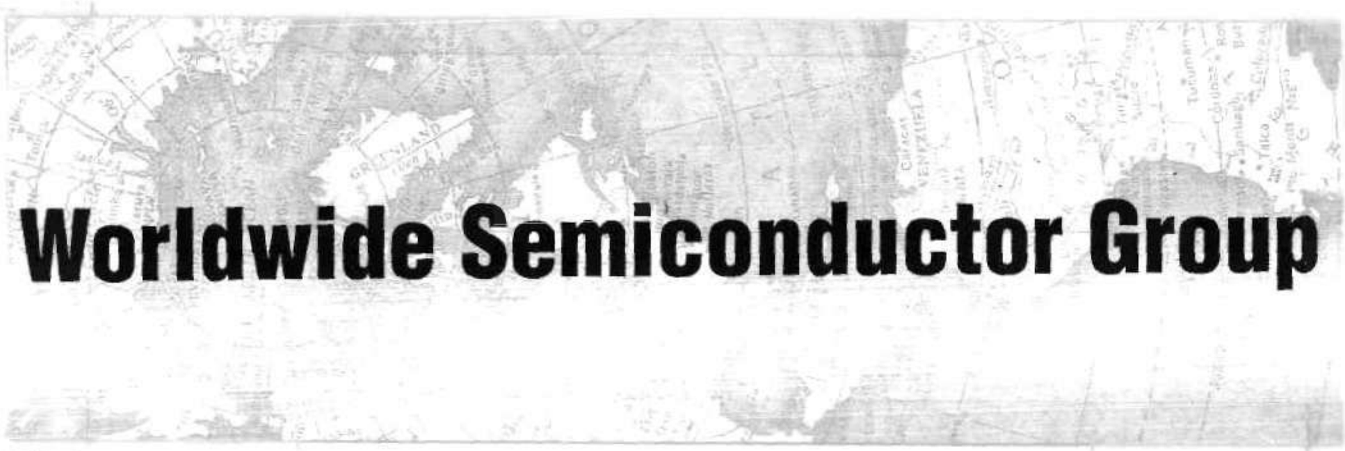
SEMICONDUCTORS '95

The Building Blocks of a New World Order

134

Conference Transcript



Worldwide Semiconductor Group

October 12-14, 1995
Marriott Desert Springs
Palm Desert, California

Dataquest

a company of
The Dun & Bradstreet Corporation

Table of Contents

General Session

Panel Discussion - General Session

New Products

Panel Discussion - Trends and Forecasts

Chapter Twelve: REACHING $300 BILLION BY THE YEAR 2000: WHAT'S IT GOING TO TAKE?

Moderators

Stanley Bruederle
Vice President and Principal Consultant
Dataquest Incorporated

Clark Fuhs
Senior Industry Analyst,
Semiconductor Equipment, Manufacturing
and Materials Service Group
Dataquest Incorporated

Panelists

Wei Shan Lin
President
Tatung Company

Marcus T. Wilson
Vice President and General Manager, Semiconductor
Products Group

Intel

James J. Kim
Chairman of the Board
AMKOR/Anam Group

Dr. David N.K. Wang
Senior Vice President, Worldwide Business Operations
Applied Materials

Roger D. McDaniel
Chief Executive Officer
MEMC Electronic Materials

General Session

Chapter Seventeen: THE IMPACT OF INTERACTIVE MULTIMEDIA ON SYSTEMS AND SEMICONDUCTORS

Moderator
Dr. Dan Klesken
Managing Director, Senior Semiconductor Analyst
Roberts, Stephens & Company

Panelists
Rob Enderle
Senior Industry Analyst
Client/Server Software, Online, Multimedia, and Software Group
Dataquest Incorporated

Jim Hood
Senior Consultant
Consulting Services Group
Dataquest Incorporated

Bruce Ryon
Director and Principal Analyst
Online, Multimedia, and Software Group
Dataquest Incorporated

Allen Wiener
Director and Principal Analyst
Online Strategies Service, Online, Multimedia and Software Group
Dataquest Incorporated

Chapter Twenty: THE INSIDE STORY ON NEW D-RAM ARCHITECTURES

<u>Moderator</u>
Jim Handy
Director and Principal Analyst
Semiconductor Memories Group
Dataquest Incorporated

<u>Panelists</u>
Hans Wiggers
Senior Memory Systems Engineer
Hewlett Packard Company

Paul Baker
Director of CPU Engineering
Apple Computer

Jodie Hughes
Vice President of New Business Development
Western Digital Corporation

Max Bouknecht
Manager
Server Systems Development
IBM

Dipankar Bhattacharya
Principal Engineer
Core Logic Business Unit
Opti Inc.

Panel Discussion - Applications

Chapter Twenty-two: HOW TO SUCCEED IN THE MULTIMEDIA CONSUMER SYSTEMS MARKETPLACE

Moderator
Greg Sheppard
Director and Principal Analyst
Semiconductor Applications Markets
Dataquest Incorporated

Panelists
Kazuaki Mayumi
Director Applications Labs
Matsushita Electronics Corporation

Dr. Takashi Kubota
Director, Senior Chief Engineer
Consumer Products and Information
Media Systems
Hitachi

Kenji Hori
President and Chief Technology Officer
Research Laboratories
Sony Corporation of America

Dr. Klaus Vokholz
Senior Director
Corporate Planning and Strategy
Philips Electronics

Note: The contents of this document are based on a verbatim transcription of tapes from the conference proceedings including: speeches, audience participation, and panel discussions. A "best effort" was made to ensure the accuracy of names, acronyms, slang words and company names prior to the printing of the document.

Chapter One: INTRODUCTION

Gene Norrett
Vice President and Director, Worldwide Semiconductor Group
Dataquest Incorporated

Good morning ladies and gentlemen. Welcome to Dataquest's 21st Annual Semiconductor Conference. It is a real pleasure to be with you here again, back at what is getting to be our home here in the desert in the month of October at the fabulous Marriott Desert Springs Hotel.

We really appreciate your support of this conference and your support of our company over the last 20+ years, and we look forward to giving you the very best service that we can at these conferences as well as throughout the year with our subscription services and consulting.

The theme of this conference is Semiconductors, the Building Blocks of a New World Order. We chose this theme today because killer chips are re-defining the role of technology in society. At the heart of today's worldwide digital revolution is the amazing versatile semiconductor. Killer chips - as we call them - are everywhere. They are in cellular devices. They are driving the Internet E-money, sneakers, in electronic toilets, talking cameras, talking picture frames and in greeting cards.

Leading edge PC', which have as much as 40% semiconductor content, are creating the multimedia lifestyle for us, as well as for our children. They haven't stopped yet. As chip manufacturers move from .35 to .25 micron geometries in the next five years, their factories will crank out over 400 billion semiconductor devices, or 70 for every person on the face of the globe, with the leading edge devices having as much as 12 million transistors.

To put this in perspective, today we have about 5.5 million transistors on half micron geometry devices. Re-inventing the way society works and plays, semiconductors are in the third year of 30+% growth, with backlogs and capacities maxed out.

Will it last? We hope that over the next two days the experts will provide a real insight into this question, as well as many other questions that are on your mind today.

This year's conference we will examine this theme, building blocks of a new world order, from a variety of perspectives and presentation styles. You will hear from 13 industry executives give their 30 minute presentations on their perspective about the dramatic future events in on-line and wireless services, computer systems, software as well as semiconductors; and most importantly, what they will mean to you.

We also have eight fireside panel discussions, featuring 40 of the industry's brightest minds. These people will tackle the key issues facing the electronic industries today. These subjects range from what will it take in the way of people resources to reach $300 billion dollars and maybe more, to the impact of multimedia on systems and chips, to the inside story on the new D-RAM architectures. These very provocative sessions will be led by eight of our top analysts at Dataquest, and they will be also augmented with a guest moderator, Dan Klesken, a partner with Roberts & Stephens. He will be tackling the panel on Multimedia's Impact on Systems and Chips. I thank Dan for taking the time out of his very busy schedule to join us here.

We hope that this conference will exceed your expectations, and will provide you with the right information to make critical technology and strategy decisions for the future.

For our formal sessions we will be meeting in the grand ballroom , this morning, as well as tomorrow morning. For our networking breaks, we will meet out in the west foyer, immediately to your right as you leave this room. Today's morning session will continue to 12:15 p.m., and be followed by a lunch in the adjacent ballroom. After lunch we are going to hear from Ron Elijah, Portfolio Manager for Roberts & Stephens Value Growth Fund.

The afternoon sessions will begin at 2:00 p.m., and we will adjourn at 5:00 p.m. We will have this room split in half, and we will have one track in this room and one track in that room, on that side of the room and take your binders with you to lunch. This evening's session will start at 6:00 p.m. with a cocktail party, and will be followed by a bar-be-que out in the Grove.

After dinner we are going to hear from the sometimes serious - but more often times humorous - comments and observations by Fred Hoar, President and CEO of Miller Shandwick Technologies. We are very pleased to have Fred here.

The dress for tonight is business casual, as we will throughout the conference.

Tomorrow your Master of Ceremonies will be Joe Grenier, Vice President and Director of our Semiconductor Group Device and Applications Program. Saturday we will have our golf tournament. If you haven't signed up and you would like to play, please see a Dataquest staff member.

I am going to call your attention to several other happenings at this conference. In the foyer we have the Dataquest staff, ready to demonstrate our user friendly electronic delivery services. Today approximately 30% of our total client base are making frequent use of these services.

We also have on display our semiconductor reports, which are contained in our various programs. Also you may want to purchase the executive summary from the proceedings of this conference. Because so much of the conference is going to be in a panel discussion - I think it would be quite valuable for you to do that. Please look inside your binders and there is information about that.

In the foyer you will also see a demonstration of our Tear Down program. In this service we are analyzing on a daily basis the manufacturing techniques and the various costs associated with the electronic systems that we are all dealing with: Personal computers, cellular phones, hard disk drives, TV games and so forth.

Also on display will be demonstrations of the technology that will be discussed by four of our industry executives in their 30 minute presentations to be given either this afternoon or tomorrow morning. This is something new that we've added to the conference program this year, and we would like your feedback on what you think of this idea. You can give us that feedback in our conference survey that we have included in your binder. We really do make a lot of use of those surveys to help us plan future conferences, and we really appreciate your comments. Please complete the conference survey and give it to one of the staff members after you leave on Friday afternoon.

We plan to do a drawing at the end of today, and then we will end up selecting a winner and the salesperson will call you and discuss your price.

This page is intentionally left blank

Chapter Two: PRESIDENT'S REMARKS

Judith H. Hamilton
President and CEO
Dataquest

Introduction: I am very proud to introduce Judy Hamilton, President and CEO of Dataquest. Judy is a 24 year veteran of the information technology industry. Prior to Dataquest, she was a Partner and National Director of Market Development for the information technology organization of Ernst & Young. She was responsible for strategic planning, market research, and communications and executing consulting on systems development and systems integrations contracts, both from their New York and Los Angeles offices.

Prior to Ernst & Young, she was Vice President and General Manager of Computer Science Corporation, a Director of Systems Development Corporation, and Founder and Chairman of Data Basics, a company that she sold to Systems Development Corporation.

She serves on many association boards, such as the ITAA, California Chamber of Commerce, San Jose World Forum and Joint Venture Silicon Valley Network. She is a frequent guest speaker throughout the industry.

In 1993, 1994, and 1995, she participated in the very prestigious Aspen Institute's Round Table on the future of information technology. Please welcome Judy Hamilton.

Judith H. Hamilton: Thank you Gene.

We are so glad that you're here at our 21st Semiconductor Conference, and it's really nice to see so many of you back here in Palm Desert. What a year of change it's been since we met last October.

William Manchester wrote a book about medieval Europe called a World Lit Only By Fire. When I read that book, what struck me about it was how static life used to be. A person living in that era grew the same produce with the same tools and the same methods for not just generations, but hundreds of years.

What a Difference a Year Makes!

- **PCs invade the home office**
- **IT goes Hollywood (Dreamworks, etc.)**
- **The Internet and Web enter the mainstream**
- **Windows 95 from the TV to our desktops**
- **Megamergers and breakups**
  - **Sybase—Powersoft**
  - **Seagate—Conner**
  - **AT&T split**
- **P6 (almost . . .)**

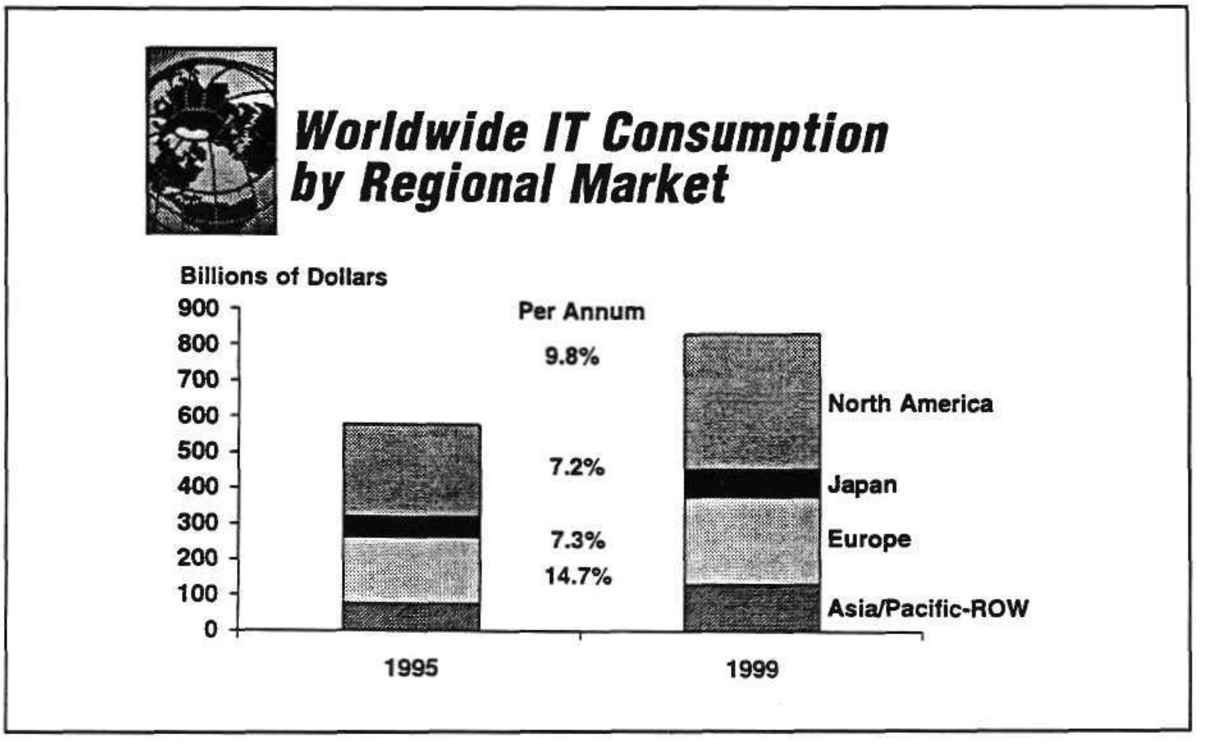
Look at us now. If you look back on 1995, from years hence, I think we'll think of a few things that were significant over this year in information technology in general. One of them is the PC entering the home in a big way. Our surveys show that practically 1/3 of all American homes own at least one PC. I think also we'll look back on this time and see 1995 as the year that Hollywood met Silicon Valley.

The Internet and the World Wide Web have certainly come into their own. In California we have been talking about the Internet for quite some time; but it's been this year that I've seen it go international. I just came back in the last couple weeks from a meeting with the Japanese Software and Services Association, and of the 25 executives there, almost all of them were Internet users and had World Wide Web with their company.

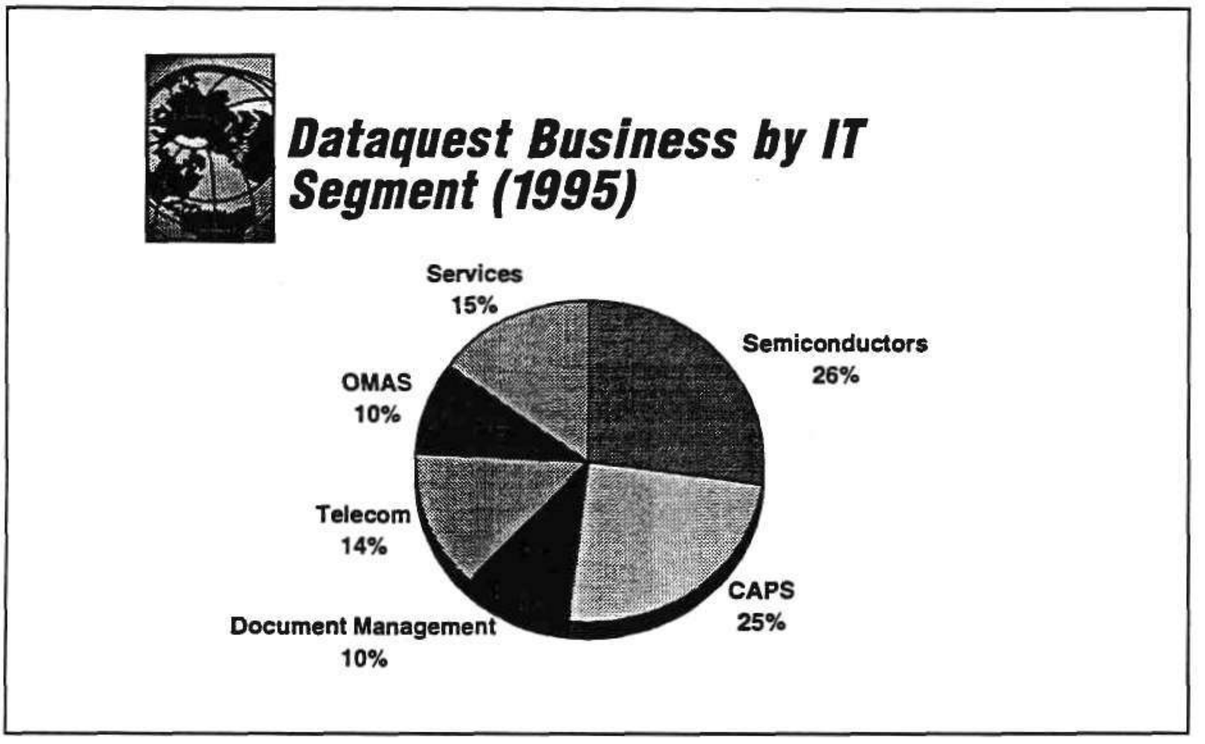
Of course, one of the most significant events this year is all of the hype around the introduction of Windows 95. None of us have seen anything like it.

Finally, we have had many mergers within our industry for a long time. This year was no different: Lotus merged with IBM and of course Seagate and Conner; but maybe we'll remember this year as the beginning of the break up of some really large companies. We have ITT, AT&T and of course EDS spinning out of GM.

There is one thing that doesn't change, and that is the robustness, the vitality, of the information technology industry as a whole. As I did last year, I would like to share with you a few of Dataquest's overall estimates on the growth of the industry and the distribution of it.

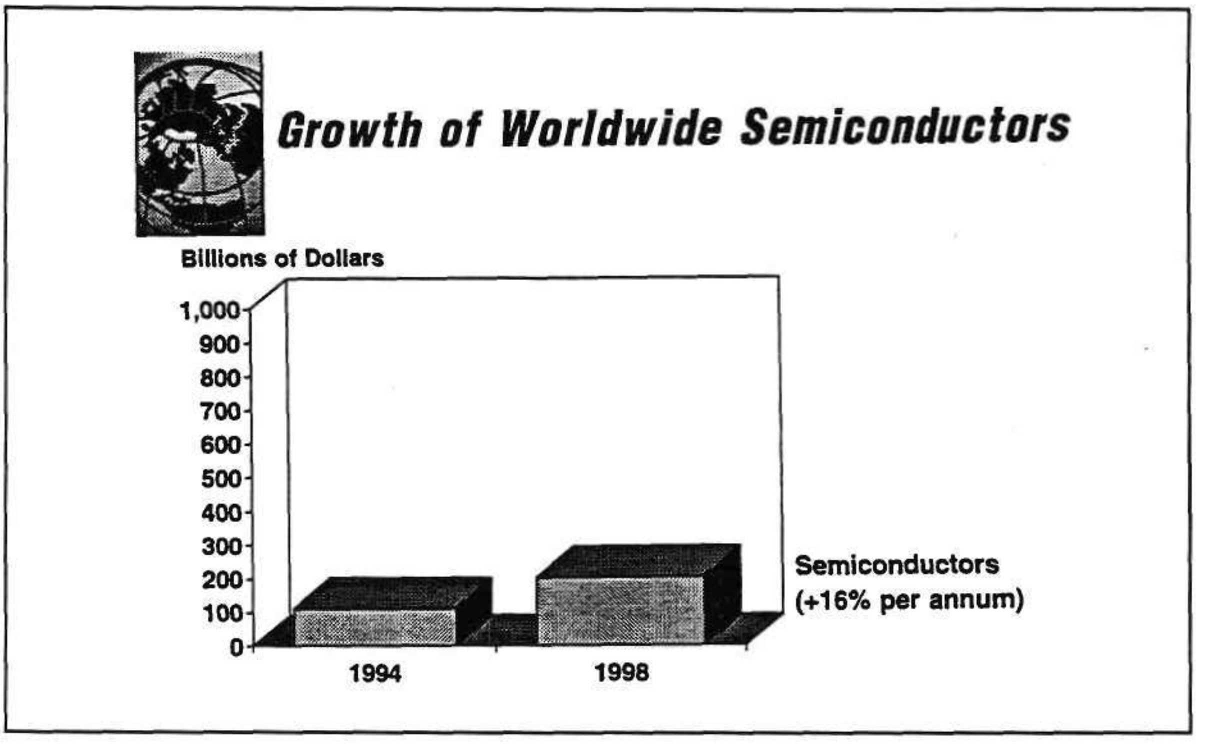


First of all by region: What we see here is regional growth projected by Dataquest over the next four years. You can see that Asia Pacific is still projected to be one the of the highest growth areas, followed by the United States. Dataquest pegs the market for all of information technology - with semiconductors folded in so they're not counted twice - at about 573 billion for 1995, projected to grow about 10% a year.



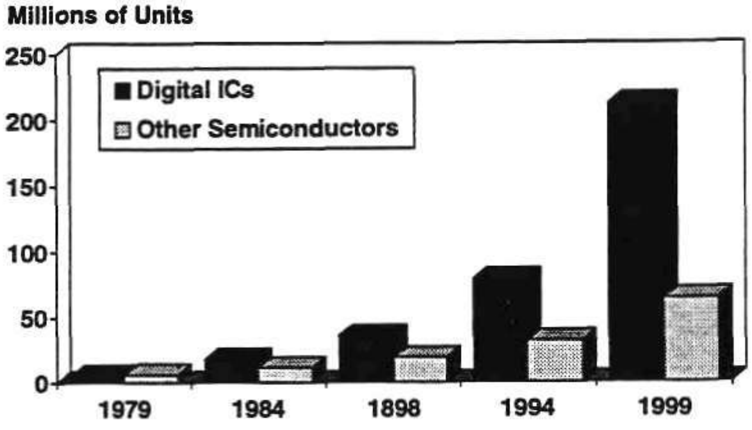
I thought you might be interested to see how Dataquest's business breaks down after seeing this regional distribution. We have about half of our business in the United States, and the other half is about equally divided between Europe and Asia Pacific, including Japan.

If you look at that by segment, you see that the segments are growing unevenly, and that we have services and software still as our highest growth areas. Again, contrasting that to Dataquest, we see that semiconductors are about 26% of our business, which is up a few percentage points from last year. The next largest area is computers and peripherals, and then the rest is divided between the other segments that we follow.

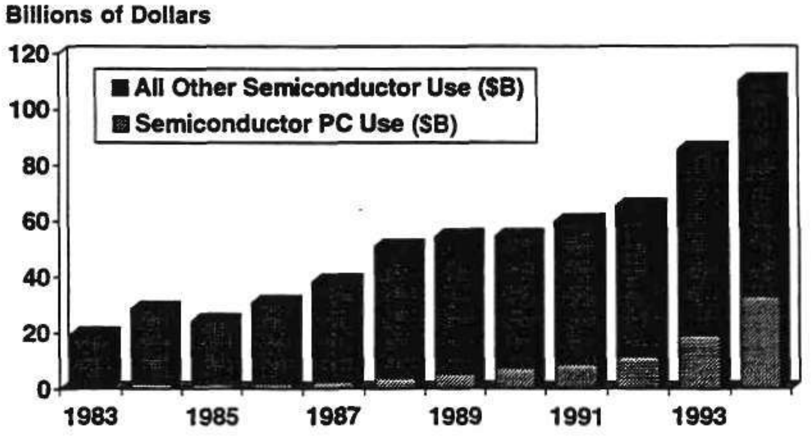


If you look at the overall growth of IT at 10%, and then compare that to the semiconductor growth, which Gene will be giving you much more detail about a little later, you see that semiconductors are even outstripping the overall IT industry. If you project these in view of the economic growth of the overall economy (which Joe Duncan will be talking about), I'd say the people in this room are sitting in a pretty good position.

Digital Drives the Semiconductor Market



Semiconductors and the Personal Computer



The things that fuel that growth are very varied, and they range all the way from multimedia to the automotive industry. These are the topics that we will be discussing over the next two days, and I would like to say we are very happy to have you here. I hope you find these two days not only informative and interesting, but that you have fun as well.

Thank you very much.

This page is intentionally left blank

Chapter Three: THE STATE OF THE ECONOMY: A TWO-YEAR WORLDWIDE FORECAST

Joseph W. Duncan
Vice President, Corporate Economist and Chief Statistician
Dun & Bradstreet Corporation

Introduction: Joe is well known to this audience, as many of you are repeat attendees. On your forms that you give us back - your survey forms - one thing keeps coming back loud and clear. You really like to have the big picture. Joe - as far as I'm concerned - does this the best of any of the economists throughout the world.

Joe joined Dun & Bradstreet Corporation in January of 1982, and serves as the Corporate Economist and Chief Statistician. He was elected an Officer of the company in 1986, and became Vice President in 1989.

Mr. Duncan has published over 100 technical articles, and is a co-author of Statistics for the 21st Century, a book addressing the needs for improving a statistical information base for public and private decision making.

Joe is a member of many associations, and he received the International Statistical Institute's Metal for Outstanding Leadership. Joe has a BSEE from case, an MBA from Harvard and a Ph.D. from Ohio State.

Joe is going to give us his view of the state of the world economy. Please welcome Joe Duncan.

Joseph W. Duncan: Gene, it is a pleasure to be here. I always enjoy these conferences because I always learn a lot, particularly about the technology in the world that is surrounding me. Since I try to integrate the technological outlook with the economic outlook, it is very valuable. I learn more here from you probably then you are going to learn from me today.

It is amazing how the issues of this conference are in the headlines. Just this morning's papers all featured, of course, Lotus' former chief executive leaving IBM, which is just symptomatic of bigger issues in IBM. Every day there is a story of re-engineering corporations and re-structuring, as Judy has already pointed out. It shows the dynamic nature of the industry that we are all part of in one way or another.

The Wall Street Journal also had an interesting story today. In the second sectionit says, "Earnings Data Suggests a Gloom is Unwarranted". I rather enjoyed that article for several reasons. Yesterday the Financial Times' main page I saw one headline that was just the opposite, because they were reflecting on the fall in prices of technology stocks and saying that the good times were over and that earnings were going to be bad and that the economy couldn't keep moving forward. If you read the Wall Street Journal article, you know that the current quarter results from corporations are really meeting expectations about the same as they have for the last three quarters. Incidentally, each of the last three quarters we've had the headline that it was over, so we want to hear from our mutual funds friends at this meeting and see what their outlook is. That's their daily business.

The New York Times today also had an important article. Sometimes people don't read inside the business section. But they should as there is always an interesting editorial comment, or an analytical article. Today's feature article was "Why is a Rich Country Down in the Dumps, if it is Down in the Dumps?" It talked about one of my favorite subjects, which is how terrible our data is. It pointed out that the current over-estimate of the CPI is in effect about $70 billion dollars out of the measured income stream, and that's the enumerator that we get to talk about average wage gains.

I don't know if you realize it or not, but in the period of the decade prior to 1993, the latest data from which we have census data, 57% of the new jobs in the U.S. economy were in professional, technical and engineering professions; not hamburger flippers and not minimum wage jobs, but high paying, highly skilled, as well as high technology jobs. 57%! For some reason we ignore this real fact and we hear all of these myths about how poor things are. The result is that these myths feed into this New York Times article.

I've been here before and you know, I'm a fairly optimistic person. I'm going to try to talk about some of the elements that relates to these issues. I really want to start again with the interconnected elements of the global economy, because we are in global competition and we are also in global opportunity.

I am going to use the Dun & Bradstreet Global Business expectations as a unique data source to look at global growth and see what lies ahead, at least for the next couple of years. I'll put some specific numbers on the economic outlook. I'll also give you some warnings about the data that flows from that, because the numbers are going to be changed shortly. Of course at this conference I should focus on the information economy because that is our business, and I will examine this industry and particularly the changing nature of the data about our business and some surprises that are due in December, then try to comment on what it means for each of you.

The interrelated world economy is easy to understand when you are in the southeast U.S.A., where the attention on Mexico is part of your daily experience and what you see and read about. I think it's useful to reflect on what happened in Mexico.

During 1994, the election year, Mexican reserves dropped dramatically. Of course the government didn't report the drop, so it took everybody by a big surprise when the peso was devalued after the election was over, and as you know there was a financial crisis. Salinas has been given a lot of criticism for that. I thought maybe it would be useful to reflect a little bit on some of the history behind the situation.

In the mid 1980's, before Salinas became President, and inflation was nearly 70%. In some years there was 100% inflation in some sectors. There was a recession in Mexico and in the U.S. in 1982/83. Whereas in 1986 as the neighbor to the north was enjoying a boom, there was a recession in Mexico. A lot of difficulty. Of course the peso was under severe pressure.

In 1980, the official rate was 23 pesos for one U.S. dollar. They changed it. They took off two zeros and you put them on the same basis it was a devaluation to 25 old pesos to the dollar by 1990. In other words, the Mexican economy had undergone a great amount of stress and it didn't just all start during the last year of his election.

The economicactivity in Mexico is interesting. They did have a slow down in 1993, but part of that propping up the economy prior to the election gave them very good growth toward the end of the election year. Today, of course, we know that they are in a recession. I talked to people last night about what's the outlook for Mexico, and quite frankly it's not an economic issue in my book, it's a political issue. The PRI has been empowered in the entire post-war period. It's having a hard time sharing power. The current government is under enormous pressure, particularly since the President wasn't the first choice of the party. He is not a party person. What you really want to watch in Mexico are not the economic developments, but rather the political developments.

Trade relations with the U.S. are strained because the devaluation means that U.S. goods are very expensive and this year we are going to have a big deficit with Mexico, adding to the other deficits that we have. Mexico is the unspoken problem in the U.S. deficit in trade with the rest of the world.

Many U.S. companies are moving to Mexico to take advantage of the cheap labor. From Mexico's point of view, they are going to get out of this recession.

The political reform movement is gaining strength. As the facts unfold in Mexico, we have all of the implications for NAFTA; and in my own judgment we are going to have a western hemisphere free trade zone soon.

Here we are, sitting with a very good economy in the United States and struggling with the problems of our neighbor, which will affect our future. That is really the essence of global economy.

Let's turn to the general economic outlook on a global basis; at least look at what the economic facts are.

I am going to do this on the basis of business expectations in selected countries. Dun & Bradstreet has a database of about 39 million businesses around the globe. We do surveys from within that database and have a rather unique study that's been around for a long time called the Business Expectations Survey. This is a unique survey in that it's done the same way in a variety of countries. We are currently publishing results in 15 countries, and we are surveying every quarter leadership in about 14,000 businesses around the world.

This process is very interesting because of a very simple concept, and frequently not fully appreciated by the press. This study began in 1947. I take no credit for this. We designed the study to gain a business point of view about what the outlook is. The survey is extraordinarily simple in concept. We asked business leaders what do you think about your own business? We asked questions like do you expect your sales in the coming quarter to be increased versus a year ago or decreased versus a year ago in the coming quarter. Of course the data from the government comes out three quarters later and tells us what the actual was, but this is a good leading indicator.

Just to illustrate its characteristics: With respect to sales optimism, we calculate an index. The people who expect things to be better minus the people expecting things to be worse. We find that it relates very closely with GPD growth, particularly at turning points. For economists, calling turning points is the most difficult thing to do.

We also ask companies about their plans to hire more workers. We have a terrific correlation with the number of jobs that are calculated for the whole economy as reported by the Bureau of Labor Statistics. In other words, when we add up all of the companies, we find out what the job outlook is in terms of the average. We also ask about price changes, and that correlates very well with the GDP deflator. A new GDP deflator is going to change those - I'll tell you in a minute - but at least until they revise the data it's been a good forecast of that.

Let's start with the U.K. For the U.K., is actually led Europe out the recession. You can see the close correlation with business expectations. We are basically going to see steady growth through the end of 1996, in the U.K., based on where its economy is.

In France: A new election, a new restructuring in their economy. We are probably going to have a declining growth pattern in France, but you can see there has been a pretty good recovery from the European recessions in terms of France.

Just for variety, I thought I would show Germany in a slightly different way. Business expectations in Germany sharply fell when the decision was made to merge East and West Germany. The German economy - which was fundamentally strong - suffered greatly. This chart shows their actual GDP, with the expectations side by side. My forecast for Germany is some weakening, but still a 4% growth by the end of 1996. That's a pretty healthy package. When you put them in the same perspective as the other charts, you can see how those correlate.

Japan, of course, is a special case. We expect Japan to recover from the last two years. I have Japan now beginning a slow recovery. By the end of 1996, they will be up to about 3% growth. Don't forget, a Japanese recession is when growth gets below 4%, so they are still going to be in recession at that point.

If we take this global growth and begin putting it together for the world economy, we don't do surveys in every country and I didn't show you all of the ones we do, we can however talk about growth by region. This just shows the OECD versus the western hemisphere versus Asia. No brand new story there. Clearly Asia has been the growth part of the world.

What is interesting is that Central Europe is beginning to turn around and the former communist block is going to be a plus in world growth.

If we look at European growth overall, this year growth will be strong, but next year, and 1997, will be equally strong. It's a very healthy global environment in terms of our major trading partners, except for Japan.

If we add up all of the countries in the world, including China and the other planned economies, global growth for 1996 and 1997 should be even better then we are seeing today.

In 1991, the global economy was at a virtual standstill. The original numbers showed a global recession. You can see now that we are back up toward four percent growth with 1996 and 1997.

Industrial countries have a lower growth rate. The real growth rate is in the rapidly emerging economies of Asia. Part of that is because of the revolution of the world - as the title of this conference suggests - in terms of the new role of information and cross-border activities in trade.

I like to look at the information industry (of which we are all a part) as having several basic elements. Fundamentally this flow of information that is now going through cheaper telecommunications and computer data exchange is really all built around a very simple concept to get new information, accurate information, to make better business decisions, particularly about a new market, a new supplier, new technology, and what's going on around us. The information industry has really built up around the concept of delivering a service. That is a service that makes for better decisions. If the information is not useable, it has very little value in terms of improving economic growth.

What's dramatic is as the cost of telecommunications has come down and as interest has grown in global trade, cross-border information is really at the crux of this global economic revolution that's occurring, and this new period that we have ahead of us, where the second half of the 1990's is going to see very strong global growth, as most of the rest of the world - except for Africa - begins to participate in this modernization effort that's made possible by new technology.

Of course we all know that telecommunications costs are declining rapidly. I am a boater, and in order to have a cellular phone on a boat that works offshore, today it costs - if you go through COMSAT - about $25,000.00 to get the basic equipment. My son works for a company that is introducing the same technology for $7,000.00, and that's available this year. We will soon see telecommunications costs continue that dramatic drop. That makes this information flow economical and efficient in terms of how to impact on decision making.

I'm going to use some U.S. data, I don't have good world data, but fundamentally our investment at the world level and at the U.S. in high tech equipment is absolutely phenomenal. In 1980, about 20% of high tech capital durable equipment was high tech. Today it's 50%; of course dominated by computers. In 1994, 57% of high tech investment was computers, compared to 15% as recently as 1980. A dramatic new industry has emerged. Prices on a cost effective basis have plunged 88% from 1980 to today for the same computing power. You all know what the chips are doing. When you sit them down on a chart, it's rather dramatic to see the amount of computing power that's surging right around us and making all of these things happen.

One of the things that is emerging from this is that high tech products have messed up the statistics. The government calculates a market basket of goods. 1987 is the current weighting for that. Computers have changed so dramatically since 1987, that the old weights that were being used don't really take into account the substitution effect of what computers are doing. Dataquest points out - for example - that last year in the U.S. household the amount spent on home computers exceeded the amount spent on home televisions. Home televisions are in the CPI. Home computers are not. Home computing, in other words, was not included in the weights. As a result we get a distorted view of the economy.

The government is introducing in December a chain weighted index, which lets the market basket reflect what was purchased during the last period, not some period a number of years ago; in this case over five years.

That's going to change the numbers that you see about the industry that you participate in. Average GDP growth for the whole economy, under the new system, will be pulled down more than half a percentage point. You are someday going to see newspaper headlines about the slow down in growth, that is going to be merely the side effect of a new way to calculate GDP.

More important than that, we are getting much closer to potential GDP growth, as conventionally measured in economic theory, which it says that from a policy perspective there is going to be less concern about an overheating economy and of course there will be a reduction in the rate of inflation because of this adjustment. So there is a reduced inflation effect. As a result of new data, we are going to get a new perspective on our economic system.

Business fixed investment for the high tech stuff, which I just showed you, will become a smaller share of the total, because they will be taking into account more realistic price effects than is presently the case.

To some of you it is going to look like your industry is slowing down. Don't worry. It's not slowing down. It's just being evaluated a little differently by the government statisticians. What's rather interesting to me is because we really don't know how to measure productivity very well. The old productivity numbers were overstated, based on the way the government economists measured it. This helps explain why poor wage growth exists. They leave out the quality impact of all of this new technology. The next revision hopefully will add the quality back in, and we are going to then end up and recognize that we really have a much higher standard of living than our economic statistics tell us. Nevertheless, our business will keep on moving forward until the statisticians get it right. As I say, the politicians will only look at the interest rate impact, so you can look for lower interest rates as a result of this data revision.

What does this mean for you? The information revolution, in my judgment, is just beginning. I know we've been coming to these conferences for a long time, and we've seen the expansion of computers for a long time. The information revolution is just beginning if you take a global perspective. The opportunity to modernize the way we do things around the globe is just so vastly enormous that it's really a great opportunity that despite this fantastic growth of experience, we have many opportunities ahead.

I usually tell audiences that when you have something that is growing faster than the whole, at some point it is going to go to a crash. We are going to talk about the sustainability of the information industry in much of this conference. Clearly there will be some ups and downs in the years ahead. The bottom line is, we are revolutionizing the entire economic structure as a result of this new technology.

Growth in high technology will slow at times, but this should be expected when you are in a high growth area. The industry itself will be huge.

Clearly innovation and change will continue to be rampant. That's the nature of the game. As we make things cheaper and better, they are used more and as a result of that our fundamental technology processes will change throughout the way we do things, from buying things in a grocery store to buying things through electronic delivery and on and on and on. There are things you all know about, but we sometimes take it for granted after it's been around for a couple of years. A couple of years from now people will take the Internet for granted. It is a hot item today. The Internet will be effective two years from now, we just will take it as a given, as opposed to a new idea.

The competition, however, will be global. That makes it tough for us in the United States. We are a high standard of living country, and therefore we are expensive in some areas. We have done very well by using our wits to figure out better ways to do things.

There is a world economic forum based in Geneva that has done a survey of national competitiveness for the last several years, and for each of the last two years, the country ranked as the most competitive global economy has been the United States of America. It's never in newspapers. Nobody ever talks about it, but we continue to prosper at global competition, because our economic system is very effective in adapting to these changes.

I think - this has already been mentioned by Judy - the household has suddenly emerged as a surprise market. Their consumption of this new technology (I think) is just beginning. When we look ahead toward truly digital delivery of information, digital delivery of a television signal, digital delivery of even a phone system through ISDM and other technologies, we are going to change the behavior of households in terms of how they participate in entertainment, how they develop in education. How they react in their neighborhoods and how they become world citizens. It's just an exciting and an enormous opportunity for all of us.

If we think about this in global terms, we are now in a world of global connections. World trade is increasing more than twice world production, because people are sharing products and sharing markets. Information technology is the key to competitiveness in this environment. It's your business, so your success and our country's success will depend upon your doing a good job of targeting customers and alliances. Thank you very much.

Questions and answers:

Question: I'd be interested to hear your view on price elasticity's on computing as these prices drop, as you discussed.

Answer: Price elasticity is normally viewed from the point of view that as you move your price point, what does that do to your market share and role? The case of what we are talking about here is the price point has moved downward so rapidly that that's really been the driver for the entire industry. I think when we look at the advances in technology that are on the horizon, the chips that are on the drawing board, the applications that are already beginning, they all have the same characteristic. It is moving as fast down that cost effectiveness curve, so price elasticity is the underlying feature of why we are allocating money now to home computers versus home televisions. It's a pervasive concept and I think the issue is going to be in the future how various devices derive from this technology and compete with each other. Those will be the more significant price trade off points.

I don't think people are going to argue about is it better to use digital television versus analog television once they're in the same price range. You are going to see a massive replacement of analog televisions. That is in a market that just blows your mind as one item all by itself.

Question: What view about U.S. deficit and the impact on your future forecast outlook?

Answer: Of course when you say U.S. deficit, there are really two deficits that we worry about in the United States; one is our trade deficit.

I've spent a lot of my personal time working on the U.S./Japan trade deficit, and it's a very difficult problem to solve because we have a big appetite for Japanese products and we don't sell a lot of U.S. products in Japan. That is a structural issue.

The deficit that counts in terms of economic forecast is the fiscal deficit. It's interesting to me as I spend time in Washington, people inside the belt way still don't have a view of what happened in the last election when the Republicans took over control of the Congress. Much of the rhetoric in Washington today is not cutting the budget deficit, not hurting programs that already exist. The only way you can reduce the fiscal deficit is to cut government spending. We've already shown how much money we can raise by higher taxes, and that's not enough.

My own forecast is that the Republican Congress is going to pass a significant bill of budget reduction. While the President is now suggesting that he will veto those reductions, I don't think that politically a veto will hold up in an election campaign, and I think that the White House knows that. In the end, we are going to have a big step forward in reducing the deficit.

There is a ten year plan from one party, a seven year plan from the other. Both of them are whistling Dixie, because this Congress is only focusing on one year of the program in terms of legal commitments. We are going to have to see that process play itself out over several more terms of the legislature, and even the Presidency.

Once again, if you study the public opinion polls in the United States, there is very wide spread support among the voters to reduce the size of government, to devolve responsibilities to the local level. That is part and parcel of the deficit reduction.

What will that mean for our trade deficit? If I am correct and we work on our fiscal deficit and are successful, that will improve our international competitiveness and we will begin reducing our trade deficit once again.

The comment I made earlier about Mexico, is overlooked by most people today. Our increase in the deficit this year is almost solely attributed to the difficulties in Mexico and the fact that our goods are now very expensive in Mexico this year compared with last year. The Mexican economy is not buying some of our - to them - expensive exports.

As NAFTA comes into play, many markets get opened up to goods that were formerly excluded from Mexico. I think that we are going to wind up in balance with Mexico within two years. That will help reduce our deficit.

Furthermore, in all of South America, I mentioned western hemisphere in my overall outlook, there is already development toward a common market, with an entire western hemisphere, Argentina, Chile, Brazil, are in strong condition right at the moment. 40% of the U.S. export growth in the last three years is to central and south America. There too, as our economy evolves and gets stronger, we are going to work on the trade deficit by being more effective in terms of our exports.

Question: You mentioned that the home computers are not factored into the economy, resulting in perhaps a wrong projection. With the new change weighting, which will include the home computers, why are you expecting a downward revision of the GDP? I would have thought it would go up.

Answer: There are two separate points there and I apparently misstated it. What is not counted in the statistics is the Consumer Price Index does not include home computers. What we are saying is the market basket that is measured is not the market basket that is being consumed.

If you did a true market basket of what's being consumed with the substitution effects being taken into account, the estimates are anywhere from at least half a percentage point to a full percentage point that we're overstating the CPI.

In measuring national income, we use a different concept called the Price Deflator. That deflator is the one that is on a fixed weight for all sections of the economy. They do have in there the total computer industry as part of the output side of production. It is counted at one point.

The problem is there has been an overstatement in the deflator of the amount of deflation that has occurred in the computer industry. As a result of overdeflating, we have overstated the growth of the computer industry in value added terms and actual counts. The computer sector, which is now 40% of private domestic investment is therefore going to be revised downward in terms of the value added part of the GDP, and that's what takes growth out of GDP. As I said to you earlier, the problem with that adjustment is it makes no allowance for the quality improvements the computer provides to society.

The assumption that the government statisticians make about the services sector is that there is no productivity growth by definition.

The only thing that is added into the equation so far as service is concerned is the change in the wages and the capital investment in the industry or added to the cost structure there is no output in terms of better health care, better airline reservations, better checking out at the cash register. None of those quality improvements are evaluated in services.

In cars there are adjustments made. For example: The air bags are an improvement in quality and safety, and the cost of the air bag is taken out of the cost of the car in terms of evaluating how much it is inflated. We have a distortion in our numbers.

My classic case is the only place we major in services productivity is in the postal service, where we count the number of pieces of mail delivered for a worker in the postal system. In my personal view, the postal service is down because it now takes three days to get a letter that used to take one day. We have productivity gains assigned to the postal service when in fact the quality is down and almost everything else we do in the service sector that has quality improvements is zero. You can see our government statisticians really have things mixed up. If you want to read more about it, get a copy of my book. I have a couple chapters on this problem.

This page is intentionally left blank

Chapter Four: FROM WIRELESS TO THE WEB: SYSTEM DESIGN AS WE APPROACH THE MILLENNIUM

Enrico Pesatori
Vice President and General Manager, Computer Services Division
Digital Equipment Corporation

Introduction: Our next speaker is Enrico Pesatori. He is our keynote speaker for this conference and we are really pleased that he could be with us today.

Enrico's presentation is From Wireless to the Web: System Design as we Approach the Millennium. A very, very interesting topic I'm sure.

Mr. Pesatori is Vice President and General Manager of Digital Equipment Corporation's Computer Systems Division. The Computer Systems Division includes three worldwide business units, each with control over their destiny. The business units include the Accounts business unit, the Personal Computer business unit and the systems business unit.

During his tenure, Digital has doubled the PC revenues and it has become one of the fastest growing PC companies in the world. He reports directly to Digital's President and CEO, Bob Palmer.

Previously Enrico has served as President and CEO of Zenith Data Systems. He has also spent 21 years with Olivetti, and has had many, many important management positions with that corporation.

Enrico was awarded a Master's Degree in Electronics Engineering from Polytech University in Turin, Italy.

Enrico Pesatori: Thank you Gene, and good morning. When Gene asked me a few months ago if I could deliver the keynote address at this conference, I quickly accepted.

FROM WIRELESS TO THE WEB: SYSTEM DESIGN AS WE APPROACH THE MILLENNIUM

As the head of a business that designs, manufactures and sells systems ranging from personal computers to high-performance servers, I am keenly aware of the importance of semiconductors to Digital's success in the marketplace.

Digital is, of course, a semiconductor company itself, focusing primarily on high-performance RISC processors. Therefore, we buy the vast majority of the semiconductors we use in our products from other companies -- many of whom are represented here today. Your ability to deliver high-quality, cost effective semiconductors has a lot to do with our ability to deliver high-quality, cost effective systems to Digital's customers.

I am delighted to be with you today and to have this opportunity to talk about some of the key trends in the systems business.

This is an exciting time to be in the information technology business. Our products and services are transforming society -- the way we do business...the way we work...the way we play...the way we interact with others throughout the world.

Yet the information revolution is not so much a great leap forward as a series of rapid, but evolutionary changes.

That is what I want to talk about today:
The evolution of customer demands and expectations,
The evolution of two dominant platforms -- personal computers and servers,
Perhaps the most transforming change of the next decade, the evolution of the networked world.

I want to start with the customer because it's the end-user that is driving information technology. For most of our history as an industry, corporate customers bought information technology to automate manual tasks, such as accounting, reservations and manufacturing. Large, proprietary systems dominated. Centralized decision-making was the rule.

But that paradigm has changed. Although automation is still important, information technology is seen more and more as a competitive advantage -- as something that effects the top line, not just the bottom line. It is the basis for re-engineering organizations and processes...for increasing time-to-market and customer responsiveness...and for improving productivity and profitability.

Retail companies, for example, have learned from pioneers like Wal-Mart that sophisticated inventory management and distribution systems are not luxuries -- they are competitive necessities.

Overnight delivery companies have learned from Federal Express and UPS that systems that keep track of every package -- from pickup to delivery -- not only save money but significantly increase customer satisfaction.

And we are all finding that giving our sales people immediate, remote access to critical information can make the difference between winning or losing an account. In other words, information technology enables companies to differentiate themselves in the marketplace.

A recent MIT study conducted for Information Week, concluded that companies that focus their IT investments on quality, customer service, flexibility and speed reaped the benefits of increased productivity and profitability. Information technology allows these companies to flatten their organizations and push decision-making much closer to the customer. It gives employees greater access to business-critical information -- in the office and on the road. It makes it easier for customers to do business with them through on-line ordering...EDI...and other emerging forms of electronic commerce.

So, it should come as no surprise that corporate end-users are pushing for more flexible, cost-efficient systems -- systems that support the way they do business. They want information technology that gives them a competitive edge. They want open systems that work together in multivendor environments, including mainframes and other legacy systems. And, they want systems that support the ways decisions are made in a rapidly changing marketplace. That is why more and more companies today are moving to client/server computing.

This demand for open and flexible systems and the shift toward client/server computing is driving the rapid growth of two platforms -- PC's and servers.

I want to take the next few minutes to discuss these two platforms and how they are evolving to meet the needs of customers. First, let me give you an idea of how we expect the market to grow over the next five years.

Between now and the year 2000, we expect both the personal computer and server markets to grow at a compound annual rate of 16 percent. Overall, the server market will more than double, from $17 billion last year to $40 billion the year 2000.

While there will still be a market for mainframes and minicomputers, it will continue to decline as server performance, scalability and availability continues to improve. It goes without saying that most of these platforms will run Intel microprocessors. This is already true for desktop and mobile PC's. And it is increasingly true for servers. With the Pentium processor today, and with the Pentium Pro and P7 to come, Intel is moving farther and farther up the performance scale.

There is plenty of room above Intel for high-performance RISC platforms. The only sustainable business proposition for RISC products, however, is to deliver a commanding performance lead -- by at least a factor or two -- over the latest Intel chip. Digital's Alpha chip, for example, is designed to sustain that kind of performance advantage over the long term.

If the ongoing debate between Larry Ellison and Bill Gates is any indication, the future of the personal computer is a subject that generates very strong opinions. Clearly the PC will evolve into many new forms to fit the technology needs of end-users from wireless portables and PDAs to so-called "smart" terminals linked to enterprise networks or the Internet. But there is one thing I am certain about -- the PC will continue to be the main engine of information technology for years to come.

In the business world, the PC is the primary interaction layer, and customers want the world of the enterprise displayed through the PC -- as easily and transparently as possible. But it is the consumer -- more so than business -- that is driving the evolution of the personal computer.

While business, education and government still account for most of the PC's sold in the world, sales to consumers are growing much more rapidly. Consumers are looking for the fastest processors...the latest in multimedia and telephony...and the newest software.

Just look at the sales of Microsoft Windows 95. Those were not IS managers you saw lined up at midnight at CompUSA. They were consumers, and they are driving the initial success of Windows 95.

There are a lot of reasons consumers are buying PC's today -- telecommuting, games, personal productivity, education and entertainment. But that is just the beginning. As the market matures, we will begin to see more homes with more than one PC -- just as most homes today have multiple television sets. We are not far away, for example, from the home network.

I am sure that in many of your homes there is intense competition for the computer. You have a report to finish. One child has homework. Another wants to play Doom. Now...imagine having a server tucked away in a closet somewhere, connecting one PC for the child doing homework and another for your home office...and a third for entertainment. As inter-networking becomes more reliable and secure, we are also going to see an explosion of another market for PC's -- the so-called tiny office/home office.

New, home-based businesses will be able to create, market and sell products and services directly to customers over the Internet or other networks. But there is one potential problem with this optimistic scenario -- ease of use.

I think it is safe to say that all of the technolphiles now have their home computers. But continue the rapid growth of the consumer market, we have to produce PC's that are not only easy to set up, but easy to use. The new generation of operating systems and advances such as Plug n' Play technology represent some advancement in ease of use.

We have a lot of work to do. Even the newest software is difficult for many technically savvy consumers to load on their computers. Until we can resolve these problems -- until we can make it easier to use a computer than it is to program a VCR -- many of our potential customers will be reluctant to buy a PC -- or a second one.

On the corporate front, ease of use is not so much the issue as ease of management. Most businesses are less concerned with bells and whistles than with managing growing networks of PC's and the significant expense involved in supporting them. They want performance, but most of all they want open and standardized solutions...reliable products...competitive prices...and dependable service and support.

One of the most important platform improvements for the corporate customer is the ability to manage PC's from a remote site. With the network management features now being built into more and more PC's software upgrades and other changes can be made over the network -- saving time and money. The most profound changes in the corporate environment are happening not on the desktop, but in areas such as mobile computing.

Portable computers are becoming thinner, lighter and more functional. Users have to make fewer and fewer compromises for mobility. And since they are not longer bound to the desktop, they can spend more time with customers and partners. Today, portable PC's account for about 26 percent of all PC sales. By the year 2000, that number will grow to more than 35 percent. Most of those users are going to be connected to private and public networks. This is already driving significant growth in the infrastructure needed to support mobile computing -- including mobile software, wired and wireless networks, and remote access server ports.

Clearly the last decade was the decade of the PC.

The next decade will be the decade of network connections, servers and distributed information. As I mentioned earlier, servers represent a high-growth market because of the accelerating shift to client/server computing. Some of the most significant growth is going to be in emerging applications, such as interactive video..multimedia..Internet connections and services...electronic publishing...and very large database and a very large memory.

Each of these areas involves new ways of distributing information. Each requires powerful, scaleable, secure and reliable systems. In addition to emerging applications, servers are taking on many of the tasks traditionally handled by mainframes and minicomputers. With advances such as symmetric multiprocessing and clustering, servers deliver both reliability and availability -- at a fraction of the cost of mainframes. That is why mainframe downsizing is such a strong and growing market.

Two of the drives of the server market are the emergence of Windows NT and the acceptance of UNIX as a mission-critical computing platform. Over the next five years, these two operating environments will dominate the server market. Today UNIX is 50 percent of the market. Other operating systems -- like Open VMS, MVS, OS/400 and Netware -- have 45 percent. Windows NT has about five percent. By the year 2000, we expect Windows NT and UNIX to have roughly equal shares of the market -- about 40 percent each. 95 percent of all customers will have a mixed environment. This will make it all the more important to have interoperability between UNIX, Windows NT and proprietary systems such as Open VMS and MVS.

Now we will discuss the trends in a little more detail. Windows NT is clearly the next strategic server operating system for enterprise computing and many large companies are already embracing it -- much as they did a few years ago with UNIX. The growing popularity of Windows NT reflects the natural evolution of the Windows desktop to the enterprise. In fact, we regard Windows NT as the key ingredient of the emerging client/server computing model. It will drive the servers that link the desktop with enterprise databases, legacy systems and global networks. From a small base today Windows NT will grow dramatically over the next few years.

According to Dataquest's own analysts, new shipments of hardware running Windows NT will increase from 850,000 units this year to almost 4 million units in 1997. That is an increase of almost 400 percent in only two years. By the year 2000, we believe that Windows NT will have about 50 percent of the low-end server market and 18 percent of the high-end market. As a result of NT's influence, platforms will start to emulate PC economics. Scale will become even more critical, especially in the server market, where it is not as important today. The favorable economics of this environment -- a standardized operating system running on standardized platforms -- is attracting some significant converts -- companies like Citicorp, K-Mart, Saturn and Dow Chemical.

K-Mart for example, recently announced plans to replace more than 2000 UNIX servers in its stores with servers running Windows NT. Citicorp is the first major bank to standardize on NT.

As Windows NT becomes more integrated with the enterprise, it will take over many of the tasks now performed by UNIX machines. UNIX is also moving up the performance curve, taking over more and more of the enterprise applications once commanded by mainframes and other large, proprietary systems. The knock on UNIX -- at lest from the mainframe advocates -- was that it did not have the performance or the reliability to handle mission-critical computing.

Advances such as symmetric multiprocessing...64 bit computing...UNIX clusters..high-performance database software...and new system management tools...enable UNIX systems to deliver mainframe performance and reliability at a much lower cost. As a result more and more customers are deploying UNIX for mission-critical computing.

Take data warehousing for example.

In the past, data warehousing required boutique software, sophisticated customer programming and massively parallel processing. Only the largest companies could afford it. Not anymore. With the very large memory capabilities made possible by 64 bit technology, companies can now deploy what amounts to a standard data warehousing solution. You do not have to be a Fortune 500 company to afford it.

Because UNIX was the first to capitalize on 64 bit technology, very large memory and very large database capabilities, it is now in a position to emerge as the dominant platform for high-performance, enterprise servers over the next five years.

Digital has been building 64 bit servers and workstations running 64 bit Digital UNIX for some time now, and the performance improvements are incredible. Our newest Alpha servers, running Oracle's 64 bit database software, are as much as two orders of magnitude faster than 32 bit systems. This kind of performance opens up vast new opportunities in areas such as speech recognition...complex simulations...gene mapping...or very large memory databases accessed in real time.

Even as I speak, a 64 bit Digital UNIX server is completing the task of indexing the entire World Wide Web -- more than 30 million pages of information retrieved from more than 80,000 computers worldwide -- a task previously considered economically unfeasible. It is retrieving information at the rate of 1 million pages a day, or 700 pages per minute. This is 15 to 100 times faster than any other retrieval engine currently operating on the network.

The advances we are making in UNIX and Windows NT platforms are building the foundation for the last evolutionary change I want to discuss -- a change, as I said at the beginning, that could be the most transforming of the decade. It is the evolution of the networked world.

Everybody today is talking about the Internet...and much of that talk is about the Internet as an electronic trade route. Security, however, remains a significant concern, and the Internet will not take off as a commercial enterprise until that problem is solved. Companies like Digital are developing products and tools that will help make the Internet secure for business.

But there is more to the Internet than commerce. It also holds great promise as the next paradigm of computing. As this world evolves over the next decade, the hardware and operating systems on the clients will become less and less of a competitive issue. Instead, clients of all kinds will connect to a standardized application and content environment like the Internet.

We are already seeing today how the Internet can be used as a private network to meet the needs of the enterprise. Businesses are discovering that it is a cost-effective way to create virtual LANs. The evolution of the Internet into the kind of network we are talking about will require significant improvements in the network infrastructure.

In the last decade, for example, MIPS in standard computers have increased more than 1000 times. But remote, widely available, telephone-based bandwidth has increased only ten times. Bandwidth will have to increase substantially in order for the Internet to become the primary platform for distributed information. The Internet is just one piece of the growing market for inter-enterprise connectivity.

Digital believes that by the year 2000, end-user spending on inter-enterprise connectivity will reach $100 billion dollars a year. The business opportunities will fall into four broad categories: communication, information, transactions, and entertainment. They encompass everything from computer collaboration and electronic commerce...to on-line services and video-on-demand. But we believe this is only part of a larger opportunity.

This $100 billion dollar market will be much like the interstate highway system. The interstates transformed commerce in America. Their biggest impact, however, was in creating vast new business opportunities along the way -- the shopping malls, service plazas, gas stations, restaurants, and motels.

Internetworking will have the same impact. It will create an environment in which new businesses will flourish. As I said a moment ago, the network infrastructure still needs a lot of work. TO build truly high-speed networks, we need significant improvements not only in bandwidth...but in processing power...interoperability...security... navigation and access.

This will require a significant amount of investment over the next few years. But by overcoming these challenges, we have the chance to literally redefine computing and the information society. I have talked about a lot of changes today -- from the continuing evolution of the PC and the explosive growth of the server market to the bast potential of internetworking. But none of these changes would be possible without the semiconductor industry and the tremendous advances that have been made in the last two decades.

Your are going to hear a lot of industry numbers during this conference, but I want to cite one statistic that clearly defines the importance of this industry. Twenty-five years ago, semiconductors accounted for only four percent of worldwide sales of electronics equipment. By 1990 that had grown to 9.4 percent. It will double this year to almost 19 percent. Projections are that by the year 2000, semiconductors will account for 28 percent of electronics sales. Clearly our appetite for advanced silicon products -- from microprocessors and DRAM to cache RAM and PCI chips -- is only going to grow.

The fact that 40 new FABs are under construction around the world is an important recognition of the need for advanced fabrication techniques and increased capacity to meet this demand. Emerging markets such as 64 bit computing, high-speed networks, speech recognition and wireless communication will require new levels of semiconductor performance and functionality.

The emergence of PDA's , set-top boxes and other information appliances will challenge the industry to deliver chips that provide both low power and high performance. In fact, it is hard to think of any significant advance in technology that will now be driven at lease in part by silicon. Semiconductor companies have been successful because they deliver products that meet the information technology needs of their customers. That brings me to where I started.

Nothing is more important than our focus on the customer -- whether it is the CIO of a major corporation or the home consumer. After all, technology is not an end in itself. It is an enabler--a tool that allows people to become more informed...more productive...and more competitive. Our success as a business ultimately depends not only on our technological excellence but on our ability to harness that technology to meet customers needs. Through a continuing partnership between systems companies and the semiconductor industry, we can deliver the best of both worlds -- great technology and great products for our customers.

This page is intentionally left blank

Chapter Five: THE SEMICONDUCTOR OUTLOOK: WILL IT GET ANY BETTER?

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

My topic this morning is, Will the Semiconductor Industry Outlook Get Any Better? It is not, will the semiconductor stocks get any better? I'm surprised you're laughing; I'm not. I'm more qualified to answer the former question then the latter question. For the latter question, I'm going to let Ron Elijah, who is going to be speaking after our lunch today, answer that question. We couldn't have a more appropriate person that could answer these questions at this time in a cycle. We are very pleased to have him.

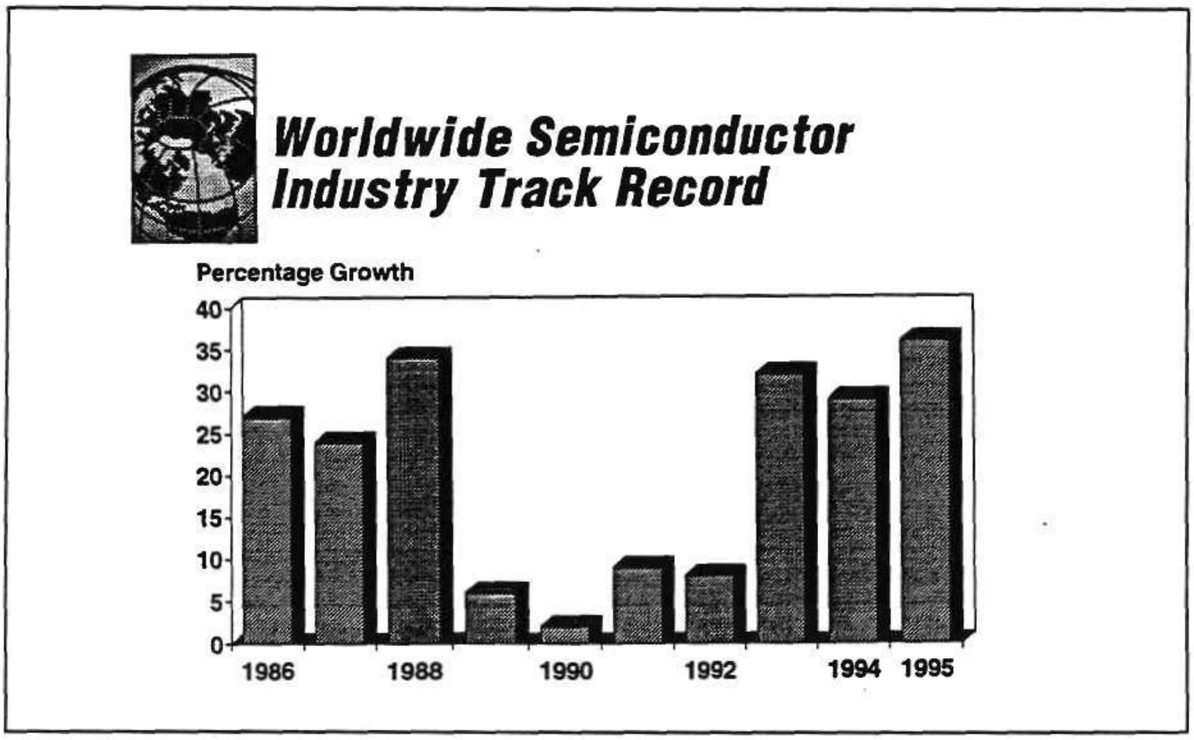
I chose this topic based upon conversations with many of our clients, especially the CEO's who have to write the capital spending checks for the year 1997, and the year 1998. Let me tell you, this group of guys is really a nervous bunch.

Let's take the semiconductor guys at Motorola down in Phoenix as an example. Their investments for 1994, 1995 and 1996 will equal their investments over the previous 37 years of Motorola semiconductors. It's pretty incredible. These guys are not the only ones in this situation. I just didn't go about adding up what the numbers looked like for the Intel's of the world, but I know that statistics are probably the same.

I would like to give you my perspective on the coming years, based upon the research of our 60 analysts spread throughout the globe. As we say - and have been saying for years - the sun never sets on the semiconductor group at Dataquest.

I hope this perspective will answer many of the questions that you have on your mind, but if not I'd like to try to answer a few of those at the end of my talk. If you don't get your question answered, please save it for the panel discussion.

Here's my agenda for today: It's rather compact but it's going to take me some time to work through it. I do want to give you your money's worth. I'm going to talk about what's happening with the industry in terms of pricing, lead times and the back log. Next, I am going to cover our device forecast by product and by region to the year 2000, and then talk about the capital spending plans that we havederived from the surveys as well as forecasted. Then I will give you some idea about what we think a supply side is going to be. Then I will summarize.



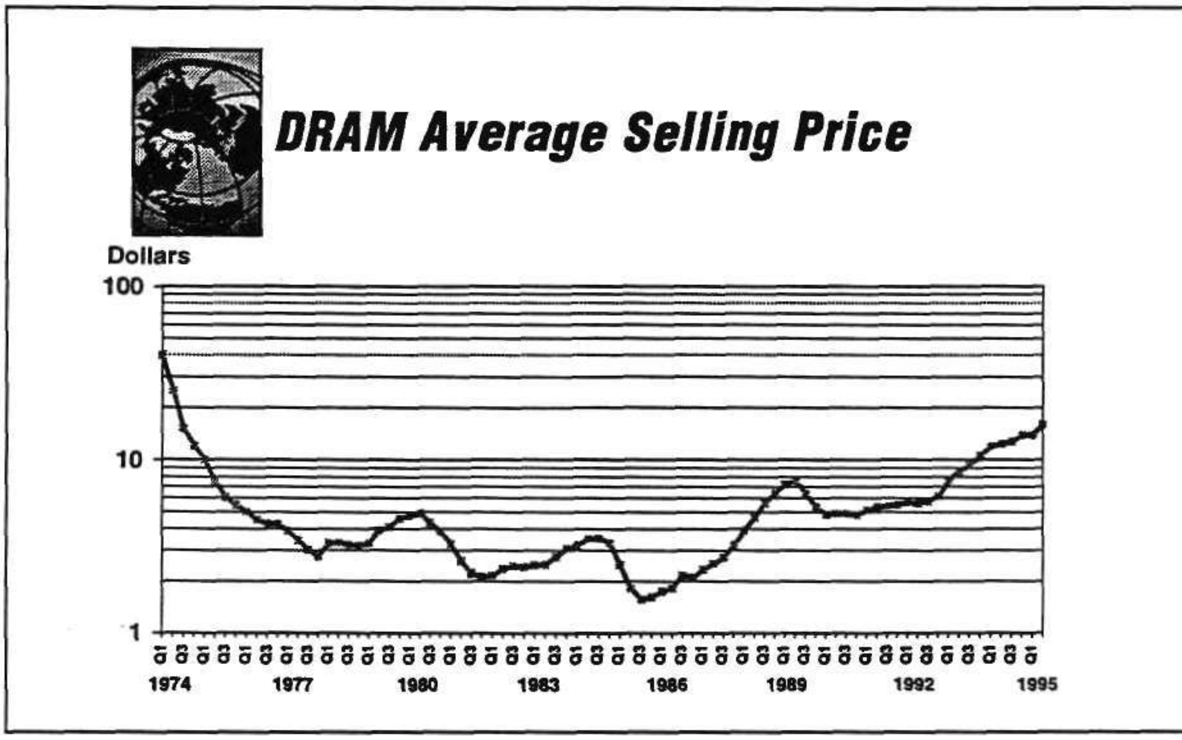
As you can see here, six of the last ten years we have had annual growth rates of 24% to 36%. The other four years we had single digit, but positive growth. These four years I think were noteworthy in that they came as the result of the downsizing of the computer industry. Some say that these years were necessary to prepare the global population for the personal computer era. I want you to also note our current estimate for the industry in 1995, as about 36%, and it is a capacity constrained estimate. It could have been 50%, if the people that write the capital spending checks two years ago had planned for having 60+ million PCs shipped, and 40+ million cellular and PCS handsets shipped this year; but they didn't. Partly because it is just impossible to plan for the pervasiveness of these extremely productive tools that we have to work with.

I'm giving here a sneak preview of the current semiconductor forecast through the year 2000. We have increased this forecast three times this year: First it was \$240 billion; then it was \$275, now we have \$330 billion dollars, and believe me this forecast will happen. As I go through this presentation, I think that you will get a feel for why we feel so strongly about this forecast.

I am going to be discussing - later on in my presentation - the applications of semiconductors that will drive this industry to this level. Here I have given you some of the applications that have gotten us to where we are today, and a few of the drivers for the future. It is truly impossible to forecast accurately out that far out for some very specific reasons. One is we cannot predict the pervasiveness of these very fast growing new markets: Personal video conferencing, video on demand and full digital set top boxes, human interface electronics, ATM and wireless telephony, finally multimedia computers and PDAs. What will enable these systems is, of course, semiconductors. Later on in this presentation I will cover our forecast for some of these killer applications.

Now I would like to talk about another engine driving the industry and explore the new paradigm of the industry, namely rapidly rising prices. For the next few slides I've taken a much longer horizon then the last 30 or 60 days. We don't think that this period of time should change the position or the perspective that we have on what's been happening with prices and what is going to happen with prices.

Prices have been rising rapidly, and the semiconductor marketeers in this audience have had a field day at expensive of the systems margins. At the same time the prices have been rising, semiconductors have been providing improved price performance at a system level. As in the case of the PC, price performance has been doubling every 18 months. Still these price increases make it very difficult for your customers, the manufacturers of these wonderful toys, to hold their margins and at the same time keep the price of their products affordable for the global population.

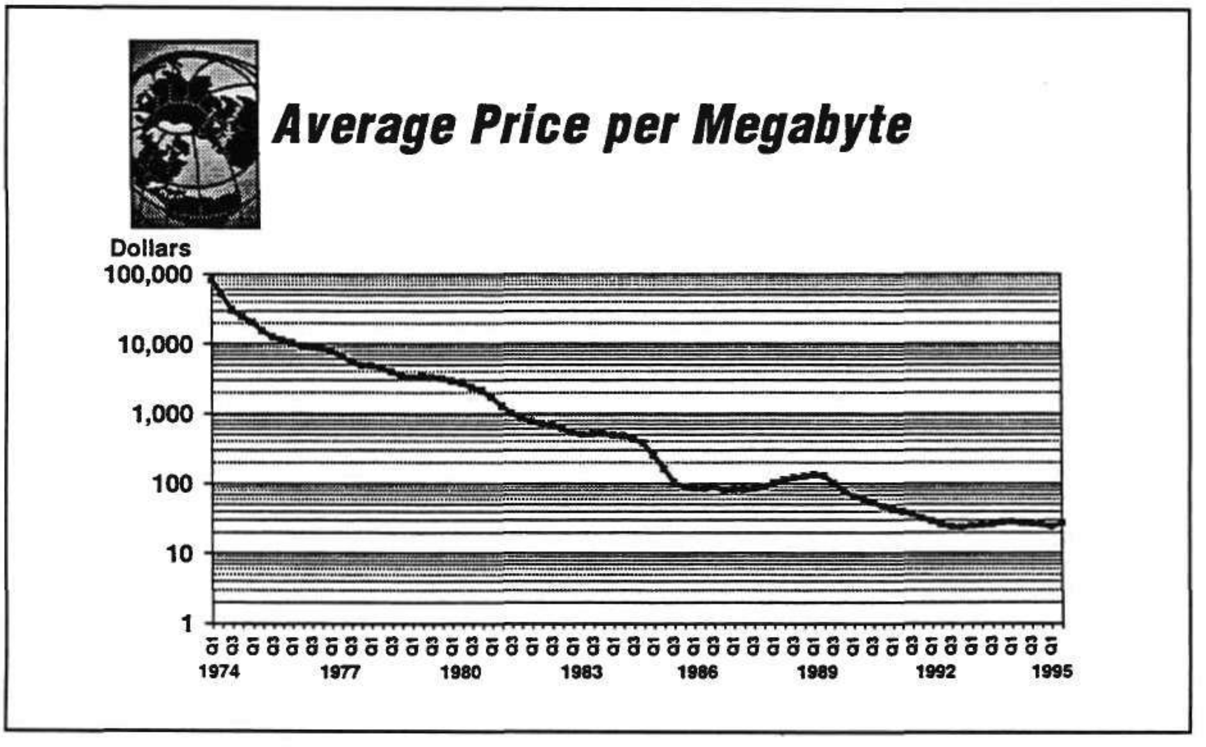


As you can see from this chart, average selling prices have more than tripled for DRAMs and MPUs; not too surprising, but very painful for the buyers. Microperipherals have not increased their prices as much as the DRAMs and the MPUs, and they have also increased in functionality. Examples include core logic chip sets, graphics controllers and LAN controllers.

Also we are dealing with systems level integration on half micron geometry production lines and moving to .35 microns and using megafabs costing $1 billion dollars or more.

Let's take a look at the industry's highest volume product, DRAMs, as an example. For the historians in the audience, I've gathered our estimates back to 1974, where DRAM manufacturers got $60.00 per megabyte for 1K DRAMs, and computers at that time were being sold with a performance of around 1 MIP. As you can see, prices continued to trend downward for quite a period of time. Then the world changed after the great PC debacle of 1985. Also in July of 1986, we had the Japan/U.S. trade agreement and what did that bring us? Increasing prices. Specifically, the 256 K DRAM shot up dramatically. In 1988, because of the DRAM demand that came as a result of the introduction of the 386, prices tended to move sidewards to upward.

