Dataquest Presents

Semiconductors '96

$300 Billion Challenge: Let the Games Begin!!

EXECUTIVE SUMMARY

The 22nd Annual Semiconductor Conference

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Prepared Especially for:

Gene Norrett
Dataquest

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Dataquest
a company of
The Dun & Bradstreet Corporation

26524 Golden Valley Road, Suite 401, Santa Clarita, CA 91350
(805) 298-3263 (800) 477-7979 Fax (805) 298-4388

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We are pleased to send you the full transcript and Executive Summary of Semiconductors '96 held October 25-26, 1996 at the Renaissance Esmeralda Resort in Indian Wells, California.

The Executive Summary is a quick-read of all 22 sessions that you may want to circulate. The large volume contains the actual proceedings of the sessions with some editing for easy reading.

Additionally, a CD-ROM of the entire proceedings is available and can be ordered by calling 1-800-311-7904.

The full transcript book contains a keyword index at the end for your convenience in looking up specific companies, topics or persons.

While print and electronic versions cannot replace the interactive, networking and sharing atmosphere of the conference, we hope the easy reference to ideas, topics, graphs and charts will prove invaluable to you. See you at next year's conference.

Gene Norrett
Corporate Vice President and Director
Semiconductors Worldwide
Dataquest

Please direct your comments to:
Nancy A. Gaylord
mmakers@aol.com
PHONE: 800.311.7904
FAX: 805.298.4388

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Session #1: Welcome

Gene Norrett
Corporate Vice President and Director, Semiconductors Worldwide Dataquest

The theme of our conference today is "Semiconductors: Three hundred billion dollar challenge. Let the games begin." We chose this theme, first of all, because this is the year of the centennial anniversary of the modern Olympics, and secondly, it is also kind of reminiscent of the challenges facing the manufacturers in the semiconductor industries.

On the other hand, the manufacturers in the explosive semiconductor industry, finding a delicate balance between risk and reward can be the difference between being a leader, or being a follower, having profits or losses, or being viewed as a valued partner to your customers, as opposed to having your hated competitor get the accolades from that same customer.

Your tasks are to avoid the many pitfalls on the road to the 300 billion dollar semiconductor market, or so, that we're projecting for the year 2000. Your rewards are seizing the unprecedented opportunities for increasing growth, profitability, and of course, market share.

As we start the fourth quarter, we're taking the first step on this road to the 300 billion dollar market, or so that we're projecting in the year 2000, which we think will be the peak of the next coming business cycle. We hope that this conference will exceed your expectations, in terms of venue, quality of delivery, networking, and of course, deal-making. That's for some of you, one of the major reasons for attending this conference, and some of those deals can involve getting yourself a job.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #2: President's Welcome

Manuel A. Fernandez
Chairman of the Board, President and CEO, Gartner Group

Good morning everyone. It is truly great to be back. It was six years ago, the last time I was at a Dataquest Semiconductor Conference and as I was telling a couple of folks outside in the hallway here before coming in, it's been like I've been in a time capsule. Six years ago, memory pricing was going down, the RAM forecast had been, was the actual sort of best, worst in the forecast, there was issues with Japan and the U.S., and it just like somebody woke me up six years later and here I am and everything looks the same. All of the friends, all of the stories out in the hall were the same, so it's unbelievable. But anyway, it really is great to be here.

Today I would like to be able to maybe give you a message from a different customer, from your customers' customers. And I give you a little bit of an idea of what's happening on them and how they are going to drive your future and my future.

First of all, I mean it's clear that, that 1996 so far has been an incredible year. Sure, the PC business continues to grow, 19% up from a year ago. The story of the year has obviously been the debacle of the RAM business. Not only has been the deepest ever, swing, from being up some 80% a year ago to being down some 40% this year, but it has been the fastest decline that we have ever seen in our industry. The previous fastest decline that we have seen was a business that went down about 50%, actually 40%, in about 14 months.

Not only has gone down some 40%, that was the previous biggest dip in some 14 months, but we have seen here that in 9 months the decline in the RAM business was 70%. While the Dataquest folks did an excellent job forecasting the inflection point that this was going to happen, I think that everyone missed the severity of this particular inflection that has taken here in this business. Clearly we are paying for the excess capacity now, and that will continue in the RAM business. I don't think that there is a foreseeable short-term change or shift. I would like to shift and give you this user view, and I will tell you in a minute that this is basically, if you take a look at what Gartner Group does, and there's a gentleman that's going to be here tomorrow, his name is Winkler, and he is going to give you the CIO view. He is going to take a look at the Chief Information Officer and he's going to try to give you some of the things that they see, from their point of view.

The information technology world as a whole: expenditures are going to go and increase from about 650 billion dollars to about 1.3 trillion dollars by the year 2000. Huge increase. But the amazing part of that whole process is that it's not only that the real dollars are going to increase, but expenditure of information technology as a percent of revenues of the world corporate companies is going to increase from about 5.8% to 9.5%.

Now, it is very clear that all of a sudden the IT world, that used to be relegated to be just a staff position, it is now in the middle of the center stage of the world, and all of a sudden there are huge questions that are coming up from the top, from the CEO, from the Board of Directors, "How are you going to be spending this money? and how am I going to be successful? and how am I going to change the top line by the information technology revolution, not to be able just to take a hit in the bottom line by that extra 4% that is going to be spent on information technology?" Clearly, information technology is being moved from a staff role, to a market share role.

Now, in addition to that particular problem, the ultimate user is having two other problems. Problem number one is that the life cycle of products converts itself into the life cycle of information technology end user products. We have seen, in the average life cycle of 14 to 16 years drop to the 5 to 6 year level and quickly moving into the 18 month level. At the same time, 1996 has been marked as an 80% increase on the number of new products introduced to the end user.

So think of this end user, the individual that eventually buys all of the products that you make, is being bombarded from the top by this budget pressure, is bombarded from the bottom with the life cycle, and the number of products available. So what's happening is that there's an incredible confusion at the CIO and the CEO level that, in addition to it, there is an incredible instability in the organization side of the business. I believe that that instability on the organization has had direct costs of what has happened with demand in the last 9 months.

Now, if you look ahead, and you would ask, as we do, to our 7,000 different enterprises that we do business with, and 90,000 clients on a worldwide basis. So we think we have a pretty good sample here. This is a pretty good statistical sample, if you would, about anybody that buys information technology and you ask them, "What are the 3 or 4 key issues that you're dealing with?" They will tell you that technology obsolescence is number one. They are now figuring that the life cycle has been contracted, but in the software side, where software obsolescence used to really be around 12 to 15 years, we think now that 70%, seven zero, of all of the products that are presently under development, or being purchased in package form, will be

obsolete by the year 2000. That is an incredible impact to the user world.

The second thing that they will be telling you is that there is a huge movement to mobility. Just to give you some numbers -- today the average budget, the average budget that is being spent by companies in United States, for mobility or work outside the office space, okay, mobile or outside the office space, is about 4% of their total budget. We are now forecasting that by the year 2000 that number is 30%. Thirty percent of all of the budgets of IT will be for outside the office environment technology.

Then there's always what I would call the killer virus, and the killer virus is this, the actual things that may happen that can blow everybody away. Some one-time killer problems, and obviously the year 2000 is one of those. Those last two digits' impact in the technology business is going to be about 600 billion dollars of expenditures to be able to make the conversion. A common European currency conversion is going to be somewhere in the neighborhood of about 250 billion dollars. Now, what will all these things lead to? Well, actually, there's one more. And that is the total negligence in our user environment today. It is that the infrastructure is being absolutely not looked after. The infrastructure that is going to be required to be able to have the office work, the ability to be able to put in all of these new products, are not being taken care of, and there is going to be the ability, the need, the requirement, to be able to invest into that whole infrastructure.

I believe that all this leads directly into a very, very healthy amount of demand for products, '98 through the year 2000. I really believe that by the time we enter the cycle of '98, '99 and the year 2000, you are going to see the biggest boom yet that we have ever seen in the information technology world. We'll be out of silicon again and all of those things

I think it's important to have one red flag, and that is that with all of this demand, and all of these one-time killer problems that may appear, the requirements to invest a significant amount of money that has to be invested, not all of the money is going to be available. So there are going to be an incredible amount of tradeoffs. I believe that there are going to be good companies that will have tremendous products, but will not make it through this next four years because they are going to get caught in a tradeoff problem. So there isn't enough money to do the year 2000 conversion, common currency, mobility, and so on and so forth. So, I urge you that you look at that, and be able to make sure that the partnerships that you have with your particular clients are ones that are based appropriately on what the end user product eventually is, and what the demand really is going to be.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #3: The State of the Economy: Looking Ahead

Donald H. Straszheim
First Vice President and Chief Economist, Securities Research Economics, Merrill Lynch

First let me describe our good looking economy, because the current economic circumstance in the United States is probably as good as it's been in maybe a quarter century. Secondly, I want to talk about our changing economy, and I want to just pick out the demographics and the aging of the baby boomers. And then the third thing I want to talk about is the changing global economy, and then last, I want to talk about technology.

First, our good looking economy. We're, somewhere near equilibrium. We've had these ups and downs in our growth rate, and the second quarter growth rate was 4.7% and the markets got all uptight, "Oh, this is too strong, and now it looks like growth in the third and fourth quarters is going to be back in the one and a half to two percent range which is a little bit below our sort of longer run equilibrium level." But the recovery now, since March of '91, is sixty-seven months old, and we had an eight-year long recovery with a soft landing embedded in the middle in the 1960s, and an eight-year long recovery with a soft landing embedded in the middle in the 1980s, and it looks like we are doing it again. The unemployment rate is now in the low five percent range, and most economists would say that is near what we would describe as full employment.

The inflation rate has been stuck at about three percent plus or minus now for fourteen years. We had ten or twelve percent inflation in '81/'82, called a halt to that, brought the inflation rate down, and it's been roughly in this range now for over a decade

Corporate earnings: 1993, 1994 and 1995 we had corporate earnings for the S & P 500 on an operating basis up about twelve or fifteen percent each year. In '96 and '97, the earnings growth is going to be slower, but the estimates from the Wall Street analysts come up with numbers that are still ten or twelve or fifteen percent.

So that looks pretty good as well and I mentioned our competitiveness — we are dramatically more competitive than we were a decade ago. After an awful lot of cost cutting and hard work and so forth, and we've make a lot of progress on getting our budget deficit under control

The trade deficit is not nearly the issue that it was a few years ago. So on a whole host of areas our economy looks like it's fairly near equilibrium, and our view at Merrill Lynch is that '96 is going to come out to be a pretty decent year in terms of the economy. Growth in the two to two and a half percent range and the same with '97, and inflation is about to rise a great deal.

The place to watch, the concern on inflation is wages, and the reason wages are a concern is that wages and salaries compensation is between two-thirds and three-fourths of national income in every economy in the world, rich or poor, including ours, and wage rates are now rising about a percentage point faster than they were in '92 and '93, and in the long run, wages compensation and inflation go hand in hand.

If the inflation rate stays under control and the economy grows only weakly in the next few quarters, not overheated, there is a decent chance that bonds will rally a bit further and we will see yields back down to maybe six and a half, but not a great deal below that, and bonds are going to essentially be in pretty much a trading range.

Let me make one other comment before I talk about some of these changes on the demographics about Washington, talk about change. I presume Clinton's going to win, and the debate now is whether the Democrats take the House and the Senate, and there is a fear in the financial community that if the Democrats take the House and the Senate and the White House, there is going to be this lurch back to the left, in terms of fiscal policy. Don't worry about it, it's not going to happen. The President is a parade leader and the parade the last decade has been about fiscal conservatism because the population is aging and becoming more conservative in many ways, and that extends to fiscal policy

Now let me talk about our changing economy, the demographics. We all know about the baby boom. The baby boom from 1946 to '64 was so important because it was preceded and succeeded by a baby bust in the depression years and World War II, in the Vietnam War, and the women's movement. So we've got this big hump in the population that's getting one year older every year. If you've got changing behavior that's predictable at different ages, and a changing share of people of different ages, you're going to have changes in the overall economy, and for the last thirty years you had all these baby boomers trying to accumulate consumer durables — a great consumer boom — and they were buying their TV sets and their VCRs and their sofas and their tennis rackets and all of that — it's over. Now they're a little older, now they're trying to accumulate their mutual funds and this phenomenon, and I'm not singling out mutual funds, I'm talking about the shift from spending towards savings here, this phenomenon is going to last about a generation because the baby boom lasted about a generation, and it's going to be a big deal. So let me just mention a couple of specifics here. Think of the number of forty-year-olds in

this country. From 1975 to '85 the number of forty-year-olds grew by a million a year; and then '85 to '95, a million a year, so if you were selling tennis rackets, "God, what a great tennis racket salesmen I am. I'm selling all these tennis rackets." Well, the next twenty years, your market is not going to grow by a million a year, it's not even going to be flat, it's going to be down. So if you're geared up for twenty more years of boom like that, you're chapter 11.

Now conversely, take the sixty-year-olds, and these are the same people, by the way, that were forty. The sixty year old market has been stagnant for twenty years, so you're geared down, you're going to leave all the growth on the table for the guy across the street who's geared up, who sees it coming. So that the changing demographics are extraordinarily important.

Now let me talk about the changing economies around the world, and I want to start this by talking about inflation. In '97 the inflation rate is going to be lower worldwide, according to our forecasts, lower than any time in the last quarter century. Take Europe as an example. The highest inflation rate we can see in Europe in '97 is about seven percent for Greece. Every other major European, even minor European, country in '97 is going to have inflation that's under four percent. In the ten major economies in developing Asia we follow, eight of them are going to have lower inflation rates in '97 from '95. The so-called transition economies — Russia and the formerly centrally planned economies — inflation's down dramatically the last few years and going to go down some more. Great progress on inflation in Latin American. Japan's inflation rate, right around 0. We don't have an inflation problem.

Let me list eight factors that are causing this. First of all, central bankers around the world are increasingly committed to inflation control. Secondly, globalization. We see it everywhere, and companies represented in this room, and our own company, we are all looking for the lowest cost sources of raw materials, and we are very rapidly getting to the point where you no longer think of General Motors as the American car company, you think of it as General Motors the car company, and it is not Toyota the Japanese car company, it is Toyota the car company.

Technology is a great plus for inflation control around the world. Fiscal restraint, we've made progress. The other countries haven't made as much as we have but they have made a lot as well, and there's a pretty good commitment, even in the developing economy. And finally, the cost-cutting and restructuring that we have been doing, really since the end of the '81-'82 recession, is beginning to take hold in Europe, and slowly in Japan as well, and even in many of the emerging markets also.

The collapse of communism. There are maybe three billion people around the world who used to work in economies that were command and controlled economies, and now they are making this transition more or less rapidly to market systems, and that's helping the inflation rate. Lastly, privatization. In many economies around the world, not just the centrally planned economies, but even in the mixed economies and market economies, there were operations that were public-sector enterprises now becoming private-sector operations. So great inflation progress — do not worry about a resurgence in inflation any time in the near future because again these are global markets, and you cannot go it alone. If you try to go it alone, you try to pump up your economy, and the cost of it is higher inflation, the market will just leave you, and you'll die, and increasingly, countries around the world understand that we are all in this mess together, and it's an extraordinarily powerful and positive thing.

The banking industry consolidation — the reason you are seeing this enormous banking industry consolidation is the computers and staff of one bank can handle the transactions of two and it's no where near over. Fifteen thousand banks in the country a decade ago, and now ten thousand headed to some very low numbers. The technology intensity in insurance is really quite similar. I was out with one of our investment bankers to see a client of ours here recently and they've got this company that thinks it's going to double their business in the next three years so they said, "Well, we don't know where to locate it, we'll bring the economists down, see what the economists have to say." So I go down there, small southern state, they've narrowed it down to three locations, right next to their current facility in this small southern state is one possibility, the second possibility was India, and the third possibility was Ireland

The technology is flattening organizations. You see this — you're driving it. In the old days you had this pyramid, and the guy in the middle would get this information fed up to him from these people below, and they would massage it, then they'd feed it up the line, and they would keep doing that. People with the requisite job skills are having their wages bid up and those without are falling off the bottom, and if you believe, as I do, and I suspect as you do, that this information technology revolution is just in its infancy, this phenomenon is going to continue.

Two last points — companies that fall behind, in these information technologies that you are driving, are going to be chapter 11. A retail firm that does not have point-of-sale data capture, has no chance of surviving. A manufacturing firm that does not have goods, or just-in-time inventory procedures, has no chance. A distribution wholesale firm that doesn't know exactly where everything is at all times, has no chance in this world, and similarly

with individuals. Individuals who do not keep up with these technologies have no chance, because your competition is going to keep up with these technologies, and they increase your productivity so rapidly that you will see these people, ultimately, who don't keep up, will be unemployed.

Last point — when I get our security analysts back in New York together, talk to them every now and then, I say the single characteristic that is going to be more important than any other in distinguishing the winning companies from the losing companies, in the foreseeable future, is, the winning companies are those that understand the power of these new technologies. Understand, adapt and proliferate, and if you don't do that, you are going to get left behind.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #4: Olympic Long Jump: From $150B to $300B in Five Years

Wilfred J. Corrigan
Chairman and CEO, LSI Logic Corporation

One year ago, 300 billion in five years looked easy. Several years of 30% growth created an illusion that perhaps the semiconductor down cycles were behind us. One down year later, over-pessimism has set in. Now let's face it, this is a cyclical industry. It always has been, it probably always will be. But it's cyclical with a high secular growth rate — something in excess of 15% plus. In the long view, the inventory correction of '96 will be a minor blip on the long-term growth of our industry. Now cyclical is NOT a pejorative, it's simply a fact. What's important is the amplitude of that cycle.

Now today, the amplitude is much less, and I think the companies are better able to handle it. They're organized differently. The global nature of the business, just like investing in stocks globally, tends to cushion any individual country's cycle, in the same way the global nature of the business cushions the overall cycle, because the countries don't operate in sync at this time.

Also, over the last 20 years, we've seen what I'd call a delamination of the business. You now actually do have an equipment industry. You know, 20 years ago, you had a minuscule, or an almost non-existent equipment industry. Many of the big companies manufactured the equipment themselves. You don't do that today, you have an equipment industry, you have a wafer fabrication industry, you now have foundries, you have assembly and test sub-contractors, and you have an increasing software content.

To return to the present, and to corrupt some Churchill lines, I'd say we are at the beginning of the end of the slowdown. And this has been an unusual one because it's been an excess capacity driven slowdown, and there hasn't been that big a change in the growth of the end markets which is quite different that ô74 or ô85. I'm very confident that within the next six months, and it might be quite a bit sooner than that, this industry will be back on its march to 300 billion at the turn of the century. Now, how can I be so confident in this relatively gloomy environment? In late '73 we were going through one of these phenomenal growth periods and suddenly in the middle of '74, it abruptly stopped. However, the very same semiconductor industry had doubled in size by 1979, so there is a little pattern emerging here, you get this pause, then you double. You get another pause, then you double. I mean, a pause is not a heavy price to pay for a double.

The computer industry has been around a long time, and they have lots of people that are very familiar with these cycles, and so they tend to jump on it very early. The networking industry, which again is an important industry to all of us today, had been growing so rapidly, and continues to grow so rapidly, that things like inventory management and MIS systems, and so on, was not as high a priority as it was with the computer industry. Now this is a lot different to a demand slowdown. Now most of the inventory slack is already taken up. We are almost ready to resume growth. Now this path of a down cycle followed by doubling of the industry in the following five years, is about to be repeated. Now, the bad news is that '96 is a down year. The good news is that there won't be another one until the next century. Real demand is still there, and it really hasn't slowed down, and in many cases the new products are going to accelerate that rate to demand.

However, the net effect of these lower prices today falls through very quickly into the end-market and is accelerating the end-use of memory for, let's take the PC example. Once people go to these larger memory sizes, that's like a one-way irreversible process. They are not going to turn around in six months time, if the memory prices go up just a little bit, and say, "You know, I'm going to buy a computer with half as much memory as the last one."

So, that's a phenomenon that I think is broadly happening right now, not just in those products but in a lot of other products. That will pay off very soon as those prices get into the psyche of the consumer. I do really believe that lower prices are fueling the customer demand, particularly consumer demand. Now certainly for the financial industry, who tends to be very focused on the U.S., consumer products have been a bad word on Wall Street for a long time. However, the next generation of consumer products make heavy use of U.S. component technology and that's a big change. The new consumer business is a good business, it's a profitable business, and it's a sustainable business, where you can differentiate the products, you can differentiate your technology. The product drivers that will fuel the growth of the global semiconductor industry are generally being produced by trend-setting customers in key vertical markets, but the main drivers are communications, consumer and computer. The three "C"s.

