we tried to focus on in the 601 implementation was extremely good performance in a manufacturing technology, but with a die size had a cost structure better than any traditional microprocessor. In fact, we made our schedule on July 15, to the exact date. Approximately 4 weeks later, we got the chip back from the foundry and it is now functional in the laboratories. It is approximately 11 mm, 120 sq. mm, half the die size. We rate its performance somewhere between 60 and 80 SPEC marks. It consists of about 2.8 billion transistors.

One thing is the underlying design technologies that you need to produce these parts. We are convinced that you have to access A world class foundry.

If you look at a major inhibitor, parts being late into the market place, in many cases the parts are late because of the design complexity and the inability to verify those parts prior to the fabrication. So we're investing heavily in the design tools themselves. If this part is functional in the first pass, meeting its parameters, it's a testament to the fact that we're able to address those views.

Mr. Dickhut

We clearly believe that a family of high volume parts like this will be successful in the industry and we also need to have a range of offerings above this that extend to the very high performance of commercial and scientific environments.

I have taken a different perspective—will RISC processors in the open computing standards really end the dominance of the X86. I'm going to look at this from a market perspective, that is, what's the market really require to be in this end.

What's the market—On the (volume pyramid), you see special purpose computing at the top, which is typically characterized by hundreds of systems a year with servers; the next segment followed by workstations, PC's and the embedded segment, typically having 10's of millions of units per year.

The three areas that I want to focus on are primarily workstations, PCs and the embedded segment.

I'd like to share some of the industry trends. The computer is becoming the chip. Every computer, whether a server or a workstation typically has a microprocessor in it. Very few people are doing any computers designed with another methodology. Performance continues to improve by 50% per year, and we see that continuing, in fact, increasing as we get into the subhalf micro. There's also this treadmill. The decline of the price per MIP continues by 20-25% per year. If you're at the system level, it's typically today at $100 to $200 per MIP. At the microprocessor level, the high end RISC space, it's about $9-$10 per MIP if you want to buy a microprocessor. In 5 years, that's going to decline to 2-1/2 to $3.00 per MIP. So we're all trying to make money while we're on this relentless treadmill, and we don't see it stopping.

Other trends are that the hardware development process improves at a faster rate than the software development process, which really leads customers to value their software investment much more than their hardware investment. And we see that continuing.

The computing paradigm shift over the last three decades, where the industry started out in batches, typified by mainframes that went to timesharing style of computing, typified by minis, and now we're in the era of distributed computing, as typified by desktop microprocessor based systems. The distributor paradigm offers a lot more opportunity for vendors to get niches in this new computing paradigm.

Part of the computing industry, as typified by the low end PCs, is really entering the commodity phase of its lifecycle. If you talk about low end IBM compatible PCs at the $1000 to $1500 level, people are tending to buy pretty much on price. They really don't care what's inside the box; they call the lowest price mail order firm, and they buy one. That trend is going to become stronger.

So with that as a backdrop, let's get into the four major criteria for getting into the segments of the markets that I identified. The first one, and foremost, is that customers want their software investment preserved—preserved to cross-hardware generations from generation to generation; they don't want to reinvest and convert or port their software to other platforms. Within the hardware generation, they also want software compatibility. Many customers are buying a multiple levels of integration. Hence, having one architecture and one software base that can span multiple levels of applications, is a key requirement for many customers.

At the same time, customers are looking for hardware platform independence. Where they really want to take advantage of the latest price performance from whatever vendor happens to be in the lead at that point in time, and really be independently decoupled from their software.

Multivendor network systems is another major requirement. No one vendor is going to be able to supply it all. There will be vendors supplying niche products for different parts of the distributed computing paradigm. Also, customers are requiring standardized hardware and software interfaces in order to be able to advantage of hardware that has the latest price performance standard such as busses, networks, APIs, etc., are becoming more required to be able to compete in this end of the market place.

What will it take to meet those requirements. Some of the factors we see to make the architecture widely used in the market place. There are three ways to do that all at the same time—by providing an open an operating system so you're really encouraged; application providers to port their applications to the operating and to the architecture. At the same time, you really want to have several chip suppliers who make sources readily available.

We see two, three sources for alpha. We no longer believe that the field of dreams marketing approach—if you build enough they will come—is going to work.

One architecture spanning the palm top to the super computer is really becoming a major factor and a key element in terms of meeting the market requirements, so that customers who buy at multiple levels of integration can really invest in one software development process, one software architecture, and be able to span all of their needs.

Another key element is providing a software migration path. Architectures do tend to have finite lives. In order to be able to get into this end of the market place, especially the PC market, one needs to supply a path for the existing software base, such as Windows NT, which Alpha plans to do, and Microsoft is importing NT to the alpha architecture. In addition to that, vendors need to make it easy for customers to migrate their software. So in addition to NT being available to run on Alpha-based PCs, we also have binary translation programs available.

In the case of customers who perhaps have lost their sources, and who still have binary files that they want translated, we are providing binary translation tools. So that if you're coming from a MIPs architecture or a Vax architecture, you can really ensure that you're going to preserve your software.

Some of the other elements in the success profile are to really have different implementations of your architecture targeted at different parts of the market. Today we have the 21064 targeted at workstations and servers.

That's been out in the market place as a microprocessor at the chip level since February, where it's emphasizing price performance, graphics and network functionality.

One implementation is really not going to satisfy all of the market segments. So we have under development two other families of Alpha microprocessors—the 21066, aimed at the PC market, which will emphasize price performance, have sufficient functionality; then we have another member of the Alpha architecture, the 21068, aimed at embedded applications, where real time and IO capability is a criteria; also having minimal chip solutions and low power is a criteria. We really believe that any vendor is going to need to have multiple families of implementations really addressing all these market segments.