Demand slackened in 1990 and 1991, and we had a flattening in prices at that time. In October of 1992, Micron Technology sued Samsung, LG Semicon and Hyundai for dumping in the U.S. market and almost immediately prices shot up.



We have seen prices continue to increase from that time due in part to the introduction of Windows, as well as a significant under-investment by the leading DRAM manufacturers in 1990, 1991, and 1992.

What about price per bit? I know that's on your mind. It is true that over the long haul price per bit has been declining. However, focus your eyes on the 1986 to the 1989 time frame. As prices were rising, so was the price per bit. Then from 1989 to 1992, we had the downsizing, as I've just mentioned. From 1992 to the present time, we have had price per bit flat to rising due to the underinvestment that I talked about before .

Japanese DRAM manufacturers have significantly stepped up their investments, but still they are under what we see as the real demand. The Korean and U.S. manufacturers have also added a lot of capacity, but still we have allocation. Also the 16 meg DRAM has been slow to ramp up, given the significant manufacturing hurdles to overcome.

Since this product represents a very large part of the semiconductor industry, let's look at now our forecast for supply and demand. In your book there, there was a typo. This chart refers only to the 16 meg device.

As you can see, we don't see any shortages ending soon. We have carefully done an intensive analysis of the PC industry, as well as other important industries for DRAMs, and combined this with our forecast models for price per megabyte. After comparing this demand analysis with the analysis of the FABs, as well as the investment models, we've come up with this estimate for what we see as the supply/demand situation. We are forecasting about a 12% this year, followed by a shortage in 1996 of about 7%, and a shortage in 1997 of about 2%.

For your information, we have assumed the average memory configuration increasing in 1996 and 1997 by about 40% to 50% due to Windows 95, as well as increased applications software. It's impossible for me to go through all of the assumptions behind this forecast, but we have our PC analysts and our semiconductor analysts here and they would be glad to talk with you at one of the breaks about some of the other assumptions.

Will it get better? I guess it depends upon who is answering the question: The DRAM manufacturer or the DRAM supplier.

Another statistic to look at is the industry back log. To get a picture of the industry back log, I've used the WSTS statistics. As you can see here, once we hit the fourth quarter of 1991, we haven't had a down quarter through the second quarter of 1995. The principle reason is the explosive growth in networking PCs, as well as wireless communications for enhancing productivity.

Despite the recent changes in the Taiwan market, from a lead point perspective, we have most PC related devices with delivery times beyond 12 weeks, and many on allocations. For more information on memory prices and availability on a global basis, please read our current analysis in the DQ Money Report that is on your table. Take a careful look at that. It includes our thoughts on what is happening right now.

Now I would like to turn to the semiconductor drivers. Before I do that, I thought I would give you a visual aid, showing what I think is happening in the industry right now. For you salesmen in the audience, you can clearly identify with the person on the left there; and the buyer on the right.

As some of you have heard me say many times, as the PC industry goes so goes the semiconductor industry. It is not coincidental that over the last four years the semiconductor and PC industry have had growth rates ranging between 20% and 36%. From our analysis, 30% of all semiconductors go into this industry segment, and it will trend up to over 35% in the year 2000. If you add in the semiconductor consumption in segments much as workstations, printers, and other PC related products, this percentage goes up to 40%.

Let's take a look at this industry segment and our assumptions behind its outlook. The PC industry has not followed the normal paradigm from 1987 to 1995. This paradigm says that as the industries get larger, their growth rate slows. Here we have six of the last ten years with 20% or more annual growth rate. One wonders if there is some kind of lid on the consumption of these magnificent productivity tools. The compound growth rate over this period has been 19%; pretty incredible.

As we look out over five years, we have made the following assumptions associated with the PC industry. First of all, as you heard this morning, the home market throughout the world will be the fastest growing segment of the PC industry, marked by the integration of advanced multimedia functionality. Second: The Asia Pacific region will be the fastest growing region of the world. Thirdly: We've made the assumption that the industry will grow 16% compounded through the year 2000, and 14% through the year 2005. We have put our forecasts along the lines of the normal trends in high technology industry. That is, as the industries get larger, their growth rate slows. However, since I said that the PC industry is so critical to the semiconductor industry, if in fact the demand grows faster than that 16%, our forecasts - as I'll talk about in a few minutes - will be larger then what we have posted here.

At the same time we do see the semiconductors revenues growing in this segment from $40 billion dollars to $115 billion dollars. This is a growth rate of about 23%. What is going to drive this? Obviously DRAMs and microprocessors of course. We also see a large revenue opportunity in integrated controllers and also multimedia engines.

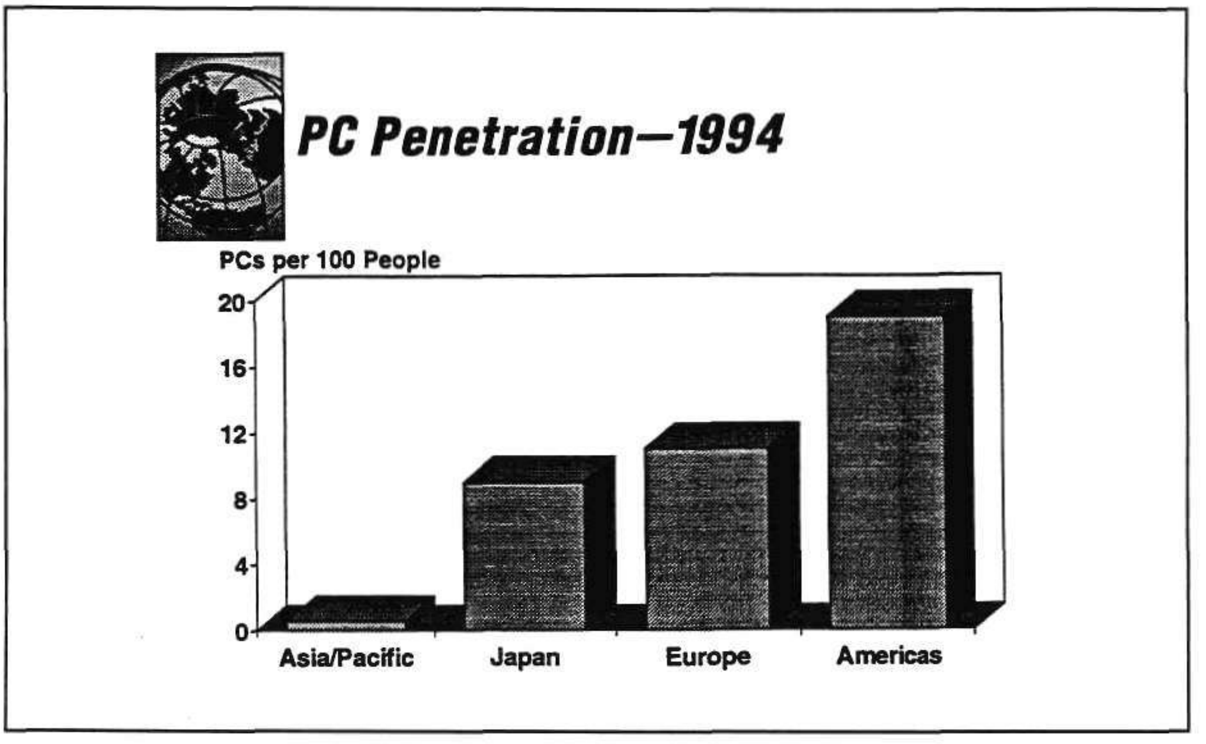
Let's take a look at the multimedia portion of the PC opportunity. PCs have three multimedia subsystems aside from the MPU that deal with multimedia information. These are the video subsystems which were initially the graphics controllers, but now it is evolving to include scaleable video support, as well as soft and hardware based compression technology like MPEG.

Secondly: There is a second subsystem, the sound subsystem, which includes the ability to convert sound in and out of its natural analog format. The current trend in synthesizing sound is towards wave table technology. Compression is definitely needed to conserve systems resources. Today we do not have a compression standard, however ADPCM for music and true speech is a leading candidate.

Thirdly: The communication subsystem is becoming increasingly important in both the home and the office. Home PCs are shipping almost entirely with modems due to the popularity of on-line services. Many office PCs are shipping also with LAN functions, as their major communications feature.

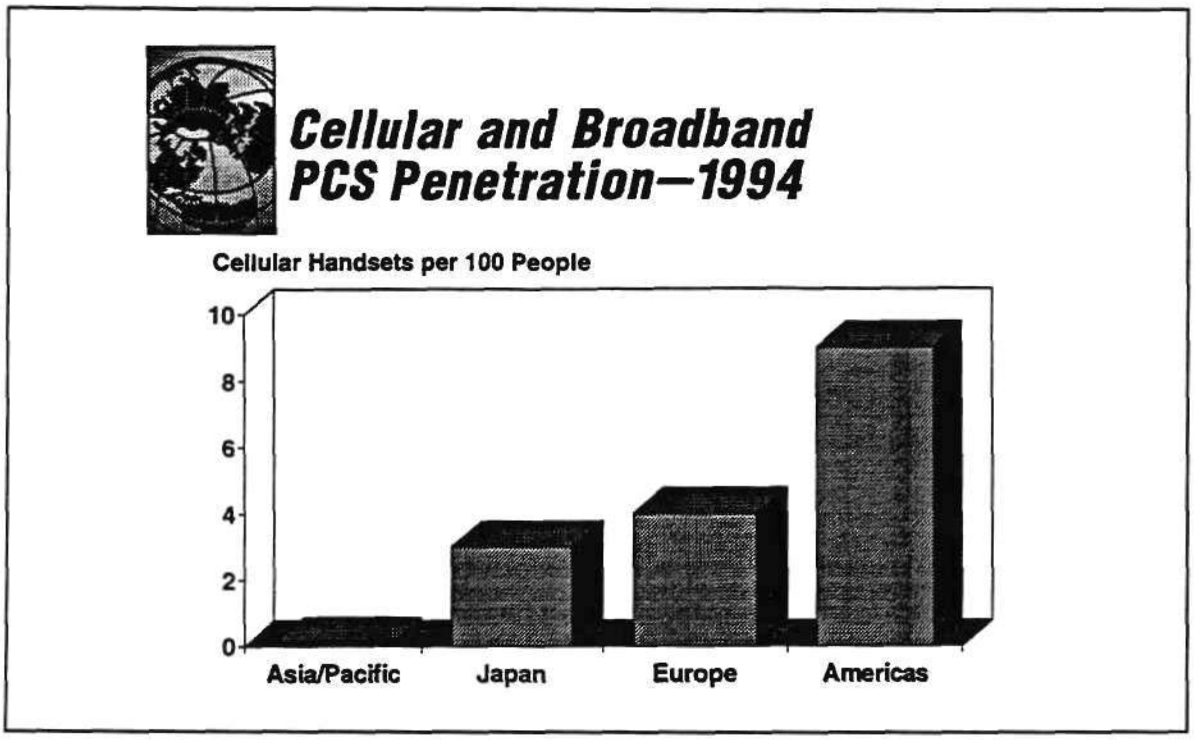
Today for the most part these subsystems remain a distinct island of chips on the mother board. However, with the technology moving to .3 microns and the increased competition to integrate features to produce differentiated products, we are seeing a rapid rush to produce fully integrated multimedia engines manufactured by Phillips'. Microunity, Nvidea and Chromatic Research. Wes Patterson will be here this afternoon to talk to us a little bit about what he sees in this exciting new area.

What about the longer term opportunity for PCs? We estimate at the end of 1994, the Americas had one PC for ever 23 people. This figure drops by more than 50% for Europe and Japan. Compared to the Americas, the Asia Pacific PC market is 1/40 less penetrated.



Due to the increases in wealth, the Asia Pacific region the PC consumption over the next five years will grow 50% faster than the Americas.

The next engine for the semiconductor industry that I want to talk about is wireless and cellular. To put this opportunity into a perspective, I want to repeat another amazing statistic that Gary Tooker, CEO of Motorola, gave to us at this conference last year. In many Asian countries, 98% of the people are waiting to get a telephone. The other 2% are waiting to get a dial tone. Here you can see that the cellular phones in the Asia Pacific region are even less penetrated then PCs relative to the Americas. I also want to point out that PCs and cellular are twice as penetrated in the Americas as in Europe and Japan. It seems that the Americas is, in fact, the earliest adopter region of the world.



The cellular and broadband PCS market will truly be an explosive one. We estimate 330 million subscribers in the year 2000, up from 77 million this year. This is creating a gold mine for the handset manufacturers. By the year 2000, we forecast 120 million handsets per year shipped, with the semiconductor market opportunity in the area of $7.5 to $8 billion dollars.

Transportation electronics: The next major market I want to talk about is transportation. We estimate that all transportation electronic revenues have grown about 10% for the last nine years, and will grow about the same rate over the next five years. Why is that? We see the following new systems diffusing very quickly across this market place. First: Heads up displays for speed, time and so forth, 32 bit integrated engine and transmission management, keyless and remote entry for security purposes, global positioning and navigation systems, and two air bags moving to more than two air bags.

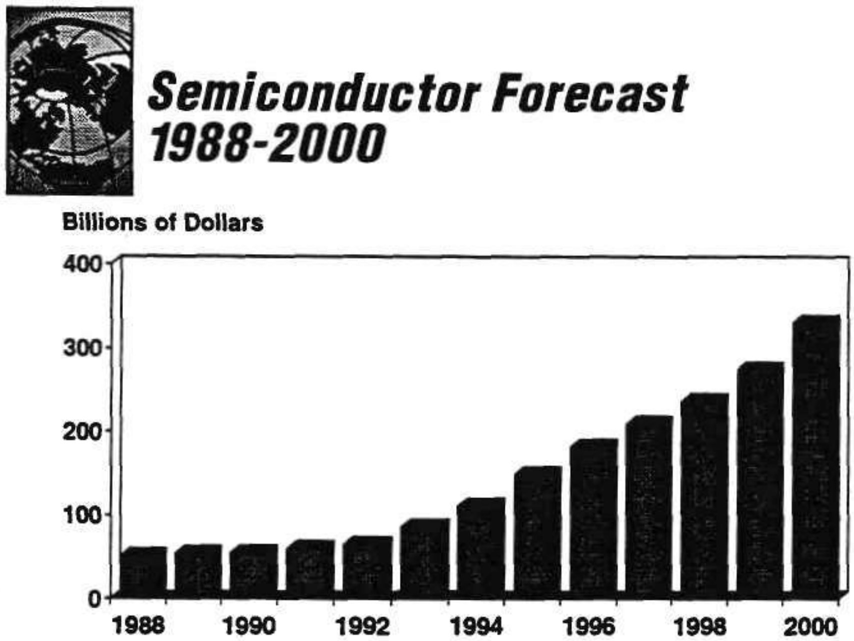
Looking at the semiconductor content, we estimate there is about $130.00 average in all automobiles today. This represents 17% of the electronics content, and we think this is going to increase to over 20% in five years, just as we've seen the concentration of semiconductors increase in the PC business over the last five years.

Multimedia/Consumer Semiconductor Opportunity

	2000
TV video games	$2.4 Billion
Digital set-top boxes	$1.6 Billion
Sound chips	$1.0 Billion
Videoconferencing	$1.0 Billion
Digital Videodisks (DVD)	$.7 Billion

The last major driver I want to touch upon is the multimedia consumer market. Here I have enumerated five of the largest and the highest growing opportunities in this market. As we all know, the consumer electronics market is not a high growth market. However, the semiconductor TAM will increase rapidly due to the digitizing of products from VCRs to dishwashers. Many of the planned evolutions of these consumer electronics systems would not be feasible without employing compression technology. Current and future generations of these systems are being enabled through the use of codec technology to handle audio and video. Codec technology is being employed as a means of reducing the size and cost of natural data types, so that they can be stored randomly or interactively accessed and then communicated.

One thing for sure, these market estimates depend upon an increasing percentage of the global population wanting to use more of their disposable income on electronics. Our surveys show that they are.



Are we so optimistic? I don't think so. Let's take a look at why. On the eve of the 21st century, the signs of the momentous change are everywhere. Never before have we seen so many positive signs for continued growth and profits for the electronics and semiconductor industries. I frequently get asked when will the bust happen? My answer is flatly I don't see one for the next three years, assuming that Joe's right and that is we'll have low inflation and low interest rates for the next three years. Economics, population, politics and most importantly technology are providing very positive forces for the electronics growth in the future.

Let's talk for a minute about economics. Looking at the global economy, D&B is forecasting approximately 3.5% growth rate through the turn of the century, reaching about $33 trillion dollars. They are also forecasting roughly 3% compound growth rate for the U.S. over the same period of time. However the fastest growing regions of the world will be Korea, Taiwan, Hong Kong, Singapore and China. It is these regions that will impact the electronic industry the most over the next five years.

Let's look what's happening with the population of the world. As my slide here shows, the United Nations estimates that the global population will reach 6.2

billion people in the year 2000. This is up from 1.6 billion in the year 1900, just under 4x growth in 100 years. The U.N. also predicts that the global population will reach about 7.8 billion people by the year 2020. In about 25 short years we are going to add to the planet the equivalent of the world's population in 1900, or looking at it another way, we are going to add two Indias to the face of the globe in two decades.

No, there are no hard cold statistics on the middle class, those people who buy a lot of electronics. However, McGraw Hill estimates that they are about 20% of the world's population. They also estimate that this segment is going to grow faster than the rest of the world, and reach 1.4 by the year 2000. At the same time, the Asia Pacific Segment of the middle class population will grow by 8%. At an accelerating rate, these folks are finding jobs, starting companies, buying cars, cellular phones, PCs, VCRs for the home and the office, and creating wealth as well as debt. Many of the companies that we talk to in the Asia Pacific region are working now to try to get into the Nasdaq market in order to get the visibility for their companies. That will mean an accelerated avenue for getting equity to enable the growth of their businesses.

From my perspective, the shift in Russia and China to a more capitalistic doctrine is the single most underestimated factor in predicting the future of the electronic industry. These markets represent approximately 1/6 of the globe who want to become more like their American trading partner. On their ubiquitous TVs, they enjoy watching Baywatch, like many of us in the audience. However, they want to live it.

It is no secret that manufacturing salaries are higher than in agriculture and many areas in the service industry. It is here that we are finding more and more workers, especially in electronics manufacturing. Today electronics is the largest of all manufacturing industries and growing the fastest. Why is this? Studies have shown that electronic industry workers buy more electronic toys than non-electronic workers. This means as they buy more, the manufacturers have to build more. As they build more, they have to hire; and so forth and so forth. The industry actually is self-generating.

Finally: What has enabled electronic systems innovation? You guessed it: The semiconductor industry. Gorden Moore once observed that the semiconductor industry comes out with chips that have four times as many transistors every three years. This result is microprocessor technology is progressing about 5% per month, and shows an order of magnitude improvement every six years. The net effect to the systems manufacturers - and PCs in particular - is that PCs of today are 1200 times as powerful as the Apollo computer that took Neil Armstrong to the moon just a short 25 years ago.

Based upon this information that you've heard so far, we are now saying that the semiconductor industry will triple in six years. Let's take a look at how we get there.

Semiconductor Revenue Forecast

	1995 $B	Percent Growth	1996 $B	Percent Growth
United States	47.8	33.0	60.3	26.2
Europe	29.0	39.3	35.5	22.5
Japan	41.8	34.9	47.6	13.8
Asia/Pacific	31.2	36.5	39.4	26.7
Worldwide	149.8	35.5	182.9	22.1

Here is what the industry had done in revenues from 1988 to 1995, a period of seven years. As you can see, we have roughly tripled in these seven years. This is a compound growth rate, just over 15%. Yes, this does include currency fluctuations.

We are now saying that the industry will triple in six years. 1994 was $110 billion dollars, and we estimate $330 billion dollars in the year 2000. We are saying we will do this without a boom or bust. It certainly will not be like the 1970's, or in some periods in the 1980's.

Let's take a look at our forecasts by region: We think that the 1995 industry will grow - after all is said and done - about 36% and reach $150 billion dollars. This could reach 41% on the high side, if prices hold up. For 1996, we estimate a most likely scenario of about 22%, but actually my range is between 20% and 30%. We also think that the existing capacity constraints will limit growth in 1996. Yes, we do have many factories being constructed and expanded, and yes we do see some changes in the spot market prices of the market. However, we still think that the supply will not keep up with demand.

From a product perspective, yes, you do see 51% growth in memories; and that could be low if the 41% for the toal industry is achieved in 1995. We are estimating about 30% growth for MOS memories in 1996. Even though the capacity shortage will be less in 1996 than in 1995, we think that the impact of Windows 95 will drive the industry very hard next year. Microcomponents will grow approximately 27% in 1996, driven by the Pentium, as well as the 486, 100 to 125 megahertz devices.

Microcontrollers will also increase nicely due to the growth of wireless, automotive and digital consumer applications. We estimate a 22% growth for that family.

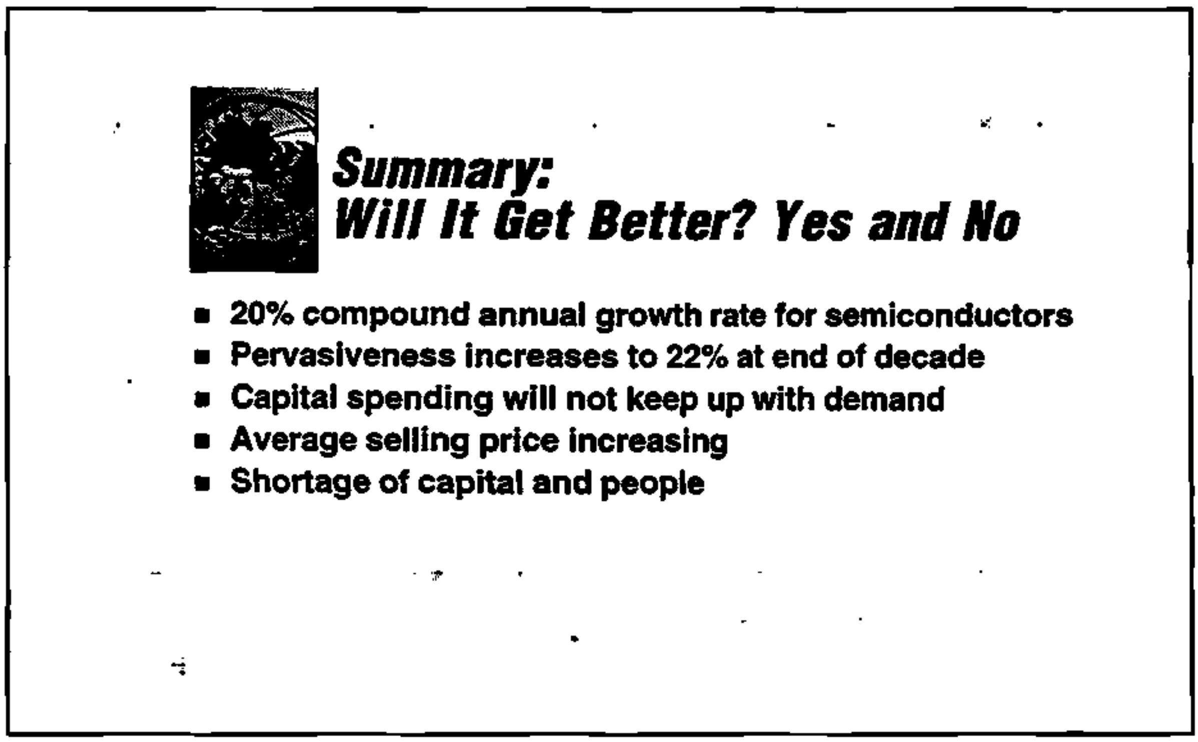
Microperipherals, such as multimedia engines, will grow about 25%, and probable DSPs programmable about 33%.

Capital spending: Here are our estimates for the annual capital spending for the semiconductor manufacturers. On your left hand margin in your books it should read billions of dollars; sorry.

We are all worrying will there be enough or will there be too much capacity? From our surveys of the chip manufacturers and the equipment suppliers, we forecast capital spending to rise from $35 billion dollars per year level this year to $70 billion dollars by the year 2000. If you add up all of the intervening years capital investment, we estimate that the average number of FABs built over that period of time to be about 30 to 35 FABs per year, or a cumulative total of 200 FABs through the year 2000, and including the year 2000.

When I hear some of you say that 25 or 20 FABs being built this year or completed this year; my thought is again too little. Capacity constraints here we go again!

As you can see also, even with this aggressive forecast we don't get a ratio of capital spending to semiconductor revenues greater than 23% to 24%, which is a healthy band for a stable market. In talking recently to several CEO's and testing this forecast on them, what I heard was that they want to do this; however they are concerned about the availability of equipment and human talent. Recently though a good friend, Don Brooks, CEO of TSMC, said he felt there would be a glut in 1997. All I can say is don't bet on it.



We are now living and working in a structural change in our economy. Some say akin to the late 19th century when boom times occurred in the oil industry. It was at this time the oil was replacing coal as the main fuel for the world's economy. Today electronics muscle is replacing human muscle in the office sweatshops and manufacturing factories of the world. The key for success in the future is increasing productivity. Either you become more productive, or you become more extinct. We forecast that the semiconductor industry will achieve a compound growth rate of 20% or more for the period of 1994 to the year 2000, with pervasiveness growing above 20%. Today we estimate this pervasiveness in the neighborhood of 16% to 18% today.

Capital spending will be up, but can the equipment suppliers keep up? To make it in the years to come, it will take a good partnership with the equipment supplier and a steady flow of human talent. Thank you for your attentio andhave a great conference.

Questions and answers:

Question: Gene do you have data on the number of FABs being started per year; and if not, would you consider starting that as a service?

Answer: We have a program now that will follow in detail what is happening with the FABs of the world, and what is happening in particular with the growing area of foundries. We just completed a very extensive multiclient study on that subject. If you are interested in that information, I suggest that you see one of our sales representatives afterwards.

This area of capacity is the most important question as I travel around and talk to both the system manufacturers and the semiconductor suppliers. We have to respond to that and we have.

This page is intentionally left blank

Chapter Six: SEMICONDUCTORS: THE BUILDING BLOCKS OF A NEW WORLD ORDER

Panel Discussion

Moderator

Gene Norrett
Vice President and Director, Worldwide Semiconductor Group
Dataquest Incorporated

Panelists

Eric Miller
Senior Vice President, Chief Investment Officer and Chairman of the Stock Selection Committee
Donaldson, Lufkin and Jenrette

Dr. Harjit Bhalla
Vice President and Director, Market Research and Planning
Motorola SPS

Joseph W. Duncan
Vice President, Corporate Economist and Chief Statistician
Dun & Bradstreet Corporation

Dr. Chintay Shih
President
Industrial Technology Research Institute, Taiwan

Martin Reynolds
Director, PC Technology Program
Dataquest Incorporated

SEMICONDUCTORS: THE BUILDING BLOCKS OF A NEW WORLD ORDER

Introduction:

Before I get started, I would like to introduce our panel members today. At the far right is Eric Miller, Senior Vice President of Donaldson, Lufkin and Jenrette. Mr. Miller is Senior Vice President of Donaldson, Lufkin and Jenrette, with whom he has been associated for 16 years as their chief investment officer and chairman of the stock selection committee. He is also Co-Manager of the Portfolio Advisory Service.

Next to him is Dr. Harjit Bhalla. Dr. Harjit Bhalla is Vice President and Director of Planning and Market Research in the World Marketing Department of Motorola Semiconductors in Phoenix, Arizona. Dr. Bhalla has had a long term experience in doing economic analysis and forecasting. He was promoted to his current position in 1990, and added the responsibility for providing a comprehensive view of a global semiconductor industry and an analysis of strategic business issues.

Next to him is Dr. Chintay Shih, President of the Industrial Technology Research Institute in Taiwan. Dr. Shih is also involved in the area of working with smaller companies in order to help them get started in Taiwan. The Institute is organized under ten divisions, serving the industry sectors ranging from electronics, computers, communications, opteoelectronics, metrology, to machinery automation, materials, chemicals, textiles, aerospace, energy and environmental protection.

Next to him is Joe Duncan. You have already been introduced to Joe.

Lastly, I have Martin Reynolds; and certainly not least. Martin is currently a Principal Analyst in our Computer Systems Operation. He specializes in PC technology directions and he's had a varied and long career in the engineering world. He's also involved at Dataquest in working with the semiconductor group to analyze the trends in semiconductors and what these trends mean to PC manufactures.

Let's get started. What I would like to do is ask a couple questions of some of the panel members, and then have a dialogue among the panel members themselves about their response.

Let's start off with a question for Joe: Are there any other times in the history of the industry when a specific industry was able to sustain a ten year period of growth and attain such continued high levels; and are there any reasons why this has happened?

Answer: Actually the history of economic growth is sprinkled with many periods of very long and dynamic growth in relative terms. If you want to, you can go back to the industrial revolution and it began to find the steam power with a way to run factories, that whole industry developed. The whole petroleum sector has already been referred to in this meeting. It had another long period of sustained growth. In many ways you can look today at the transportation industry and look back over its contribution at the world level up until 1987. They had a spectacular period of 20 years of growth, as automobiles became part of the engine driving economies, particularly the less developed countries.

Yes, there are many periods of highly sustained growth as economic transformations take place. It is true, however, that every one of those has been marked with some rocky movements. It's not a straight line up. Furthermore, any thing that grows significantly above the overall growth rate at some point bumps into a ceiling. I always get leery when I see a sector growing 15% or 20%, because it's unlikely to always continue.

The unique part about the current time though is in addition to the economic change, we are in a period of unparalleled social change. We begin to look at transferring economic progress to the developing part of the world; a phenomena - incidentally - has been going on now for 20 years. The developed part of the world has been growing twice the rate of growth of a developed nation. Over the next 20 years, I think it's safe to say they'll retain that difference. So when you say that Asia is a big opportunity; of course you are speaking about the obvious, because that's where the growth is.

SEMICONDUCTORS: THE BUILDING BLOCKS OF A NEW WORLD ORDER

Panelist Eric Miller:

I would like to try to provide some perspective of the role of technology in the securities market. Some of you may have noted in the paper, today happens to represent the fifth anniversary of what we call the new phase or an additional phase of very long term bull market. In this five year period we covered a lot of ground. The Dow Jones average has doubled. The NASDAQ average has gone up 200%. Our index of technology stocks is up some 300% in this time.

It clearly has not been a straight line affair. 1994 - it seems like a long time away ago now - actually was a bumpy year and a difficult year. Starting last November, we began another very sharp leg up, and clearly 1995 has been spectacular. The Morgan Stanley High Tech Index was up 62% in the mid September. The Philadelphia Stock Exchange Semiconductor Index was up 114% for the year through mid September.

The real leadership of this market from October 1990 to this year, has been technology. This does pose a very important question to many: Is it all over, or is there much more to come? I won't try to answer that, but refer to some aspects. First: Why the leadership of technology? Clearly this is what this conference is all about. The information age didn't begin in October, 1990, but it really accelerated from that time. It seems likely to stretch on for the indefinite future. This amounts to huge earnings potential for an array of new companies and of course some of the old companies.

It happened for other reasons to coincide with what's been a great phenomena in the securities business, which has been another major expansion leg for mutual funds. Mutual funds primarily have represented the most important demand for stocks in our market. There was a major interest in them in the 1960's, but it pretty well got snuffed out with the problems of the 1970's and we didn't see a renewed interest that is, a romance with mutual funds, until the 1980's began.

Over the last five years we've seen such a huge amount of money going into mutual funds such that 70% of all of the money now invested in mutual funds has come in the last four years. In 1993 alone, we averaged per month $10 billion dollars going separately in the bond mutual funds and equity mutual funds we have averaged $20 billion per month.

In 1994 the pace slackened a bit. It picked up again last November. So far this year, in fact in July and August were record months. It was a little different. It was different from the standpoint that not nearly so much money is going in the bonds. Not nearly so much money as 1993, is going into international equity funds. The major concentration has been in domestic equity funds.

Another major difference, which is important, is that a sharp increase in the proportion of this money is for retirement; retirement funds, retirement plans. Most of the major mutual fund companies say that at least 50% of their incoming new money is earmarked for retirement funds, which presumably means they are going to be more stable.

Much attention has also been directed to the Magellan Fund of the Fidelity Group, and deservedly so. First this fund passed an asset value this summer in the sum of $50 billion dollars. To put that in perspective, the entire mutual fund industry hit $50 billion in equities in 1983.

It's also remarkable and significant because this fund is run so boldly. You would think when an amount gets bigger and bigger it would be run more conservatively; but not so. The manager, Jeff Venik, makes very big sector bets. His biggest bet by far has been in technology. In June, from some 46% of his assets were in technology. Of the ten largest holdings, five were technology stocks, two of which were semiconductor companies: Intel and Micron Technology..

Other funds of the Fidelity Group also had 40% or more invested in that sector. As a matter of fact, earlier this week the Wall Street Journal had a listing of some 11 diversified funds with $1 billion dollars in assets or more that had between 38% and 70% of their assets invested in technology. This, of course, leaves out some of the specialized funds that invest perhaps only in technology or it might be in energy or whatever.

The driver of all of this growth is what's dominant in all our business today, namely performance. The portfolio managers, no matter where they are, are basically in the race of their lives. Basically this means that if they are behind they are scrambling to catch up. It meant that last year when most were behind, the first half of this year when most were behind, they recognized that technology was the lead horse. Many were using every pause in the growth trend, every price dip in the market was an opportunity to buy.

That led us to rather a feverish few weeks in June and in July, which was exacerbated to some extent by the beginning hype of Windows 95. It isn't just the mutual fund managers that have been under this performance pressure, but those who are managing pension funds, charitable funds, individual accounts. It's basically pervasive. The competition performance of our other funds, but also basically the standard reports of S&P 500 index. In turn technology has been an increasing component of that index. It's up to 13.5% of the total. Semiconductors have risen from 1% to 3.5% of the total. During this year there were two technology stocks added to the S&P 500, which were Applied Materials and Micron Technology.

As index funds have gained in popularity, and they are estimated to be about $300 billion in asset value, even though somebody is not making a specific security selection, nonetheless as money flows in those funds, more also is going into technology and specifically semiconductor companies.

There was a fraying of the group, starting in July, starting with the earnings warnings out of Intel and Microsoft. Over the last six weeks we had additional warnings. Last month and early October, Advanced Micro and Motorola gave us a warning. Clearly since July there have been some cutbacks in the positions by some of these major holders. Magellan which had been 46% in technology, indicated at the end of August to be down to 41%, and most others have also been trimming. There are indications that in the last three weeks the specialized funds, technology funds, have seen actually net redemptions. There is no sign - this is important - there is no sign that diversified mutual funds have seen any redemption.

There are some in Wall Street who are calling this a major top. The are alluding to technology as a fad, as a frenzy, as something like a disaster ready to happen. They point to stock price curves that have traced a parabolic formation.

They refer to conferences that have been overflowing. The Montgomery Securities Conference in San Francisco that attracted 1,800. Robertson Stephens had a conference and had 2,000 people. Our own firm, DLJ in New York had an emerging growth conference where we had 1,400 just a few weeks ago. Magazine covers have been showing many issues with Bill Gates, Andy Grove and some others. Comparisons have been made the past great booms in technology and crashes; 1961/1962; 1983/1984; skip one 1967/1969; and the question is asked who is left to buy?

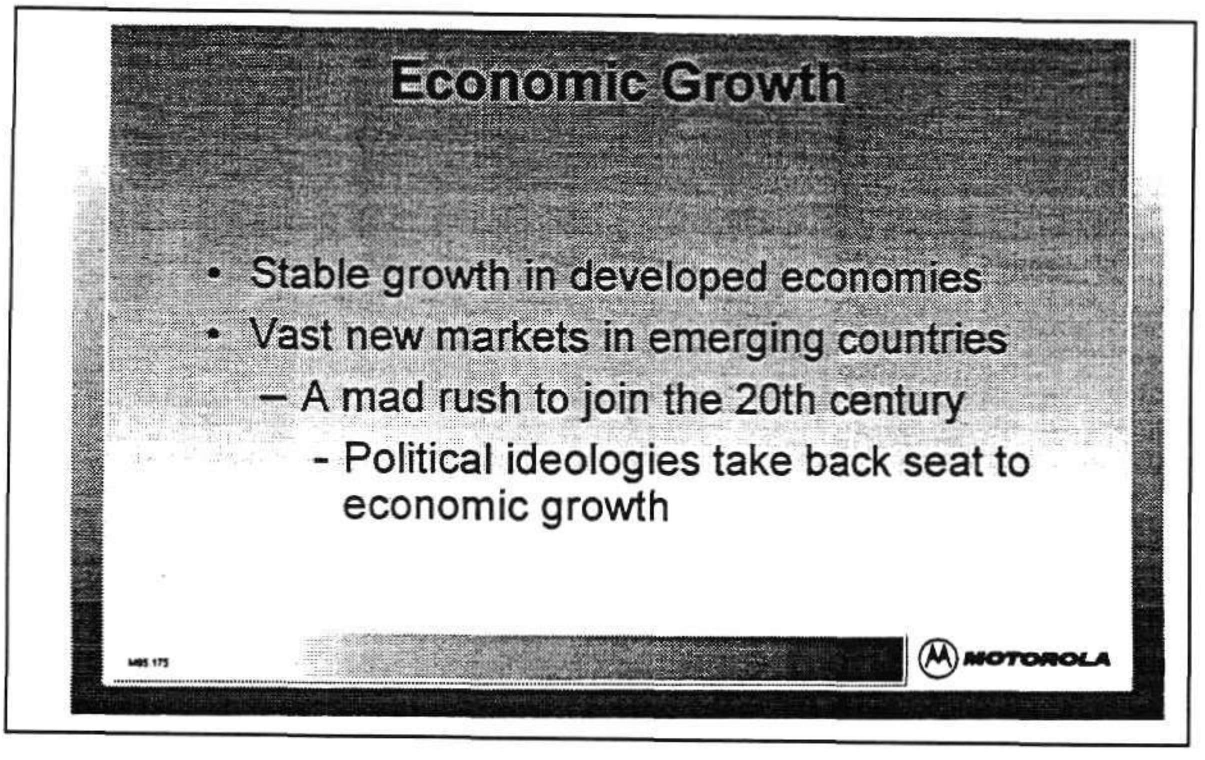
Our answer at DLJ is that this is a correction and a consolidation in this market. We don't think it's complete. We feel there is still a lot of anxiousness on some of those every court of the big gains, not to give them back therefore perhaps do some further trimming; especially as some of the worries regarding pricing and inventories perhaps aren't going to be immediately dissipated.

We do feel the long term fundamentals are truly powerful, and that this information revolution is more broadly based, more self-feeding then anything we've seen in the past. There is a lot more to come. An important question in our market is fund close. We doubt any early disillusion on the part of the public. As long as interest rates remain relatively stable; which we think they will, we feel good about technology. I don't disagree with what Mr. Duncan said a little bit earlier. We feel basically that our economy is likely to remain much smoother and much healthier than some specific markets, some of which are likely to have a much more volatile and emotional character of stocks. It involves funds, it involves challenges; the selection I think you will be better geared to make during the remainder of the conference as we hear some more specifics. Thank you.

SEMICONDUCTORS: THE BUILDING BLOCKS OF A NEW WORLD ORDER

Panelist Harjit Bhalla:

Good morning. Glad to be here. We've heard a lot about the semiconductor market and how its complexion is changing. Just to put it in perspective, in 1993, when it grew 29%, everybody was kind of a little cautious, a little wary. In 1994, it went up about 31% and there were whispers of remember 1985? My God, this is it. It's about to blow. In 1995, the thing is poised to grow 40%. All of a sudden now we realize that we may be looking at a different market. It may be a different beast then what we have been used to before.



I am going to touch on three factors that I think are contributing to the new complexion of the semiconductor market. The first factor I think has been touched upon in detail by Joe and by Gene is the economic growth; two aspects to it. One is a more stable growth in the mass economy, and I think that's stemming from the fact, from what was referred to before as the global interconnectedness, and the fact that no one country now can manage its fiscal and monetary policy without regard to maintaining to stable posture without being punished by capital growth and things of that nature.

The other phenomena that is there is probably going to have in the long term a much bigger impact on the total market, which is the emerging of these new countries that we have been hearing about: Russia, China, East Europe, India. These counties are coming out of various parlitarian rules. As a matter of fact in China right now there is a big struggle to balance the economy that controlled politics and how that goes we'll see. The fact of the matter is that all of these countries are going to show very high growth rates, very high growth in personal income; a lot of consumers and billions of consumers and trillions of dollars of purchasing power. That is all going to feed - not all, but at least a lot of it - is going to feed into electronics.

The second trend I think is critical that we've been hearing about the new applications. My take on that is what is really doing it is that the electronics are having a real impact on the lifestyle of the consumer. This is no longer a business phenomena. We are not talking of passive devices like telephone or TV. When we talk about a PC and we've heard that the growth is coming from the home, the PC in the home is not the same as the PC in the office. The PC in the home - and we use the term multimedia, a generic term again - but the PC in the home is an appliance. It is to educate, to entertain, to get information, to send information and to be connected. Actually networking and the need to be connected is what is driving the lifestyle of the consumer.

To me that is a very fundamental change and it's not the old time game. It's not the old time mobile radios and stuff like that that comes in one year and goes out the next. This is here to stay. The beauty of the PC is that it has the capacity to evolve. That is what is going to make this market different in the future then what it has been in the past.

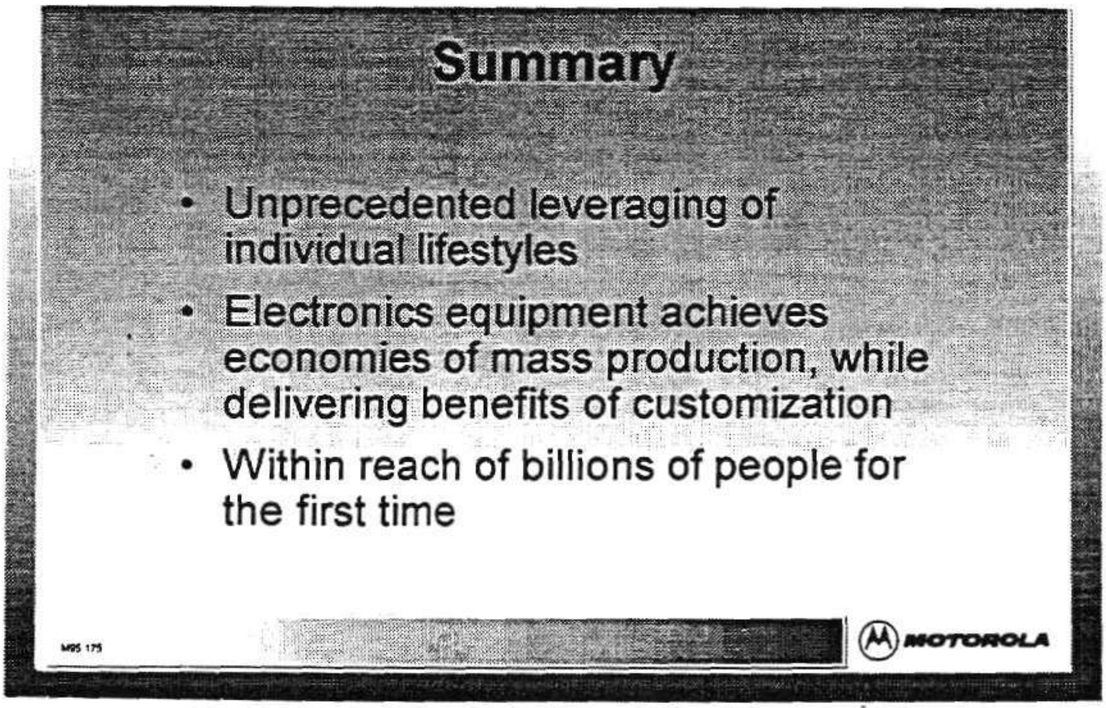
This phenomena is not really only restricted to the advanced economies. When you look out to these emerging countries, consumerism is rampant. They want the latest and the greatest and as soon as they do have the money - and they have a lot of money - they go out to buy these things. Those markets are by no means mature. It is not that we are dealing with mature markets.

It is not that we are dealing with products that are going to reach a certain level of performance and then level off and become old hat. That's number two.

Number three I think is really what gives the kick to the future. We all talk of convergence. To me convergence, hides a much larger meaning. I view it as equivalent to a big bang theory; it's a point of similarity. Everything comes together and then bang.

There's an explosion and you have new markets. These markets really will be new. They will not be linear extensions of what exists today. The shape of these markets will be determined by the value to the consumer and how it adds to his lifestyle. From that rubble - if I may use the term - new leaders will emerge. There will be shifts in the leadership. We have seen that happen before when we went from radio to TV, from tubes to solid state, from mainframe to PCs, from a few networks to a lot of channels on the cable.

Nobody has a legacy right in this market. To assume that you can add two and two and come up with the answer I think will be the wrong strategy at this point in time. These markets will be defined in the future and there will be false starts. It will be an evolutionary process, and it will be a process of the natural selection from the Darwinian theory of evolution; the fittest will survive.

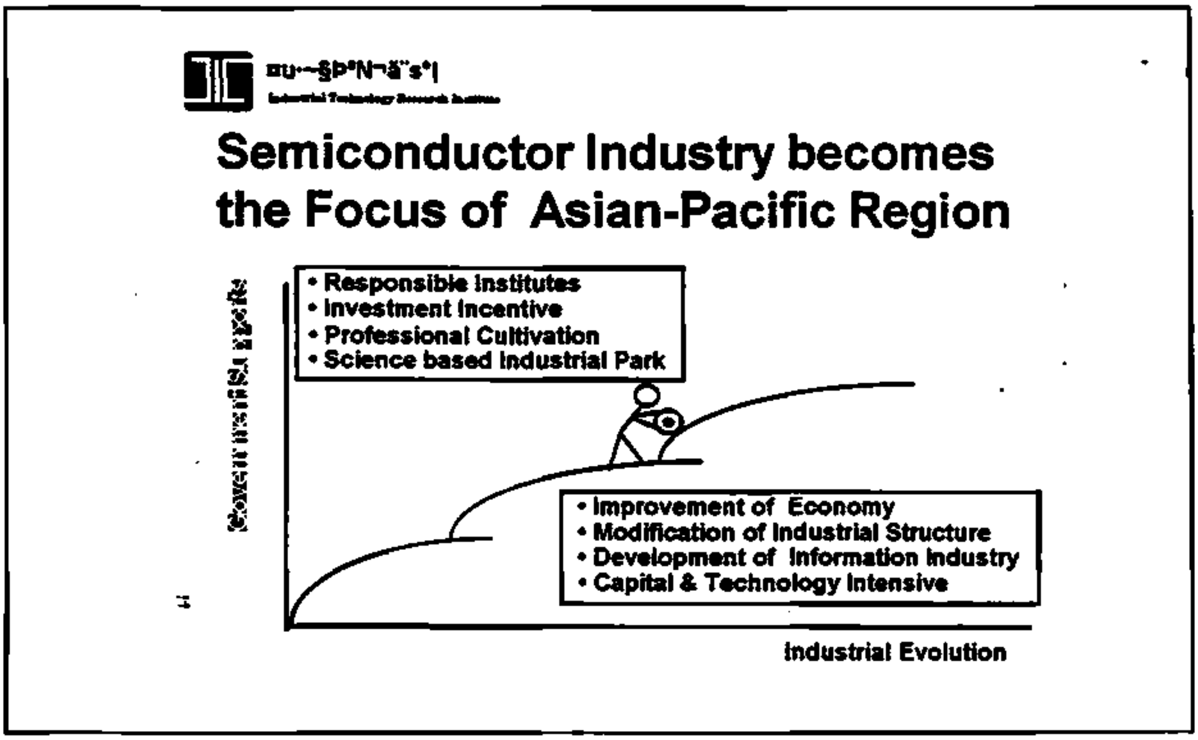


In summary, basically there's a time coming in which the consumer will have unprecedented leverage on his lifestyle in electronics. The electronics are gaining ever more capability and affordability, and there will be billions of new consumers looking for these products.

Just to put it in a slightly different perspective then what Gene did, I'll take the time frame from 1980, 1995 and 2000. In 1980, most of the consumption was in the advanced economies for the semiconductors and when you look at the market it was about $14, $15 billion dollars and about $15.00 per capita consumption. It moves up to about $45 billion dollar market and about $47.00 per capita consumption in 1990; that's tripling pretty good. In 1995, the market is going to be $150. This is tripling in five years. When you add in the extra kick of the consumption that is still to come from these emerging economies, we will have hundreds of millions of new affluent consumers in the future. We are not talking of a peasant in a hut. The tripling of this market almost seems to be a given over the next five years. Thank you.

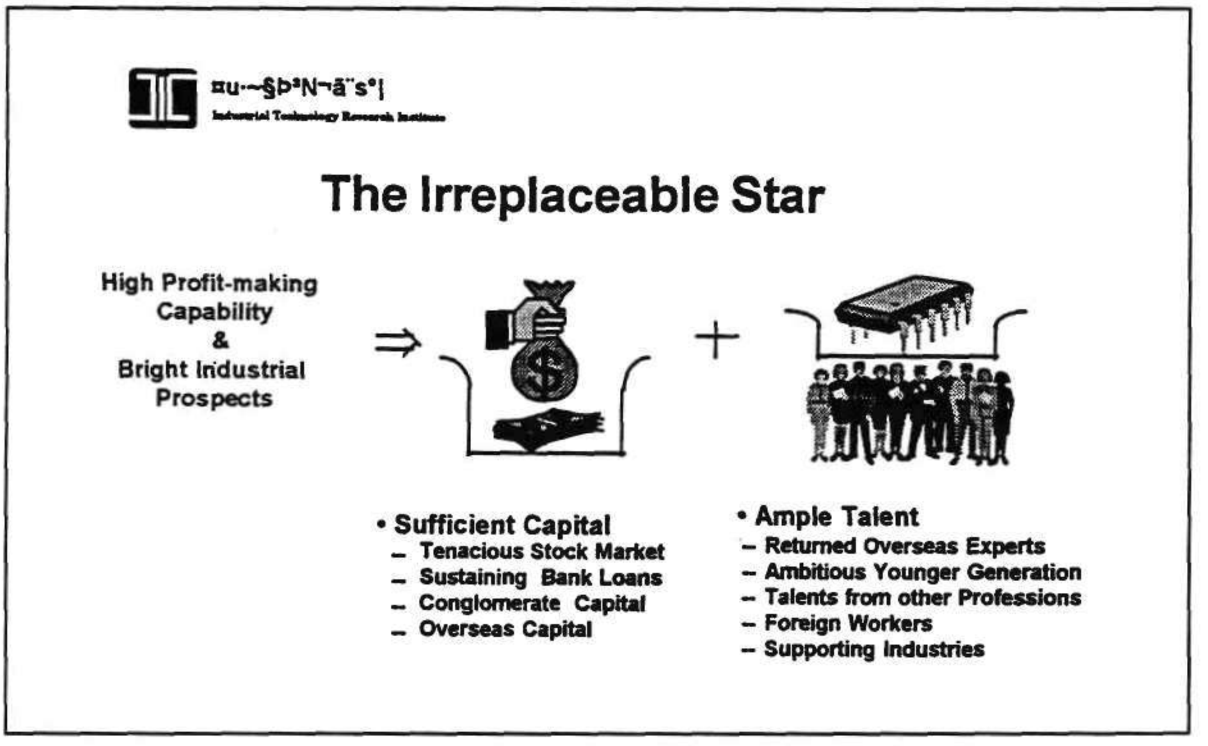
Panelist Chintay Shih:

I would like to point out that as a previous speaker already indicated that Asia Pacific will be the most important market and a major player in the next decade in the semiconductor industry. I would like to give you some of economic indexes for this region.

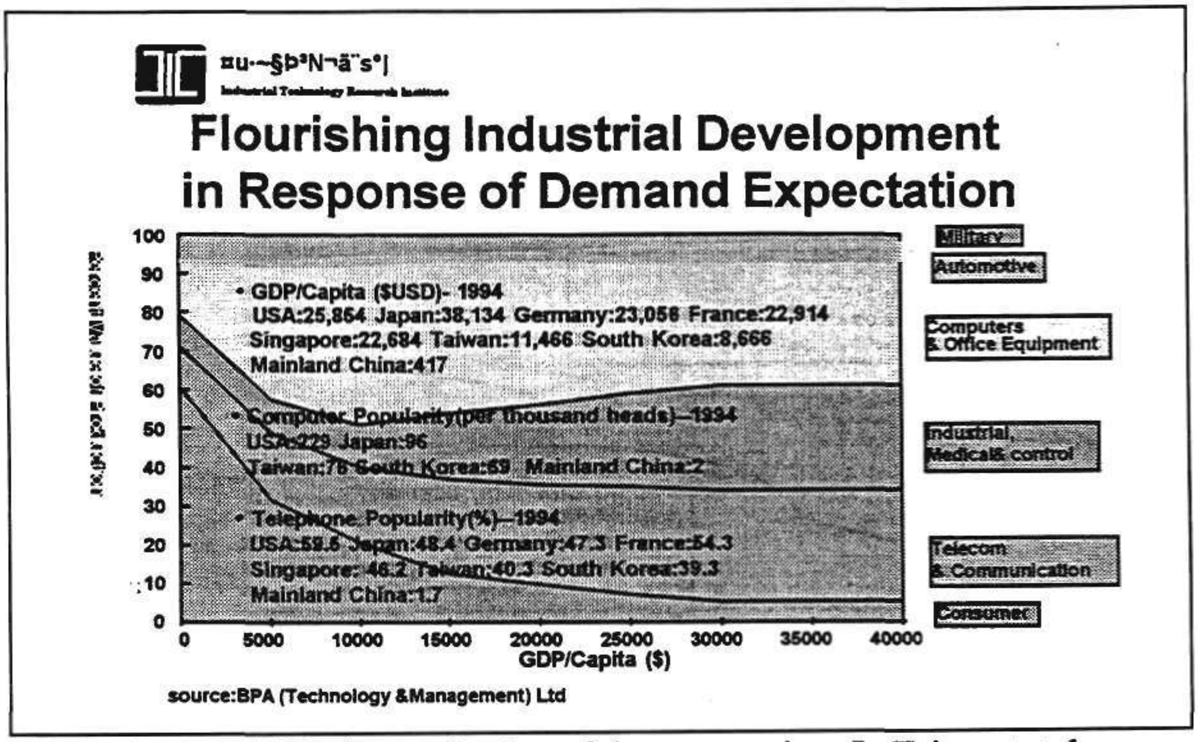


For the Asia Pacific region, the most important part of course is Taiwan, Korea, Singapore, Hong Kong, China, and the rest of the Asian countries.

Look at their economic growths for the last 30 years. It has been very impressive. The four dragons, or the four tigers' GDP growth rate has been in the area of 15% over the last 30 years. In 1965, their total GDP for these four countries was only 1.3% of U.S. GDP in that particular year. In 1995 - this year - the GDP in these four countries will be $720 billion. That is about 11.5% of the U.S. GDP.



The government in this region particularly plays a very important role in their industrial structure transformation, and with accumulated wealth, those countries - particularly Korea, Taiwan, and Singapore - were very actively promoting the high tech industry; especially in the information industry.



Look at the year 1994, the production of these countries: In Taiwan total production was 11.6 billion in Singapore: 11.4 billion. Korea: 5 billion. China: 2.1 billion. Total of them producing 14% of the world production of electronics. Taiwan and Korea particularly enjoyed 28% growth rate, 8.6 percent for the total world over the last decade.

The many governments in this region have specifically encouraged and in fact provided tax incentives to establish a good infrastructure in areas like science and industrial parks. I'll give you an example: In Taiwan the science park is probably more densely populated than Silicon Valley. Within about ten to 15 minutes drive, there are 17 IC factories and there are 14 more being planned.

The Taiwan and Korean IC industry specifically have shown a very high growth rate, and also a very high return on investment. The ROI has supported a huge investment in the recent years. In 1994, the IC investment in Taiwan and Korea was over 3 billion, equal to a month investment that U.S. semiconductor manufacturers invested in 1990. The growth rate of the capital investment has been 25% for the last four years.

The wafer consumption resulting from this investment completed through the 1997/1998 period will be over 680 million square inches, which is the level of U.S. silicon consumption in 1993.

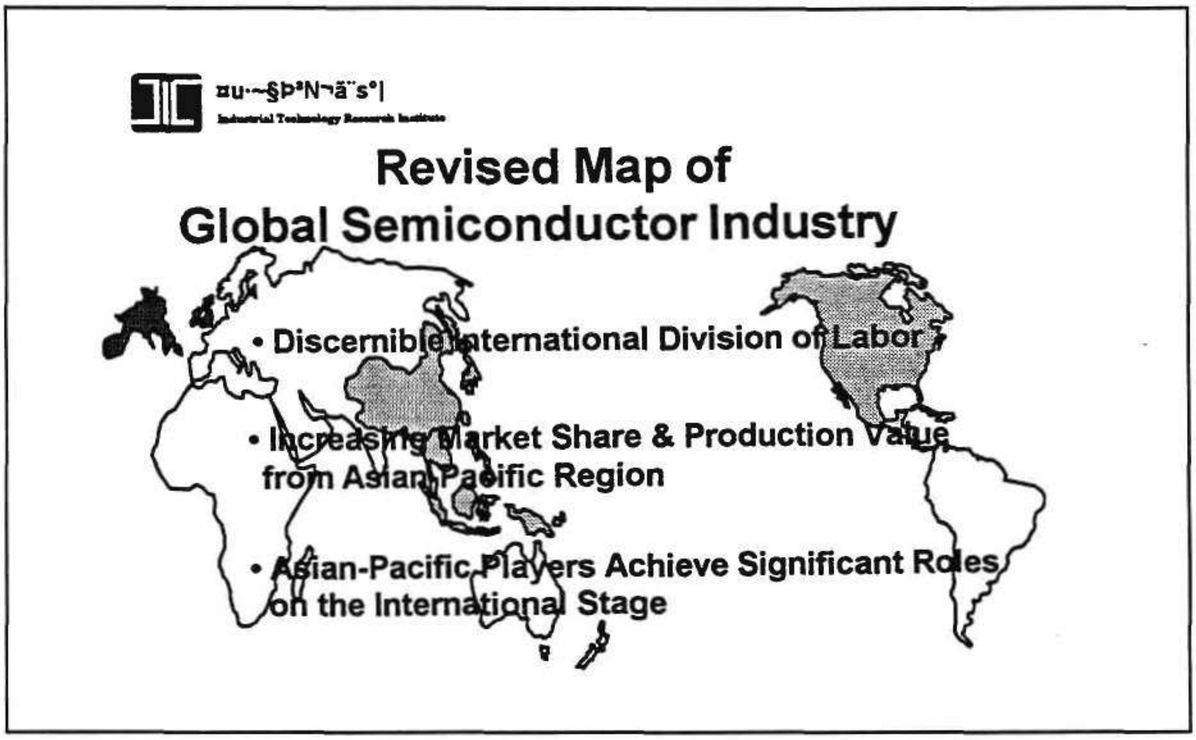
There seems no shortage of capital and no shortage of human resources. Mainly because of the good education system in Taiwan and Korea, and also due to the now returning engineers who have worked in the United States as entrepreneurs. These entrepreneurs have become the major entrepreneurs for new businesses in Taiwan.

Take Taiwan for example: Returning Chinese engineers represent about 1/3 of Taiwan R&D manpower in Hsinchu Science Park. The supporting industry has also gradually built up in Taiwan and Korea. Examples include the photomark services, design companies, assembly of silicon wafers, and other equipment support functions.

Will this situation continue for the next five years? Lets look at their performance. The four tigers' have only 1.5% of the world population; however if you include China, this would be 1/3 of the worlds' population. The four tigers' plus China's average economic growth rate has been four percentage points more than the average of the world in the past, and is predicted to continue over the next five years. Although the four tigers' population is only about 1.5% of the world, the total trade is 14.4%, and foreign reserve is 16.6%. With a high growth rate of the computers and communications equipment, the demand for semiconductors will exceed the investment of suppliers. So demand will exceed supply.

Just by simple calculations, let's look at the computerization of this area, Taiwan has only 76 PCs per 1,000 people, Korea 69, and China 2; versus 229 per 1000 in the United States. This would mean that if computerization in this region would be equal to the U.S. level, that would mean 6.5x of today's PC market.

In the telephone market, penetration is low also. In Taiwan it's 40.3%, in Korea 39.3%, in China has only 1.7%, versus 59.5% in the United States. In this region manufacturers would need to install over 700 million lines to reach the level of the United States today. That is truly a huge market.



In conclusion, I think it seems that Asia Pacific has achieved success through the international division of labor. For example, Korea is now a big player in MOS memories. Over 95% of Korea's IC output is now in memory. Taiwan is dominating the foundry. One-third of their production capacity is in foundry.

There is efficient and cost effective chip assembly and tests throughout this region. In 1993, this region has produced more ICs than Europe.

There are eight companies from this region already in Dataquest's top 50 list of all IC producers. With the success of foundry services provided from TSMC and so on, several U.S. IC companies will also be able to grow beyond a billion dollars. Cirrus Logic is a good example.

The foundry business could become the next major growth for this region; Charter Semiconductor in Singapore, Softmicron in Thailand, and three more foundry alliance companies which have been created by UMC. Several more are coming from Taiwan investors and two will come from Korea investors.

The demonstration effect for this region: China is aggressive and perused IC investment and there are many IC multinational companies in Japan and U.S. and

Europe seeking joint ventures. Malaysia, Indonesia are setting up facilities for IC development.

Overall, the Asia Pacific region will continue to invest in the semiconductor industry and become a big market itself. There will be more significant players from this region in the future. Thank you.

Panelist Martin Reynolds:

Normally I get to talk about all of this boring technology stuff. Today I have maybe some slightly broader viewpoints to go after.

I would like to start with a question and I'm asking for a show of hands if you would participate with me. How many of you here really think that you get a good deal from your banks? How many of you here think you may be don't get the best deal and the best service from your banks?

How about cable companies? How many of you think that maybe your cable company could give you perhaps a little better service in exchange for all of that money that you give them? Okay, thanks.

What I am looking at is this little thing that looks like a ladder on the left. What I want to talk about first is the rate of change. We as people live for the moment. Somebody once said that life is sort of like a ladder and you are walking up the rungs. Of course, the closest rung has a very big gap. That's sort of today. The most important time in your life is today. The next rung down is a bit smaller and that's yesterday. Then the rung after that is smaller still and that's last week. Then we start getting into last year, and then the last ten years, and the last 50 years.

What this sort of comes to is that things never change as quickly as we expect in the short term, but in the long term we always kind of get over run by them. It always changes faster in the long run.

Where I thought I would start with this was with communication costs. Today there are kind three ways that you pay for communications. With a cable company you pay an access charge, kind of a flat rate every month. With Internet you may pay an access charge, which is a flat rate; or you may be measured, how much time you spend you pay for. With the telephone company we have something called tariffs. The tariff is kind of like a license to steal, because it means that they set the price that you pay and they all kind of keep the price high because they sort of own the whole business. I think there may be some room to change there.

I look at what it costs me to send a megabyte of data to Europe just the other day. I did it by telephone. It cost me about $8.00 with a 14.4 modem. If I use ISDM, it's about $2.00, about a quarter of the price. If I use the Internet, it costs me about $0.25. If I use ISDN Internet, we're down to about $0.06. You can see here that there is room for some change. As bandwidth increases, and as things like the Internet become more prevalent, we are going to see a change in the way and how much we pay for data transfer. In fact, at some point in the next few years we will find that data access costs become independent of distance. In other words you pay for the time you use or you are going to pay a flat rate for the access, but where you call is not going to be important.

Communications cost is one thing, but the next piece of the puzzle is bandwidth. That's where the semiconductor guys come into this. Silicon drives bandwidth. To handle the kind of data we are going to be seeing going around the world in ten to 15 years time, we are going to need gigahertz modulation. We are going to need tremendous compression. All of this is going to drive innovation in the silicon and the system industries.

What's enough? Well, with telephony it's about four kilobytes per second, which is really pretty easy. You can do that on an analog system. Video conferencing: Maybe 15 kilobytes a second, something sort of like that. High quality sound for CD-ROM, CD type quality: We are looking at about 30 kilobytes per second with some advanced compression. Motion video: You are up to about 150 kilobytes a second for something that the average consumer is going to say that's okay. Then for high quality video, you are looking at about one megabyte per second, for really high bandwidth, high quality communications. That says we've got to have things like ATM and Internet speed coming into people's homes all of the time. All of this stuff will come. We are going to see this bandwidth.

When you put the bandwidth and the communications together, what do we really find when it becomes essentially a flat rate cost to send any kind of message anywhere and that cost is very small? My belief is that the PC, or its derivative, becomes the telephone of the next decade.

That makes me think a little bit about cars. If we gave everybody in Asia a car, we'd run out of oil in five to seven years if they used them, which they would. You can't give everybody in Asia a car to develop the economy. You've got to give them something else. The PC becomes the tool to help those economies grow.

What that means then is that white collar work starts migrating away from metropolitan centers. Telepresence, the ability to be performing your function independent of distance becomes a very, very important feature of the next decade. What that means is that work goes perhaps where the environment is best. There will be a lot of people moving to places like Palm Springs to live and work. They can afford it. They will also move to where cost is the lowest. The industries that are really at risk here I see as banking, insurance, any kind of finance, sales, support, service. All of these industries become at risk when you start putting this kind of telecommuting Telepresence system together.

In fact, the industry that I decided to pick on today is banking; cable we'll save for another time. I got to thinking that when I have the Internet I don't need to write checks any more. At some point I am going to be able to send a secure encrypted message across the Internet to get my bank to do something with my money. Then I thought well, where will this bank be, because it's on the Internet. The answer is it really could be anywhere. It doesn't have to be in the U.S. That means that it's not going to be subject to U.S. taxation rules and I'm not going to face the paperwork I might have to do for moving money around.

I got to thinking about this some more, and probably in 15 years (2010) we'll find that 80% of the volume of all financial transactions in dollars will be done on the Internet. Then you get to thinking well, will that be Bank of America? The answer is it doesn't have to be. It could be something totally new. The potential to go beyond money somewhere in the next decade, where the Internet really becomes the medium by which we move these financial transactions around; when that happens government, banks, the major institutions begin to loose control as they've had in the past and we become even more a free market.

You see countries today trying to cut off the Internet. They think they need to shut down this kind of access. The truth is without the Internet they won't have access to the global economy. The Internet proves the magic of semiconductors and systems. It's going to turn into this global thing that cannot be controlled and become an individual entity to itself that everybody participates in.

I think there is a big threat here for the banks and some of the other industries. We'll know in 15 years whether I was right or not.

Just to kind of put this in perspective, I'd like to throw up a few lost causes. You probably remember the mechanical watch, the ones that ticked like tick tock, tick tock, instead of click click on the little numbers? They're kind of gone now. I found a calculator in my garage the other day with a little handle on the side and you turn it and it rings. A wonderful piece of equipment, tremendous engineering; they're of course all gone. Slide rules? Vinyl records? Then you get into the endangered species like mainframes, travel agents, banks, insurance salesman, photographic film, newspapers, magazines, large telephone banking and insurance companies. All of these businesses are at risk over the next ten to 15 years as this information revolution brings more capacity, more function into the home and business.

Really what I would like you to think about is how semiconductors can participate in that. How you continue to drive bandwidth and functionality and continue to drive systems that meet these needs. Thank you.

Moderator: Thank you, Martin. I'd like to ask the panel a question and have each person give a quick response to it. It's a question that has been on many of your minds, on my mind, and many of the people in the financial world. "Has the semiconductor industry really changed so fundamentally in the last five or ten years such that we can expect to have more continued, smoother growth in the future, rather than the bumpy growth that we've had in the past?" How about we start down here with Eric.

Panelist: Yes, I think so. I think primarily because some of the major companies are investing so much more in the long term. Their technology is leaping ahead at such a great rate, it's become more and more self-generating.

Panelist Harjit Bhalla: I guess relatively speaking the answer is yes; but in absolute terms I think the industry would go through periods of slow growth as opposed to 30% or 40%. I think what is going to happen is that the whole cycle shifts up. The base becomes 12 or 15, as opposed to minus 20 or minus 15 that we've seen in the past sometimes. Mainly because the life cycle of the electronics equipment is very high. If the economy holds up, then the only thing that will drive it down is a lull in the particular equipment life cycle.

Panelist Joe Duncan: Frankly I don't look for a smooth course at all. We are - as this session is labeled - facing a new world order. Let me just deal with two quick aspects of that.

In the 1960's and 1970's, the concept of industrial organization was vertical integration to everything under your control. In the 1990's, it is quite the reverse. It's alliances, loose relationships. Jobs growth has been in small companies, not big companies. Industrial organization today is incredibly different than it was just 1/3 of a century ago.

let's look at the population for example. We look around the world at the big economic sectors like China, which 30 years ago was very small in terms of its middle class population. My estimate is that in the last five years we've added 100 million middle class households in China. In India nearly the same number.

In terms of education, China has a literacy rate of 90%; India only 50%. If you look at the upper educated people, the relative education in India is 6x that of in China. Then you add in the former Soviet bloc. There we find highly educated populations who have been starved for consumer goods for over 70 years. You will have a cumulative demand on the consumer side. The question is how do you make that real? I think you make it real by the fact that the 1989 marked the end of the cold war. We are now trying to redistribute money and moving planned economies to market economies. That's creating totally new economic structures. I think the technology point you made about bandwidth communications are driving forces, but it's going to be an environment where you have economic, political and social revolutions. It's not going to be easy.

Panelist Chintay Shih: I think that I look for continued growth as a result of high growth in communications. It used to be that businesses were the sole consumers of information. But now because the PC has penetrated the home, there are new users of information. PCs are going to create many new applications. Because of these new applications, there is more semiconductors. If you think the demand is high now with increasing wealth in countries such as Taiwan, Korea and China - I think this growth will be phenomenal in the future.

Panelist Martin Reynolds: I think the key here is that we've got really pent up demand for all of these technology. As long as you can supply it, the market will just keep growing. However, there are groups of people in this world that don't quite understand that and run a different agenda. You find a lot of them in Washington. They are quite capable of doing something that could potentially derail this whole industry for a couple of years.

A very simple example: If we assume political problems in the Korean peninsula reach the point where Koreans lost DRAM production, you can see the whole PC industry would just stall. If we went back to days when there literally wasn't enough DRAM to meet the demand by PCs, then the whole industry would be compressed by this shift.

I think barring that kind of major political problem, we're set for growth for the foreseeable future.

Moderator: As I alluded to in my speech, the importance of low interest rates and low inflation is really critical to forecasting the electronics industry and the semiconductor industry. Looking at world perspective, do you think Joe Dunan, we can feel secure that the people who are handling the valves today will be making the right decisions two years, three years down the road?

Panelist Joe Duncan: Let me counter that or answer that by saying the people that are handling the valves don't have any control. I'm dead serious. If you think about global financial flows today, they are fundamentally electronic in character. They are not even traced through the central banking system. The central banks play a very small role when you have mutual funds holding the great quantities of financial resources, when you have organizations like GMAC funding the car loans they are taking away from the banks and on and on and on. The mythology that there is somebody out there pulling the levers of international finance just doesn't hold anymore.

On top of that, when you talk about financial flows, let me give you a couple of numbers. If you look at the total volume of speculation in Euro dollars alone, it's 60x the total value of world trade for the year. Neoclassic world economic theory said that your trade deficit determines your exchange rate. If you have speculators operating at 60x the volume of trade, that old economic theory doesn't hold.

I really don't think that interest rates in a policy sense are a driver of this. I do think you have to look at what's likely to happen to inflation rates and one of the great benefits that we have in the world economy today is efficiency and productivity gains are being seen around the world. That's taking pressure off inflation and giving people a higher standard of living, even though we may not be able to measure a national output correctly.

Moderator: Eric Miller here is a question for you. The U.S. semiconductor and other high technology companies are having an increasingly larger impact on the world's stock markets. Will we then see these other international markets become more volatile in the future, such as in the Asia Pacific or in Europe?

Panelist: First, those other markets are more volatile already. There are fewer major stocks that dominate that market. That will change as the economy starts to grow. Their markets are increasingly tightly linked. They may not be moving in lock step, but the magnitude has changed. I think that the world markets increasingly move in the same general direction. I think for some time to come the markets abroad are likely to be more volatile then our own.

Moderator: I'd like to ask Martin Reynolds a question about some of the aspects that he sees in the electronic industry. Today 80% of the business use of computers we're finding is spent communicating, E-mail and the like, rather than computing with the computer. What applications do you see coming along in the future that may change the usage of computers?

Panelist Martin Reynolds: I think probably the single biggest application is going to be when computers gain the ability to really recognize speech. Unlike handwriting recognition, I am absolutely confident that that day will come, probably in the next five years or so. Once that happens, we'll start actually talking to the computer and having the computer begin to first of all write for us and then begin to work on spoken commands. It is probably going to be the most significant change of the next five to ten years in terms of the computer on the desktop. Still it's communication.

Panelist Chintay Shih: I agree that probably in the future that the computer will be spoken to; but still the use will still be mostly for communication; for example the video conference. Again although there is a lot of computing involved, still the principal purpose is communication. Human interface, such as speech recognition, intelligence agent, would be mostly increasing the function of communication.

Question: I'd like to ask Dr. Shih a question. In Taiwan I know there's a policy you follow of looking for domestic self-reliance. Where do you see investments in equipment making going from here? You import most of your semiconductor equipment, correct? Do you see Taiwan and Koreans investing in this area eventually?

Panelist Chintay Shih: There has been some discussion about equipment or material supply situation in Taiwan. In the past most of the investment or the research funding are going into the semiconductor technology. Because now there is $15 billion investment in semiconductor manufacturing using 8 inch wafers, it seems that we are gathering the talents in Taiwan to begin to look at the development of semiconductor manufacturing equipment. There will be some - I think in the future - maybe some investment will go into this area. Of course, Taiwan is still a small part of the world semiconductor industry. Right now it's only about less than 3%. Even with all of this aided capacity, I would think that the market share would remain between 5% to 10% in the year 2000. It's still not really a big market for manufacturing.

I think the approach may be would be more of a joint venture in this area.

Question: I'd like to ask this question of Mr. Reynolds. My wife often cautions me to make sure I don't use my credit card over the Internet. What do you think it's going to take to overcome the consumer reluctance to use this commerce or as buying and selling tool? Also, I want to tell you my watch still clicks.

Panelist: There is a big concern about security with the Internet, but my belief is that absolutely that it can be solved. We have kind of a bunch of blindfolded men bumbling around trying to figure out the solution at the moment, but they do seem to be going in the right direction. One of the keys is that security will to some extent depend on your physical presence. You will have to be with the computer, typing in your password, to generate a highly encrypted message that goes across the Internet. Not within the next year or the next two years, but certainly within the next five years I think we will be very, very comfortable doing business across the Internet.

Question: I'd like to address this question to Mr. Duncan and Mr. Miller. We've sort of seen a consumer love affair with PCs and electronics. That's driven a lot of our success here. At what point do you think the consumer kind of hiccups to digest the technology he's got and how does that play out? Does that seem to be happening to you? Do we have any analogs from other consumer products as to how they've kind of grown in fits and starts?

Panelist Joe Duncan: I think in some way that has been touched on several times this morning. Perhaps the quickest thought I would have in terms of an analog is television, which when it was introduced was a slow introduction to the household. There were early adapters of television. The early adapters were willing to put up with snowy screens where you couldn't really see the image.