Let's take consumer electronics market for example. Most U.S. investment themes, if they involve personal computers, workstations, storage, networking, have their roots in the United States because the key suppliers are in the United States. The key end-markets are in the United States. But the consumer electronics market for the last 20

years has been driven outside of the U.S. Much more important in Japan and Europe even though the U.S. has been a big participant as a buyer of these products, very little of the manufacture and design has been done in the U.S. So what are these products that I'm talking about? DVD - Digital Versatile Disk it was called, now Digital Video Disk. DVD is a very important product. It will replace the VCR, it will replace the CD in the PC. This is a market that's certainly in the early going, is dominated by a small handful of Japanese companies, perhaps soon to be followed by Korean companies and Taiwanese. But this will replace the video cassette recorder. It will replace the laser disk, and it will supplant all the CD-ROM drives within the next few years. This gives you a 15 to 20 times increase in the capacity of a CD-ROM, and even though they will be priced higher to begin with, if you look out 3, 4, 5 years, I think the price is going to be very comparable with the existing CD.

It's estimated that DVD will achieve the same U.S. household penetration in 5 years that it took the VCR 11 years to get to. It took the audio disk about 7 years to begin to exceed tape. That will probably happen in 4 to 5 years with the same phenomenon in video. So the VCRs will be replaced much quicker than the old tape players for audio. This is going to be a major penetration, and if you keep in mind that today, 50 million VCRs are sold a year, and this is simply a replacement market for a market that already is pretty much saturated. This also enables products like the James Bond automobile map of the whole U.S. on a single disk. These sort of products will probably sell for the $1,000 to $2,000 range, by that time frame. They will be as pervasive in automobiles as cellular phones are today.

Another example is I look at digital video cameras — the next generation of hand held video camera. Once you start reaching U.S. consumer and European consumer price points, once you start to get below $1000 range, you start to see some real volume. These have much higher resolution than analog cameras. You can freeze-frame images, download them into computers, you can show them on your TV set. Then we have digital still cameras, which really do the same thing to still cameras. Market research indicates that about 48 million cameras will be shipped in 1999.

Let's talk about Internet browsers. Nobody was thinking about Internet browsers two years ago. This is going to be a big business in itself. If we don't really know exactly how many Americans go online — it depends on which survey you get — but we know the numbers are at least 35 million. I know one new product that has hit the market is Web TV, which allows you to use your TV screen as an Internet access device and it works just fine. That growth will skyrocket, and, of course, once that infrastructure is enhanced by these little boxes, of course all of the services that now start to flow into those boxes start to become an even bigger industry.

Reality is — and in the boxing game, a good big guy will always beat a good little guy. In the same time, half micron will always beat .8 micron, and .35 micron on cost will beat .5 micron, and .18 micron will beat .35 micron on cost, no matter what you put into these fabs. I mean, in reality the capital investment in the semiconductor industry hasn't really changed much in the last 15 years. All that's changed is the granularity, so instead of building five 200 million dollar fabs, you build one 1 billion dollar fab. The semiconductor content in the electronics products is increasing rapidly. This year the semiconductor content is expected to approach 20% of the world's $850 billion electronics market. By the year 2000 we are projecting semiconductors will represent 28% of all electronics products.

But let's not forget the most important sales driver for this $300 billion long jump. Only 4% of the world's population resides within the U.S. If you say, "Well, maybe there's 50% or so more people in Europe, and there's maybe 50% less people in Japan . . ." The three primary markets for the sort of things that we make historically have been bought by less than 10% of the world's population. Now if approximately one out of every two chips manufactured by U.S. companies are sold overseas, this has been a fact through the '90s with the percentage continuing to increase, it's over 50% at this point in time, and I think it's going to be quite a bit more in the next five years.

In China, there's a population of more than 1.2 billion, there are only 250,000 TV satellite subscribers. Many of you will use the pay phones, or use your cellular phones during the next break, and while you are doing that, remember that the majority of people in the world today have never made a phone call. We've seen explosion in phones just by selling the second, third, fourth and fifth to Americans and Europeans and Japanese. Just imagine if we can just sell one to 10%, 20%, 30% of the Asians.

Now to do these things we've got to have free and open access to global markets, and you know, I've spent a lot of the last 10 years involved with the SIA on this subject, and perhaps one of the most encouraging things I saw in these last trade negotiations was, I think the Japanese, and more recently the Koreans, are starting to hone in on the same sort of issues that we are, as they see much of the market being outside of their own countries. Suddenly it's very important to them that there are not barriers to sell into Asia. It's very important that there is copyright protection. So suddenly our issues are starting to become the same issues and a lot of the discussions today are much

more constructive than they were 10 years ago, but we have to continue to push that.

You know we may soon be the economic bell weather for the nation. If we look at the percent of the market that we represent, you know we are rapidly approaching this 1% of the gross domestic product, or I guess the gross world product, which is a big percentage, I mean it is something that you can now start to track once you get to that 1% sort of range. Electronic instrumentation, computers, and the rest of the electronics industry, now represents 3 1/2% of the GDP of the United States. And if you look at the total semiconductor industry, 1% of world GDP in the year 2000 is very dramatic sort of numbers. So the key drivers, as far as we're concerned, are certainly the customers, particularly the consumer customers, futuristic products, advanced technologies, system on a chip integration, rising chip content, global markets

We will not reach 300 billion by bemoaning our fate. I would like to close on a quotation from President Teddy Roosevelt, who might have been talking about the semiconductor industry when he said, "Far better to dare mighty things, to win glorious triumphs even though checkered by failure, than to take rank with those poor spirits who neither enjoy much, nor suffer much, because they live in the great twilight that knows not victory nor defeat."

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #5: Dataquest's Worldwide Outlook for Systems, Semiconductors, and Equipment

Gene Norrett, Moderator
Vice President & Director, Worldwide Semiconductor Group, Dataquest

Greg Sheppard
Chief Analyst, Semiconductor Application Group, Dataquest

Gary Grandbois
Vice President & Director, Semiconductor Industry & Manufacturing Group, Dataquest

Clark Fuhs
Principal Analyst, SEMMS Service, Dataquest

GREG SHEPPARD

This is really an interesting year to be talking to you all about real positive things that we see from a demand. Needless to say, let's say I am the optimist here, certainly, of the three you'll be hearing from, in terms of what we see moving forward.

Today I'd like to paint a picture for you for what we believe the environment is going to be, particularly with focus on next year, but also a long term view through the end of the decade. We feel that, demand for semiconductors is going to remain very healthy. I think the main question is in everyone's mind is what price are we all going to fetch for those particular functions.

First off the top here is our worldwide electronic production forecast. This is the key way that we measure the demand environment for semiconductors. After growing at a double digit rate over the past two years, 1994 and 1995, the market for production of electronic equipment has slowed to 6.2% in this year, reaching a value of 840 billion dollars. The reasons for the decline are two-fold, 50% has to do with the dollar and the yen. The dollar has appreciated against the yen, since we have a great deal of electronic production based in Japan, that helped pull down the overall number. About half of the decline is an actual softening of the production of electronic systems. The long term outlook is that we expect the demand environment for chips, based on production, to stay in the relatively high rates, over the 8% range. This sets up an environment where the chip market should grow in the 18-22% range through the end of the decade.

We slice up this electronic production by type of system, and we measure roughly 100 or so different types of equipment at Dataquest. We maintain very detailed models on unit projection by region, semiconductor content, and in general, and how is this driving and changing the demand patterns in the chip business from a regional perspective. The fact of the matter is that we had slowing the Americas, market, as we describe it. We measure all of the Americas in our data now, so we have broadened our measurement of that area. Likewise with Europe, includes the Middle East and Africa. Europe remained pretty much flat year to year, but Asia-Pacific, which is normally the big double digit growth engine, has slowed somewhat. For next year we are predicting that all of the regions will see some growth, except for Asia-Pacific, but slowing somewhat

If we take the semiconductor market pie chart of where industry is going to be, we figure, 137 billion dollars this year - 1996, and segment it into the systems that are using these chips, we see that the PC market accounts for roughly a third. This what goes inside the PC box itself. We count the storage and printer section as noted here. The second largest demand for chips is other computer systems. It is quite a sizable market, for things like workstations, server systems, midrange up through supercomputer-type systems, and is quite a big user of chips. Likewise LAN/WAN voice and public communications systems is another good slice. Cellular and cordless handsets. On through automotive. It's important to note that for other uses, which is about a third of the market here, there are literally tens of thousands of applications out there which are impossible to measure. Let's focus in on the PC area. This is a forecast from Dataquest's PC service, and we note that — and this is the forecast of worldwide PC shipments on a unit basis — we note that in 1995 the market had grown 26% on a unit basis. We are projecting that this will be in the 20% range for 1996.

Looking at the 1997, they are expecting the market for PCs to grow at 18%, so a further slowing and then kind of hovering, out through the end of the decade, as the unit shipments of PCs approaches 150 million units annually. Now if we translate this market into semiconductor demand, this is where we get the interesting kind of ski slope happening here, where we're seeing the demand for chips and PCs which are comprised of DRAMs, microprocessors, graphics, multimedia, and sound communication chips that are embedded in the PC. We

note that the overall market for chips consumed by PCs will decline on the order of 10% this year. This is, of course, driven mainly by the decline of the memory, particularly the DRAM market. This also shows that the elasticity of the DRAM market, i.e. maybe more bits shipping because they are cheaper, wasn't enough to overtake the decline in pricing.

Now let's take a look at a few other markets. This first one is a look at the rigid disk and optical storage area. The bottom line is that optical storage chip demand will grow at almost 25% next year, and then rigid disk drive demand is somewhere in the 15% range. We are expecting these to both cool off over the long range as new product is introduced and prices come down. This is an extremely cost competitive area for chip companies to play in. There are companies literally designed in and out every nine months on the basis of features, and cost. It's still a fantastic unit market, it fills fabs. Overall, if you look at some of the things going on in the rigid disk area, we have the densities of bits you can put onto any disk platter growing at 60% a year. If we thought the DRAM guys were crazy, these guys in the rigid disk area are even crazier, in terms of what they are able to accomplish.

It's controlled by a few major big OEMs, on the order of half a dozen of so. There are some new technology opportunities in magneto resistive or MR, partial response maximum likelihood, PRMLs, I've noted here. We are spinning these drives faster and faster so we can get the data off faster. These are all contributing to new types of chips that will be developed. There is the DVD market, which can be used both as an optical storage mechanism for PCs and as a consumer player.

Now I'll shift over into the communications space for a while. Local area network systems continues to be a very healthy market for chips. It's going to grow in the 25+% range for next year, and continue to click along in the 15+% range thereafter. What is driving the local area network market? Well, expanding desktop connectivity, and also upgrade of existing systems to higher performance, higher speed. There are three, or actually four, big companies that are the big giants in this area: Cisco, 3Com, Bay Networks and then we can throw Cabletron in there as the other one. It makes it kind of fun to track as an analyst, but it certainly speaks to the health and vigor of this business. Key equipment, the NICS, or network interface cards. Hubs, and switches, and routers, are the guts of the network. These are all very rich in semiconductors and all very hidden from all of us, from our daily lives. Something in the order of $500 of equipment is installed behind each PC to get it connected to the network, to the LAN or WAN. This is running with 20 to 30% chip content.

Other happenings here is the movement towards 100 megabit Ethernet technology known as fast Ethernet, and now the one beyond that known as gigabit Ethernet is entering the scene. It is just right in early standards body discussion. Then, of course, the asynchronous transfer mode market, ATM, as the next generation technology, and once again, I've noted some of the impact areas for standard chips sets, or ASSPs, ASICs, and so forth.

Over in the WAN side, this is Wide Area Networking, this is where the Internet is making its play. We are seeing services being rolled out that support Internet, and then equipment being put into place to support those services. The most common Internet hardware out there now is the modem. We think this market will continue to clip along from a chip perspective in the 20% range or so. In addition to this, there is some new equipment being introduced, frame relay, it turns out that a good percentage of the world's Web sites are hooked up via frame relay. T&E carriers are the digital transmission lines, that kind are in the bowels of the public telephone company, but also being delivered out to businesses. Then asynchronous transfer mode is also a technology used here. So we are seeing both a technology and a set of services that are being rolled out.

Over in the public telecom side, this actually has a different profile. We see it actually accelerating toward the end of the decade in terms of chip demand. This is due to the fact that we have numerous projects underway around the globe. There are something like 500 million, or so, access lines worldwide currently, and that is projected to grow to over a billion lines by the year 2000. This is addressing the market that Wilf was speaking about earlier, India and China, putting in phone access for the first time. Likewise we are going to see in the developed countries of the world, upgrading to broadband capability to be able to handle fast Internet access and video multimedia services.

Global communications: this is cellular, cordless, and we count cordless technology in this as well, as well as pagers. If you take a look at just the digital part of this, as these systems go digital, that market, we figure, can grow exceeding 40% next year, and then starting to slow somewhat into the 35% range out through the end of the decade. The overall market is seeing some inventory problems, if you throw in the analog cellular technology as well, and there are some suppliers that are doing well, and some aren't. This forecast is predicated on the fact that we will see cellular subscribership tripling between now and the end of the decade. Our wireless, our personal communications group is forecasting that we will see upwards of 360 million subscribers, by the year 2000.

Just a couple of words about consumer. Essentially what is happening here is that the consumer electronic giants are turning to these digitally enhanced, next generation

systems, as really as a way to regain profitability, to get sales back up, particularly into their current markets. So we have seen a variety of new systems come out. Although it's important to note that these are all dependent on the availability of services, particularly in the set top box case and the availability of content. Those are all key issues that we will be tracking. The two hot items for this year are the digital still camera, as that's rolling out in earnest. We actually got some cameras we are looking at inside our shop right now, trying to figure out what the chip technology is in those, and where that will be going.

Just a quick word on other usage areas. Automotive: after taking a bit of a pause this year we are expecting vehicle production and electronic content penetration to accelerate starting next year. In 1998 we will start to see navigation systems start to become regular options, particularly with BMW, I think is going to be the first one who will have it as an option you can get right from the factory. Military aerospace: basically we are in the throes of all the world's aviation planes being updated and the upswing in satellite building to support all these new direct broadcast satellite services. In the appliance world, with the movement towards electronically controlled appliances ala The Green Movement will be an important factor.

So in summary, from a demand perspective, growth is going to be good. The number of units of systems that are pulling the gates, the bits, and transistors, is going to be in good shape. Once again, what is the price going to be is the big question. The PC and mobile communications areas will continue to be drivers of growth; high speed LAN and WAN systems, public telecom systems, digital entertainment as that's growing 3 times faster than the overall consumer electronics area, will be important, and then the resurgence of automotive over the next couple of years as well.

GARY GRANDBOIS

I am going to talk about semiconductor devices. I really want to talk about where we've been in 1995, this pot hole or relapse we are seeing in 1996, and when the rebound will occur. It will occur very soon. 1995 was an exceptional year. It really capped three years of very strong growth. We saw 31% growth in 1993, 29% in 1994, and 37% in 1995. Now that's a three-year compound annual growth of 32%, that's a doubling of revenues in three years — pretty substantial growth. And since we got to 151 billion dollar markets in that time, it seems that it would be a cake walk to get to 300 billion in five years. But of course, we've hit the pothole in the growth to the 300 billion, we'll talk a little more about the forecast, but we aren't likely to see this kind of growth in the near future.

So in 1995 we saw tremendous growth, led by DRAM, because the normal price per bit decline didn't decline. It was stagnated for a while, it held up due to capacity limitations, and so it was an unnatural market. But that unnatural market was also driven by the very strong growth in PC units — 70% growth in Japan in 1995 really led the growth for the worldwide growth of 25-26%. That has slowed only slightly into 1996. Other factors have caused the decline that we are seeing now.

I'd like to talk about the semiconductor mix in 1995. Memories and microcomponent ICs, the PC-driven products of the past decade, now are almost 60% of semiconductor revenue. That's very strong growth and change. Ten years ago, in 1985, memories and microcomponent revenues together accounted for only 29% of the market, and obviously it's doubled its share of the markets in just a decade, pushing all other products into what seems like another category.

When you consider that the PC market only grew at a 15% compound growth rate over that time period, that is pretty phenomenal growth, and an increase in semiconductor content in personal computers at that time. We have seen a growth and emergence of the PC market that probably can't continue in that manner. In some of the categories, for instance, logic and ASIC, and I want to make sure that it is understood that these are kind of gross categories, where logic ASIC included bipolar logic, standard logic, bipolar standard logic, so the ASIC growth which was substantial, is held by being grouped into a single category. In the past few years, DRAM was the king as the normal price decline was suspended as mentioned. And microcomponents have settled into a more natural growth rate, rather than what was seen in the past.

So what is happening in 1996? In fact, the PC market continues strong, 19-20% unit growth. Even with the inventory problems we had earlier this year, we are still seeing a growth in the bit consumption. It is growing again, about 67-68%, over 1995. So the market from that standpoint is still looking very strong. What has changed, of course, is that we have gotten back on the normal price per bit decline curve and we have done it very rapidly.

Over time, the price per megabit for DRAM has been consistently maintained, resulting in about a $25/megabyte price in 1995 and a very rapid decline since. Because of that constant price per bit in 1995, we saw a continual growth, month by month, throughout 1995 in revenues, peaking at the end of the last quarter of the year. With a rapid decline, of course, no amount of bit increase in 1996 is going to be able to hold revenues up.

So with this came a lot of expectations. We expected Windows 95 to drive the demand for memory. Windows 95 is doing well, but Windows 3.1 is still the operating

system of choice, so it took off a little more slowly. We expected very strong PC shipments in the fourth quarter that weren't realized. The market was already slowing down, as mentioned earlier. So that led to the excess inventories in early 1996, inventories that we had to work off. Coupled with the inventories dumped into the marketplace, we had a four to 16 megabit transition and that freed up a great deal of capacity, because the area per bit in a 16 meg device is much less than for a 4 meg. That added to the capacity that was already coming on line, and we got into a capacity glut in 1996. To add a little insult to injury, as Greg showed you, some of the markets have slowed down — PC market probably the least, but some of the other markets have come along and impacted certainly other products, if not DRAM.

How severe is the downturn? This slide shows 4 different periods of MOS memory downturn. It plots two years by month. If you take a look at the red line you'll see that 1996 is as bad as 1985, it's a very severe turndown, very rapid. In fact, earlier this year, and at the end of last year, Dataquest was expecting a softer downturn, one more like 1989. So our forecast was a little high, to say the least, the market turned down far faster and far deeper than expected. We had thought 1985 wasn't going to be replayed, and we are seeing the replay of it. The white line that continues is our forecast for the next few months of the year.

So this is how the revenue plays out by year for the next five years. 1996 will see a 9.4% revenue decline, 137 billion dollars. Then we will see a 13% rise in 1997, and from then on, actually, we get back into a very strong growth phase, where we will see better than 20% growth in the final three years of this forecast period.

How did our forecast change in the last six months? We had come down substantially in our April forecast, but we weren't expecting the deep downturn that I just showed you a few slides ago. It has been much steeper, we were expecting a flat revenue growth, we're expecting this year 46% revenue decline for DRAM. That translates to a change in our forecast of about 11%. The slowing of markets, especially the industrial and consumer market, has additionally impacted the non-DRAM products more than we expected. So that's another 6%, that has changed our forecast. So that's the 16% swing in 6 months in our forecast.

This is how the forecast plays out, by quarter, over the next couple years. We are just starting the rebound. As you can see, on this chart, we expect to see about a one percent increase in revenues in the fourth quarter of 1996. In fact, if you look at the blue portion of the bar, the bottom part, you can see that non DRAM products actually have been continuing to grow — that's a 5% growth in 1996. Certainly it's a slowdown over what's been done in the past, but it's a continuing growth that will rebound also, as the markets strengthen in the coming years. So what we are seeing is largely a DRAM driven downturn, and the size of it is substantial, and it is very painful to look at the size of that DRAM pedestal on the fourth quarter of the 1996 and compare it to the fourth quarter of 1995. We are at the bottom, we are on the way up, and we are very optimistic about this forecast. This is how it looks on a quarter by quarter growth comparison. As I mentioned, we are looking for about 1% in the fourth quarter of 1996, and then about an 8% growth in the first quarter of 1997.

By product: you see the very large downturn in memory. The bright spot here is the microcomponent category, especially driven by microprocessors and microperipherals, two products doing very well on the 20% PC unit growth in 1996. Those products are more impacted by the declines in the consumer market and industrial market, and actually the microcontroller portion of microcomponents is also impacted by that, and that pulls the microcomponent IC growth down to what might be 18-19% through the 14% level we are looking at here. So this breaks it up by product type, and you can see that we are expecting really all the products to rebound into double digit growth in 1997.