Other factors I want to emphasize are longevity of the architecture. People really want to preserve their software investment as long as possible across multiple hardware generations. It's been a well understood concept in the industry that applications tend to consume on bit of addressing every year. So with a 64-bit architecture such as Alpha, you can see that there's plenty of life left in terms of the addressing capabilities that would be needed for future applications.

Another area is promoting standards. One standard is the PCI (peripheral component interconnect), that will be emerging in the PC space, in order to standardize putting together elegant chip solutions from different vendors.

Another factor is not only access to, but control of the future semiconductor technology. If vendors are going to be price performance leaders, what you're going to have to do to get any share of the market, having control over the semiconductor technologies is going to become a more important critical factor.

As we play this game out in the future, I think that's become more of a critical factor in order to preserve marketing advantage, and be able to capitalize on the leading edge technology.

What are the inherent RISC advantages? Over the last 10 years, we found, when all other parameters are equal, that the RISC architecture provides a 2X performance advantage over CISC architectures. Specifically, we found that the RISC architecture is much better for performance scaling over time. Alpha has been designed to be able to be scaled over a 1000-fold over the next 25 years. When you think about that, that's a pretty tremendous amount of scaling, and a pretty long life time. We think that RISC architecture really allows you to do that much more than a CISC implementation.

From public data, the 21064 consists of 1.7 million transistors. It was initially introduced in the market place at 150 megahertz; there will also be a 200 megahertz offering coming in several months. The P5 consists of a 3 million+ transistors and will reportedly be introduced at 66 megahertz.

Apparently the RISC architecture, implemented with Alpha, has a minimum of 2X performance advantage, and probably a 3X performance advantage. There's also a year's difference in time when these parts are introduced. Also, there's a cost advantage in terms of the number of transistors per function that it takes to implement RISC versus CISC. You can see that the implementation on the 21064 has a significant advantage. That plays itself out in the semiconductor space, in that fewer transistors mean higher yield, which means lower cost for the RISC machine.

So we see those advantages playing themselves out in several ways—one, there's going to be at least a 2X performance advantage. At the same time there's going to be a significant cost advantage due to the additional complexity that SISC machines carry. There's also going to be less development time involved in order to develop these microprocessors, given that they're less complex, and there's also going to be lower development investment on the part of the microprocessor.

In summary, any vendor who meets all of the market requirements has a chance to be successful player in this game. If I define what an end of dominance scenario would look like, I could see that a viable scenario could be five years from now, that there's three RISC architectures broadbased in the market place, each having 15 to 20% share of the market with the X86 share being 30 to 35%, and the rest being split among a lot niche players. We think that could happen perhaps as early as 4 to 5 years from now, and is a real possibility to happen by the end of the decade.

Questions & Answers:

Question: For single chip microprocessors, by the end of '93, what will be the cost for delivering approximately 100 MIPs of performance; and at that point in time, what will the high water mark be for single microprocessor performance?

Mr. Bechtolsheim: $100 for the first one; and 200 specs for the second one.

Mr. Mahon: $100 to $200 range; 150-200 spec marks.

Mr. Hester: $100-$200 range; I see the possibility of optimized design points, within the next year, if you trade off optimization for energy versus floating point performance. If you wanted to optimize the design more for commercial of things, maybe 200-250 spec marks.

Question: With the overwhelming momentum behind Windows NT in the market place, is there any significant reason why you wouldn't want to have a port of Windows NT supporting your architecture?

Mr. Bechtolsheim: Two weeks ago, Microsoft announced that NT was slipping by at least 3 months; second, we don't really see any shipments of NT until the middle of next year. Speaking for the technical market, in the midst of designing something, the last thing you want to is switching operating systems, particularly if it doesn't offer you any advantage to what you already have. In the commercial market, I think it's a different story. It's more a question of what functions NT bundles will offer that are not available today, to PC networks.

Mr. Mashey: I believe it's got to viewed as either Plan C, D or E. I don't believe it's real. I don't believe any operating system pops into reality. It seems to take several years for that to happen. To bet against Microsoft does not seem to be a really prudent business decision.

Mr. Hester: If you expect to be successful in the high volume RISC business, by definition you're going to be supporting whatever operating environment exists at that price point, in the industry. There's a number of viable players; NT is one of those; there are number of others. Clearly, what we're going to be driven by is what the operating environment is that exists. Software technology is moving in parallel with the processor technology. It's going to be a lot more feasible to have some more personalized environments, more so that has been in the past, that may help us address some of the flexibility we need on the software side of things.

Mr. Mahon: I think there are going to be niches in the future for other architectures. But if you talk about broad based full line suppliers, I think it's going to be the system oriented companies that have the best chance.

Mr. Bechtolsheim: I think it's going to be based on marketshare, and the top three will really be SPARC, Power and MIPS. It's not that the other ones will go away, but in terms of volume, the question is how will they grow to the volumes you want to be in to be a successful player. The total market is only so large. So the history of market share has been that the largest vendors have been gaining and the smaller market vendors have not been gaining.

Mr. Mashey: I think all five are still going to be around, so it's hard to argue that. I think we're going to be around, if only because lots of other folks need alternatives. The very thing of the system vendor that has controlled its own destiny completely, and controls the chips, occasionally makes other people reluctant. I think what happens is I doubt we will have anybody in the MIPS camp that's as big as IBM.

Mr. Mahon: I think that they will be around. It takes more than volume to make a business. Profit helps.

Mr. Hester: We're investing to be one of the survivors. I agree with what's been said. There's going to be a number of players, a small number. Exactly how that's split up between the major players, I think it's hard to say, but I do see a small number, 2 to 5 that have a majority of market place. The market is only big enough to support that.