Then we went through a series of modifications. The first big revolution (of course) in television was color. Today it's not uncommon for households to have several color television sets. If you look at their use over the day, many of them are sitting idle most of the time; much like our computers which are sitting on our desk idle. I think there is some analogy there, but over time they became just a part of the household way of life.

Computers haven't reached that level yet, but I will tell you that personally I have a LAN at home. That means I have a home local area network where I have my server and my printers and my heat generating equipment out in the garage. I have a couple of computer work stations so I can work in whatever room I want to work in. I am not saying that everyone will do that, but when the children start competing - as I said earlier - to do their homework with the mother who wants to do finances and the husband who wants to write a report, you'll have relatively key terminals hooked in to household network. If you think about that in terms of consuming semiconductors, sure consuming lots of semiconductors to run that network. I do think there is that analogy.

Question: (Inaudible)

Panelist: We had the latter analogy of looking backwards. All you have to do is look backwards in time at ATF tariffs and ask yourself how quickly did that change? It was convenient. It was utility. Mr. Pesatori talked about this subject this morning. Plug and play is a little bit of a dream from my point of view. I haven't gotten plug and play to work, but the concept is interesting. That's the industry responsibility to in fact get those standards and to get the support system to go with it. It's not just reliability, it's usability.

Panelist Harjit Bhalla: If you look at a video game it truly is plug and play. You plug it in and you play. What's important to consider is that today's 20 to 30 year old were brought up on the video games five to ten years ago. They have the willingness to adopt technology and the ability to use it if it's right. And - by the way - they also spend almost all of their income on their habit; an important point.

Question: This question is addressed to Dr. Shih: You mentioned a couple of times about 18, 8 inch FABs and about $15 billion dollars of capital spending. I have five questions regarding that issue. First of all, over how many periods of time? Is that from 1995 to the year 2000?

Answer Chintay Shih: The amount is 18 FABs. They are all announced I think, except maybe for two or three. The others are already either in construction or are planned construction in the near future. I would say this commitment will be for the next two or three years.

Question: My next question is most importantly in your estimate, how much of the $15 million dollars do you think is going to actually happen?

Answer Chintay Shih: How much of this investment will really happen? I would say 80% would be real.

Moderator: We are out of time. I would like to thank our panel for tackling this very difficult topic.

There is one thing for sure; we know that semiconductors are going to be increasing important to the electronic industry as we see with almost every area of electronics: PCs to cars to cellular phones. I'd like to thank you all for your very interesting questions this morning.

Chapter Seven: THE NEXT STEP IN HIGH-SPEED INTERFACES

Geoff Tate
President and CEO
Rambus, Inc.

Introduction:

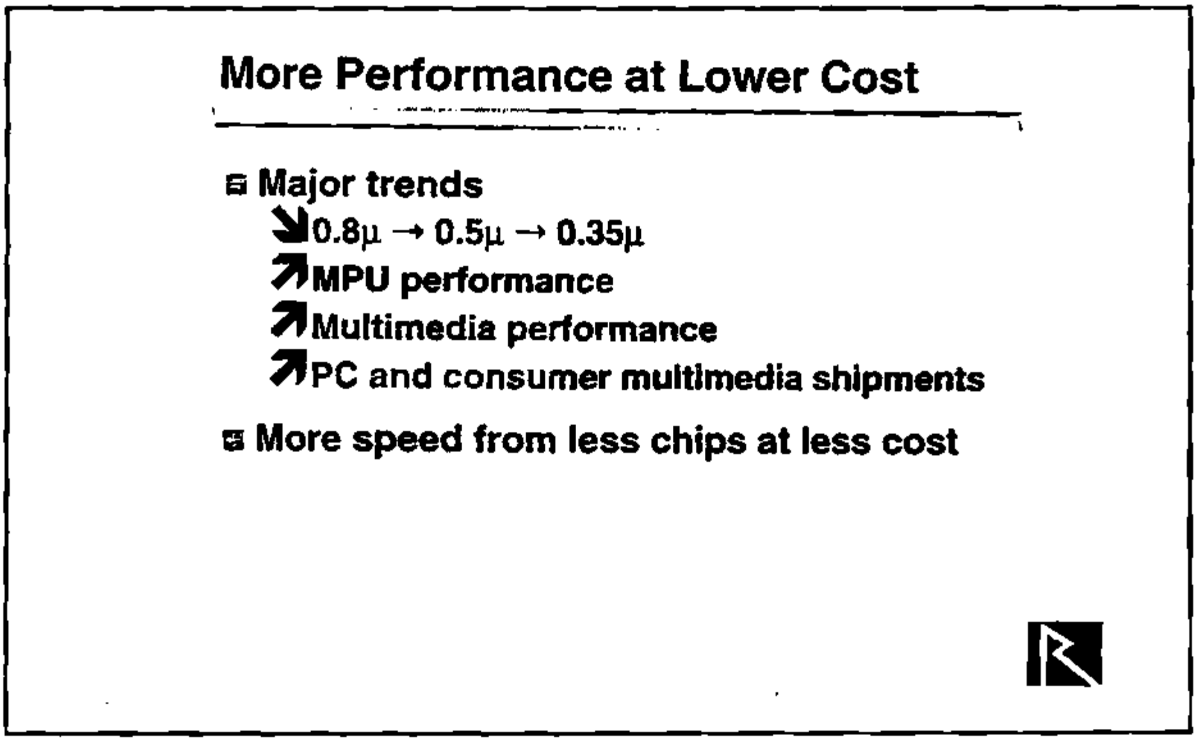
Our first session this afternoon is going to be a discussion by Geoff Tate, President and CEO of Rambus, Inc. Mr. Tate joined Rambus as President and CEO in 1990, during the company's first year of operation. Mr. Tate previously held positions of Senior Vice President and Corporate Officer of Advanced Micro Devices, responsible for all microprocessors and peripherals, including the Intel compatible X86 and 29,000 microprocessor families. He was with AMD for over ten years.

His earlier positions included managing the Bipolar Gate Array Business Unit, the PLD Business Unit and the Microcomputer Business Systems Unit.

Geoff has a BS Degree in Computer Science from the University of Alberta and an MBA from Harvard and completed his MSEE course work from Santa Clara University. I know most of you in the audience know all about Rambus, but I'm sure Geoff is going to tell you things you didn't know about Rambus and where we're going with the new high speed interface technologies. Please welcome Geoff Tate.

Geoff Tate: Thank you, Gene. To explain some of the basic trends that are going on will require a little bit of getting into some technical detail, but I promise I'll move through it pretty briefly at a high level and end up with some interesting real life examples.

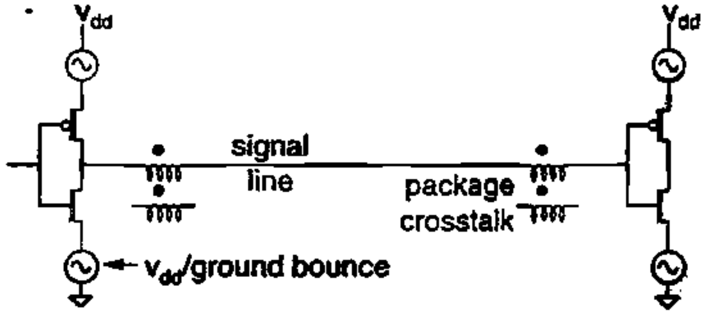
The traditional methods for interfacing and moving lots of data between chips are running into physical and economic limits as performance and integration climb in high volume systems. Why is that? There are some significant trends going on. You are all aware that processed technology is integrating, moving from .5 to .35 micron in the near future. This process technology is driving the performance of all matters of logic devices, microprocessors and multimedia, and driving the increased growth of high volume, low cost PC and consumer products by lowering the price point of these products.



The end result is that in these high volume systems what's required in high speed interface is a lot more speed from less chips at less cost.

As technology is scaled, we are seeing on chip clock speeds gaining pretty much linearly, or even faster. 100 Megahertz microprocessors are becoming routine; but off chip clock speed, using traditional CMOS, IO and wide BUSES, things are running into some physical limits around the 66 to 80 Megahertz area, certainly less than 100 Megahertz. I'd like to explain a few points as to why that is.

Problems with CMOS I/O



- Package bounce & crosstalk affect I/O levels
- Noisy outputs: rail-to-rail, fast edges
- Not well suited for transmission lines

Off chip IO using traditional CMOS IO techniques have a lot of challenges at the speeds we're running at. Certainly CMOS IO when it was developed was never intended to run at the 50+ Megahertz range. Traditional IO approaches do not take transmission line into account, but at these kinds of frequencies all PC board connections become transmission lines, it's a matter of fact.

Noise

- SSO (simultaneous switching outputs)
- Cross talk: leadframe, printed circuit board
- Made worse by
  - Bigger swings
  - Bigger packages with larger leadframes
  - Faster edge rates
  - Faster clock speeds

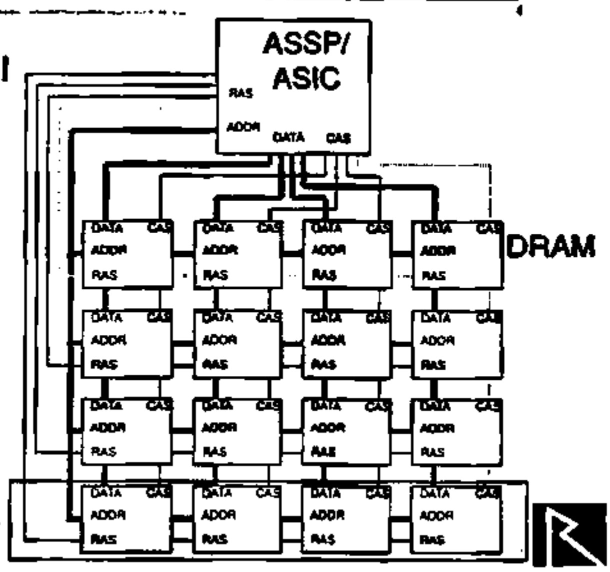
Noise is a big problem at running at high speed. Noise comes from a lot of things: Simultaneous switching outputs, cross talk between signals, faster rates that are required for higher frequencies.

Skew is another big problem I think a lot of people also overlooked in the past. Data to data skew, clock to data skew, chip to chip skew.

A traditional approach to get higher bandwidth in systems using CMOS IO besides turning up the clock frequency has been to go to wider and wider buses. One of the results of that is bigger packages, but the move to bigger packages means larger lead frames, and that itself brings more capacity and more inductance and makes the whole problem a lot harder. Large sockets for wide buses, variable capacity loads as you add SIMMS into PC memories. There are a lot of hurdles in running even at the speeds that people are dealing with today.

Traditional Memory System

- Unequal signal lengths & loads creates large timing skew
- Skew increases as SIMMs are added



This diagram here shows some of the problems with CMOS IO. In a package, because of simultaneous switching outputs and ground bounce, the VDD of that package can shift, causing the levels in that package to change, but not change in sync with the other package that it's communicating with. The outputs of CMOS are inherently noisy, with three volts wings and fast edge rates required to get these higher frequencies. A CMOS IO structure was just not designed for transmission line environment.

The source of noise is simultaneous switching outputs and cross talk, and the point I want to make here is that as we're going to bigger packages with larger lead frames, as we're going to faster edge rates and faster clock speeds in the traditional CMOS IO systems, all of these noise sources are aggravated.

Finally: Transmission lines and signaling with CMOS IO. When you switch a signal things don't just go from zero to one as if it were Digital Logic; this is an analog world. There is a damping period that takes time for the signal to damp out. You don't want to switch the signal and then clock the signal before the ringing has finished. In a typical PC memory bus, when you do a few memory calculations it works out that this damping effect for CMOS IOs results in about an 80 Megahertz maximum. So there are a lot of physical constraints in running CMOS at a high speed.

To show an example: We took a PC in our office and just moved the scope around and here was a typical signal in the PC. You can see on the top of the high edge a ringing signal, and this is ringing over a period of tens of nanoseconds, and you can see a pretty ugly glitch that I'm sure wasn't intended to be there. This is from a commercial Pentium PC CMOS IO.

Final approach in memory systems, and Rambus is a company focused on high bandwidth memory, so high speed interface for memories. In traditional memory systems, signal skew is a big problem. Despite all of the signal integrity issues that I talked about, the other problem is that that chip up at the top, that controller chip, when it sends out data and address, the data takes a different route to the D-RAM's as compared to the address as compared to the control signals. What results here is differences in arrival times at the D-RAM, measured in multiple nanoseconds. Multiple nanoseconds of Skew isn't a big deal when you are talking about 10 Megahertz or even a 33 Megahertz. When you are talking about running at hundreds of Megahertz, nanoseconds can kill.

For high speed low cost systems, a new approach is needed for interface, and not just for memory interfacing. Intel - for example - with the PCI bus (I think) is a good example of the new approach for high speed interface. We've got to design interfaces for chip to chip communications as a total system solution, not just as an isolated component or signaling activity.

New Interface Approach

- Engineer as a total solution
- PCI bus
  - I/O bus for PC's
  - 33Mhz data transfer rate
  - Constrained CMOS I/O
  - Constrained board layout requirements
  - Transmission line design
  - Equal loading on signals
  - Expansion strategy: connectors, modules

If you look at the PCI bus, it's an IO bus for PCs. It has still a relatively low data transfer rate, but to get the performance reliability the CMOS IO structures are significantly constrained in the Intel specifications. Board layout is significantly constrained where you can place the chip and how far they can be from the bus is very specifically defined. It's certainly designed for transmissions lines. Signal loading is equal to minimize skew. There is a very well thought through expansion strategy for connectors and for modules. This is the kind of thing you need to do in the future.

Rambus has done the same kind of thing for high bandwidth memory, bringing high speed interface to low cost systems. What we've developed is a high bandwidth memory subsystem. Our expertise is in moving data between memory chips and logic chips. Our design criteria was to do this at low cost. Everything that we will talk about from here on focuses on minimizing signal pins and maximizing bandwidth using standard submicron CMOS, standard plastic packaging and standard FR 4 printed circuit boards. At Rambus we focused on developing a total solution.

Outside in the demo area, after the talks, there are example systems using Rambus technology so you can get up close and see exactly what it looks like in real life.

The Rambus technology is on the bottom part of the block diagram. What Rambus focuses on is the interconnection between memory chips and logic chips: The bus structure of the sockets, the PC board layout and the small amount of interface circuitry on the logic chips and on the D-RAM chips required to interface to our bus.

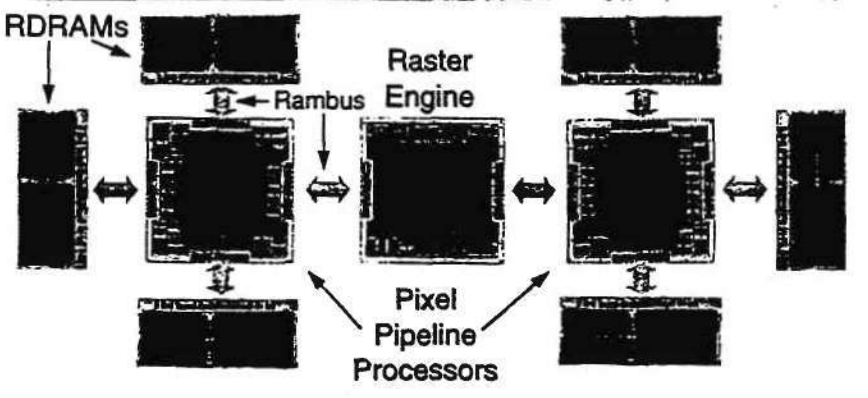
With our approach we have 500 Megahertz data transfer rates using the same technology as today's standard products. That's pretty fast. That means that every two nanoseconds we're moving a bit over each wire on the bus for 500 megabytes per second. What are some of the things that we've done to do that? We've got a small signal swing, less than a volt; but that's only really a small part. We've designed this for a transmission line environment. The output structures are very different and much more complex and have a lot of feedback circuitry in them to maintain constant current to avoid overshoot and undershoot for example.

Another really key thing is that we multiplex in our bus data address and control. When you look at the Rambus channel, all signals are equal length; all signals are equal load. That really goes to minimize skew between parts.

We have low pin count. The Rambus interface takes about 30 pins to move the same amount of data that traditional CMOS IO moves with about 120 pins.

Just like I showed you a scope photo from a commercial product, this is a scope photo from a commercial product using Rambus technology. Here you see Rambus data moving over a wire. Every two nanosecond period another bit is moving down the line for 500 Megahertz data rates. The swings in this case are about 800, 900 millivolts. This is a term transmission line environment, so you can see almost no overshoot, undershoot, or ringing. It is very clean, even though the frequency is dramatically higher. We have designed this system so it will work from one D-RAM up to dozens of D-RAMs. It can cover the full range of customer applications, including sockets for upgradability.

SGI Indigo2 IMPACT 3D Engine

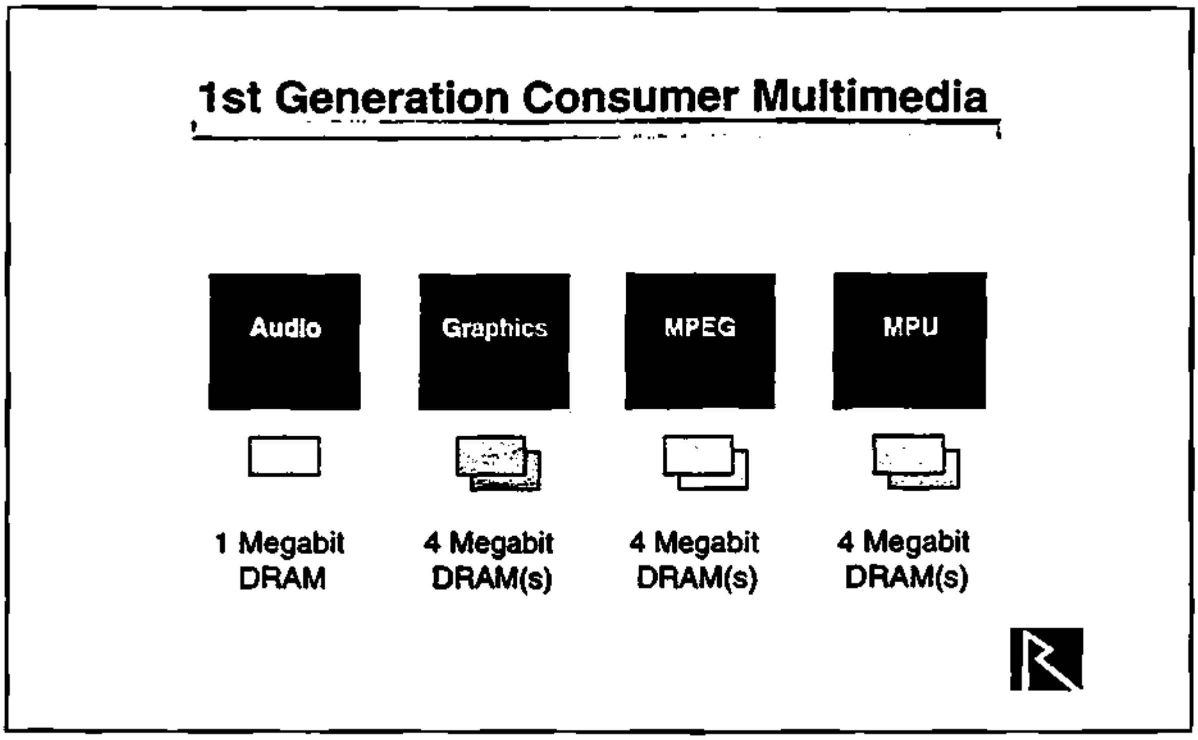


- 3 Gigabytes/second bandwidth
- Rambus ASIC-to-ASIC data transfer

That was the dry, dull technical part. Now I want to show a few real life examples. The fonts here didn't quite line up, but it's in your notebook properly. This is the dye photos of the Rambus compatible chips on the 3-D graphics board of the Silicon Graphics Indigo 2 Impact Workstation, which has been shipping since August.

The chips on the outer periphery are Rambus compatible D-RAMs. The three chips in the middle are ASIC devices. If I had a pointer I could show you the Rambus IO cell, which is on the edges of each of the ASIC chips and relatively small. The SGI chips have as many as four Rambus IO channels on a single chip, so this is a high end application of our technology.

In total on this board, there is three gigabytes per second of bandwidth delivered into Silicon Graphics 3-D graphics engine. Also SGI has used Rambus to transfer data between chips too to save pins compared to CMOS IO, between logic chips.



The second example of our technology is in consumer. The product that I just shows you sells for $30,000.00 to $40,000.00. The total system, not just the Rambus graphics board. The next product I'll talk about will sell for $250.00 starting next spring, and uses Rambus technology as well.

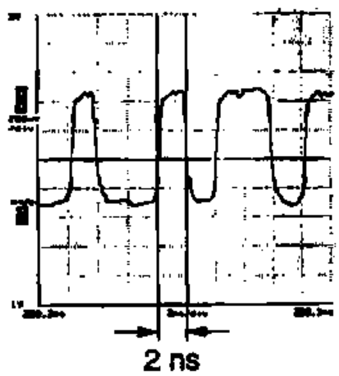
First a little background: The systems that you can see today, set top box systems or game systems you buy in stores, have an architecture like this. Multimedia is achieved, but through non-integrated solutions. There is an audio chip, a graphics chip, an MPEG chip, and a microprocessor in a Sony box or a Sega box or a set top box today. Each of them has their own separate memory.

The result - in looking at a photo, an actual production game system that you can buy today - is a fairly large board. It has good performance, but relatively big, lots of chips and a higher cost structure (I'm sure) then they would like.

What's happening is the next step, the second generation for consumer high volume multimedia products, is integration. Memory is integrating from four megabyte to 16 megabyte in terms of what's the cheapest cost per bit. Logic technology is integrating a generation as well, so it's possible to combine multiple

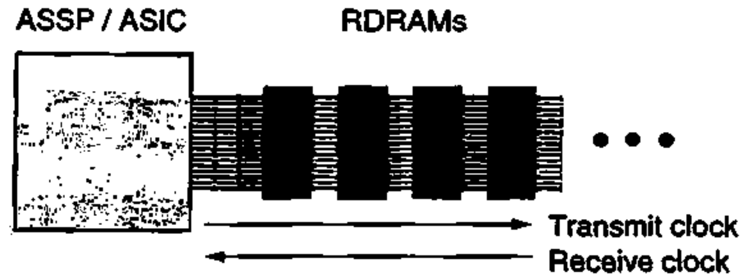
Low Swing Signals

- ≤1V swings
- Terminated transmission line
- Drivers/receivers optimized for buses: 1 RDRAM or dozens



Besides signal integrity, minimizing skew as I mentioned is critical. In the Rambus approach we just keep things very simple. We have a constrained layout requirement. The bus can be fairly long, the bus needs to be laid out so it's straight. By keeping the bus straight and having all of the signals run in straight bus, we keep everything equally loaded, equally short, and keep skew into the hundreds of picoseconds as opposed as into the nanoseconds, like in traditional solutions.

Minimize Skew



- All interconnects equal length
- RDRAM lead frame: short, equal length
- Skew very, very low
- Clock and data travel together

Another key thing to remember is that in these systems you want data to go both ways. You want data to go out; you want data to come in. We actually have clocks that go in both directions and move the data with the clocks. That's another key thing for keeping skew low.

Finally: We move data on both edges of our clock. This effectively doubles the data rate compared to if we had not moved the data on both edges of the clock. This sounds easy to do, but very, very few systems do it because it's not really that easy. To do this requires space lock loop technology and advanced skew control.

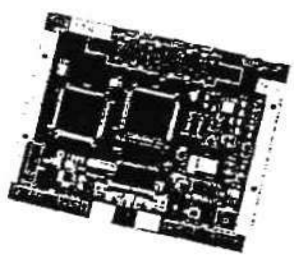
The end result though is using the same 16 megabyte technology if you compare eight bit wide page mode parts, eight bit wide synchronized RAMs, and eight bit wide Rambus D-RAM, the Rambus D-RAM comes in with the peak data bandwidth of 500 megabytes per second, using the same technology as the SD RAM at 66 megabytes per second and Page Mode or EDO at 30 to 50 megabytes per second. A tremendously higher bandwidth using the same economics.

functions onto a single chip. This integration means that you have to have a lot more bandwidth out of your memory chip.

With Rambus it's possible to build a system like this, a single microprocessor, a single multimedia ASIC, and one or even two Rambus channels in a consumer system, delivering 500 megabytes per second or a gigabyte per second.

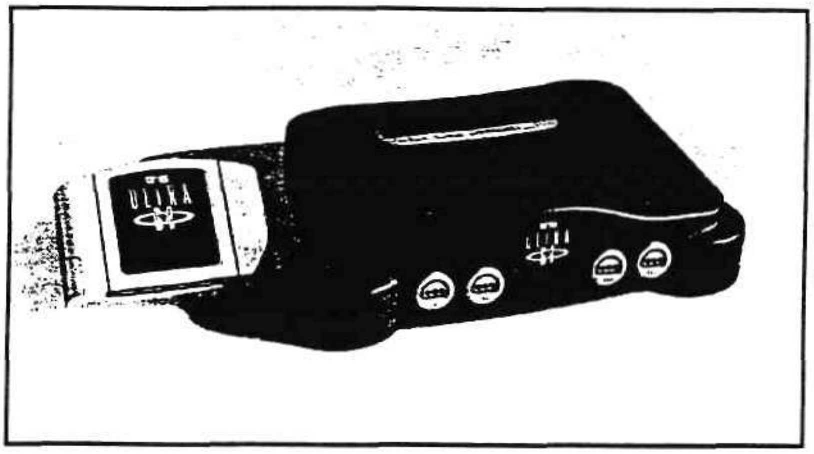
Hard to believe that that's something a consumer system requires, but multimedia requires tremendous bandwidth.

Nintendo Ultra 64 Game System



- 2 layer printed circuit board
- Unified (graphics, video & main) memory
- Consumer external memory upgrade

Nintendo Ultra 64



This is a photo which is actually the first time it's being publicly shown of the hardware, the game board, of the Nintendo Ultra 64 Game System. You can see on this board there's really four chips: There's a MIPS microprocessor; there's a single ASIC chip, which has all multimedia functions and through which all memory references for the microprocessor close; and there's Rambus D-RAM; there's also - it's a little hard to see - a socket here for external memory upgrade. All of this is working on Nintendo Systems today. The first public showing of this will be in November, and retail sales will take place early next year. This is a two layer printed circuit board, with 500 Megahertz signaling, and it's the first high volume application of unified memory in the consumer space. This actually is something that could be what a PC looks like, a low cost PC, a few years from now as the same trends hit the PC space at the low end.

Also because we have a narrow bus and a small socket, Nintendo was able to design this system so that the box has a small hatch in the front. Into that hatch you can put memory upgrades. Nintendo has designed this system so that down the road when they need more memory, they can sell memory through the retail channels and anybody from grandma to grandkids can take that memory, open the hatch, plug it in and five seconds later have an expanded memory subsystem; something that can't be done today on any PC.

The final real world example I wanted to show before and after: This is a current generation high performance PC graphics board. It is extremely respectable, well selling part, but it uses wide bus CMOS IO interfacing. This particular system has a 128 bit wide bus.

The Seros Laguna, or GD5462 visual media accelerator. This is a single chip which integrates all of the logic functionality on the previous device, connecting to a single Rambus D-RAM which integrates all of the bits and provides the same or greater performance then the video RAMs on the previous board. This board is available this quarter; it will be shown at Comdex. Using Rambus D-RAM it achieves with a single device performance faster then video RAM out of a single plastic package and one Rambus D-RAM, supporting up to 1600 by 1200 resolution. Seros has designed this reserving a second Rambus channel for the 1996 version, which will have one gigabyte per second in the same 208 pin plastic package.

Questions and answers:

Question: I came into your presentation a little late. Did you say anything about unified memory?

Answer: I showed the Nintendo Ultra 64 System, a game system that will be publicly shown in the end of November, which is the first consumer unified memory product. Rambus also in the future will show up in PCs for unified memory, but not until a later date.

Question: Geoff, it's quite an exciting technology. I know it's probably not your specific concern, but there's a lot of concern in general in the industry about overcapacity potential for dynamic RAM. Clearly with the consolidation of memory within unified memory, the possibility exists for you to exacerbate that problem basically by making more productive, smaller amounts of memory for use in a PC system. Have you actually analyzed that effect, or have you been in discussions with anyone on the effect that Rambus could have overall on dynamic RAM trends in the industry of supply and demand?

Answer: That's a good question. The amount of memory people need is a function of the application. In the case of games, it's how big is the program, the texture maps, the images they want to move around. The use of Rambus technology does not change the number of bits in the system. What Rambus allows them to do is move to higher integration at lower cost, like 16 megabyte technology, and get more performance out of the same amount of silicon. Our technology is adoption and won't change the requirement in terms of bits for D-RAM.

Question: The performance road map for Rambus seen to go beyond 500 Megabyte per second in the near future?

Answer: We already are working on moving the parts up to 533 Megahertz, a small change. PC customers have asked for 533, because it's an integral multiple of 66 Megahertz, which is a magic PC frequency.

We also planning speed grades of the parts, just like there are speed grades on other types of D-RAMs. The exact numbers aren't ones that I'm free to quote right now, but we'll be having speed grades of parts available for PC applications - for example - next year as well.

We think that the Rambus signaling technology through incremental improvements can move up in frequency over the next three or four years to the 800, 900 Megahertz range, at which time we would plan to replace it with a completely new signaling approach around the turn of the decade for a Gigahertz Plus per wire.

Question: On behalf of those suppliers yet not assigned Rambus technology, I'd like to say I believe that Rambus technology is very good and it's very effective, but the issue is price performance. If you really can have a proprietary solution in a commodity market, the nature of the commodity market; I really believe in the technology, the low voltage. The issue is trying to cut the royalties and the latency as much as you can. I think there are other solutions other than Rambus to respond to the market. Because I thought that this presentation was kind of biased toward Rambus. I have to express my opinion that there are other solutions that Rambus can provide the solutions.

Answer: It's certainly a competitive world. I think that the important thing when we talk to system companies isn't component specifications or individual component costs. What really matters if you are a game buyer is how good and how fast is say the Nintendo Ultra 64 compared to its competition. It's the overall system price performance.

Rambus technology; the key things as I said for something like a game system or graphics is we allow them today to use 16 meg D-RAMs instead of four meg D-RAMs, and allow them to use higher integration, single chip solutions as opposed to multiple chips, more expensive pad limited solutions. The system price performance I think of Rambus products as they ship into the market will prove to be demonstratively better then existing four megabyte EDO or video RAM graphics in game solutions. Time will tell.

Question: As far as the cost differential, where do you see right now that the difference on a megabyte per megabyte basis between the Rambus and let's say Synchronized RAM, EDO type D-RAM and then the future trends?

Answer: Sure. In the graphics and in the games market place, what people really want to know is how does a 16 meg Rambus D-RAM compare in price to video RAM, or to four megabyte EDO D-RAM, 16 bits wide; because that's what people use to build frame buffers today.

Rambus 16 megabyte D-RAMs right now the volume pricing is about the same cost per bit as four megabyte EDO D-RAM, wide D-RAM, which makes it substantially cheaper then video RAM. For graphics and games customers, the component cost of the Rambus memory is as cheap or cheaper to buy then other memory types. Not to mention we save them pins on their controller part, which can save them package and test cost, and if they are pad limited can reduce their dye size and further improve the value proposition of Rambus technology.

At the 16 meg level, a 16 meg Rambus D-RAM, a 16 meg Synchronous D-RAM or up to 16 meg EDO D-RAM are all going to end up in a fairly narrow price band. Here I'll talk about pricing as volumes have ramped say in the 1997 time frame. We would estimate that Rambus D-RAM will be a little more expensive then SD RAM by 5%, and SD RAM will be a little more expensive then EDO D-RAM by about 5%.

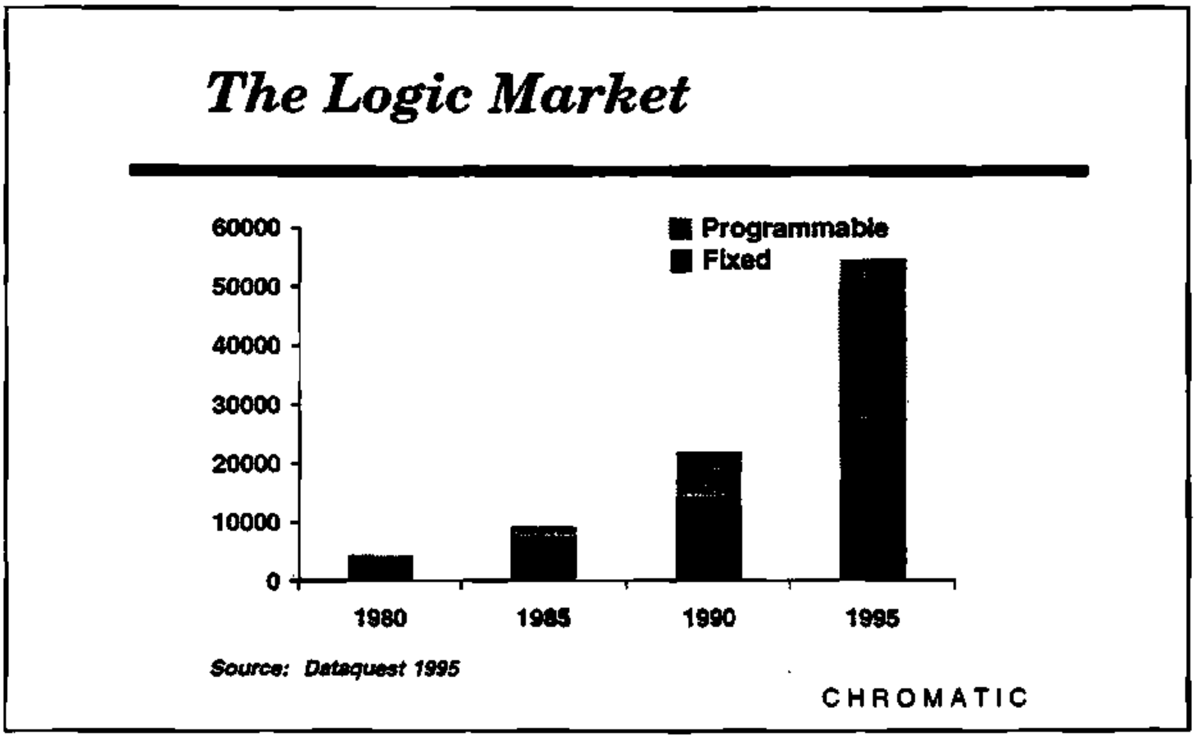
The Rambus D-RAM delivers almost in order of magnitude more bandwidth for that 5% and has dramatic advantage in pin count, which makes a big difference as well on the cost of the logic chip. I think our price performance story is very good.

Chapter Eight: PROGRAMMABLE ICs: BEYOND MICROPROCESSORS

Wes Patterson
President
Chromatic Research

I'd like to start by making it clear what this talk is not. This is not yet another projection on the future of microprocessors; nor is it a recycled presentation that I did just before I left Xylinxs. This is intended to be a way of sharing some observations that I've made and ideas that have occurred to me over the last 20 years that I've spent in the programmable logic business, starting out with 6800 at Motorola and continuing on to what I'm doing today. The agenda that I have in mind is to define what I mean by the programmable logic market in its broader context, and then try to share with you why I think the programmable piece of the logic market is growing so much faster than the fixed portion; then try to set some directions for where programmable logic might go. Have we seen all of the innovations that we are going to see in programmable logic? You can probably anticipate that the answer to that is no. I'll try to show you by example where I think we might see some future new innovations in this general area of programmable logic.

Let's start off with just a simple definition that there are two kinds of logic: There is fixed logic where what you see is what you get. In other words, what the manufacturer ships is exactly what the chip does. There is programmable logic which what you program is what you get.



The growth rate for these two segments of the logic market differs substantially. If we look at the period from 1980, programmable logic devices shown here in the green bar have grown in excess of 30% per year, while fixed logic has grown at less than half that rate. We are just on the verge - according to Dataquest numbers - of the crossover between these so that the programmable logic device revenues will exceed the revenues for fixed logic devices.

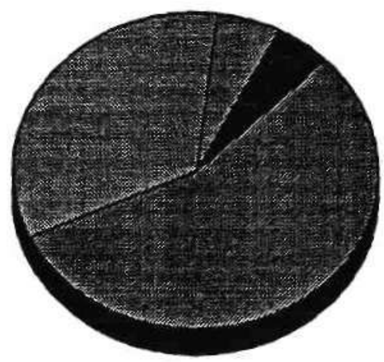
Programmable Logic Categories

MPU

MCUs

PLDs

DSP



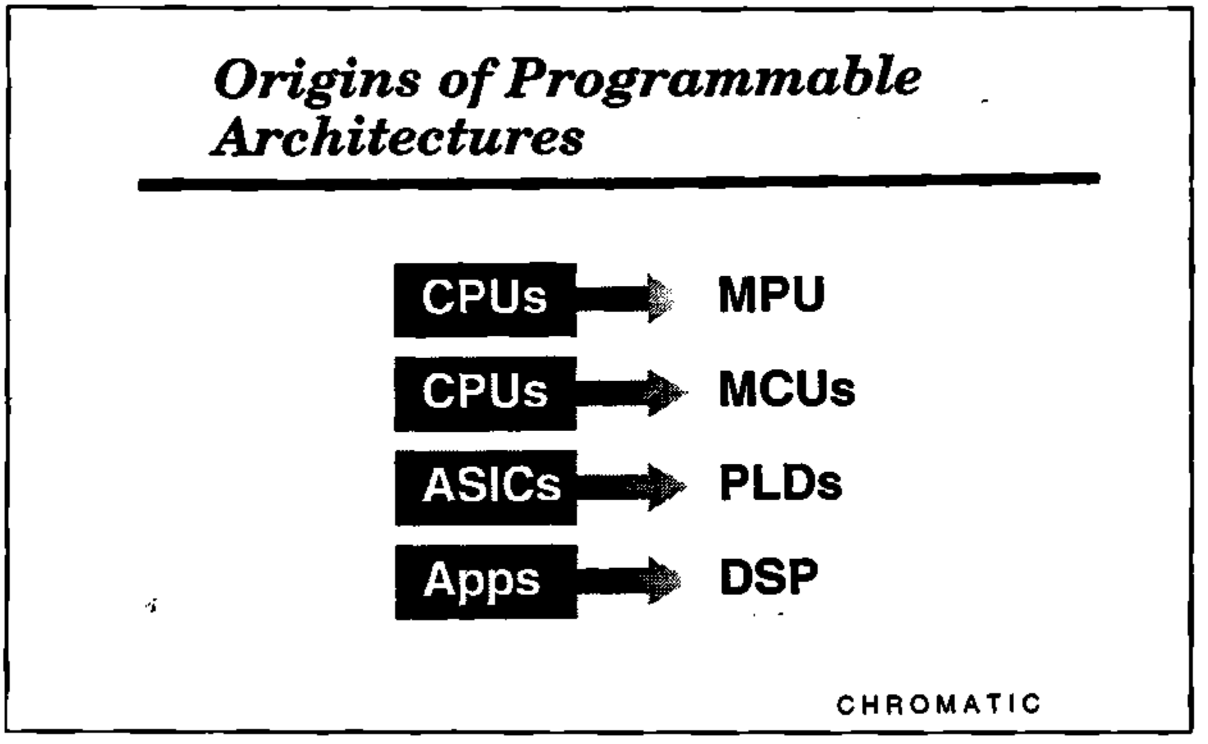
1990 - 1995 CAGR 30%

Source: Dataquest 1995

CHROMATIC

Before we get into the reasons for why that's occurred and my projections, I'd like to be a little clearer about the pieces that make up this area of programmable logic. In my view there are four of them: Microprocessors are clearly the largest; microcontrollers; PLD's, programmable logic devices; and digital signal processors.

It's interesting to look at each of these in terms of when they came about and where the ideas originated. Microprocessors, at least in my recollection, were pretty straight forward extensions of architectural ideas that already existed in the computer business. They were shrunk down to fit what they could do on a chip in those days. The architectural origins (I think) are fairly clear for these devices that began to appear in the mid 1970's.



Microcontrollers similarly were derived from computers and from microprocessors, so the architectural origins here are also fairly clear cut and we saw the first microcontrollers devices begin to appear in the late 1970's.

In the late 1970's and early 1980's, we began to see the first programmable logic devices or PLDs. Here I think the architectural origins really come from the ASIC business, either from PLAs that were occurring in ASICs, or somewhat later from gate arrays.

The fourth category that I've identified, digital signal processors, also began to appear in the early 1980's. There is an embarrassing mistake on this chart, and you'll understand why it's so painful to me when I get further into this presentation. I think the architectural driving forces for DSPs are not applications as shown here, but they are really algorithms. It's these signal processing algorithms that actually have driven the architecture for DSPs.

You will note that this is the end of the categories that I have identified for programmable logic devices, and the most recent of these is now more than ten years old. In somewhat biblical terms, we've had ten years of innovation of programmable logic devices, followed by a ten year drought when there has not been much new. There has been a lot of innovation and evolution, but not much new has occurred. I'll come back to that in a little bit, but let me try to move now to the ideas of why has programmable logic grown so much faster then fixed logic.

To keep this simple I've identified what I call the three P's. I think that programmable logic is growing because of performance, price and programmability.

If we look at performance, in general, of course, faster is better. In many applications there are thresholds where below a certain threshold there is no market for a device, no matter how many other benefits it offers. Above that threshold, if it's fast enough it can begin to address certain applications. If we look at the PC - for example - there was a minimal PC market available for something powered by an 80 80, because it just couldn't do enough. It couldn't provide a useful enough user interface. It couldn't do a useful set of applications. I think if that's all the performance we had today, the PC market would be a small fraction of what we have been talking about this morning.

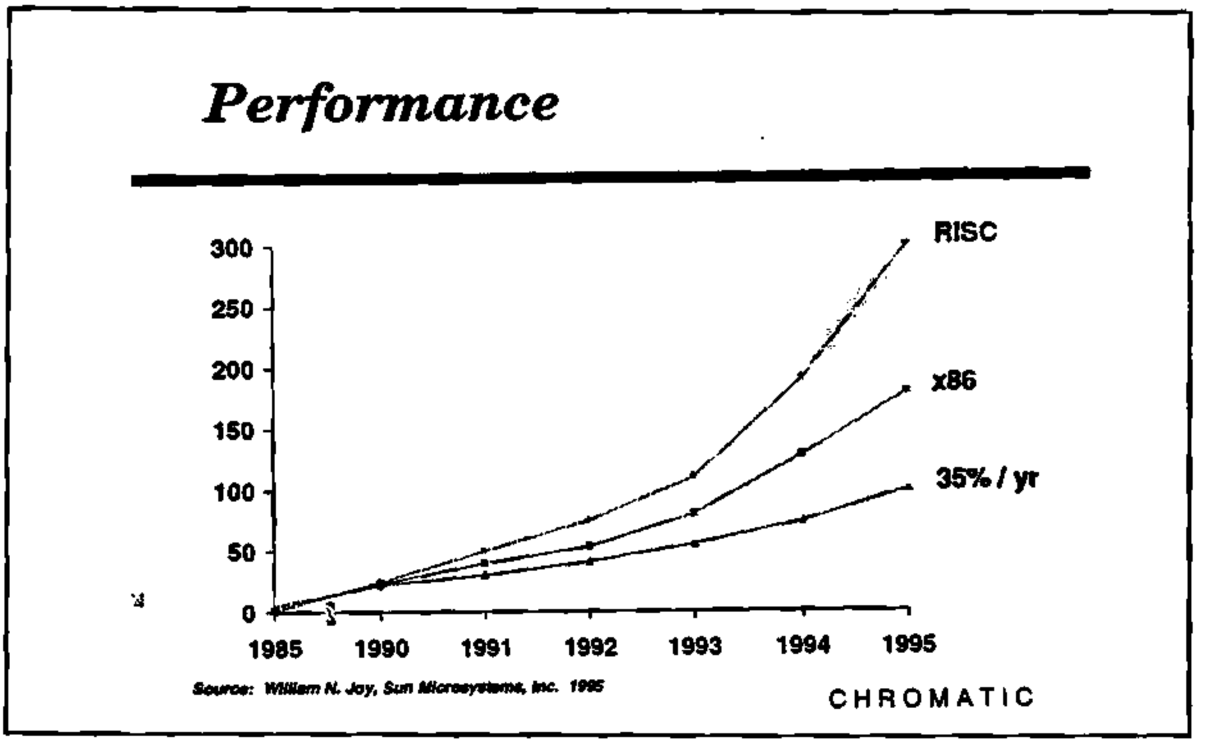
This is a case where there seems to be an insatiable appetite for MIPs, and it seems that at least today Microsoft can use every MIP that Intel can deliver. This is a market where there is more or less a continuum of performance and market expansion.

For microcontrollers, the first threshold was much easier to reach. The first high volume microcontroller applications occurred in automotive engine control. There all we had to keep up with was the Kilohertz rate of things happening in the mechanical world.

For PLDs, in my view at least, performance is the single most important opportunity for further expansion of that market. I think that the pricing is reaching levels which are compatible with high volumes. I think densities certainly still have a ways to go, but people can always use more than one chip if they need it. The real issue barring the use of PLDs in many applications today is simply that of performance.

For DSPs, similarly there is a performance issue. The DSP is either fast enough to either keep up with certain real world signal processing functions or it's not.

The nice thing is that many of those thresholds are not moving, so as technology progresses the programmable logic is catching up and when it gets to that threshold, programmable logic will provide the solution.



This chart is an interesting one to me primarily because of the vertical scale. This is a chart that Bill Joy did. I didn't label the vertical axis here, but it's equivalent units of CDC 6600 mainframe computing power. I think most of the people in the audience can remember what that mainframe was like. My recollection of the 6600 was that that single mainframe when I was in college was expected to meet the entire computing needs of a campus of 30,000 students.

The lower line here, the 35% shows the historical rate of improvement, and that has largely been driven by process technology. Above that you can see what happens when architecture begins to kick in. You can see the X 86 improving over this period at the rate of more than 50% per year. Above that you can see RISK processors improving at the rate of 64% per year.

We can see that there are really two sources of performance improvement. The electrical advances tend to improve everybody. This is sort of the rising tide that lifts all ships. Smaller process geometries, better circuit techniques tend to contribute to the performance of all solutions, all kinds of programmable solutions, and obviously all the fixed solutions as well.

It's architectures that really allow programmable logic to be differentiated. The fact that these four categories of programmable logic that we've talked about exhibit different architectures is one example. We can see that that creates the ability to meet the performance and the cost needs of various markets. It's my conviction that it's in the architecture area where new innovation is going to help open up new markets for programmable logic.

Pricing

- **Transistor re-use**
- **Exploit VLSI densities**
  - **Complexity**
  - **Return on design investment**
- **High production volumes**
  - **More applications**
  - **Longer lifetimes**

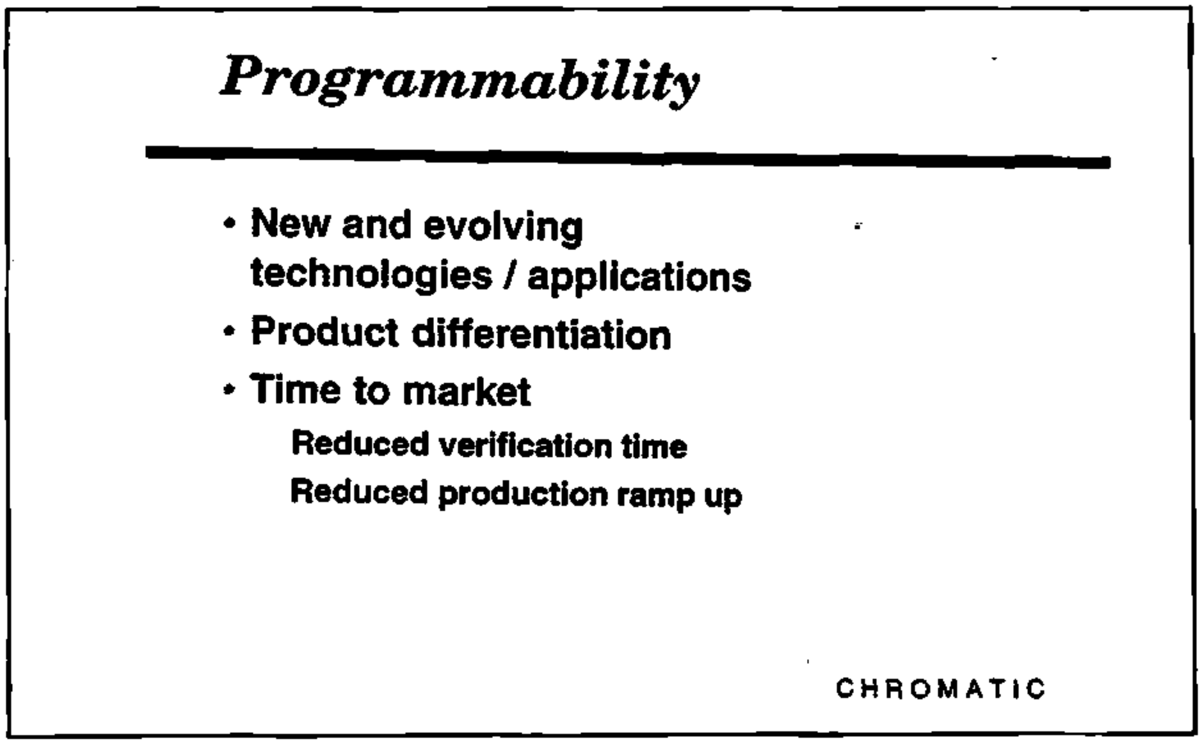
CHROMATIC

The second consideration is pricing. The general trend, like for all semiconductors of course, is to get to lower cost. The relevant question here is what specific price or cost advantages can a programmable logic device exhibit over a fixed device that does the same function? Clearly in any application that involves reprogramming, a programmable device offers the opportunity to use the same transistors at different times for different functions. That's obviously a way of getting device cost down.

Programmable logic is also a superior way to exploit the potential of higher and higher VLSI densities. If we are going to put 1 million or 10 million transistors on a chip, it's much easier to manage that complexity if we are building a programmable device, because we can push some of the complexity over into the software that's going to run on it.

Programmable devices also enjoy wider markets, because they can be used for different applications. They also have a longer production period. They don't become obsolete so quickly because the software can be upgraded to keep them in production. For that reason there is a chance to get a better return on the design investment, which as Gordon Moore has noted is increasing at the rate of 2x per generation.

It also provides higher production volumes over a longer period of time, which helps these devices come down the learning curve faster, and as a consequence are more cost effective relative to fixed devices and this is also helping to drive this faster growth of programmable solutions over fixed.



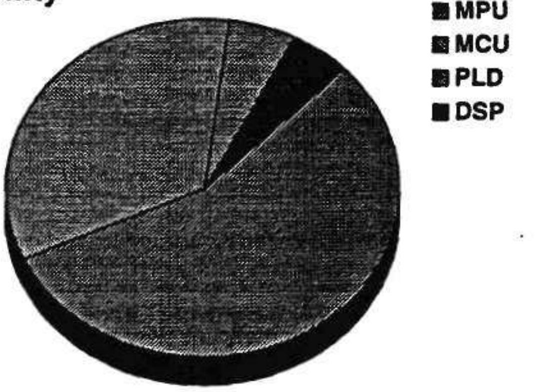
The third consideration that I believe is important in the market growth of programmable devices is the ease of programmability, or the fact that they are even programmable at all. This whole conference is about the rate of change in the electronics industry. There are new applications, applications such as communications and multimedia are still being defined. They are still evolving. They are changing. It's just much easier to keep up with these changes if you are using devices that can be reconfigured after you buy them, rather then having to junk something you've bought and start over.

From the end customer point of view, programmability is also important because it affords an opportunity for product differentiation. That's critical to expanding markets and also to adding value.

This last bullet here probably raises some eyebrows. There are a number of people in this audience (no doubt) who believe that talking about software and time to market in the same sentence is self-contradictory. I think if we keep the discussion on apples and apples, if we think about systems of similar complexity, it's much easier to ship a system on time if part of the complexity is embedded in the software, despite all of the frustrations about product deliveries that are held up by software, because the turn around times are much shorter. It's much easier to manage those details. It's much easier to get a product to market if a lot of the true complexity is handled from a programmable point of view. That's one element of programmability.

Programmability

Strong correlation between market size and ease of programmability

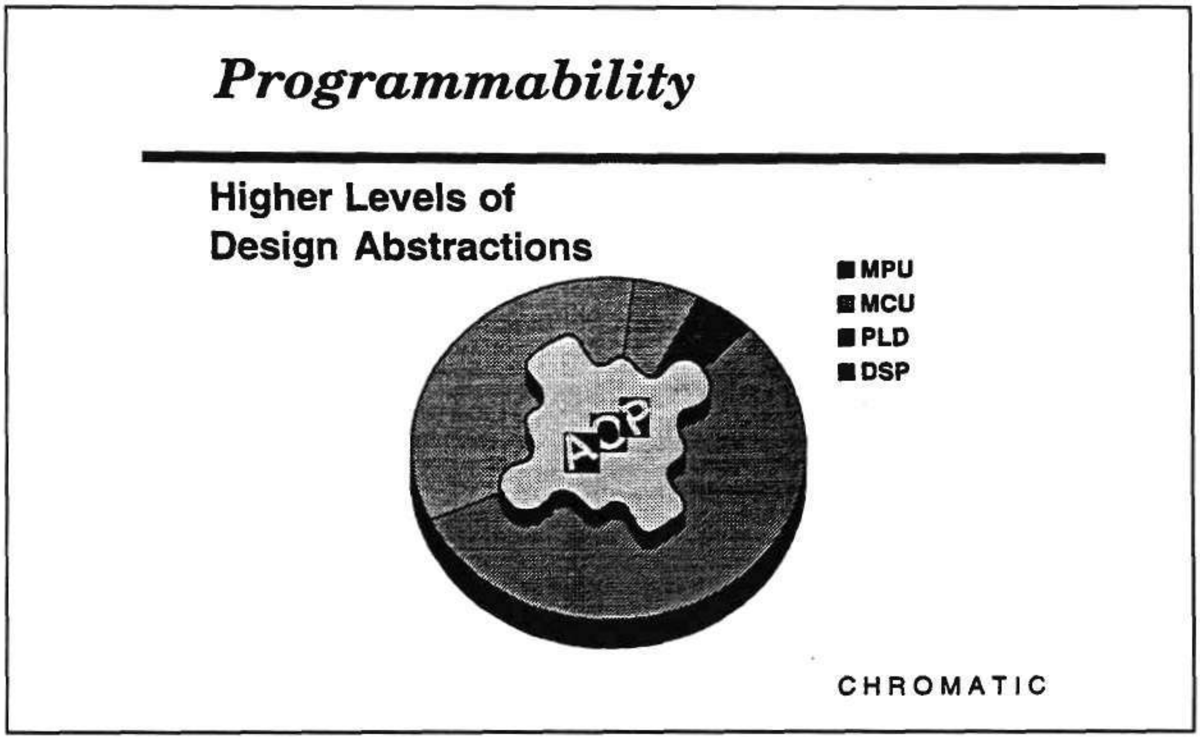


CHROMATIC

A second consideration is just the ease of programmability. This is just an observation in passing, that if we look at these four segments of the programmable logic market, there is a perfect correlation between the market share of these devices and the ease of programmability. Microprocessors: Most of the programming is done by third parties, that is not the manufacturer and not the end user. They are clearly the easiest to program devices and they are supported by the widest range of software development tools.

Microcontrollers are typically programmed by the OEM, and they are probably less easy to program then microprocessors, but still pretty straight forward these days.

For PLDs: I think there is a lot of work going on, some not yet announced. There is some very interesting emerging architectures in the PLD arena, which directly address this question of ease of programming. I think that is going to substantially increase the growth rate of the PLD market.



Finally, I am not the first to suggest that difficulties in programming has been one of the major limiting factors in the growth of the DSP market, and that to the extent that that can be addressed there will probably be faster growth in that segment as well.

Let's go back to this question that I raised a moment ago about this ten year drought and talk about whether it's true that all of the forms of programmable logic that will ever be known have already been invented.

I'd like to suggest this afternoon that there is a new emerging class of programmable devices that I am going to call application optimized processors. I'd like to start out by describing what I think are the general characteristics of such a processor, and then I'll offer you an example to make it a little more concrete.

AOP: A New Programmable Category

- **Programmable ICs**
- **High-performance architectures**
- **Optimized for specific applications**

CHROMATIC

Clearly to fit in the scope of this talk, these devices have to be programmable. They are aimed at high performance, so they are architectures that are optimized to deliver performance. They are also optimized for a particular application for all three of the P's that we talked about: Performance, price and programmability.

One of the benefits of these application optimized processors is that they can help to simplify complex designs by dealing with higher levels of design abstraction. In a system that today is created from a number of fixed logic devices, there are quite a few fairly complex physical interfaces that have to be dealt with. A highly integrated programmable solution can replace these and give us something that's much easier to understand. It's much easier to deal with these complexities. Therefore we can reduce costs and we can get to market quicker.

Programmable devices are also easier to verify. We can deal with the details at a higher level. We can deal with them in real time. We can execute this software in real time on this high performance processor. If we need to make changes we can do it in days rather than weeks or months if we were using ASIC, for example.

Let me be clear that I'm not suggesting that these application optimized processors are going to apply to every logic problem that we know about. I think this particular chart makes more sense if you read the list of numbers from bottom to top. I think that an application optimized processor will probably cost $10 to $20 million dollars to develop, if we count the cost of defining the architecture, designing the IC, building that and writing the software to go with it. If we take $10 million dollars at the low end of that, we can try to estimate the end market size that's the minimum size that would justify such an effort.

If we are looking for a 10% R&D investment, the $10 million dollars that we spend on this design would have to be reflected in a $100.00 semiconductor market, and if semiconductor content is 15% of the system, retail price; then we'd have to look at systems that will generate at least $700 million dollars in incremental revenue in order to make one of these devices fit.

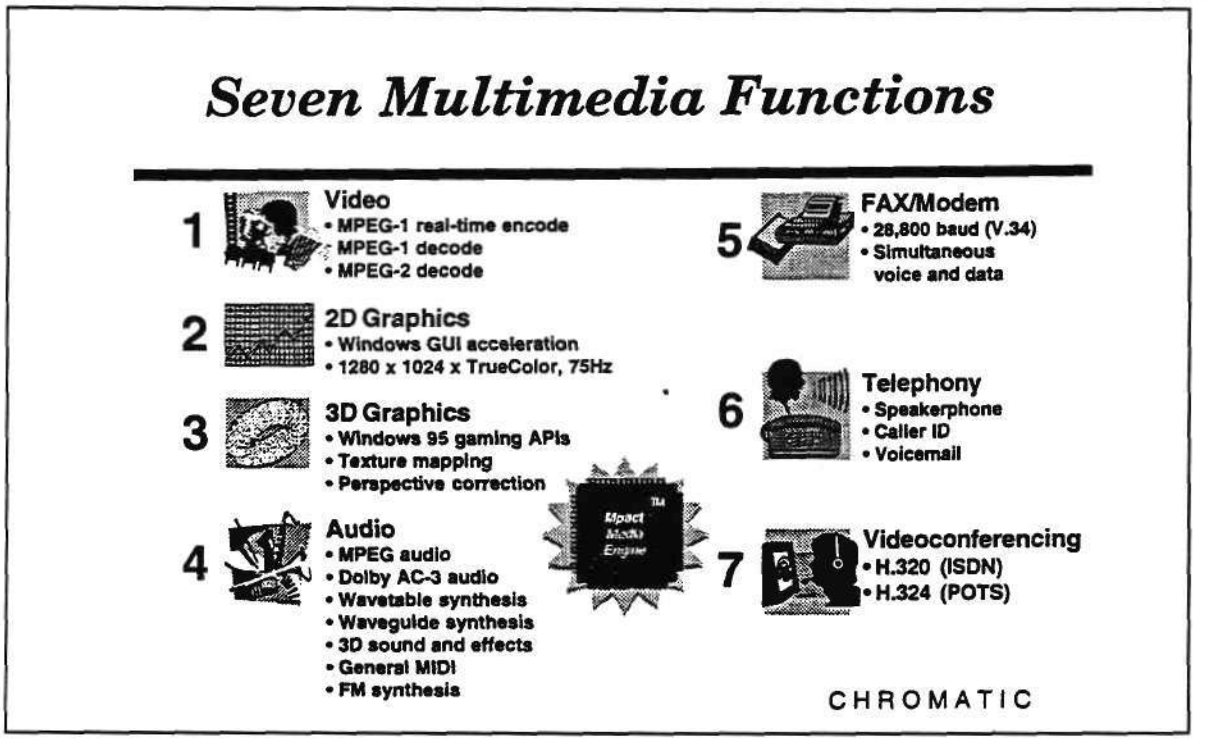
Before we go on to talk about an example, let me suggest what some of the potential implications of application optimized processors are. I think that one is that it's going to bring software in as an important part of the value added equation, giving semiconductor companies or pseudo semiconductor companies an opportunity to add value in another dimension. That in turn - as Gene suggested - may cause some blurring of the distinctions between hardware and software and how people like Dataquest track these revenues.

I think it's also going to blur these nice, clear definitions of programmable architecture, because in this application optimized environment, we are going to feel comfortable picking and choosing from various programmable architectures to meet the needs of this particular application. These neat boundaries that we talked about at the beginning of this presentation are probably going to blur.

Finally: Because of this opportunity to add value through software, we are going to see a blurring of the manufacturing and design part of the semiconductor business. We will come back to that probably at the end of the presentation.

Let's take a look at an example of an application optimized processor. It probably doesn't surprise anyone that the one I've chosen is the media processor that our company has introduced this week.

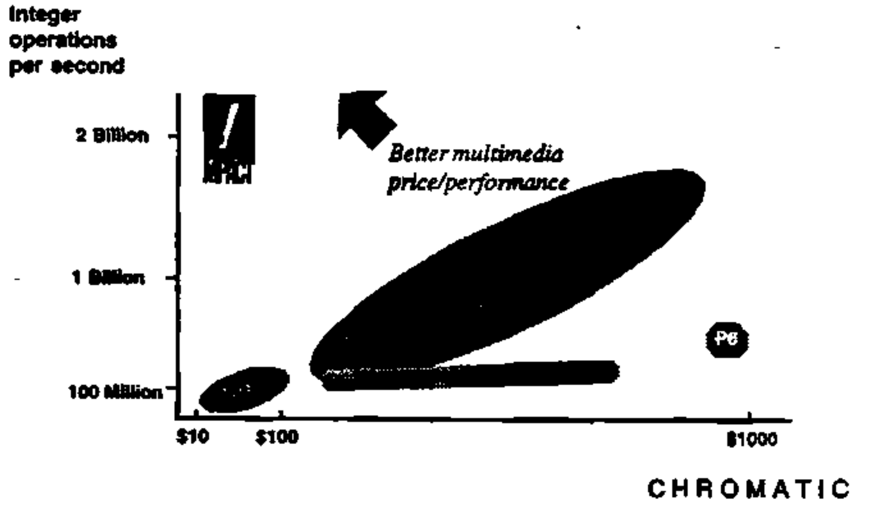
The original intent of Chromatic was not to be an application optimized processor supplier. In fact, the goal of the company was to be a software supplier that would use existing processors to create a single chip solution that would do all of the multimedia functions in a PC. After surveying the market, the company founders concluded that there was no suitable chip in the market. There was no chip available that could do all of these functions at a price that was anywhere near what the PC market would demand. The charter of the company was modified somewhat and we took on the challenge of defining an architecture that would let us do all of these functions: Graphics, video, audio, communications, telephony, video conferencing; to deliver all of these with a single chip.



To do that we clearly had to optimize the architecture, because we are looking at very, very high levels of performance to get to a level that would let us run a significant number of these functions concurrently. If we look at this graph of performance and cost, clearly our customers would like us to be as high up in the upper left hand corner as possible, but you can see here that the contrast between an application optimized processor and the more familiar processors that we've talked about earlier. You can see that this processor offers an order of magnitude, improvement over things like Epidium because it's very focused in the job we're trying to do with it. Yet it's in the same price range as much lower performance devices; again, because we have singled out the problem we are trying to solve and we've optimized for that.

The particular problem that we are addressing lends itself to this kind of application optimized processor because communications functions, video graphics, audio functions lend themselves to parallelism. The first thing is could we build a device that exhibits a great deal of parallelism. The second opportunity that we have is that we don't have to run existing software. By having the flexibility - if you will - to create new software for this, it's opened up architectural technologies for us like VLIW that are very, very difficult if you are saddled with the requirement that you have to run existing software.

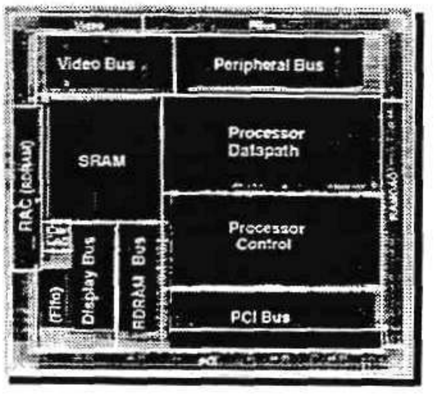
The Fastest Multimedia Processor



You can see here that the data path for this device is more than ten times as wide as the data paths that you see on the fast general purpose microprocessors. A perfect example of an architecture that can use the benefits of Rambus that Geoff talked about, we need extraordinarily high data rates in and out of this chip, so we take full advantage of the 500 megabytes per second interface to a Rambus memory. We've mixed and matched a rather broad suite of either current acronyms or architectural devices, depending on how you look at it. With a single instruction we can operate on multiple data elements. We can issue more than one instruction per clock; that is we are a VLIW processor. We can also process vectors, which occur very frequently in these applications with a single instruction.

Mpact Multimedia Processor

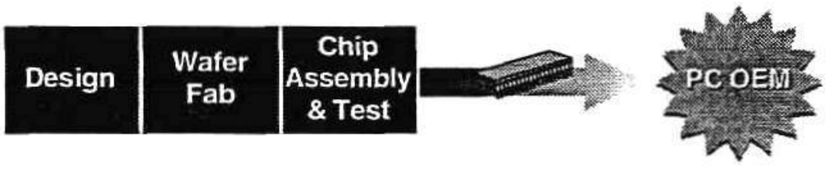
- **High Bandwidth**
  - 792-bit bata path
  - 500 Mbps interface to Rambus DRAMs
- **Advanced Architecture**
  - SIMD
  - VLIW
  - Vector Processor



CHROMATIC

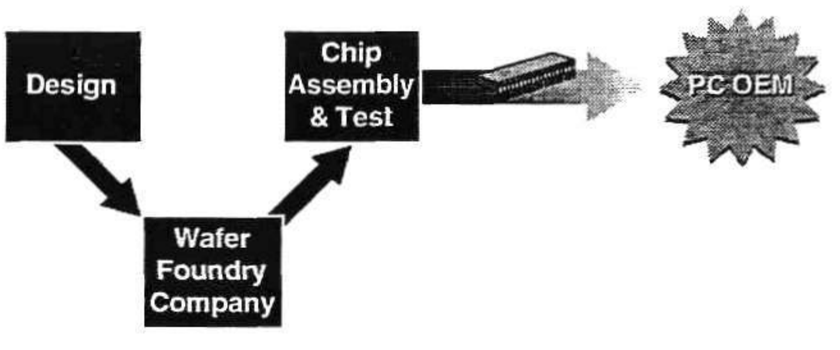
The second innovation for this company, beyond this processor that we've just talked about, is the business model. We can start by comparing ourselves with the existing, well established models; the first of which is the Jerry Sanders real men have FABs models. I think it's less a matter of Jerry's perspective on that, and it's more a matter that younger companies simply can't afford a FAB. That was true five or ten years ago, and it's extraordinarily true today.

Traditional Semiconductor Business Model



CHROMATIC

Fabless Semiconductor Business Model

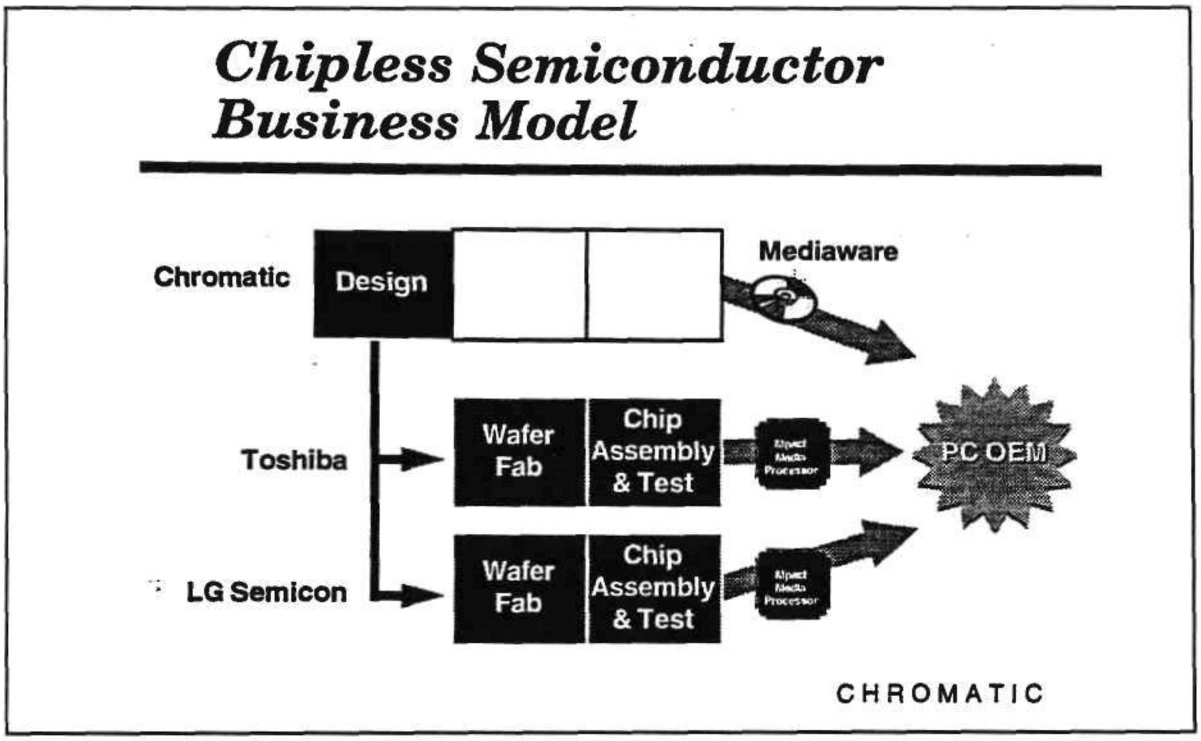


CHROMATIC

The way around that dilemma - at least until recently - was the FABless model. Certainly Xylinxs was one of the early companies to use this and it's worked very well for Xylinxs. In this case the weight for fabrication is subcontracted and the company recovers its value added in effect through a surcharge on that foundry generated silicon.

However, this particular solution doesn't work for the market we are addressing in the current semiconductor environment. The process technologies we need, half micron and .35 micron to get to the performance and cost targets that we've established are simply not available from foundries. The way for volumes that we need to deliver millions of units to the PC suppliers are not available to a new company from foundries in any process technology.

We had to look for a new business model in order to make sure that we had a viable way of delivering this silicon. As a result we've created what Gene referred to in the introduction, the chipless semiconductor company. We have tried to look very carefully at where we are adding value. A company like ours can add value in design. We can add value through software. We can add value through marketing. We really can't add value, obviously, through semiconductor manufacturing; nor can we really add appreciable value by doing assembly and test.



What we decided to do as a consequence is to bring on two strong partners, Toshiba and LG Semicon. They are going to build this chip and they are going to sell them to the end customer. Even though we are here at a semiconductor conference, we will never generate revenue by selling semiconductors. Instead, our business is selling the software that enables these processors to do the tasks that we've talked about earlier.

One consequence of this is that we've created an exceptionally effective way of getting the silicon to the customer. First of all, we are using advanced process technologies. We are using very high volume, cost effective suppliers. They are selling these devices directly to the end user without any mark up on our side. Finally: In today's environment particularly, the mere fact that this device is available from two suppliers is a big benefit.

In summary, I think the drought that we talked about earlier in the development of new programmable solutions and new programmable architectures is over. I fully expect to see a number of these application optimized processor solutions coming to market over the next few years. I think this will become one of the new drivers in this ongoing shift from fixed logic solutions to programmable logic solutions.

I'll quit by apologizing to Gene for the confusion that this is going to cause to Dataquest to try and figure out what really counts as semiconductor revenue. I appreciate your attention and I would be happy to answer any questions that you have.

Questions and answers:

Question: The difference here seems to be that you've licensed a specialized processor to a couple companies.

Answer: I think your observation's right. It's not that the FABless companies actually do assembly, but probably the critical difference is that the traditional FABless company - if we can use that term for something as new as a FABless company - generates its revenue by selling integrated circuits. In our case, we're not doing that. We don't generate any revenue from selling devices. We are not in the business of selling chips. We are certainly in the business of going to see customers. We are out there trying to win designs, just like any other semiconductor company would. It's essential to us, to our future, that we win designs for these chips. At the end of the day, it's Toshiba or it's LG that will take the purchase order and deliver the silicon.

The financial side of this for us has to work because we can make a business out of putting the software into these processors. I'd be the first to admit that this model isn't going to be applicable to every new start up. The FABless companies aren't going to go away and they're not all going to switch to this model. It's just a new variable. It's a new potential way of structuring a company to achieve some particular objectives.

Question: Wes, how do you recoup the value that you have in the software in the chip? Do the royalty payments come from the semiconductor partners or do they come from the users of the chip directly to you?

Answer: Our revenues are licensed software fees from the same company that buys the chips. There is a customer - let's say it's a PC OEM - and they are buying chips and they are buying software from us.

Question: Would your solution spell the demise of the add on card market? How would you support the installed base with the solution that you are offering?

Answer: I think the add on card market will continue to thrive because there are a lot of PCs out there that don't have all of these multimedia functions. There's millions and millions of existing PCs that will be upgraded over some period of time for new communications functions, multimedia functions, digital video disks, etc. We certainly expect to see add in cards with our chips - or others like it - on them, to the extent that this chip and potentially others like it start to go on mother boards. The plug in card market itself will probably get smaller, because more and more of the functions are going to be integrated onto the machine at the time that it's shipped.

Question: Wes, who warrants the performance of the product, you or the chip vendor?

Answer: The chip vendor is the one who publishes the data sheet and stands behind those specs.

Question: Wes, I had two questions. One, there is the software that goes with the chip, so is that a joint marketing that you guys do, because I'm guessing that the silicon is useless without the software.

Answer: And vice versa. You bet, it's a very highly cooperative marketing effort.

Question: The other thing is if there's a problem between in the working of the solution, you do the design or the semiconductor guys selling the chip - which is the hardware; who is responsible and how do you differentiate whether the problem is in the hardware or software or does Chromatic do all of the support and take all of the ownership?

Answer: I think this is one of those cases where if there's any doubt both the hardware vendor and our company will assume it's our problem and work on it until it's clear that it's where the problem is. It's clearly to mutual benefit to sort out the problem. It seems like there's very little likelihood of a finger pointing issue here. Both companies have to work together to solve any problems that arise.