These bars compare the five-year growth forecast versus what was the five-year historical growth. Excluding memory and microcomponents ICs, pretty similar growth. Microcomponents is settling into a very decent 18-20% growth over the forecast period. So, we're saying that the market can support that kind of continued growth for that category. Memory looks like it is down quite a bit, and it is, because of this pothole of 1996. But if instead of looking at the 1995 to 2000 compound growth, we look at from where we are standing now, from 1996 to 2000, actually our forecast is a 29% compound growth over four years. So we think memory will start to come back. Certainly we are going to have a capacity glut for the next couple of years, but in 1998 we start to see very strong revenue growth, and memory coming back, strongly contributing to semiconductor revenue and growth.

Looking at it by region, all regions share the misery in 1996 — Japan more so because of the change in exchange rates, so there are simply fewer dollars per yen, so that kind of accelerates the current downturn in Japan. But this is how it plays by region. Also, we see very good growth in 1997 by region as most of the regions show double digit growth. So again, a rebound is not a single region rebound, but the market will return in all products in all regions. What is different about this forecast is the change in Asia-Pacific growth. Asia-Pacific growth drops virtually in half over the forecast period. A number of reasons for that, and it was mentioned by Greg earlier that of course the market is maturing, it is becoming a more

significant part of the total market, and can't continue that kind of growth. The other factor is a lot of the Asia-Pacific growth was due to Japan manufacturing moving into Asia-Pacific sites. With a weaker yen, that manufacturing movement, that migration, is slowing down. So we don't expect to see as much migration to Asia-Pacific, the market itself is getting larger, and becoming a more significant portion of the total market. By the year 2000, the Asia-Pacific market will be one-quarter of the total of the worldwide market. So it cannot continue this 35-34% compound growth when it gets to be that size.

So in the past we have forecast that Asia-Pacific will grow and surpass Japan within our forecast period. So a little slower growth in Asia-Pacific than previously forecast. Pretty consistent market share for both North America and Europe — 33 and about 18% respectively, and if you take Japan and Asia-Pacific as a unit, they remain about 48-49% of the total market over the forecast period.

So in summary, we have seen another DRAM cycle, we had hoped that we weren't going to see another one and that we weren't going to see one as deep as we had seen in 1985. Nonetheless, it occurred, and we are seeing a very deep dive in 1996. The good news is, we are on the way up. We will see a little bit of revenue growth in DRAM in 1997, non-DRAM products have continued to grow strongly, and recovery is starting right now. This transition of memory and microcomponent ICs taking more and more market share is probably going to slow down. Some of the products delineated by Greg, the advanced consumer etcetera, will demand more discrete, more analog, so we see a rebound in some of those markets. We are looking at the convergence of computers, and consumer entertainment, and communications. So the market is changing but the market is looking good. We are looking at 290 billion dollars in the year 2000. A little below our expectations in the past but still very optimistic. Thank you.

CLARK FUHS

Good morning. I should mention to you that I am the supply side guy. For those of you who are not familiar with our service, we tend to cover in detail all of the equipment segments associated with front end manufacturing, basically anything having to do with the fab. Turning silicon into money, and translating money into silicon.

Supply side economics has often been called voodoo economics, and occasionally people look at me like I am talking voodoo, but we will try to bring these issues down to some simple concepts for you. The capital equipment industry is currently in a downturn, driven by, of course, overcapacity. What I will talk about this morning is how we will recover from this downturn and when those opportunities might emerge. We will start off with a report card of what we were saying at this conference a year ago, and what has happened since then. I will present our forecast outlook in general and then take you through a scenario as we see it likely for the recovery.

First I thought it would be fun and interesting to show our forecast conclusion slide, from a year ago at our mid-year seminar, unedited. The question that we raised was: Are we ready to call the silicon cycle dead? Our answer was: Yes, yes and no. It had to do with the three areas that have typically been associated with spending downturns in the past. The electronic equipment market, which could normally be caused by some sort of a worldwide economic recession, which we did not see at that time, and we still do not continue to see that.

A PC unit slowdown was not in the cards, based of the drivers that we were seeing. However, the silicon cycle was not quite dead because we saw that it was going to be narrowing to the DRAM cycle. Something that we had mentioned a year ago is the magnitude of the cycle should diminish over time. I know that's the conventional wisdom, but I'm beginning to question that wisdom. The things that drive the cyclicality in the business happen to be the DRAM, and that is concentrating in our industry, it is not diminishing over time. In the early 1980s, DRAM was roughly in the high single digits, as far as percent of the market. Today it is in the mid-20% range. Semiconductor consumption within the PC was under 15% just five years ago. It's about a third of the semiconductor market today. That is the cyclicality driver in our business and I do not think that is going to go away, ever, and I do not think that will diminish in severity, at least in the next cycle, beyond this one.

One thing we were saying last year is that we were going to watch for clear signs of the transition to the 16 meg DRAM, and we were looking for 60-65% yields. Now that becomes a critical trigger because the cost per bit is roughly — that is the cost over point for cost per bit, to have a supply driven transition. In retrospect, this happened a little bit quicker than we had anticipated. The question that I've gotten lately is, "How can this industry go from undersupply to oversupply so quickly?" There are a couple of reasons for this. The first one, we pointed out, is supply driven. As I mentioned we were interested in the timing of the transition, going from the 4 to the 16 meg DRAM because that creates silicon efficiency. Referring to the third bullet here, the key is bits per square inch. If I have a 4 meg DRAM that has an average die size of 50 square millimeters, and I have a 16 meg DRAM that has an average die size of 80, I can increase the bits per unit four times and only consume 60% more silicon. So my bits per

square inch goes up by a factor of three just by doing conversion from 4 to 16.

This slide presents the cycle visually. When the industry is stuck at a product unit density, such as a four meg DRAM, bit demand, which averages about 60% a year, tends to drive silicon then very directly. The top part of this chart represents the boom times, where we are actually stuck. Typically this industry is in undersupply. When we have a typical 60% bit demand, silicon demand increases by roughly 35% into the DRAM sector. This creates the need for more equipment and a capacity-driven spending cycle. Capital spending cycle slows in the bottom half of the chart, during times of bit oversupply and the industry migrates to the next generation of DRAM. We are in the lower right hand corner of this circle today. We just crossed the time when the industry is taking that step function jump upward in bit capacity. During these times where you have an average bit capacity of 60%, silicon demand is flat to down. Even today, and we can actually do some transition, and we did some modeling quickly last week, starting in the third quarter of this year, for three quarters, we can actually see wafer start requirements declining, going into the DRAM sector. That is with a bit capacity, or a bit demand issue of about 70% of the market for growth. This is a normal thing in this industry, and that's what has really worked about this. The complicating factor of the increased expectations that Gary had alluded to, means that we have a double barrel supply and demand-driven slowdown. This has increased the severity, hopefully not the length, of the downturn. We actually think that this downturn is going to be shorter that the average two-year slowdown, and the reason for that is the strong end use markets.

The past series of slides basically explains the difference in our forecast today versus a year ago. The two forecasts basically have the same profile, as we built in a supply-driven DRAM slowdown in '96 into '97. However the better than expected 1995 capital spending picture is leading to a more difficult 1997. With 1996 being the lever arm of the fulcrum. A one to two year pause in the equipment industry in 1997 and 1998 is still in our outlook. The next major growth in spending will start in '98, into '99, driven by capacity.

Now let's look at some specifics. 1996 is a year which turns from growth to decline, but will net out with about 17% growth this year. The only reasons 1996 remains a double digit growth year, are there were strong backlogs coming out of 1995, and a few companies such as IBM, TI, Siemens, and some of the dedicated foundries, have continued to grow investments in the first half of this year. Korean companies have also grown, but in moderation. The Japanese companies have already cut back, but they are still investing in shells. Shells are where you build a fab, you build a building and you put in a minimum equipment complement in order to test the process, setting up for the next generation. So the number of fabs that you see going in will remain inflated, as we have more shells being built right now, but the equipment will not go into those fabs at nearly the rate that was anticipated originally. DRAM companies everywhere are currently cutting back the budgets. We do not think that 1996 spending levels can be maintained. In particular, we expect in 1997 that investment into the DRAM area for equipment will be cut as much as 30%. Asia-Pacific and Japan will be hit the hardest, as these are the DRAM production centers. We do expect spending on advanced logic capacity to be maintained and begin growing toward the back half of next year.

In general, companies will continue to invest in quarter micron technology and equipment, in order to gain experience for the shrinks that are about to come later in the decade. So we have just gone from a capacity-driven upturn to a technology-driven spending pattern.

Another question I get a lot is: Are there too many fabs being built? When we analyze the amount of silicon, in terms of square inches, that is required in order to meet the near $300 billion market in the semiconductor forecast, we believe that there should be roughly about 35 new fabs per year being built. Currently by today's announcements there are too many fabs coming on line in the next two years.

What our analysis also says is that there needs to be more new fab announcements to occur before the end of the decade. So while I'm pessimistic, as Greg would put it, in the near term, we have the distinction of having the only forecast which has a plus 40% or more growth year in the time horizon.

Again our forecast for front end wafer equipment profile follows the profile noted on this slide. The recovery pattern starting in mid '97, and progressing through '99, will depend on how today's overcapacity will trickle through the industry. After the wafer fab equipment market contracts in 1997, it stabilizes in 1998 to about the '95 levels. We do see resumed strong growth, as the need for the capacity will again become the driver, leading to an over $40 billion market in the year 2001.

Our current forecast shows the first sequential growth quarter will be the fourth quarter of '97, it may actually be a little bit sooner because I think it's going to be a little bit worse than we thought in the back half of '96. The quarterly outlook has produced the annual forecast of the previous slides where we show 1997 declining by nearly 16% in 1998 as a single digit growth year.

The industry is currently experiencing a DRAM oversupply coupled with a product transition. In order to

determine how capital spending may recover, it is important to understand how this excess capacity will migrate, or trickle, into other areas. In general, capacity can be split up into three major areas, in the semiconductor manufacturing infrastructure. The first is DRAM, the second is advanced logic, and the third is power discrete. Capacity is very fungible, or very changeable, going from product to product, so it is really impossible to do a supply/demand issue on E-proms or Flash, or S-RAMs, or ASICs, or any other specific advanced logic area, because a stepper does not really care what kind of chip is on the wafer, all they care about is what the wafer is, and the wafers that are going through.

There are two general blocks of capacity now available from today's conditions. These two blocks are being redirected into other semiconductor product areas today. Based on how this capacity is migrating, we believe that the first area of spending recovery will be in the advanced logic area, as early as mid-'97. So in '97 you will see metal etch, for example, perform better than polysilicon etch. The microcontroller, analog, mixed signal, and telecom chip capacity will mean extra recovery, but probably not until the end of '97 and into '98. The DRAM segment is expected to be the last, probably later in 1998.

Power and discrete chips have very specialized processes not found in old DRAM fabs. So these segments are relatively isolated. It is not impossible to convert a DRAM fab to run power discrete, but you have to make an investment into some additional process flows, and run along a learning curve in order to convert these fabs. So we expect this first block of capacity to be relatively isolated, but we expect capital spending patterns to be closely tied to demand in these product segments.

The second block of capacity is comprised of idle, or underutilized, advanced 16 meg DRAM capacity, which is limited to two-level metal, but is at .4 to .5 microns. Because these fabs generally lack the process sequences of self-aligned silicide, which is required for advanced logic, and three levels of metal or more, they cannot effectively, immediately, be redirected into advanced logic or fast S-RAM. Therefore, they are limited to commodity S-RAM, and other non-volatile memory, or a limited span of logic products that do not require three levels of metal.

Therefore we believe the first areas of spending recovery will be in the advanced logic area, since this will be one of the more isolated places, and equipment companies positioned for these markets will have more moderate slowdowns. The companies that are positioned for the DRAM factories are actually going to have more severe slowdowns. Microcontroller, analog and mixed signal, and telecom chip capacity will be next to recover, and we will watch Motorola, among others, will be a key company as far as a spending pattern recovery here. The DRAM segment, the root cause of the problem, is expected to resume robust spending at the very last.

So in summary 1996 is a transition year for wafer fab equipment, industry contraction. The industry should bottom and start recovery as early as mid-1997. But the downturn is really severe and it is likely to be shorter than normal, because of the fact that the PC unit growth rates are very healthy, and very strong, and we do expect a resumption of capacity spending to come back in the 1998 time frame.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session

Session #6: Luncheon Presentation: Will the Internet Break Microsoft?

Roger B. McNamee
General Partner, Integral Capital Partners

No transcription was available for this speaker.

Session #7: Emerging Opportunities in the Battle for the Local Loop

Gregory L. Sheppard, Moderator
Chief Analyst, Semiconductor Application Markets Program, Semiconductors Worldwide, Dataquest

Robert L. Bailey
President and CEO, PMC Sierra

Russell K. Johnsen
Vice President & General Manager, Communications Division, Analog Devices

Stephen J. Edwards
Assistant Vice President, Telco Broadband Networks and Applications, Northern Telecom

Glenn H. Estes

President, Telesis Technology Laboratory

Lisa Pelgrim
Industry Associate, Networking Program, Telecommunications Group, Dataquest

Agenda: Introduction, Defining the Terminology, ISDN and ADSL, New Delivery Techniques, What It Will Mean for Semiconductor Companies

INTRODUCTION

Over the past ten years the IT industry has taken great strides to produces fantastically powerful PCs and workstations. We've seen the ability to process information increase at least 100 times or so over the last ten years. What we have in place on the desktop is something equivalent to the original Cray-1 in compute power. At the same time, local area network systems have also increased on the order of fifty to a hundred times as well. However, once you leave the building onto the public network, that hasn't kept up. We have a gap forming here in terms of processing power at the desktop versus what the ability of the public infrastructure is to handle that and the Internet has brought that to people's attention in no uncertain terms.

DEFINING THE TERMINOLOGY

There are a lot of acronyms in this area. First off, we have POTS, which stands for Plain Old Telephone Service — the original analog twisted pair of lines coming to your home that analog modem technology takes advantage of. We've seen announced initiatives to take this technology up to 56 kilobits. ISDN, which is a digital type of technology is capable of up to a 128 kilobits per second so it's the next step up. ADSL, which stands for Asymmetrical Digital Subscriber Loop is a technology that enables the twisted pair lines going into the home to handle much higher data rates, potentially up to as high as 50 megabits per second. This technology is part of what we call XDSL. There is another technology known as HDSL, which is being used in what we call the T-carrier marketplace but there are some proposals out there to make this a home high speed access alternative as well. Cable modem technology has to do with attaching a radio frequency-based modem to send data over a coaxial cable line the cable TV service provider already has in place. HFC and SDV are really variations on a theme: HFC, Hybrid Fiber Coax technology blends both fiber optics and coax and SDV, Switched Digital Video is a similar technology which involves dedicating bandwidth and switching it directly to each home. ATM, Asynchronous Transfer Mode, is a set of technologies to provide a connection from point A to point B virtually through a scalable network.

SONET is the fiber optic technology that's being deployed primarily in the U.S.and there's the international variant of it known as Synchronous Digital Hierarchy or SDH. If you look at the core of the what's going on with the long distance companies and the local exchange companies the fiber optic technology going in is SONET. Finally, MMDS and LMDS are essentially wireless ways to deliver high bandwidth to the home.

When Dataquest takes a look at these markets and looks at the impact on chip demand, we figure that we're easily looking at, just in upgrades alone, a four billion dollar chip market by the year 2000.

ISDN AND ADSL

In 1995, the Internet met the consumer world and it had a profound effect on the modem market. The modem market grew that year by fifty three percent and it shipped over eighteen million modems to North America. We are starting to see some competition in that area of modems and analog modems are starting to get ready to compete against ISDN, ATM, cable modems and XDSL modems.

When I say XDSL I am including ADSL and the other types of DSL technologies in there. Over the past couple of years we've seen significant speed improvements for analog modems, and those speed improvements are going to be quite drastic in the future. The main factors driving the modem industry are really coming out of the consumer and the SOHO market. The Internet has been a phenomenal driver for this market and the other really big driver right now which touches more into the corporate world is the telecommuter market. That means you have a great forecast of all these different products.

Analog is still going to be king through the end of this century, though through the end of the forecast period, it does start to flatten out a little bit as the other products start to increase. The reason that analog is maintaining such a large share of this market is that it can be used almost everywhere; When you're traveling around, you're going to have to fall back on analog. The PC companies are including analog modems in the majority of the PCs that are now shipping. One of the things that is starting to put some pressure on ISDN are the new 56K modems that have recently been announced by all the key players in the industry. Consumers want more speed at the lowest cost.

XDSL is something that is a little bit farther off but we do expect to see some commercial climate beginning in 1997. We have, we're very bullish on that as you can see from our forecast.

Cable is another interesting product that's starting to be rolled out. Cable is really facing a lot of challenges which is why we don't see it growing as quickly as ADSL. Cable companies don't have experience in managing a network and in doing Internet access that's something that they are really going to have to learn about as part of a learning curve. It is not simple technology, it's very complex and it's going to be quite an obstacle for them. They are, however, seeing a lot of competition from the direct broadcast people so they are in they are very motivated to do this, they are sort of in a do-or-die situation.

NEW DELIVERY TECHNIQUES

The local loop has been remarkably stable for well over a hundred years and the bandwidth of that circuit has remained unchanged at less than 4 kilohertz of delivery. The law has changed in the last twelve months and that's probably one of the most interesting and dynamic things that we have about this industry today.

There is an issue of tying up those telephone lines too long. We've had an independent estimate suggest that to actually upgrade the switch infrastructure in North America to support longer holding times would cost the local exchange companies 6 billion dollars in equipment purchases. That would be capital expenditure with no incremental revenue. Clearly there is a need to migrate to what I would call the power users to these high speed services.

Our forecast suggests that ISDN may be at the 3 million level by the year 2000, and high speed access with ADSL might be around 5 million actually being stronger than indicated at around about 2 million users. NorTel's high speed network solutions cover both coax and copper-based infrastructures and incorporate intelligent networking which is a very key part of the overall service delivery. They are based on the notion of providing end to end ATM connectivity, which we think is very important to scale to mass market proportions.

An end to end service perspective is required for the service providers, whether they be competitive local exchange carriers or cable companies. They will need to have a system perspective. It's not just sufficient to deliver high bandwidth. You actually have to be able to deliver services that work. One approach is called a four arrow approach. It consists of the access network itself — both coax and copper access networks using ADSL technologies. ATM connectivity from the home or small office through an ATM modem back into the network, through the SONET networks into the ATM backbone environment and then for connection to contents there is a service intelligence layer. Then there is the application layer which is things like Web browsing or work-at-home applications etcetera.

We are proposing a system that delivers 20 megabits of symmetric service to a number of homes, anywhere from 50-250 homes in a shared bus environment. This is a symmetric approach and we have been very cognizant of the issue that in telecommuting, one person's download is another person's upload into the network. We've tested this system under high bit rate transfer of 9 megabit files, with 14 PCs doing that simultaneously and we found performance 40 times in excess of what you could achieve on a 28.8 modem.

ADSL technologies are ideal connectivity solutions for small companies that typically are today buying T1 and maybe HDSL solutions. If its tariff for Internet service is $30-50 dollars a month, it's going to be easy migration since they're paying a thousand dollars today.

WHAT IT WILL MEAN FOR SEMICONDUCTOR MANUFACTURERS

If you take a look at the communications market, especially in the broadband arena, it is really going to really bode well for the complete semiconductor industry. A lot of things are stacking up to provide a tremendous amount of opportunity in our industry.

A tremendous amount of people are maniacally, crazily focusing on Internet access so we've got market demand out there.

New transmission technologies — this alphabet soup of various transmission technologies that are coming down the pipe — are lining up right now to be able to provide the technology to be able to conquer these problems of Internet access and they are also adding and enabling, new carriers in the local loop.

And finally, the government seems to be doing some of the right things at the right time. They're deregulating the local loop, they're deregulating the telecommunications infrastructure all around the world, and that's really putting new pressures on the phone companies and breeding a lot of competition that will enable new markets. So I think, you know, governments are working, in concert finally with industry and markets, to be able to provide a lot of new opportunities.

There's a whole host of different delivery techniques that people are looking at. It's a question of not which one is going to win, but which ones are going to win faster. The fact is that a lot of these are going to be co-existing and it's up to us to try to figure out a fast enough form to be able to get at that. We in the semiconductor industry are oftentimes the very ones that have to develop a lot of the core technology that is going to be deployed.