Question: Would you comment on this approach versus NSP?

Answer: I think at least at the moment the existing architectures, the Pentium or the Pentium Pro, are not very well suited to the performance that consumers expect from multimedia. If you look at the kind of video - for example - that's available from NSP, I think it's well below most consumers' expectations of what they want to see when they think about video. Within this very narrow set of applications, there is a 10x performance advantage of this processor. It costs about the same as an NSP system, and delivers quite a lot higher performance.

Question: What's your strategy with respect to third party software development?

Answer: We think that there is going to be a role here. We are already talking to some third party software companies because to expand this market we'll need to have as broad a range of solutions as we can put together. We fully expect to be working with other companies.

Question: Wes, you alluded to this a little bit, but I'd like you to expand on it. The NSP approach says that these functions go into the processor at some point. With your strategy, that probably will occur with higher performance processors to some extent. What does that mean to your business and what does that mean for the main processor vendors? Are you pushing out the need for higher performance processors, or are you really symbiotic with that?

Answer: I think there's plenty of appetite for higher performance in the PC box. The challenge of adding this kind of performance to an X 86 processor, the marginal cost for doing that is very high. (A): You are starting with a dye that is already pretty big. (B): You are starting with a company that's used to very high gross profit margins. (C): You are starting with an architecture that is ill suited at best for these new kinds of natural data types that were never imagined or envisioned when this processor architecture was created. Although it's easy to appreciate Intel's objective for doing everything in the box, it's not at all clear that that's the best way to do it, either in terms of performance or cost effectiveness.

If we are wrong about that, somebody still has to provide the software to do all of these functions, and we are amassing a great deal of expertise in this area. In the end maybe it doesn't matter all that much to us.

Question: Are you planning to publish specifications so that the systems companies can write the software if they so chose?

Answer: We will probably get to that point, but I think we are going to start by working selectively individually with customers and third party softwares, because in this environment there is not room for a robust Windows 95 kind of operating system that can keep software separate and keep software applications from interfering with one another. We'll need to be sure that the software works as a whole and we'll have to play that role at least for a while.

Question: Wes, isn't the chipless model the result of really the competitive environment today? If you had a choice, would you; let's take the clock back ten years when foundry capacity was generally available. Would you structure it this way or the way it was done in Xylinxs? I think I know the answer.

Answer: I'm not sure I know the answer. Maybe it's just a matter of getting used to the idea, but I think there are some interesting advantages to this approach. I think that the customers appreciate having multiple sources. Clearly we can get at least one generation to maybe two generations more advanced process technology through this approach then we could get as a foundry customer. I can tell you that we're getting a heck of a lot better turns on first silicon then we ever saw from a foundry, because it's viewed as the product from these companies.

Finally: I think over the long term that at least for us there's probably a better balance. It's more fair in compensating each company for the added value. Like I say, I may be guilty of just accepting the world as it is and believing that the only solution that's available is the best one, but I think that for this particular business this is a pretty appropriate model.

Question: Wes, when do you forecast is the first time we'll be able to see the chip and the software together in a system or a subsystem for the general public?

Answer: I think people will be buying PCs with these chips in them in the second quarter.

Question: Will there be any demonstrations before that?

Answer: We'll be shipping boards. We will be filling orders from customers for sample boards this quarter. For people that are really interested, they will be able to see a demonstration.

Question: Hi Wes, this is just an interesting logistics question. I'm quite a keen advocate of Rambus, and in this model who's licensed it? You or Toshiba and the other company?

Answer: The Rambus license is between the semiconductor companies and Rambus. We're not involved in that loop.

This page is intentionally left blank

Chapter Nine: MICROMACHINES: WHAT ARE THEY AND WHERE DO THEY FIT?

Jerry Curtis
Vice President and General Manager
Sensor Products Division
Motorola

Introduction: The next talk will be a talk on micromachines, What Are They and Where do They Fit? We are very pleased to have Jerry Curtis, who is Vice President and General Manager of the Sensor Products Division at Motorola Semiconductor Products Sector.

This division that Jerry heads up was formed last September as a result of Motorola's commitment to semiconductor based sensing technology. Jerry has been with Motorola for 23 years, serving in a variety of interesting responsibilities in the wafer manufacturing and business operations for discretes, ICs and opteoelectronics products.

In the current assignment, he is charted to lead the market technology and product development efforts of the semiconductor based sensors and actuators for Motorola. These products use micromachining as an enabling technology. We have a demonstration of this technology out in the foyer; I hope you had a chance to take a look at it.

Let's give Jerry a good warm welcome and talk on micromachines.

Jerry Curtis: Good afternoon. It's my pleasure to have the opportunity to address this gathering of business and industry leaders. Micromachine electromechanical structures (or MEMS) are a very important new technology which will have a significant impact on the future of electronic devices, products and systems.

As you may know, the electronics industry has relied on the ability of the semiconductor industry to dramatically increase the number of transistors on a microchip; increasing the functionality while driving down systems costs. The initiatives required to manufacture millions of microscopic elements in an area no larger than a postage stamp has been one of the most pervasive evolutionary forces shaping microelectronics.

We are continually upgrading and increasing the power of electronic computing and memory circuits. As powerful as they are, they do little more than root and switch electrons through circuits. MEMS devices combine these electronic features with the physical world that will sense emotion, light, sound, heat and other physical forces. This incredible coupling will produce dramatic technical advances across diverse scientific and engineering disciplines. In other words, microstructures combine the electronic and mechanical properties of silicon to produce powerful new technologies.

The key to continued MEMS advancement is indeed micromachining. It is the premier technological enabler, allowing miniaturized, high performance products to be mass produced. This new generation of products will be formed by combining precise silicon etching - or micromachining - and wafer lamination or fusion bonding with more traditional integrated circuit processing techniques such as photolithography, diffusion, implementation and thin film deposition. Structures with thin diaphragm devices are the basis of products such as pressure sensors and microvalves. Suspended mass structures and devices are used to make vibration sensors and accelerometers. The same processes are also used to manufacturer purely mechanical devices such as grooves and nozzles.

We have come a long way since the early 1980's, when the first micro electromechanical systems and micromachine devices were introduced. The early products were for automotive and manifold absolute pressure sensors used in engine control units, and also invasive disposable pressure sensors for medical blood pressure and other small semiconductor based products.

The technology is developing. Through the intervening years, micromachining has evolved to become a very credible and popular technology used to produce commercial devices found in your car, home, in the office, in the surgery, and in quite literally millions of miles into space.

Your being here today proves that the interest in micromachining has obviously expanded. As a member of the ARFUS sponsored MEMS industry study group, with representatives from such research and industry leaders as Tektronics, ARPA, Abbot Laboratories, Baxter Health Care, Boeing and Sun, we are realizing that this technology is going to permit the fabrication of devices that are smaller, more reliable, faster, more efficient and more effective then ever thought possible. MEMS will indeed be the door to a whole new world of electromechanical applications and markets.

It's essential to point out, however, just what micromachining technology is today. Microelectromechanical structures can be divided into three groups: Static, dynamic and kinematic. Static microelectromechanical devices include three dimensional structures such as nozzles, capillaries, capilaric columns, circular orifices and miniature electrical connectors. The dynamic microelectromechanical are diaphragms and membranes, microbridges, cantilever beams and resonators. Kinematic devices include micromotors, microgears, pin joints, springs, etc. Today most MEMS structures come from the static and dynamic groups, and are used as components in larger systems. Kinematic or moveable devices are growing in many applications, especially in microrobotics and microsurgical devices.

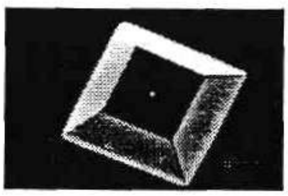
How is this micromachining done? Although there are new micromachining processes being developed almost every day, three main processes are currently in place at the commercial level: Surface micromachining, bulk micromachining and LEGA, which is a German acronym which in English basically means lithography, electroforming and micromolding.

Bulk vs. Surface Micromachining Chart

Bulk vs. Surface Micromachining

Features	*Bulk Micromachining*	*Surface Micromachining*
Core Material	Silicon	Polysilicon
Sacrificial layer	———	PSG, (SiO_2)
Size	Large (typical cavity dimensions are several hundred μm)	Small (high precision controlled by thickness of the film; typical dimensions are several μm)
Processing factors	Single or double side processing (front and back side) Selectivity in material etching Etching: anisotropic (depends on crystal orientation) Etch stops Patterning	Single side processing (front side) Selectivity in material etching Etching: isotropic Residual stress in films (depends on deposition, doping, annealing)

Typical silicon diaphragm used in pressure sensors (bulk micromachining)



Motorola's accelerometer G-cell (surface micromachined)

Surface micromachining is a technique for fabricating three dimensional and mechanical structures from multilayer stacked and patterned thin films of polysilicon. This micromachining approach is attractive because smaller structures with better dimensional control, as compared to bulk micromachining can be done.

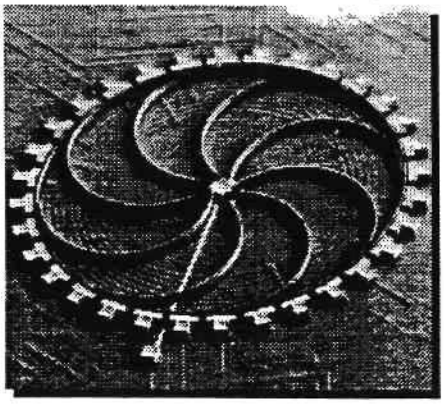
For sensors and actuators, the most prevalent user of this technology, surface micromachine structures permit the integration of signal processing to circuitry on the same chip. The advantages of which include higher sensitivity and accuracy, compensation for parasitic effects, faster data acquisition, improved reliability and lower costs.

An example of a surface micromachine sensor is the G-cell from Motorola's accelerator product family. Bulk micromachining is based on single crystal silicon that is etched using wet silicon etch. The anisotropic etching properties of single crystal silicon result in three dimensional structures. Examples of bulk micromachine structures include cavities, spirals, and cantilever beams. What you see here on the chart is a typical silicon diaphragm that is used in micromachine pressure sensors. The view is taken from the back side of the chip, so you are basically looking down into a cavity.

Not to digress, but silicon is a fascinating material. It has unique properties that make it twice as strong as steel, with a density close to aluminum, which is roughly 1/3 the density of steel. Silicon is entirely elastic and uniquely resistant to temperature changes and extremes. In other words, silicon is the critical enabling element for bulk micromachining and is being applied to such well known semiconductor based products as accelerometers, thermal infrared sensors and inductors using CMOS technology.

LEGA, the third fabrication method, is newer. It basically features three dimensional mechanical structures with high aspect ratios or height to width requirements. Production heights are usually several hundred microns, roughly the fraction of a human hair. The process combines x-ray lithography, or in some cases deep UV lithography, with thick resist layers and electroplated metal overlays for three dimensional structures. A leader in this emerging micromachining technique is Delco Electronics. Today Delco is applying micromachining to Gyroscope devices. Gyroscopes or sensors are typically found at the core of inertial navigational systems which are used in aircraft ships and cruise missiles. Although gyros have existed for decades, they are rarely used in high volume, mass production because of high cost.

Ring Style Gyroscope



Produced using LIGA

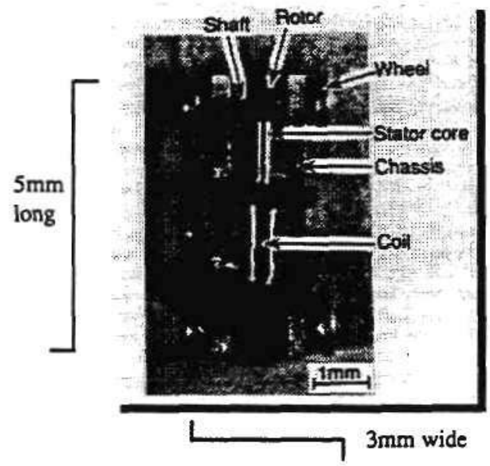
DELCO

Delco's three ring gyro uses the LEGA process. This tiny micromachine is formed in the top of a CMOS wafer. The process such as this can basically be built on top of CMOS, without interfering with the underlying structure. It's built with a sacrificial layer and thick resist mold that's electroplated metal that's used to fill the mold. The machine is then released by dissolving the mold and the sacrificial layer. The result is the finished structure you see here, a resonating gyroscopic ring.

The close up view shows two tiny capacitive electrodes, located on the perimeter of the metal ring. These electrodes are the gyroscopic nerve center, driving the ring into signal sensing resins.

I would like to take a moment to show you the incredible potential of this technology, micromachining, represents. For some time now, Nippondenso has been studying micromachine locomotion and performance. The genius way they brought the two principles together was to build a real functional car. A car that's no larger than a grain of rice, as you can see on the chart. Nippondenso first built the car's micromotor, an electromagnetically driven step motor, mounted onto the chassis. The motor's roller was then joined to the front wheel shaft using a zirconium rod, micromachined with a 250 micron diameter.

Top View of Chassis



With microstep motor, wheels and shaft.

The chassis and wheels were stainless steel. The body shell was nickel film, with a thickness of 30 microns. The chassis was molded then shaped and contoured by numeric control micromachining. Chemically electroplated with nickel, the lower part of the body was removed through electrodischarge machining and plated with gold to prevent oxidation.

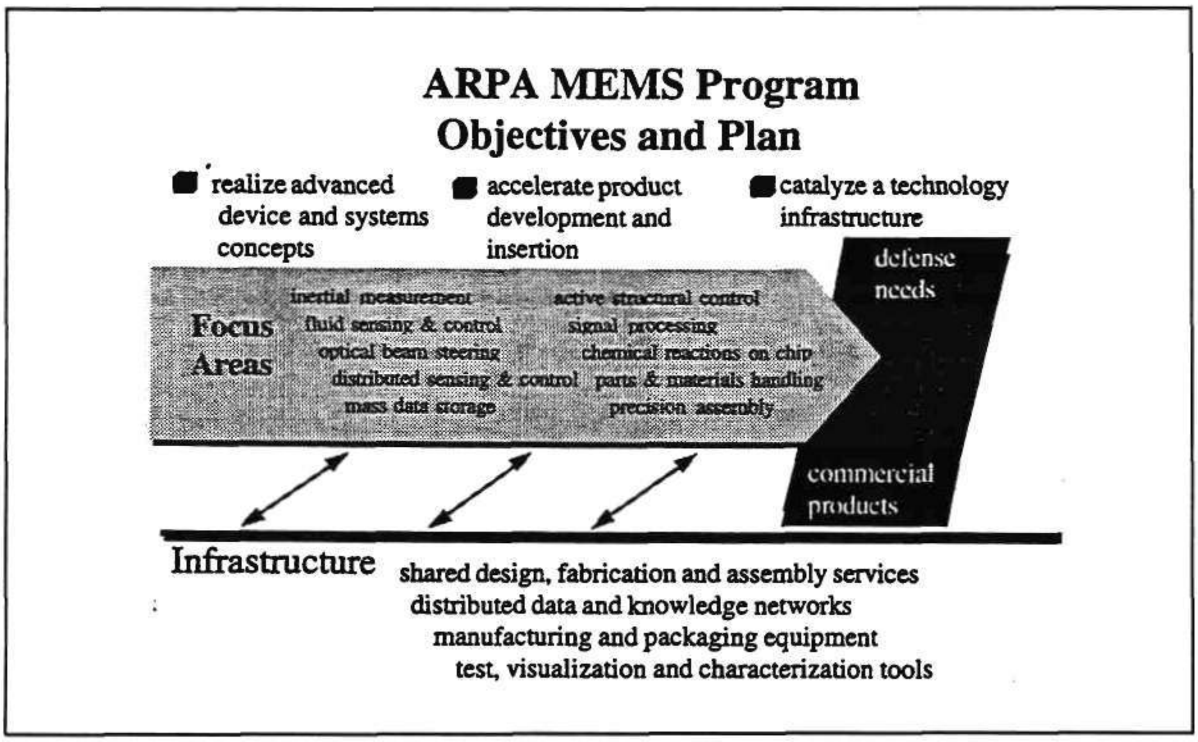
The microcar was assembled using a mechanical manipulator typically used for cell handling in bio research. Microparts were affixed using cyanoacrylate adhesive to make the world's smallest car, measuring seven millimeters long, 2.8 millimeters wide and three millimeters high.

To move the car, the micromotor was produced using both bulk and surface and micromachining. The motor was powerful enough to make the tiny vehicle travel at a top speed of 100 millimeters per second. Here you see it running over sandpaper, and the sandpaper particles are about 200 microns in size.

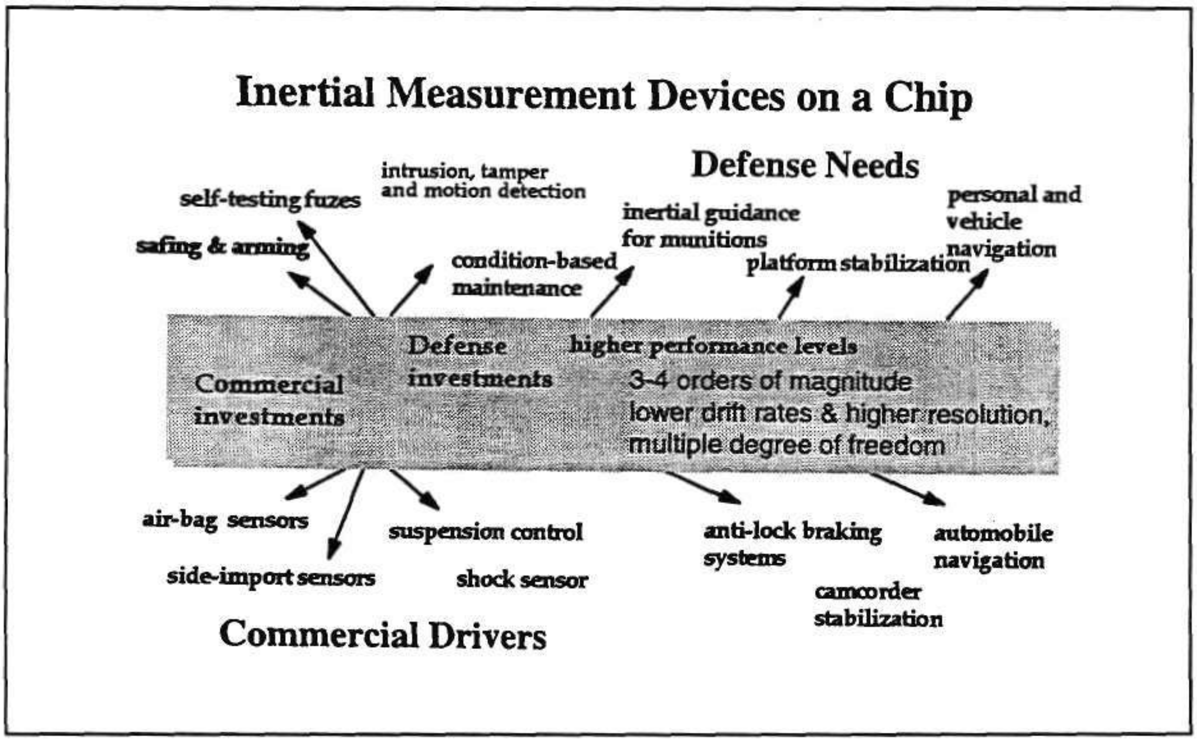
Obviously we won't be riding around in microcars, but I think this illustration gives you a good idea of how micromachining technology can be used to solve real and complex challenges or meet new needs.

This brings us to the most significant and complex challenge facing high volume commercial applications of micromachining. The successful melding of micromachining processes with standard IC fabrication techniques, combined with standard packaging and testing that have kept the industry from really developing. Progress is being made, in large part due to aggressive research and development activities of semiconductor companies, universities and research institutions worldwide.

The ARPA, Advanced Research Projects Agency (ARPA), located within the Department of Defense is working in partnership with the universities and commercial industry to identify solutions for successful and powerful marriage of IC technology and micromachining technology.



ARPA's long term goal is to merge information processing with sensing and actuation to create new systems and strategies for both perceiving and controlling systems, processes and the environment. ARPA's short term goal includes demonstration of key devices, processes and prototype systems using micromachining technologies. Specifically, ARPA is aggressively pursuing the development of these products into commercial systems, while lowering the barriers to technology and through mass commercialization.



The development of inertia measurement systems on a chip is an excellent example of how ARPA is striving to reach its goals. The ARPA team identifies commercial drivers and defense needs and then uses both commercial and defense investments to leverage the resources of each to produce new products such as - for example - air bag systems for the commercial market and personal vehicle navigation for defense.

As you can see, ARPA and universities and industry are actively pursing MEMS to not only synergize the continued evolution of MEMS, but to leverage commercial and industry expertise; to reduce the development time necessary to move this successfully into the 21st century. In fact, by the year 2000, just four years away, the worldwide MEMS market is estimated to reach $14 billion dollars, with primary applications in the production of pressure and inertia sensors, optical switching, fluid regulation and control and mass storage of data.

This chart identifies the evolution of MEMS technology used in small machines and sensors. Integrating more of these devices with electronic circuits provides a window to the world of motion, sound, heat and other physical forces. The vertical axis shows information processing ability. The horizontal axis indicates the device's ability to sense and control. With the exception of the DMD - which I will talk about a little bit later - in the upper right hand corner, the majority of today's microelectromechanical structures are located in the small box at the lower left hand corner. Future applications are represented in the circle stretching to the right and spread throughout the chart.

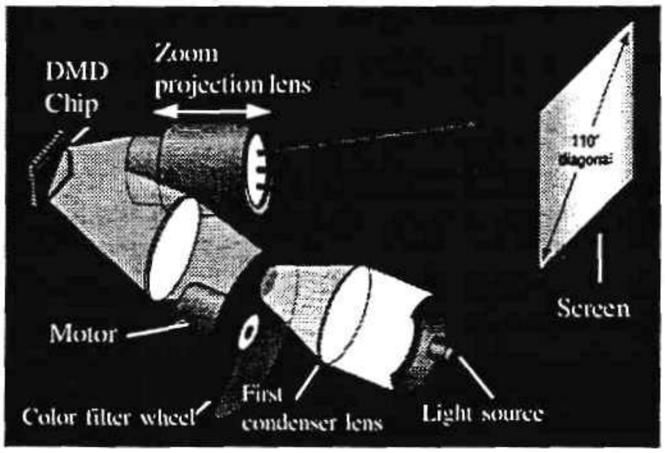
In addition to the universities currently developing programs in conjunction with ARPA, it is safe to say that virtually every major university has MEMS research and development as a top priority. Even the Internet has a MEMS home page, which you can look up the status of various university and industry micromachining projects in areas from stimulation probes to x-ray lenses to microvalve actuators to gyroscopes to microflow pressure sensors. Applications using micromachining technology are proliferating and at a rate that makes it challenging for all of us involved to keep pace.

What does MEMS mean to business and industry? Will this technology really go into the marketplace in the ways we envision? With every aspect of MEMS are challenges, and with every challenge there is distinct opportunity for growth and profitability. Today large semiconductor fabricating facilities are using micromachining at the commercial level, and development is proceeding at an unprecedented pace. From Motorola's standpoint, micromachine sensors and actuators are a key new product in technology thrust. Other companies are also working to develop technologies and products which in turn are creating whole new markets.

I will describe some very exciting and innovative commercial, industrial and medical applications that exist today, as well as those that are on the horizon.

This is a lead in to the next speaker, but this is Texas Instrument's product. It was first introduced to the commercial world. It's a MEMS fabricated product for a high resolution, large screen projector, based on a digital mirror device or DMD, which I mentioned earlier. The DMD is being successfully produced at high volume and at low cost using standard semiconductor FAB techniques.

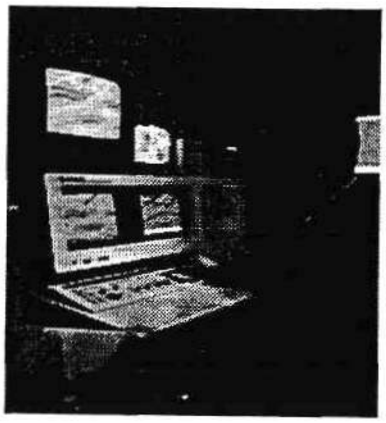
Texas Instrument's
Large Screen Projection System



This is a close up look at the MEMS micromirror devices that are at the heart of this product. The elements, or pixels, that make up the image are controlled by micromachine mirrors. Each pixel is made from 16 micron wide aluminum mirror that reflects pulses of colored light onto the screen. The pixels are turned off and on by an electric field that causes the mirror image to tilt to one side or the other. In one direction the light beam is reflected to illuminate the pixel. In the other way it's basically scattered, leaving the screen dark. The result is a high degree of brightness and resolution for a much sharper picture. These micromachine mirrors compensate for the inadequacy encountered with other technologies like liquid crystal screens that have inherent difficulty in large screen applications.

Micromachined Sensor Products and Systems

Sensors:
Devices that provide a useful output to a specified measurand



Actuators:
Part of an open or closed loop control system that connects the electronic control unit with a process.

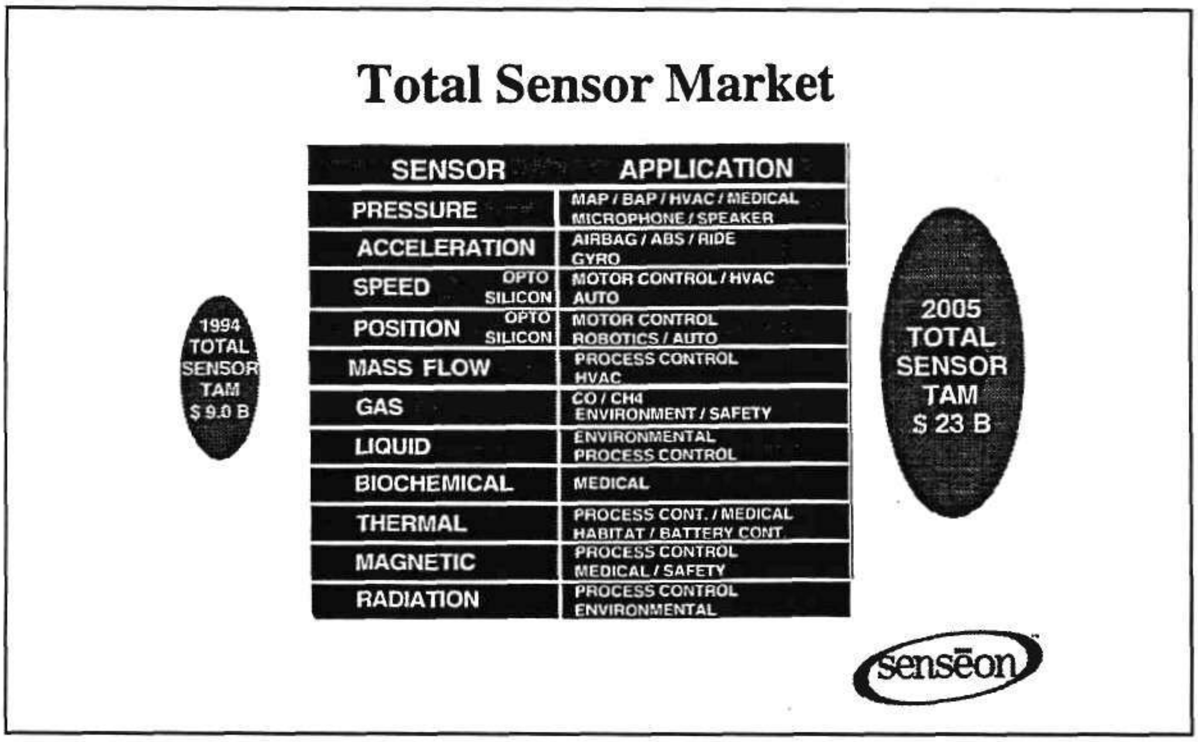
senseon

Motorola has been applying micromachining to the research, development and manufacturer of sensors and actuators since the late 1970's. Very briefly, the differentiation between sensors and actuators is that sensors are devices that provide a useful output to a specified measure, and actuators are part of an open or closed loop control system which connects the electronic control unit with a process. Motorola's current sensor and actuator portfolio includes pressure, temperature, chemical and acceleration devices.

We see the MEMS base sensor market experiencing tremendous growth over the next ten years. This chart identifies certain families of sensor products with various applications and opportunities. As you can see, we think the total sensor market, which includes non-semiconductor based sensors, will more than double over the next ten years. More importantly, the semiconductor based portion of that will go up over in order of magnitude.

One example of how we have integrated MEMS into our sensor product is to look at our acceleration sensor. In this product we have used both bulk and surface micromachining. Bulk micromachining was used to make the devices for Medicap, while surface micromachining creates the capacitive element. In order to keep the number of math steps and process complexities down for cost reasons, we used a two chip approach. The result is an accelerometer that incorporates a polysilicon seismic mask suspended between two fixed polysilicon plates with a G-cell. When acceleration forces act on the seismic mask it moves, basically changing the capacitance and that's picked up by the CMOS control chip, which then signals the air back MCU, which decides when to fire the air bag according to automotive algorithms.

We have successfully combined surface micromachining and bulk micromachining and patented processes that allows standard wafer FAB techniques. In addition, we can put it in the plastic package which again further reduces costs and makes it a repeatable and reliable product for mass markets, where in the past you couldn't really do that.



Micromachining is also utilized to a great extent for our pressure sensor devices and our soon to be introduced chemical sensor product lines. So far Motorola has invested tens of millions of dollars in MEMS, and we are continuing to develop and refine new micromachining techniques. We have a dedicated MEMS wafer FAB and dedicated packaging and test facilities in place and being expanded. These investments are being made in Europe, Japan, Asia and North America.

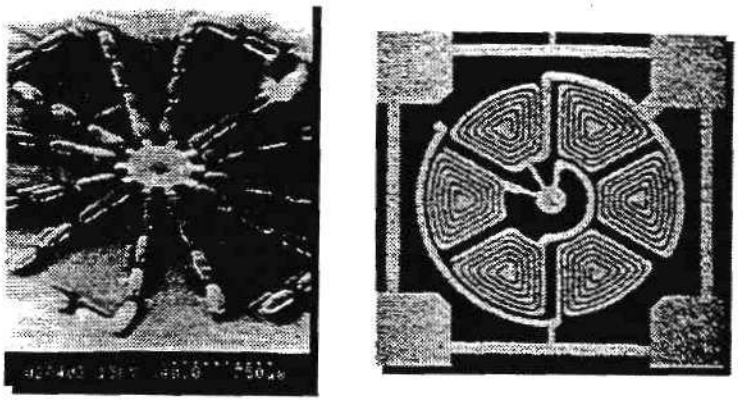
Turning our focus to the future: This is where application of MEMS is limited only by your imagination or our imagination. One of the fastest rotating machines in the world is the micromotor. It spins at hundreds of thousands of revolutions per minute. It has been developed by researchers at Sandy and National Labs. Imagine how this tiny machine could be used to unclog arteries, perform delicate procedures of neurosurgery or study abnormal cells. According to Sandy's Paul McCorter, the leading scientist on the project, whole development is five to ten years away; but within two years the device could be use to align optical fibers, position optical mirror switches or actuate miniature pumps. The microengine is actuated with the connecting rods, like in a conventional internal combustion engine, but rather than pistons the microengine uses two interlocking comb drive trains that generate electrostatic forces electrically powered by a microprocessor.

IBM is making tremendous strides in the development of low cost, high density data storage device that uses a fully integrated multilayer MEMS chips; a millimeter size wobble motor and actuator. The device, which will be a millimeter size single chip, is anticipated to contain the same amount of data as a typical CD-ROM. This microminiature hard drive could then be used - for example - in a cellular telephone to store a national phone directory, or perhaps in a vehicle navigation system that would store detailed regional and national maps, which would help people like me from getting lost.

To reduce assembly costs for these tiny data storage devices, IBM plans to integrate millimeter size mechanical platforms for the recording systems. Bits will be stored on a media surface on X/Y coordinates.

Micromachining tuning fork style gyroscope sensor that will be able to be accurate within 100 degrees per hour is being developed for gyrobased navigation systems in automobiles. There are a number of companies working on this and it's targeted to be available around 1998, and cost less than $25.00 per unit, which is quite a departure from today's technology.

Sample Micromotors that could have Medical Applications



For medicine, the application of micromachining is particularly exciting. One innovation that's currently in development is an electroplated metallic probe used for neuromonitoring and stimulation. Fabrication using a comparatively inexpensive poly based micromachining process, the probes offer several advantages, one of the most of which is their very small size and configuration that can minimize tissue damage. These probes will be relatively easy to fabricate using existing technologies and offer the added advantage of integration, putting circuitry on the chip to make a smart probe.

MEMS technology is exciting. It's real. It's enabling a revolution of sensing and actuating market. If you can reflect back on the semiconductor industry and what's happened in the last 40 years, it's unprecedented in the history of the industrialized world. Over that 40 year period, the semiconductor market grew to over $100 billion dollars last year, and is forecasted to be as high as $300 billion dollars by the end of the decade. That's what they're working out next door.

Using the analogy of the human body to the semiconductor industry, first we develop discrete devices, power devices and such that were like the muscles of the body. Then we developed IC technology, which with the microprocessor being the pinnacle of that, are like the brain of the body. Both of those markets are huge multibillion dollar markets today and growing rapidly.

Sensing will allow us to address the senses, like the body, and we believe that this market will in fact be large, like the other markets. It's already happening. We are limited only by our imagination of how to apply this technology to satisfy application needs we see today and create whole new markets and applications we have yet dreamed of.

The future is bright. It's exciting. I invite you to start to imagine how this technology can allow you to solve problems and create opportunities for your systems and products. Thank you.

Questions and answers:

Question: Was that IBM example actually a miniature storage device, as a hard disk?

Answer: It's like a mini hard disk is basically what it is, using micromachining technology.

Question: With multiple cylinders and all of that?

Answer: I don't know all of the details of it, but it's basically that's the technology they have been pursuing for very, very high amounts of data in a very, very compact space; so that it would in fact fit in something like a cellular phone, which is pretty exciting.

Thank you very much.

This page is intentionally left blank

Chapter Ten: THE EMERGING MARKET FOR DIGITAL MIRRORS

Dr. Randall Ledford
Vice President and Deputy Director
Digital Imaging
Texas Instruments, Inc.

Introduction:

We've saved the best for last. A very new and exciting technology, digital imaging. We are going to hear from Randall Ledford, who is Vice President and Deputy Director of the Digital Imaging Group at Texas Instruments.

As Randall said to me, he probably has more degrees than many of us in the room here. He has a BS degree from Lake Forest; three undergraduate degrees; two MS degrees in computer science and EE; and a Ph.D. from Duke in physics.

He started his career at Bell Labs in 1976, and then joined TI in 1980. In 1990, Dr. Ledford became the General Manager of the Process Automation Systems Division and he was elected a Vice President by the Board of Directors in 1991.

From 1992 to 1994, Dr. Ledford was general manager of TI's Enterprise Systems Division, with a responsibility for management and manufacturing software applications systems and solutions for telecommunications, voice applications and process automation systems.

Currently Dr. Ledford joined the TI's Corporate Digital Imaging Group in 1994, and is currently Vice President and Deputy General Manager, responsible for commercializing this technology. Let's welcome Randall; the last speaker of the afternoon.

Randall Ledford: Thank you for that wonderful introduction. Gene, that was probably the second best introduction I have ever had. The first was at another conference and I had to introduce myself.

DIGITAL IMAGING

Agenda

➤Introduction - Digital Information Infrastructure

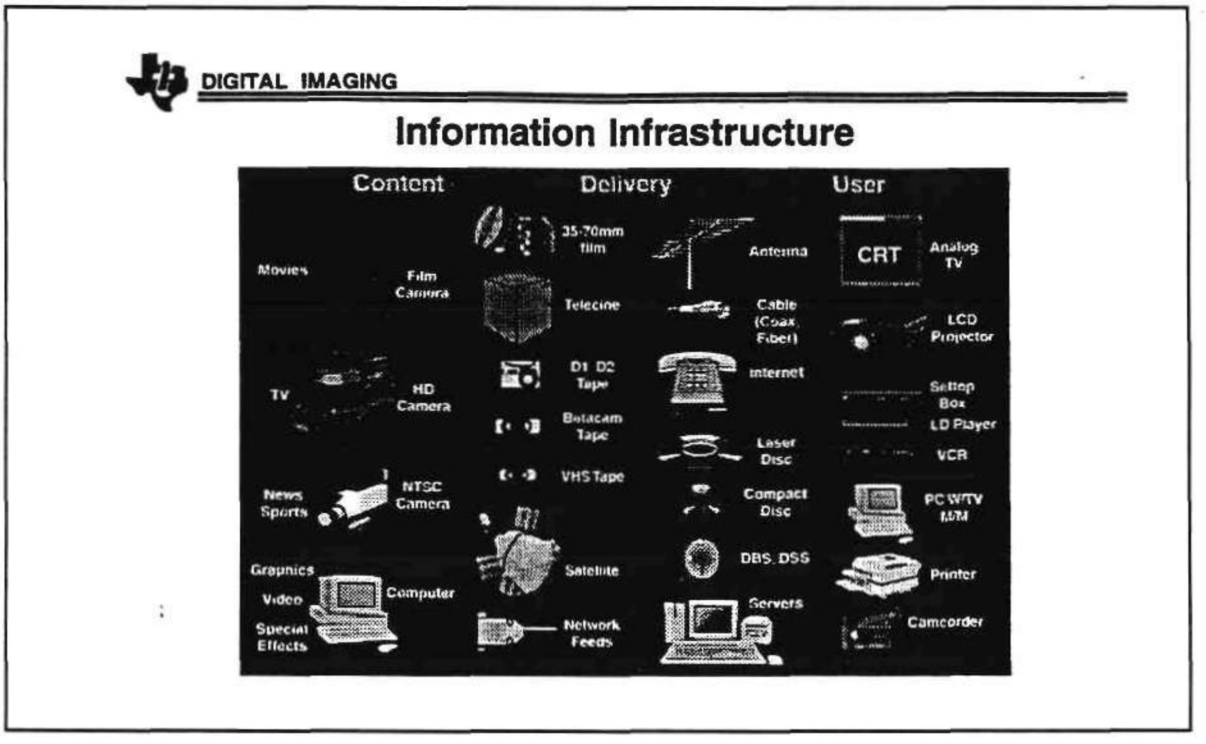
- What is a DMD?
  (Digital MicroMirror Device)
- What is DLP?
  (Digital Light Processing)
- How Does it Work?
- What are its Applications?
- What are the Markets?
- Conclusions

I am honored to be here - to talk to you about a new technology, and actually I feel very fortunate that Jerry was in front of me to talk about micromachines, because really what we are talking about is a confluence of many technologies: Micromachines, semiconductors and digital information, which we are very excited about and I hope that I can contain my excitement and enthusiasm for this a little bit and give you an objective overview of what we are talking about.

What we are really looking at is a semiconductor device, the digital micromirror, which modulates and controls lights. This DMD, digital micromirror device uses what I call digital light processing, DLP, which uses advanced signal processing techniques.

The agenda that I want to go over with you today is I want to give a little bit of an overview of where we see the world going in digital information and the infrastructure supporting that. Then I want to introduce you to the two acronyms, DMD, digital micromirror device, and explain a little bit of how it works beyond what Jerry just did. Digital light processing and how does the DMD actually work. Since it is the last presentation of the day, I have a couple of videos which I hope will break the monotony of listening to yet another speaker. I'll let you see first hand how some of these things work.

Finally: I'm going to talk about the applications and the size of the markets and the potential we see for this particular device.



This particular slide is our view of where we think the world is going and a bit of the information infrastructure. Much of what we've heard today, this morning, at lunch, has been based in technology and information and the digital revolution. We look at this and we can sort of segment it or break that up into three parts: The content. At our lunch table today we talked about that yes, we have 60 TV stations or we have 500 TV stations and yet nothing's on. One of the challenges here is for the content providers to take advantage of some of the technology streams that are being made available.

Delivery is one of the fastest growing and most explosive areas in terms of satellite communications, cable TV, and what's coming; especially what's coming into the home.

Finally: We see that interaction with the user. This morning we heard from Digital that ease of use and how this interfaces with the human being will be the ultimate test of the acceptance of a lot of this technology in the market place.

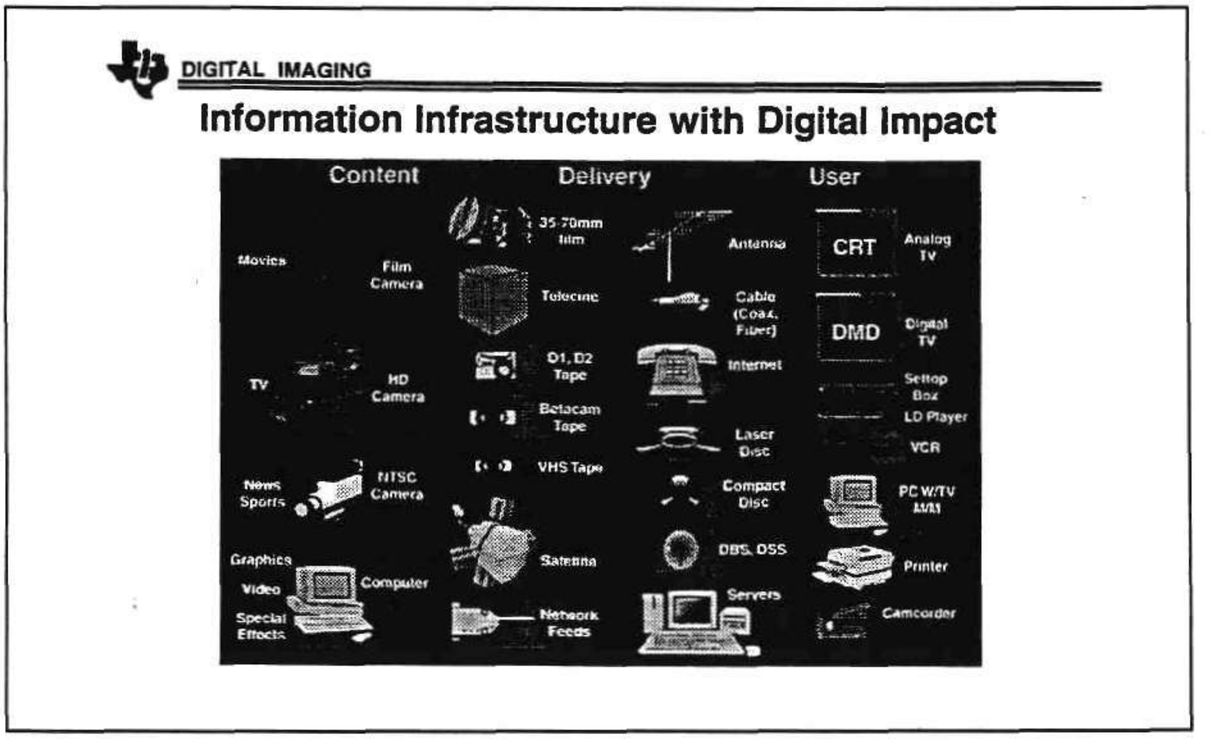
What's the environment out there? There is no question that we are in the middle of a digital revolution. Very simply stated, a lot of people are not only requesting but demanding that they get the right information at the right time, any place, anywhere. From our view of where do we utilize DMD's and digitalized processing, we see it meant for much brighter displays.

DIGITAL IMAGING

Digital Information Environment

- We are in the Digital Information Revolution (Information Anytime, Any Place)
  - Larger, brighter, realistic displays
  - High quality, multimedia capable Hardcopy and Displays
  - Extension into the home
  - Rapid growth of Color Hardcopy use in office
  - "Print on Demand" -- offset quality color
  - Knowledge-Rich Transactional Services (pay-per, on-demand)
- Greater Demand on the Human Interface

For example: This display is probably an LCD display machine, probably costing in the neighborhood of $100,000.00. It's not quite bright enough. The resolution is not what we could potentially have. Later on I'll come back to this and talk to you a little bit about what we can do in the display arena.



Looking at this infrastructure, this is the same slide that I showed a couple of slides ago. The march to the digital revolution is occurring. The highlighted areas here denote areas which have already made the transition from analog to digital, from content to delivery to user, there are already a number of digital applications and digital tools and digital technologies that are being used.

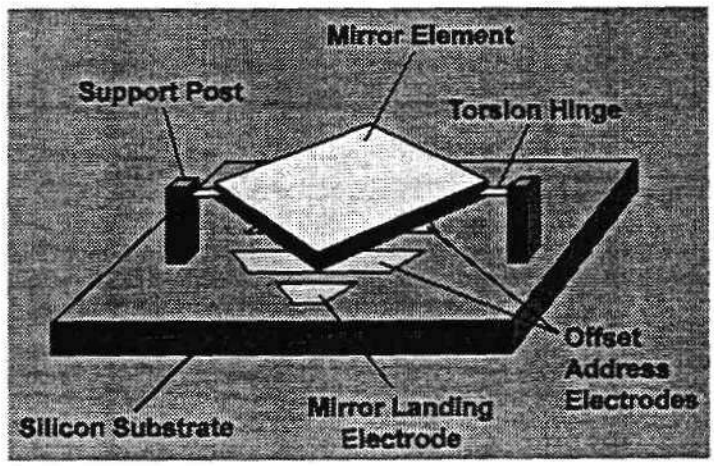
Steven Speilberg today films his movies in a digital format. These are transmitted through digital machines, edited on analog machines, and the key right now is that each of these A to D's and DA's represents a filter and those filters represents certain types of information losses at each step.

Let me move on and talk about the digital micromirror device itself. As I said earlier, this is a convergence of semiconductor technologies and micromachines. The DMD is built on top of standard CMOS, on top of S-RAM, eight micron CMOS. It is a true micron machine, as Jerry just pointed out. The mirror itself is made of deposited aluminum and each mirror is on 17 micron centers. It is a truly digital device. It has only two states when powered, on and off. It can rotate approximately ten degrees in each direction. Electric fields are what controls it and flips it from one state to the other.

The mirror itself is supported on a support post and uses a torsion hinge to help move it quickly from one position to another.

DIGITAL IMAGING

Digital Micromirror Display Pixel



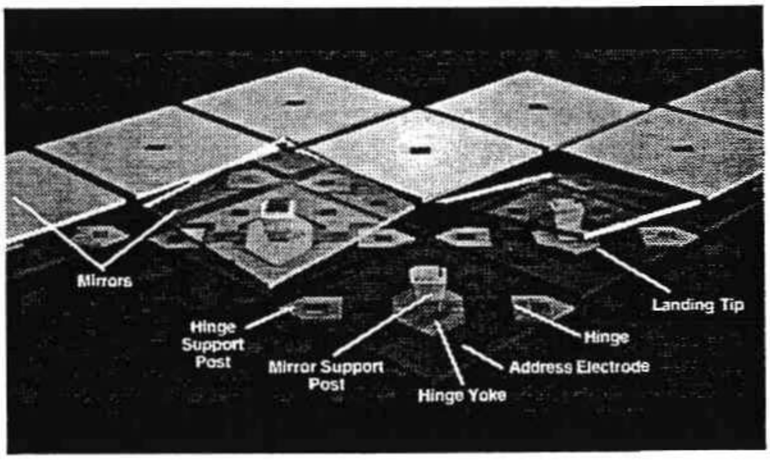
When you put several of these mirrors together, you create an array of mirrors. This is a cut away view of what a DMD chip would look like, showing the mirror superstructure, the micromachine sitting on top of the CMOS semiconductor below. When you put many of these together, you get an array which can be used to control light, to modulate light, and do it much faster. As a matter of fact, your current TVs have a refresh rate on each of the pixels of about 1/60 hertz or each foss per dot is refreshed at approximately every 16 2/3 milliseconds.

The DMD switch is approximately three orders of magnitude faster, in the neighborhood of 15 microseconds; being able to modulate light very quickly, very crisply, and contributing to the resolution.

DIGITAL IMAGING

DMD Hidden Hinge Pixel

Hidden Landing Tip Version (HH-II)

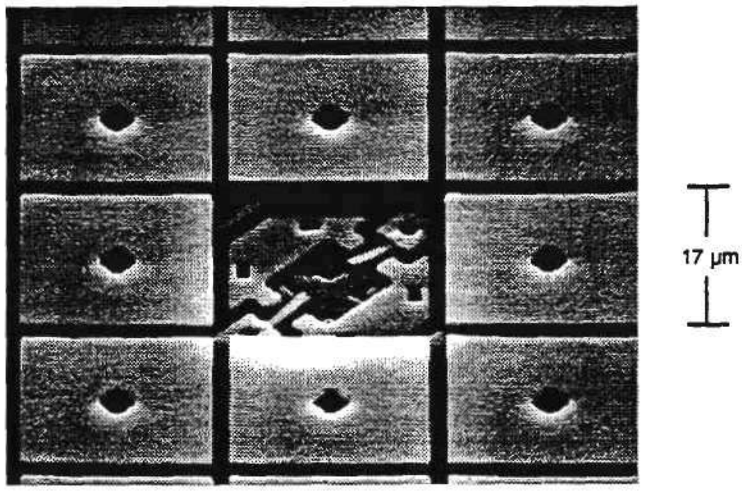


Here is an actual scanning electron microscope cut away of the DMD surface. The pixels are square. A couple of people looked at this and said they look rectangular. That's just because of the angle of the photograph. This is a cut away showing the super structure underneath the mirror itself. These are macromechanical parts and notice that one of the changes here from the round phospher dots of current CRT projectors are that these create square pixels, which is one of the standards which is emerging for high definition today.

DIGITAL IMAGING

HIDDEN HINGE DMD PIXEL ARRAY

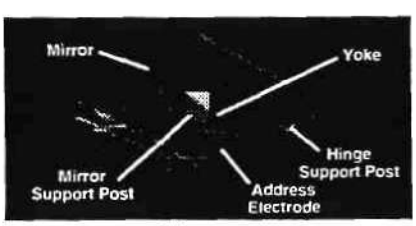
Mirror Removed to Show Underlying Structure



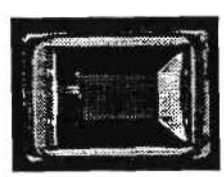
Square pixels give much higher light field factor, resulting in brighter colors and greater contrast. This maximizes the area from which light can be reflected.

DIGITAL IMAGING

DMD™ Configurations



Element

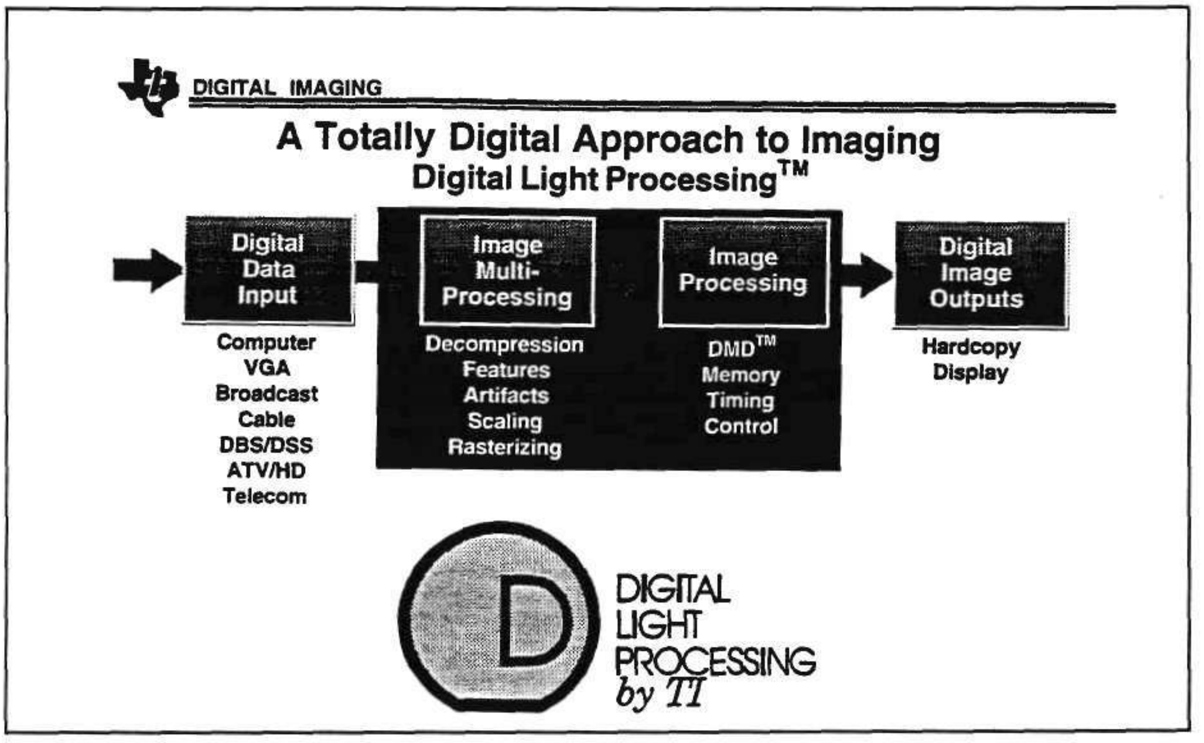

Area Array


Linear Array

Currently we are fabricating two specific types of DMD devices for display purposes, and one for printers. The linear rate that you see at the bottom is used for printers, which we also call a hard copy application, and it's 7,064 mirrors by 64 mirrors. Those of you who have been in printing will recognize that this will enable you to do an A3 print lengthwise at 600 DPI.

The other type besides the linear array is the area array. This is what we use for making displays, projectors, and potentially televisions. You can note that one mirror equals one pixel. We can make a VGA display by having an array device of 480 by 640 mirrors on a device. Likewise, we can do super VGA with an 800 by 600 device, and we have prototype devices which go all the way to 2,048 by 1,156 mirrors. That is we have chips today that from the smallest; and if you think of 400,000 mirrors as small, we have those devices up to over 2.3 million devices on one mirror. For those of you who haven't seen it, there are those examples out on the table.

Let's build up from the device itself into what is digital light processing. As information becomes increasingly more digital, we are developing a method which we call digital light processing. This builds a lot on our current technology of digital signal processing, DSPs, and we just think of light as yet another kind of signal. We use this to image the information, whether it's in a hard copy printer or in a soft copy display, with a minimum information loss.



As the digital information is created and sourced from the left of this slide, DLP, digital light processor, uses a number of microprocessors, specialized DSPs, multimedia video processors (as depicted in the center), to create a truly digital way to display data.

Let me switch to how these systems actually look. This is what we call a digital display engine, a DDE. This is composed of the microprocessors, the memory and support electronics to create an image and to project it.

This particular DDE uses three DMDs. You can see that at the bottom. Those are for the three primary colors of red, green and blue. Using the S-RAM memory, we can flip these and change them to produce the entire range of colors using these very high speed systems. Likewise, we can use one chip and a color wheel and do full color as well, and we also have two chip systems.

It's TI's intent not to manufacture projectors or not to manufacture printers using these or to manufacture TVs. Our intent is to make these DDEs, or digital display engines, and to sell them to a number of people. (I'll name some of the people who publicly announced a little bit later in the talk.) We have formed some very close strategic alliances with suppliers, that you see at the bottom; and what we will be developing and delivering are those subassemblies or DDEs to potential OEMs and distributors for fan out into the various markets.

Let me go over very quickly how does this all work: This is a very similar photograph to what Jerry showed, and you can see here that this is a pictorial of how a digital display engine creates a picture. First collimated light is focused by a lens system on a rotating color wheel, which you can see here. The light then strikes the DMD in the back. When the pixel needs to be read, the micromirror is turned to the on state, and during the time the red light is coming through the color wheel, it projects this through a lens onto the screen. The light from the mirrors is reflected through this lens system to a screen. Likewise green and blue are combined as well. By varying the amount of time that the mirror is on, one can produce the full pallet of colors.

Here is an actual picture of a picture produced on a DMD. The size of this with the dime is for comparison purposes. The mirrors here create the balloon image which you see. The middle picture is a blow up of the actual surface of a DMD, showing the star which is on the balloon. This snapshot is frozen in time to show how the different mirrors are turning on very quickly to produce an image.

As I said earlier, the pixels are square, not round like dots, resulting in much higher color fail factors and much brighter colors.

Finally, I will repeat again that these start from VGA 640 by 480 all the way up through high definition with over 2.3 million mirrors.

Also let me switch over to the hard copy or the printer. It works very similarly. There is a light source, a lens focusing system, but on the upper left you see the linear DMD, which turns on and off and the paper passes beneath it three times, multiple passes, to produce the full range of colors.

With that, I would like to see if I can show you a cartoon effect of this if we can get the video turned on from the back. This is about a 45 second cartoon of what I just showed you. This is our marketing hype here, showing mirrors moving very fast.

Here is the picture of a DMD; that's what I just showed you right there. That chip is actually making the picture. There is the balloon. The blow up of the pixels. They are changing colors very fast to create the images which you see there.

Turning on for green. Turning on for blue. As they go very quickly the eye becomes the final digital analog device in this case, creating the star.

Here is the display: The light source, color wheel, DMD. Red going to there. Green coming on through this color wheel. Faster and faster the wheel goes until all of the colors blend together to make the image.

In the hard copy printer: A light source of blue pass, a red pass, a yellow pass, and you get a final hard copy print at near photographic quality.

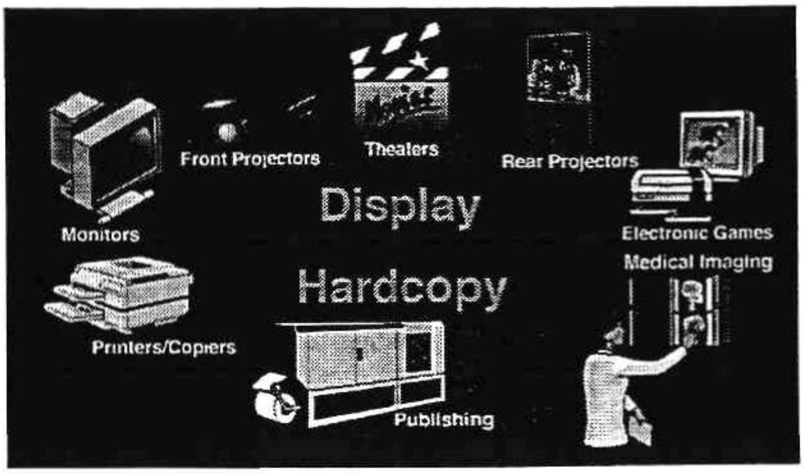
Let's talk a little bit more about the applications: We have looked at this for quite some time. TI started looking at the digital micromirror device back in the mid to early 1980's. It actually can trace its roots back to the 1970's at Bell Labs, at some mirror devices. We became very serious about this at Texas Instruments in 1991, when we created a group to exploit it, commercialize it and put it in there.

Our people, and the people that we have worked with, have identified over 100 different applications for light modulation. What we have done is we have focused our initial efforts on the two that I've been discussing: The display or soft copy and the printing or hard copy, which provides (we think) the best opportunity. I'll show you some market data a little bit later.

Displays can be used, of course, in a variety of human interface activities such as computer monitors, group workstations, front projectors, rear projectors, in the office, in the home, and even in large auditoriums like this and theaters.

DIGITAL IMAGING

Display and Hardcopy Opportunities



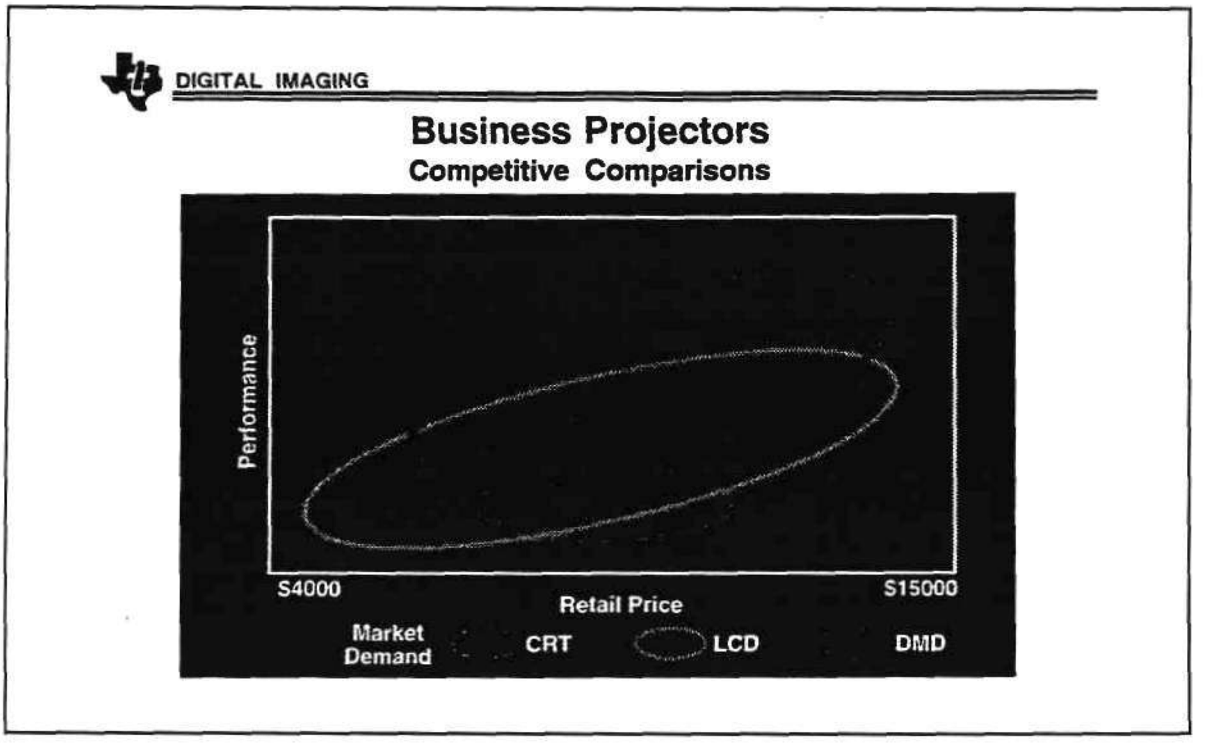
The applications for the hard copy, or the printer, we see more in the graphic arts because of the initial price point that some of this material will be at, and also because of the near photographic capability.

Our first product development will be in display. The first one of these products will ship either late this quarter or early first quarter of next year. We started the display activity about a year before the hard copy and the first hard copy products will follow in about a year, or that would be 1997, after the display products.

I wanted to try to show a little bit of a comparison here of the various technologies that are in the market place. This turned out to be a very challenging and very difficult exercise. When you start talking about displays, there are so many different characteristics that come into play. We cheated a little bit and we just did two axis: One was performance on the vertical access and price on the horizontal axis.

This particular one is one of the three market segments that we've looking at; this is business projectors. The three rings represent LCDs are in yellow, the CRTs are in red, and the DMD is in red.

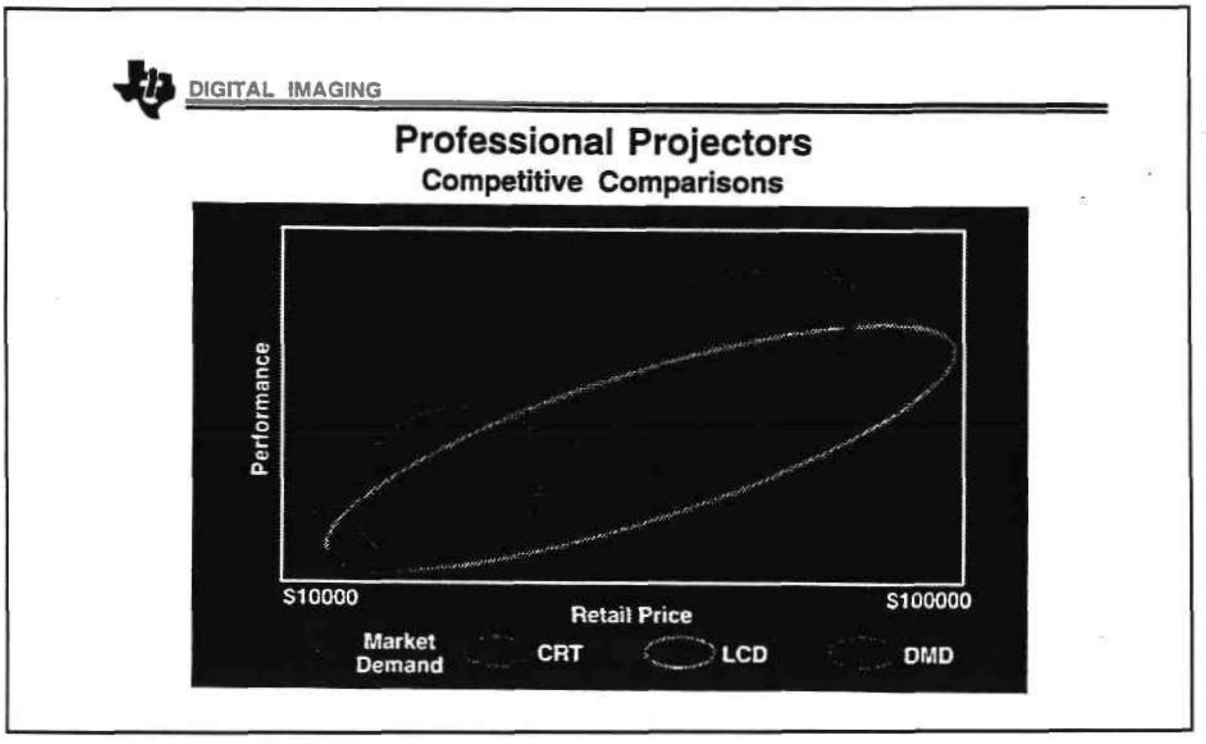
The performance axis constitutes a number of things that our engineers, our marketing people; but we used outside consultants and outside resources considerably in trying to put together what are the truly important things. They include brightness, resolution, size, weight and a lot of other specifications.



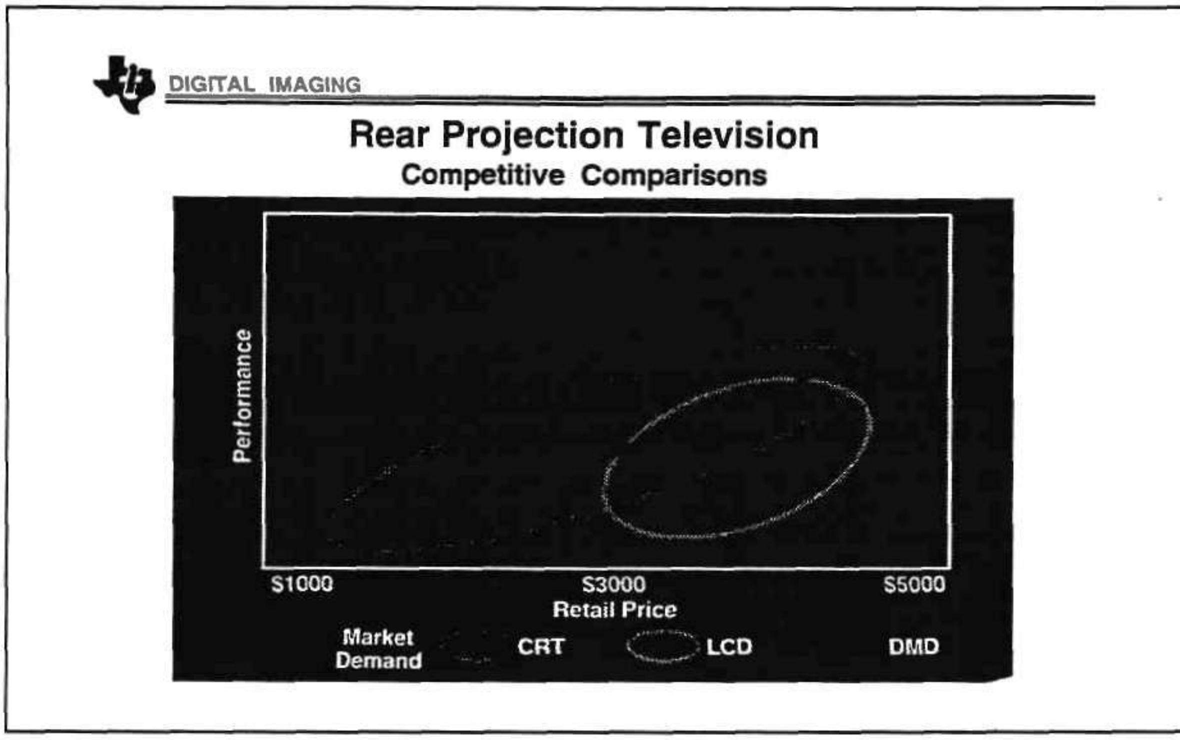
In this particular one on business projectors, and when I say business projectors I should perhaps define that as a small conference room, ten people or so. Typically that market is served by LCD panels that one puts on top of a view graph machine. If you've used those, you typically have to buy a brighter view graph machine because of the polarized light requirements of LCDs and the transmissive properties of the LCDs themselves. The brightness just isn't there.

One of the things that you see here in the performance, especially in the brightness and the resolution, DMD overcomes two of the significant drawbacks of LCDs because rather than having it be a transmissive property, it is a reflective property and mirrors are highly reflected.

I'm not going to tell you that DMDs are the perfect solution for every activity. Actually there are certain areas of LCDs and CRTs are very uniquely positioned for.



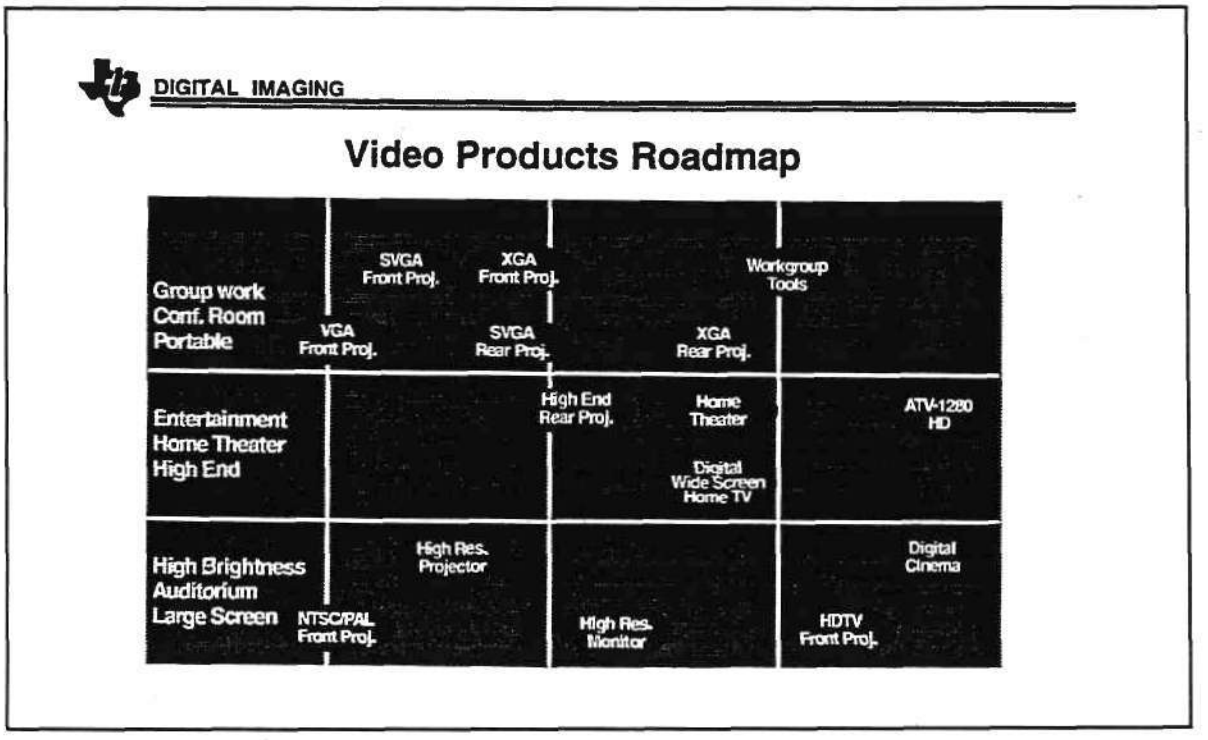
This next slide is professional projectors, and a professional projector I would define as a projector that one would use in this room, which I believe this is - perhaps I shouldn't name the projector being used here - but it's probably in the hundred thousand dollar range for price. The price on this particular one, if you can see the bottom axis, goes from about $10,000.00 to about $100,000.00. In this case we think the DMD has tremendous advantages over LCDs, but in particular over CRTs because it's just very, very difficult to get the brightness out of CRTs of anything this size. The DMD goes upwardly on these axis and has a lot of advantages.



Finally: The third segment that we are looking at in the display activities is in rear projection televisions. This price scale goes from $1,000.00 to about $5,000.00. At the low end CRTs are excellent solutions; as a matter of fact getting below what we call large screens, which is probably 35 and 40 inches and greater. The only way that one can get a large screen TV is with a projection system using CRTs or LCDs.

Below that point, direct view CRTs or picture tubes are the prime best way to get this done. Really for the brightness performance, this is where we think there is a real advantage for DMDs.

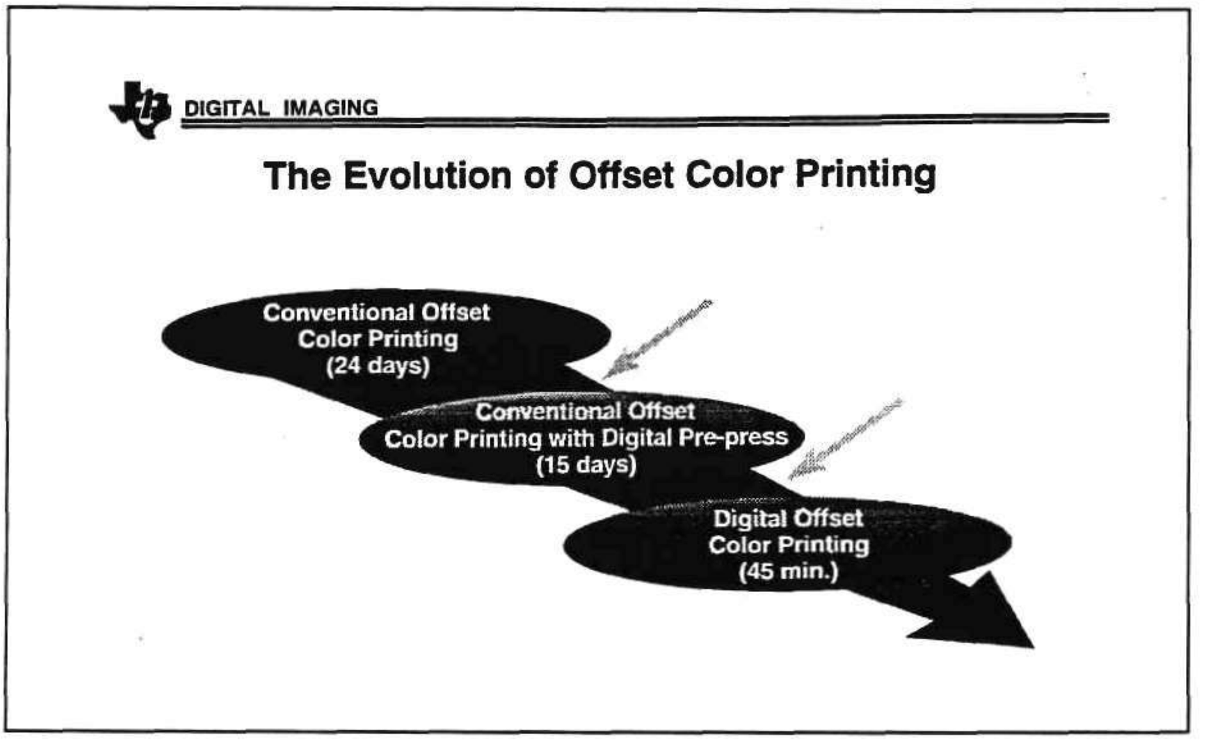
For example: The largest picture tube television that you can get right now is typically a 35 inch television. I do think Mitsubishi makes a 40 inch television. I believe it weighs between 300 and 400 pounds, a half inch glass for a picture tube is very heavy and I believe it requires special furniture to hold that. Our engine, which is on the table outside, weighs about ten pounds and television manufacturers say they can make a 40 inch or a 50 inch or a 60 inch rear projection television in the neighborhood of 60 pounds. It has a tremendous advantage in terms of the weight characteristics.



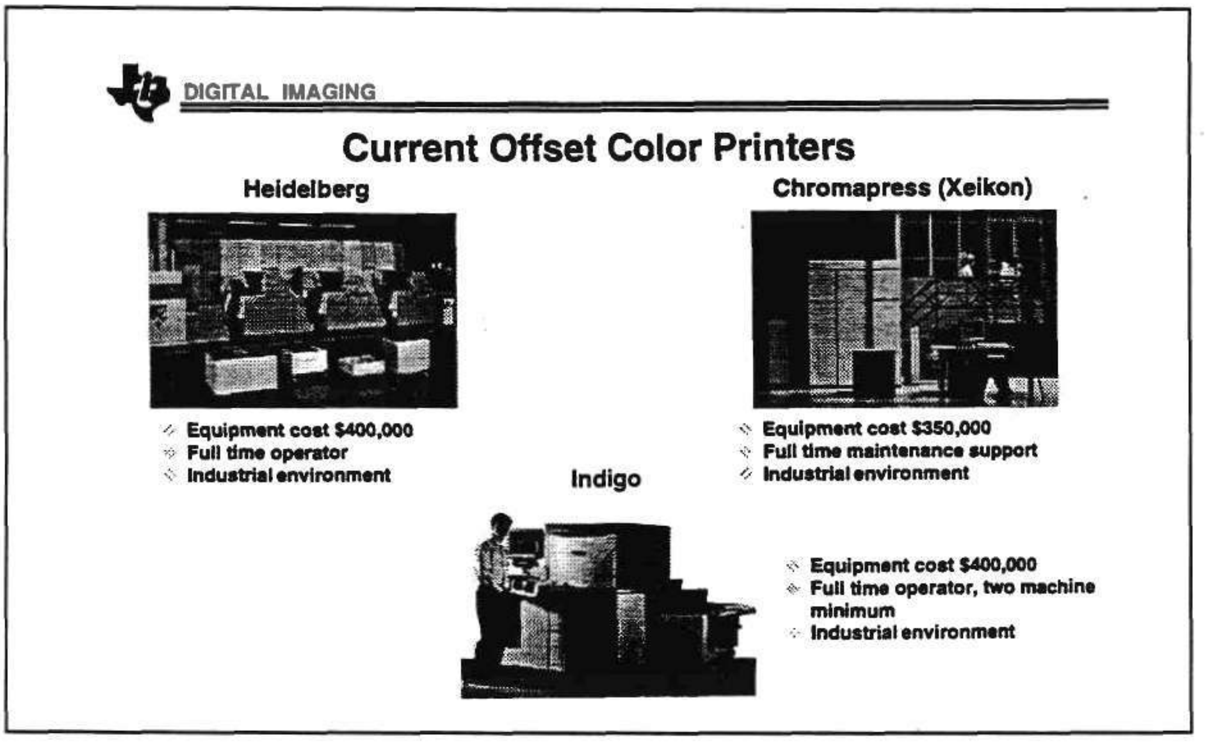
Here is a road map of some of the video products that we are talking about. Along the three horizontal axis are the three segments I just described to you: The business projectors for small conference rooms, the home or TV and the professional projectors. In the last six months, there have been a number of public announcements made by other countries that they would be introducing products using the DMD and digital light processing technologies. These product announcements have come from Proxima, In Focus, In View, Electro Home, Brimar, Runco, Bitachron, Nokia, and Sony - who has not made a product announcement - has made an announcement that they are delivering a technical evaluation for some of their displays yet to be done.

From display, let me switch over to the printing application. I am going to ask you to think in a little bit different fashion here. We're not just talking about the quality of print, we are talking back again about the digital information and revolution that we are facing here.

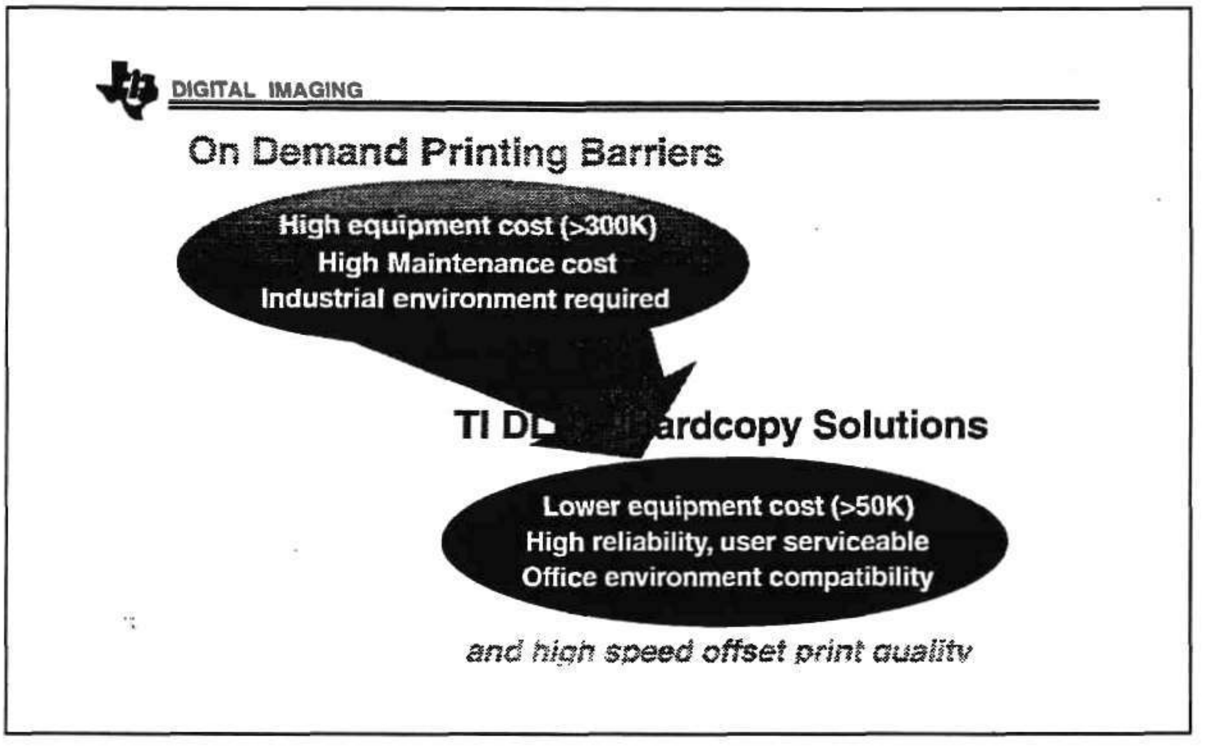
In the 1980's, we saw the conventional printing improved quite a bit with the pre-processing of print material using digital processing and cycle time went down from perhaps a month to a couple of weeks.



In the 1990's, the push and challenge is to create a fully digital process with the same quality characteristics of conventional offset printing, but to push the cycle times down to less than an hour. What that means is that for the first time we're going to be able to do print on demand. A lot of your book stores, if they can solve the binding problem, will be able to print books when you want them when you enter the store, as opposed to having to have expensive and extensive inventory, distribution and warehousing processes. We see a tremendous push right now from the publishing industry to be able to enable print on demand.

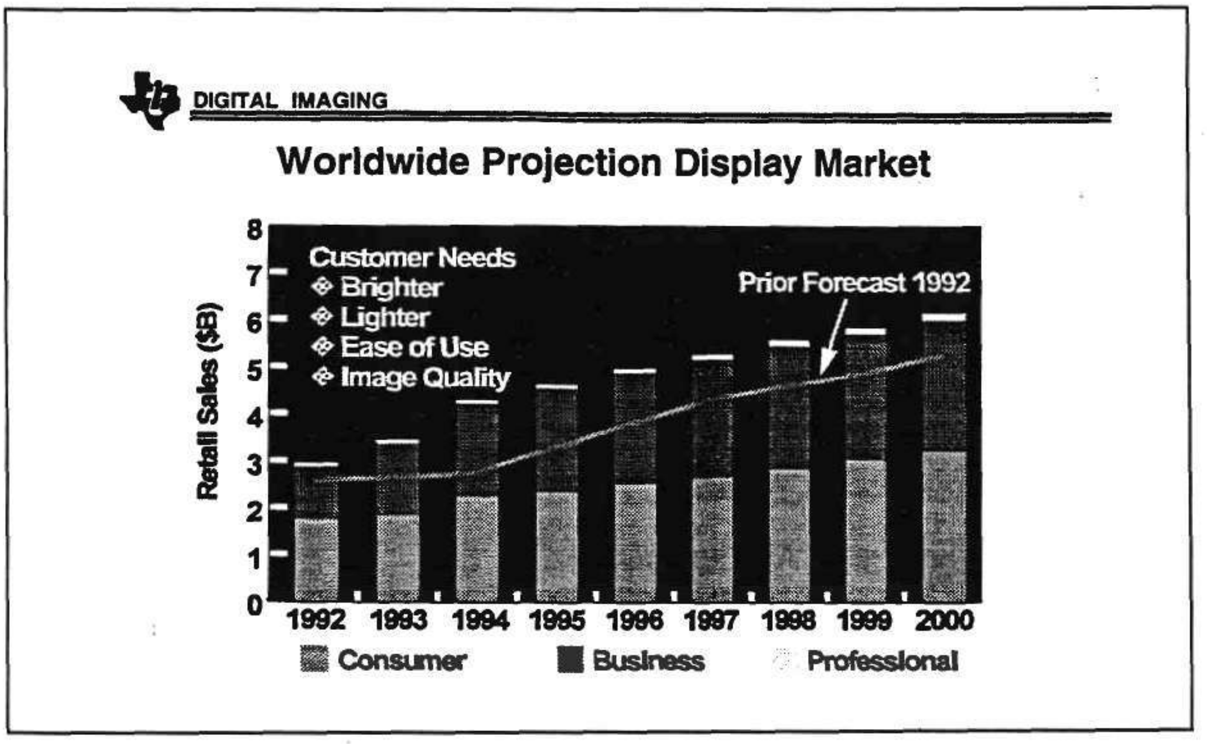


If we look at the best of the best of printers today, now I'm talking about high end printers, not your PC desktop printer here; these are three of the best print machines in the world today from Heidelberg, Chromopress (that you may know from Zycon) and Indigo. These have a series of common characteristics. They are all in the $300,000.00 to $500,000.00 price range. They require at least one full time operator. They require a controlled environment. They do produce very high quality and they have very high speed characteristics.

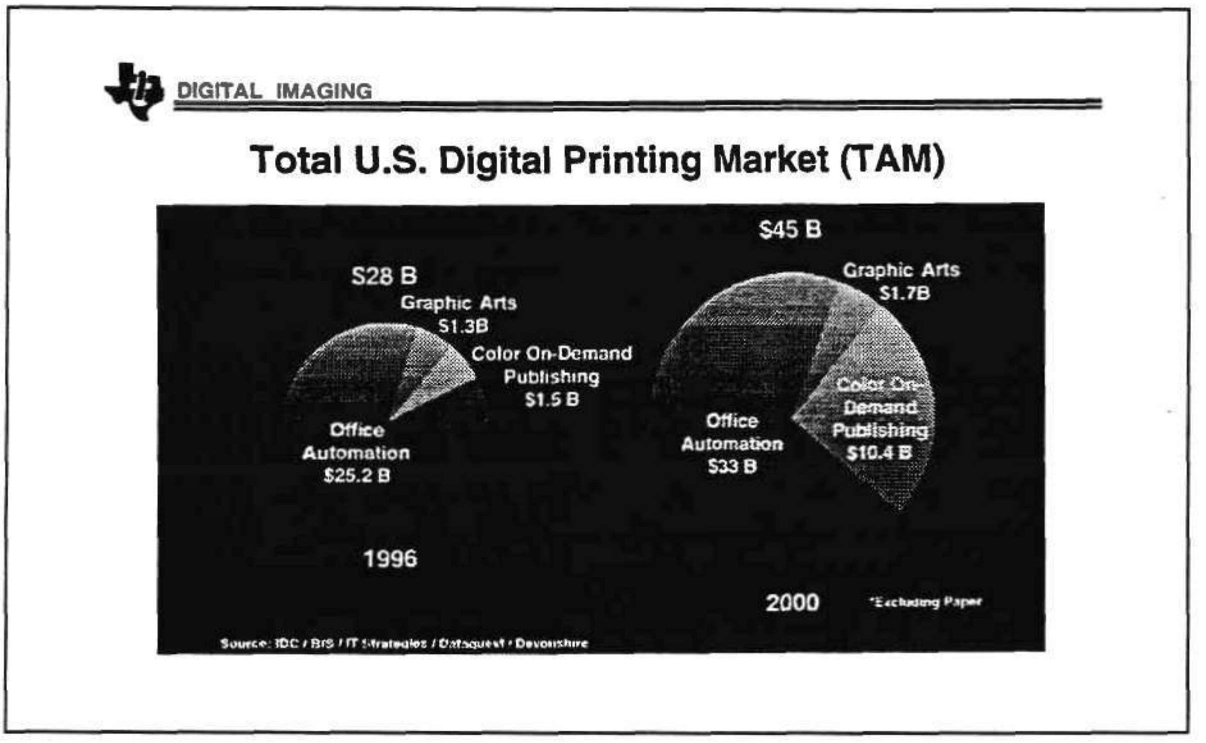


The draw back in participating in the print on demand is that they have to be set up, and they are really run in the batch production environment versus a print on demand environment.

What we have been able to demonstrate with some of the partners that we have shown our display engines to is that we can overcome many of these print barriers of high equipment costs, high maintenance costs and the environment. As a matter of fact, we think we can produce the same quality using the DMD technology and not in the $300,000.00 to $500,000.00 price range, but as low as $50,000.00 to $100,000.00 environment, and producing near quality prints at the same time.



Let me switch over to the market places for just a minute. Here is some data from Stanford Resources. I believe they produce this data every two years. This is the size of the market that they see for worldwide projection displays, the kinds of displays we just talked about. By the year 2000, this worldwide market is projected to be about $6 billion dollars. The green line on here - incidentally - was their report from two years earlier. You can see for yourself that this market is growing much faster than any people anticipated.



In the display market, we also have a multibillion dollar potential. The data for this comes from five different sources, including Dataquest, and as with the case in display, the DLP engines are not attractive at the low end, the low end small TVs or the small printers. At that graphics art display and the high quality needed for near photographic production, we see that this is the fastest growing area and this is where we are targeting these activities.

Let me conclude here by showing you one final video.

DIGITAL IMAGING

Summary

- Enables True Digital Imaging for Displays and Hardcopy Products
- Large Compelling Displays
- Near Photographic Color on Plain Paper
- Cost Advantage Potential
- Multi-Billion Dollar Market Potential
- Enables the Digital Information Infrastructure

Let me just summarize here. I listen to that and I kind of wish I had that resonant character actor voice that we employ for all of our videos here.

We think this is a very exciting technology for all of the reasons that I've tried to explain to you. I've tried to communicate how this works, and what you just saw on the video.

The market potential for this is measured in billions of dollars. As we heard from our lunch speaker today, TI is one of the attractive stocks. I'm not going to try to do a sales job on that, but one of the reasons that TI is getting a lot of press right now is this technology is viewed as the next major leap in being able to take digital information and display it to greater resolution and brightness then any other technology on the market place today.

We have yet to ship our first product. As I said earlier, we hope that that will occur either late this year or early next year. The market is big. We need a way to take digital information and display it to the human being. We think there are huge markets out there to serve.

Again, I know it's late in the day and there's a lot of tired people in here and the next item on the agenda is cocktail hour; but I will be delighted to take a few questions. Thank you very much.

Questions and answers:

Question: The cost projections on the systems were higher than I expected them to be. Is that because of the semiconductor cost? What keeps the prices up so high?

Answer: Let's talk about the first product that we'll introduce, and that's the business projector. Again, the way I think of that is a competitor to the LCD panel that you put on View Graph machines or some of the small projector boxes that you would buy from Proxima, In Focus, or In View. Those boxes right now that you interface in the computer probably high end is about $10,000.00 right now and the low end is around $5,000.00. This technology coming out of the chute will enable those three companies who have about 55% of the market share in the U.S. to be under that $10,000.00 point. I'm not setting the prices, so I don't know exactly where that's going to be, but that will be a one chip system. We still have much volume ahead of us to ride the volume curve to bring down the overall system costs. A lot of the costs are value added, putting in the casings, putting on the computer interfaces. We are just doing the digital display engine itself. The engine itself is basically the electronics you saw. We can supply power supplies and optics to go with that if necessary and some fans. We work with our OEMs and our distributors and exactly where we draw that line for functionality.

Our cost is in the early stages of the semiconductor learning curve. The final market price is a combination of that and what the distributors add to it.

Question: Are the individual pixels monostable or bistable? In other words, do they return to a fixed position or do they stay where they were last set and if so if they are essentially bistable could that be used as a sort of memory?

Answer: In the unpowered position the mirror is flat. As quick as it is powered it has only two positions: We call it left/right, on/off zero or one. It is only in one of those, and those are where it has switching of the 15 or so microseconds. It is bistable, complete bistable device in its powered off position. Incidentally, some of the reliability tests you saw right there; we have seen no evidence that there is any fatigue in the micromachine or the hinge or whatever we've done for billions - probably trillions - of cycles and we don't see that. I believe that was part one of your question.

Part two was a digital storage device? You could potentially do that. As I mentioned in the main part of the presentation we've identified over 100 applications for a light switch. I believe you asked is a digital storage device. These are 16, 17 microns. The mirror itself is 16 microns. The spacing is one micron, so the mirrors are 17 microns centered. That's probably a pretty inefficient way to do memory, if I understood what you were asking.

However, we do have a lot of interest in being a light switch for optical fiber, switching context stuff, being able to switch in one state or another. That's one of the hundred other applications, including some medical applications for high resolution, high quality images so that when surgeons are performing their activities they have a very, very accurate image of what they are doing.

Question: There appeared to be a hole or a small square in the middle of the mirror. What is that?

Answer: That's an interesting artifact from our original design. If you recall - and I know this is putting a big demand on you to recall this - what Jerry showed was hinges that you could see from the top when he showed the picture. We have since put the pictures underneath, i.e. a hidden hinge, to get more of the mirror exposed so the whole surface is a reflecting surface so you can maximize the light, maximize the brightness. In doing that, there was a center post that had to support the mirror. The hole you see is that center post coming up.

Interestingly enough, that has become a point of technical contention within our own group. The display people say well that's like one square millimeter. It takes one square millimeter out of 16 squares, so it's not a whole lot. It has a very, very interesting side effect in the hard copy activity. When, if you know much about electrophotography, you do electron depletion of a photoelectric cell, then toner comes into in. This hole actually makes for more of a square form, which makes for much better control of the dot size. In addition to being able to do 600 DPIs, you actually get to vary the size of the dot itself, which gives amazing clarity. It is the post and it has some technical pros in the hard copy side of the business. It could be covered up, should we chose to do so in the future.

Question: Could you discuss the light source and the life time of those lights versus how you replace them?

Answer: Absolutely. One of the interesting challenges of the display world today is light sources. This varies quite a bit over the three market segments which I discussed, which were the business, professional and the consumer. Only about a year, maybe two years ago, light as measured in the standards of the people that we talk with - television manufacturers or whatever - talk about luminance projected on the screen versus watt of the light bulb. About a year or two ago it was below one lumen per watt that you could actually get about half a lumen per watt was state of the art.

Today we have worked very closely with these suppliers that I discussed and we think that we are at the state of the art right now. We can do three lumens per watt. The life times of those, the first product that we have coming out is in the neighborhood of 300 to 500 hours of light; that's the business projector. However, for a consumer application like a television, our television distributors and OEMs tell us that we need more like 10,000, and we have a bulb that does that. It has about a 10,000 hour life time. It does about a one to two lumens per watt. We have different bulbs for different applications and it gives us different brightness. Does that answer your question? Good.

Question: Recently I believe a consortium in Europe announced major research commitment to three color microchip laser technology for digital imaging. Would that be a competitor of your technique, or would that be something that would fall outside the price performance areas that you have outlined?

Answer: I am not familiar with that particular announcement. Obviously lasers are a potential for light sources for this or any other projection system. The lasers that we have looked at, combining it with the life time question before, do not have sufficient life time or brightness or cost effectiveness today. That is a technology that we are closely monitoring for future light sources. Your particular example I am just not familiar with and can't comment on.

Again, it was my pleasure to present today to you and thank you for the invitation. You know the next item on the agenda. Thank you very much.

This page is intentionally left blank

Chapter Eleven: ON THE CUSP OF THE FLAT PANEL DISPLAY REVOLUTION

Panel Discussion

Moderator

Jack Roberts
Director and Principal Analyst, Graphics and Displays
Dataquest Incorporated

Panelists

Joel Pollack
Senior Product Marketing Manager for Display Products
Sharp Electronics

Peter H. Goebel
Executive Vice President and Chief Operating Officer
Ulvac Technologies

Douglas J. Bartek
President
Visual Systems Interface Company
Cirrus Logic, Inc.

Dr. Malcom Thompson
Chief Technologist and Director of the Electronic Imaging Lab
Xerox PARC

Moderator:

We have a distinguished panel of gentlemen I would like to introduce to you who are going to each discuss their particular aspects of the changes that are going on in the industry and what we can look for in the future. After each of them has an introduction, I will then open the floor for questions.

Our first panelist is Joel Pollack, representing Sharp Electronics. Joel is Senior Product Marketing Manager for Display Products.

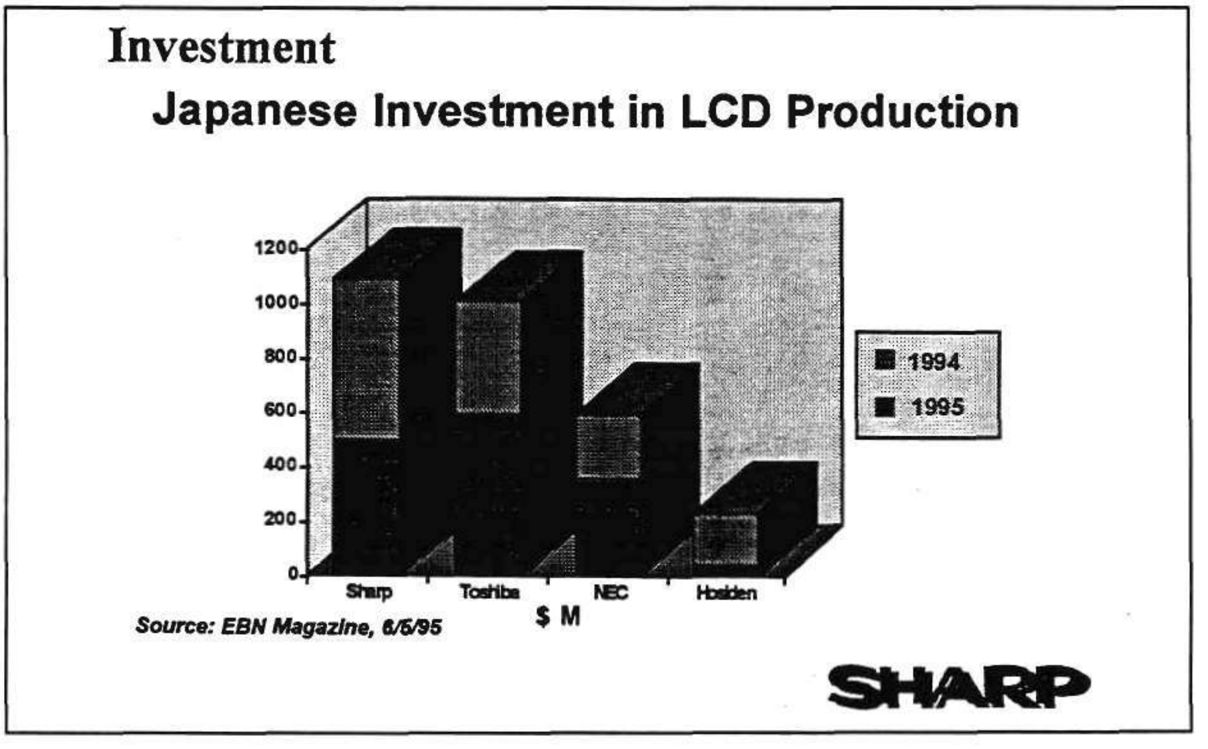
Seated next to Peter is Harry Marshall. Harry is Chairman and CEO of Silicon Video, Incorporated. Silicon Video is a maturing start up, I guess, in terms of introducing some new technology into the market that I think you may find very interesting.

Next to Harry is Doug Bartek. Doug is President of Visual Information Interface subsidiary of Cirrus Logic, and will be representing the driver and controller aspects of the flat panel display industry.

Last, but certainly not least, is Dr. Malcom Thompson. Malcom is representing Xerox PARC, where a lot of fundamental research has been done in flat panel displays and where he has the role as Chief Technologist and Director of Electronic Imaging.

Joel Pollack:

Thank you for coming to this track. I am looking forward to telling you a little bit about my perspective on where I think the future is going; some important factors on some elements of change for the display industry.



Let me begin with a slide that gives one key factor, and that is let's look at some investment issues. If one looks at this particular plot, this one from an EBN article last June, it shows from the Japanese perspective the capital investment in flat panel displays. Certainly maybe not like D-RAM, but an enormous increase in investment has been made by the Japanese in the last two years. At Sharp we've invested - as you can see here - over $1 billion dollars building the world's largest active matrix FAB, and many other things happening.

In addition to this, a lot of investment in the Korean side as well: Samsung, Hyundai, Goldstar. Why is this? What is it that people believe is going to happen that merits this sudden increase in investment? We've certainly enjoyed a tremendous growth on the back of PCs, on portable computing.

Do we think that the world is going to buy that many portable computers in the future to sustain it, or are we looking to other things to make it happen?

What I would like to talk to you about today is to give you some vision that we at Sharp see for things other than PCs, the non-PC market, what other shifts will happen.

Let me take you through a potential day some time well off into the future, where you might see some panels. You can envision, we talked about the home market, the notebook PCs maybe aren't there yet; but desktops, more than one per household. Perhaps more vertical applications. Here we see instead of the dog chewed and rained soaked newspaper a family looking at their flat panel displays, getting customized information coming in from the satellite dish conveniently located outside; and up and down link. Perhaps your children will be reading their music at their piano from a similar type of display. Other types of home applications enabled by the fact that the cost of displays is dramatically coming down and is enabling a technology which is not only affordable, but is becoming increasingly reliable. The acceptance of this thing we think will further increase.

Certainly the transportation market: More so in Japan where they are the early adopters, but we will see it in the U.S. By the year 2015 smart highway will exist between Baltimore and Washington, D.C., and we'll see proliferation of it. Even now GPS has become inexpensive. It is possible for you to chose the best routes as to where you want to go with your automobile by perhaps consulting your GPS screen and doing things that are just not possible today. All of that compute power in the automobile will manifest itself in better user friendly types of interfaces that will give you opportunities as displays become more rugged, as they become affordable.

This is an image that we call the Cosmic Communicator; something in between the notebook computer and the cellular phone. Something where you can use it as a communication tool. Something that is up and down link types of E-mail. Perhaps a voice recognition device; maybe a language translator. What will the imagination hold for hand held computing devices in the future, particularly when there are real problems that they solve and they become affordable and rugged enough to take to these markets.

When you get to the office, instead of having one display that occupies too much of your desk, how about a display that looks more like your desk; something big enough that could put all of your work out in front of you at the same time, put all of your tools at your disposal and easily enough to clean your desk at the end of the day with a push of the button. My desk could certainly use that.

In the near term, perhaps such things would be projection displays, where you might have it implanted somewhere in your desk. The possibility for having larger area displays, higher resolution displays and these kinds of interfaces, looking at the sort of capability and where the track has gone for resolution as time has gone on, this may not be so difficult to conceive in the distant future.

Already we are seeing a tremendous acceptance of overhead projection devices, where all of this compute power - the color and the graphics - is there. The concept of having conference rooms connected with one another the world around, having interactive white boards, having a free display of information where you can share ideas to make telecommunications and video conferencing real. We are the verge of having that. Having panels that improve in their capability for transpasivity so that you can use them in just about any kind of conference room will make these a lot more user friendly.

Then specialized devices: Here we are showing a version of a medical device. It would be something that perhaps a medical technician would have or a physician shows a patient a heart monitor. At the same time bringing up freely patient records, even as much as image information, so that you would have at your disposal all of that back up information you really ought to have when dealing with a crisis.

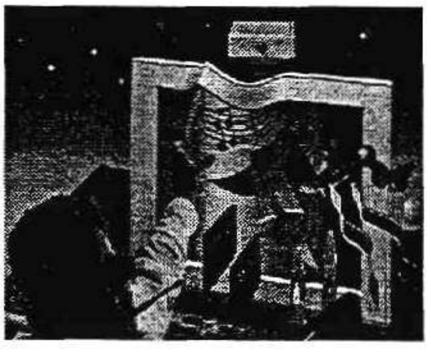
This is a vertical application for medical, but the same thing is true for test and measurement. We are seeing a conversion happen today from CRT based instrumentation to flat panel displays across the industry of scopes, logic analyzers, etc. We are seeing this happen in some of the more service related industries such as automotive and other test and measurement. We are seeing that industries such as the financial industry, industries such as factory automation, POS, ATMs are right now in the process of converting to flat panel displays; increasing the demand tremendously.

The airport of the future: If your day takes you to the airport to go somewhere else, you will come to the airport and see ATM machines. You will see kiosks. You will see opportunities to have further interaction with an information database that will be freely available and convenient for you.

As you get on the airplane, that airplane of the future won't look like today's. As the flat panel display technology becomes more affordable, why not have it in every seat. Rather than going and waiting for that battery to die on you on your notebook computer, wouldn't it be a lot nicer if it was really built in? Someone passing out CD-ROMs so that you can in fact take in any application you would like to look at and give you a lot more painless ride as you work your way across the country or to other parts of the world.

What's going to happen? What are some of the enabling things that will bring this about? One this is a dramatic reduction in power. The biggest consumer of power in today's displays is back lights. Back light technology is getting a lot better. Also flat panel displays are becoming much more transmissive, almost a two fold improvement over last year will be shown by 1996. In other words, half the battery requirements.

LCD Trends



- **Significantly lower power**
- **Brighter for outdoor viewing**
- **Wider viewing angles (120º cone)**
- **SVGA → XGA → EWS**

SHARP

With that, instead of reducing power, if you want to use that display in a brighter environment, like taking your computing power out onto your DEK or using it in a bright ambiance such as some medical arenas, the displays will now enable that where they couldn't before.

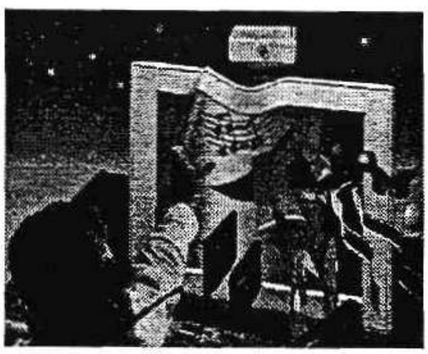
The one thing they are compared to with respect to CRTs: Viewing cone. We see on the horizon, in 1996 and 1997, technologies that will take the viewing cone of active matrix LCDs out to 120 degrees symmetrical viewing cones, making it useable for a range of viewers looking at a single display.

Of course with this will also come improvements in resolution. Going for next year you will see a lot of notebook computers embracing an 800 by 600 format as a standard. As memory becomes affordable and the overhead isn't there that adds expense, I would expect that you will see things migrate up to XGA for transportable types or products and perhaps even EWS formats.

Last of all, I see that there are some paradigm shifts that will occur. As these become more portable, usable in greater environments, really good connectivity will have to happen. It doesn't exist today. I think the expectation will be there for people to have really good connectivity; maybe in RF link, maybe up and down link sort of systems that will allow you to really go freely where you want to and have mobile computing follow you. There are times when maybe I wouldn't want it to follow me, but it's nice to think it could.

As they become more portable and lightweight they are more easily dropped. They have to be rugged against six foot drops to concrete. With that will come technology for plastic LCDs, today already possible on passive matrix LCDs, plastic substrates. They are more expensive than glass substrates, but they are considerably lighter in weight and they are considerably more rugged.

Enabling Technologies and Developments



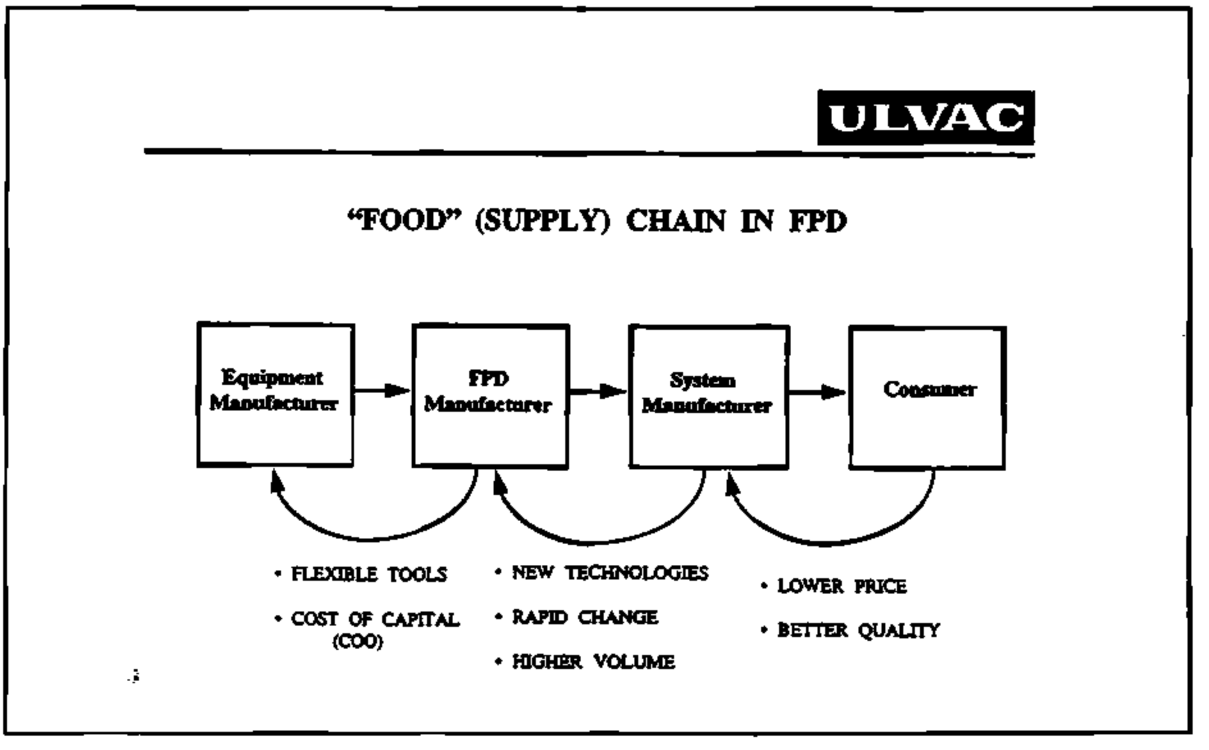
- **RF linked computing**
- **Plastic LCDs**
- **Low temperature poly-silicon devices**

SHARP

I think probably the biggest change that will happen is when the drive electronics gets integrated with a single display. It will save space. It will fit into a smaller area. It will be more reliable. It will be more transmissive. It will be lower power. It will be the one thing that allows it to converge with the economics of a CRT and we think the one thing that will allow us to go to really high resolution panels in a reasonably small space. I believe that low temperature polysilicon, not what we have today on courts, but polysilicon on glass will be an important technology for the future.

Peter H. Goebel:

Thank you. My main discussion this afternoon to you will focus on the demands and the challenges that face the equipment manufacturer who happens to be on the low end of the food chain in the flat panel display market.

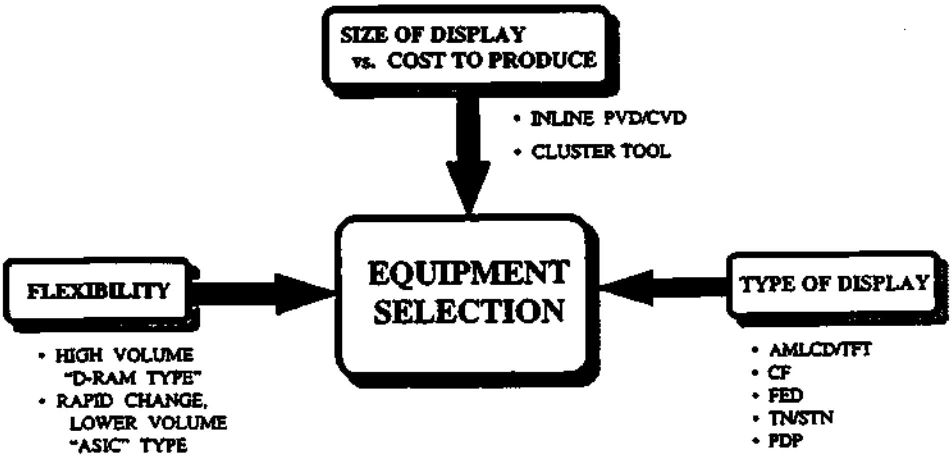


A food chain that starts with the consumer who exhibits an ever increasing appetite for more products that have the typical characteristics of a consumer demand or flow of price and better quality. That type of demand is passed on to the system manufacturer, who has to cope with that kind of market by coming up with products that exhibit better contrast, better response, better viewing angles, lower power consumption as Joel mentioned, and of course all of this at a lower cost.

The flat panel manufacturer who is faced with that kind of demand from the system manufacturer works in corroboration often with the equipment manufacturer to come up with equipment that transcends single technologies. That is perhaps the essence of our survival in the market as an equipment manufacturer.

ULVAC

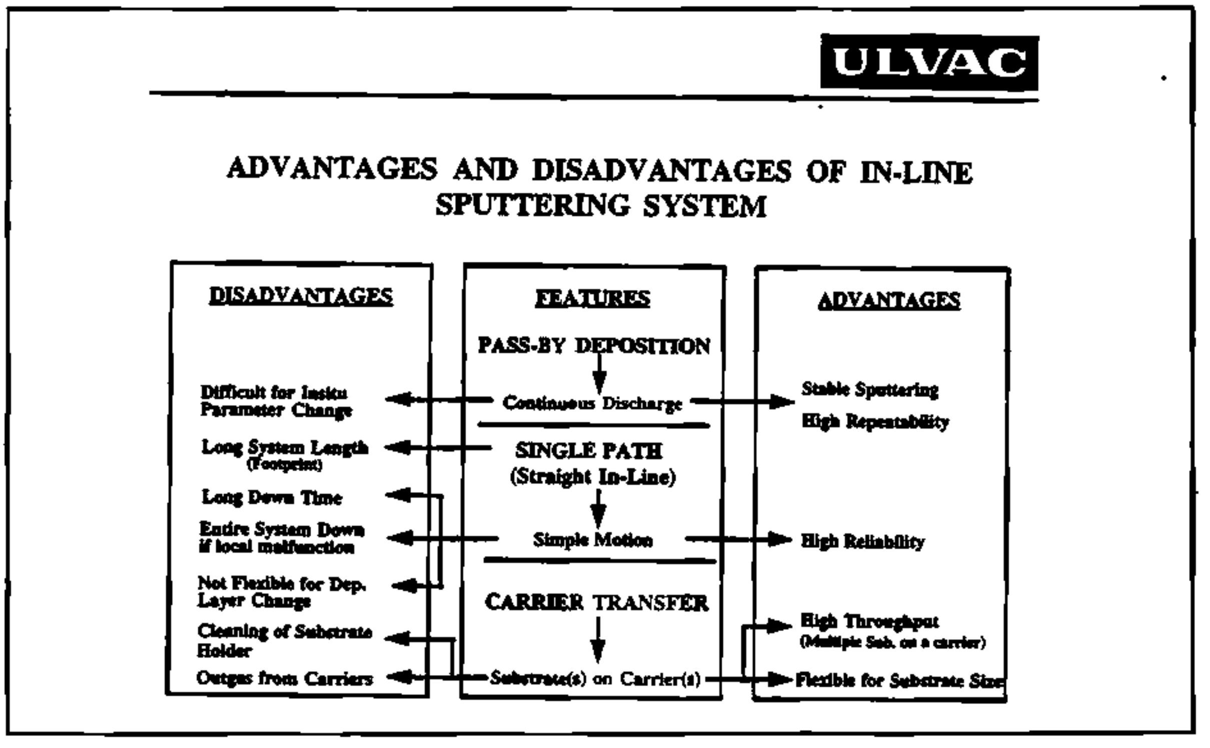
Forces Influencing Equipment Selection



Equipment selection that happens in this area is made based on very diverse selection criteria, ranging from the type of display that the manufacturer is producing to the flexibility that the manufacturer expects out of the equipment; is it a D-RAM type manufacturer or someone who for instance has a 10.4 inch panel size line set up, cranking out 20,000 panels per month; or is it someone who expects rapid change, an ASIC type manufacturer who has different panel sizes, different technologies they are trying to run through their equipment. Of course the size of the display also comes into play making equipment selection.

We are not only looking at a technology variables in this market, but we are also looking at a market that is ever changing. I don't think that anyone would have expected a year ago that today in the flat panel display area that there is an over capacity for panel sizes of nine inches and greater. There has been a tremendous build up in Japan, Korea and Taiwan in manufacturing capacity, and as a matter of fact at this time demand is less than supply capability.

However, this does not exist for nine inch and less. In nine inch and less there is ongoing strong demand and there is just enough capacity. We as equipment manufacturers have to cope with that. There has been a reduction in the scheduling of new lines that are going to be coming on for flat panel displays, which again gets passed on to us as suppliers of equipment to those lines.



On the top of that we are working to establish relationships with the U.S. manufacturers who have now decided to get into this market, but with a different technology. Most U.S. manufacturers are embracing FED technology as the hope which will perhaps provide a lower cost forum for them to produce flat panel displays. Most of you are aware of the fact that Pix Tech has licensed their technology to Motorola, TI, and Raytheon, who are starting pilot production for flat panel displays using FED technology.

On the corollary, Japan, other than Futaba, has not embraced FED. They are continuing to believe in AML CD and for larger sized displays - like the television industry - are very heavily investing in plasma technology. There have been announcements of investments made from Fujitsu that they are going to build - and are in fact building - manufacturing lines for plasma displays for televisions, initially of 20 inch diagonal televisions that have a target price of $4,000.00 to $5,000.00 for the final product to the consumer.

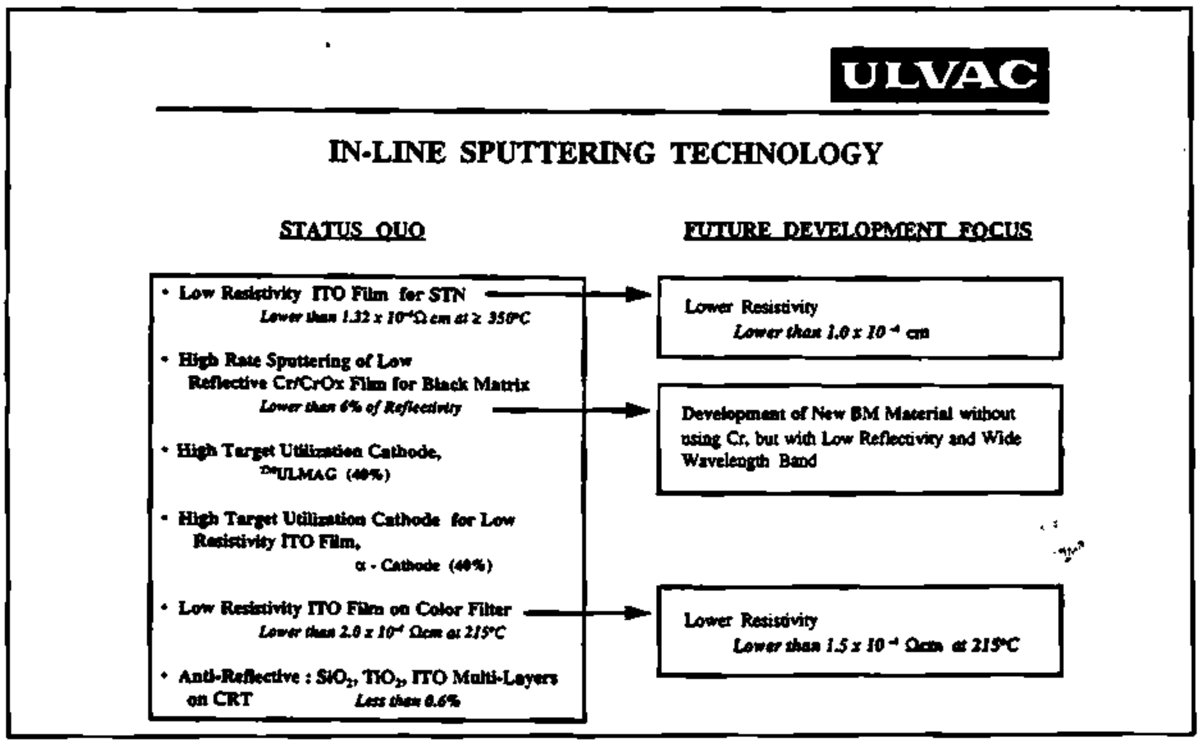
There has been an exciting announcement made by Sharp, (Joel's company) who are this year in the Japanese market are going to introduce for the holiday season a 10.4 inch flat panel television at a price of around $1,500.00. Obviously what Sharp has done is diverted some of the capacity they had for 10.4 inch PCs into alternative demands, which in this case is a great desire to have a TV that has the capabilities that flat panels can produce.

In this kind of market place, Ulvac, as an equipment manufacturer, has to produce products and processes; which means that we have to have flexibility. This chart by no means is trying to mesmerize you with details. What it merely is trying to point out is that over time since we have been in the support of the flat panel industry; and by the way Ulvac also manufacturers equipment for the semiconductor industry. I think there is a lot of synergism between these two technologies and those companies that are successful also have successful semiconductor manufacturing operations.

You can see that we have supported and continue to support the STN market, which is by no means dead. There is ongoing technology development going on way into 1996. Black matrix is being supported, more fascilic NTFT, polysilicon TFT. New additions to this development are listed on the bottoms, first of all field emission. In field emission devices we have to produce a cone which is done by evaporation technology. That is a very difficult manufacturing process and we at Ulvac are looking at alternative solutions for that. Also we are supporting the plasma display investments.

What it basically says is that we need to adapt ourselves to this incredibly flexible and changing market. This happens to be an analysis of the type of products that we make in sputtering plasma enhanced CVD, etching and evaporation; and it shows that for each of those technologies we have plus the tools that adapt themselves to these panel sizes, another big variable in the market.

One of the ongoing discussions that we have with equipment manufacturers go about whether one should go with a multichambered cluster type tool or an in-line type piece of capital equipment. We support both. It is a must that we must support both. In the status quo column, you can see that we have developed technologies for sputtering, specifically in this case, that show fairly low IT overlays activities. It shows that we had to address the area of maintenance; how often do you have to maintain your piece of equipment. We have developed antiexfoliation treatments for the shields that are necessary in sputter chambers. We have continued to evolve the gate insulator technology and, of course, the substrate sizes. This by no means means that we are finished. We need to continue to focus our development on areas such as stress control for metal film, suppression of aluminum hillocks, maintenance free systems that perhaps could run 24 hours a day for one month without having to be maintained, ultraclean technology that has already been applied in semiconductors needs to be transferred to flat panel display systems.



The last one on the bottom perhaps may be of interest to those of you in the audience in the FED area. There is a belief by our process development teams that we can apply our long pro sputtering technology to provide you with a way to create aluminum cones, rather than using evaporation technology. That's a very exciting, new development.

If you get away from cluster tool technology, of course there are many in-line large sputtering systems that Ulvac has manufactured and installed in all areas of flat panel technology.

Again, there is an ongoing demand for changing and adapting those systems to the latest requirements of the market. Specifically I'll mention three areas: One is the low versatility of ITO films for STN has been accomplished, but there is a demand in the market for low resistivity. There is a very high rate sputtering of low reflective chrome on chrome oxide films, the black matrix, which needs to be enhanced for new black matrix materials where we don't use chromium. ITO films need to have lower resistivity.

I just want to conclude, basically giving you a very brief outline that says to multichamber or to in-line: What are the advantages? If you are a high volume manufacturer, there is no better technology than an in-line system which provides stable sputtering, very repeatable low cost and highly reliable. If you are in the ASIC type environment, certainly a multichambered system is more appropriate.

In summary: I think what I have tried to point out to you in this brief dissertation is that equipment suppliers to the flat panel market have to live by the theme: Remain flexible. With this I want to pass it on to Harry. Thank you.

Harry Marshall:

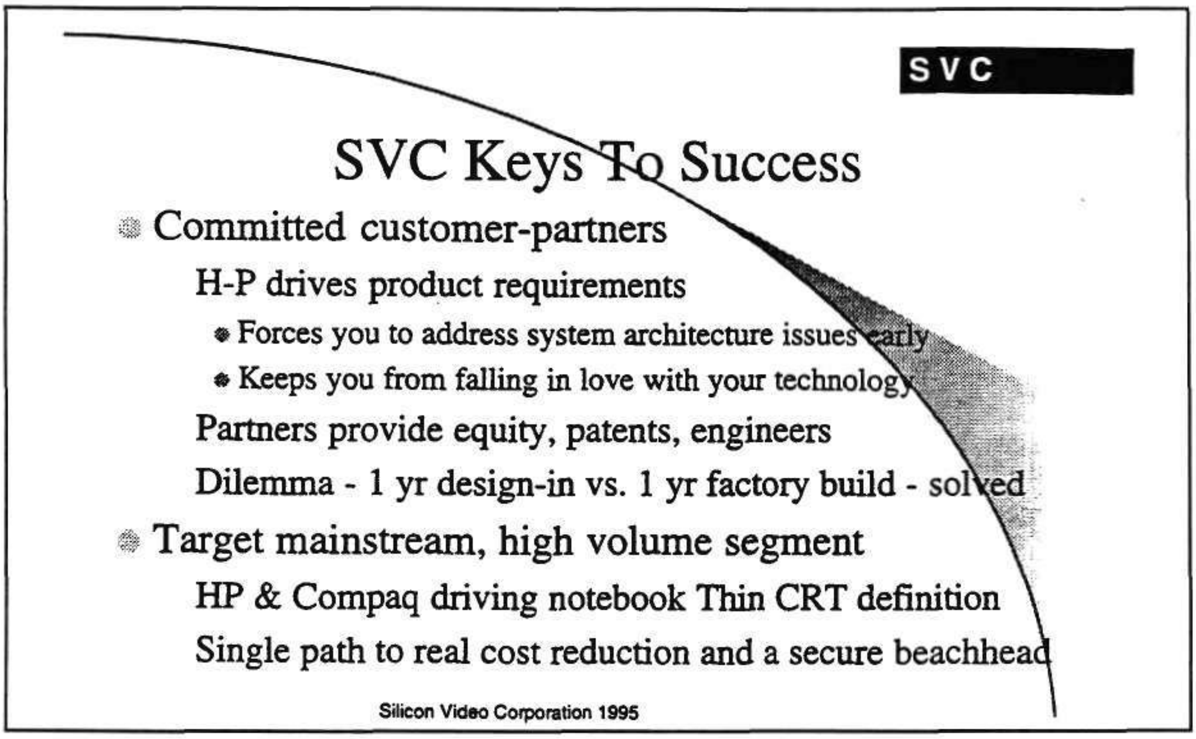
Thank you, Peter. Thank you, Jack, for the invitation. In the first two speakers you have certainly seen an excellent collage and pictorial collage from Joel about the applications we all envision for the future; and I think from Peter's presentation if you didn't you should have come to understand the magnitude of the range of technologies and the difficulties that have to be dealt with to produce a very cost effective display that will meet those applications of the future.

I think I probably, at least for the entrepreneurs in the group, probably represent something of a paradigm shift. We are trying to prove that it is in fact possible in this world to have a start up company in an environment that has billions of dollars being invested by large Japanese companies and Korean companies and the few Taiwanese coming on. It is not impossible to raise the capital. I'm going to try and show you how. I think the underlying assumption here though is that FPD is not synonymous with AMLCD. If it were, I wouldn't be here. We in fact think there is a different technology, and in fact there are probably multiple technologies which others will tell you about.

To give a little credence to this, I would like to give you a little bit of our strategy and why we think it's possible to be successful. First of all, it comes down to the bullet point number one on this slide: You can't go into the enemy camp where they're strong. You have to invent a new technology, and we call it a new class of display. Many talk about a field emission display or an FED. We call ours (and I know you can't see this) this is a four millimeter thick full CRT, implemented with .1 to .2 micron devices in the back plane for field emission with ceramic structures that hold off 5,000 to 6,000 volts with high voltage fosters on the face plate. A fully functioning VGA display in a small forum, because it's manufactured on small wafers; but highly scaleable to large areas.

That's what I mean by a new class of display. A highly proprietary, high performance that is capable of competing with the AMLCDs of today and the future, as well as being able to be manufactured at low, low, low, low, low costs. You can't compete in this business if you don't do it on a cost basis.

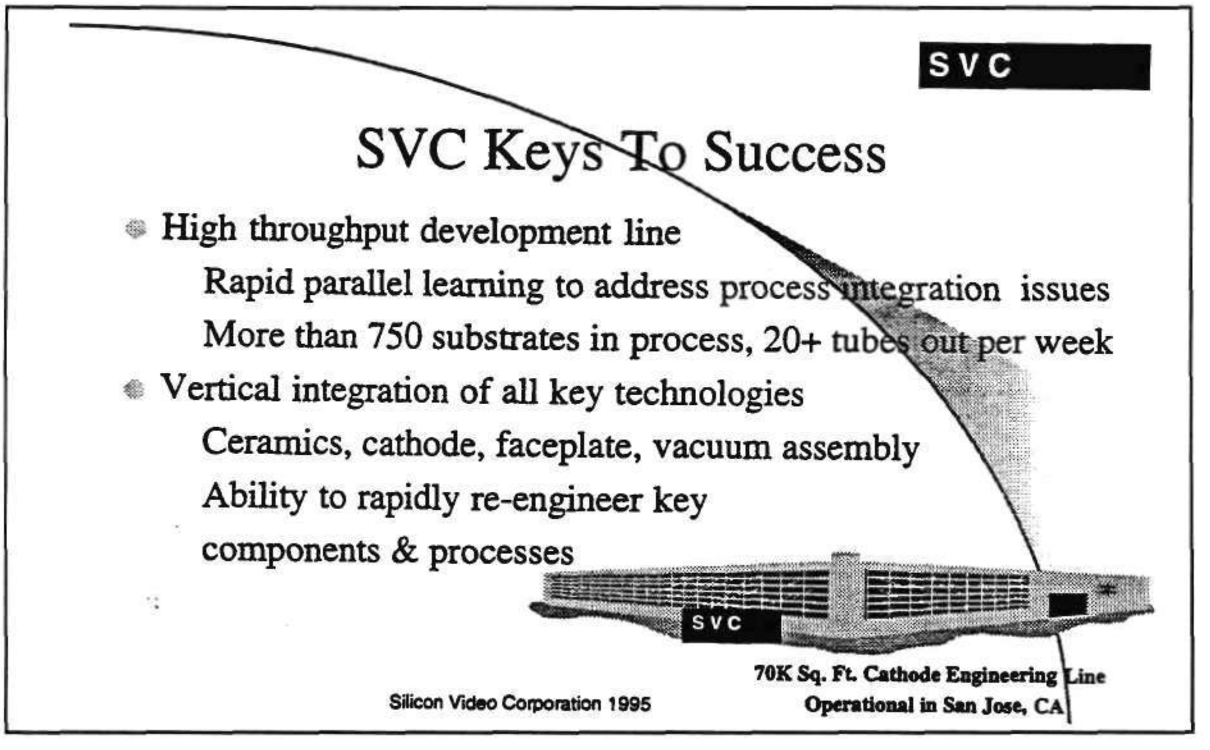
That's really the main point here. The rest of them are how do you do it? You do it with customers driving you to the one main market, and that's the notebook market. That's where you define costs and volume.



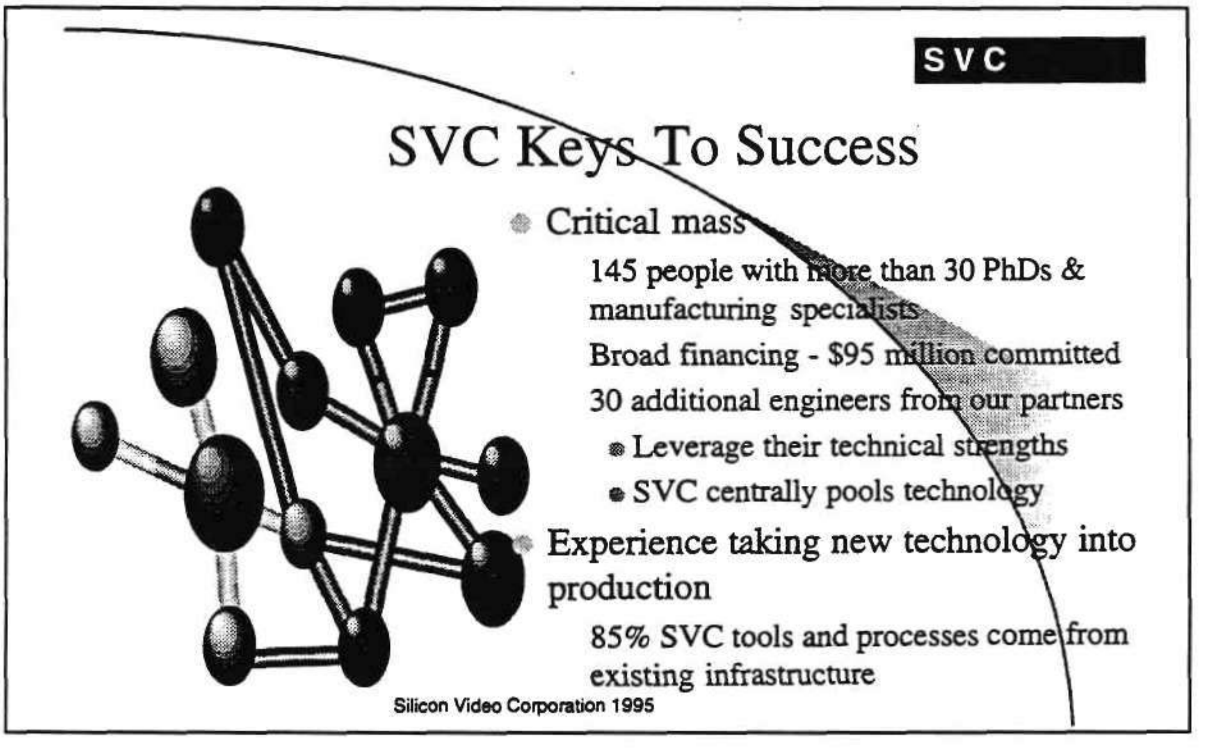
We decided long ago we couldn't do it by ourselves. We needed all of the help we could come up with and that was from customers, other manufacturers, developers, suppliers, and if we do it right in this notebook market with that set of customer partners, we will depend on them (and ourselves) to carry this manufacturing technology into other arenas and other applications. Of course, don't depend on the venture capital community to fund this effort. You better depend on broad sources. All of those that are from the U.S. are partly an owner of this operation.

What underlies our strategy? Very briefly in the long term it is dependent upon, once again, the only market that we know of that drives high volume. You can't be in this business - just as you can't be in the D-RAM business, unless you are in the multimillion unit kind of business. For the display business of today, that is the notebook. We also decided; as I said the corporate partners were critical to crossing this chasm. In our case the chasm is building this large facility, but more importantly yield is everything. Getting it up to - in our models - that tells us that's 38%; yours are probably similar. That's quite a feat and is not done in a month or to.

If I back off and generalize a little bit, what are the keys to the success of our sales or anybody else? We think it's committed customer partners. We've had this three and a half year relationship with Hewlett Packard. We are broadening it to other corporations. It's been critical really to helping us not fall in love with our technology, to keep ourselves focused on how we are competitive in the future: 1998, 1999, 2000, and into the next century. They are not interested in supplying the equity, the engineers or the patent structures that we need to implement it without a differentiable product. That's why they're here. Then of course target the mainstream with the folks that are going to be in the mainstream.



Another key point we think is that you don't invent a new class of technology without adapting; as was mentioned earlier. Many of the disciplines and engineering approaches that are prevalent in the advanced semiconductor technologies or today. D-RAMs are used often, as a good example. It is a process technology we are working on and it is not a technology, it is a whole sequence of technology. If you try and invent your way to success in a lab, you are probably going to have an infinite development cycle. Accordingly, we took the financial risk frankly of implementing a serious development line where we process up to 1,000 pieces of glass at any one point in time. That glass in our case are our wafers. The schedule is set so that we are generating about 20 outs per week of these things so that we can make modifications all in parallel at any one point we probably have 40 or 50 different process modifications in the line. That's the only way you bring this development cycle down. Obviously the negative to that is it costs a lot of money.

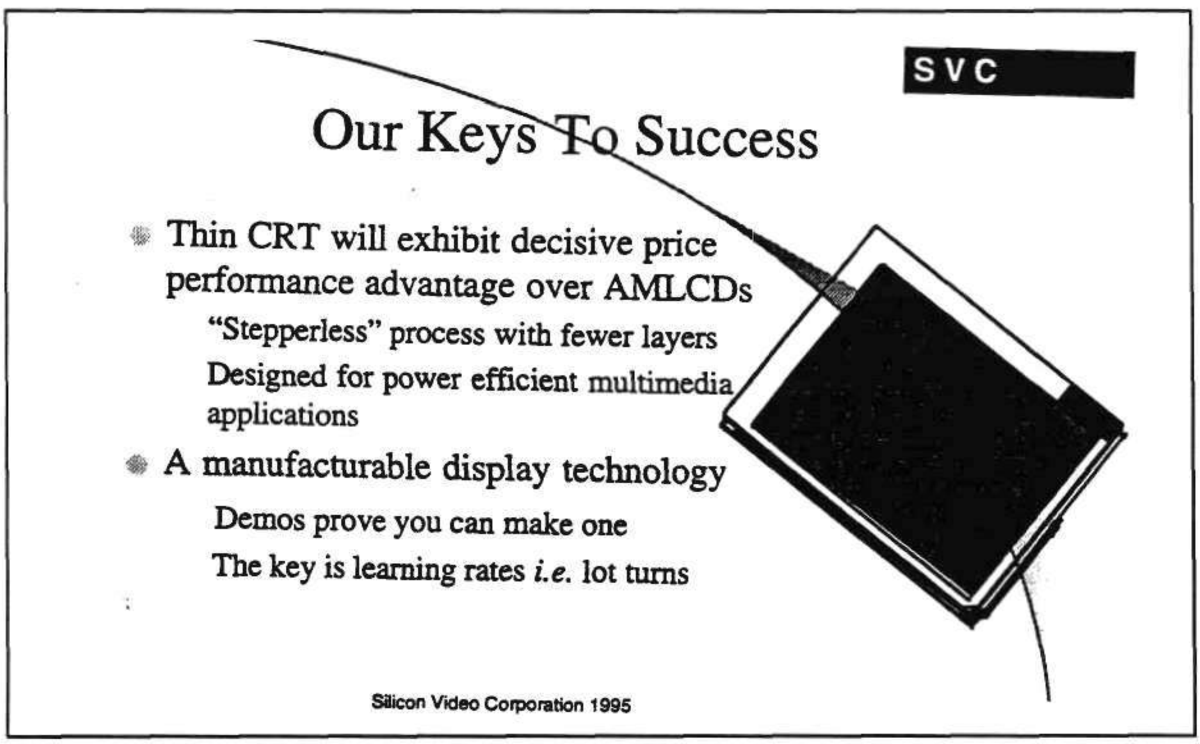


The other side of this is that you cannot only not do it by yourself, but you need to invent almost all of the technologies yourself. In a process technology based business, you've got to do it all. You don't just invent a field emission cathode for a thin CRT. You have to invent the spacer structures. You have to invent the black matrixes that were mentioned. All of this has to be done in an evacuated environment and of course it needs to be rugged, etc., etc., etc.

It translates to a lot of people, many of which who probably almost had terminal academics, but we managed to get along with 30 Ph.D.'s because we combine them with a lot of manufacturing expertise.

In addition to that, in addition to the semiconductor business, what you better have is a number of people you have a lot of experience bringing these kinds of technologies to market. On our panel we have such talent already here and are represented here and we do in our company as well. That is the only way you'll get there. This is no place for on the job training.

In the end result, what you better have is a display that can exhibit decisively better price performance, i.e. cost. The way we've implemented this has not been the standard; usually what is referred to as field emission based displays using steparlithography. We have taken the costs out of every piece of machinery we can, but at the same time the equipment side of the business is intimate with the processes and a very expensive part of the equation. If we do this right, we think we will have a display technology that will be competitive with AMLCDs, and to do it we haven't taken an approach that just develops a demo, but in fact develops a process. If that process is the way we believe it is, in the future we think you'll see a display that on this web chart shows as being on the outside edge of the equation. We hope and we believe that field emission based displays, particularly in our case thin CRTs, are quite capable of meeting all of the specs required for all of those applications in a scaleable technology in the future.



Conclusion: Very briefly it is our belief that thin CRTs will in fact win on cost. They will win on power. They will win on brightness. All of these will be different mixes and different applications. It will closely match the AMLCDs in many other characteristics. I am not trying to say that there's not a place for both - there certainly is - and they are well down the learning curve. I am saying that there are huge markets that will be tapable by a different technology, a bit of a paradigm shift if you will.

There are certainly many additional long term large applications. The only unusual factor about all of this though is that they all require high volume. In our business you must process large wafers. Sharp processes 550 by 650 sheets of glass in their latest facilities, as does Samsung. It would be like trying to compete in the D-RAM business with say .35 micron devices being processed on four inch wafers. You wouldn't last long. In our case as a start up, we had to start with competitive tool set and we have to be able to generate those economies of scale.

However, if we do that we believe that the scaling and yield and material cost advantages will prove to be decisive NDN, DN is probably in the next century.

Lastly: While we have very strong customer partners who want notebooks, they want to have a differentiated product. When you walk down the row at Fry's you can see the one that has the differentiated display on the face of it. The barrier, however is that $300 to $450 million dollar plant. Our approach - unlike others - is to be in the manufacturing business, but to be in it with partners, with manufacturing partners who are seriously working in the lines the same way. For example: TI has a partnership with ACER and they put together their D-RAM facilities for Taiwan. IBM with their D-RAM facilities with Toshiba and Siemens. We are going to do the same thing with manufacturing partners for thin CRTs, and in fact working on bringing those partners into the equation right now.

Douglas J. Bartek:

Good afternoon. Jack asked me to spend a few minutes and talk about an integrated circuit manufacturer's perspective and certainly from that perspective the flat panel display revolution provides enormous opportunities.

First of all there are opportunities in the global sense of making computers more mobile and thus easier to use, and therefore helping to increase overall PC sales, which naturally results in more semiconductor sales. Second, and more specifically, the semiconductors which directly influence and enable flat panel technology to be useful, and that's things like graphics controllers and video controllers and panel drivers and those types of circuits.

I am going to talk about these types of things in a minute, but to begin there is really a chicken and egg situation with respect to advanced graphics and video controllers and advanced display technologies that we've heard about, and also advanced applications. All of these have to move forward simultaneously to be accepted in the market place.

Flat Panel Display Revolution

- Color TFT LCDs
  - Increasing Capacity / Lower Prices
  - Larger viewing areas
  - Higher resolutions
  - 256K colors becoming standard (for multimedia applications)
- Color STN LCDs
  - Lower pricing & new features driven by color TFT LCDs

CIRRUS LOGIC

For example: The advances in color TFT technology over the last year or so, coupled with applications for full motion video on the personal computer have synergistically driven demand upwards for both. In color TFT displays, we have certainly seen over the last year increased manufacturing capacity and resultant lower prices. That has led to more and more portable PC manufacturers choosing TFT displays over STN displays. The key differentiating features of today's - as well as tomorrow's - portable PCs are larger viewing areas and higher resolutions. This is all made possible by both the display technology and the semiconductors controlling the panels.

10.4 inch diagonal panels are fast becoming the standard for even valued notebooks in the design cycles that we see, and 11.3 inch to 11.8 inch panels for the premium notebooks. 800 by 600 resolution has replaced 640 by 480, in even the value notebooks; and the premium notebooks have moved to desktop controller resolutions. That's the 1024 by 768.

A minimum of 256,000 colors are now standard on notebooks, and they are actually required for good multimedia applications.

Speaking of multimedia, this is of course the simultaneous usage of graphics, full motion video, sound and lately communications. Multimedia has rapidly moved from the premium notebook class to the high volume mainstream value notebooks. This is being driven by business applications such as presentations, sales automation, interactive marketing, computer based training, and also by entertainment applications such as games and movies and yes, even education applications like video encyclopedias and the like. It is all being enabled by semiconductor technology.

Flat Panel Display Revolution

- **Multimedia in Premium <u>and Value</u> notebooks** (mainstream, high-volume markets)
  - **Driven by: Business & Entertainment Applications**
  - **Enabled by:**
    - **Software Codecs**
    - **Hardware Codecs**
    - **New Driver Technology**
    - **New Controller Technology**

CIRRUS LOGIC

Hardware codecs for MPEG 1 are available today in different form factors. A full MPEG add in card subsystem costs about $100.00 to $150.00 retail. We supply such dedicated MPEG 1 devices at Cirrus, but frankly with the right graphics controller software, running on a Pentium or even a 486 DX 100 will do MPEG 1 just fine.

I'll talk about some of the graphics controller features to look for in a minute, but let's talk now about the new driver technology coming out of the IC industry.

Example of New Semiconductor Driver Technology
Cirrus Logic 6-bit Column Driver Family

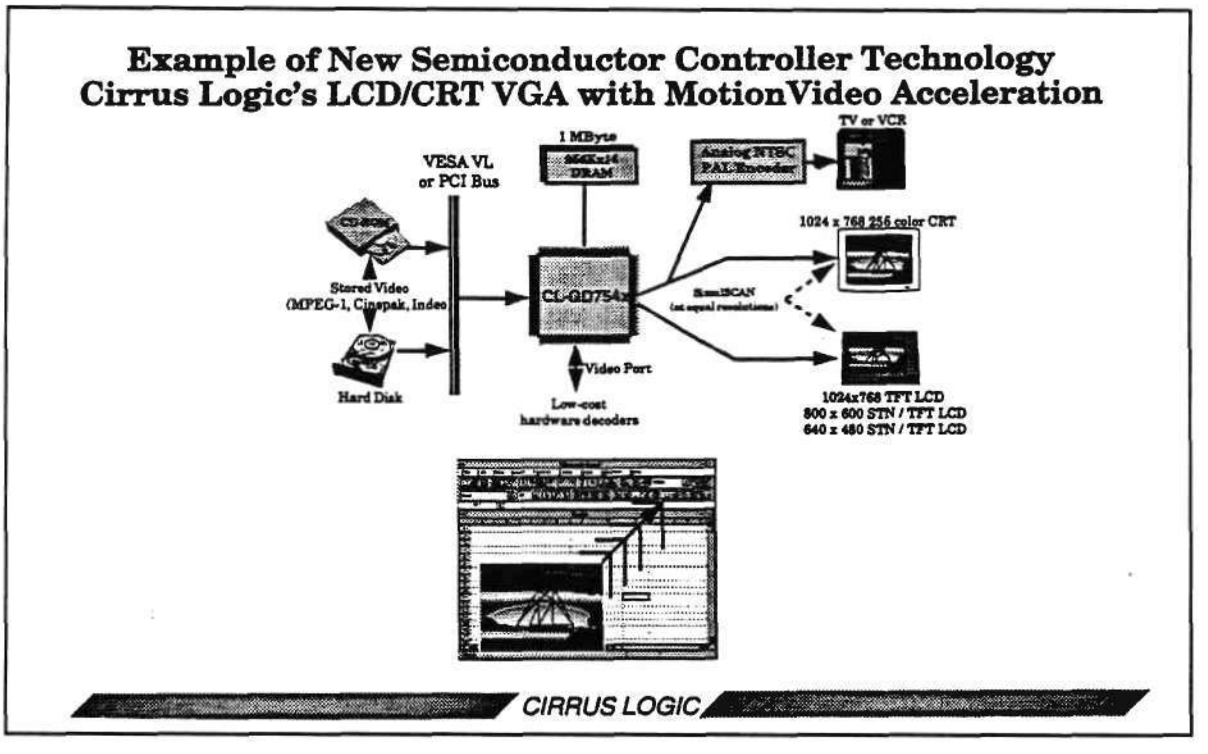
- **Superior display quality**
  - 256K colors
  - Excellent color uniformity
- **Cost-effective**
  - 201 --> 240 >> 309 outputs per driver
  - 10 --> 8 drivers for 640x480 LCD
  - 12 --> 10 --> 8 drivers for 800x600 LCD
  - 16 --> 14 --> 10 drivers for 1024x768 LCD
- **Increased display: module area ("bezel-less display")**
  - TCP --> COG drivers enable 11.8" diagonals
  - Smallest die size
- **Reduced power consumption**
  - Weighted resistor-string DACs

CIRRUS LOGIC

This is driver technology that again is enabling the acceptance of these newer types of panels with higher resolution, more colors, etc. An example of this is Cirrus Logic's six bit column driver family for TFT displays. The change here was in several areas. First of all: The move from three or four bit technology to six bits, and that's six bits for the red, six bits for green and six bits for blue; 18 bits total. That's what gives the 256,000 colors. There is also some unique circuitry which gives better color uniformity by supplying plus or minus ten millivolt accuracy on the DAK outputs. There is also more outputs per driver than in the past, which means fewer chips required.