Semiconductor companies are having to take a step more than we had in the past. Systems on a chip for this business really doesn't cut it anymore because we're having to develop the technology. You have to do not only the systems on a chip, but you have to add onto it the system architecture, the software that has to bundle around it, in order to create an entire solution. That's how you're going to win, and I think we've got an opportunity to do that. Communnications is clearly a sweet spot and we have a tremendous opportunity in front of us. Thanks for your attention.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session

Session #8: Next Generation Digital Consumer Electronics for the Mass Market

Dale L. Ford, Moderator
Senior Industry Analyst, Semiconductor Application Markets Program, Semiconductors Worldwide, Dataquest

Dwain Aidala
Vice President and Division Manager of Personal Mobile Communications Division, Mitsubishi Wireless Communications Inc.

David Taylor
Director of Marketing, C-Cube Microsystems

Andrea Cuomo
Vice President, Headquarters Marketing and Strategic Accounts, SGS-Thomson Microelectronics

Todd Oseth
Vice President of Business Development, Information Technologies of America Division, Sony Microelectronics

Agenda: Introduction, The North American Multimedia Dilemma, Semiconductors and Multimedia, Accelerate

INTRODUCTION

The digital wave is coming into the home laden with content. We've made significant advances. In fixed content, we've moved from tape to optical. In between we've gone through various other delivery forms such as tape, diskettes, and even vinyl. Coming into the home, wireless delivery. We've gone to satellite systems and back again. In the cable world, we've moved from cable now to where we have cable companies, the telcos and even utilities competing to deliver digital content into the home.

With that digital wave coming into the home, we also have the digital surfboard — the television, the videogames, the set-top boxes, video CD players, DVD players and Internet access devices providing the platform where consumers will be able to view digital content that ranges from movies and videos to audio sound entertainment, videogames and the Internet.

In the consumer electronics world we've gone through a period of calm, a period of relatively flat growth in many mature markets but if we look at this new equipment as a digital surfboard, the surf is definitely up. We can catch this wave and ride it. Chip companies, content providers that are ready to go will reap great benefits.

The decline in memory prices came at a very opportune time for this next generation consumer electronics, which requires increased memory content. The high DRAM prices were creating a barrier to acceptance of these products into the home, The decrease in memory prices was good medicine for this section of the industry. The traditional consumer electronics market represents an essentially flat market going forward, with the decline in chip prices. We more than doubled the revenue for semiconductors from 1995 to 1996 going from two billion dollars to 4.2 billion dollars in products going out the door and much of that jump came from the direct broadcast satellite and the new 32 and 64 bit video game generation. Moving forward, set top boxes will represent an important market opportunity by the year 2000 — 41% of this 8.3 billion dollar pie. They'll be followed closely by videogame controllers with 21%, video CD players with 13%, DVD players with 11%, and then other products, such as HD TV, digital cameras, digital camcorders, digital VCRs, DVD audio representing the rest of our forecast.

THE NORTH AMERICAN MULTIMEDIA DILEMMA

That movement from analog to digital and from standalone to network has very important ramifications on what you need to supply as a semiconductor supplier. It makes all of our crystal balls much more cloudy.

One of the things you'd noticed on his chart was the direct broadcast satellite semiconductor components was fairly large, but the network digital set-top box was still being forecasted to take off next year, and part of that comes from the wonders of standards in North America. There's lots of them, and that's part of our dilemma. If you look at the delivery of interactive TV into the home, you start fighting with the different standards of DBS, switch digital video, HFC. How those standards come into play comes from who the players are. Is it a telco? Is it a cable company? Or is it a new industry that forms, such as what's happened in direct broadcast satellite? In those four areas of networked consumer electronics you have four major infrastructure investments that have to come and those infrastructure investments are driven by semiconductor content and by people defining what the end consumer will pay for.

Is the TV the gateway or is the PC the gateway, and does the hybrid device get developed? If so, it is an Internet TV or is it a PC TV? Do you start providing an Internet phone

capability, or do you move into the wireless side? As you get into broadcast TV, is it HD TV? Is it digital NTSC? All of these provide very significant challenges and obstacles to the growth of our business.

What do they all have in common? They all are digital. They all have fundamentally the same building blocks and they all represent brand new business opportunities for integrating voice, data, and/or video for the consumer electronic marketplace. So it's a huge marketplace for end-to-end equipment from semiconductor side but the barriers to semiconductors is the non-standard standards of networks and protocols. This entails several things: one is a very fragmented marketplace, and it also leads to a very high confusion factor in the end customer.

The life cycle for consumer electronics is significantly different than what has historically been in the computer industry, what has been primarily targeted at the corporate marketplace. When we sell a large screen TV, we do not expect to see that customer for somewhere between 5 to 7 years, much different than the two-year type of product life cycles that we see in the semiconductor industry. Those things have to be taken into account in our business planning as we develop and build new equipment and even more important, business models for those new equipment. In the consumer marketplace because of the rapid changes that undergo in the semiconductor side, there is a fear of technical obsolescence in the consumer.

How do you approach this diversity of standards in a way that is cost-effective, but still leads to a rapid growth in the marketplace?

SEMIICONDUCTORS AND MULTIMEDIA

Our role as semiconductors companies is to fuel this revolution. By building cheaper and more integrated silicon chips, we have made and will continue to make possible the economy of scale that will bring multimedia to mass success in set top boxes.

The real challenge for the semiconductor industry will be around the terminus, where most of the dollars are. Today we see DVD players, set top boxes, network set top boxes, digital VCRs, network computers, not to mention digital still cameras, digital VCRs, and the automotive car information systems, etcetera, etcetera, and you saw a lot of examples today. We're at the beginning of a new year, and different products will appear in the marketplace, and the consumer alone will in the end decide which one will win.

What can we do in this changing environment? First, we need to focus on key technologies, such as microcontrollers, MPEG decoders, analog signal demodulators, signal recreation algorithms, embedded memories, and master them strongly. Datacom technologies, including modems, ISDN, XDL, XDSL, ATM, wireless, and whatever is going to increase bandwidth and mobility will be the other key component for the success of multimedia, and we are back once again, to the basic two technologies, which are communication, and display content.

These two elements, mastering the basic technologies and having advanced simulation tools, enable us to bring quickly to the market, chips, together with heavy close links to customers to lead the fast-changing market.

ACCELERATE

We see that the DSP world is extremely important, because of the functionality that it brings, and the overall performance, and the costs. FPGAs to allow us to rapidly get into the market, get through the product life cycle, through the profit life cycle, and then move into either custom design if the product merits. Of course, the CPUs we will continue to push as far as we possibly can, and we will always be the ones that are pushing Intel to make even faster machines. 3D graphics, communications -- these are the areas that are going to make this whole multimedia consumer marketplace come together, and we hope that all of you that are in the semiconductor arena, are able to provide some of those functions for us.

This is the name of the game: accelerate, accelerate, accelerate, to be early in the market and maintain your competitive advantage, and of course, you need to have a lean and empowered organization, with a strong, unified strategic drive, a larger local economy, to keep the pace with the market, and strong and entrepreneurial leaders, able to successfully take and manage in both races, in the new race, and we, in our company, are ready. We have the technology, we have the tools, we have the people. No industry in the world has the pace, the fierce competition, and the globality of semiconductors, so I'm sure that when the challenge comes, our industry shall succeed. To paraphrase John Belushi, 'when the going gets tough the tough go shopping,' and I'll be glad to lead the happy crowd to the nearest mall to buy the latest multimedia product featuring the most unimaginable semiconductor technology.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #9: LAN Switches, Round Two

Dr. Prabhat K. "P.K." Dubey
President & CEO, MMC Networks Inc.

Agenda: Introduction, Switches and The Future, Ideal Attributes, Challenges, Round Two LAN Switched, MMC Networks

INTRODUCTION

Networking is a very exciting industry and in this session, you will learn some exciting things that are happening in the networking industry. Networking infrastructure is key to the next two decades. This year more networking nodes will be installed than modems bought. At the same time Dataquest forecasters predict 150 million PCs will be bought and sold in the year 2000. The networking industry is a high volume, high growth industry, growing at almost 42% per year.

The networking industry is also going through a massive change. The latencies are getting bigger, the effective bandwidth per user is now roughly 1/1000 of whatever the wire speed is. In other words the networks are very clogged.

SWITCHES AND THE FUTURE

Switches have been installed in the dividing closet in enterprise-wide and wide area networks to deliver to the user bandwidth on demand on an asynchronous basis. In other words, as opposed to sharing the same piece of wire and hoping you get a connection established even if it is a slow one, now a user is in command and control and something in the infrastructure is slave to the user by giving you a switched connection as opposed to a shared connection. The switch industry has gone by a big upside in the last two years. This year, the industry will register this year some seven to eight billion dollars in sales. Switches have taken the industry by the storm and this is the way the networks of future are going to be built.

As a result, the LAN switch industry from '95 to 2000 is growing more that a hundred percent per year and is going to be a big industry by the year 2000. The other trend you will see here is that Ethernet has given way to fast Ethernet which is 100Mbps speed and fast Ethernet is growing very, very rapidly. You'll also see the emergence of 1000Mbps for gigabit Ethernet, and this is the other trend in the LAN data networking side of the equation.

The third trend you will see is a new protocol called ATM or asynchronous transfer mode, and the factors that are driving it are higher bandwidth demand, demand for scalability and multimedia applications which are video-rich and voice-rich not just data communication. ATM is being installed in the backbone in a very rapid way.

In the backbone you will see gigabit installations as well as ATM installations. The drivers for gigabit are higher bandwidth to the desktop to solve the congestion problem in the backbone, and it's easy to migrate since it is the Ethernet world here.

So, to summarize the key to the networking technology, the key to delivering bandwidth on demand, the key to delivering high bandwidth on demand, the key to delivering voice-, video-, and data-rich contents on demand, the key technology is switching technology.

IDEAL ATTRIBUTES

The ideal attributes of switching technology can be summed up in four things. The first thing is scalability; in other words the switching technology should be scalable from low end to medium end to high end so that the equipment maker does not have to reinvent technology as a point solution somewhere. As more and more people got on the shared networks, we have a need for switched networks. As more and more people get on the switched network, one of the key criteria for buying is going to be aggregate bandwidth of the switch or something called capacity. People are going to demand higher capacity switching engines.

The second attribute is features. Switches today are delivered without many features. When somebody is buying switching equipment, the purchase criteria is all sorts of features. What sorts of ports are configured? What sorts of uplinks? What sorts of diagnostic features, maintenance features, LAN emulation, policing, accounting, all these things while the equipment vendors are spending most of their time developing switching technology and much less time in the feature development. The other two attributes are cost and backward and forward compatibility.

While switches are being touted as the elixir to all these problems, the shift to switches themselves creates new sorts of challenges.

CHALLENGES

The first challenge that a network administrator faces is to make sure that the client/server traffic is decongested. The bulk of the traffic is from user to server, rather than user to user so the server traffic must be fed in a pipe. Needless to say, the backbone traffic where everything aggregates must be a fatter pipe. There must be on-demand adequate bandwidth to the desktop. The transition to switched networks must be smooth and take into account any legacy LAN and or ATM. And the new switched network must be

easily managed to encompass move/add/deletes, troubleshooting, security and performance analysis.

The other challenge is that the cost must be low enough to get capital budget approval and the right sort of equipment must be selected based on the horsepower of the switch and flexibility in different ports for different users.

It is clear that the current LAN switches do not have adequate capacity or features, to solve the network administrator's problems.

ROUND TWO LAN SWITCHES

The next round of LAN switches must have adequate horsepower, must have adequate high capacity, it must be rich enough in features for trouble-shooting, for move/add/delete, for performance analysis, and things of this sort. It must have extensive network management capability, it must be scalable and stackable and must be affordable.

The round two of LAN switches must have capacity scaling to 20 Gbps in the corporate use environment. It must have great flexibility as different users will ask for different sorts of ports for Ethernet, fast Ethernet, gigabit and ATMs of different sorts. It must have VLAN, virtual LAN for simplifying the network administration, providing security and improving the efficiency of the network. It must have a remote monitoring capability, RMON, for observability of switched traffic, for troubleshooting, and management. It also should have switch-router combo for reduced latency and costs. In summary, you will get higher capacity feature laden for maintenance, troubleshooting, and things like that.

MMC NETWORKS

MMC Networks invented a switching technology called ViX technology which is a switching routing architecture, focusing on the switching-routing area of the problem only. We have expressed the ViX architecture in a packets switching, which stands for Ethernet packet, or fast Ethernet packet, or gigabit packet, and ATM switching, ATM cell switching, and these two platforms are now in production. The two products, two switching platforms that we've introduced fit into the high-capacity high-feature box.

Our packet switch platform has a capacity of 4 Gbps and this is roughly ten times the capacity of the normal switches that are available today. It does have future proof in terms of providing ATM uplinks, and every board is configurable — it supports many features, it's cheaper and it allows our customers to differentiate their systems at the feature level, and at the network management software level. The same way the ATM product that is in production today is applicable up to 40 Gbps bandwidth, which is more than adequate bandwidth in the corporate backbones, it is a complete ATM switching platform.

It is scalable to 40 Gbps, the ports are flexible and we have also completed numerous feature chips to make sure the LAN switches of tomorrow are really here today — and it's a dramatically lower cost of switching.

The current switches that are available today do not have adequate horsepower nor do they have adequate features and our company is dedicated to enabling round two: cheap, high bandwidth, full-featured switches.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #10: Embedded DRAM Technology: The Next Major DRAM Technology?

Prakash Agarwal
President, Co-Founder & CEO, NeoMagic Corp.

Agenda: Introduction, Advantages of Embedded DRAM, NeoMagic, Challenges, Embedded DRAM Applications, Summary

INTRODUCTION

Something that is really going to impact the semiconductor industry in the next five years is the idea of embedding DRAM and logic on the same chip. Clearly we're moving to the system on a chip, but there are going to be pieces of this industry that are not necessarily completely integrated, at a full system level, and embedded DRAM and logic is going to be a big hit in the years to come.

But is Embedded DRAM really the next major DRAM technology, or is it going to be next major semiconductor technology? This session will talk about why embedded DRAM technology is so important, and what are the benefits, what have been the challenges, and what are the challenges ahead of us.

THE ADVANTAGES OF EMBEDDED DRAM

You heard about "system on a chip" and we feel that system on a chip cannot be implemented unless you're using embedded DRAM technology. What is a system or a subsystem? Any system or subsystem contains some logic modules, some memory modules, some analog pieces and the industry has been implementing more and more logic functions into a single chip and including more and more memory capacity. To have a true system on a chip, you would have to integrate logic, memory and analog all in a single chip.

In the traditional integration approach, you take a bunch of logic blocks, 100,000 gates to 200,000 gates, or 1 megabit DRAMs to 16 megabit DRAMs. People have been incorporating more and more into a single logic chip or single memory chip. With that approach, you get the integration and you can reduce the number of components but you do not really see a major performance enhancement, nor do you see power reduction. Embedded DRAM technology not only gives you performance but it reduces the power consumption in a big way. More and more integration helps from the economic side.

The most obvious performance bottleneck in any system is in the memory bandwidth. If you can solve the problem of memory bandwidth, you can improve the performance quite a bit. There are ways you can do that — either you can have faster buses, or you can have wider buses, or you could have both. The problem there is, as you go wider or faster, it takes more real estate to implement the system. It increases the complexity of the board design. It takes more power consumption, and costs more, with more components, more pins, more real estate, more EMI. The real solution is embedded DRAM. When you combine DRAM, you are no longer restricted by any of those problems because you get the widest bus. You can make it as wide as you want because it's all internal.

What saves power? Low voltage operation, power management and slower clock operation — or you can have narrow buses and fewer I/O passes. The industry has made a lot of progress in low voltage operation, even getting down to less than 3.3 volts. Same thing goes on power management. If you slow down the clock or have narrow buses, the problem you get into is you have lower performance. You want embedded DRAM because that gives you the widest bus with zero I/O passes switching simultaneously. If power consumed, especially in CMOS, is the most consumed at the I/O pass because they're designed to drive very hefty printed circuit traces on the motherboard, when you eliminate that by combining DRAM and logic into a single chip, you have eliminated the most power hungry circuits in your chip.

NEOMAGIC

NeoMagic is focusing on the graphics side. You take today's comparative graphic solution, the 256-pin BGA, and two megabytes of 16 DRAMs. That's 5 chips but with embedded DRAM you replace the basic 5 chips with 1 single smaller chip.

Any time you have a single chip versus multiple chips, you reduce the manufacturing cost. It makes it so much simpler from the manufacturability point of view, from the testing point of view. More important than that is granularity savings. Take graphics, for example, let's say you want to run 1024, 768, 64 thousand colors, or whatever. Your next application requires 1.1 megabytes of memory, you're forced to go to two megabytes of memory, you have no choice, That's how the standard DRAMs come. They come in half a megabyte, one megabyte, or next thing you have to go to two megabytes of memory. They're wasting that 900 kilobytes of memory, which you don't need. When we're combining embedded DRAM to logic, you put in 1.1. megabyte — no more, no less.

The simplicity is in fewer wiring layers and less inventory. All of that translates into ease of use and faster time to market. Time to market is so important in this business, if

you can save three months off your design cycle, you can be ahead of millions and millions of dollars.

CHALLENGES

What are the challenges and why hasn't anybody else done it? We really have to understand the dynamics of memory and logic. There are two different industries: Memory is a component-oriented business, whereas logic is solution-oriented. On the logic side you have to provide complete solution, demo boards, BIOS, drivers, software, and on the components side they just do not understand the overall system solution. Memory is manufacturing intensive and logic is design intensive. The more you innovate, the more successful you going to be on the logic side.All these things create this perception that memory is memory and logic is logic. The memory groups do not understand logic, and logic group does not understand the memory side of the business. Once you start combining those two together, there a lot of design complexities because what you need to do, is you need to run your logic and analog on the commodity DRAM process. What that means is now you have to understand the memory process, how you should target your logic and especially analog and not get lots of noise because DRAMs are very sensitive to noise issues.

Testing is a big issue. DRAMs are giant gang-testers, where you test hundreds of them at one time to bring the test time down, whereas logic is done one piece at a time. How do you resolve some of those issues? How do you work out an economical, profitable model with your DRAM supplier where it becomes a win-win? Those are the challenges that one has to face.

EMBEDDED DRAM APPLICATIONS

What are the embedded DRAM applications besides graphics? You can classify into three different categories: performance-driven, battery-operated, or even cost-driven. You can apply this technology into all of these areas. Looking at some of the semiconductor opportunities in those areas: 2D/3D graphics accelerators, audio/video, compression and decompression engines, video conferencing, DVD controllers, CPUs and DSPs.

The mobility aspect of information technology is going to increase at 30% and the reason is all of these new applications, even multimedia. What is multimedia? Multimedia is presentations, training, entertainment, education, and what that means is it requires portability so that a traveling salesman or traveling real estate agent can be on the road and not have to call a factory for information and can even change the presentations on the fly if he needs to. That will enable all these things.

Looking at the embedded DRAM technology, what we need in the future is primarily having two metal type of technology. We need to add a third metal, or even go beyond that. It can be done. Try using the 64 megabit DRAM technology, that's coming up very, very fast. That will allow more and more memory to come in because multimedia requires lots of memory and a lot of gates. 64 megabit DRAM technology will enable us to put more functions, more features and more memory into embedded DRAM applications.

Tighter metal pitches. The DRAM technology is basically poly-silicon driven and it's not so much optimized for metal, whereas to get the speed out of your logic you need to have tighter metal pitches. It can be done, it's coming, and, also, shorter cycle time. The DRAM sensor takes 23, 25 mass set compared to only 13 to 15 on the logic side. It takes longer production cycles and being in the PC industry and knowing how fast the market moves, we really need a shorter cycle time here. The key thing here is, you want to do all of that on a commodity DRAM process. You do not want to build a specialty DRAM process to do embedded DRAM because you want to leverage the cost and technology of your commodity DRAM.

SUMMARY

In summary, there's a lot of interest in embedded DRAM right now and it is probably due to what has happened in the commodity DRAM market. This technology is going to be a major semiconductor technology, providing us this system on a chip type of application. It should be focused from that direction. It's a major opportunity because those who have been focusing on long-term vision are going to be very, very successful.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #11: Ultra High Speed DRAMs: Unlocking the Potential

Fu-Chieh Hsu
Chairman and CEO, MoSys Corporation

Agenda: Introduction, Defining Terms, The Driving Forces for Speed,Why DRAM? The Multibank Concept, The Mcache Concept, Conclusion

INTRODUCTION

You have heard about how the DRAM dragged down the whole semiconductor industry and how the embedded DRAM has tremendous potential in serving a lot of the application segments. In this presentation, we take a slightly different look at the DRAM and particularly the special niche application segments of the DRAM. One of the potentials that really exists in all of today's advanced DRAM processor technology but so far has been underutilized is the ultra high speed DRAMs.

DEFINING TERMS

What is speed? Is it bandwidth? Is it latency, or is it throughput? Speed is all of these. Speed is access time, and speed is also bandwidth. The bandwidth people are talking about is actually the peak bandwidth, which is usually defined as the width of the datapass times the clock rate, the frequency. Speed is also the throughput, in which, you consider the reduction in the usable bandwidth due to the access latency. Speed is really an application-specific concept, so how to optimize the speed is really dependent on specific application environment.

THE DRIVING FORCES FOR SPEED

One of the most obvious is CPU performance. We have seen CPU performance continue to increase at a very, very fast rate and to allow balanced system performance, the memory has to perform in a proportional fashion. CPU performance is nearing 200 megahertz and will continue to climb to speeds exceeding 1 gigahertz operation. The basic process capability is definitely fully capable of supporting devices or circuits at those speeds.

Memory architecture is definitely needed to match such explosive performance increases for the various processor technologies. One of the techniques actually has been used successfully is to decouple the access bandwidth from the internal access time. I think we can see that in the specification or the device of the synchronous DRAM or the RAM-bus DRAM. However, the improved access time is equally important.

WHY DRAM?

Why DRAM technology? DRAM traditionally has been viewed as low performance but low-cost technology. The DRAM processes fundamentally are not different than the logic processes used by the advanced microprocessors or the various DSPs the media processors so the process technology itself is fully capable of operating at whatever frequency the processor is capable of. The DRAM with its smallness of all memory types promises to be the lowest cost memory technology today and perhaps in the next several generations. From the bandwidth point of view we believe that there's really no limit on what DRAM memory devices can achieve, provided the right architecture is being used. From the access time point of view the DRAM internal access is always a 2-step access so by definition it's always going to be somewhat slower than the high speed devices such as SRAM. However this internal, inherently slower, access time can be compensated by several techniques such as clever circuit implementation techniques or clever partitioning.

THE MULTIBANK CONCEPT

In a fairly traditional memory partition, a DRAM partition typically involves read or write access of 4 to 8 words, or maybe 16, but typically of that order. Most processor applications now involve multi-processing or the multi-thread, multi-tasking types of operations so with a single bank type of DRAM device, when reaching from the task to tasks the probability is the majority of the time the DRAM has a page missed. Even though the memory itself, has a fairly high data rate or peak bandwidth, most of the time the memory bus is idle while the memory performs recharge RAS and cache access operations.

In the multibank memory architecture concept, the same memory array is partitioned into logically multiple large numbers of small banks so with that we can accomplish a statistical advantage. While the task is being executed on the memory, when there's complex multi-task switching, from task A to B to C to D, there will be very high probability that when the task returns to A, the page is still effective. With that memory system, the subsystem is allowed to work most of the time, achieving high efficiency while still basically utilizing the same basic DRAM array.

The multibank concept was specifically developed and engineered for the multi-processing environment. Repeated access to the same area of the memory ensures a high hit rate of the memory access and this results statistically in the memory with the multibank concept delivering SRAM performance because the majority of the access is page access.

THE MCACHE CONCEPT

With this clever circuit technique we are able to achieve SRAM access time. The deterministic latency approaches SRAM capability and it achieves much higher bandwidth possibilities. The MCache product is a direct plug-in replacement for the SRAM, so it's exactly the same in the performance capability. Although inherently DRAM is slower than the SRAM, with appropriate architecture and the circuit design techniques, DRAM can be a very, very high performance memory suitable for almost any applications existing today, whether it's currently served by the DRAM devices or served by the SRAM devices.

CONCLUSION

We certainly believe that DRAM devices should be application specific. With that, we have the flexibility to optimize the DRAM circuits and the DRAM memory array to deliver the highest performance possible for that particular application. Many other side benefits go with that.

DRAM technology will always have the lowest power of memory devices that operate at a similar speed. It has the lowest cost. It can deliver same or better performance because the small cell size of the DRAM it allows much more flexibility and capability in terms of higher levelS of integration, leading to possibly single chip solutions and embedded solutions. The MDRAM and MCache products are only examples of application specific implementation that take advantage the latent performance capability of a DRAM technology. We believe that this application specific concept, using a very high performance DRAM core can be adaptable to any system partition and requirement.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #12: How to Win the Digital Communications Race

Hatch Graham
Senior Vice President & General Manager, Personal Communications Group, TCSI Corporation

Agenda: Introduction, Setting the Scene, Service Providers, Emerging Standards, What Can Change, Summary

INTRODUCTION

Network and business management software for all the big PTT's, RBOCs, the big service providers that are building out this new wave of infrastructure will have much more of an impact on semiconductor manufacturers in the future more than it has ever in the past. This presentation highlights the need for semiconductor manufactures to be prepared to change and change quickly and some of the components and types of technologies that you might keep in your arsenal to prepare for this sort of change.

We are going through a change where we're getting access, access to our products, whether we're mobile, whether we're at home, we're having all sort of different issues related to networks and how they provide services to us. It's becoming more and more convenient and we're able to get more and more information than ever before. I've figured out what communication is all about. It's about access to transfer information from a source to a destination. From the beginning of time to now the goal is still the same — its just now we're packing in more information.

SETTING THE SCENE

What digital communications is doing is just expanding the limits and you're going to see how more and more access points come about because of digital communications. Semiconductor manufactures have to really study the changes in digital communications to be ready for it.

What's happening now is as significant to commerce as anything that's happened in the past. I know that we have not invented a new way to transmit something but what we are doing is making it affordable for the consumer to be able to get just about any information anywhere.

Integration of the three C's: Computers, Communications and Consumers. By the year 2000, a hundred million phones are expected to have been sold. By the end of the decade, over a billion people are expected to be on the Internet. The consumer now can be much more proactive. Any product may have and need, affordable interactive access to a network.

There are very complex value chains emerging. There are equipment system manufactures, there are content providers of the service, there's service providers. You have worldwide deregulation that's causing competition among companies unlike ever before. They are basically doing what semiconductor manufactures have done for quite some time striving to become more competitive, improving customer care and reducing time to market.

SERVICE PROVIDERS

There's something called integrated service management; broken down into four parts, you have business management, service management, element management, and then network management. There are things called object orientated software on client/server systems. What it really all boils down to is that the service providers now have an increased capability at the service centers to manage all of this equipment out there, change it in and some cases, buy software four states away to provision you with what you want upon your demand.

The types of things that are in business management, are financial control, marketing, payroll, service management, billing. Service provisioning; you need to be able to request the service you want and not have to be stuck with it when you don't want it. Element management is basically all of these networks you read about every day — broadband, PCS, cellular, you read about plain old telephone is something you've had for quite some time, but SONET, ATM, SS 7, call processing type things. These are all networks that make signal processing more convenient to get you your data. The realities that these networks really do have to do some tough work.

If there's a problem today, there can be something called fault management with error flags that come up in these service centers and there can be several hundred errors that show up that have to individually be audited, be logged in, be corrected, for one problem, one transformer going down. The reality is they handle five million events per day. This peaks at thousands of events over just a few minutes so these are very complex issues and as this access comes to you consumers, and you use these services more, these systems have to get better and better and better.

EMERGING STANDARDS

Communication access can be broken down to five blocks: There's is a conversion process which takes a signal, typically from a carrier frequency and brings it down towards the base bandwidth that you operate the signal processing in. Modulation is where a lot of the action is. In some cases you pick up the signal from the conversion so you can do digital signal processing in a DSP chip or in some cases you need to dedicate circuitry. Error correction, that's where decoders, Reed-Solomon coders

and things like that come in. Compression has really enabled digital signal process to help the consumer. Compression so that you can essentially get more signals within a given capacity or you can improve the quality of the voice or of the audio. Formation — basically you have a stream of data and at a certain point you need to turn it into something that can interface with the network or the consumer and so I call that formation and some people call that media access, control interface. Every point-to-multipoint network has to address this and it is all semiconductor based.

As these networks succeed, standards emerge. As soon as these standards are set, they evolve and they evolve rapidly — in some cases before the standard is even agreed on, there is the next evolution of that standard. Portions of that access technology are affected more than others. The point is, semiconductor manufacturers must plan to optimize this change process as all these new ways of having access to a consumer, all these new networks come up, they're all going to be a little bit different. There has to be a game plan that says we can adapt to just about any new access type as rapidly as possible so that we can be in the market and be selling products before any body else. There's always going to be an improvement on capacity, there's always going to be quality improvements, throughput, all of these things are going to be very important.

WHAT CAN CHANGE

Across the life of a standard typically if it does change, it evolves it becomes a new standard but through the life of that particular standard that RF circuit in a lot of cases can remain fixed. The modulation scheme, the way that you do timing recovery and some of the carrier tracking specifics — these sort of things, they remain the same. Error correction need to be a little bit more dynamic. There are always trade-offs between bandwidth optimization and correcting the signal. The real change happens in compression algorithms. This is where in every standard there's always a push to get more people per given bandwidth, to get better quality.

Adoption of the appropriate memory. As more of these networks come in and more access to products, you can imagine that there will be more software coming down from a network to a product. So there will be a need for more memory on a chip, more memory within products. There will be a need for reconfiguring of your imbedded processor by loading different information into your memory and reconfiguring the processor or the actual instruction set, you could literally have multi mode technology. This is coming.

SUMMARY

There is a proliferation of networks. All of the big RBOCs and PTT's are essentially revising their systems to offer you more services and that means that the products that you buy will have access to any kind of information whether you're moving around or sitting still. There's going to be an endless change to the service needs and there's a similarity to the access of this communications.

It provides an opportunity for semiconductor technologies to be balanced out and be optimizing cost and performance and configurability and time to market as these new networks come up, and as these new access points are integrated into the products.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #13: DSP Chips: The Hottest IC Segment in Sight

Joseph Grenier
Vice President and Director, Semiconductor Device & Applications Program
Semiconductors Worldwide, Dataquest

Agenda: Introduction, What DSP Does, DSP Applications, Market Drivers

INTRODUCTION

The goal of this presentation is to raise the awareness of DSP, its many applications and the important role DSP will play an enabler in communications, consumer electronics and PC multimedia. Not enough attention is focused on DSP and it deserves more focus. Part of the reason why DSPs don't get much attention is that people don't have a good idea of what they do. When it comes to DSPs even folks in the semiconductor industry have to struggle to get a definition.

WHAT DSP DOES

A good example of an application that requires A digital signal processing solution is an automotive noise canceling system, where ambient analog noise is picked up and digitized with an A to D converter. A digital noise signal is then processed and sent to a D to A converter where the processed noise signal is converted back to an ambient audio cell or an ambient analog sound feedback which should perfectly cancel out the original noise signal and you'll hear nothing but silence.

One characteristic of digital signal processing is that it is real-time processing, there can't be a delay — otherwise in this particular application you wouldn't hear silence but you'd hear strange sounds because of ineffective noise cancellation. In order to do real-time processing DSPs have to be very, very fast.

The second characteristic of digital signal processing is that it usually deals with real world signals, analog signals that either originate or terminate in the real world.

A third characteristic of digital signal processing is that it's very math intensive. For example in this application to cancel the noise, another noise signal has to be created by digital signal processing that is exactly opposite, in phase and amplitude to the original random noise signal. Intuitively you can guess that this is a very complicated thing to do, however this is what DSPs are best designed to do.

Basically analog signals originate in the real world are digitized, the digitized signals are processed in some way and then converted back to analog signals for presentation back to the real world. Not all digital signal processing deals with analog signals so this is a simplification to help you understand the process here.

There are a number of ways of implementing a digital signal processing solution as shown here. They range from discrete logic implementations to host MPU signal processing, sometimes called native signal processing, to digital signal processing done with MCUs and MPUs to a programmable DSP chip to an ASIC with a DSP core and finally to fixed-function DSP chips.

DSP APPLICATIONS

A fixed-function DSP is one that is designed to do only a specific task — it can not be reprogrammed to a different task. On the other hand, programmable DSPs are just that, they are general purpose DSPs that can be reprogrammed to do many different tasks. Programmable DSP chips is a very high growth area for digital signal processing. A programmable DSP is basically a microprocessor that is very specialized to do arithmetic operations very very fast. The sequence of arithmetic operations that it performs or the algorithm can be programmed by the user for his own particular math intensive application.

DSP has long been used in military weapons systems. Vision, imaging and pattern recognition are areas that DSP excels in because of its ability to process real world images. Food inspection is a good example — fruit on a conveyor belt passes video cameras at several feet for second and images of the fruit are processed to pass or reject the fruit based on attributes such as color, size and texture.

Clearly communications is a leading application segment for DSP chips, about half of all the programmable and fixed function DSP IC revenue results from sales to communication applications such as modems, fax machines and cellular phones. Communication applications require real-time compute intensive functions, such as voice and data compression intercoding, carrier modulation and demodulation, speech recognition and text to speech conversion. More examples of signals that originate in the real world. The digitized signals have to be processed with high speed in real-time and the compression and coding and encryption algorithms are very math intensive. Further, the DSP solution has to be low power to prolong battery life at low cost because cellular phones are becoming consumer devices. All the traffic on the information super highway will be digital, not only will it be digital, but it will also be compressed with digital signal processing.

Digital compression is a key enabler of tomorrow's communications and the super highway and

communications in what I call, the wireless super highway, such as direct broadcast satellite TV, direct broadcast radio. Digital compression will be vital in the success of PC multimedia, video conferencing, interactive video training and games and digital consumer products such as digital camcorders. Digital compression requires fast, low cost real-time number crunching capabilities to execute the compression routines or the algorithms. Today's DSP chip technology along with industry compression standards or algorithms like JPEG and MPEG can make this happen.

Today's autos already have several micro-controllers and DSP use will also find its way into cars in those applications that require fast real-time processing. We've already mentioned noise canceling systems and some cars already have DSP-controlled automatic adjustment of the suspension system for smoother rides, Jaguar in conjunction with TI has developed a night vision system that uses a near infra-red camera to allow drivers to see objects in the dark that would not be visible using normal headlights. DSP is used to process the images detected by the IR camera.

In consumer electronics, DSPs will be used throughout the new wave of digital electronics wherever there is a need to process audio, video and other images like photographic images. The restoration of Hollywood films is an interesting application: Snow White took 18 weeks with 60 work station operators using 40 work stations and 3 shifts and 7 days a week. With digital signal processing the restoration could be done in much less time with much less money and operators.

DSPs are also finding their way to arcade games in motor control chips and in power tools and home appliances DSPs are replacing MCUs in some cases.

MARKET DRIVERS.

So what's driving all these diverse applications? Collectively, they have all been driven by the three main characteristics of DSPs. In the past DSP applications were limited because low cost and low powered DSPs were not available and what was available was expensive. When DSP were first introduced, back in the early 80's, they cost about $200 per mip. Today the going price is about a buck per mip. Thus, the availability of low power, low cost and low cost per mips DSPs is what's causing the explosion in the DSP market and each of these characteristics are creating new markets.

The 1995 market grew 62% to reach more than 1.6 billion, but what does the future look like for programmable DSPS? we expect a programmable DSP market to reach nearly 7 billion dollars by the year 2000. This represents a compound annual growth rate of about 32% over the forecast period. For 1996, we expect a market to grow 33% and to reach over 2 billion dollars. Well 1996 growth that 33% is less than the 62% of 1995, this doesn't indicate a slow down of growth it's the law of large numbers beginning to apply when you're coming from a small base like DSP has been doing you cannot continue these high growth rates.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #14: Java versus Intel: And the Winners Are...

Raj Parekh
Chief Technology Officer, Vice President and General Manager, Embedded Products Group
Sun Microelectronics

Agenda: The Paradigm Shift, Intel And Java, PicoJava, Performance Advantage, Conclusion

THE PARAGIGM SHIFT

Every time a new market emerges, a new paradigm shift takes place, it creates some opportunity for new winners and new losers. We believe that at this point in time with Internet, World Wide Web and emergence of Java it creates the paradigm shift.

With this new change of paradigm, let's look at how Intel's view of the world is. It's extremely straightforward, it's very easy to understand they're going after the PC, the desktop and the laptop. They did excellent marvelous job in standardizing as well as creating a very high gross margin business for themselves. Java's view of the world, is much broader, far, far beyond just the desktop. It is into the networking world, it is into the bridges, hubs and routers, it is into the communication world into telephones, into the entertainment industry, into an automobile, direct to the consumer.

With this size and shape of the world, the kind of a potential market Java exhibits, is measured in millions and millions of units, far larger than Intel or any CPU, or any MPU, or any individual DSP, or any other product. Because of the wideness of the market, and it goes from the pagers to the games to the set top boxes and the net computer and enterprise and the control side of it. It becomes extremely interesting and an extremely dynamic market.

The real question is, "What are the key success factors?" How can we really penetrate such market? And looking at the next slide we think that one of the key aspects here is the universality of the application. It is an application you write one time and it runs, not on one computer but it runs on any computer. And it is highly modularized, so actually you can merge multiple different applications together. Telephony is well understood market and PC's are also well understood market. But how to do screen phone, which has part of the telephone and has to connect to the screen and it works like a little Web on your phone. So that is how the combination of different technologies plus Java has became excellent way to provide that connection.

INTEL AND JAVA

Looking at X86 or Intel's way of doing the business and Java way of doing business is rather interesting. We are not going for single source, we are going for multiple sources almost in every geography of the world. Second thing it does is, because the nature and modularity you can actually operate at much lower frequency and optimize power quite significantly so that if it is in your pocket in some way, shape and form the batteries will last literally forever. In case of a desktop connected application you will demand tremendous performance. It can really scale up extremely easily because all the work that has gone into it when we created the architecture in the first place.

PICOJAVA

So the Picojava we have designed, which is a core that will be available for people, is available for licensing. We will create the product based on that. Sun will create the product based on that but many other people will also create the base. Now the span of this product is the simplest pager to most complicated Net computer and everything in between in multiple different dimensions. The reason we were able to do it this way is simply this is not a general purpose processor. This is more like, think of it as a DSP for Java. This processor executes Java natively, all the instructions of Java natively and 'yes' we took care of the legacy core issue by ability to execute C++ in this processor.

The primary design target and the primary dimension for this product is the world's best execution of Java. And in this particular core we are talking about 60,000 gates, we don't measure ourselves in how many millions and millions of transistors are there. We don't take pride in making it bigger or more complicated, we take really pride in making it simplest, easy to use and that flexibility so that people can scale it up, down, for different applications, integrate other functions with it because that is the only way to create the minimum cost product and Picojava has achieved that particular goal for us.

The Java Processor will touch your life one way or shape or form in near future. Some of the partners which we have made either public announcement or we have let the world know are; NEC, Samsung, LG semiconductor, Mitsubishi, Nortel. They have already announced their intentions one way or other to make use of the chip and create products based on this. These are not small companies, they are all industry giants and they are extremely serious about this product all the way up to the chairman level.

PERFORMANCE ADVANTAGES

Nothing happens unless we have a very significant performance advantage. There are 2 ways to upgrade the interpreter as well as the just in time compiler and this is a different trade off. One way makes it more general purpose but it is slower. The just in time compiler is somewhat faster but it takes more memory and it is very specific to individual processor. However with Picojava running at the same megahertz clock rate and with 60,000 gates, we should be able to run a lot faster. We are experiencing at this point in time a 5 times advantage over a Pentium running the fastest thing known, called a "JIT Compiler."

That's why it creates the lowest cost solution. Not at the chip level only but also at the system level because the memory requirements and other requirements start going down. So with this power of the language, what happens, what it has created is rather interesting momentum. I don't know whether I should call Netscape an operating system or not, or what, but look at the other numbers. The number of programmers working on Java exceeds 200,000. At the peak, Windows programmers were noted close to 400,000. Java is already halfway there and growing very, very rapidly. 57 colleges and universities offering Java classes and claiming that most of them are so full and people are on waiting lists, students are on waiting lists. 150 books published in one year, somebody's certainly reading. This is rather amazing; 80,000 Web pages running Java, already!

CONCLUSION

Having said all of this, who are the winners? Intel or Java? I believe that the emergence of Java is breaking the paradigm that you have to have one operating system, or one CPU architecture, if you don't do it you are dead. That particular phase has changed, and consumers are the true, true winners of this particular paradigm. And in conclusion, the ability to adapt entirely different technologies, different applications, and the possibility of evolving to universal applications is unique. All of those have become extremely powerful way do deal with it and on top of it we have created a business model which makes a huge difference for us.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #15: The New Paradigm for Online Services

Mark Walsh
Senior Vice President, America Online Enterprises

Agenda: Introduction, We Were Wrong, How Not To Fail, Lifetime URL

INTRODUCTION

I am the business-to business guy at America Online. AOL is the world's most successful, so far, the world's most successful consumer oriented online service and has penetrated many homes and desktops and in fact is being used by a significant portion of our members for business purposes.