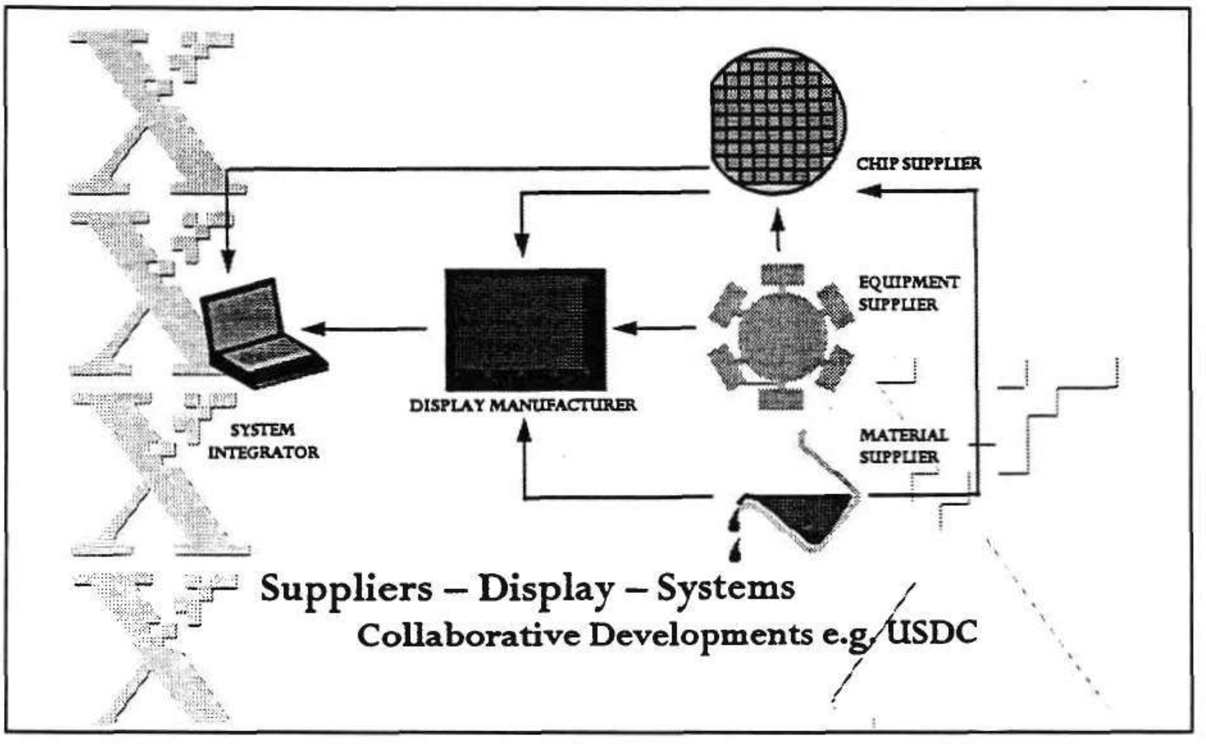
For example: If you look at the third example down there under the cost effective line, to drive an 800 by 600 panel with 201 outputs per driver, you need 12 drivers. With 240 outputs per driver, that reduces to ten chips. With 309 outputs, you only need eight drivers. There is an obvious cost and power savings in going from 12 to eight drivers per panel; but in addition fewer drivers also mean more effective display area. Coupling that with the normal method today of attaching the devices methods like tape carrier packaging going to direct chip on glass, and there should be in the near future very cost effective 11.8 inch diagonal TFT panels.

Finally, an example of new graphics controller technology is this one: It's the GD 7548. It was a device introduced just a couple of weeks ago by Cirrus Logic. This part not only accelerates graphical user interfaces like Windows and OS2, but it also accelerates full motion video from software decoders such as MPEG 1, through what we call motion video acceleration, or MVA for short. This MVA also delivers things like YUD, RGV color space conversion, continuous hardware scaling, mixed color depths through a multiformat frame buffer. What all of this means is that it enables simultaneous display on a CRT of as much as 16.8 million colors, or true color capability, on top of a 256 color surrounding graphics screen. As a result of this multiformat frame buffer, only one megabyte of D-RAM frame buffer is required to provide this kind of capability.



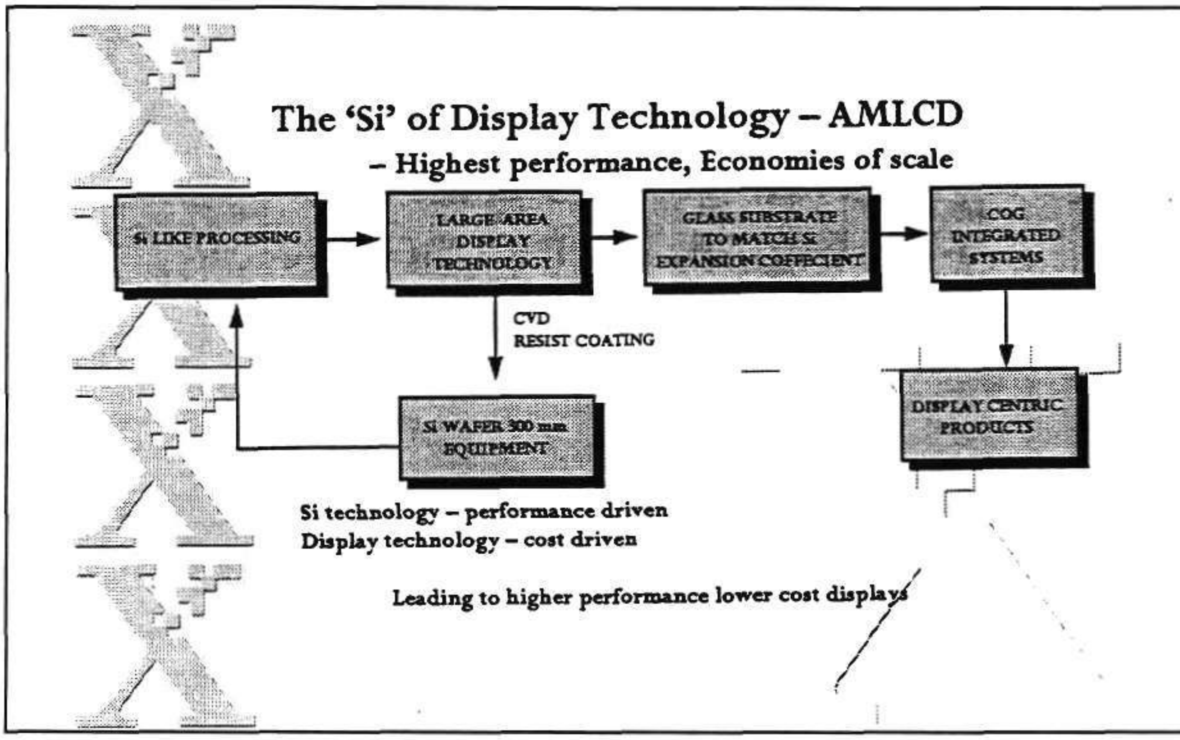
In summary: Display technology and semiconductor controller and the driver technology are all moving forward rapidly to enable the multimedia revolution for the PC. That will make more and more pervasive this revolution in all of our lives, both as a supplier of the technology and a user of that technology.

Dr. Malcom Thompson: Good afternoon. What I am going to do is I am going to address the inter-relation between systems, silicon and the flat panel technologies and the industry itself. As I am the last speaker, I am going to try to take a high level view of this and talk about how the food chain is developing and what issues there are.



Firstly, let me talk about that. Here we have a description of some of the interaction between the supplier food chain and the silicon industry and the flat panel industry. It's quite interesting that if you actually look at the way the flat panel manufacturing infrastructure has developed, it's primarily to the large extent the semiconductor suppliers, both in equipment and materials, that are providing those tools for flat panel industry. They are supplied close to the silicone and to flat panels. Of course, the silicon itself is basically integrated around the display, whether it be drivers, controller chips or whatever, and thirdly you then have a systems integration into the products which really combines the silicon technology and the flat panel technology.

What you are going to see in the future is a much more intimate interrelationship between those three. I'll take that through from equipment over to systems in the next few minutes.



What we've seen in looking at this, we see that there are some interesting trade offs as you go down that chain. That was one of the reasons why when we formed U.S. Display Consortium, we made it actually a vertical consortium, which involves the PC manufacturers, as well as the display manufacturers and the suppliers. We have now 147 companies from small start ups all the way through to companies like TI, AT&T, Xerox, etc. Our focus was really to develop the infrastructure for these manufacturing technologies.

It was quite interesting to see that world wide players like Applied Materials - through AKT, their flat panel subsidiary - are playing a very dominant role in being increasing market share. Small companies like Photon Dynamics is having a very dominant position at the other end of the chain, which is the inspection end of flat panel displays.

If we go the next step, there is an even more complex interrelation between these whole things. If you first look at liquid crystal displays, I kind of define this as the AMLCD is really the silicon of the display technology in more ways then one. One: It's a very dominant technology at the moment and I think it will remain so for a number of years. Two: It uses silicon type processing. It's a pretty simplistic process compared with anything that we see today in integrated circuits, but it nevertheless is a silicon technology. Out of that it's produced large area tools.

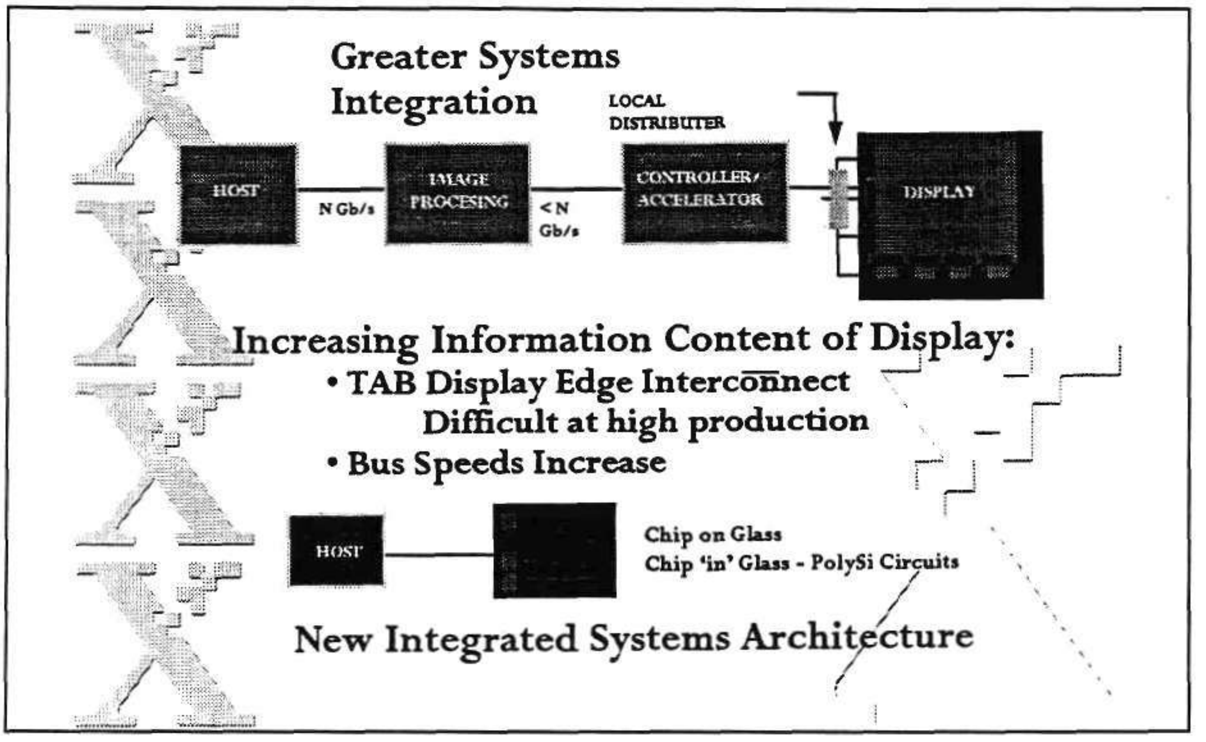
It was interesting to see that at Semicon West, Applied Materials showed a 300 millimeter wafer PCD tool there. It was actually a flat panel tool that had been modified to do 300 millimeter wafers. It's interesting to see how the tools in the flat panel industry are actually supporting the silicon industry as well, and how those two are intertwined.

In addition to that, as you go to very large substrates, we are looking at different coding techniques for photoresist. By the way, a year or so ago there was more photoresist used in flat panel displays then in all of the semiconductor processing in the world put together. We are consuming a large amount of material because of these large sizes. Therefore, that needs rather sophisticated new coding techniques because as you well know, we waste most of the photoresist. That in itself is going to supply the silicon industry with some new tools.

If we go further up on that chain, we see today that Corning - which is a dominant player in supplying glass to the industry in the flat panels - has basically developed a glass which has the same thermal coefficient as silicon. The reason for doing this is then you can start integrating chip on glass onto the glass of the display and you become a completely integrated system, of which the display constitutes the larger portion of the product. We have display centric products where the display is acting like the PC board, as well as the display itself.

You have a combination. Silicon technology has driven performance for a long period of time. What display technology will drive is cost. I think there are two things together which really is going to drive some of the displays, particularly in LCDs and some of the others, to be a very much lower cost, high performance display technology.

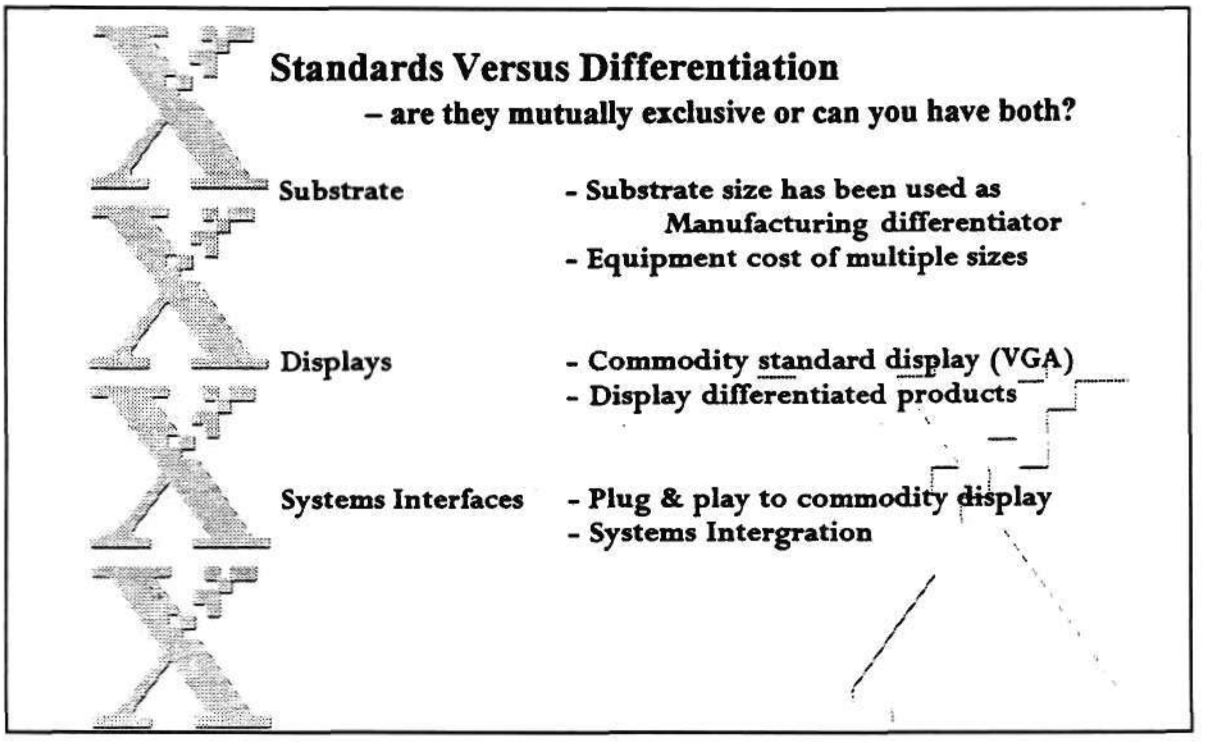
As I say, the performance of these displays is really increasing very rapidly.



If you look at the traditional view on the top of the diagram of what the kind of bit levels there are between the host through to the display, these are pretty hefty transmission of information you have to handle. As the display gets larger and larger, and as the number of pixels and the color and gray scales increase, this whole notion of having to be very innovative about the architecture of how to basically drive the display and how to get that signal around the display becomes increasingly more difficult. The bus speeds are becoming really colossal.

This really means it forces you to a point where you have to do larger and larger integration. Not just because of the packaging issue, but because of the whole bus architecture issues. I think this forces you into new integrated systems architectures. As I said, chip on glass and eventually polysilicon on glass, which you can get also to other functionality, not just drivers. You can make D-delay converters. We've made 90 DB linear amplifiers and a whole range of things. There is this drive towards higher and higher systems integration.

Where does that leave you in the end of the day? Are we ending up with a set of standards where we have commodity type products and everybody doing the same thing, or do we have differentiated products? Let me just take it one bit at a time.



Firstly: Substrates. Up until now basically a game has been played on substrates. Basically how many VGAs can you get on the substrate and I'll beat yours because I'll make a slightly smaller VGA, or I'll be first to get the next largest substrate. This game is a wonderful game. When you enter this business you have no problem. There is no lack of choices of standards. There are none. This is a real issue in terms of up until now, and it's being used as a sort of manufacturing differentiation by some of the leading companies in Japan. I think what happens is that's at a detriment in terms of the cost of ownership and the standardization of handling of tools.

What is clearly evolving: I think there will be one more generation of sizes and then I think there will be standards. For two reasons: One: It is becoming so expensive. Two: There will be a much more diverse range of products. It won't be such a simplistic argument of how many VGAs you can get on a display.

In terms of the displays themselves, is it going to be dominated by commodity type displays like a VGA, which it is today? The problem there is when you take a PC - for example - basically what is going to differentiate your product? I think there will be two sets, rather like the semiconductor industry, which is divided into D-RAMs, ASICs and microprocessors. I think from a functionality and from a business standpoint, you will see differentiation. You will see commodity products, differentiated products and custom products.

Finally: From a systems integration standpoint, there is clearly a need for plug and play. As I demonstrated before, there is an integration issue going on, both upstream and downstream in terms of the system integration. There are some real challenges there because you're not producing discreet components, you really want to do more and more integration.

In summary: The flat panel industry and the silicon industry are really intertwined, and it's intertwined with the applications and systems. The cost is being radically reduced. It's being done in two ways. For instance: AMLCD displays. It's reduced the numbers of mass steps. Secondly: The other real push is for higher throughput in manufacturing equipment. In fact, it is soon going to turn out basically that most of the real secrets and the real challenges actually lie with the manufacturing equipment rather than display technology itself. Maybe it's the systems innovation on top of that that you need to provide to get differentiation.

In AMLCD, Amorpha Silicon continues to be dominant. I think it will be for the foreseeable future. However, there will be a whole wide range of applications which other technologies from pagers to very large screens. As you can see, we do need another technology for very large screens.

I think customers will drive us to much higher performance and at lower - if not comparable - costs that we have today. Thank you.

Panel Questions and Answers:

Moderator: Thank you, Malcom. What I would like to do now is see if there are any questions in the audience. Does anyone have any questions for our panelists?

Question: (inaudible)

Panelist: Feral electric LCDs was the question. Feral electric LCDs have been around for a long time. They are clearly capable of going to very high resolution. There are a couple of issues with them in the past: One is they were not very shock resistant and I think that was an issue that claims to have been solved. Secondly: they used a very small cell gap, which makes the manufacturing very much more difficult. Canon - for instance - has been threatening to release these onto the market for I don't know how many years now. I believe there are some available.

It also has a limited color capability and gray scale. I think it potentially has some niche applications. I personally don't believe it will be a very dominant force. I think what's going on today is a sort of price performance competition between STN and AMLCD.

Question: I wondered if Mr. Thompson, and perhaps anyone else, was interested could expand on his comments about manufacturing equipment. Where do you see that there are - you mentioned throughput - but could you be more specific in the areas of manufacturing equipment as far as where the needs are being met for the foreseeable future and where there are needs for major improvements in equipment performance.

Panelist: I think basically what we need is we need to basically be able to get a better cost of ownership out of the manufacturing equipment. There are a couple of issues. One is cost of ownership basically in terms of what we call attack time. Today basically we use about 60 seconds or one minute for each process step inside of the system. I think that needs to be more radically reduced, as well as the size goes up there so that there is a better cost of ownership there.

The whole issue when you use vacuum equipment is what is the real utilization factor of that equipment, especially when it's under vacuum and you have to bring substrates in there. I think there needs to be a significant improvement there.

There is an issue of whether you've go cluster tool or whether you go in-line and it's already being mentioned. The one advantage I would say to cluster tool is that if you are moving in a rapidly changing technology, at least you can change it and it's much more flexible. If it's much more stable, then in-line I certainly think has a very large throughput.

Finally: The cost of ownership issue, which is the one I'd like to go back to in terms of photoresist and other chemical materials like filters, is we really need to have a much higher utilization of the materials. We are basically throwing most of the materials away. With color filters - for instance - they are very, very expensive. Techniques like actually printing color filters I think would be extremely valuable. In addition to that, there are other challenges in there which is a move much more towards dry etch rather than wet etch to reduce the actual cost of materials as well.

Panelist: I think just to amplify on some of the things that Malcom mentioned; cost of ownership is clearly one area that we as equipment manufacturers need to help the industry with. If you look at today's expenditures - for instance - in the semiconductor industry, a $1 billion dollar FAB today is the norm. Of that, the major portions of that expenditure is for capital equipment. We need to bring the cost of capital equipment down. The second part of that is the ability of that equipment to stay on line. In other words the time between repair, the time between maintenance. Alternative technologies need to be developed to do away with wet processing, a very costly and environmentally unfriendly process. A lot of work is being put in by the manufactures of capital equipment to come up with what is called dry processing; plasma technology which also provides some alternative means for post-cleaning.

We as manufacturers have to continue to be adaptive and responsive to the changing needs of the market, and the market is still changing all of the time.

Question: I have two questions. The first one is how you see Korea's competition with Japan in this technology? The second one is what is the recent progress of the U.S. consortium?

Moderator: Joel, maybe you would like to take the first stab at it.

Panelist: With regard to the Korean entry to the market, certainly there are a lot of resources they bring to bear and we've seen the emergence of Samsung. To date Samsung has invested on the order of $800 million dollars in capital equipment. We've seen them and many of our non-PC accounts, and to some extent the PC accounts, not necessarily from a cost standpoint. A lot of people anticipated Korean manufacturers would come in there and try and grab market share on strictly a pricing standpoint. It hasn't necessarily been so. Initial entry has been with VGA products, but now they are starting to show products that are very competitive with some of the best things coming out of Japan in terms of transmission and other aspects; in terms of prototypes.

How they will ramp it up and what impact they have: It will play itself out in probably the next year or two. All of us who deal with Japanese manufacturers are looking keenly to see what our colleagues in Korea will be offering. I think probably this JESS show that will happen next week, the Japan Electronics Show, will be an interesting forum to see where things really stand.

Moderator: As for the question regarding U.S.D.C., Malcom maybe you and Peter would like to handle that one? You've probably been the most active in the U.S.D.C.

Panelist: The goal as I said was basically to develop infrastructure for a wide range of technologies. We are at the stage where we started two years ago where we have a larger number of members then we ever foresaw. It's now at 143 members. It's a wide range of people who are entering the industry, from the equipment supplier and the material supplier. We are really quite surprised and delighted that that is the case.

Where we are in that development: I guess there are two outputs that we are looking at at the moment. The first tools that we developed - for instance plasma etching and inspection tools - are going to BETA sites the end of this year, the beginning of next year. Secondly: We have developed some very detailed road maps; this is with the users, the laptop computer users and other users in a wide range of things; because, of course, one of the interesting areas that the U.S. does dominate as a user of this technology, we have developed road maps internally which link the food chain together from the suppliers all the way through the manufacturers into the system users at the end. That's another output that we are generating for our own internal use.

Moderator: Does anyone have anything to add to that?

Panelist: Just a point that we as equipment manufacturers, in order to support U.S.D.C., have through SEMI, which has formed the NAFPD, which is the North American Flat Panel Display Association. The U.S.D.C. members are in fact the flat panel display manufacturers and the equipment manufacturers are joining through SEMI. We support that effort. We are part of the technology road mapping. We are part of ensuring that our equipment development programs are in line with the technology requirements that U.S.D.C.'s road map outlines to us. It's a very collaborative effort.

Panelist: It's an excellent relationship.

Panelist: One more comment on that. Even though I represent a Japanese manufacturer, we have a U.S. FAB facility where we are doing final assembly. Our goal has been to grow our ability to do more and more U.S. manufacturing. Those ventures which the U.S. display consortium has funded can in fact develop those component materials which can be utilized in our facility is certainly of great interest to us and have great benefit.

Question: Let me follow that question up with one of my own, and that's what do you gentlemen believe will be the effect of the potential government funding cutbacks that may have on the U.S.D.C.?

Panelist: That's a constant source of debate every year. This year it doesn't lack any less interest than any previous year, which we have survived.

The Clinton administration put together a North American Flat Panel Initiative, which the DOD was committed to. It was dual use technology, as they called it, for both military and commercial. It got caught up in a range of politics. That's still very unclear as to where that puts us at this point in time.

However, the DOD continues to get more and more money from the Republican Congress. We get caught up in political issues; that's the bad news. The good news is the DOD is getting more and more funding. It's a little unclear at this stage as to how we are going to develop.

When you go to Congress, there is actually a much wider grass roots support on a broad set of issues to the kinds of things that we are doing. the issue is really clarifying what we are doing in a broader sense, that we're not picking winners or losers, but we're really trying to provide an increased infrastructure for the industry.

I am optimistic, as I was last year, and that came through. We got all of the funding that we needed. I'm optimistic that that will be the same this year. It won't be without some careful discussions in Washington.

Moderator: Does anyone have anything to add to that?

Panelist: I think that my background with SEMATECH is perhaps a good analogy for U.S.D.C. Initially Semitech received funding from ARPA and it's role was to develop a U.S. infrastructure which was again to become competitive with the Japanese semiconductor industry in the end of the 1980's.

Semitech has turned its tables and is now self-funded. In other words, Semitech member companies are supplying the funding to ensure a continuity of its effort, which is to work as a collaborative, to develop new technology road maps and to ensure that the infrastructure of the U.S. is in tune with them.

I think U.S.D.C. similarly will end up that way. I think that some of the funding that U.S.D.C. has gone to U.S. manufacturing companies of equipment and materials; I think that was a shot in the arm at best, but certainly didn't in any way match the real need of that market to develop materials and equipment. I think the U.S.D.C. member companies realize that a much larger investment in this industry, such as in the semiconductor industries. When the time comes that the Hewlett Packards' and the IBMs and the TIs start to make large investment in the flat panel area, at that time also U.S.D.C. will be the beneficiary for that kind of investment. I think it also will become self-funding.

Panelist: I think that's absolutely right.

Panelist: Jack, if I might I would like to add that in addition to U.S.D.C., there are great individual direct support from ARPA to individual companies. We have been a big beneficiary of that. I would agree with Malcom that when you get into the individual members of Congress, and particularly into the DOD and ARPA, you find really intelligent support for those programs under the dual use concept and I don't see those going away anytime in the next year.

We, like Malcom, had some heart attacks earlier in the year, but we managed to get through that. We will probably have heart attacks the next year and the year after. This gentleman on our staff, there is one program called PRT, which was invented by the Clinton administration. Tongue in cheek we now call that the RTP program, the Republican Technology Program, and what it will be next year I do not know; but I can guarantee you there will be something.

Moderator: Perhaps we have time for one more question.

Question: For the statements about FED display, the emission display; is it ready to go for mass production?

Panelist: I can answer that for us, and I'll try to generalize a little bit. In our case we've been developing this technology for the last three and a half years. Pixel is probably the best known of the alternatives that started in France, and Tolay National Labs has been working on it for over ten years. We will be in prototype production. I showed you a working display up here that was developed in a four inch glass line. That line will become a prototype line next year for five inch quarter PGA displays by the end of the year.

We will not morph that line, but in parallel develop a facility for processing very large area competitive sets of tools; probably I would guess unless things change, or if Malcom is correct about the standards settling, probably 550 by 650 sheets of glass which should be quite capable of processing very cost competitive, very performance competitive displays normally at the 12 inch glass and above.

The whole trick with field emission based displays in the technology is that it can be processed with lower defect densities - we all believe - and with much simpler processing cycles. That, of course, remains to be seen in high volume.

This page is intentionally left blank

Chapter Twelve: REACHING $300 BILLION BY THE YEAR 2000: WHAT'S IT GOING TO TAKE?

Panel Discussion

Moderators

Stanley Bruederle
Vice President and Principal Consultant
Dataquest Incorporated

Clark Fuhs
Senior Industry Analyst, Semiconductor Equipment, Manufacturing and Materials Service Group
Dataquest Incorporated

Panelists

Wei Shan Lin
President
Tatung Company

Marcus T. Wilson
Vice President and General Manager, Semiconductor Products Group Intel

James J. Kim
Chairman of the Board
AMKOR/Anam Group

Dr. David N.K. Wang
Senior Vice President, Worldwide Business Operations
Applied Materials

Roger D. McDaniel
Chief Executive Officer
MEMC Electronic Materials

Introduction: We've all heard the projections of a $300 billion dollar market; actually it's closer to $330 these days for the year 2000. That's going to require a lot of equipment, silicon, and the manufacturing know how and assembly to get it done. We've collected a number of people from the industry to talk about the issues and the challenges they see ahead. We have a few slides to go through to get everybody in tune on the assumptions. We'll hear from each of our panel members for a short period of time; five to seven minutes each. Then we will raise a few issues of our own in summary. Please think about the questions you want to ask of these distinguished panelists and we'll make sure everybody gets a chance to at least get most of their questions answered as the time allows.

Stan, would you like to begin?

Moderator: Yes. Before we get started, Clark and I would like to introduce our panelists for today in the order that they will speak. We will start at the top of the food chain and work down to the foundation, the silicon industry.

Our first speaker is going to be Wei Shan Lin. W.S Lin is President of Tatung Company. The company is 78 years old and based in Taipei, Taiwan. It is a publicly owned corporation, with more than 150,000 shareholders. It has 30,000 employees, including 10,000 overseas. It is a conglomerate with worldwide sales of $4 billion and manufactures and markets 300 different products, including heavy electric apparatus, home appliances, electronics, computers and telecommunications in other systems. At present, computers and computer peripherals make the most important contributions to the company's revenue.

In order to make the most of competitive advantages of different countries, Tatung has operations in Japan, Korea, the United States, the United Kingdom, Thailand, Malaysia, Singapore, Indonesia, Germany, Canada, Australia and Hungary. Now Mr. Lin is concentrating on developing Tatung's high technology capabilities. The company has become a major supplier of computer peripherals to a number of famous brands in the United States. Mr. Lin travels frequently to the United States to visit companies in Silicon Valley so he can develop technologies and markets for products and components in the computer hardware and software fields.

In an article in October, 1991, and this is important to this session, Asian Business identified Mr. Lin as the man best suited to turn Tatung into a major international player in the 1990's. To do this Mr. Lin is working to establish strategic business alliances with high tech companies in the United States, Europe and Japan.

Moving from the systems industry down to the semiconductor industry, the next speaker will be Marcus T. Wilson. He's Vice President and General Manager of the Semiconductor Products Group of Intel. Mr. Wilson is Vice President within the Semiconductor Products Group. He is responsible for the overall strategy and synergy of marketing programs for all divisions of SPG, which include embedded microcontroller division, embedded processor division, memory components division and military and special products division.

Before becoming a group marketing manager in August, 1994, Mr. Wilson served as a General Manager of the Embedded Microcontroller Division, called EMD. There he was responsible for embedded control products, including eight and 16 bit microcontrollers, the Intel 186 and Intel 386 embedded microprocessors.

Prior to becoming General Manager of EMD in 1991, Mr. Wilson served as General Manager of the Automotive Division, which develops, manufacturers and sells microcontrollers to the automotive industry. Before this he was Director of Corporate Strategic Accounts.

In his first eight years at Intel, Mr. Wilson had several positions in field sales including Southern Regional Sales Manager, District Sales Manager and Field Sales Engineer. Before that he worked for Texas Instruments.

Marcus is going to talk about new industries that are developing other than the PC industry. The industries that are coming beyond the PC and are going to contribute growth in addition to that fast growing industry.

Moderator: Following Marcus will be James Kim, who was originally born in Seoul, Korea. He came to the United States as a student in 1955, and became a citizen in 1971. He earned Bachelor's and Master's Degrees in economics by 1961 through the Wharton School of Finance and Commerce at the University of Pennsylvania.

Mr. Kim was Assistant Professor of Economics of Villanova until 1970, where he taught economics theory and conducted some seminars. From Villanova he took a leave of absence to participate at the Agency for International Development Project in Korea.

Mr. Kim founded AMKOR Electronics in 1968, and has guided its growth and diversification as Chairman and CEO. AMKOR, headquartered in Westchester, Pennsylvania, has established its reputation as a leader in semiconductor assembly, testing, packaging and technology. Additionally, in January of 1992, Mr. Kim became Chairman of Anam Group in Korea.

In the fall of 1977, just to give you an idea of the diversity of the panel members, Mr. Kim founded the Electronics Boutique. Beginning operations with one kiosk type store, in a King of Prussia Plaza Shopping Mall. This was a new concept in the retail sale of electronic products and has been outstandingly successful; growing from one kiosk to 400 in-line stores.

Mr. Kim was President and CEO of that firm until 1984. He still serves as Chairman and CEO.

Mr. Kim is currently serving as Director on the Boards of VLSI Technology and CFM Technology. He is past Chairman of both Korean Athletic Association of Philadelphia and the Korean Association of Greater Philadelphia.

Mr. Kim is very active in various organizations in the Philadelphia area, and he was awarded the honorary degree of Doctor of Commercial Science by Villanova University in 1990.

Our fourth speaker, from the equipment side of the house: Dr. David Wang, who is Senior Vice President of Worldwide Business Operations for Applied Materials. He was named to that post in January, 1994, and he's globally responsible for managing and driving the company's business, including account management, installed base support services, customer satisfaction and sales in corporate marketing.

Prior to his current assignment, Dr. Wang was Vice President responsible for the Applied Materials CVD and Etchtechnologies Group, as well as General Manager of the company's Asia Pacific business operations.

In addition, Dr. Wang has been a principal developer of the plasma etch systems in early applied materials years, as well as the Precision 5000 CVD and etch systems, and the new Centura high density plasma systems.

Dr. Wang also received the SEMI-Lifetime Achievement Award in 1994, for his contributions to the semiconductor equipment industry, particularly in the design of Precision 5000. Dr. Wang conducted research in the plasma etch, plasma CVD and x-ray lithography at Bell Laboratories in Murray Hill, New Jersey, before joining Applied Materials in 1980.

Dr. Wang earned his Ph.D. in Material Science from the University of California, Berkeley.

Down to the foundation and Mr. McDaniel will also talk about his view on what this industry is really like. Roger McDaniel is the Chief Executive Officer of MEMC Electronics, Incorporated. MEMC manufacturers and markets high purity silicon worldwide for the electronics industry and is the second largest silicon wafer producer in the world.

Mr. McDaniel joined Monsanto originally in 1962, and held positions in engineering, manufacturing commercial development, marketing, finance and planning and international operations. In February, 1988, he was appointed Vice President of Operations for Monsanto Electronic Materials, a position he held at the time that Huls A.G. acquired the business from Monsanto. Mr. McDaniel was appointed President and CEO of MEMC Electronic Materials in April, 1989, at the time the company was formed as a unit within Huls.

Mr. McDaniel has also taken part in engineering the successful initial public offering of MEMC Electronic Materials, the first silicon company to do so. They trade on the New York Stock Exchange under the symbol WFR.

Mr. McDaniel is Chairman of the Board of Directors of SEMI, a trade organization for material and equipment manufacturers. He received his Bachelor's Degree in Chemical Engineering in 1962, and an MBA degree in 1966, both from the University of Kentucky. He serves on the Advisory Board of St. Louis' University's Institute of International Business.

Moderator: Well the question we are discussing today is the idea of a $300 billion semiconductor industry. In 1995 we expect the industry to achieve $150 billion. As Gene told you today, our forecast for the year 2000 is $331 billion. What's it going to take to do that? Is it possible to do this?

REACHING $300 BILLION BY THE YEAR 2000: WHAT'S IT GOING TO TAKE?

When we first started doing this it was supposed to be $300 billion industry. We raised it by another 10% on top of that. I guess now the idea of $300 billion is kind of a no brainer. It could shrink by 10% and we could still make $300 billion.

The PC market is the industry that is driving the semiconductor industry today. This is the third in, and what we are proposing is four cycles. In the 1970's and the 1960's, military applications drove the industry. In the 1980's, consumer electronics drove the industry. In the 1990's, we are being driven by the personal computer, which to my way of thinking is very much like the automobile was quite a while ago. In the 2000's, we expect communications to be the driving force in the semiconductor industry.

In putting together the idea of achieving $300 billion dollars, we made a number of assumptions. We made some market assumptions, and then we made - in addition to that - some technology assumptions.

The market assumptions are that the PC is driving industry growth. The PC is a unique product. It's a high volume product. We expect shipments to grow 17% compounded over the period we are talking about to reach 120 million units by the year 2000.

What compounds that growth is the facts that relate to semiconductor content. About 56% of factory revenue will be spent on semiconductors by the year 2000 for PCs. A typical system will have 48 to 56 megabytes of memory. That's working memory. We forecast that by that time, or we estimate that by that time to support that volume we are going to see shipments of 35 million Pentium pro microprocessors and another 65 million what we call P7 processors; huge volumes of very complex chips.

On top of that all, high performance is another factor. Clock speeds will well exceed 100 megahertz by the year 2000. They are already exceeding 100 megahertz today. We expect the D-RAM price per bit to decline by 10% to 15% per year over the long term. Obviously that will require some acceleration from where prices have been going in the last few years; but slower than what it has historically been.

Further technology assumptions that we have is that revenue per square inch will continue to increase at about 5% or 6% per year. The technology trend will continue to follow Moore's Law, and there will be a tremendous ramp up of 200 millimeter wafers. Most of the fab expansion today is in the larger eight inch wafer size.

However, there is still a tremendous growth at the smaller wafer sizes, particularly six inch. Six inch will continue to be the dominant wafer size in the year 2000.

We also are assuming no appreciable ramp of 300 millimeters wafer consumption by that time. We expect, as you heard this morning, a lot of new FABs. This is a 1996 to 2000 manufacturing outlook; if you add 1995's that number goes to about the 200 to 210 level for the number of new FABs. That represents a cumulative spending, starting in January 1st next year going through the year 2000, at $250 billion dollars.

About 2,400 MSI, that stands for million square inches of silicon a year of new capacity has to be added at the silicon wafer level. We estimate that will cost about $6 billion dollars in capitalization of the silicon wafer industry. We believe 85 to 90 million six inch wafers may be needed in the year 2000, and that's probably conservative. We estimate about 47, 50 million eight inch wafers.

Polysilicon capacity, which is the little bitty triangle that the whole industry sits on, that is the raw material that the wafer manufacturers buy to melt to grow the crystal. The capacity there needs to double from present capacity to about 22 kilotons.

What is significant about that part of the industry is that from about 1987 to last year, there have been no appreciable capacity increases in that segment of the market. This is a new thing to do.

Semiconductor manufacturers also expect to continue to drive costs efficiency. Contract manufacturing foundries are expected to be a large part of the infrastructure and a large part of the driving forces and increasing the efficiencies of the industry.

REACHING $300 BILLION BY THE YEAR 2000: WHAT'S IT GOING TO TAKE?

Panelist Wei Shan Lin:

Ladies and gentlemen: Good afternoon. It is my honor to participate in this conference.

(Note: At the time of printing, slides were not available.)

From here you see in 1989, it is about $2 billion of the IC production value. The fourth line is the market demand in Taiwan. From 1989, $2.1 billion to almost $6 billion in 1994. The total production value in Taiwan by 1994 was only about $3 billion dollars, so you will see gain. From 1989 it is about 10%, and by 1994 it is about 16%.

The fourth line is showing Taiwan's IC production value. In 1989, it was only $400 million. Actually there is some ratio of that is being exported. This projection would be to the year 2000, about $12 billion dollars in value. Global IC production value in 1989 was $46 billion. This original projection of about $250 billion. Going now this is upstream, and even the Dataquest forecast has been adjusted two or three times. I have been briefed by all of our other system companies that PC shipment will be over 100 to 125 million units by the year 2000. If you multiply by two with today's figure, you would get about $250 billion, but of course there are some other products, CD-ROM and the other applications, the air bag, ABS in the car; as well as the growing demand for cellular phone systems worldwide. The global growth rate from 1994 to 2000, is about 17.5%. Taiwan's growth rate is about 34%, which is somewhat higher.

I add that in the past three or four years we have seen a tremendous growth in Taiwan's IC industries. Of course almost the majority of the companies are making a good profit margin, so they are Weiting to expand into the so called billion dollar FAB, the eight inch FAB.

Over here I wanted to give you some forecasts about the so called IT industry; information technology industry, the hardware industry in Taiwan. You will see that actually the total IT hardware industry in 1994, was about $14 billion U.S. dollars. That will grow in 1997, to about $24 billion U.S. dollars. Actually by this year, 1995, our total production value of computer hardwares will be $17 billion dollars. That will place Taiwan as the number three production country in the world; next to the United States and Japan.

You can see this ratio of growth estimated in 1994 through 1997. Of course the compound growth rate will be about a 38%. However, the domestic growth rate is still beyond 10%, beyond 5%.

Here I make some comparison of Taiwan and Japan and Korea's PC industry. You can see a pie here. You can see Japan being competitive in notebooks. Korea is a somewhat more particular market. The production weight in Taiwan is shifting more to notebook PCs. We started manufacturing some of the key components, such as display tubes, LCDs, some of the memories. We, of course, are the country with the fever for procurement from large worldwide PC companies.

From the above figures and facts it is indicated that this region stands on the fastest growing market for not just IT industries, but also for other consumer electronics, for automotive products, and so on.

To meet the demand of this worldwide demand, the Pentium is driving the PC speed faster and faster. It certainly requires more memories and more high end CPUs. Of course we are all experiencing a very big worldwide shortage, so of course I come here to this meeting to participate in this conference; trying to make some friends. Of course we are arranging some partnerships with world class companies in order to meet our own companies' demand. By the year 2000 production will increase to probably 8% to 10%, which is the country's mission.

Thank you for your attention.

REACHING $300 BILLION BY THE YEAR 2000: WHAT'S IT GOING TO TAKE?

Panelist Marcus T. Wilson:

Good afternoon. I'd like to take a cue from John F. K. Junior and answer your most pressing question first so that we can get down to business. I see that Dataquest made some suggestion that there might be 100 million Pentiums shipped by the year 2000, so I would guess that someone is going to ask me in what year will Intel ship 100 million Pentiums?

The first answer to that is I would still like to be a Vice President tomorrow; so I'm not going to tell you that information. I will tell you that we are not concerned about having the capacity to ship 100 million units by the year 2000. We are estimating that that number will come sooner than the year 2000. We are certainly entering exciting times, and our industry continues to grow; and it continues to prosper, as evidenced by the financial returns over the past year. As the title of this discussion implies, Dataquest is anticipating that it is a $300 billion dollar market.

I also think it's an exciting time because the 21st century is upon us. I read an interesting article on the millennium a little while ago, and it said when asked to close their eyes and imagine the shape of technology in the 21st century, scientists and industrial planners described a world filled with intelligent machines, multisenstial media and artificial creatures so highly evolved that they seem to be alive as dogs and cats.

I don't know about the dogs and cats, but all of these predictions are really based off of the semiconductor industry and what it's been doing in the past and what they expect to see to continue in the digital world.

Growing the semiconductor industry to $300 billion in the year 2000 will require more than just the growth in the PC market. I don't think the current PC market will be able to absorb the number of processors that can be produced, given the amount of capacity that will be in place; at least from the amount that I see us putting in place at Intel.

This year data processing is expected to account for about half of the total revenues of the worldwide semiconductor market. The number is expected to remain steady through the end of the decade. Consumer electronics and communications are the other markets that absorb large numbers of semiconductors. I believe that growing the semiconductor market may require expanding these markets as well.

What we are concerned about is developing new uses and new user for semiconductor products, for products in the area of intelligent machines, multisensory media, artificial creatures, if you will. They will be developed and they will become commonplace in the next century.

Let's look at some of the uses and some of the ones that we can see today we are beginning to see emerge. First communications: Telecommunications, smart digital communications, space stations, smart phones, digital handsets. All of these are already emerging as a very high growth industry. Digital wireless capability for such devices as laptop computers and personal digital systems will contribute to a large growth. Developments in these areas will include specialized mobile radio, low earth orbiting satellites and personal communications services.

In Europe, the mobile communications market is one of the fastest growing sectors of the European telecom market. They have a strong user demand for all kinds of wireless technologies. Telecom is really Europe's PC market. GSM is secure. There they are really using phones and faxes the way that we use E-mail in this country. As the technologies are deployed, they will be used in different ways to accommodate the worker in his environment.

I understand that in China they use digital pagers and have code books where they send coded messages for the pagers. That's an effective way of communications and pagers are exploding there.

Another area is networks: Microprocessor growth in networking will continue to grow as they enable the network ease of use and increased data throughput. Things like multimedia, image sharing, video conferencing, LAN and telecom integration. Also remote networking access will allow all of the road warriors of the world - and it seems like we're all becoming one - this remote network access will allow us to work any time, any where.

Anything that allows human beings to work together to communicate, to do work remotely, seems to have a future; much like the telephone did at the turn of the century, only it's happening much faster now.

Embedded microprocessors will also enable rich image processing by linking digital cameras, faxes, scanners, printers, digital copiers to PCs. Even the smart home is beginning to emerge. As we do things like use the house wiring as our bus, embedded processors and controllers in appliances will enable people to control their lighting, their air conditioning, their security systems; and do so while traveling, while at work, or even at home. They havethings like servers in the home and be able to access those any where, any time.

Of course, the automobile industry is part of the mobile environment, and also it's part of its own increasing growth in electronics. While the growth of cars is not expected, the growth of electronics is. Dataquest has identified 25 newly emerging electronic ap's for intelligent cars of the future.

New users continue to surprise us. Today we can see things emerging as in government; things like intelligent highway experiments, embedded electronics to monitor and control speeds, collect tolls, do deductions. Those also will extend into things like utilities, the IRS. State and local and federal governments will do things like Driver's Licenses electronically.

Other countries will leap frog into these technologies. China has a great need to be able to collect taxes and to be able to manage that system. They are looking at jumping into the electronic age to do that.

Banking the world over needs security so that it can connect to the consumer and allow the consumer to play on that network and move money around.

The emerging countries and the third world countries will catch up to modern day by skipping rungs on the technology ladder. A lot of countries that never got into mainframes will jump into technology at the PC and server level. In some cases they'll employ this technology in innovative ways, much like I mentioned earlier about China and using pagers. As they catch up, they will certainly find different ways to use technology.

The growing world population will help this business grow. As more of the people become senior citizens and the kids come along and play with virtual reality and education, they will invent new ways to use our technology. They are likely to create a much larger demand for semiconductors then we have ever expected, and we don't see those yet.

Even such things as farming, where they are embedding microcontrollers in the soil to monitor the soil and analyze the soil conditions and the presence of disease, those applications will begin to open up.

Health care: Where they monitor the patient continuously and are alerted to changes in patients' condition. It allows them to monitor the patient remotely.

I'm sure there are other things that we can't imagine. I've only tried to cover some of the things that are at the edge of our field of vision and are beginning to emerge. Some of those will explode and truly create this demand. I don't think that the number that's proposed here today is off. It may be a year or two, but it's certainly coming. As we look at that, I think that in our own industry we certainly believe at Intel that we are putting that capacity in place to meet that demand.

For instance: I heard a number from SEMATECH the other day that said if Intel built 100 million Pentium Pro PCs, if you assume that you were using eight inch FABs with 20,000 wafers per month as an output, what would that require? The analysis said it would take four CPU FABs, one new flash FAB, and 25 D-RAM FABs. I know that the five FABs, the four CPU and the one flash FAB is not going to be a problem for Intel. I am wondering today though where the 25 D-RAM FABs would come from.

This doesn't touch the number in terms of FABs that Dataquest was showing here, but just looking at our little piece of the business there, we certainly are concerned about where the FAB capacity is going to come from to support all of the devices that go on the desktop, in the mobile communicator of the future.

We really come down to having a couple of areas of concern about that. Can others grow and if they can, will they invest in the semiconductor business?

For instance: The drop off in the build of demand over the past few years that was made reference to a moment ago. Japan's recent banking troubles don't indicate that they would be investing heavily in the future. China, who is certainly concerned about their ability to collect taxes and fund their infrastructure growth will be more concerned about other things. The former Soviet Union is not clear what they are doing in terms of taxes or in the banking system today. First of all: Will the money be there? Will the countries be willing to invest? Will the companies be willing to invest? Will they invest in the right product?

A more pressing issue for us: If I think that Intel is going to have the capacity for the computer industry and for some of the other emerging technologies, the real problem for us today is where will the technically skilled people come from that we will need to man such an industry to develop these new ideas? We can certainly come up with the money. We can come up with the concrete. I think we can buy the equipment. The people that have the skills that we need to participate in the engineering and get us there are really our greatest concern. Thank you.

Panelist James J. Kim:

Thank you. My presentation will be primarily in the area of assembly or packaging and assembly and test area. I was a bit surprised when Gene Norrett called me and asked me to make this presentation today; to participate in the panel. In the past, packaging assembly was always left out, always a dirty job for somebody. I guess the industry is beginning to recognize the importance of packaging as the chips are becoming more complex.

Amkor/Anam

ASSEMBLY SUPPORT FOR $300B

• Total Semi Sales	+119%	(137B to 300B)
• Total Semi # Sales	+ 43%	(206B to 295B)
• Total Semi ASP	+ 40%	(.59 to .83)
• Assembly Activity	+ 90%	

This morning, all of you are aware that my number is out of date already. It's supposed to be 140 billion or 150 billion; then I was told maybe even 400 billion; so who knows.

Anyway, from an assembly point of view the answer is yes. We can support it. Let me go over some basic numbers so that you understand, because these numbers are not published often enough for you people.

First of all, as you can see the growth would be definitely more than 200%, or actually 119, but it would be 150%, 160% now. The number of units, we believe units will increase only 43%, or maybe 50% now. Because of the D-RAM area, as you know, increases will come. If you look at the total semi, ASPs are going to be 40% increased. Many people ask me why the price increase? As you know, D-RAMs are becoming to 64 mb, therefore unit price will increase, we believe. Therefore unit increase will be in about the 40%, 50% area.

In the assembly activities, because of the IO areas, we believe increase will be about 90%. Maybe we need to adjust according to numbers and maybe it's 100%, but it will be about that area.

How to support it? We believe the factories' productivity will increase roughly about 7% per year based on improvements and so on, and facilities will go up about 40% over the next five years. Packaging material will increase from 30% to 40% area of the package. The current number of factories we estimate in the market to be about 200, or the equivalent of about 40 million square feet. I think there for new factories, the requirement based on that will be about 80. Of those 80 - according to our estimates, the numbers we that we looked at - about 35 new ones have started or committed, including AMKOR, we have a commitment of about five new factories already. I believe, based on our information, that about 35 of them have started. The additional ones we need is only about 45; so we are satisfied.

Amkor/Anam

ASSEMBLY SUPPORT FOR $300B (continued)

• Factory productivity	+ 40%	(7%/year)
• Package material content	+ 10%	(30% to 40%)
• Current # of Factories	200	(40M Sq. Ft.)
• New factories required	80	
• New factories started/announced	35	
• Additional factories required	45	

By the way, go back to that previous page. Did I mention the D-RAM market units will grow by 40%. In the D-RAM market, the assembly facilities do not change too much. You do not need a new facility to accommodate those because unit increase is not as big as you think.

In terms of dollar terms, we estimate that the productivity we talked about, about a 40% increase of productivity, will require roughly \$2 billion dollars of additional investment for factories. The productivity improvement that we talked about will require about \$2 billion dollars. The first one is for the square feet that I'm talking about; 20 million square feet, \$100.00 dollars per square feet will require about \$2 billion dollars additional investment for facilities, and \$2 billion dollars for the productivity increase. New equipment to fill the new facilities will be roughly about \$9 billion dollars to the \$10 billion dollar area, such that to accommodate the \$300 billion dollar problem that I started with - that I'm sure has to be upgraded now - but roughly about \$13 to \$14 billion dollars will be required for the packaging area or assembly and test.

Amkor/Anam

ASSEMBLY SUPPORT FOR \$300B (continued)

- New factory investment required \$ 2.0B (20M Sq. Ft.)
- Productivity investment required \$ 2.0B
- Equipment investment required \$ 9.3B
- Total investment required \$ 13.3B

Amkor/Anam

ASSEMBLY SUPPORT FOR $300B
(continued)

- Most challenging areas:
  - Assembly equipment suppliers
  - Leadframe/Substrate suppliers
  - Upgrading existing factories
  - Significant packaging technology challenges

What are the challenges for us? I think first of all assembly equipment suppliers must have the patience to stay. There may be ups and downs, but we need their support for the industry to continue to grow. In the past, if you go back to ten years ago or even seven to eight years ago, there were questions about some of the manufacturers and they disappeared in the United States. Fortunately many of them stuck around and they advanced their level of technology to a point where they were able to do complex chips at the moment.

Next is the material area, and where we have some concern is lead frame areas. Again, as you go into new packages such as the BGAs, the substrate becomes an issue. Amkor/Anam is investing a significant amount of money to research this area, but we need the support from the suppliers in this area also.

The other each factory must upgrade to accommodate, as well as the new factories that we are planning to build in Korea, we are going for almost all automation. The materials will be handled without hands, and so on. These upgrades will be required. Again, we need assistance from industry, especially the manufacturers of equipment.

Panelist David N.K. Wang:

The globalization for equipment certainly needs a global infrastructure. For the semiconductor manufacturer, if they want to invest outside of their headquarters, they also have to start to recruit and train experienced management people with a global perspective. This becomes a real key.

The global infrastructure to support more than 150 new semiconductor FABs will need to recruit and develop human resources. In many developing areas, in Asia Pacific, in the last five years such as Thailand, Malaysia or mainland China; those areas could become a very good opportunity for many semiconductors to invest, either directly or with government or with other companies in a joint venture type of investment.

However, in that area there's not enough well trained, educated semiconductor high tech engineers and operators. This becomes a very big challenge.

Also we need to establish global information data sharing networks. For example: Most global semiconductor companies, like Texas Instruments, they have joint ventures and subsidiaries all over the world: In Singapore, in Italy, in Japan, in Taiwan and certainly in the U.S. They use the equipment and they also need to globalize the equipment selection. They call it a harminization of the equipment and the technology. In this case, any equipment supplier must have not only a global infrastructure to support the operation of the equipment on site, but also have to develop a global network in order to provide the message to support every FAB from the one company.

On time deliveries, start and service: Nobody could really accurately forecast the business in 1995. In early 1995, there was a large ramping up of production and it caused a lot of stress for all equipment suppliers to deliver equipment on time. In the next five years, if we are talking about over 150 FABs, we really need to understand where will be the FAB, and when will be the FAB, and what kind of FAB. Therefore we can be ready to deliver equipment on time, and also have enough manpower to do a stop and after stop service in order to support this $300 billion dollars.

To do this, I believe the relationship between our customer and us and between us and our vendors, which support the components in order to manufacture equipment, must be addressed. I would like to show a formula I used as a relationship ways to semiconductor manufacturers.

Back to 1970, the equipment supplier just simply delivered the hardware, without any process capability in the system. The manufacturer of semiconductor people can develop their own processes.

In the 1990's, equipment is not adequate. You must have an associated process with current specifications. That we call the results on wafer. In 1990, the first half of 1990, not only results on wafer, but also has to maximize the productivities. For the next five years, toward the end of the century, we must not only have all of this, but have to have a strong partnership to work together. The partnership can help to reduce the cycle time, cut down the learning curve of starting a new FAB, and increase the productivities and help to deliver on time, help to train the customers, the engineer operators, to make this $300 billion dollars become reality.

Thanks for your attention.

Panelist Roger D. McDaniel:

Good afternoon. When I was asked to participate on this panel, I was not sure whether the issue was how do we as suppliers keep up with the semiconductor industry as it doubled in size over the next five years, or how do we accommodate the 50% slower growth rate implied by the mere doubling, compared to what we've seen in the last couple of years.

In the past five years, the semiconductor industry has increased annual sales by $85 billion dollars. Now Dataquest is projecting revenue of $180 billion increase over the next five years. Can we make it happen? I really believe that we can. The "we" is the equipment manufacturers, the software producers, the semiconductor houses and the suppliers and material and equipment. Collectively we must drive the utility costs of semiconductor based products to approximately 20% of today's levels in order to create that market demand.

Semiconductors are value based on their accessible memories and the number of instructions they can process in a unit of time. We collectively have got to focus on that utility and we've got to drive it down, as we have in the past. The price of memory has declined an average of 32% with each doubling of cumulative production experience during the past 15 years. Prices have fallen to a fraction of what they were.

This has been achieved despite the fact that the cost of semiconductor fabs has increased with each new chip generation. Further, the price of materials and equipment used to manufacture each new generation has also increased.

What's required to continue to drive the cost down the experience curve? I believe that it can only happen if each participant in the industry recognizes the valuable contribution of the others. Everyone in the supply chain has to participate.

Let me illustrate what I mean: If you go back to 1994, there was a big controversy in the industry. Our equipment price is too high. Dataquest did a paper which was entitled Are Wafer FAB Equipment Prices Justified? In their concluding paragraph, they said the following, "Semiconductor companies in particular should not think of their equipment companies as simply suppliers from which to extract the lowest possible price, but as partners and enablers that allow them to be profitable." I believe the same could be said of the material suppliers, and all of us saw that very quickly when there was an explosion which shut down Sumitomo's epoxy resin plant for a brief period a couple of years ago. We've got to focus on the utility costs, not price.

Let me give you an example: Are 200 millimeter wafers cost about 85% more per square inch than some of the older generation of products. They allow the semiconductor manufacturers to realize great economies and in turn to produce devices at a lower price.

Given that we can work together and create the market, the question then becomes can we supply it? I believe that we can. I believe that we have to recognize that the market growth is going to be 200 millimeter driven, as the other speakers have said. The 200 millimeter will grow at a rate of about 10x the rate of the older materials, the six inch and smaller diameters.

300 millimeter will not be a major factor in a $300 billion dollar market in the year 2000. We have to focus on developing the 300 millimeter market, and we have to really continue that effort. We must not let it get in the way of producing the 200 millimeter product that is going to be required to generate a $300 billion dollar market in the year 2000.

SEMI has made a statement recently that $14 billion dollars will be required by the industry and its suppliers to develop the 300 millimeter capability by the end of this decade. It's absolutely essential that it be done, as I said; but it's got to be done in a way that doesn't drain resources. SEMI is going to take a proactive role in trying to facilitate that result.

Again, let me state that each element in the supply chain has to be financially healthy if we are going to support the semiconductor industry. It's been estimated that the silicon manufacturers worldwide will have to invest $6 billion dollars of new fixed capital to support the growth in the market that's been outlined.

In August, the Silicon Group of Japan's Society of Newer Metals announced that it's 11 members posted 1994 operating income of $178 million dollars, that's a 5.3% margin on sales. It was their first profit in three years. EMR pointed out that out of that they had to pay interest, finance costs, taxes, and any extraordinary expenses. I don't believe that any segment of the food chain can grow beyond its purse strings, so I believe that that industry has to become healthy or the whole system is not going to be healthy.

We have to continue to move away from this concept of the food chain to the concept of an ecosystem model, which recognizes that the relationship among the participants are very, very complex and the system's health depends upon the health of all components.

Maybe in the future, if we are successful in improving the view of the industry, and we are able to improve the profitability of the silicon manufacturing industry, maybe we will speak in random order. Thank you very much for your attention.

Panel Questions and Answers:

Moderator: As everybody was speaking, I saw two key things that are needed for the next five years: One was people. The people resources. One was capital; we need capital. The silicon end of the food, the ecosystem - he's got me going - is not profitable enough by the numbers to invest any more then they already are. I think that where that capital comes from is a big, big question mark.

We heard about partnerships. Is there going to be a sharing of capital? Does anybody envision the sharing of capital and the sharing of people in the working together to meet the requirements, to build the capacity? Does anybody see that?

Panelist: I definitely see a sharing of capital. I think our company - for example - has established joint ventures. We have a joint venture in Korea with Samsung as a partner, and we have just recently established a joint venture with Texas Instruments. I believe that new models will be developed as we go into the future. They have to be in order to accommodate the growth that is desired.

Moderator: Do you share that from the semiconductor side? Do you think that needs to be part of the equation as far as capital sharing?

Panelist: From my point of view I think that the main thing that is going on today is a sort of partnering. As people go after opportunities or growth they will work much closer together, all the way down to the project level. There will be new players coming in or different kinds of funding situations put together. I don't envision governments funding heavily or the large buy out of one company over others. I think that won't happen so much as there will be a pooling of resources around projects.

Panelist: I would like to make a couple of comments. One is I am really sympathetic to Roger's point; that is in this food chain someone - like us who are in the packaging far end of it, assembly and test - often we are neglected and really try to squeeze even 1/10 of a penny out of it. What happens is if we do not sustain ourselves, we cannot invest for the next generation of packages. That's what really is happening. I hope that through this sort of a meeting we come to realize and support; and I heard the same story a few years ago from Scott Toulett of K&S; almost went out of business. A few years ago if we hadn't supported him, I think K&S may have gone out of business at the time. Today they are doing very well, of course, but he was appealing to the investors for support.

The second comment I would like to make is I think it's already happening, partnerships are happening in some ways. The TI/ACER situation is one, and I think more of these will happen, provided industry leaders' egos will get controlled. I think once we do that, I think we can together. Even assembly - as you saw it - just to meet the demand we might have to invest anywhere from $10 to $14 billion dollars. It's a small sum from the FAB point of view, but in the food-chain-end of us is a significant amount of money.

Panelist: I think I would add that in view of the worldwide shortage, you see there is probably an extra five years or even beyond of some measures to keep up with the supply. Looking at just Taiwan as a case, you see we have only a few big ones. Those are just reaching $2 billion in sales last year. They are growing to $2 billion dollars this year, and they are putting at least one or two new million dollar FABs. About six $1 billion dollar D-RAM factories are either under construction or being planned. All together it is probably like Dr. Shih mentioned this morning, it is about 12 to 18 total. Some of it may be just underplanning. It might not be realized.

At least 10 to 12 will be realized. You see that worldwide in this space of time, what we need at least 160 FABs. Of course Taiwan is standing in a good position, because we have almost $95 billion dollar foreign reserve.

We are seeing even in Thailand there is a company called Alphatec. It is the first company in Thailand to get into the FAB. Singapore is expanding its foundry business. Certainly Japan will continue the leadership in memories.

Moderator: I think I would agree with you that a couple of years ago we were probably asking where is everybody going to come up with the money to build the billion dollar FAB, and I don't think that question is an issue anymore. I think there are a lot of them out since that has happened.

Do we have a question from the audience yet?

Question: I have a question for Dr. Wang: What you showed in your slide of production by linewidth has major impact in production of next generation D-RAM, 64 Mbit D-RAM requires less than .35 micron linewidths to be able to produce in a cost effective way. How difficult is it to produce equipment or FAB equipment to produce less than .35 micron geometries; and if it's very difficult, does it have a major impact in the price crossover of 16 and 64 MEG. Will it delay until after the year 2000? What is your thinking of the cost impact of the FAB equipment at less than .35 microns?

Panelist: The .35 micron and above accounts for more than 95% of the devices generated in the year 2000. The 64 megabyte typically is .35 microns. 64 megabyte production should be in the period of 1998. Therefore from 1998, will be some 256 megabyte production; but it's still a very small amount.

In terms of the equipment, today we believe is a transition of above .35 microns to .35 micron and below. The equipment providerd in the next few years should be able to carry all the way to the end of the century, except some 200 millimeter equipment we will need to make. When we make 300 millimeter equipment, these will become a production tool for the one gigabit, maybe in 2005. Therefore the equipment to master carry not only 300 millimeter, but also has to be a .18 micron equipment technology.

Therefore I believe that if you don't go into a 300 millimeter from now to the end of the century, the equipment cost will not really change much. Also I believe any other equipment company also shares the same idea; our effort is doing a continuous improvement to increase the capital productivity to lower the cost to consumer, to increase the reliability and out time; all of those issues.

Moderator: Do we have another question?

Question: Yes, my question is addressed to Mr. McDaniel: Do you think with existing capacity of polysilicon as well as polysilicon wafers, is it enough to support a Dataquest forecast of about $185 billion dollars of semiconductor production in 1996, as well as about $330 billion dollars a year in the year 2000? If not, what's your plan?

Panelist: I don't think that the installed capacity is adequate, but a number of companies - including our own - have announced expansion plans. When we look at all of the expansion plans that have been announced, I think that there still is a slight shortfall when you look out beyond 1997. There will have to be further announcements.

Question: So you think 1996 is pretty much covered?

Answer: No, I think with capacity that is probably going to be coming on, I believe 1996 will be covered. It's very, very tight. I can tell you that. It's extremely tight. Plants do have to come on as planned and the capacity has to be brought up quickly.

We have a plant - for example - that's coming on in the first quarter in Taiwan and a number of expansions in our other plants. In order to cover 1996, it has to work. The same is true of all of our competitors.

Question: I wanted to ask a question to the group in general: Where do you think the factories are going to be built? Does it make sense to have them closer to the customer or closer to the rest of the manufacturing operation?

Moderator: Maybe James, you can start.

Panelist: We have our locations in Korea and also in the Philippines. We have looked at still other locations such as Viet Nam and China, but have yet to come in. There are many reasons why, but I don't think this is the appropriate place.

However, we are also building a model right now and testing by simulation on the computer whether - as this morning as somebody mentioned - the manufacturing environment in the U.S. is definitely improving, in my opinion. We are very seriously looking at setting up some specialized new packages to be done in the U.S. We even selected a site in Phoenix. However, whether we will actually do it or not depends on some other further study; but we are very close to making that decision. Again, their partners should be the important influencers. For some of our end users cycle time is critical and so on. I believe jointly we might be able to start out early. Just on our own, maybe quite further field studies.

Question: Where do you think is the best location for FABs?

Panelist: Well, we traditionally have built our FABs in the United States. We do have one in Israel now and one in Ireland. I think we will continue to move out of this country for FABs, but we will also continue to use this country.

It depends on the infrastructure and how competitive it is, as well as how serviceable it is for us in those countries and in other countries and how accommodating those countries are to our needs. Then, of course, there is the issue of the people and the quality of the work force that we depend on. FABs have become a highly technical area for us. We have to weigh all of those factors.

I think it's a competitive environment. The countries are competing for that and some of them are coming up with some quite good alternatives.

Panelist: I think the manufacturers, I agree with most of our speakers. Where are the capitals? Where is the market? Where are the people? I believe we're still in the developing area like Asia Pacific, if you take Thailand or Malaysia, those areas; southeast Asia. The government may get involved in order to develop electronic business and electronic industry. They want to have the FAB layer.

One example: About two months ago I was in Malaysia. The government, because they have very strong back end operations, they are talking about to the year 2000 they want to see ten FABs. They feel it's very aggressive, but they feel very confident they may be able to get five FABs. They provide land. They provide some tax free exemptions; those kinds of things.

Certainly the technical resources are important and the cost. I guess today it's very difficult for people to say I'm going to Japan to build some FABs, because Japan is coming out. We are seeing the capital the Japanese spend more and more outside of Japan.

You are seeing that Korea is going to Oregon or Austin, U.S., so it's become U.S. still the best place to making FABs, even in terms of costs and the competition, the infrastructure, everything. The market is in Asia Pacific, so sooner or later that area must grow.

China, who is already seeing many joint ventures there; Motorola announced $1 billion dollar investment from 1996 to 1998 in China. People are going to follow. You see paging in China. China may take another five years.

However, from all the surveys, it seems like in the year 2000, the capital spending distribution in Asia Pacific, including Korea, is the largest, 35%. In North America it's about 33%. Japan dropped to about 20% to 25%. The momentum is going to that area. I believe that China, Southeast Asia, Taiwan, will be the future five years of the FAB.

Question: We heard them talk this morning about the NAFTA growing to be the western hemisphere, and we historically haven't put anything south of the Texas border, the Arizona border, in terms of building semiconductors and all. With NAFTA and with this growth that we see, and also because of the virgin territory and the wanting to grow industry in Latin America, is anybody thinking about starting to build FABs down there? I was down in Brazil recently and there is a big movement to try and get on the technology band wagon in Brazil; but I don't ever hear anybody mention it. It seemed like our entire focus is on that side of the Pacific, rather than back on this side of the Pacific. Does anybody care to comment on that?

Panelist: I agree with you.

Panelist: Brazil and Mexico are growing in the PC market. Just like yourself, we still want to grow the FABs. Of course, in the future we either see the United States or some other location in Southeast Asia. Of course the one reason is their being so far. Another reason is the language over there is supposedly a Spanish speaking country, so that is probably a real handicap.

Panelist: I would just like to add a comment. What typically happens and how we see new regions develop is that they have the electronics system manufacturing happen first, followed by the test assembly, followed by the front end. That's really the place to look first to develop the manufacturing infrastructure for electronics.

This page is intentionally left blank

Chapter Thirteen: WELCOME ADDRESS

Joe Grenier
Vice President, Semiconductor Device and Applications Group
Dataquest Incorporated

(Slides not available at printing)

Good morning. My name is Joe Grenier, and I am the Manager of the Memory Micro ASIC and Semiconductor Application Research Teams at Dataquest.

Yesterday we spent the whole day talking about a $300 billion dollar market and some of the applications that are going to drive it there. Today we are going to spend the bulk of our time talking about more major applications that are going to get us to $300 billion.

Before we do, I'd like to digress for a few minutes and talk about some of the little known, more interesting applications of semiconductors. The purpose of this talk is to indicate to you the continuing pervasion of electronics in our lives; and to show you that really it's only a matter of creativity which prevents further pervasiveness of electronics in our lives.

I'd also like to point out that some of these applications may seem trivial today in their individuality, but collectively they are going to help very much in reaching that $300 billion dollar market.

This slide, courtesy of Motorola, shows their view of the microcontroller market by the year 2000. By then Motorola expects 222 MCUs to be found in the home, 35 in the car, 42 in the office and four on our person. Motorola lists some of the applications there. I would like to offer up some more examples that do not just include microcontrollers.

You have probably heard of the V-chip or violence chip. The Zylog 16 bit DSP TV control-and-on-screen display chip now has the recommended TV program rating, decoding and control system. This chip can decode the broadcast program, compare it to the viewer's standard, and then block the program if required. Viewers need to enter a password to unblock the program.

The big issues here however are not technological. For instance: Who determines a program rating? Also some believe this is a violation of free speech. Lastly: How secure are the passwords from children figuring them out? Nevertheless, Zylog believes we may see a V-chip in TVs in a year or so.

I personally think that Zylog could make a bundle with an F-chip or a football chip that would block weekend football games. Only the lady of the house would have the password. You can imagine the domestic deals that would be made under this scenario.

How about a model train with an intelligent wireless control system that eliminates the wiring and switching of conventional train layouts? Here's how it works: Shown here is a hand held remote control unit. Commands such as the throttle setting, which is a red knob, are digitally transmitted on 27 megahertz RF to a base unit in the train layout. The base unit receives the signal and then modulates a low frequency RF signal to communicate with every train, switch or accessory in the layout, using the track as an antenna. The base unit also provides the necessary collision avoidance and arbitration between contending transmissions from the handheld unit. Individually addressable receiver modules in each train demodulate the base unit RF signal to control the speed and direction of the train's motors, the operation of lights, couplers and other features of the train.

A sound module, called Railsounds, provides 12 bit, digital audio playback for up to six channels simultaneously for an almost unlimited accommodation of effects. The sounds are digitally recorded from real trains, stored in a two megabyte EPROM, and played back through acoustically balanced speakers in the model trains for startling lifelike sound reproduction.

Each of the four units discussed, the handheld unit, the base unit, the receiver module and the sound module, all contain Microchip Technology MCUs. The system was developed for Lionel, who used to be the world's largest toy company. It was developed by Liontech, a developmental company co-founded by Neil Young, the musician. The system will soon be available at a price between $1,000.00 and $1,500.00.

I forgot to mention that this system is entirely and fully controllable from a PC. This is a fairly expensive toy.

When I was a kid I always wanted a train, but never got one. Now as an adult and at these prices, I'll still never be able to get one. Some things in life we never seem to catch up to. However, there's probably going to be a pretty good market for these trains. After the man of the house gets his football game blocked by the F-chip, he'll just have to go play with his trains.

Microchip Technology has provided some other unique MCU applications: A portable EKG monitor. This is a small, battery powered EKG monitor worn by a heart patient during his normal activities at home or in the office. When the patient feels chest pain, he presses a button, which stores the preceding 30 seconds of EKG data, as well as the following 60 seconds. They the unit is attached to a phone and the 90 seconds of EKG data is sent to a remote doctor or hospital for analysis.

Another interesting use is the agriculture field monitoring units, small nail-like rods are stuck in the field at appropriate intervals. Each rod contains a moisture sensor that sends its data through a small RF transmitter to a data collection site at the edge of the field. The purpose of this system is to allow farmers to maximize crop yields through efficient watering.

If you can't watch football and you don't want to play with your trains, you can always go play golf. This is Smartscore. This is a product that is really appropriate to talk about at the resort here. This is the first voice controlled golf score keeping system. This handheld device, which is in reality a single function PDA, is manufactured by Trillium. It contains, along with MCUs, a DSP Communications voice recognition chip.

Golfers tell Smartscore the results after each hole, and Smartscore instantly displays gross score, the net score - taking into account each golfer's handicap - and the number of putts. As golfers step up to a tee, they press a button and Smartscore announces and displays the hole number, yardage, the foursome score and tee-off order. It will also call golfers by first name or initials and it can store up to 200 names.

It is a sophisticated score keeper. It performs stroke scoring, match scoring, skin scoring, and will save the scores for up to 200 games. It can analyze previous scores by course or by opponent. It can perform statistical analysis like driving accuracy, greens in regulation, average putts per round and sand saves. It can also communicate with your home PC for more sophisticated trend analysis.

Smartscore contains a course encyclopedia, stored in a two megabyte PCMCIA card, which contains detailed information on over 6,000 U.S. golf courses. Included are each hole's yardage, the par, and handicap order for men, ladies and champion chip tee's, and the USGA course rating and slope rating.

For instance: For the course here at the Marriott - which is included in Smartscore the blue, white and red tee's are included. Ultimately all 13,000 U.S. golf courses will be included.

It is trained to recognize each owner's voice. Now psychologists tell us that when people lie their voice changes subtly. I wonder if Smartscore will be able to detect a golfer who makes an error on his score and be able to reject the golfer's input based on subtle voice changes.

I caddied for many years at a champion golf course in Michigan, and I know golfers sometimes have lapses of memory on a particularly bad hole. Maybe that's a feature for the next generation Smartscore.

Incidentally, outside I placed data sheets on the Smartscore. I think this would make somebody a wonderful Christmas present. By the way, it's $295.00, and they start delivering them December 1st. I would have had one to show you, but they only have prototypes right now.

Besides Smartscore, DSP Communications voice recognition chips are used in several other products. For instance: They have shipped tens of thousands of voice recognition chips to Japan for use in the Kenwood CPS, Car Navigation System, which responds to voice commands. Another product is a voice dialer for cellular phones. Did you know that car accidents go up by a factor of two when using cellular phones?