I was asked to today to talk about a new paradigm. It's being used so much that I almost feel that in some ways its my legal obligation daily to say new paradigm, or paradigm shift. Robert Oppenheimer was the chief scientist of the Manhattan project, the group scientist in World War II that invented the atomic bomb and after about six months of work in Los Alamos, Oppenheimer and his team had successfully created the first atomic bomb and had a prototype called 'Fat Boy' which they were going to detonate in Alamogordo in a test and a bus circulated the Los Alamos facilities gathering all the scientists together to take them out to Alamogordo for that initially detonation at 6am on that fateful morning and Oppenheimer noticed that the mathematician Dr. Brock Johnson, was not on the bus and he said we have to have everybody and he went to the bungalow, and he knocked on the door, and Dr. Johnson came to the door in his bathrobe and Oppenheimer said, "Come on, you've got to come with us, we've all worked so hard for six months, this is an amazing creation that we've successfully completed it's a whole new age, we're going to change the world. Come on, out with us!" And the mathematician said, "No, you don't understand. If I got the math wrong, none of you is coming back."

WE WERE WRONG

We got the math wrong in this business, big time. All of us did. I know we got the math wrong on the low end at how successful this would be, how fast. Sure, my chairman Steve Case always felt it would be a large consumer medium with millions and millions and millions of households, but I think even he in his most private moments admits that this hockey stick curve growth of membership and usage is amazing, stunning and unexpected. Now we've got the math on the high side, on how much commerce and transactions and shopping and stock buying and EDI and all that stuff would happen, how rapidly. It seems to be taking off now, but that delay is how we got the math wrong.

What's next in this business? We expect to have 10 million members by the mid to end of 1997. Some of our competition will stay with us or perhaps grow as big or larger than we will. We think that the connectivity side of the online business and the content side will become more and more separate, much as it did in the cable, broadcast television and other media businesses, even the movie business. We think that Internet weaknesses will become more and more glaring.

We think that the Internet's going to break, as you probably have read the Metcalf article about this and I don't care how many people say we're adding more T3's and everything's just lovely, and no problem. The perception of the consumer at his or her desk or at his or her den, is that the Internet is slowing down. Now whether its true or not, becomes immaterial.

We are transitioning to the world wide web and to become the world's largest Internet access provider. From a closed set of production tools called Rainman that makes the screens you see on America Online, we have migrated to an open system of tools and sites we point to and aggregate for our members called the Net. In fact, we went from a closed to a closed system. We bought a browser company called Book Link that was the original browser we used in AOL about a year and a half ago, now we buy and use browser from Microsoft Internet explorer and Netscape.

I would contend they are as closed as the old closed proprietary on line systems. Open is good yet the battle is to own the proprietary code for browser. I think the war going on is not about openness, it is about closed. AOL used to have no advertising on it. Now you're going to see lots of advertising. AOL didn't used to have much commerce but you're going to see a much higher, much higher, stress of buying things on AOL. Trading stocks, buying roses, buying records, buying business information, buying cars, buying insurance, buying travel. We didn't used to have much daytime news, in fact, my whole team was hired to do nothing but drive daytime news by building private AOL's for companies and corporate users.

We used to have outside suppliers, Sprint, BBN and others were our network carriers. Forty percent of our revenue dollars went to outside connectivity companies. We had to buy our own company, ANS, get into our own hosting business to control our cost structure. The marketplace forced us to.

Many of you have seen on television our new branding campaign. We're much more involved in sponsorship in more mainstream media to brand our companies products.

A transition in geography: we used to be simple US centric, look at the name, America Online, but in fact we have launched global joint ventures where we've kept the three initials AOL, just like AT&T means America, but people knew it globally as AT&T, we think that will occur with our brand as well. A transition in content: we used to be a reseller. We just simply took news feeds or other sports news and we added no real value, we had no equity in this content. We were just a repackager, and now through our joint ventures, through our venture capital fund, called Greenhouse, we are owners and equity owners in a wide variety of content plays.

A transition in audiences: we used to be solely consumer. We were the cool alternative to CompuServe and Prodigy and MSN. We are simple, we are reliable, we are integrating, we are cheap, we are multi platform and that is becoming more and more appealing to businesses. In fact, we think that simple wins in the market place. Just because something is hard, doesn't mean it is good. Just because it is easy, doesn't mean it is childish. Nobody ever learns their phones. Most importantly the business market place is adamant about not being obsoleted again. They are adamant about not investing in platforms in hardware and connectivity in content, in services, in packaging where you will tell them in a few years, "Oops, got to upgrade. Sorry." It's not going to happen and that demand for flexibility we think puts my company and some others, in some interesting places. AOL is in a marketplace that is morphing daily, our partners are morphing daily. We have an interesting dance of love and hate in every meeting we go to, be it visiting Satan, I'm sorry Microsoft in Redmond where we're both a partner, a supplier, a customer, a competitor, a litigant, all these roles in one room and the same is true when we visit Disney or Viacom, or Netscape or Lotus or IBM. All of us are very wary of each other.

HOW NOT TO FAIL

There is no proven business model however, we know that this business, be it business oriented or consumer oriented must be a religious conviction. If your company considers online or interactive services a marginal play to protect some franchise you already have or to extend and protect something you already do, you will fail.

Dow Jones had one of the first, in fact at one point, had the largest on line service called Dow Jones News for People, now it is marginalized. Reader's Digest owned something called the Source at one point in the eighties, the second online service in America. It is dead, bought by Compuserve. Genie, owned by General Electric, at one point was the second largest online service in the world. Tremendous consumer reach and business reach but it was sold and is now dead. Sears and IBM own Prodigy, dumped over a billion and a half dollars into it, sold to a Mexican company for a lot less than a billion and a half dollars, many think it has lost its ability to survive in this niche. H & R Block at one point owned all of Compuserve Information Services, the largest online service provider in the world, it is now struggling to find itself. MCI News Corp. bought Delphi which was the third largest on line service in the world. They announced great plans, then a year later, they sold it for nothing. All the regional Bell operating companies in the US and many worldwide have tried and tried to get in online business. They are trying again with Internet access provision deals but all them, at least in the past, have been quite sour. In this business you've got to eat it, you've got to sleep it, you got to breathe it, and you got to live it and you got to die by it so we think that marginalization for larger companies is very difficult to do.

LIFETIME URL

What's going to happen in the future? More pipe, more bandwidth, more content, we'll get way deeper into the education business which is a fantastic market which is always slower to adopt than it should be. You will see the adoption of these products earlier in life, earlier in your business career, earlier in your physical life on the face of this planet. I predict that by the end of this decade, and this century, you heard it here first, that you will receive an e-mail address or a URL at birth, like you do a social security number. You will have a lifetime URL. Migration of commerce will occur real fast, when it finally happens, it will occur real, real, real, fast and business, will be running the asylum. The inmates are running the asylum.

I would suggest the MIS function of American and the global corporations that are important to all of us as customers is under severe duress to prove its' value. At AOL today over thirty percent of our users are female, that up from like five percent not that many years ago. You will see more business on America Online and more business on the net. You will see more purchases from the business platforms; EDI will finally work. My joke is that EDI will work because the manager will go home and be using into it to pay his bill, or her bills and go "How come I can't do this at work?"

EDI will finally hit and consumer use will drive it. You will see far less platform dependence and frankly far less chip dependence in future applications, be it the network computer from Larry Ellison, settop devices for televisions using coax, the X2 modem doubler from US robotics or ISDN or ADSL. Whatever pipe is going to happen it will mean less chip and less platform dependence for services and programming like AOL and in fact you will see more programmed services. I know it sound suspiciously like television but it will be a lot like television.

F. Scott Fitzgerald was once asked what it was like to become poor, because he died penniless. He said, you know, first it happens very slowly then it happens very suddenly. That's what's happened here. It hit and it hit big and I think that whatever you think it's going to be, you should double or triple it because we are seeing evidence that this is an incredible paradigm shift and to that point I would conclude with the following phrase that I think sums it up: shift happens. Shift happens and it is happening more rapidly than anybody would have ever predicted because we got the math wrong.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #16: The Technology Investment Outlook for '96 and '97

Charles A. "Chip" Morris
Managing Director and President, T. Rowe Price Science & Technology Fund

No transcription was available for this speaker.

Session #17: Asia Pacific and China: Looking Ahead to 1997.

C.D. Tam
Senior Vice President & General Manager
Motorola Asia Pacific Semiconductor Group

Agenda: Motorola Revenue, Government Supports, Surpassing Japan, Shift to China, Hong Kong's Future, 5 Year Plan, Motorola in China.

MOTOROLA REVENUE

Motorola Inc. revenue was $27 billion US. dollar last year, and 37% of this revenue came from USA. The combination of Hong Kong and China represents 12% of revenue, and 8 years ago, business in China was virtually zero. It is not a secret that electronic production in the world has been shifting towards Asia Pacific for many years. Historically, this was driven by the lower manufacturing cost in Asia Pacific. Today the real reason for producing continuously in Asia Pacific is to serve the increasingly large domestic consumption markets created by the improving living standards of a population base of over 2.5 billion people.

Even through 1996 is supposedly a comparatively slower year, electronic equipment production continues to grow in Asia Pacific. What about semiconductors? This is Dataquest latest projection for Asia Pacific. After many years of 35% annual growth, the Asia Pacific semiconductor consumption market does have a recession this year, primarily caused by the falling prices of DRAM. This adjustment is the first time in 11 years. However, the non-DRAM semiconductor demand continues to grow at a 9% rate, even through this so-called recession. So for 1996, for semiconductor suppliers, the problems are: First, at the beginning of the year there were high component inventories at most of the customers. The second one is because of very fast build-up of fab capacity, ASP does drop significantly. DRAM, of course, led the pack with 80% drop. Some of the more mature commodity prices also dropped. But commodity semiconductor prices actually only decreased at the learning curve rate.

This semiconductor recession is not a general economic recession, as the economy in Asia Pacific continues to boom. This is a excessive capacity-induced recession, and we should be able to correct it in due time. Definitely, there is some slow down in the rate of wafer fab capacity investment in Korea, Singapore, Taiwan for the short-term. Raising funding in the private sectors has become a bit more difficult than before. There is still plenty of money in Asia Pacific but the investors are more critical and more choosy. Construction of new facilities are still ongoing but at a slower pace. The investment momentum of the past two years still means Asia Pacific will still have the highest percentage of new wafer fab capacity coming on stream next year, in 1997. We estimate this to approach almost 34% of all the new capacities next year.

GOVERNMENT SUPPORTS

Now, you know that the governments in Asia Pacific, such as Taiwan, Singapore, and Korea, would get into the act in order to maintain the country-level competitiveness during this slowdown. For example, the Taiwan government recognizes that, since the private semiconductor sector, through their own efforts, as well as strategic alliances with foreign company, are closing the wafer processing technology gap in manufacturing. We are almost at parity with the US and Japan. They surely don't want to see this momentum being lost, so a series of financial incentives have recently been announced during the Taiwan Semiconductor Conference last month. Today, 17 industrial parks are planned to attract foreign investors, and to become a high tech island, before the year 2000. This, industrial park will be categorized as science-based, technology-based, software, aerospace, biotech, incubator, and research-based. Special operation zones have been planned to allow the enterprises stationed within the zone to enjoy zero tax, free of, freedom to hire foreign workers, because Taiwan actually run out of workers, direct transportation with mainland China, etc. In fact, there will be new incentive programs for companies within these industrial parks: 5 years exemption of tax, share-holder investment credit, acceleration of machine depreciation, joint venture funding from the Taiwan government, the executive loans 2% lower than typical interest rate from banks. Taiwan has sufficient capital resources at the government level because of the US 19 billion dollar foreign exchange reserve. So, when things slow down quite a lot of governments in Asia Pacific are jumping into the act. There are not letting their countries lose momentum in the electronic and semiconductor arena.

SURPASSING JAPAN

"When will Asia Pacific overtake Japan?". Because of the weakening yen, there is some thought that, maybe the time will be extended to the year 2000. However, there are other things happening within the region, such as, some domestic markets in Asia Pacific, like China, will mandate in-country production, and that could move the year to 1999. In the 21st century, Asia Pacific will be driven by not just one market segment, but 7: personal computer, wireless communication, automotive, telecommunication networking, multimedia, smart-card, and energy and environmental control. Every one of these market

segments has increasing semiconductor content. But, Asia Pacific also sees another phenomenon. That is, the creation of domestic consumption markets have accelerated dramatically. Take, for example, using pagers. In 1990, there were 23 million pagers around the world, over half of which were in USA. By last year, pager use had grown to 95 million, and Asia Pacific was almost 60% of that. So, in the span of 6 years, the Asia Pacific market passed the USA market that took 15 years to create.

SHIFT TO CHINA

Obviously, the China factor can not be ignored. Why? There are 1.2 billion people, so as living standards continue to improve, the buying power becomes higher. There's another thing that has been going on: it's called the Hong Kong/China transition and its impact. There are 2 typical misunderstandings about China. First, China does not have enough money. Second, China state-owned enterprises are inefficient, and therefore the entire China electronic industry is inefficient, and thus, the impact to the world will be small.

Let me explain some of the things that have been happening in the last 8 to 10 years. The world does not understand the Hong Kong/China factor. Since opening China in the early 80's rich overseas Chinese have been channeling investment through Hong Kong to China. In fact, over the past 10 years, 80% of the foreign direct investment in China come from overseas Chinese in Hong Kong, in Taiwan, in southeast Asia, channeling through Hong Kong. The 20% foreign direct investment in the past 10 years came from USA, Japan, and Europe. For example, Motorola's half billion dollar investment in China, is part of the 20%.

HONG KONG'S FUTURE

Hong Kong has been moving low and mid range manufacturing across the border. To give you an idea how big this has become: today, 4 Million people in China, across the Hong Kong border, are working for Hong Kong companies. So, efficient factories and management were introduced in the south, by Hong Kong and Taiwan companies. Thus, the Chinese have a whole breed of new factories, which are different from the less efficient state-run factory. The result is that per capital GNP jumps. Thus, a domestic consumption market emerges, so that they can buy more pagers than the USA.

The Taiwan government has a foreign exchange reserve of almost 90 billion US dollars The Hong Kong government has a 70 billion US dollar, foreign reserve, and they don't know what to do with it. That's the difference between Hong Kong government and Taiwan government. Some of this 70 billion dollar reserve will soon get used, more or less like the Taiwan model. Most Hong Kong companies keep the marketing, product design, and material sourcing in Hong Kong, but have all the end product manufacturing, like PC board assembly, system assembly, just across the border. The most sophisticated components are done in Hong Kong, or Taiwan, Korea, and Singapore. Now that China has a dependable manufacturing base, new policy are being put in place, just like Taiwan, Korea, and Singapore Governments have been doing for many years, in "focusing to get efficiency.6 The difference is that China has a large domestic market to use as leverage.

5 YEAR PLAN

For China, in the 1996 to 2000 5-year plan, their top priorities are: 1, reinvigorate her agriculture, 2, development of some of the more interior poor parts of China, 3, inflation control, 4, reform some more of the state-owned enterprises by learning from the foreign companies, and 5, joint ventures operating in China. Their 5-year plan for the electronic industry is to focus on strategic development in semiconductors, communications, transportation, distribution systems, channels, software, audio/video, and medical. There 3 gold projects: golden bridge, golden card, and golden tax, the last one being more important, as quite a lot of people try to not pay tax, in China. So they want to automate it, and computerize it. In the ninth Chi, 5-year plan for China, for the electronic industry, their goal by year 2000 is to achieve an annual growth rate from now to year 2000 at about 20% plus. The total electronic industry will reach about 75 billion dollars. As a comparison, last years Taiwan IT industry production was about 20 billion dollars.

They would like to export about 25 billion dollars out of the 75 billion dollar production, so the remaining 50 billion dollars translate to end user sales about 63 billion dollar domestically. What does all this number really mean? What it really mean is that at least 63 billion dollars worth of electronic end products, or semiconductors, they will not be importing. They will be trying to build it themselves, either through 100% foreign-owned company, through J/V, or through China domestic enterprises. So the import of finished end-products from other countries, let's say Japan, will be much reduced in the future. Since end-production, will be in China, semiconductor consumption will, of course, also shift there. I want to share with you our experience in Motorola, in China. In the Motorola factories in Tianjin, GSM and soon CDMA digital cellular phones are being manufactured. I can tell you that Motorola makes some of the smallest and most sophisticated cell phones in the world, and there's no problem making them in China.

What's the scenario for the China electronic industry? Foreign investment is being encouraged, for certain leading edge technology areas, like semiconductor and other designated sectors. They have a preferential policy

for these sectors. For example, early pioneers can have 100% foreign ownership and still have access to China domestic market, and, if you don't want to invest 100% yourself, let's say for advanced integrate circuit manufacturing, China will be willing to put in money and operate like foundry. However, investing in mature industries, like color TV, then there will be an export requirement, while you can sell domestically. The more mature the segment, the higher the export percentage for new factories built to serve those mature segments. So, for the mature product, if you want to access the China domestic market, you also have to export, so your semiconductor consumption's not just for product built for China consumption, but also for those that you would export. Now this will have impact to countries like Malaysia, and Thailand, because Malaysia, Thailand, do not have a big domestic market as compared to China, and so there will be manufacturing resizing going on in 5 to 10 years.

Continuing with the Chinese electronic scenario: the government will also try to support the creation of large conglomerate groups. This is like the Korean model. Basically, China government wants to help to create or merge something like 30 large conglomerate groups with about 10 billion RMB annual sales by the year 2000. China will also make capital investments, and the foreign companies are expected to contribute some technology, capital, and job opportunity. There is a word of caution. You really have to know China, China's culture, and the negotiating techniques, and build a strong relationship before you can really achieve the ideal compliment.

MOTOROLA IN CHINA

Where is Motorola's semiconductor investment in China? Remember, by middle of next year, Hong Kong will be part of China In Tianjin, the northern part of China, our assembly and test facility alone is producing about 500 million integrated circuits a year. This includes microcontrollers, so it's not simple logic or analog devices at all, and the facility actually reached 6 sigma quality level in less than 1 year. Why? Because even a technician on the production line has bachelor degree. No other country has every technician with a bachelor degree. So I hope that this gives a concise overview of Asia Pacific and China, even though this year is a recession year for the semiconductor industry, again recall that most of the products except for DRAMs are still growing, and that is a tremendous market possibility.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #18: What Do the Users of Technology Say?

Scott Winkler
Vice President and Research Director, Platforms and Operation Software Technology, Gartner Group

Agenda: CIO Role, Recentralizing, Groupware, Year 2000 Problem, Intranet Phenomenon

I'd like to shift the conference focus from the supply side to the demand side, and talk to you about the users of technology. There are two types of users with whom we deal at Gartner Group, the users themselves fall into the category of end users in the business units of organizations, and then the Chief Information Officers, the so-called CIOs, who are centralized buyers or standards setters.

CIO ROLE

The Chief Information Officer of large to medium sized organizations is in a squeeze. They are being asked to take on more responsibility, and sometimes with dramatically less authority. The CIOs are also running scared. We see a trend, which is not working in their favor: the half life of a CIO these days has decreased to about 18 months. The turnover is very high. Their number 1 goal, is to enable their businesses to get things done. To absorb new technology is not anywhere near their number 1 goal, and in many cases absorbing new technology is the last thing that they would like to do.

I'd like to cover 5 points about what they've told us. What they want to say to us is "Slow it down". They want us to slow down the pace of technology, but they don't really mean it. So let's explore what they're saying, and what they mean by it. They'll talk about speed, saying not so fast, and deal in technological obsolescence. They'll speak about the users. The CIO has end-users who, during the day, are business users, and during the evenings, and on weekends, are consumers. The CIOs are asking us at Gartner Group to help them understand which technologies are going to give them benefits, they don't want to adopt those technologies that are going to fizzle out or become fads. And they want to know why the Internet is a technology enabler for them, and why it is not a productivity drain. What they see too much today is a lack of productivity associated with the Internet, as opposed to a boost.