Another product for their chip is the Interpreter 6000, which is a voice recognition system for the financial community, manufactured by Ficomp Corporation. The Interpreter 6000 is now being used by traders on the trading floor of Bear Stearns to directly enter order into the computer by voice command. The trader speaks the order in a normal voice, and the order then appears on the computer screen for instant verification.

The system recognizes only the voice of the active trader, and eliminates background noise and high voice level conversations through noise suppression.

We will see a lot more products using voice recognition shortly. For example: Home appliance and toys that respond to voice commands. The voice command of a car's audio system. Voice passwords for the home or auto are either here now or will be here shortly.

Arkenstone is a non-profit organization dedicated to developing high technology products for the blind, dyslexic, and visually impaired individuals. One of their products is Strider, which is an orientation tool for the blind which uses a small global positioning system satellite receiver, combined into a talking laptop computer.

(Start videotape Maps):

When you are visually impaired and can't read a map, finding your way from someplace familiar to someplace you've never been before can be really challenging. Even verbal directions are often based on visual cues.

Go left at the light, then two blocks past the school. Turn right towards the hills. After the speed limit sign then go north three blocks past the third street.

Atlas Speaks is Arkenstone's talking map, designed to be used on a standard PC, with a speech synthesizer or Braille display. With Atlas Speaks, you can explore your own neighborhood, or you can find your way around a new city.

Once you get the directions you need, you can print them out on a Braille printer, enter them into your Braille speak, or even use a tape recorder, or you can use Strider, our portable talking map. Strider is Atlas Speaks software, loaded onto a talking notebook computer. It has an earphone and a keypad, which allow you to communicate with Strider. Slip it into a backpack or a carrying case and you're off.

Strider has one important difference: Strider uses a global positioning system to constantly monitor my current location and to help me find where I am going.

This is Mark May, Arkenstone's VP of sales. Mark has his dog, Josh, and his Strider. This is what he hears as he walks.

DTPS satellite reception is excellent.

Using information from satellites developed by the U.S. Department of Defense, Strider actually knows Mike's location at all times. If Mike tells Strider his desired destination, Strider will actually help him find it.

Left turn right here at 3:00.

(End Tape)

There is an article in U.S. Today which may already make this product obsolete, and it's just hitting the market. The article is on computer chips and the eye; it may give sight to the blind. Technology moves on.

Arkenstone's main products are sophisticated reading tools for the visually impaired, using text scanners, speech synthesizers, software, Braille printers, and PCs. They have shipped thousands of units all over the world.

They have their own PC called Arkenclone. Arkenclone was made possible by a $1.5 million dollar donation by Intel of 486's and Pentiums. Due to the nature of Arkenstone's nonprofit charter and the donation, these PCs are only available to people with disabilities.

Now you might ask how is a visually impaired person going to see the Intel Inside label? Intel came up with a solution. This is a Braille Intel Inside label for the Arkenclone computer. It says Intel Inside in Braille and Pentium Processor in Braille. How do you beat a company like that that pays such attention to details? I know Intel lawyers were quite a bit involved with this.

I mentioned that Arkenstone is a nonprofit organization whose mission is to increase access to information for the blind. If you have anything to donate, Jim Fhruckterman, their President & CEO, will be happy to talk to you. Jim tells me he needs SIMM modules (who doesn't), as their systems are voracious users of memory.

Trimble Navigation provides the GPS receiver used in the Strider product on a PCMCIA card configuration. Trimble also provides a small GPS receiver, which can plug into the serial port of your laptop computer, shown here as the PCMCIA card.

They also have Scoutmaster, a handheld GPS receiver, which is small enough to put in a pocket.

Besides these mobile applications, Trimble's GPS systems are used in long haul trucking and shipping, commercial dispatch and cab companies companies. So does a Russian bank that wants to keep track of its 20 armored vehicles. The bank plans expansion to 300 vehicles. Does that tell us something about the Russian economy?

Public safety is another area. The Phoenix Fire Department, the Denver Regional Transit District, Chicago 911 and Boston Paramedics all use GPS.

Another application is heavy equipment; such as machine guidance. Shovels and loaders are guided to precise design grades. Graders do their job quicker and allow centimeter level precision.

How about an aerial guidance system that allows one to three meter accuracy for application of agricultural materials?

GPS is even installed in the golf carts here at the Marriott; however, I really don't understand this application. If you need a GPS system to find your ball, my suggestion is you stick to playing with your trains or negotiate the F-chip password from whoever has it.

My last application is the Raven, a human powered airplane. Raven's goal is to set a new world record of 100 miles of human powered flight.

(Start Tape: The Raven. In native American mythology it's a spirited bird. It's long been a tradition to name human powered airplanes after birds, and so the Raven. An airplane that will be flown by a team of undergraduate students and industry professionals. An airplane that will set four new world records in distance and duration for human powered flight.

The Raven is the first project of the Puget Sound Industry and Undergraduate Studies Research Program, working in cooperation with Seattle's Museum of Flight. The program's mission: Enhance undergraduate education by fostering communication between students and industry professionals.

We are also looking to enhance the undergraduate experience, give the undergraduates a chance to actually get out into the industry before they graduate. They need hands on experience, and this is hands on experience. It gives them a way to meet professionals. We have over 30 businesses represented in our professional class. The students can meet all of those professionals. They can talk to them about their businesses, what they do and what they're working on.

To meet this goal, students and professionals are working side by side, volunteering to design, construct and eventually fly the Raven, an airplane that began as a one man project for Paul Ilian.

I have been involved with human power flight since about 1980. It represents getting the most out of the human and out of technology.

The Raven is designed to be a long distance, high performance, human powered airplane. We want to make the kind of performance that we can fly at 100 miles.

End Tape

The specifications of the Raven are the power plant: 140 pound human, 1/4 horse power. The weight of the aircraft that you saw in the tape is 75 pounds. Take off weight is 275 pounds. Fuel capacity: 14 pounds of water and a peanut butter sandwich. Wing span: 115 feet. That's 11 feet longer than a Boeing 737. Cruise altitude: 18 1/2 feet. Cruise speed: 20 miles per hour. It can traverse a path of 100 miles over the water, down through Puget Sound. The planned date to set the record is sometime in 1997.

This a very sophisticated airplane, employing a microprocessor controlled variable pitch system for the propeller, and an all electronic autopilot system that gathers data from sensors and offloads the aircraft's tricky handling system to the autopilot, allowing the pilot to totally concentrate on pedaling. All he has to do is just pedal for five hours.

The Raven is a four year project being developed by the Puget Sound Industry and Undergraduate Study's Research Program. This is another non-profit organization. They need another $300,000.00 to complete the program by 1997.

That's enough of unusual applications. Now we can get back to the more serious and bigger drivers.

Chapter Fourteen: ACHIEVING 0.1 MICRON TECHNOLOGY: WHAT WILL IT TAKE?

Jim Owens
Chief Operating Officer
SEMATECH Inc.

Introduction: Our first speaker will be Jim Owens from SEMATECH. He is Chief Operating Officer. He joined SEMATECH in 1994. He is responsible for the consortium's research and development programs, including technical operation at its Houston based facility, and the joint development and equipment improvement programs with the U.S. suppliers.

Prior to SEMATECH, Mr. Owens served in numerous upper management positions at National Semiconductor, including analog operations, corporate quality, strategic operations, worldwide advance technology and manufacturing operations and technology. Please welcome Jim Owens, who will tell us about the challenges of getting .10 micron technology.

Jim Owens: Good morning. I don't know who in Dataquest ever dreamed up this topic for this particular conference here, or exactly what they expected me to talk about in terms of the .10 micron; but I'm really glad that they did and that they invited me to come and speak about it.

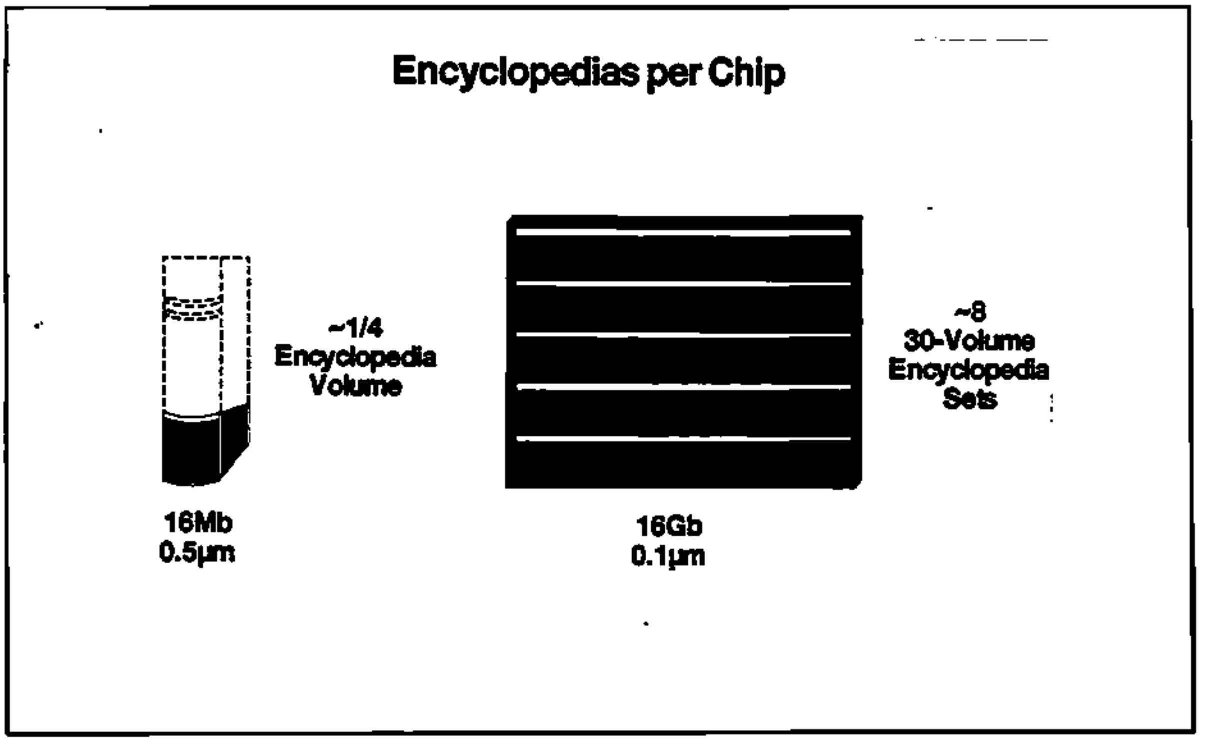
First of all, it gives me a chance to talk about the future instead of the present, instead of having to deal with reality. Second: I really like talking about the future, especially the future that is so far away out there that nobody really cares too much about it. By the time we get there, if anything that I predict and say doesn't really happen, none of you out there are going to remember it anyway. If for some reason some of the stuff I predict does come about, I hope somebody out there does remember and gives me a little bit of credit for it. If you don't, then I'll try to remind you whenever the time comes.

Anybody that is expecting a really highly technical presentation today is going to very disappointed. First of all, it would probably take a two or three day symposium of the brainiest people that we have in the world to try to figure out what's really going to happen in .10 micron. Even after those two or three days, I would guarantee you that whatever they predict isn't going to happen.

Second of all, I found out years ago that I wasn't very good at doing those highly technical predictions; especially when my boss came in one time and said you understand now why I couldn't do those partial differential equations correctly because I couldn't even meet my budget, where all I had to do was simple adding and subtracting.

There are a lot of other items that really need to be addressed in terms of meeting .10 micron. It's not all just a technical challenge. I am going to mention a few other things in terms of the timing that's required, as well as money and as well as people.

Before we get into the details there, I think it might make sense to take a look at what really is .10 micron anyway? One way of looking at it, trying to relate to what people can relate to pretty easily, is taking a look at an encyclopedia. Today if you go down to a computer store, you can now buy a 16 megabit D-RAM for your computer, if you really want to. What that amounts to is you can put about 1/4 of the book from an encyclopedia into a chip about the size of my thumbnail.



What .10 micron represents though is a 16 gigabit device, 16 billion bits of information. With that you could probably put about eight complete volumes of an Encyclopedia Britannica onto a chip. They will end up being a little bit bigger than my thumbnail. There is a lot of information that goes in there.

Whenever I'm talking about this, there's not going to be any pretty pictures in that encyclopedia. This is just words. There are no pictures to go along with that. It's really phenomenal to think that we will be able to put that much information into a single chip.

From a timing point of view and when is this going to happen, what I've done is I've gone back and pulled out the national technology road map. What you see here in the left hand side is 1995, and what is going on today. Again, there at the top what you'll see is that you can go down to your local computer store and get a 16 megabit today.

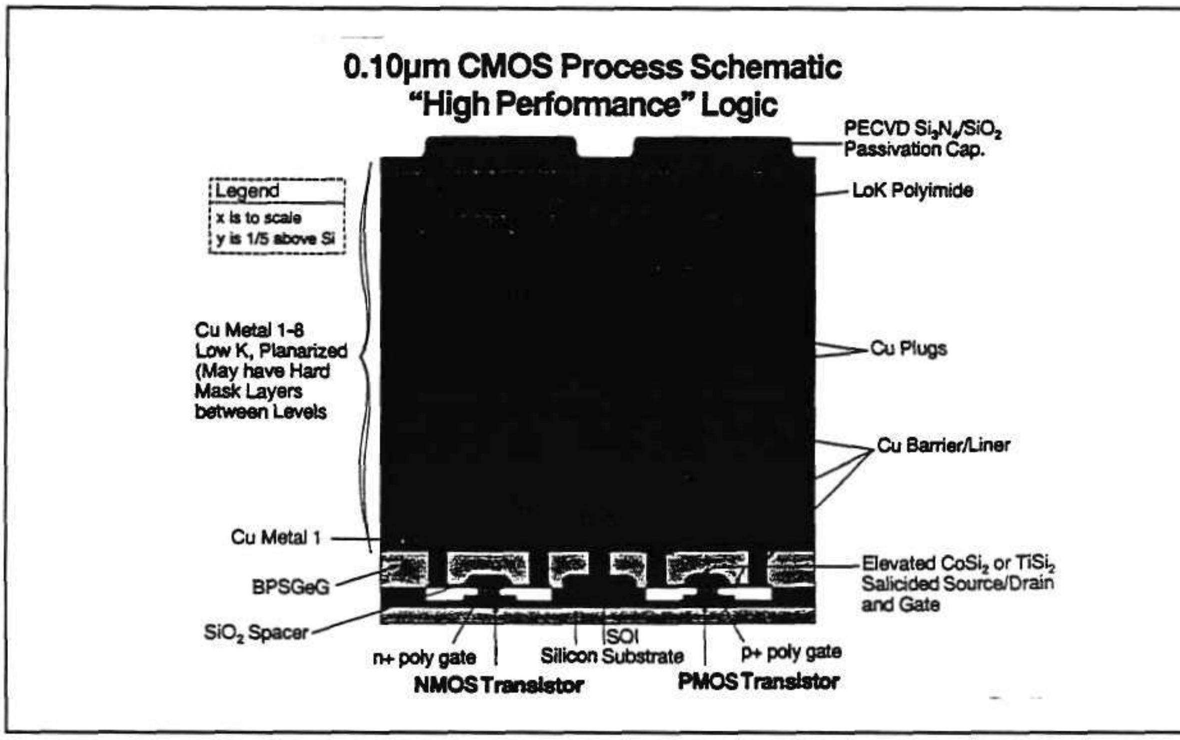
What's happening in the development side, out in the R&D labs, is going on at 1/4 micron. There are working 256 megabit chips today in the R&D labs. There are working other types of products such as Gate arrays and microprocessors that are using 1/4 micron technologies. They are not in the production mode. They won't be for a few more years. Technology wise they exist today.

Where does .10 micron come in? If we basically stay in Moore's Law and everything keeps moving every three years, this says we are out to the year 2010, before you can go out to the local computer store and buy this technology. You'll be able to buy the technology and some high end applications about some three years before that. About six years before that is when the actual process development and product development will start taking place. This is true development - not research - but development science. That's around the year 2004.

If you take a look at that then, that means it's only about eight years away from today before the R&D labs really start trying to develop a production type of process that they are going to use a few years later in production. From a basic research point of view, such as some of the interconnect issues and lithography issues that we are going to face in order to get down to .10 micron, that research needs to start now. In fact, a little bit of it has already been started.

The engineering is full of challenges. It would take several days and a lot of highly technical presentations that I personally don't think that I would like to sit through. I am going to try to hit a couple of the high points in terms of what is it going to take in order for us to get down to .10 micron.

The best way to do it is to take a look at a cross-section of a potential .10 micron device. The first thing you ought to notice here is that basically all you see is interconnectors. Most devices will probably end up with anywhere from four layers of metal up to eight layers of metal.



A couple things I want to point out here: This is the interconnect, which is where you see the predominance of what is going to be going on. This little area right down here is where all of the electrical activity really takes place. These are the transistors. Here is your NMOS transistor and your PMOS transistor.

A couple things on this: One is showing that we'll definitely be using SOI technology out here in the future. SOI technology has been around for years and years. People keep predicting that it's going to be used and it's never happened. I think that with some of the more recent advances, and the fact that everything is now so much smaller, that SOI will finally reach the place where it can be used in production and daily production on normal type products that you buy.

You'll also notice that the elevated source and drains here are gates, so they are actually sitting here on top of the silicon. Although I've got here copper listed in terms of plugs and metal, etc., I'll talk a little bit more about that. Right now you should look at that as metal layers.

From a cross-sectional point of view, the thing to remember is that it seems to be interconnected predominant. In fact even today that's true. A lot of the hard work that's going on in the development labs, as well as fighting yield problems out there in production line, is related to the interconnect much more so than what's down there in the silicon.

This little tiny yellow line here that barely shows up is where all of your electrical activity occurs. This really shows that it's all interconnected. All we are trying to talk about is trying to connect all of these transistors up.

To give you another idea in terms of dimensions here, is that all of your electrical activity takes place on the very, very skin of a wafer. I'm sure most of you have seen wafers. The electrical activity occurs in a very small skin of the surface. The rest of the wafer there is strictly for support so we don't break more of them than what we already do.

I'm going to talk about device functionality. I'm not going to get into a lot of technical details. What this is meant to show is the fact that in R&D labs lots of people have already made working devices down at .10 micron, and even below. These devices are very, very similar to devices that we use today. They use a lower operating voltage. There are still some reliability issues and concerns, etc. Technically we can make today MOS like devices at .10 micron and below. I don't see it as a technical problem in terms of trying to figure out how to do it. There are still lots of engineering challenges that are going to have to be worked out before we take it into production, but technically it already exists. That isn't even an issue or a concern as far as I'm concerned.

Let's go into one of the hot topics: Lithography. Lithography is always a hot topic. I've never been to a SEMATECH board meeting yet where we didn't talk about lithography. There are lots of choices out there, and let me talk a little bit about each one.

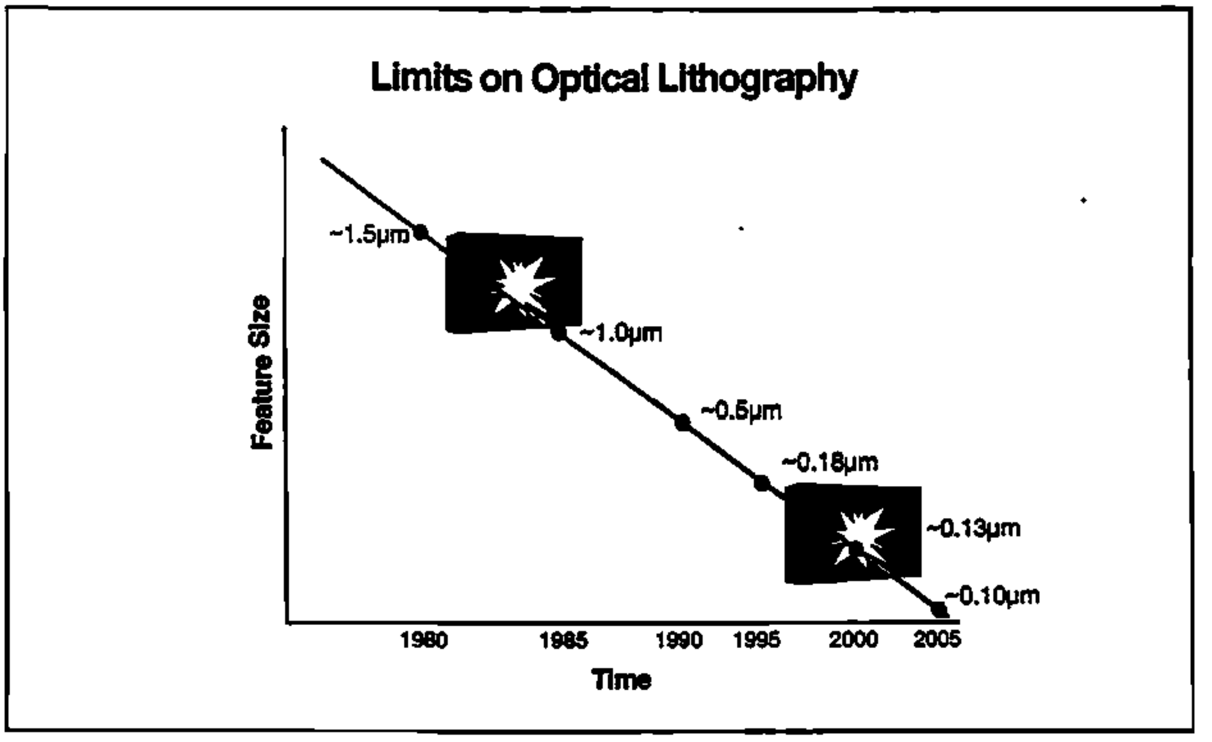
The first one up here is optical. I think everybody's familiar with that. That's what we've been using for years. The next one is x-ray. There's been millions and millions of dollars sunk into x-ray programs, here in the U.S., as well as in other places in the world. So far though nobody is really using that into production, but a lot of people think that somewhere along the line we'll have to use it.

DUV: I don't know how many people really know what DUV stands for. Raise your hands. Does anybody know what DUV is? Good, I'm glad to see that there aren't too many hands because this is really a secret code word. What it really stands for is 10x x-ray. It's a reduction process using x-ray, where as this is a 1x x-ray, this is a 10x. Because of some political issues and so forth people call it DUV's, instead of calling it a 10x x-ray.

E-beam has been around for a long time. It's used in production today at higher geometries. Technically it certainly has the potential of going down less than .10 of a micron. There are lots of issues in terms of overlay accuracy and CD controllers, etc.; but from a resolution point of view, E-beam could do the job.

Ion beam is another technique similar to E-beam, except here you are using a stream of ions in a new and direct ride onto the wafer, etc.

This doesn't show up too well, but we have a lot of brainy people and I don't know if you've ever talked to some of them, but sometimes you think all they do is live, dream and do nothing but think about semiconductors. Every now and then they do have some other thoughts going on. There is a lot that's still unknown. We are still quite a few years away before we have to put this in production and something else may occur.



Let's talk about optical lithography. That's sort of where we are today. Historically we keep predicting the demise of optical lithography. If you go back to around 1980, I remember being in discussions where a lot of the best technical people in the world said that around 1 1/2 micron is the last time we are going to be able to use optical lithography. Once we go below that, like 1 1/4 micron and certainly one micron, we're going to have to use x-ray. I think everybody knows what happened to that barrier.

It proceeded through the years, and so right now - as of about three months ago - the best brains of the world were saying we're going to be using optical down to .18 microns. There are more and more people now believing it, especially since some of the people now are starting to be able to use the 248 I-line type of lithography, even down closer to the 1/4 micron type of geometries.

Now what they are predicting is that we are going to run out of steam using optical somewhere at .18 microns. This slide actually is a little bit out of date. I'm here to predict that we are actually going to be using optical down to .10 micron. Nobody out there at this point is saying .10 micron. My lithography people at SEMATECH, when I told them I was going to say this, they didn't feel so comfortable saying that. I said they didn't have to worry about it; it was me that was going to make the prediction.

Actually, just within the last three weeks we had an industry steering committee, a lithography twig meeting, and now some of those people are actually talking about that they think they are going to be using optical .13. Just within the last three months, they've started moving down to the next generation also. I will personally be very, very surprised if at .10 micron we're not using optical.

Again, optical will run out of steam somewhere; but it's not going to be a .10 micron. It's going to be below that.

Actually we could probably do .10 optical today. There is some work that has come out of the University of New Mexico that uses interference patterns called Moray Patterns, out of a laser. By combining these laser beams, you can actually cause interference patterns that would make very, very small geometries. These geometries here are not actually a .10 micron. These are about .20, these little circles here. They also use a wave length of 488 nanometers; not 193, for example. There would be no problem at all using this exact same technique in terms of taking this down to .10 micron; and in fact none on these pictures here. They have done some work that shows .10 micron lines and spaces. Using some similar type techniques, we can probably actually use this approach in terms of making geometries down to .04, .05 microns.

This is not a production process. You use interference patterns, so you are somewhat limited in terms of some of the types of geometries that you can get. As products get more and more complex, you are going to start seeing more and more systematic patterns in those products, including microprocessors, not just D-RAMs. In certain areas you might even be able to use these types of techniques to make very, very small geometries.

Again, .10 micron will be optical. We're not that far from being able to do it, even today.

Let's go off and look at interconnect. On the interconnect side, lots of different choices: Gold, copper, silver, etc. The industry started off using gold. We still use gold, especially in some of the packaging processes, although you don't find it on the wafers very often anymore. Gold actually has the lowest resistance, which is becoming more and more of an issue because of speed and because of noise on the circuits.

That could be a possibility. Copper is certainly a possibility. There is lots of work going on today in terms of going to copper.

Optical: In the research papers you continue to see optical networks and people talking about putting them on wafers. By the year 2010, yes, you might see a few special applications, but in general it's just not practical. I don't see it as a production process in keeping low cost.

Silver is somewhere between copper and gold in some of its properties.

Aluminum, of course, is what we use today.

Just as a quick comment, I can remember eight, nine years ago people saying hey, we are going to have to quit using aluminum because we are going to have to start using copper. That hasn't happened yet either.

LDR stands for low dielectric constant. Again, this is the oxide in between all of those metals. We've got to get a lower dielectric constant material in order to keep the capacitance, the coupling between those metal lines as low as possible.

Damscene is a process in which it's sort of a reverse type of metal process versus what we use today. You cut trenches into an oxide and then put the metal in it. The reverse is cutting the metal itself.

Selected deposition: We still have 100 guy here that's trying to think of a few other items here.

What is going to happen in terms of interconnect? What are we really going to be using? I think this is much more of a crystal ball prediction. I've seen this one go back and forth quite a bit. I've seen several promising things. I've seen it fall flat in their face. the same thing has happened here that happened on optical: Everybody kept predicting the demise of aluminum, and we've been able to keep pushing that technology further and further.

I think the general consensus at this point in the industry is that by the time we get down to .10 micron, we will be using copper. That is not really clear in my own mind just because of what's happened in the past and what some of the problems and issues are with copper. We can still very well be using aluminum, even at .10 micron.

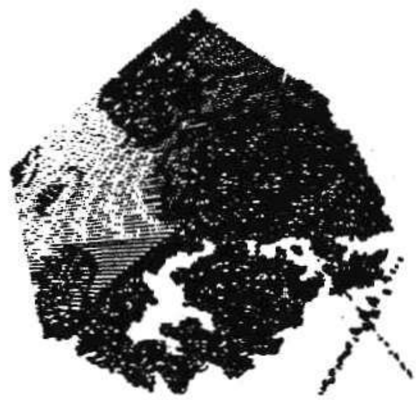
My prediction would go along the lines of it's either going to be aluminum or copper or gold or something else.

As I pointed out, and I think it was visually made very clear, interconnect really is the biggest problem. Interconnect is going to be the performance limiter. If you look at the national technology road map, you have to realize that this is only our second revision that we have now. The first one came out in 1992, and the next one came out in 1994. There were a lot of inconsistencies in the 1992 one. We cleaned up most of them in 1994, but there are still some problems with it. Especially the further out you go, the more inconsistency that we probably have in it.

In terms of interconnect, you start looking at this and you start realizing that it's not clear that where you can really do all of these at the same time. The component density that we are talking about is like 50 million logic transistors per square centimeters; a lot of transistors. You are talking about 160 watt type of processors; packages in order to handle that and trying to keep those cheap; clock frequencies of one gigahertz, which then also introduces more processes on the interconnect side in terms of how you can do that without basically it being an antenna that all of your lines are antennas radiating to each other and the other one is a receiver. There are lots of issues there. They are going to have to be worked out. All of these though really, to a large extent, are related to the interconnect issue.

The other thing this thing brings up though is that we have to do a lot better job in the future in terms of our models.

Modeling



- Need understanding and models at the atomic level

- Ion implanter into silicon
  - 11 15keV Si atoms (random) onto Si crystal

What this is, this is a picture, a model simulation of implanting 11 silicon atoms into a silicon crystal. The atoms are coming in up in this direction. You can see all of the scattering that goes on, etc.

As we start talking about these geometries, we really need to start looking at all of our models from a molecular point of view. Right now our models are all macroscopic. They assume crystalline structures, etc., etc. When we start talking about these geometries, we need to understand the atomic relationship, the interaction of one atom to the next atom, as well as the atom that is five or six atoms down there. It becomes a lot more complicated.

Computers now are starting to get to where they have the computing capability that you can actually start doing this. This particular simulation here was done in Los Alamos, on one of the most powerful computers in the world. Even so, just to do 11 atoms into silicon took them several hours to do this. Computing power continues to increase, so eventually this type of capability will be in work stations that the engineer can have on their desk. We really need to have this type of capability and some of it is starting to come along.

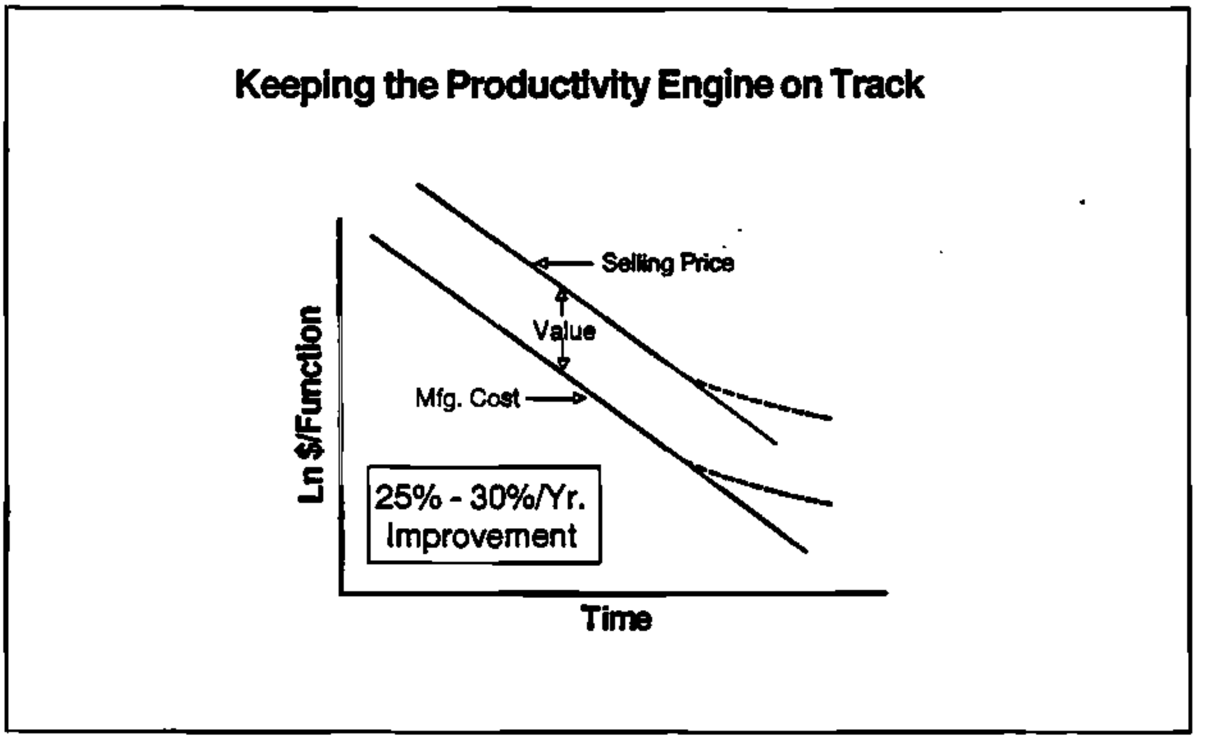
The limits right now, for example, for these computers are looking at a cube of about 1,000 atoms on the side. Still, that is a billion atoms that you are calculating all of the interaction that's going on between those.

There are lots of other engineering challenges and I don't have the time to go into them. Plus I don't know too much about quite a few of them, nor would I like to predict a lot of it.

Operating voltage is going to be around one volt, somewhere between .9 and one volt. You start getting much below that at room temperature there are some physical limits there in terms of what you can do.

There is a really interesting issue coming up in terms of design, and that is we in the industry really don't have the tools to properly take advantage of these smaller geometries that we are doing. In other words, how do you design a 50 million transistor or a 50 million microprocessor type product? It takes a lot of power. Right now to a large extent in the industry what we do is just throw more people to it. There were hundreds of people that worked on the Pentium for several years. If you start looking at it and predicting out, by the year 2010, if we don't make some improvements you are going to have thousands and thousands of people working on just designing one product.

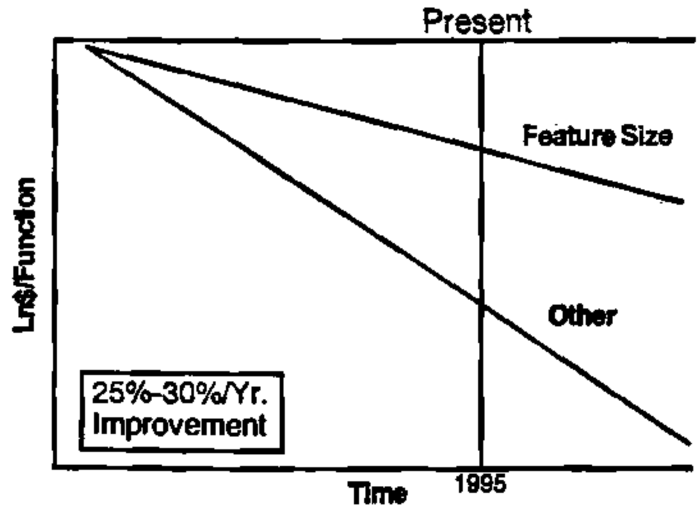
For a quick engineering summary: Technically it is going to be there. There are lots and lots of challenges. Some of them are not going to be easy, but by the time we get there and we need it, the technology will be there.



Is the money going to be there? I think that's the tougher question. Everybody who has ever heard me speak before has seen this curve. Any time I get up I always talk about the historic productivity curve. If you remember nothing else out of this whole presentation you should remember this, because it will also help you remember what else I had to say.

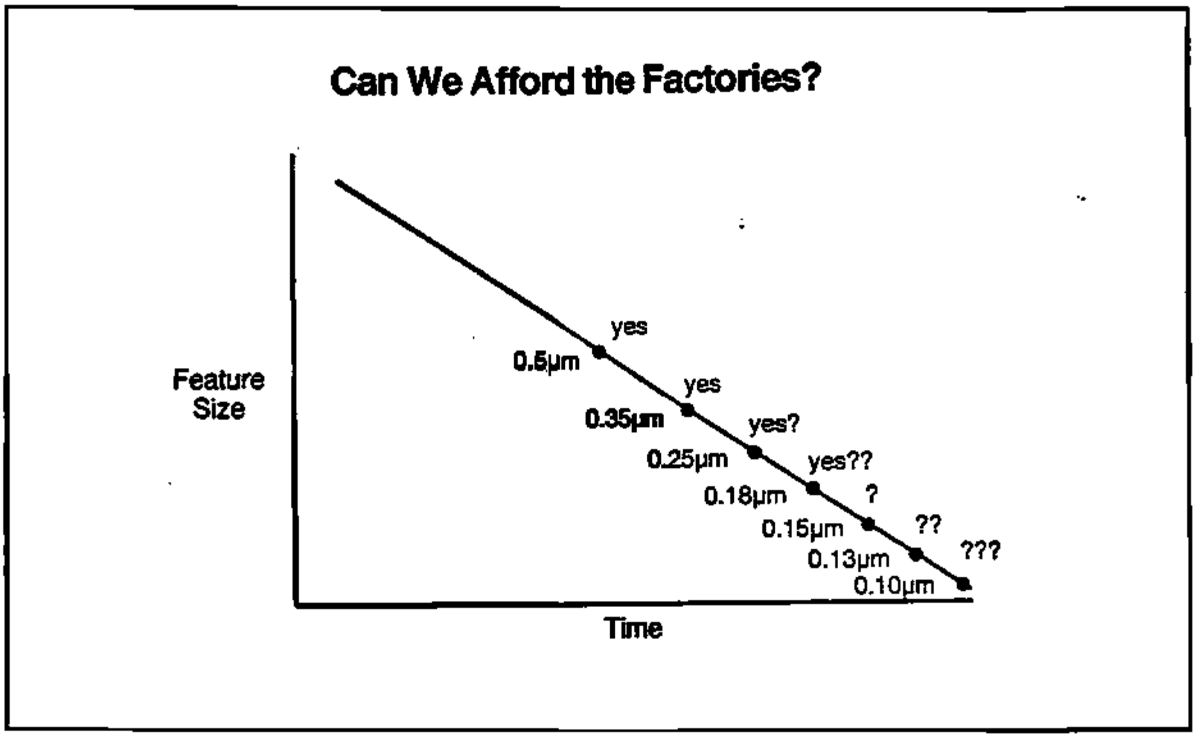
This industry has seen a 25% to 30% improvement in cost per function every single year since it existed. We all know that. We all know there is some big number out there, because we all think well, I'm not going to buy that computer today because if I want three more months I can buy that same computer for a lot less money, or using the same money I can buy a lot more power. That's all this thing here reflects.

Historical Productivity Curve

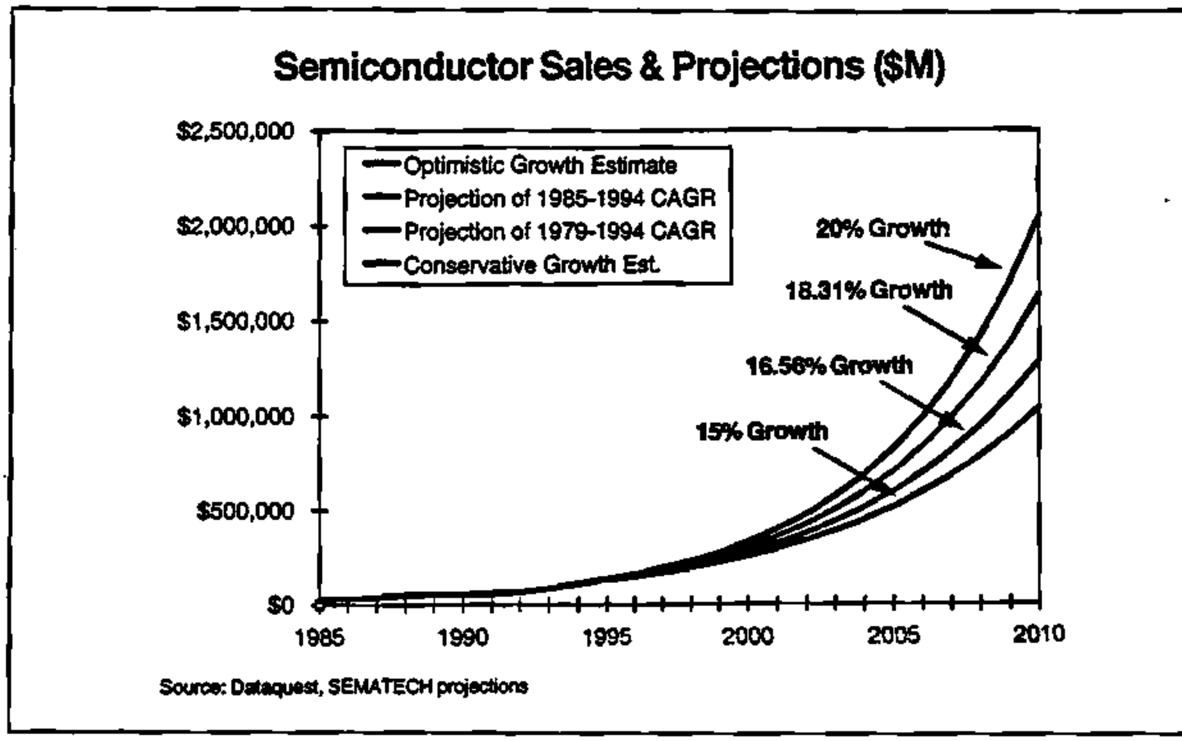


Feature size shrink is an economic necessity

Eventually this industry will come off this curve. Whenever it does, it's going to have some major impacts in terms of how this whole industry works, major financial impacts; not only in the industry, but also the U.S. and the world economy. As I said, I just outlined here that we are not likely to come off this curve because the technology is not possible, not in the next 15 years.



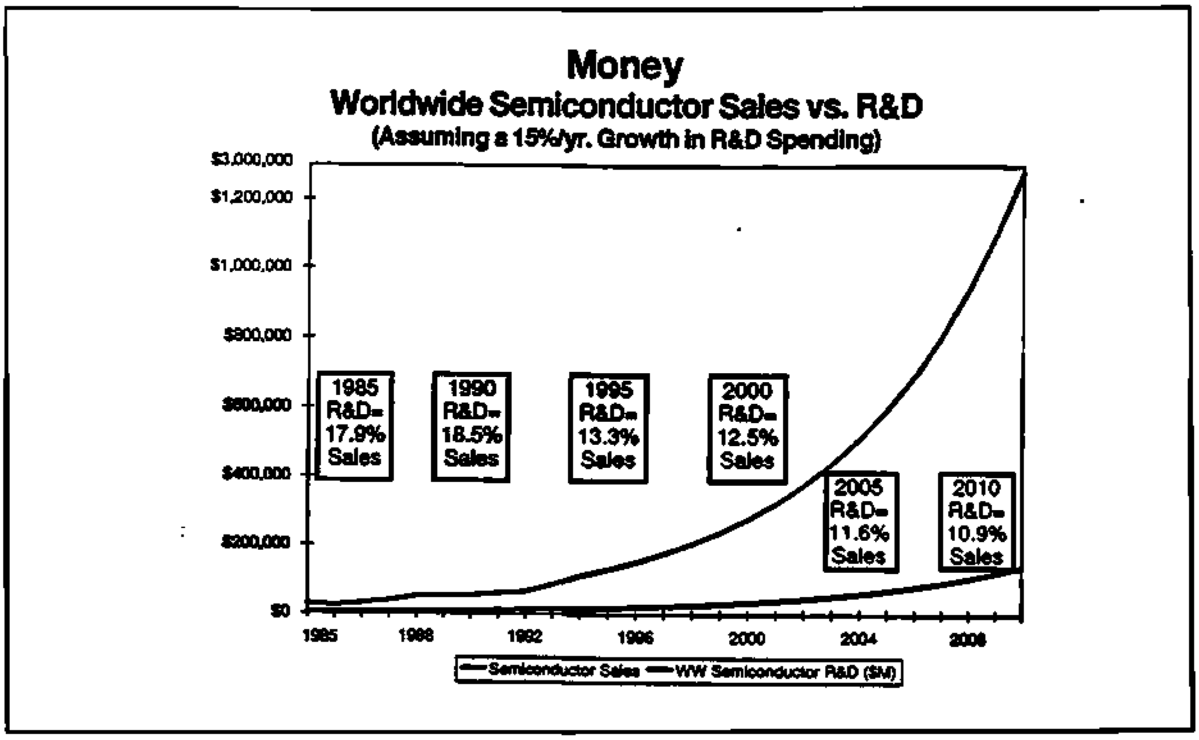
A bigger concern is do we have enough money to build the factories? Can we build those products cheap enough? Although technically it is feasible, there is still a big R&D bill in order to accomplish it.



This is the exact same curve. What I am trying to point out is that in order to stay on this curve, lithography is about half the reason we have been able to stay on that curve. There is a very, very strong driving force to continue to go down to that next smaller feature side. If we don't, we'll come off that curve pretty quick, with a lot of dire consequences. All of the companies are going to have a very, very strong push to continue to push down that geometry side.

Can we afford those factories? Obviously people are already building .5 micron and .35 microns. At SEMATECH we've done modeling, and assuming that all of the suppliers meet the tool requirements we shipped out there and sent out there for .25 microns, the answer is yes. We will stay in that curve. We just started to work at .18 microns, so we don't have any real results at this point, but we'll start having some of those numbers about nine months from now.

Basically though, based on what historically has happened, my guess is that we will have enough money to do it.



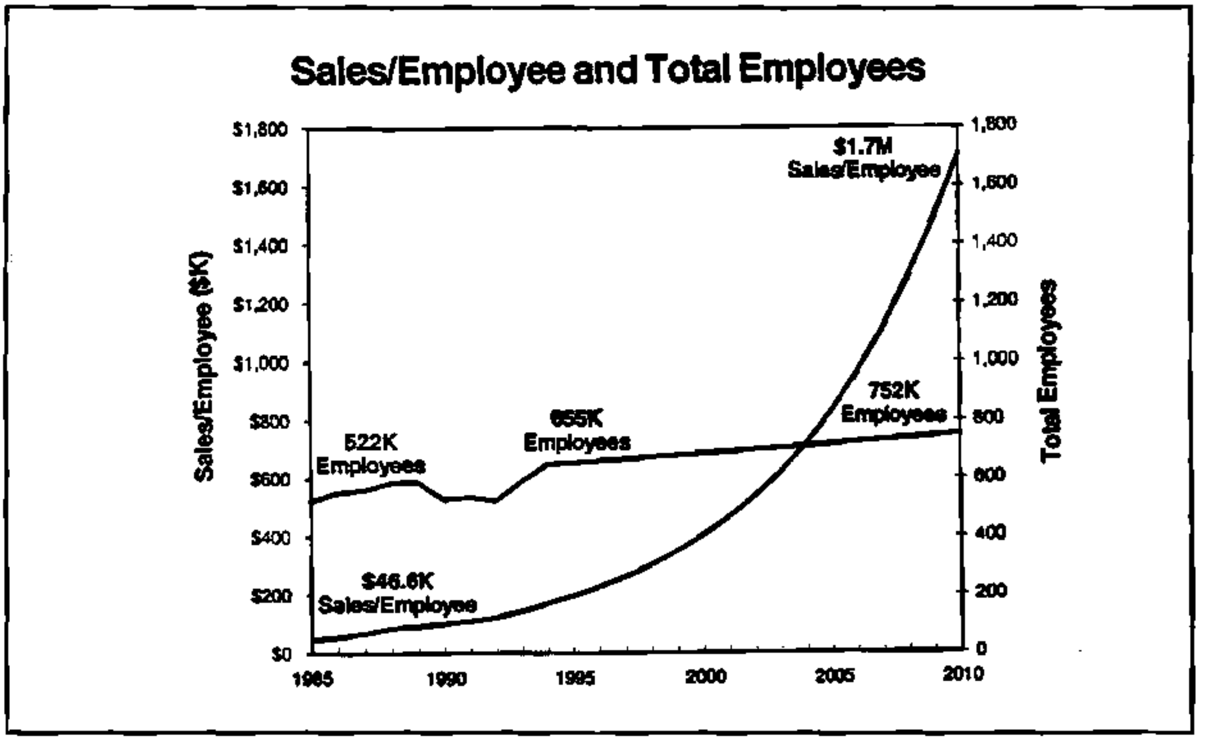
Here's the semiconductor sales and projections: Since this is Dataquest, I made sure that we used the Dataquest numbers here historically. These are different predictions. This is a very conservative prediction at 15%. The purple line here represents what the compound annual growth has been since 1979. This is for the last ten years. This is optimistic in terms of 20%, but based on what's been happening and what everybody now is predicting, that might even be the more realistic one.

You notice here a very strong growth. What that means from an R&D point of view is that since R&D is usually set as a percentage of sales, this R&D is going to go up very high also.

If you look at it also though, another thing I want to predict here is that the percent of R&D that the industry spends is going to decline. If you look at it year by year, you will see that on average it probably has been declining. By the time we get out there in 2010, it will be down there at around 10% or 11%. Even so, in terms of absolute dollars there are a lot more dollars going in. You are talking about just the R&D part of it getting close to what the total sales are today.

I think the money is going to be there. It's going to take lots of it, so it's a good thing it will be there.

The other thing is that I think you'll see a lot more free competitive working together, such as SEMATECH, JES, SRC, some things that are going on in Japan even today. I will also point out here, I've got make sure I put SEMATECH up here in a slide somewhere, otherwise they won't reimburse me whenever I go back for my expense report. I think you will see more and more people working together. Whether STU, an open consortium like this where you have lots of companies or more joint alliances then are going on now.

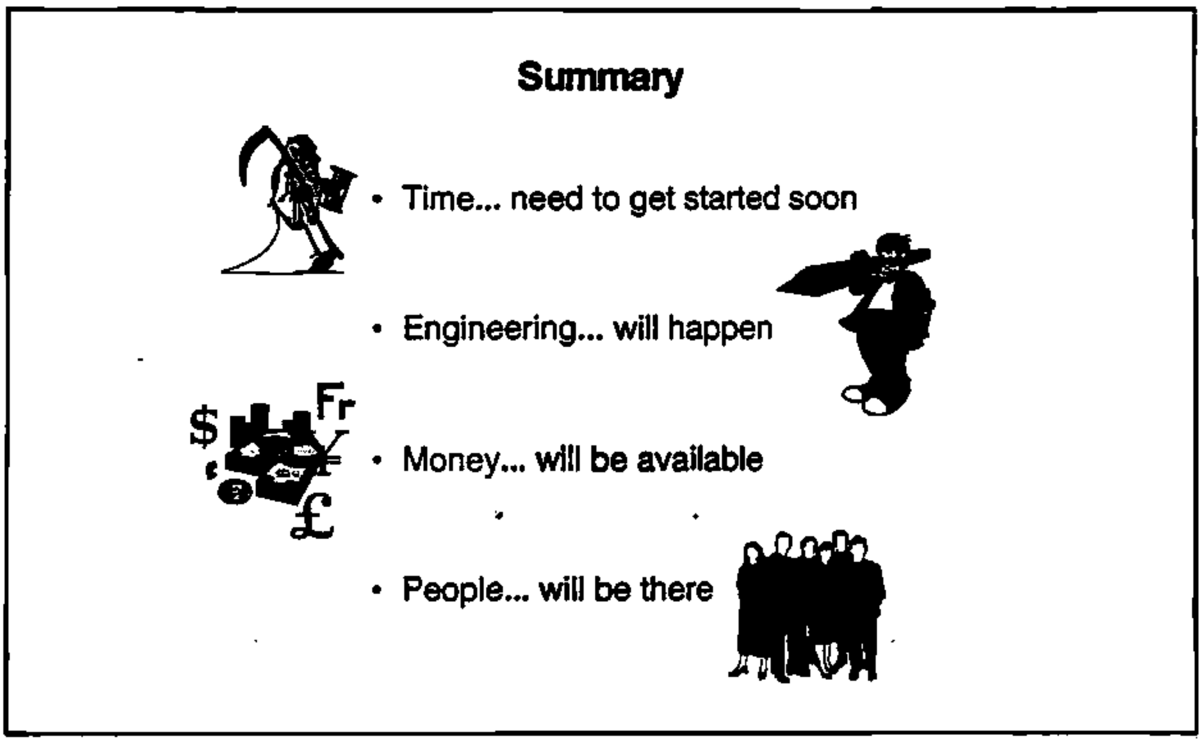


People: Right now that's a big issue. I remember companies alone that have about 13,000 openings in the U.S. alone. I don't know how many people are available, but what's happening really is a lot of musical chairs. People are wondering are we going to have enough people out there in the future?

Again, using the semiconductor sales forecast here, I'm going to use the 16.56% growth line here, since that historically has been what it's been. Then take a look at sales per employee and the number of people that it takes.

What you find is that even back in 1985, we had 522,000 employees worldwide, somewhere around that number. Today it's around 655,000. If you look at it from sales per employee, it's gone from around $47,000.00 to 1994 in the U.S. is $185,000.00. You predict that out. What it says by the year 2010, we are going to be up there to $1.5 to $2 billion dollars per employee. It seems a little bit phenomenal, but the fact is if you look at the number of employees that have happened over the last several years it's been flat. In fact, we have less employees today than what we did in 1984. 1984 seemed to be a peak. It's hard to capture all of the numbers because of a lot of contracting goes on, etc., etc. today. The accuracy is definitely questionable on this.

We haven't really increased the number of people worldwide in semiconductors over the last ten years. In fact it may be smaller, even though the sales have grown tremendously. I think what you are going to see in the future is something very similar. There is going to be a need for more employees, and there are going to be blips and there are going to be problems and times where we don't have enough people, but overall there will be enough people there.



Summarizing time: We need to get started soon. It's only eight years before we start designing products at .10 micron. The basic R&D needs to start right now.

Engineering: I think I went through there. The engineering will happen. I think the dollars will be there. There are lots of challenges, but we are already making devices in R&D labs at .10 micron and below today. Again, although there are engineering challenges, we will be able to overcome those and figure out how to put those into production.

The money will be there. The money will be there because we will be able to stay on that historical productivity curve that keeps driving this industry. It will be there for the R&D, so even though the R&D is going to cost a lot more, the total amount of R&D dollars available is going to start approaching these total sales worldwide today.

The people will be there. Although we are having a problem today in terms of hiring people, at least in this country, overall and on average the people will be there in the quantities and the quality that we are going to need.

That somewhat concludes my presentation. Before I open it up for questions, I would like to take this opportunity to recognize somebody, which I don't often do. I have an assistant back here. She is right here in this row, about the third row from the back and it looks like she is sliding into her seat right now. Pam has really helped me out tremendously during the last 20 months I have been at SEMATECH. I do about two presentations a week, and she's the one that puts them all together. This is the first time she's ever seen me present outside of an employee communication meeting at SEMATECH. Pam, thanks for putting up with me and my procrastination and last minute things I always want to change.

Questions and answers:

Question: At these densities, it's intriguing to think about systems that are shipped today as boards or boxes being shipped on a chip. How much compatibility will we see at .10 micron between logic process requirements and memory?

Answer: I'm not sure I follow the question directly, but first of all one of the things you are going to see is that packaging is probably going to disappear as we know it today, so you are going to have more direct chips. The chip will be put directly on the board, there is not another package. You will start seeing those coming closer and closer together, and perhaps seeing some of the wiring going just from chip to chip and not even an intermediate board in all cases. I'm not sure if that answers your question, but when ever we start doing that, then you have more flexibility in putting memory and logic together, whether it's on the same chip or not.

Question: The question I have is on the R&D expense revenue ratio chart you have. You showed that back in 1985, about 17.9% in 1990 going from 18.5%, and going down to 13.3%, and then continuing on down, out into the future. I may have missed it, but what do you think is going to drive down that percent to revenue ratio of R&D?

Answer: The primary drivers, of course, is going to be the fact that the sales are going to probably be higher. The growth in sales will probably be higher, but businesses will try to keep the growth in R&D closer to what it has been historically, so that what you end up with is starting to separate out.

Also, there are only certain things that you are trying to do from an R&D point of view. I think as this industry continues to mature, businesses will start approaching the same thing that has happened in other industries, and that is as they mature, the percent that they are willing to spend on R&D decreases somewhat over time. You have to realize though that even in 2010, and it going down to say 10% or 11%, it is still an industry that will be spending more on R&D as a percent probably then almost any other industry in the world. I think just because the business is growing, the sales are growing so fast that R&D won't follow it quite as much.

Question: The educational status of the United States is a little more pessimistic about people in the high tech industries than you seem to be. Have you made any assumptions about education, as to how we are going to get all of these people?

Answer: I did on the education and the employees the same thing that I did in lithography and that is I just looked at history. I can remember over the last 15 or 20 years several times where the industry has gone back to universities and pounded on them and saying you're not producing enough engineers. We need more, we need better quality, etc., etc. Usually about the time they start putting that pressure on the universities in the next year the universities have surplus engineers that are graduating that the industry can't hire.

What I am talking about here is an overall long term average, and not the cycles that we will go through. There are definitely going to be times where we need more people than what we can get, and there are going to be times when there are more people available then what we need.

Question: Jim, most of the issues that you addressed in terms of technical feasibility were at a substantially basic research level. There is no question in my mind about our ability with the science that's being done in the United States, or worldwide today, to answer those research issues; but there seems to be a gap between the basic research that's being done and the eventual research that has to be done to apply those at the production level. Is there some way, is there any involvement or effort by SEMATECH, SRC and other organizations to take advantage of that basic research and start to steer it towards applied research and production level research so that the companies don't have to rely completely on their own efforts to do that?

Answer: That's a very good point. Just some more quick background, and that is that a lot of basic research that goes on has a declining budget. You have ARPA, the government, that are starting to fund less and less of that going on. SEMATECH's budget is going down. Some historical research labs that the industry is dependent upon such as AT&T, IBM and even farther back to Fairchild; those dollars just aren't there. There is a real concern in terms of fundamental research not being there and therefore a bigger gap between that and getting into development and then into production.

The answer is that SEMATECH is concerned about it. We've got a few proposals that we're working with, SRC and the National Science Foundation, in terms of trying to set up some centers of excellence at the universities. The ideal would be that you have one university where they just start concentrating on one particular aspect of the technology. We bring industry assignees into that, as well as other research assignees into that so that we try to establish a link from the development side onto the research side. Also by doing it in a central location, we think we could probably do it for a lot less dollars.

This page is intentionally left blank

Chapter Fifteen: DO SEMICONDUCTOR COMPANIES JUST INTEGRATE TECHNOLOGY NOW?

William H. Davidow
General Partner
Mohr Davidow Ventures

Introduction: Our next speaker is Bill Davidow, General Partner of Mohr Davidow Ventures. Dr. Davidow has been a high technology executive investor for 20 years. Before joining Mohr Davidow Ventures, he held a number of management positions at Intel Corporation, including Senior Vice President of Marketing and Sales, Vice President of Microcomputer Division, and Vice President of Microcomputer Systems Division.

Dr. Davidow holds a Ph.D. in Electrical Engineering from Stanford; a B.A. Degree from Dartmouth College; and he is the author of the best sellers: Meeting High Technology, Total Consumer Service, and The Virtual Corporation.

Dr. Davidow is Chairman of the Board of Rambus, and serves as Director of five other companies. He is also director of the Stanford Hospital and Smart Valley, Incorporated.

I would like to mention Dr. Davidow's hobbies: He reads books, writes books, helicopter, skis, amateur astronomer, tennis, wind surfs; how do you find time to do anything else?

Please welcome Dr. Davidow, who will talk about the new business models emerging in the industry.

William H. Davidow: Thank you, Joe. I have been listening to all of these great predictions about the $300 billion dollar business we are going to have by the year 2000. I really believe it. Then I began thinking about a trip I recently took. I was on an island in Fiji and there were no electric lights. There was no electricity. I was kind of scratching my head and saying $300 billion dollars is equal to $50.00 worth of semiconductors for every man, woman and child on the planet. I wonder how we are going to do that if we don't get some electricity into some of these areas.

DO SEMICONDUCTOR COMPANIES JUST INTEGRATE TECHNOLOGY NOW?

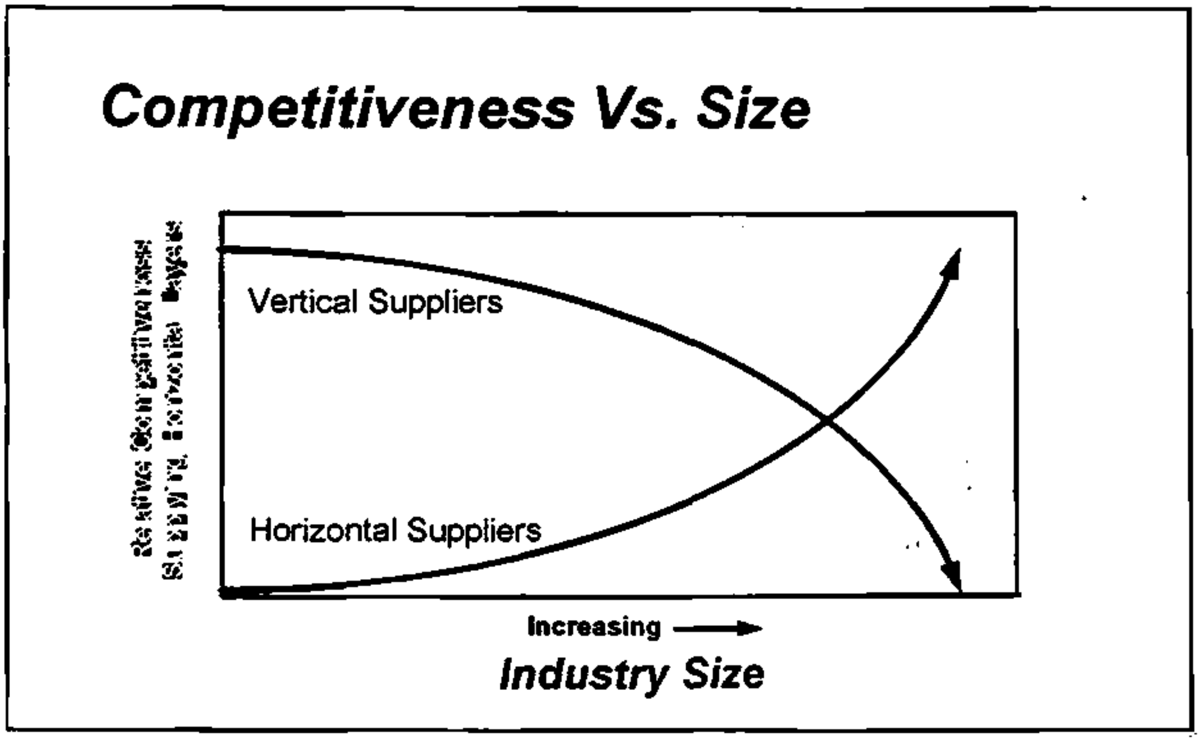
Not too many years ago, I was at a semiconductor conference and Gordy Campbell received a very prestigious award for having the most productive and most profitable semiconductor company in the industry at that time. In the audience was somebody not known for his modesty, Jerry Sanders. He decided to taunt Gordy and he got up and made a great pronouncement. He said real men have FABs.

What is going on in the semiconductor industry today is similar to what happened in the computer industry in the past. I think if we look at the computer industry, we can see what has happened there.

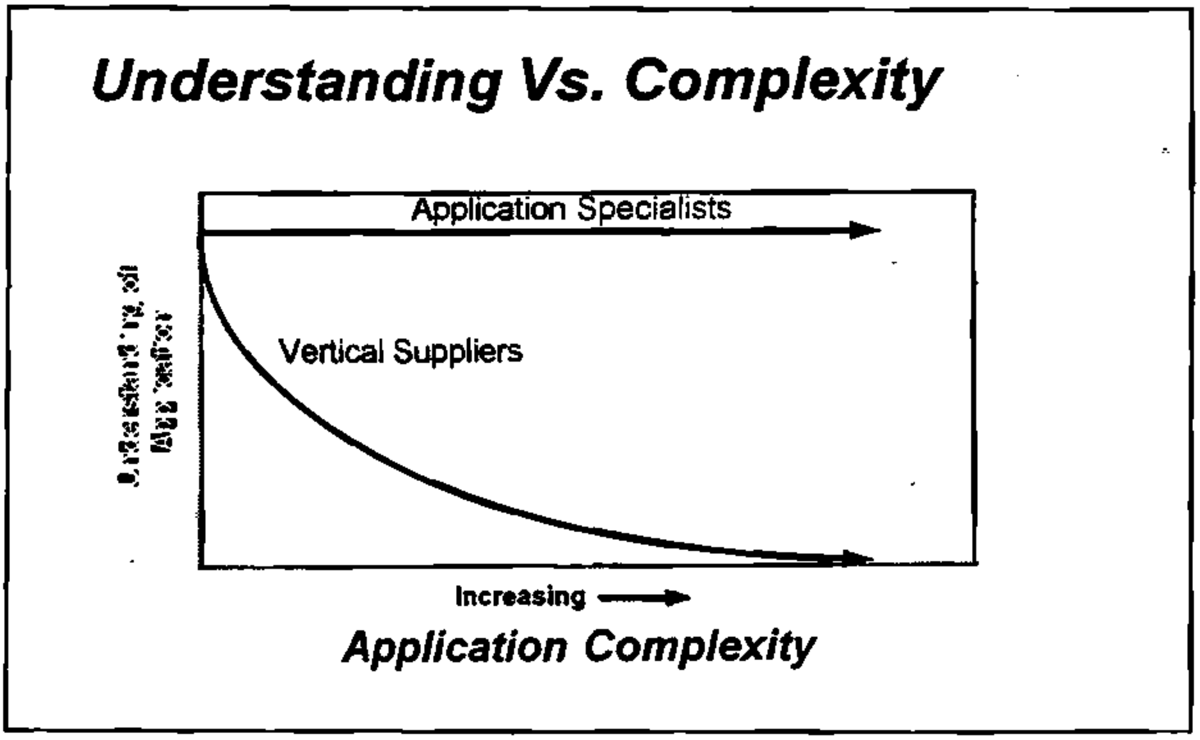
Andy Grove, a few years ago, used to point to this model of the computer industry. He pointed to the model of IBM in the 1970's, when IBM was invincible. I can remember looking at IBM when I was working at General Electric, realizing that they were spending more money on R&D than our total sales were, and wondering how we were going to catch up. At that time IBM made semiconductors, they manufactured hardware, they wrote operating systems, they developed the languages that ran on those operating systems, and they did applications for customers.

Andy (in this example) pointed out that Moore's Law changed all of that. What it did, as he said, was it was as if it ran a bulldozer through the industry and flattened it out. It reconstructed the industry, or de-constructed the vertically integrated suppliers. Suddenly you had Intel, who was supplying the processing horsepower. On top of that, you had a number of manufacturers of IBM clones who were making the computer hardware. A totally independent company arose to supply the software in Microsoft. On top of that software now, much of the applications work is being done by companies such as People Soft.

There is a good reason why this happens in industries. I think we can generalize this. On this slide, without much of a scale, I show the fact that as industry size increases, and as the number of companies participating in the industry increases, it becomes a lot more logical for horizontal suppliers to come in and supply, because of economies of scale, to a number of companies.



The vertical suppliers who are vertically integrated at each one of these places becomes less and less efficient relative to the horizontal suppliers. At one time the model of the industry was something like Texas Instruments, which had built its own process equipment, built its own packaging equipment, made its own silicon, made its own semiconductors, packaged them and shipped them to customers.



Today all of us are interested in buying tools. As an example: One time when I was at Intel we did most of our own computer aided engineering and layout tools. Then the companies grew up that were horizontal suppliers of those tools. Today many of us use packaging services that are on the outside, because it is more efficient and better for us to do it.

There is something unique that is going on in the semiconductor industry. This has been driven by Moore's Law. As the complexity of what we are able to build has become vastly increased, our understanding as semiconductor companies of what the end use application is, has continually decreased. What is happening is that application specialists who understand things like ATM or graphics or multimedia applications have grown up. These companies understand what to do with the transistors that we are putting on the wafers by the millions.

I think what is going to happen is you are going to see more and more opportunities for horizontal suppliers to come in and supply more services and in fact create more companies that fill horizontal niches.

Pattern of Deconstruction

- ✓ Companies Lose Key Competences
- ✓ Hold on too Long
- ✓ Under Invest in Core Competence
- ✓ Re-engineer Themselves

The pattern of de-construction of a company, as I see it, is that vertically integrated suppliers lose key competencies in certain areas. However, because they have large numbers of people whose jobs depend upon the company continuing to invest in those key competencies, they hold onto them too long. They challenge every outside supplier that comes to them with a good idea.

While they are maintaining their investments in these declining areas of competence, they are in fact using funds that could be invested to buoy up their core competencies, and they tend to under invest in their core competencies and tend to become less and less proficient in the areas in which they are most expert.

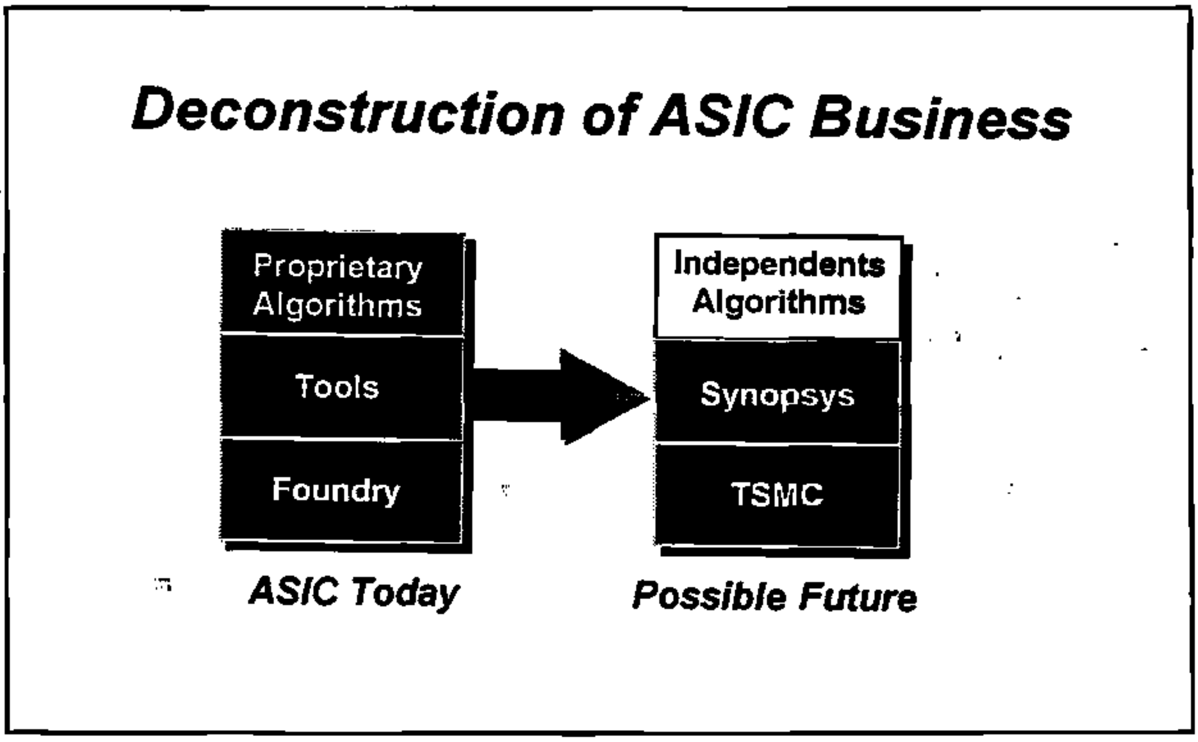
Finally things get so bad that they drop out of markets, re-engineer themselves, become smaller and more tightly focused companies and hopefully go on to prosper again.

What generally happens then is in periods of rapid change companies fail to leverage the competencies of others. Those that do so are often the losers. I have made that mistake myself. I was running a business at Intel, the microprocessor development business, where we were doing basically unique PCs and I failed to leverage the economies of the personal computer and almost ruined the business as a result of it.

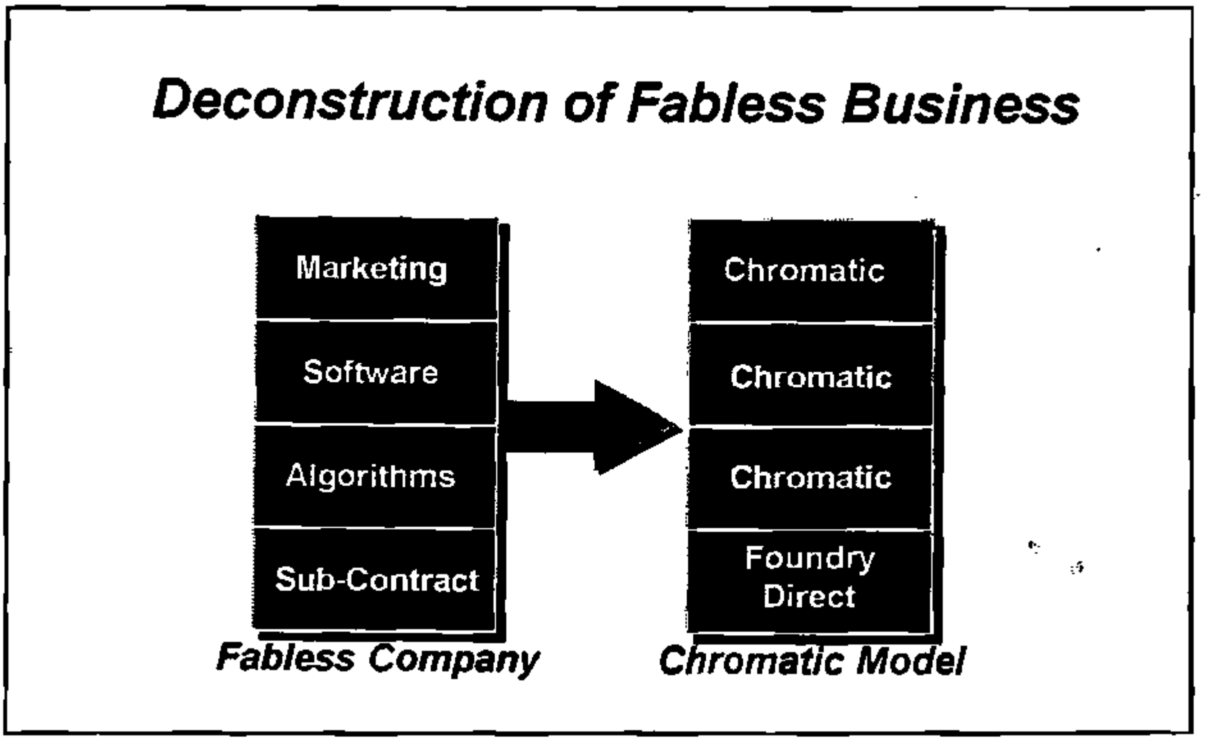
Semiconductor Core Competencies

- ✔ Process and Foundry
- ✔ Packaging
- ✔ Circuit Design and Algorithms
- ✔ Component Related Software
- ✔ Multi-Chip Assemblies
- ✔ Marketing and Distribution
- ✔ Integration of Layers

Semiconductor companies have a number of core competencies: Whether it be in processing, in foundries, in packaging, in chip design and algorithms, component related software, multichip assemblies, marketing and distribution has been a very, very important competence for many of the FABless companies. One of the others is the integration of all of these various layers together in a rational system to serve customer needs.



How might an ASIC business look if we de-constructed it? An ASIC business basically consists of a foundry with tools and proprietary algorithms that the ASIC supplier sells to the customer. My estimate is that approximately 30% of the value added of an ASIC supplier is in the tools and the proprietary algorithms layer. A number of years ago we started a company which was called Silicon Architects - which we recently sold to Synopsis - which was aimed at providing the 30% of intellectual capital that would turn any foundry into an ASIC supplier. today what is going on is that a company like TSMC can add the Synopsis tools to what they are doing and have access to the independent algorithms. As a result of the value added by silicon architects. Many of today's foundries that are just capable of processing silicon will become ASIC suppliers in the future.