So let's start with the speed of change. CIOs want release schedules to be tuned to business priorities. Receiving a steady stream of technology over a year is much less desirable than receiving one big package of technology on an annual basis. Now, of course, they've heard for years about the up-ensuing, and up-coming technological marvel of things like object-oriented technologies that will allow them to make smooth upgrades as they go. Frankly, they are very skeptical. They do not believe that will ever come to pass. Those technology companies who have reoriented themselves to the business user and said "I get it, and I'm going to give you a big upgrade every year, versus a small upgrade every month", have won the reverence of these users.

Now, the CIO's view of the end user is also something that's in play here. They believe that the users have the money, and therefore they have the power, and therefore their perception is the reality of the day. Five, six, and seven years ago, there was a user/end user revolution. The CIOs lost a dramatic amount of their power, and many were washed away in a major trend. The users believed they could do everything faster, cheaper, more productively, and much more in tune with what they needed to accomplish at their local level, than their large, monolithic, centralized IT infrastructure could deliver for them. In the end, the user organizations found that they took on more than they wanted to: that they were creating their own, small IT departments. They had tremendous organizational, organizational inefficiencies. They did not know how to own or operate their IT, and, frankly, it wasn't their business calling, and within the last 3 years, we have seen the pendulum swing.

RECENTRALIZING

We have seen it swing back to an era of organizational, centralized, authority to some degree, control to a lesser degree, influence to the highest degree. So the new generation CIO is one, who works for the end users, who does what the users want him to do, to operate the systems, make sure they're backed up, make sure they're available 24 hours a day, 7 days a week, and to integrate those systems both internally, and for the rest of the world. But whatever the users desire, the users are going to get. There are very few organizations we have met, less than 5%, where the CIO can make things happen, and make decisions stick, technically, regardless of user input, a very small portion thereof. One thing that the CIOs have told us universally, is that the users are influencing technology, because technology decisions are coming through the consumer channels. Thirty-two bit operating systems for personal computers is very topical, amongst these users, whether they be Windows 95, or Windows NT on the desktop. Still, the vast majority of business users are running PCs with 16 bit Windows operating systems and it will be 2 to 3 years before we see it turning over to being a majority position of 32 bit operating systems in the installed base. However, of those who are moving quickly from Microsoft Windows to Windows 95 or Windows NT, we still find a very small portion of them, with a true

business reason to do so, and who are building a business application on top of the new platform, that exploits the new platform or buying 1 that exploits the new platform. This is fundamentally a situation where the organizations are both staying current as well as responding to user demand, because the users come in, where they run their PCs at home, and what runs on the PCs at home is Windows 95. The two companies, though, that are leading the charge in end user marketing are both Microsoft and Intel: clearly the ones who have the most to gain by such an upgrade. But, it creates a question for the CIO about which of those trends are the ones that are necessary, and which ones are just trendy.

The ones that we see being adopted less consistently are multimedia, and things like Internet at the desktop for business users. In the business space the CIOs are much less aggressive on the acceptance of multimedia for lack of business justification, and so, therefore, it's our expectation that these types of technologies are going to continue to be led at the consumer level, and only creep into the business space when there's an application that justifies them.

The second point here is one that CIOs tell us most often: that skipping technology generations lowers their risks and saves them money. We have found, in the last six months, CIOs once again slowing down their willingness to accept new technologies into their organizations because of a lack of fundamental justification that they can understand. These organizations are becoming much more savvy, and understanding that the first release of anything is to be avoided. The number 1 influencer of these organizations still is the popular press and the trade press, and they continue to read and look at the sensational stories of what doesn't work, and be less influenced by those stories of what does work.

GROUPWARE

The one area of the most heightened interest today is the so-called area of groupware. For some time there were organizations adopting groupware strategies, which 3 years ago meant they were adopting Lotus Notes. The most common reason that Notes was adopted, was because everyone else was doing it. Some who adopted it, and paid a fairly large sum, not only in the software license fees, but of upgrades to their Local Area Network infrastructure, and upgrades to their personal computer infrastructures, then turned around and asked themselves just 6 or 9 months ago "Did I go in the wrong direction, because of the explosion of Internet and the intranets that are available for similar types of activities?" We separate those users into generally 2 camps: those who had a business application for which Notes was the right answer, and those organizations are doing fabulously for the most part. Alternately, those organizations who tossed in the technology because it was trendy didn't do much with it, other than using it for bulletin boards, and for some casual conversation, have found that they could have gotten away a lot cheaper if they'd not reacted so quickly.

Now, the big question of the days revolves the Internet, and intranets, and in many ways, the extraordinary explosion of Internet and intranet news and technology has been negative for a technology adoption. It has slowed people down dramatically. Many existing plans of CIOs have been altered, have been slowed down, have been dropped, and have been changed, because of the emergence of Internet. A lot of money that was going to be targeted for solving some business problems is now being retargeted to solving the infrastructural issues for Internet and intranets in large organizations.

YEAR 2000 PROBLEM

However, a higher priority still remains: the worst computer virus of all time, and that's the year 2000 problem. As we speak, to CIOs, they are now understanding the magnitude of the problem. The result is so profound, the year 2000 problem is so enormous, the spurious results, system crashes and unavailabilities that will occur in many businesses and, and organizations are so significant that there is nothing that can have a larger priority. This is going to slow down purchases in other areas. So I had one CIO tell me he used the year 2000 as a catalyst: an opportunity to visit the highest levels in the corporation, and the Boards of Directors, and cry "Fire. Something bad's going to happen here, if you don't fund something new, and some, fund something that's going to fix this problem", and Oh, by the way, he tucked the funding for the new network infrastructure in the year 2000.

Now, finally, there are two points to be made. When new technology comes along, this causes pause, and re-evaluation of what's going on. In the end though, what it does is, it cause uncertainly and delay, and what's necessary to avoid those uncertainties and delays is to provide more of a continuity, as opposed to a discontinuity. I'll go back to my group-ware example. There are many organizations in the world who are all over the place, who are global and worldwide, and are having an extraordinarily difficult time running meetings, doing data interchange, doing knowledge interchange, for whom the concept of groupware is an extraordinarily clear value. They know what they're going to accomplish; it is very easy for them to see it, and then they reorient their companies to be able to take advantage of the technology itself. I'll also point to another provider of technology, at one of the higher levels in this chain: at the application level, and that's, in the manufacturing space, and process control space for SAP of Germany, and their R3 product. Once again, a product that costs a fortune: many, many

millions of dollars of implementation to go into an SAP R3 project. However, the clarity of the value to some organizations is so precise. It is so clear what they're going to get, from being able to run their businesses more efficiently, and to be able to deal in a process of new manufacturing, that they're willing to spend anything to get there quickly.

INTRANET PHENOMENON

Internally, the intranet phenomenon is one that is information dissemination oriented, and you see a tremendous investment today, by organizations, who recognize, that if they have something to say to all of their employees, the easiest way to say it to them all, is to publish it on the internal intranet private home pages of departments, and corporations, and organizations. This is a very powerful phenomenon. It substitutes a very simple and clean methodology, the home page, for a very difficult problem, internal communications, and so we expect the vast majority of these organizations to take advantage of that simple and easy method for promoting information throughout their organizations.

We also expect them to take a big step backwards after that and say, "Okay, how else might I use this?" and not be so aggressive in assuming that their entire IT infrastructure is going to be replaced by intranet technologies. There are some interesting promises, platform independence, productivity, etc., but we would not expect CIOs, from what we've learned from them over the years, to be very excited about exchanging the technology they have today for something new and different, and if they going to get somewhere from here, it's going to be slowly and gradually, as opposed to quickly and abruptly.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #19: Mainstream Multimedia: Which Long Distance Approach Will Win?

Nathan Brookwood, Moderator
Principal Analyst, Semiconductor Application Markets Group, Semiconductors Worldwide, Dataquest

Wes Patterson
President, Chromatic Research

Prakash Agarwal
President, Co-Founder and CEO, NeoMagic Corp.

Carl Stork
Director, Windows Platform, Microsoft

Robert Maher
Vice President of Engineering, Cyrix

Martin Reynolds
Vice President, PC Technology Program, Computer Systems and Peripherals Worldwide, Dataquest

NATHAN BROOKWOOD, DATAQUEST

As we go forward over the next couple of years, we have recognized a need for incremental processor performance, especially to handle several new applications – multimedia, 3-D, and so forth. There are a lot of different approaches that vendors have taken to providing those extra cycles. What we are going to try to do this afternoon is sort out which of those approaches might have certain advantages in particular environments, and which of them might actually over time be more or less useful. Compounding this is the fact that Intel has gone out and told the world that MMX and AGP are going to solve all of their problems. The balance sheet for MMX: it brings several advantages over the alternatives that we'll talk about later in the panel, including what I would call "ubiquity," that is a common architecture that everybody can count on. So it's a common target for ISVs to develop and incorporate into new software packages. The disadvantage is that it is a mediocre solution. It's a compromise, there are bandwidth issues, there are data size issues, and so forth, that keep this from being a superb solution across the price performance spectrum. And in general we feel that it will be better for low-end products, although it's going to be introduced initially in high-end products. Some of those products will undoubtedly fit very well with MMX. Others will basically still be too slow, and will create opportunities for external hardware accelerators and therefore, opportunities for media processors, and PGA accelerators, and so forth, going forward.

CARL STORK, MICROSOFT

Multimedia is becoming an expected part of the PC platform. Over time, PCs have become much more interactive. Another trend that's happening is, that in the consumer space, more and more media are becoming digital. That started with audio CDs and the trend is clearly continuing with devices like DVD, DSS broadcast, and DVC (which stands for Digital Video Cassette) camcorders and cameras that use the 1394 interconnect. We're on the verge of a lot more digital multimedia in the consumer electronics space. The IEEE 1394 standard is a very high speed digital pipe, that in today's version goes up to about 400 megabits per second and there is work on extending that above a gigabit per second. That kind of bandwidth is going to be needed to get higher quality audio and video.

For Microsoft, mulitmedia really fits into four major groupings: 1, the DirectX, APIs and driver interfaces, which provide relatively low level abstraction of the multimedia capabilities; 2, Open GL, which is a high-level 3-D modeling language; 3, Active Movie; and 4, ActiveX animation, which deal with media streams, and then some research investments that have had the code name of Talisman, all built around the Windows base.

So, the question that was asked was: Which approach will win? We think that if ISVs select a certain approach and write applications that are dependent on a certain approach, well that will almost certainly determine which approach wins. What ISVs really want is a common platform. Lastly, ISVs don't really want to have to place a bet among the different approaches. So it's not that likely that you are going to find most ISVs writing directly to something like a media processor instruction set, or writing directly to something like MMX. In most cases they'll be working through libraries and other software packages that actually implement functions. Then ultimately, it will be

up to customers to decide what combination of hardware capabilities, price, and so on, sell the most.

ROBERT MAHER, CYRIX CORPORATION

In terms of MMX, the advantages it gives, I really think it does provide an added benefit for the PC platform. Number one, it provides a baseline capability for the PC to do some multimedia applications. Without MMX on some of the next generation processors that are going to coming out in 1997, we would not be able to do MPEG-2. The largest bandwidth, the biggest bus on the personal computer is the bus that interfaces to the processor. There are issues with latency, which is a big problem, but we've solved that, for instance, with our GX processor, where we integrated the memory controller. With that memory controller onboard we have bandwidth as good as 3-D graphic cards do. The bandwidth issues that you see will be alleviated with some new architectural enhancements. There will be new media processing capable engines, added to the processors to address that.

The CPUs today are typically 6 to 8 million transistors. Over time that is going to grow to huge numbers, and the frequency is going to go up, and that's just going to give us more capability to address, do multimedia processing, as well as have cycles left over to do other things. If an application or number of applications outpace what a CPU can do, such as real time 3D, then there's a real need for a media processor. In the 3-D arena, there is clearly an insatiable appetite for more processing cycles in the rendering stage, the unit, or the media processing capability will be in a separate unit, external to the processor.

WES PATTERSON, CHROMATIC RESEARCH COMPANY

The thing that's important for the opportunity we're discussing here is that this change is in the function of the PC, from being a computer to a source of entertainment and communications. In my experience, there's really no precedent for this. The computer industry has evolved using fundamentally the same data types. When we move to entertainment, there's a new kind of data, and that makes newer architectures appropriate, because there are better ways to do computing on video, graphics, and audio data types. Intel recognizes this they see the split in computing demands between conventional computing and their estimates of multimedia demands. If high quality DVD is a reality next year in the market, then the multimedia demands will be very great. I think that there's really no upper bound for multimedia computing requirements because more processing capability translates to better quality. So, we don't think that we are anywhere near a point of saturation. We can see a requirement, in just a few years, for something in excess of 10 thousand MOPS, to solve all these problems with reasonable degrees of concurrency. I think that Nathan did a pretty good job of explaining the pluses and minuses of extending the CPU instruction set relative to multimedia. One that he didn't cover is that some multimedia functions require real time response, and the host side solutions don't really have good access to a real time operating system.

Dedicated peripherals — the conventional way that this is done clearly has an advantage. They're high performance, they can do high concurrency, but they also have the highest cost. I think that shows that there are other bottlenecks in the system The PCI bus can become a bottleneck, drivers can bump into each other and cause conflicts, and the lack of a real time operating system on the host, can also be an issue. Some of you know that media processors are, as the name implies, processors — they're programmable, in our vision they are dedicated to PCs, so they are capable of dealing with graphics, and audio. They're very high performance, they have to be able to deliver multimedia functions concurrently, at very high quality. They are not, at least in the traditional sense of the term, DSPs, although there are a number of DSP-like architectural features. They're optimized for the PC, they work on the PCI bus. They're programmable, so they're not just a collection of multifunction ASICs put on the same piece of silicon. The chip that we've designed was developed to work in cooperation with the X86. A lot of the software that we're writing runs over on the host processor because it's done more efficiently there. The advantages of media processors are that it's the lowest cost solution to deliver the full range of multimedia functions. Because they are a software-based solution, we can also do a fair amount of load balancing between what takes place on the media processor, and what takes place over on the host. If the host is MMX equipped, then we can use those resources to further improve the concurrency or the quality. The biggest issues for media processors are the same ones that affect any new technology, general skepticism of anything that's this new. There are projections now for the size of the media processor market to be about 9 million units next year, growing to over 55 million by the year 2000. We're the first to market, but we're not going to have this market to ourselves. NEC, Phillips, and Samsung have all announced products in this market space. In summary, we think that media processors, working together with the host CPUs, are going to deliver the best level of multimedia performance, at the right cost point.

PRAKASH AGARWAL, NEOMAGIC

In my opinion, multimedia is not application, it's a combination of the following technologies. It combines text, graphics, video, and audio. And if you look at the application of these combinations of technologies, presentations, training, entertainment, and education, what's really important to notice here is, they all require portability. So which solution will win? The one which is simple, and solves the portability problem. Portable computers have not offered as much performance or features as desktops. Their battery life is not as good as needed. Portable computers need to do anything which can be done with a desktop computer. So, as that starts happening, you'll start seeing multimedia become really interesting. I do not believe, as multimedia functionality gets complicated, that a CPU alone would be able to do that. The reason a lot of people have problems integrating graphic, video, audio, and 3-D is because it's being offered by different vendors, different software drivers. Once you start integrating them together, whether it's a multimedia processor, or multimedia accelerator, you are solving that simplicity problem. Embedded DRAM technology, which NeoMagic has pioneered, does offer performance, and the reason it does offer performance because biggest problem you have dealing with the multimedia applications is memory bandwidth. In our experience, embedded DRAM technology is the only semiconductor technology which can offer you all those benefits at the same time. If you look at performance, a comparable solution has been 32 bits wide or 64 bits wide. NeoMagic, MagicGraph,— are 128 bits wide, which gives anywhere from 45% to 80% higher performance. A comparable power solution takes 2 watts of power, ours is less than 400 miliwatts. At the system level, that translates into one hour to two hours extra battery life. Form factor — five chips versus one chip. Which long distance approach will win? Multimedia accelerators based on embedded DRAM technology.

MARTIN REYNOLDS, DATAQUEST

Everybody wants to know when the PC market is going to slow down. For 1995, 18% of all computers sold were portables. Those computers go primarily into the business market, they don't go into the home buyers. What that leaves us, in business, is 49% of all computers were desktops, sold into the business environment. The balance therefore, is 33% of all computers sold to the home. Business buyers, when the economy goes a little sour, don't back away from buying PCs. They like the productivity, the benefits they bring, and indeed, the PC market has been fairly recession-resistant over the last few years. We know that with home buyers, if they feel insecure about their future, when it comes to Christmas, it's not PCs, its ties and slippers again. So, if the economy turns down, we can expect to see the PC market take a hit.

I would like to draw your attention to the Universal Serial Bus. This is a PC technology, any of you designing devices or semiconductors for communication, where you need a simple serial interface that can carry high speed data need to look very hard at USB. It's going to be very cost effective and ubiquitous within the next few years. We're not that aggressive on the $500 PC. Users are very much in control. If you, as an IT manager, deploy Internet computers around the office that don't have the features these people expect, for example, from their home computers, six months later, you'll go out and you will see PCs purchased from the paper clips and pencils budgets, sitting by the network computers that you bought them. And six months after that, they'll be just PCs and the network computers will be gone, and you will be looking for a new job. So, deploying network computers in business is fraught with risk. For the home users, people say, "Well, if we could give people a $500 computer to take home, and surf the Internet, then we could get all these people connected, without them having to buy an expensive PC." That's another flawed argument because most people that have a PC at home today aren't connected to the Internet. Although there are lots of them, it's still a relatively low penetration. So, the assumption that we can get more people on the Internet, with an inexpensive device, is unnecessary and probably wrong. We in the PC industry think the Internet is wonderful. It's easy for us think that everybody wants this, when in fact they don't. Related to multimedia is what I call the upside-down PC. This is a device that we see having more multimedia silicon, if you like, than processor silicon. An Intel-type processor, with a multimedia processor from Chromatic, or Samsung, or Philips, that drives things aimed at entertainment and not productivity. So, HDTV, we think, would be a function of this kind of box. DVD, games, this thing can play the same games that you can play on your big PC, and some limited Internet, but primarily though, this is a device for passive viewing. That means it has got to cost $500 or less. It has to connect to a TV set, and it has to include exotic features, like AC3 sound. We think this could represent the third wave of home computing. This becomes a device like a VCR, that sits in the stereo rack, that drives all these advanced entertainment features. Could be a very, very high volume application, in the next decade. A only couple of points that I'd like to make here is, it's very difficult to compete in 3-D graphics if you don't have a fab. Ultimately, the quality of your 3-D graphics depends on how many, and how fast the transistors are that you can deliver. That depends on how much you can charge for the part, therefore, it's ultimately dependent on your cost. Talisman, Microsoft's new 3-D architecture, it's exotic to watch, it's very compelling. A couple of problems with it, it has five very large chips, a media DSP, a compositor, a polygon object processor, a smart DAC, and a big buffer, 4 megabytes of DRAM. It's

very, very expensive to build today. We believe that a lot of the ideas from Talisman will find their place in the market, but at the moment it's fundamentally a well supported unknown. With Microsoft behind it, that's a lot of pressure. Can MMX displace media processors? Well, we think MMX performance will roughly follow Moore's law — every year and a half or so, it's going double. But we think media processors can stay ahead. The reason for that is, media processors are much easier to scale. When you're processing these video streams, as a processor, you know where you are, you know where you're going, there's no need to have good predictors in there. You know where your next piece of data is coming from, and you know where the next piece of data is going to. So it's relatively easy to crank up the clock speed, and as long as you have the bandwidth, into the media processor, you can deliver scalable performance. If the MMX enhanced X86 processor can do all of these things, then there's no point in having a media processor. But we think 3-D, for example, can take as much as you can throw at it. Video compression is another major challenge, that we don't think that the Intel processors will spend their time best doing over the next few years. And other applications will keep media processors, we think, ahead of the MMX curve. To do speech recognition without an algorithmic breakthrough, you need a bigger processor, bigger hard drive, more memory to make it all work. So we think media processors have a way to go yet. In the long run, we think that the media processors ultimately become the video controller, the Swiss Army knife, if you like, of the PC. We'd expect to see AGP, Intel's high speed bus, delivering high bandwidth for large objects, brought from main memory to the graphics subsystem. Obviously, integrated DACs for audio and videos, this becomes a very simple subsystem, and possibly even, it's the place for 1394. So, I think to sum up, I think in the long run, I see media processors as the dominant solution for multimedia in the PC. Thank you very much.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #20: Sync or Swim: The DRAM Bandwidth Challenge

Jim Handy
Director and Principal Analyst, Semiconductor Memories Program, Semiconductors Worldwide, Dataquest

Neal Margulis
Senior Vice President, Research and Technology, S3 Incorporated

Avo Kanadjian
Vice President of Marketing for Memory Products, Samsung

Tom Dye
Director, Austin Design Center, Chief 3-D Graphics Architect, Cirrus Logic

Dr. Michael Nielsen
Director of Engineering and Chief Engineer, Digital Media Systems, Silicon Graphics

Agenda: Introduction, Synchronous DRAMs, SDRAM and SMA, Memory Architecture and 3D, Criteria Selection for Memory

INTRODUCTION

This panel session is about the need for improved bandwidth in DRAMs and the first question is. what kind of speeds do we really require? Bandwidth for the higher end of what is needed in DRAM this tends to be today: what is needed for graphics, 3D, MPEG video, that sort of stuff? Some needs in DRAMs are very random. You've got things like cache line refills, general CPU accesses and those things that need to have very low latency. On the other hand, you've got other needs that have high bandwidth requirements but aren't really concerned too much about what the latency is — those are things like some graphics operations and video output. Different types of DRAM architectures satisfy different sides of that. Random addresses need very fast first access — streaming that does well for things like video output but there is no such thing as a solution for all kinds of problems. We see a lot of system approaches to getting the bandwidth out of the system that can take advantage of lower costs, lower DRAMs, and we also see more varieties of DRAMs being aimed at these problems.

SYNCHRONOUS DRAMs

The idea of a synchronous DRAM was suggested to us many moons ago by system engineers who wanted to improve performance by having accesses happen during the precharge period so we developed an internally double-banked memory architecture. We have inputs and outputs that are controlled by the master clock and the only thing that isn't synchronized with this whole development is the fact that a lot of the ASIC core sets are not out in the market in order to take advantage of the performance improvements of a synchronous DRAM — with the exception of companies that have control over the development and production of their own chip sets.

In 1996 approximately 10% of Samsung's DRAM production will be synchronous DRAM and by 1998, we anticipate that percentage will increase to 70% and over.

Synchronous DRAM is a revolutionary solution but once it is implemented it will have incremental improvements in performance with such new concepts such as putting in four banks instead of two banks and, of course, with improving the processes and getting higher performance parts altogether. We believe that synchronous DRAMs will definitely be the solution for a lot of the new applications that are coming on line, such as multimedia, multimastering, and AGP and we're ready from a production point of view to transition the market from standard DRAMs to synchronous DRAMs.

SDRAM AND SMA

The industry is moving towards SDRAM for main memory. It's higher performance, you can get single clock bursts and it easier to design with. It is also very well suited for what we call SMA (shared memory architectures). With SMA we refer to an integrated memory subsystem including an integrated controller that controls just one set of system memory.

SMA, by moving the entire frame buffer into main memory, provides a lot of integration, cost and flexibility advantages. The memory can stay in one place, it doesn't need to be bused around the system to different memory subsystems. So especially for multimedia data which tends to be streaming-oriented, there are a lot of performance advantages to dealing with one pool of memory.

Because the graphics controller is integrated into the main memory controller, you can do a lot better job with system memory arbitration and reduced latency. We clearly believe that EDO has another year of really dominating the percentage of systems going out. SGRAM needs to perform at a significantly higher megahertz rate to match

the performance that EDO does, because EDO has lower latency. In the products we bring to market now, we bring EDO version and an SGRAM version and when it comes to our customers, the overwhelming majority are choosing to deploy their systems based on our chips with the faster EDO memories, rather than SGRAM. We do, however, see the path to above 100 MHz requiring synchronous memories but it is just not going to be here for the first half of '97.

MEMORY ARCHITECTURE AND 3D

It's very difficult to have to look into the future when you have a new memory architecture coming down the pipe, or a number of new memory architectures. You know that your design is a year out, and you have to pick the right one because you'll sink if you don't pick the right one. VRAM is really not applicable any more for the mainstream market. There are a few high end niche players that use VRAM for specific applications but, all in all, it is a little too costly for mainstream.

Over the long run, EDO also won't compete with the new memory architectures. EDO is a good burst RAM, it's got the capability of doing fast burst page fetches that are nonsequential which SGRAM and SDRAM don't have, so there are some advantages there but as you bring the frequency of asynchronous memory up above the point the EDO will run, the synchronous memories have an advantage in bandwidth.

The other observation is that SDRAM, as we see it, is good for system memory but it really doesn't compete too well in the mainstream. SGRAM competes much better with its special features, the block clear, and the mask per bit functionality allows a simple lower cost 3D accelerator to work fairly well. There will be a period of time where the system memory evolves from EDO to SDRAM, but then after that, the belief is that the system memory will have to switch to a protocol-based memory that allows a much higher frequency to get the bandwidth — because of the difference between going with more pins and more switching outputs versus less pins and higher frequency. It's our belief that the frequency will win out in that scenario.

SGRAM will continue to evolve, SDRAM will continue to evolve, but manufacturers are going to have to pick up the transmission theories that are required to have lower voltage swings, to be able to run these memories at higher frequencies.

In 3D graphics, triangles are drawn from multiple directions, which means that you have to be able to fetch data in different orders. The faster not wider issue is going to be a trend in memories. Another feature that is good for RAM bus and 3D is the protocol concept because in a protocol you can embed a packet of information and that information then is transferred over to the memory, and the memory then can decode that packet and do special features which everyone would like to be able to see in future versions of memories. There are a lot of functions that can be better placed in the memory. I think as time goes on, the protocol technique allows us to not have to go relay out a board or change a package to add a pin to get another function.

CRITERIA SELECTION FOR MEMORY

One of the first things that we look at, obviously, is the cost/performance ratio which is critical for us. There are certain applications where the cost is more important than performance and vice versa. The second criteria is availability. A lot of our system manufacturer won't take that risk of single source.

Another one is market acceptance and that is very important because that is ultimately going to drive cost. Design and implementation costs are important as well. Certain memory devices that require more design costs and have a longer lead time to market.

Another criteria is future growth path and we believe that a protocol-type memory is the type of memory that will ultimately win in the future. We are typically trying to pick what is going to be the next emerging standard.

There is also the issue of a vendor wanting to collaborate with us because we are normally selecting a DRAM technology before it actually physically exists. Partnering with vendors that are very willing to put in a large amount of investment becomes a very crucial aspect to us.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #21: Packaging Performance Breakthroughs: Is the Industry Ready?

Nader Pakdaman
Principal Industry Analyst, Semiconductor Equipment, Manufacturing, and Materials Program, Semiconductors Worldwide, Dataquest

Igor Khandros
President and CEO, FormFactor Inc.

Barry Lieberman
Ph.D., Engineering Manager, Test Tools Operation, Intel

Ray Bryant
Manager of the Profit Centers, IBM Micro Electronics

R.P. St. Clair
Engineering Manager, Systems Development Engineering, Memory Test Division, Teradyne Inc.

Reed Bowlby
Interconnect Technology Planning Manager, Motorola Semiconductor Products Sector

Agenda: Introduction, Packaging Application Roadmap, The Near Future Outlook, Packaging Performance Breakthroughs, Major Challenges

INTRODUCTION

This session will focus on packaging and test, the capital spending and the equipment market. A panel from different sectors will assist in providing us with an outlook, an understanding of the ground rules of what is happening in packaging, a perspective on what's going on in the memory arena and the impact that memory has had on capital spending and the growth of the market in the past couple of years. We will talk about some alternatives and some of the ways that the bottlenecks are being addressed in packaging and test. Where do we need to go? Where do things need to develop? Who is going to take ownership? Who is going to actually manage to keep the cost/performance where it is required for this market to grow? A three hundred billion dollar market is one thing, but definitely the margins, where the growth is and the performance factors will drive this industry.

PACKAGING APPLICATION ROADMAP

This general packaging application roadmap takes the different types of packaging and actually puts them together with their areas of coverage and what kinds of applications will be driving them. All across the map, as semiconductors go into more different types of applications and different types of ICs, both the demand for lead count and performance are increasing.

The lead count increasing and the lead spacing is actually going down. With such a phenomenal upswing in technology both in terms of the number of leads and the complexities — which has direct impact on cost and direct impact on test — you build the chip and then you hand it over to someone and you have the luxury of test and the afterthought of packaging. What will happen in this realm? Who is going to take ownership and how are we going to manage the industry and the infrastructure for that? The number of pins will be in exponential growth, especially for the high performance All across you see an increase in the number of pins and increasingly complexity.

So what does that mean? Where is the cost and where are the cost centers? where are the bottlenecks and who pays for what? In a very generic sense if you take cents per pin and you multiply by the numbers that you saw in the previous slide sometime in the next decade, we're going to talk about $120 packages, at the very least putting ten dollar semiconductor chips into $20 packages. Someone has to make sure that cost fits not only the performance but the viability of the business. We can do this same thing in test. How are we going to actually manage to go from here to here and then further?

THE NEAR FUTURE OUTLOOK

Clearly there are three major drivers in packaging today. One is the increasing functionality that the SIA roadmap and all of our product menus would show over time. Decreasing cost is a key piece of that.

One thing that is starting to show up as a significant difference is taking place in the way we're interconnecting the die to the package and the package to the next level of assembly. This transition is going to cause some discontinuities that provide an opportunity for any particular provider to either do well or not do well depending on how we manage that change. The SIA roadmap shows increases in power, increases in speed, increases in I/O.

One of the areas which is not focused on as much is what the pitch changes are going to be driving: the pitch of the chip level, the pitch at the substrate demodule level and what that may provide as a cost reduction opportunity — and also what the increased power requirements for a device will force us to do at the package level. This may also force some changes in the way the business is run between the silicon designer, the package provider, and the system menu user who puts this out to the market.

There is a significant proliferation of package types and it certainly isn't clear which few of those may become significant volume drivers in the industry. One of the challenges to the packaging industry is how do we take this list of options which are very ill defined in any specific application and help the silicon designer and the package user at the system level find a solution.

We talk about decreasing package cost while supporting an increase in functionality. Those increases also drive increases in mechanical problems and thermal problems now, as you start to take that package and shrink it down, and try to have the silicon play a more dominant role in what the mechanical aspects of the package will be. It's clear that you have to have a robust package to go through a much wider range of applications and environmental stress than it's ever seen before. One of the drivers that have to be looked at in this cost equation is that the cost per I/O is shrinking.

It doesn't make sense to pass cost around, just ship it from one piece of the package solution to the next. It has to be eliminated, taken out of the system completely. This reduction in package size and increase in functionality is driving significant cost challenges at the board level. In order to put fine pitched devices down in fine pitch packages, we're driving either increased layer counts or tighter lines, tighter spaces, finer drilled holes or photo defined holes at the board level, which is also part of that total cost equation that we have to step up and figure out how to eliminate. The way that this is going to be achieved is that we've got to look at a more collaborative effort between the silicon producer, the designers, the packaging community and the system user.

PACKAGING PERFORMANCE BREAKTHROUGHS

The first primary component of the performance treadmill we've been on in this industry is the fact that the wafer fab people have had so much success scaling silicon technology — but that success has come at a price. That price has been the large capital investment the industry has made in wafer fabrication technology.

What other industry can claim that kind of product enhancement over such as short time?

Let's look at a packaging and interconnect metric as opposed to a silicon driven performance metric.In the ability to drive package density or package interconnect density, we can only claim a linear improvement, as opposed to a logarithmic improvement. As the absolute number of package pins has increased, notice what's happened to the percentage that are devoted to power and ground.

When we look toward the next generation of die, the power distribution problem of supplying clean power to the die is becoming a critical problem. The absolute current that you're supplying and the overall power is increasing because of the transistor density. It would probably not be physically possible to build these parts if it wasn't for the fact that the power per transistor is going down. At the same time the net trend in power and current is up so the challenges of providing clean power to these parts so that they work properly in getting the heat away, becomes a major challenge.

MAJOR CHALLENGES

We face a major challenges as an industry going forward. These problems are possible to fix, but they must be fixed in a way which is not a niche solution. So what do we do about all these things? We've heard about things such as: multichip modules to solve the transit time and the flip chip, other kinds of high density ways of packaging, known good die. If we're going to package die in a multiple configuration known good die is clearly the technology that's required in order to keep the costs down. We have to have the same ability to not add cost as we move through the manufacturing process. Known good die has to solve two problems: it has to solve the burn-in problem, and it also has to be able to make some measurement of speed of the device — or some other method has to be found to bin the device.

There's the new test methodologies to solve the p over t problem and there's the cooling. Those are five technologies that are ripe for exploitation to solve this problem but it has to be done in a manner which is cost effective.

The markets are ready for packaging performance breakthroughs. We need better solutions. The supplier base probably has to elevate effort, and places for improved funding have to be found and a better infrastructure has to be developed, where road maps are being shared and there is a better coordination between the various facets all that have to play together to move to this next step.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

Session #22: 1997/1998 Capacity Status: What Will be Tight and What Won't?

Clark Fuhs
Director & Principal Analyst, Semiconductor Equipment, Manufacturing, and Materials Program, Semiconductors Worldwide, Dataquest

Eberhard Klasse
Vice President, Sales and Marketing, Wacker Siltronic Corporation

Arthur W. Zafiropoulo
Chairman & CEO, Ultratech Stepper Inc.

John Luke
President, TSMC-USA

Evert Wolsheimer
Vice President, Product Technology, Xilinx

Agenda: Introduction, Wafer Capacity, Equipment Forecast, Strategies For Cyclical Markets, Fabless Semiconductors, Overcapacity

INTRODUCTION

This group of panelists addresses infrastructure issues and capacity issues in the semiconductor industry. In terms of what types of devices are being manufactured in the fabs today, power discrete consumes about a quarter of all silicon consumed worldwide in terms of square inches. That's a shocking number to a lot of people. Very low revenue per square inch but a lot of square inches, so a lot of capacity is required in order to feed that particular need.

The majority of capital spending is in leading edge and mainstream products, and then it would migrate and trickle down into some lagging technology areas. In the middle area, the lagging area, is microcontrollers and telecom chips, mixed signal, smart power. These are some of the fastest growing products areas in semiconductors today. An infrastructure change that is going to occur is that the middle area will increase in importance. As capacity trickles down this chain of product migration, there's going to be less to trickle down as time goes on. This has evolved a whole new set of equipment companies that are targeting this lagging and sunset technologies.

Another area of infrastructure that is developing — and this goes across all of the product areas — is the foundry and the fabless model. About 9% of all silicon that's processed goes through a foundry today, and we expect that, in the next 5 years, to grow to about the 15% or 16% level, and ultimately to about 25% or 35% of all production.

WAFER CAPACITY

After growing 26% in area 1995, it looked like wafers would grow another 30% in 1996 but growth came down steadily and we estimate that, by the end of this year, it will have come down to a growth rate of about 12% for all of the silicon. But there is still a solid growth of over 10% for the six inch wafers, and of even over 50% for the 8 inch wafers. Four inch wafers and five inch wafers, however, have come down compared to last year.

For the next years we expect that this pattern will continue, with a growth of the 200 mm slowly going down in as much as these wafers command a higher and higher share of total wafer area.

Wafer shortage should no longer prevail. Basically, the supplies for 1997 were geared at the earlier, higher expectations, so there should not be any major problem in wafer supplies for 1997 and the years to come. I didn't break out epi. It's extremely difficult to make an exact prediction now for epi wafers, with the 64 meg DRAM being partially on epi. But our assumption is that with the major expansions in the industry underway, epi wafers should not be tied.

If there should be any bottleneck at all 1997, it could be poly-silicon but from 1998 on, poly should not be any problem any longer.

The whole situation, however, is rather volatile because we heard from previous presentations that not all the wafer fab capacity in the IC arena, is going to be utilized. There is idle capacity that could quickly be used in case of an upswing and if this should happen, there could be some constraints in supply again.

EQUIPMENT FORECAST

1997 is not a question mark for equipment. It will be available. Regarding book to bill ratio in equipment, we've seen a dramatic change in the past half a year. In February we see the book to bill ratio being the highest in the past number of quarters, about 1.4 to 1. What happened really, is the demise of memory — and it hasn't just been DRAMs, it's been SRAMs and Flash — has really

impacted the rest of the industry. The demand issues are still in place. We see strong demand for the end product in all areas but the capacity has far exceeded the demand. So we see today a serious problem from the equipment side where book to bill ratios have suffered significantly. It's hard to believe these numbers can go much further down, so these numbers will probably settle out around this .75 as we go forward.

We've broken out the three areas which are: front end, test, and assembly. Assembly relates to North America and has the book to bill exceeding 1 to 1. Cycle is a four-letter word and the next go-round in this cycle will be around the year 2001. This industry just hasn't learned, and we've grown over the years.

In the test equipment area, that there's a great separation between the shipments and the bookings. We're taking backlog down. That backlog will continue to be eroded until those lines cross. Some companies report a backlog of one year, some six months. A one year backlog can be very misleading so that you can ship things out two quarters and still be within your window of one year. It's hard to ship things out two quarters when you have a six month backlog so that we still see cancellations, push-outs in the new factories. There's a divergence between bookings and billings indicating people are eating the backlog. So we have yet to see the real true bottom of some equipment companies. We will not see this industry recovering until these two lines cross. It's my feeling this will occur in second to third quarter next year. I think we'll see things recovering by the end of next year, gradually increasing through '98, and then strongly increasing in '99. This should be a great three year run in our industry.

The assembly equipment has done a cross-over in book to bill above one. If you look here at the monthly shipments, it's about 30 million per month. This is mainly U.S. This reflects things such as yield increases, and the slow rate of die-bonders and probers so we're seeing a little bit more excitement here, but I think that this recovery will be short-lived. Then we'll see a book to bill again below 1 to 1, until the full recovery occurs.

Looking at the front-end, which is the major section of our entire industry, we see rates dropping from a maximum of about 1.1 billion per month to today at about 700 million in bookings. I think we'll see companies look at a sharp decrease in bookings going forward. I'm projecting that these numbers will be about half of what they were at their peak. So we're getting closer to that point, so downside is far less than what the upside potential will be going forward.

STRATEGIES FOR CYCLICAL MARKETS

When I look at running a company, and I look at what you should look at, and look like, as a business today: How should you form your corporation? How should you drive it? What strategies do you put in place for these cyclical markets?

One is you develop advanced technologies so that there's a leading edge to your company. You feed the R&D and preproduction area and that area continues to grow even through a downturn. The second thing is market share. If you have small market share in a downturn, that's a good place to be. You can grow market share in a downturn.

If you're diversified with a core technology, it's extremely important. Having a counter-cyclical strategy in diversification is very important, and the other part is retrofitting older factories. People still spend money in a downturn. It doesn't go to zero. They look at their older factories more carefully in a downturn. By having a strategy in your business of counter-cyclicality, it will prevent serious cyclicality within your business, so you can manage your people more effectively.

The other thing is to be the low-cost producer. In bad times, people still spend money but they look more carefully how they spend it. As we grow our industry, and our businesses, we've got to be more creative on our product strategy, on our pricing, and our financial packages.

FABLESS SEMICONDUCTORS

There are some questions about what's going to happen to the foundry business. The data we're showing here says that out through 1988 it's a $240 billion industry growth, with sales growing at a compounded annual rate of 20%. How is this going to happen?

If you take a look at what fuels our business, it's the number of fabless semiconductor organizations coming on, also vertically integrated people coming to foundries for additional incremental capacity. Shortening product life cycles in the market drive more and more complex devices.

If you get a foundry that can offer you the advanced technologies and a path to migrate down the technology curve on future size, you can ramp up pretty quickly for new designs and hit the market windows as they open. Another thing a state of the art foundry can do is provide technology that's not resident in a company and more and more of device functions are incorporating analog functions on the chip itself. That implies a whole different kind of a technology in fab.

It also allows a customer to focus energies on new designs. Certainly a preservation of capital, when you don't belly up to the bar for a billion plus dollars. For a vertically-integrated company, it's easy to augment existing capacity by going off to a foundry.

One other thing we've seen in the last 6 months or a year, is the advent of what I'll call third party design houses. We've seen people like Cadence and Mentor getting into the business, not only supplying design tools but going to offer design services. A chip user can now take a net list to one of these design houses, have the design house spit out a database tape and now that system house can come directly to a foundry with his own custom-designed devices. This is one of the phenomenons that are just starting. Right now probably 90% of our customers are semiconductor suppliers but we're going to see an advent of system companies coming directly into a foundry because of this further decentralization of the industry.

OVERCAPACITY

During this current over-capacity situation, there is an excellent opportunity for some of the subcontractors to differentiate themselves from other companies by offering great cycle times, great yields, great service and great pricing. They can start taking over managing of die banks for fabless companies. They can enhance their engineering support level. It's key that the foundry suppliers realize that the way they treat the companies during the tough times will have an impact on how they are looked at in the over-capacity situations.

Note: Please refer to the companion "Complete Conference Transcript" for the full text of this session.

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