The FABless semiconductor business has added tremendous value for their customers. They have done so by subcontracting assembly, by adding algorithms and software, design methodology to those silicon foundries, and by having a number of unique marketing skills. This has created companies that have hundreds of millions and even billions of dollars of sales today. They have grown to this size by exploiting niches where they had applications expertise that the vertically integrated semiconductor suppliers lacked. They will continue to do this.

Yesterday we heard about a totally different model for a FABless semiconductor company, and that is the model that Chromatic is using. What Chromatic is doing is designing the microprocessor or the DSP, licensing it to companies like Toshiba and LG. It is supplying the algorithms, the software and the marketing expertise to get that product designed into the motherboards of computers. This may sound like a strange business model, but as far as we can tell with Chromatic, approximately 30% of the value of the applications will in fact be software. You can create a relatively big company by just selling software related to chips.

I would submit to you that there is another example of this de-construction which we are all very familiar with. Actually, all Intel does is supply the silicon. All Microsoft does is supply the software. If Chromatic is successful, we will be able to demonstrate that algorithms hold as well for DSPs as they do for microprocessors.

Role of Assembly Houses

- ✔ Complex Systems--Few Chips on Substrate
- ✔ Capital and Skill Intensity of Assembly
- ✔ Chips from Multiple Sources
- ✔ Value Added Packaging Layer

Assembly houses have been fascinating to me, but I think assembly houses are going to have the ability to add more and more value in the future, and much of the packaging that goes on inside vertical IC manufacturers is going to move to the assembly houses, where they will assemble their chips on PC boards in some form of multichip module for customers.

This is going to be a very capital intensive and skill intensive business. It is going to require them to be able to buy wafers from multiple sources, and probably do a lot of the post-processing on those wafers themselves so that they can get them into a technology that will be compatible for value added assembly at a later point in time. Look for assembly houses to change the role that they fulfill within the industry itself.

Role of Royalties

- Generally a Punishment or Toll
- Little Attempt to Deliver Value
- Horizontal Layers
  - Pooling R&D
  - Active Support for Partners
- Rambus Model

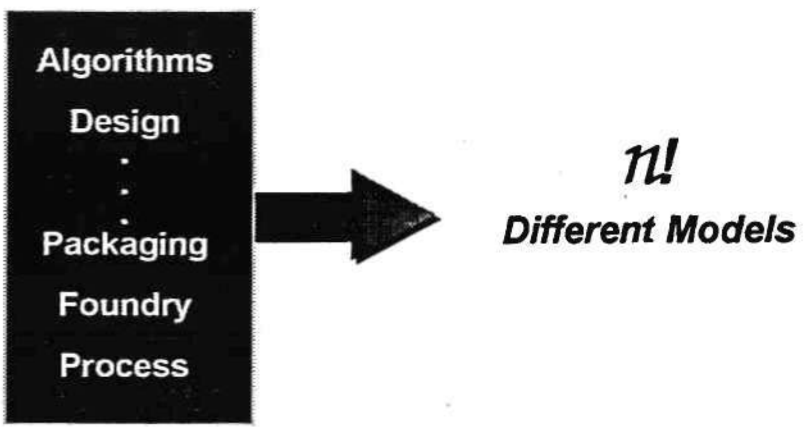
The role of royalties is as well going to change. In the past royalties were a penalty. They were a penalty for having to either intentionally or unintentionally violated somebody else's patent. They were a toll. They were a punishment. In the future, as R&D costs become higher and higher, there is going to be an advantage in pooling some of the commodity processes and developing them as a group of companies together.

You have the model that Rambus has chosen to pursue. What they are doing is developing a very, very high speed memory technology that they are licensing throughout the industry. What this enables companies to do is pool R&D. It is actually a way of saving money in the overall process of providing technology to customers.

Vertical Suppliers

- ✔ **Continue to Dominate Industry**
  - **Purchase More Services**
- ✔ **Internal Capability Challenged**
- ✔ **Intel Example**
  - **Massive Volume, Time to Market, Optimized Processes**
- ✔ **Supplier Opportunities**

Deconstruction of Vertically Integrated Suppliers

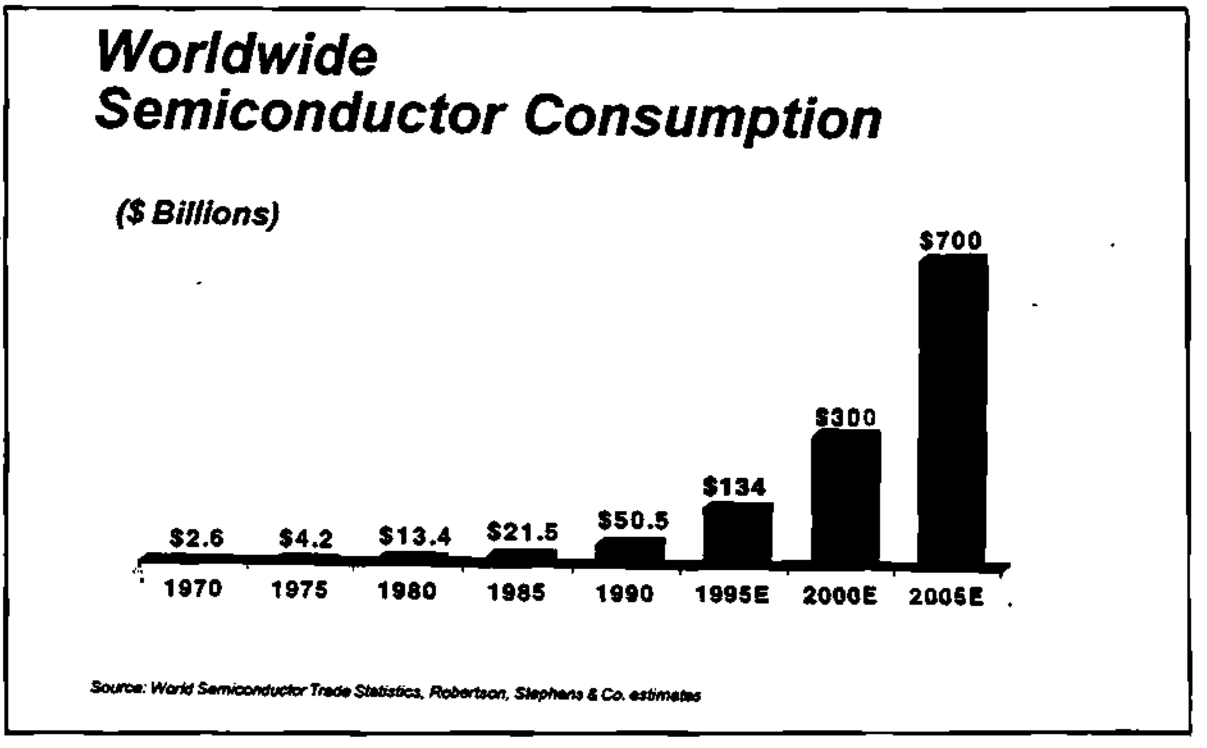


Where does this take us? Am I predicting the demise of the vertical supplier? I don't think so. I believe that vertical suppliers will continue to dominate the industry. They will continue to grow and they will increasingly purchase services on the outside from small, tightly focused companies. Their internal capabilities are going to be continually challenged over time, and they - if they are going to get the most use out of their resources - they should be looking to the outside and constantly asking whether I should make or buy it myself.

Intel is an example of a vertically integrated supplier that I am sure is going to continue to be one. There is good reason for them to do so. They have massive volume requirements. It's hard for them to plan on foundries being available. They gain time to market by being able to integrate process and design, and they have optimized their processes for the products that they are delivering to the customer. Yet even Intel itself creates massive opportunities for the focused, horizontal supplier.

I think that the industry is going to begin de-constructing into a number of horizontal layers, and that there is going to be no one model for semiconductor businesses in the future. As a matter of fact, the business models are going to become more and varied. I think that this is going to create tremendous opportunities as our industry grows and grows and grows.

I borrowed this data - the forecast - from Robertson, Stephen's Dan Klesken, which shows how the semiconductor industry is forecasted to grow; and his estimate, which I think he would say is a little low now, is for a $300 billion dollar business by the year 2000; and a $700 billion dollar business by the year 2005. I would point out that $1 trillion dollar business is the equivalent of selling $150.00 in semiconductors to every man, woman and child on the planet each year.



I chose to round up and assume that at some point during my lifetime the semiconductor business - and not too far away - is going to be a trillion dollar business. At that point, a billion dollar company is nothing. Intel today represents less than 2% of a $1 trillion market. A $1 billion dollar company at that point would have 1/10 of 1% market share. I can remember when we used to think a $1 billion semiconductor company was massive. 1% of the market would contain 100 $100 million dollar companies.

What I would like to suggest to you is that while we may all want to focus on the giants, I think there are going to be hundreds and hundreds of opportunities for $100 million dollar and $1 billion dollar companies to fill the niches that are left over. As my friend in Texas says, we spill more than that every day.

Thank you very much.

DO SEMICONDUCTOR COMPANIES JUST INTEGRATE TECHNOLOGY NOW?

Questions and answers:

Question: What I would be interested to hear from you is where you think the margins will be heading, when you think those will start to fall off.

Answer: The question is when will profits become terrible again. That is very hard to predict because it really depends upon when capacity begins to equal or exceed demand. What I do believe is that the industry, from an application point of view, is going to become so highly segmented that even when capacity begins to exceed demand, you are still going to see people with unique positions that are going to be extremely prosperous. The semiconductor industry is just dividing and dividing and dividing. It's no longer legitimate to talk about the semiconductor industry as if it's some monolithic type of thing. The semiconductor industry is going to be hundreds of different specialty suppliers, each supplying their own little $10 billion dollar niches. It's not going to be as easy to analyze it in the future.

Chapter Sixteen: MULTIMEDIA 2000

Michael L. Hackworth
President and Chief Executive Officer
Cirrus Logic, Inc.

Introduction: It is my pleasure to introduce Mike Hackworth, our next speaker, who is the President and CEO of Cirrus Logic.

Mr. Hackworth joined Cirrus Logic's founding team as President and CEO in January of 1985. Under his leadership, this Silicon Valley company has grown from a start up venture to a worldwide corporation with more than 2,800 employees.

He has successfully overseen the acquisitions of eight companies, and expansion of Cirrus Logic's portfolio of products and technologies. He has led his company into a joint venture with IBM to form Micrus, a wafer fabrication manufacturer.

Since completing the IPO in June, 1989, Cirrus Logic has experienced dramatic growth. Now posting analyzed revenue of more than $1 billion dollars, the company has been profitable quarter to quarter since before the IPO.

Mr. Hackworth was named Semiconductor Entrepreneur of the Year in 1990, by Ernst & Young and by Ink Magazine. Please welcome Mike Hackworth, who will talk about multimedia in the year 2000.

Michael L. Hackworth: Thank you, Joe. As you can see by the introduction there, we decided to eat some of our own cooking, and with some trepidation here attempt a reasonably state of the art PC oriented presentation program.

Before I begin to share with you some of my ideas on multimedia through the year 2000, and the business implications of it, I'd like to flash back about five or six years to a PC conference that I attended similar to this. About 1989, when the question was being put forth what is multimedia going to be in the coming decade, the decade of the 1990's. Speaking on that topic were Allen Kay, a fellow at Apple Computer; Jim Clark, who is the Founder of Silicon Graphics, of course Netscape now; and several gentlemen from Evans and Suttelen, which is a world class 3-D graphical imaging company in Salt Lake.

Alan Kay said something at that conference that has stuck with me. He said his vision for multimedia was when his six year old daughter on a Saturday morning, on the family room floor, could sit down and create her own 3-D interactive cartoons on a machine that cost less than $1,000.00. For the balance of that presentation, various people were talking about what it would take to make that happen.

I thought that definition was fantastic, because it captured in a very simple concept the requirements document, the interface, the price point, the human interface, friendliness that would be required to really create a true rich multimedia experience.

Here we are. We're half way through the decade. By the way, that was a point in time when the venture capital community and some of the industry pundits were saying multimedia is the artificial intelligence of the 1990's. They were very skeptical. What is it? All hype.

Here we are, five years later, and we've made a tremendous amount of progress. It would seem that we are on a trajectory to the year 2000, that we will probably realize that vision that Alan Kay put out.

One thing that I think is an enormous challenge that the industry faces in realizing that vision was tied up in one word that Alan shared. I certainly realized it when I worked with Marcom and some of our consultants in putting this presentation together; that was the word create. When we think about multimedia and experience it today, it's fundamentally in a playback mode. That's where really all of the investment and technology and what we experience at the present time is headed. The ability to create - the offering side of that - is an enormous challenge, to make that user friendly six year old child on a Saturday morning on her family room floor an under $1,000.00 machine. We are a long way from that. I'm not sure we will see that in this decade.

We all talk about the tremendous progress that we have made, but seeing is believing. Video game developers deserve a lot of credit for stimulating the demand for multimedia and PCs. In fact, it's probably really the engine for a home PC at this moment in time. Anybody remember Pong, back in 1973? By the way, if you do remember Pong, there was a sound, there was a pong every time it hit the paddle. Our friends at Macromedia, who developed the director program that we use to create this package - this is the authoring side - are not quite together yet with Bill Gates and we couldn't give you the sound, can you believe that? We have work to do.

We've come a long ways since Pong. We've had Asteroids. We've had Mario Brothers. The state of the art today is probably represented in something like Descent.

"The information superhighway may be mostly hype today, but it is an understatement about tomorrow. It will exist beyond people's wildest predictions."

Nicholas Negroponte,
Founding Director
MIT Media Lab

CIRRUS LOGIC

Today we are seeing arcade quality video games migrate to the PC, complete with full motion video, 3-D graphics, surround sound, all making it a very rich multimedia experience. If you think we have come a long way since Pong, you really haven't seen anything yet.

"The information superhighway
may be mostly hype today,
but it is an understatement about tomorrow.
It will exist beyond
people's wildest predictions."

Nicholas Negroponte,
Founding Director
MIT Media Lab

CIRRUS LOGIC

How this exciting future might shape going forward has been addressed by a number of visionaries. Nicholas Negraponte, the Founding Director of the MIT Media Lab, had this to say. (By the way, the Media Lab is celebrating its tenth anniversary this year). Negraponte may be right. Today's hype about digital convergence and the great promise of the super information highway may well be understatements by the 21st century. I'm not going to engage today in a content with he and those other visionaries. As the interactive age blossoms, the semiconductor industry will be facing some very daunting challenges. In fact, it's amazing Bill, David Al and I didn't converse any before this meeting, but you'll see some synchronization of what he had to say and what I have to say. These challenges, of course - the flip side of them - are tremendous opportunities.

For my presentation this morning I want to focus on those challenges. As we race to the 21st century, there will be multiple drivers of growth in this interactive age. These drivers of growth will set in motion some changes that will create new realities for chip makers. I'll focus on those realities in a minute, but first let me review the growth drivers I see shaping the industry for the next five years.

Growth Drivers In The Interactive Age

- **Humanistic Interfaces**
- **Internet & Broadband Communications**
- **Multimedia Applications & Content**
- **Unprecedented Affordability**

CIRRUS LOGIC

At the top of the list is more humanistic interfaces, or more natural ways to interact with the computer. As this becomes more and more natural, the market will expand. Let me give you a definition of perhaps the ultimate naturalness: In the late 1970's, the federal government legislated emission requirements and miles per gallon requirements on the American automobile industry. Quietly, unobtrusively, unbeknownst to you driving your automobiles, at that time the equipment of the PDP8 was inserted between your foot and the injection nozzles on the engine of your automobile. It was a completely natural interface, totally transparent to the user that brought tremendous technology and advancement to the automobile. If we can do that kind of natural interface in interfacing with these PC tools, the market will expand dramatically. We have seen great advances and more yet to come.

The next tremendous engine of growth will be communications: The Internet and broadband communications. By broadband, I mean high speed digital cable, high speed digital fiber, high speed digital transmission direct satellite, ISDN to the home, ATM, whatever.

I was at a talk recently where a friend, Mr. Gilder, the futurist, was speaking. He said 1995 will be a landmark year in communications. He predicted that we will see the number of E-mail messages surpass the number of postal messages. He said it will probably be the year that the number of digital data bits exceed the number of voice bits that are transmitted over the U.S. carriers.

This is going to be a tremendous engine of growth. Today that occurs at 14.4 kilobits, 28.8 coming on, ISDN at 56; and eventually something like ATM at 25 megabits, and more. It cannot be underestimated, the power of this growth.

In fact, one could say that the Internet is the killer application for bringing all of this high speed communication into the home and into the office.

Speaking of killer applications, it takes me to software and multimedia. It's been widely said that software drives hardware demand. Hardware without software is a solution in search of a problem. This is particularly true in the interactive age. The proliferation of multimedia applications and content will most certainly create and stimulate turn over and demand for new hardware.

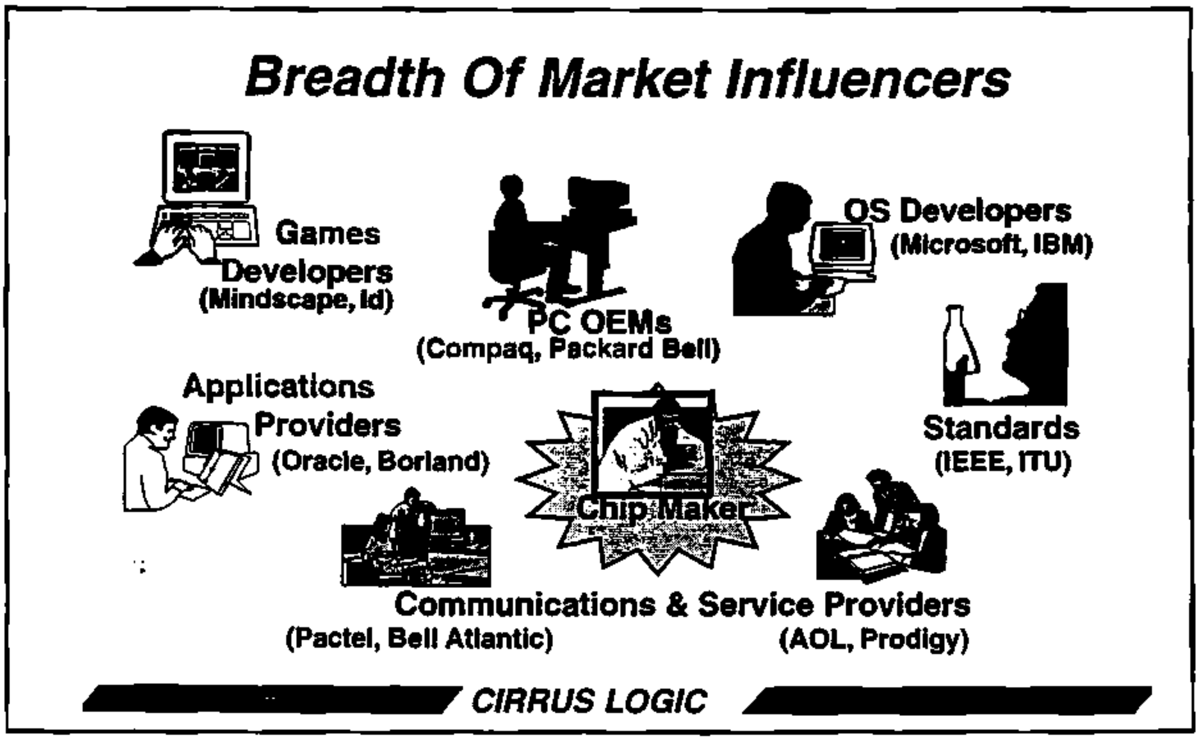
Finally, affordability will reach unprecedented levels. I was very pleased for Jim Owen to be predicting .10 micron technology.

These growth drivers are creating new realities for the semiconductor industry. Our silicon world is changing dramatically.

Succeeding as a chip maker in the interactive age will require having access and capability to combine an ever broadening range of technologies into a chip set or a single chip. The multimedia technology mix of 3-D, full motion video, FM and wave table sound synthesis, audio and video decompression, wireline and wireless communications is an incredibly broad, rich application skill set that will be required for semiconductor manufacturers to develop their chips.

Having that broad technology portfolio won't assure success. It's merely the ante to play the game. Applying that technology to innovate solutions at the system level will be absolutely critical. This is not anymore a building block business. We no longer design a collection of widgets that somebody else will assemble into a system. We design systems, period.

We should begin to view ourselves in the semiconductor industry as systems companies masquerading - if you will - as chip companies.



There is an enormous breadth of market influencers that chip makers will have to contend with in order to define meaningful pieces of silicon in the future, these system chips. Up to now, of course we deal with our customers, the PC OEMs; and we deal with Intel, the microprocessing manufacturer. As we now reach out and cover more of the system responsibility because it's all on one chip, we have to interact with game developers, OS developers, application providers, service providers, carriers and the like.

As the microns continue to their inevitable shrink down toward the .10 micron, the tendency will be to put all of this on one chip. What will it look like? It's a little crazy. It has S-RAM, D-RAM, flash, mixed signal, high performance logic, inevitably all on one chip. The ramifications to the equipment makers are profound, because today there are specialized FAB modules for many of these processes and specialized dedicated equipment for the process steps.

New Realities

Our Silicon World Is Changing

- **Extensive Mix Of Technologies**
- **Breadth Of Market Influencers**
- **Higher Manufacturing Complexity**
- **Increasing Product Complexity With Shorter Life Cycles**

What Are The Implications?

CIRRUS LOGIC

It's even more profound for the test equipment industry, where there are specialized testers for D-RAM, Pro Logic, and for analog continuous time signal processing. This will now have to be combined into single test equipment.

Finally: Increasing product complexity will be an enormous challenge. In 1985, the PC XT had approximately 10 million transistors on it. Today a typical multimedia PC we estimate has about 150 million transistors, with about 1/3 less the components that were in that original XT machine. IT seems like the PC is more or less following Moore's Law.

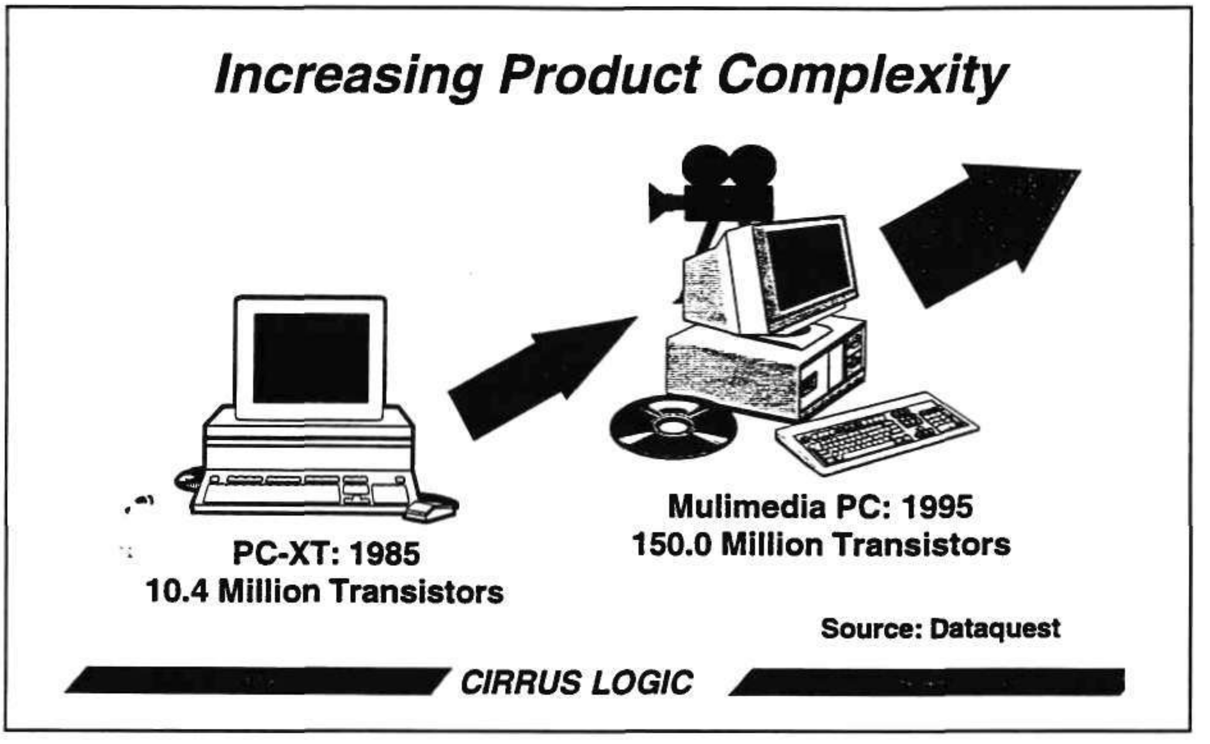
The Value-Added Chain

(Animated Sequence)

- **Today's Scenario**
- **Tomorrow's Status Quo**
- **Tomorrow's Opportunity**

CIRRUS LOGIC

The implication of these realities is that R&D is being forced down the value added chain. I've been out of the semiconductor wafer fabrication business for ten years, and as the intro said we just formed our first manufacturing joint venture here about a year and a half ago. At Phillips I know how much we spent on process development. At that time it was one of the three largest research laboratories in the world for process technology development. I was greatly concerned about how we would do that in a joint venture FAB, and more particularly how our Asian foundries would be able to continue the technology treadmill, moving to smaller and smaller feature size.



What I discovered in getting re-engaged with the equipment industry, is that the R&D burden, the R&D activity has shifted from the semiconductor industry to the semiconductor capital equipment industry; not 100%. This is good, because process development is taking place at the capital equipment end, and then is leveraged across many semiconductor companies who did not have to reinvent the world. From a capitalistic free enterprise system standpoint, it's a much more efficient delivery vehicle.

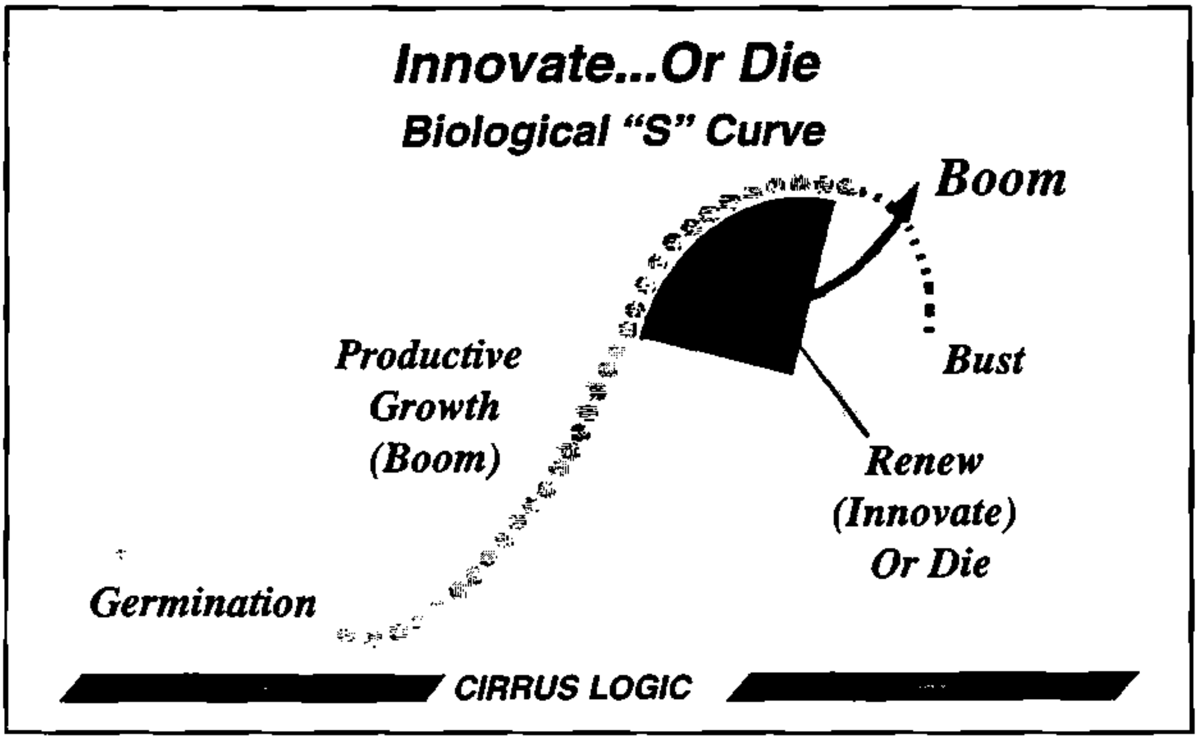
It's also of necessity. Today the processing equipment is very complex inside chambers of these tools where the process is defined by the tool itself. In fact, there are tools with multiple chambers and multiple process steps, and those are defined by the equipment provider also.

The R&D dollars are moving down the food chain and the role has shifted to the equipment provider.

A similar phenomena is happening at the PC OEMs. A few years ago PC manufacturers spent 6% on R&D. It's not uncommon to see leaders in the industry today spending 2%, or even less, on R&D. The burden that was once borne by the systems company has been pushed down to the semiconductor company. Today we, with the chips we provide, provide complete system software solutions turnkey, even in some cases with a complete board level design, FCC approved, to our customers.

Watch the chip guy. He is growing and is value added in this chain. There are some companies that have broader ambition than this.

Those who chose not to invest run the risk of being squeezed out. The process is really inevitable.



The message is innovate or die. In biology, there is a phenomena called the S-curve of life. The bottom part is germination, fits and starts, cuts and tries, many attempts, many failures; a few succeed. The right seed in the right orientation takes root and a sprout grows. An analogy for a company is the bottom of the curve is the start up phase of a new company, or maybe it's the start up phase of a new technology in an existing company, and then finally something takes root. A replicable process is found and high growth takes place.

That continues for a while, and in biology they have a phenomena called contact inhibition, where so many cells have multiplied that oxygen can't get to the surface of the cells and decay sets in and death is inevitable unless a new sprout is formed and the cycle is repeated. I think there is an analogy of that in the industry as well. We can see that with Chrysler Corporation. We could see that with the main frame industry. We could see that with boom/bust cycles in entrepreneurial companies in Silicon Valley. The point is you have to establish a new root and start the cycle all over again or go bust.

Actually there is an interesting analogy that is very much topical right now, and that is taking analog continuous time signals, converting them to digital, and then processing them in the digital domain, using DSP processors. It's been going on for years in modems - that's how you build a modem - but there was a string of companies that started along with fits and starts, cuts and tries process was around five or six years ago; ITT. More recent attempts: M-Wave by IBM, the big multimedia DSP chip from TI; fits and starts, cuts and tries. Native signal processing from Intel; to be determined. Companies now in Silicon Valley: NVidea, Chromatic and others, Phillips Trimedia; all example of this germination phase.

The market is the ultimate purifier. One or more of these will go through the filter and become a strong growth technology for the future.

Chip makers' survival will depend not just on feature size reduction and integration of more components on the chip, but innovation as well. Innovation is not just how we combine the chips, but in architecture and in software.

Let me give you an example of system marketecture at Cirrus Logic: Up until a couple of years ago, the detection of magnetic pulses stored on a wafer was done through an analog continuous time technique known as Peak Detect. It was done through discreet ICs, a collection of ICs, and a large collection of passive components; where ultimately a cleaned up digital signal was passed to the digital processing chips.

With the technology coming down to .6 micron, it became possible to put a very large number of components on the chip. The solution wasn't just to combine those into one chip, but to go to a completely different architectural paradigm called Partial Response, Maximum Likelihood, using huge numbers of digital chips to do that same function.

To do that same function, but at the same time increase the capacity of a Winchester disk platter by 50%, and at the same time reduce the component cost to do that function by 30%; and at the same time provide a programmable technique to Winchester disk drive manufacturers that would allow them - as the drives went down the line - to tune the drives to improve their yields by as much as 5%, 10%, and in some cases 20%, a tremendous economic gain. That's what is meant by a new system architecture.

In that chip, in that new PRML chip, is an enormous amount of software code. That software code is developed by the semiconductor company. In fact, one might argue that semiconductor companies in the future, following this paradigm, are really software publishers and the silicon is the medium.

This phenomena of taking analog continuous time signals, converting them to digital, which then allows you to put it on the same silicon platform as the digital computational functions, is to me the most sensible definition of digital convergence. For analog continuous time functions into the digital domain, converge them with computational and you have digital convergence.

Once we are over the hurdle of survival as the semiconductor industry and we're practicing in this new paradigm, the chip makers now can thrive on change. We can innovate again even more new system architectures: Like the Chromatic multimedia engine, or the Phillips Trimedia engine with its very long instruction word. These brand new, bold new architectural concepts will enable new applications such as video conferencing on the PC for a couple of hundred bucks or less, over twisted pairs, standard old POTS telephone line. If we do that with this increased R&D burden, we increase our value in the food chain.

The bottom line? There is a Latin expression about all of this: Carpe Deum. I have a better expression: Occasiano madripa, sunovo amitrius. What's that? Seize the opportunity or miss the boat.

This page is intentionally left blank

Chapter Seventeen: THE IMPACT OF INTERACTIVE MULTIMEDIA ON SYSTEMS AND SEMICONDUCTORS

Panel Discussion

Moderator

Dr. Dan Klesken
Managing Director, Senior Semiconductor Analyst
Roberts, Stephens & Company

Panelists

Rob Enderle

Senior Industry Analyst, Client/Server Software, Online, Multimedia, and Software Group

Dataquest Incorporated

Jim Hood
Senior Consultant, Consulting Services Group
Dataquest Incorporated

Bruce Ryon
Director and Principal Analyst, Online, Multimedia, and Software Group
Dataquest Incorporated

Allen Wiener
Director and Principal Analyst, Online Strategies Service, Online, Multimedia and Software Group
Dataquest Incorporated

Introduction: Back in 1976, Dan Klesken responded to a one inch square add in the Dallas Morning News and came to work for Dataquest. He met Jim Riley in April of 1976, and the rest is history. Dan then spent the next seven years at Dataquest helping to establish the Semiconductor Group.

Today Dr. Klesken is Managing Director and Senior Semiconductor Analyst for Roberts, Stephens & Company. He has extensive research experience and knowledge of the semiconductor industry, and is highly regarded as one of the top experts in the field.

Prior to joining Robertson, Stephens and Company, Dr. Klesken was Vice President and Senior Semiconductor Analyst with Prudential Securities. Previous to that, he was a General Partner and Senior Semiconductor Analyst with Montgomery Securities for seven years.

Dr. Klesken holds a B.S. and M.S. Degree in Electrical Engineering, and a Ph.D. Degree in Electrical Engineering from Carnegie Melon University. Please welcome Dan Klesken for the next panel.

Moderator: Thanks very much. We had a very good start this morning, especially Mike Hackworth's presentation on multimedia. I would like to carry forward now with the panelists here. We are going to talk about the impact of multimedia on systems and semiconductors.

I've got four Dataquest analysts on the stage with me to talk about this. Three of the gentlemen are in the Dataquest Online Multimedia and Software Group: That's Allen, Bruce and Rob, on my far left. Jim here on my left is a consultant really focusing in the communications area.

I'm not going to read through the details of the full biographies that's in your book, but I am going to give you a couple of quick highlights on each of my colleagues here on the stage.

Allen Wiener, on my far right, is a Principal Analyst in the Online Strategies Program and with the Online Multimedia and Software Group. He is a Principal Analyst in that group, servicing the Worldwide Multimedia Group.

He was previously with the Electronic Information Services Department for the San Francisco Chronicle and Examiner. There he was involved with every aspect of new product development for the GATE, and on-line service that was introduced in May of 1994. Allen's responsibilities included developing the business plan, the capital operational budget, as well as technological development, editorial coordination and new product marketing. He has also developed a world wide web home page for the GATE on the Internet, and was responsible for its design and maintenance.

On my immediate right is Bruce Ryan. He is a Director and Principal Analyst in this group. He's in charge of all of the multimedia research at Dataquest. Bruce has over 18 years of experience in a combination of computer industry marketing, as well as five years of experience in the computer systems product management area, also in film, graphics and multimedia production.

Bruce has a B.A. in Film Directing from the University of California Berkeley, where he received two national honors as an exceptional film student. The first bestowed was by Warner Brothers. He also has pictures at Warner Brothers and the National Endowment Counsel. He was also awarded the National Endowment for the Arts in 1974. He has also earned an MBA from San Jose State.

At my immediate left now is Jim Hood, who is a Senior Consultant in the Consulting Group at Dataquest. Jim has a Ph.D. in Engineering. He is a Controlling Analyst with Dataquest. He is responsible for all of the custom consulting projects in support of strategic planning, business planning and market analysis in the area of telecommunications.

Jim has over 25 years of experience in the industry, many with equipment suppliers including Grange Associates, Patel and Merrit.

Finally on my far left is Rob Enderle, and Rob is a Senior Industry Analyst in the Online Multimedia and Software Group. Prior to joining Dataquest, Rob was a project leader for both competitive analysis and software marketing for IBM's Storage Systems Division. At IBM, Rob was developing the branding strategy and a product comparison matrix and report forum for IBM's distributed storage management product as their Distributed Storage Manager. He is also a Team Leader for company wide efforts to re-design software marketing and sales for UNIX.

The rest of the details are in your hand out. I'll let you read through that, but clearly I want to use these experts on the stage with me now to talk about what's happening in this exciting area. Mike Hackworth gave us that nice kick off with his multimedia lead off here. Let me ask each of you on the stage here, in your own words and in your own experience, what does multimedia mean? What is it? Where is it going?

Panelist Allen Weiner:

Related to the on-line business, multimedia is really in its infancy. The basic uses that we are seeing right now for on-line services and the Internet are primarily basic communication things such as E-mail, bulletin boards, chat, etc.; and also surfing the world wide web. Those are the primary uses of technology that we are seeing in on-line and on the Internet.

We are beginning to see the impact of multimedia, particularly - and Bruce will point this out later - as more and more people have multimedia PCs. We are seeing a number of companies like Real Audio and Zing, as well as new technologies like video virtual reality modeling languages being used to develop applications on the Internet and on-line services to make use of multimedia capabilities. One of the things that I say is that these tools will be the first that allow companies to build businesses that people will pay for; real businesses on the Internet that really have some depth and breadth.

There are a lot of other issues obviously that we'll address during the panel like infrastructure and whether the infrastructure will be enough to deliver these to the home.

That's basically one of the things that I see happening right now.

Moderator: Bruce, what does multimedia mean to you?

Panelist Bruce Ryon:

I look at it pretty simply. If you really look at multimedia, it's been around for 65 years with the introduction of talking pictures. Based on that view, I really break the multimedia market or definition down into two parts: You have a computer that is an intelligent microprocessor driven device, and now we are adding audiovisual elements to it, not in analog form, but it's now in a digital form.

On the other side you take a television, which is already an audiovisual device, and then you are adding microprocessor technology to it. They become somewhat the same types of devices, but as you can see in all of your research they are used very differently in different aspects. In many cases people like Andy Grove want to see the PC take over the TV. We can argue about that further down in the discussion here. For the most part, computer based, TV based.

A lot of people ask me well, what's the difference between desktop publishing and multimedia, because in effect you are mixing text and graphics with desktop publishing. The way that I make that distinction is that you are really dealing with time based media and multimedia sound occurs over time, video occurs over time, whereas in graphics you really are dealing with a single static image. That's my definition. It's pretty simple.

Moderator: Jim, with your communications background, what does it mean to you?

Panelist James Hood: From my point of view, it really is the convergence of the audio to visual, all of the various sensory ways of communicating with people; combining those all into one. I also happen to like 3-D, so I would like to throw 3-D into it also as a possible way of enhancing people's ability to receive information.

Moderator: Rob?

Panelist Rob Enderle: It depends on what environment we're talking about. Multimedia has different representations in different markets. The home market, of course, is primarily games, entertainment software and some education software. In the business market it's primarily training and certainly video conferencing falls into that realm as well.

The business market is the most interesting in that multimedia has been thought to be a significant opportunity, but it hasn't migrated in the business world, primarily because of the constraints over the network and constraints with regard to the deployment of multimedia programs; in other words licensing issues, cost issues and the rest. The two markets are two different things. I do agree with certainly Bruce's definition as far as what multimedia really is as far as a definition.

Moderator: Let's turn to the home for a minute. Multimedia really is making a big push into the home. The success of the Pentium PC last year and this year has certainly been driven by multimedia in the home.

THE IMPACT OF INTERACTIVE MULTIMEDIA ON SYSTEMS AND SEMICONDUCTORS

We really haven't had any prepared slides for this presentation, but Bruce has just finished his third annual update on a study of multimedia in the home and applications. I am just going to ask Bruce to take a few minutes, go over to the podium, and give us some of the results that we've seen from this recent study.

Panelist Bruce Ryon:

Actually what we've done yearly now during the summer we interview about 300 users in the United States. Why did they buy multimedia? What do they plan to be doing with it in the future? Are they going to add on to their computers?

In fact this last year we looked at those who had multiple PCs in the home. What we found was about 1/3 of those who own multimedia PCs, also had more than one PC. We actually analyzed exactly what they were doing.

This report is going to be published next week and it's the third annual, and we are actually comparing any movement that we've seen over the last couple of surveys, but what I would like to show you now is some interesting data. Over the last couple of days we have certainly heard a lot about the movement of semiconductors and growth and so on. I wanted to point out some interesting facts that are occurring over the last couple of quarters in the multimedia market.

What I am going to show you now is a quarter by quarter growth and actual shipment of multimedia PCs. This started in the first quarter of 1993, and the last two quarters are Q1 and Q2 of this year. You can see that multimedia PCs have actually started to decline in the market, and I really attribute this more to a cyclical behavior in the market. We are now seeing a leveling off of the market in effect, and we are now getting to more seasonal behavior.

If we look at quarter over quarter growth, we can see it is very seasonal, with the last two quarters being on the downward trend. Here's a more seasonal analysis of the data as well. We think it will probably be about 15% to 20% over last year, so we're still seeing some good seasonal growth, but we're seeing a leveling off in the market.

What's even more interesting is multimedia PCs, as a percentage of the overall PC market, now we can see also that the multimedia PC market is declining as an overall part of the market. We think it will come up this quarter and next quarter, certainly because of the very strong Christmas sales for multimedia PCs.

I would also like to point out something that we've been seeing in our data, which has just been confirmed by a fairly large survey that was done. We asked how many households had PCs. What we found is about 28% of the households in the United States have PCs at this point. We also asked do you plan to buy a PC in the future? A full 62% said they had no intention of buying a PC anytime in the future. About 10% of the people that didn't have PCs said yes, I am interested in PCs.

If we take a look at who is intending to buy these PCs, we can see from the green line that the lower bottom of the line is the average household income. The interest in buying PCs tends to be in the lower income levels.

We're really in a product transition. We believe by 1997, it will start coming back up. Right now we are at a price point that is too expensive for most people in the home market. As part of our home multimedia research, we talk a lot about video games and ask a lot of questions about video games.

What people are basically telling us is they will start buying video games again once they come down into the $187.00 price range. Right now they are at $300.00 and above. We are seeing product transition now, but we think it will come back up in the next two or three years.

Video game software is declining as well. Again, this is a product transition that we think will correct itself.

I just wanted to highlight those figures to show you that we are now seeing more cyclical behavior in these markets, and that we really need to discuss this when we talk about multimedia in the home.

Panelist: The number one question that everybody asks about the Internet and on-line service, how do I make money in this business? I think that this relates to a lot of the things that Bruce was just talking to. One of the things that we came up with is offering value. That's easy to say: You need to offer value. As part of our group we have come up with some things in offering value. I think that that's the issue that sort of pervades everything that we're talking about in creating new devices, what applications are people going to be willing to spend money on? I think that's the issue that has a number of interactive trials basically on hold and has board rooms in the U.S. West and Time Warner scratching their head. What are the kinds of things that we can offer that will allow us to pay for the build up of this infrastructure? That is sort of something I would like to throw out. It's the whole value proposition in all of this.

I think that most recently, in my industry, one of the things that we're hearing quite a bit about which I think affects everybody in this room is the use of this technology behind the firewall, or within the enterprise right now. I think that there is a lot going on. There is more development going on in using multimedia and interactive technology within an organization, within the enterprise, as a way of corroborating and sharing information then there is outside. I think that is going to have great implication on the development of other applications as well.

Panelist: I was just going to add that one of the things that goes on in the home market - and many of you have heard this characterization of this market - it is an almost for free market. People will invest in a computer in the home based largely on work related reasons; that is they are doing work at home or they are running a home based business. That is really the primary driver. Where you see the gains and word processing come into play is really once the product's in the home. The thing that really justifies the product in the home is work related activities. There is a very high value placed on paying for work related activities. Once you get into other kinds of applications, then the value chain comes down.

Education is still in that high part of the value chain, based on people who want to invest in their children. About 75% of those who have multimedia PCs - as an example - have children. There is an interest there in investing in education.

The one thing that we really have to really understand about that market more than anything else is that education software only drives about the age range between about four and nine. Once the child becomes nine or ten years old, then it's word processing and it's reports that drives the market more than anything else for education or home education. It isn't any multimedia products. It isn't any Carmen San Diego, but it's really getting reports done, and that's where the real value is.

Once we start taking the value chain downward in the games and so on, then people start saying bundle it. When I buy a piece of hardware or a peripheral, give it to me for $20.00. I don't really want to pay a whole lot of money for it, because I think the value of it is about $20.00.

One of the charts that I didn't show is that over the last three years we see a significant drop in margins for the software developers. It used to be about $25.00 to $30.00 that they would gain on average over their entire product line for home products; but now that has gone down to $10.00 in terms of average margin for products across their entire product line.

That is an issue right now that is going to become more and more difficult for many of these developers to start putting out products. I think Dr. Davidow's presentation this morning about lots of different companies being able to participate in a semiconductor side isn't going to be true in the software side, because now you are basically seeing the major players like Acclaim, Electronic Cards and Microsoft take over the entire industry, because they can operate at these lower margins because they have that volume in place.

That's a factor that's really going to drive the market. The partners on the application side are going to be the Microsofts of the world, not necessarily smaller players.

Moderator: Rob, how about your thoughts about delivering value in the home or in the business?

Panelist Rob Enderle:

That's the key. Obviously, Allen mentioned that a lot of the set top box trials haven't been going particularly well, primarily because the product that's been provided didn't justify the cost that was charged. A lot of the direction right now with trying to come up with this value, this concept of providing that something are willing to pay for. Whether it's the home market or the corporate market, you see a certain number of things that have been deployed to address at least the cost side of it. You've certainly recently seen that AT&T has inbundled itself and is putting a number of satellites in the air to provide very low cost, high bandwidth pipelines to the home and bypassing some of the constrictions, the shortcomings of the in place network. Once again, that addresses some of the problems. It still doesn't apply or address value.

As we see the banks now beginning to look seriously at on-line banking and take out a lot of the charges that they've added to the service. That too could drive value into the home. It would show the home market, which is the biggest opportunity that appears to be left open. The quote of 63% that didn't have or weren't planning on having PCs. That's where Bill Gates sees his opportunity. That's certainly is what Andy Grove sees as opportunity. These are the folks that have to be convinced that what they absolutely do need is a PC and get them on the front end of the curve rate, as opposed to the back end. That's where the change is going to come.

Panelist: I think the others have mentioned that you've got to always try to remember that those of us in this room are not the typical consumer. The typical consumer, in fact in the cable TV industry that I was in for a while, we always referred to that person as Joe Six Pack. I think that characterization is pretty good. Joe Six Pack comes home at night, gets a six pack of beer. He sits on the couch and really watches that stuff that's on the air and he's really entertained by it. That is the typical consumer out there. You and I are not the typical consumer. What we think we want, we represent only a very small percentage of the market. If what you are trying to do is to figure out and design products for the mass market, you've got to remember that that person, that family, is very different from you and I. What they want, what they need and what they perceive as value is very different from what you and I perceive. As these products develop, you really have to keep that in mind in order to find those killer applications, those really good applications probably are not the kind of things that you and I would sit around and think that's what I really want.

Panelist: To amplify what Rob said about banking, I don't think that cyber banking or interactive banking is going to come as soon as everybody thinks; at least in the United States. Actually banking electronically has far more of a positive implication overseas. One of the things I was just reading, Deutches Telecom, which is going to become a major on-line provider in Europe, is going to use cyber banking as one of the core elements of their service, mostly because in Germany the banks are open from like 10:00 to 2:00. It doesn't really coincide with the normal person's schedule, so they are going to be able to extend banking capabilities.

In the United States I think that it's going to take far longer for this wallet concept, where you can sort of bank from anywhere that you are, the thing that Bill Gates and companies like Check Free talk about. In the real world it sounds very good, but actually what Jim said is right on the money. We have a very insulated view of this industry, particularly us. We are in Silicon Valley and we deal with other companies like ourselves. As the traveling that I've done across the country - and no offense to these places - but going to Boise and Kansas City and Milwaukee and all of that, I wonder whether people are really ready for these advanced applications. I think that it's going to take generations. It's going to take the generations of my daughter (who is three). By the time she is 15 or 16 it's going to become part of our lives. I think that's the kind of development time that we're looking at.

Panelist: I do a lot of end user research, and I think the thing that keeps coming back is that we always see about 10% to 15% leading edge groups that consider themselves hobbyist and they'll go out and get the latest and greatest technology. What's interesting, as I always see when new technology comes out and you see a big surge of sales; when I was in the film industry we used to call it legs, does the product have legs? Will it last beyond that initial surge of people that are just going to go out, always that first group that's going to go out and buy it.

Once you get beyond that 15%, all of the end user research that I've been doing shows that people are using just basic applications, that the highest usage of the home PC is word processing. It's even actually both for work and for personal use. The second highest after work and word processing is games. People are just used to very simple applications that they can fire up and use.

I spent four years as a systems integrator working with design firms and ad agencies and television stations in San Francisco as a systems integrator. In just working with the people that were using technology as a design tool, they just said just tell me what I need to know to get this job done. I'm on a deadline. I don't want to know any more than that. That just backs up and gets reinforced by the research that people will generally learn to use about whatever the 10% to 15% of the features that they need to use in order to get the job done, or get the pleasure or the entertainment. There's always that 15% of the market that we always kind of look at when they first come out and buy the product as the leading edge and the key markets will continue. We really have to look beyond that demographics that it's not the hobbyist.

Panelist: The point that Bruce is saying, all of the research that we've done in both the consumer on-line services like Compuserve, America On Line, etc., and the Internet; the killer application is - and will be for the foreseeable future - electronic mail. That's the killer application. All of these other things are going to be secondary. While people are figuring out how to get additional bucks out of people, it's going to be electronic mail.

Moderator: Let me address the idea of education for a moment and put out my own experience here for a moment and ask you to comment. I've got college aged kids. I also have an eight and a seven year old at home. We use Score in Memo Park, my home town. Actually Bill Hewlett, of Hewlett Packard, is the major backer of this company and there are now about ten stores ringing the bay area. Score is a little store front over on the Alameda De Los Pogas in Memo Park. There is a couple hundred square feet. There are a dozen MAC computers in the room. A MAC server in the back room. Simon & Schuster spent a couple years developing the software, and the kids go in there and after they register with their name and their ID number, they put in whether they want to do English, reading or grammar, and they can select these and they get 20 questions. If they get 16 or 20 correct on a multiple choice basis they get a little magnetic score card that they can stick on the refrigerator. My kids collect them and then they go back and get a baseball card or a football card. My son got a hockey stick, a hockey helmet, and he's working on a football now.

All summer long they were totally disinterested. My wife couldn't get them over there. She couldn't get them over there the first week of school. Last Monday, after three hours she had to physically drag them out of there. They finally catch on.

I've got a friend who is a Stanford professor, and he's taken the same concept, that idea of reading, English and grammar, and taking it into the mathematics world. His son in one year, on a special elite program over at Stanford University in the last nine months went from second grade mathematics to sixth grade mathematics on an interactive program there at Stanford. Now, of course, John Newkirk is trying to take this into the commercial world.

Let me just throw out the idea; Bruce you touched on it briefly. Once we get up to about page 10 or 11, we just get caught in the idea of word processing and text. Is there a way that we can use computers to stimulate learning? When I go to Asia and I go to Europe, I think what we are finding there is people are buying these computers. They are justifying it for work and for education, but the education turns out to be more fun and games.

Panelist: You've hit on some very sensitive issues there. For one thing, until every school room in the United States has computers, and enough computers for everyone to use, and they have the necessary connectivity to the Internet, etc., and the necessary budget to buy the appropriate CD-ROM software, we are going to be facing a very troubling issue, and that's the haves and the have nots.

There will always be people like my daughter and your children who have access to this. When they go home from the store they will probably have the capability at home to extend what they've learned at these store fronts. Until it becomes more of a societal issue and we don't have this class of haves and have nots, it's going to be a really difficult one to deal with. Who's going to take on that role?

Panelist: It's an interesting issue. I was the Home Business Development Manager for Home Entertainment at Apple, and they didn't have an Education Development Manager for a while, and so I had to work with the Home Education Group quite a bit. I learned a lot about how the computers are used in the schools.

There are basically two issues going on: One of them is to really use the computer as an interactive learning device, which has had a kind of mixed success. On the other hand, it's just the pure ability to learn how to use the computer. When I showed that chart of the people that don't own computers now, the one driving factor for them is the ability to learn how to use the computer; not necessarily to become better educated with the computer, but to be able to be competitive as a human being in the job market as they get older. There is a big issue within the school systems now. I am involved in my children's schools and through grants and so on they got a bunch of Macs and an Internet network and so on. On talking to the teachers, the thing that they struggle with is my child has one teacher to 30 students. The issue is I as a parent would like to get that down to one to ten for the teacher. The issue for me is do I want to invest more in the teacher/student ratio, or do I want to invest in computers? My belief is that in talking to the teachers they say that computers are great. They are great for rote learning, for interactive learning and some things. They can really bring an understanding and the knowledge level up in certain areas. They are really about 15% to 20% of the overall educational curriculum and experience that needs to be provided to the child. When we concentrate on computers only in the education area, we also have to bring in the teachers and how do those computers interact with the teachers and where is the emphasis?

Many of you saw or read a Michael Shrage article. He is the MIT fellow that does a weekly column for the L.A. Times. He talked about how in many cases we are really putting the emphasis too much on computer technology and not on our actual curriculum technology in effect. I am probably misplacing a word there.

It's an interesting issue. As Alean said, it's the haves and have nots. The have nots are really looking to the issue of being computer literate, not necessarily getting better educated using a computer.

Moderator: Jim, any thoughts?

Panelist James Hood:

I have a ten year old who goes to a school that is a very heavy user of computers. Again, they use them for the rote type of learning. They integrated them into their curriculum very, very effectively; but I think you're right. It's about 15% of the learning that is that rote type of learning. That's good, because it offloads the teachers from having to work as much on that. Still, it only works in a subset of the learning environment and in fact that school constantly has problems with getting software that is really well written from an educational point of view; so much of it has been written from a game point of view and the game stuff is just not nearly as effective in learning and in teaching as really well written educational software.

It is something that's evolving, but again I think it only takes a small part of the learning experience.

Panelist: I think one of the biggest issues in the business in working with developers that are in the education market, it's a very tough business to make money in. It's a long lead time sale. You're margins are very, very small. You have to have the cash flow and the low overhead to make it in the business. You may have a contract one year with a school system and then lose it a couple of years down.

From a business model standpoint, it's only the very tough and dedicated that can make it in that business as a business case. I think that's one of the biggest issues. The schools never have any money. The taxes keep getting cut for education. It's kind of a vicious cycle that we are going to have a hard time getting out of unless there is a bigger commitment.

Panelist: You can sell the games, but you can't sell the really good software.

Panelist: Right.

Panelist: That's kind of where the business is.

Panelist: If you look at it, there are really only two or three companies in the education business, and they own practically 90% of it. It's probably a billion dollar market total.

Panelist: I just finished heading a panel for the ITA on the east coast, and one of the guys who was sharing the panel with me (out of Intel actually), told me that there is a college - talking about the collegiate side of technology deployment - on the east coast that is being funded to provide all of its students at a freshmen level with brand new think pads. These students then get brand new think pads at a junior level, and these think pads go with them when they go out into the world.

Part of them is the clear seeding program that IBM is underwriting to make sure that the technology gets out into the market place, that people do in fact not only recognize the IBM brand and the IBM hardware, but the concept of a mobile computer and the concept of taking the work home; technology ennoblement.

Also one of the things that we were discussing quite a bit was this change in paradigm. As you go after the home market, and you go after these people that are not currently buying hardware and software - Mr. and Mrs. Six Pack (I kind of like that) - the paradigm really shifts. In the market place in the past what you had is a lot of money going towards development of products and not a whole lot of money going to marketing. Some certainly going to sales, your direct sales forces and whatever, but now as the paradigm shifts, and as we've seen it with the games which also penetrate in a number of areas in the home market place, most of the money actually goes to marketing, towards advertising and promotional activity.

To give you a recent example: The budget for Microsoft's Windows 95, to develop it was $120 million dollars. To market it for the launch was $300 million dollars. That's a 3:1 for marketing and development. Primarily to target that group of folks that currently is not buying hardware and software.

It really means that you have to shift your focus. You have to start thinking like Proctor & Gamble. You have to start thinking like a General Motors. You have to start thinking about what are the things that these guys want to do to move their products in the market place that wasn't the most educated or wasn't the most wealthy; that wasn't the most affluent I should say. People can watch TV and can be motivated by what they see on the tube. It's really a change in the way you think of the market and a change in the way you have to move products into that market.

Moderator: Let me get back on the technology route again, and let's talk about what's the state of the technology today? What are the bottlenecks in terms of taking multimedia into the home and into the office? Rob, do you want to help us start there?

Panelist: Well, a couple of clear ones: In the office place the biggest bottleneck right now is the network. Multimedia takes a lot of bandwidth. Pump video across a twisted pair and you just do not get an adequate performance. To get around that, of course, you've got compression schemes, but the only real way that you've been able to do it is by putting high bandwidth networks out into the corporate environment and that gets extremely costly, particularly if you are only using it primarily for education software and thereby you really can't justify that extra cost.

As technology has moved forward, obviously the cost threshold came down, just like it did for telephones, just like it did for automobiles, or any the other technologies that headed into the market place. That's one of the biggest bottlenecks.

The other side is hardware. If you've got 1,000 PCs in a corporate environment and you want to bypass the bottleneck, now you've got to deploy 1,000 CD-ROM drives. They may only cost a couple hundred bucks each, but a couple hundred bucks times 1,000 starts getting expensive. It requires the CFO's involvement, and once again it holds up deployment. It's largely monetary, largely infrastructure. Basically the technology has to move to a point in the corporate marketplace where you can deploy centrally multimedia applications. That's what has to happen before the cost really gets down to a point where it gets attractive to a lot of folks.

Moderator: How about communications? Talk about it both for the office, as well as the home; talk about both aspects.

Panelist: I think I'll probably start on the home piece of it. As far as the home, you've really got only two communication pads to the home: You have the twisted pair telephone service and you've got the coax coming from the cable companies.

The twisted pair is a fundamental limit. It works fine with a modem. The twisted pair that exists in the United States is now generally capable of handling ISDN, so you can get 56 kilobits. That's about the maximum you can get out of that.

That plant that exists has a book value today of $53 billion dollars. What it costs to install that was about $90 billion, and it still has a non-depreciated value of $53 billion. You don't just go start ripping that out and replacing it. Telephone companies have been installing a lot of fiber, but still when you look at the chief miles of fiber versus the chief miles of copper, it's only 3%, 5%. You're looking at a system that has a fundamental bandwidth limitation. I think realistically the majority of twisted pair that's out there can handle ISDN, so you can get 56 kilobits, you can get 256 kilobit line. Even on that they still are not the inexpensive interfaces as in your PC and inexpensive telephones yet. Those aren't on the market yet. The last time I went into a computer store, in fact I specifically looked to see if there was an interface box for ISDN, and I couldn't find one.

The phone network has a fundamental limit. I think that ISDN is about the maximum you are ever going to be able to get out of into the home. Again, it's a huge investment: 95 million subscriber lines in the United States. $53 billion dollars worth of value.

There's a plant that's pretty limited in terms of what you can do. It works great for the kind of applications that Allen talks about for people using on the Internet today. We use those at home and they work great. I think they work great. My wife thinks it's a little slow.

For those kinds of applications it's fine. When you start trying to get video and you start trying to get multimedia and you start trying to get more pizazz into the commerce, then you really are pretty limited by that communication path. That then puts you pretty much into the coax plant that the cable companies have put in. That plant; again that has a value of about $18 billion dollars. It took a lot of money. It took a lot of time to install that. Cable has been around now for 50 years or so. A lot of problems with that plant is that it's one way plant. It's broadcast plant. It sends the same signal to everybody. It certainly has the bandwidth that you want.

In order to convert it into an interactive capability, you get the reverse path. It's going to take an extensive modification of that. There has been some work done on that, but it is still a long way to go to be able to get high bandwidth, true interactive capability to the home.

Panelist: I think that the bandwidth issue is a fascinating one. I think one of the sort of almost disservices that the world wide web has done is it sort of projects the image of what could be done if you had ultimate bandwidth.

If you look at some of the more sophisticated home pages, and if you imagine that the person would have high bandwidth and you think of all the enhancements that you could add with sound and video and Lord knows what. I think what that has done is that has forced a number of companies, the teleco's, the long distance carriers, the cable companies, to sort of revisit the whole issue of bandwidth.

On one hand they know - as Jim said - to upgrade the bandwidth is an enormous task, an enormous financial task. After making money, the second question everybody always asks is what is going to be the one wire into the house that is going to eventually solve all of these problems? One of the things that Rob said when we got together a while back is it may be something that we can't even imagine as we are sitting here.

One of the things that I would propose that we have sort of been in the midst of an interesting phenomena in the last eight months or so; that's the advent of direct broadcast satellite. I think that the advent of direct broadcast satellite, which does not have a back channel as it exists now, has an interesting possibility. That sort of ties in with something that Rob mentioned about AT&T deploying a new satellite system to deliver technology. In addition to AT&T, two other companies in the last month have announced as well; one being MCI, and the other being Pacific Bell. Pacific Bell has moved its strategy from being a total LAN line operation to saying well, we'll do LAN line where it makes sense, but we are going to fill in the rest of the gap with satellite delivered services.

I think DBS has opened peoples' eyes to the fact that people are willing to spend $500.00, $600.00 for a dish to give them more programming options. MCI's solution is that we'll use the MCI long distance network as our back channel to provide them with two way capability. I'm a heretic. I don't know. I don't think cable or telephone has the answer. If they do, they sure haven't shown it yet. I think together one plus one does not equal two in this thing; one plus one equals zero.

Panelist: Direct broadcast satellite is one of the areas that I cover. I think that's only going to happen if you practically give it away.

If you look at the DBS market, it's largely been the traditional, rural areas that have taken it on. If you look at the shipment rates, the 2 million per unit shipment rate, which is the satellite market to begin with was in about 1 million to 1.5 million shipment rate.

Panelist: I would disagree with that. I think a lot of the problems in the early numbers with DBS shipments was the fact that one company had a lock on the patent and technology.

Panelist: The issue is does it have legs? Are they going to be fighting it out for the same 150,000 units a month, or are they going to be fighting for a bigger and bigger pie?

Panelist: The two things that I would say is number one: The thing that struck me is I saw the dish now at Costco, which means it's hitting mainstream. The other thing has to do with value. Can they offer enough value beyond just being a replacement for cable? There is a tremendous pent up demand of a lot of frustration over cable and the customer service and the fact that you pay a lot of money and don't necessarily get anything. Yes, there is a pent up demand and they are going to meet that.

Panelist: It has been my contention as somebody who has followed the cable industry - maybe not from as inside as you have - let's say that all of that could be resolved. Let's say that it could be done; it could be done cost effectively. I think cable has some historic problems that really stand in the way. Number one: They are traditionally terrible at customer service. You are talking about a very customer service intensive business. Number two: It's going to require people to have additional outlets put into their home. In addition, cable has not proven to be - as an industry - very good at managing innovation. Pay per view still is just a drop in the bucket.

Panelist: I think that says more about the end user than it says about ...

Panelist: I think they have done a very bad job at marketing and promoting the new technology, such as pay per view. I just don't that they explain to people the value. They don't give them value for their money. I think that there are a lot of sort of infrastructure issues beyond the technical infrastructure issues that cable really needs to overcome.

Each year the National Cable Television Association sets new guidelines for customer service, all of which are ludicrous compared to other industries of customer service. Until they get their act together, I don't think they should even bother investing a dime.

Panelist: Jim Kidex, who actually is the inventor of the hybrid coax, Jim was one of the two people who really came up with that concept and proved it to the industry. Jim is one of the first people that will stand up and say the cable industry has to learn to provide the people with what we are charging them for. Time Warner that he's with (I think) does the best job of that. That's still the best of a group that's not a real sterling performer; but I think that's an issue that also can be overcome.

I will make one comment to you: Your telephone is actually down more than you realize, but because it's not on 100% of the time a lot of times, you don't realize it.

Panelist: I would like to bring up another point about infrastructure costs. So much of what we see really in the multimedia market and telecommunications isn't just pure labor. So much of the infrastructure replacement is going to come down to labor. If you take out the labor component, the technology is actually a fairly cheap part of it.

We just did a big analysis of CD-ROM content development and went over the costs. I knew this from my film work that the single biggest cost is really in the labor. It really has no component related to the technology. What's happened is the labor costs have gone up while the technology has come down, but the skill level of developing content keeps moving up. We've talked to one of the largest developers of multimedia games, and this guy said he would be willing to pay $.5 million dollars per year for the right multimedia producer.

Those are issues which become a very, very important part of can we have technology that would wind up reducing labor, rather then increasing labor. We have an issue of greater and greater skill levels being required to deal with the technology. We are actually going like this based on the labor rather than like this, based on the technology.

Panelist: I agree.

Panelist: A lot of that is being shipped overseas; isn't it? If I recall, Bangkok was saying that they were doing an awful lot of content of production.

Panelist: I think if you look at the various components, the actual production, hand labor is being shipped to the far east in many cases. The Simpsons is actually completely drawn in Korea. The actual sourcing, if you are doing any kind of video or any kind of animation, generally you will keep that with your most highly skilled animators. Once you've found what the animation is, then it's just fill in the numbers and fill in the lines, then you can move it over to the far east.

The high skilled people, the really creative people that are doing all of the creative work, that's where there are very, very high costs involved.

Moderator: Let me see if I can change the subject here on the last leg of the panel. We've talked about a lot of cost issues, content issues, offering issues, etc. We're not all chip men here, but let's see if we can bring some of these ideas down to chips and systems. What I would like to ask you now is this, and I'll start with Rob again. We've talked about some bottlenecks. We've talked about the cost issues and so on. Where do you see semiconductors helping to resolve some of these bottlenecks, some of these costs issues we talked about. Any ideas?

Panelist: Certainly we are seeing that Intel's concept - and perhaps the trend setters - are bringing the technology down into the chip. Whether it's native single processing to get more video capability, I don't know another way to put it, this kind of technology; or the P6, which has much better performance to move multimedia types of applications or be able to display programs. Clearly the effort therein is to try and approach it from a hardware related chip.

On the other hand, you've got folks like Microsoft, and their view is to approach it through software, doing things like soft MPEG, etc;, trying to address it from a software standpoint and being somewhat hardware independent. At least in those two vendors, you've got two different schools of thought on how to approach at least one part of the bottleneck, which is the part that addresses the overall picture.

Moderator: What can chips do at the communications interface?

Panelist: Unfortunately you can't do anything about the labor issue or how much it costs to put this plant in. It is labor intensive. Certainly in terms of getting ISDN - as an example - as a commonplace in the residential market, certainly that's a matter of getting the devices, the cost down. That I think is very, very doable. That's not a stretch at all.

When you really want to move to the broadband network and into the true highband network into the home, again the interface device is now going to have to become far more sophisticated than it is today. If we are using digital video, obviously that set top box has to be able to do the digital decompression. We are looking at HP TV, so again that's a very, very semiconductor, specialized semiconductor intensive market.

Being able to extract, if I can really extract the information for my PC, my multimedia information for my PC off of that same broadband network. Again, I've got to have all of those devices to do that.

I really think, however, like we have talked about constantly at Dataquest, that that killer application that says people are going to start moving to the broadband networks and the set top boxes; I think we are all convinced that it will occur. We are probably not real clear on exactly when, and it seems like each year it goes a little bit farther out.

Like Allen keeps saying, the applications that people are using on the Internet today don't require a lot more bandwidth then they have. Those are good applications and those are going to grow.

What we are going to see is an evolution, just like we see in virtually all markets. As the demand exists, as the applications are really there that make people want to have this higher bandwidth and higher capability, it's going to increase constantly in the market for the ultimate bandwidth and for the circuitry that has to be associated with that in the home. Ultimately that set top box will be mass deployed. Bruce probably is more willing to predict what year that is than I, but it's certainly out there. Every step of the way, every step of the evolution the devices are going to have to be there in order to allow it to happen.

Moderator: Bruce, do you have any specific ideas or suggestions for our chip makers in the audience on what they should be focusing on?

Panelist: I think the thing is to work with a standard body more than anything else. I think that where everybody can, they do. I'm particularly excited about the 3-D engines coming up from the various developers. One of the things that I get a little stressed about though is - obviously I understand the motivation and the proprietary designs and approaches - but one of the things I think that really helps the markets grow is to be able to standardize on things like open GL for the 3-D market. I've never been a big fan of the work that's gone on in the video area, largely because number one: Video content is labor intensive. We are finding that anybody that's involved in video content is just blowing themselves right out of the market because they're not going to get the volume enough to be able to pay for the development and the software. The 3-D area is a whole new area where you can give developers and animators the ability to create whole new environments using these 3-D engines, which I think is very, very exciting. It takes us up to the next step up with some real value add on top of what we have; plus it can be fairly cheap. Also you're not necessarily depending on CD-ROM speed, which we are still having a problem with in terms of access rates. Obviously the transfer rates are going up and up and up, but the access rates when you are dealing especially with a twitch game isn't going to matter. You are still working at 200 milliseconds access rate and it really isn't going to matter.

I am just really excited about the 3-D area, and I would say that working for standards is really critical, because I think that is really going to open up the market. I think that is one of the great things about what was done in the MPEG area. Even though I'm not a tremendous fan of the video area right now - on the PC anyway - I am a big fan on the television area. One of the things that the MPEG standards brought was the standardization that everybody adhered to and then we're seeing the market expand based on the fact that developers could write to one standard. One of the problems we are going to see coming up in the 3-D area is which 3-D board is supported? Is it going to be the end video approach? Is it going to be the chromatic approach? Is it going to be the 3-D effects approach? Every one of these guys has got a different approach in terms of animation development.

I think standards and really working together, working with specific groups that you think will become the standard is really important.

Panelist: I think that in addition to standards, I think it's imperative that the technologists work very closely with content developers. When I say content developers, I am talking about a broad range of people from publishing aspect, from music industry, from the advertising agency. I think that it's imperative to know the kinds of things that they would like. They are not the technologist. They say well, I think that this is the kind of application that will work in the future. You build me the device and you build me the way to bring that to the home. I think the combination of the creative mind and the technological mind together will go a long way to bringing things down the road, building things that have value, building things that people will want to pay for.

Who knows? They may even address some of the infrastructure issues. If there are more things of value and applications that people are interested in, then you have U.S. West saying maybe it is worth the investment; or TCI or whomever. I think that it really starts with bringing the two cultures together: The technologists and the content providers.

I know from my background working at the newspaper, I wouldn't have gotten anywhere without the engineer to work with me and I would say well, I think the service should look like this and the service should do that. His job was to go out and make it happen. The synergy between those two industries is really crucial to getting this show on the road.

Panelist: Two really good examples in the 3-D area is Creative with what they did with the Glint chip, and then also what they did with the developers. They worked for over a year with their developers in developing and having games available when they start shipping; coming very, very soon here now. Also Rendition is another good example, where they worked very, very closely with two or three of the major game and animation developers, really working to have the game developers give them input on how to design the chip itself. I totally agree with you. I think there are some good examples in the market already of that going on.

Panelist: I do a presentation on how to partner. If you partner from strengths you're smart; and that's what really needs to happen here.

Moderator: I think I'm going to do this. I can sense that we are getting close to lunch time. We have a few minutes left yet, but I think I would like to have Joe make our final remarks. I'd like to invite those of you in the audience who would like to spend a little bit of time networking with us here up on the podium here; please join us here yet for a little bit of Q&A, one on one here in a small group here.

Joe, I think we are going to end it here; let you give our remarks and comments for the afternoon. Then please, those that are interested, come up and ask us your individual questions and we'll spend a few minutes with you here up until we are ready for lunch.

Joe Grenier: Thank you very much panel members.

This page is intentionally left blank

Chapter Eighteen: E-MONEY: ANOTHER HOT ENGINE FOR SEMICONDUCTORS

Colin Crook
Senior Technology Officer
Citibank

Colin Crook: It's my judgment that this is going to be the hot market for semiconductors beyond the year 2000. I'd like to explore with you as to why I think this is the case, and to explain to you money and silicon become infused together and are going to revolutionize the economy going forward.

I work for Citibank. I'm fortunate that my boss, the Chairman, is an engineer from MIT, so it's quite interesting having the Chairman of a large global bank also being an engineer from MIT. We are a very large consumer company. We have around 70 million customers globally. We are a global operation. We're prodigious users of technology. Technology has always been the basis for a lot of our competitiveness vis-a-vis other companies.

What I would like to do is spend a little bit of time giving you some appreciation for what's going on in the information economy. Just around the world's telecommunications industry, there are approximately 500 billion financial transactions that need to take place in order for all of us to make phone calls. There is an enormous number of financial transactions: Data processing, accounting, invoicing, all of which - by the way - don't create any value; in order to track people - not computers, just people - making phone calls.

A massive accounting/billing system is required just to run the phones of the world's telecommunication network. You don't have to be a rocket scientist to figure out what's going to happen when we have literally hundreds of millions of computers making phone calls and communicating with each other. The Internet is a good example of how this is not going to work.

To run the U.S. economy it takes about 200 billion small financial transactions with people like you and me shopping and so on. 200 billion financial transactions.

The U.S. banking system every day transfers the entire gross domestic product of the United States through silicon. I ship about $1 trillion dollars a day through silicon every single day within Citicorp. We move about $1 trillion dollars across our silicon chips. This may shock you. It may surprise you. That's the nature of how money in actual fact is information these days.

$1 trillion dollars within Citibank's flow through our systems, our networks, through our silicon chips onto disks, across communications network. We transfer to the Federal Reserve every day around about $600 or $700 billion dollars transferred across networks. You have a look at this and you realize that money is in actual fact information. It's the ideal product for information.

We're beginning to see already experiments taking place in the market where people are trying to get ideas of value and money, embed it in silicon (or variations of it), and start to experiment. Mondex is such an experiment taking place in the U.K., developed by National Westminster Bank. They are running a serious experiment to try to embed real money inside a small card in order for people to carry out financial transactions.

While it's being developed there, this ability to transfer value and carry out financial transactions across the Internet.

Digicash group out of Holland, run by David Chom. Smart Cash. Cyber Cash. The Financial Services Technology Consortium, which we started up with electronic checks.

There is a warning sign here. I spent a lot of time in marketing. What you are looking for indicates where there are beginning to be experiments. Whether these experiments work out or not is a separate issue. The point is the idea is very embryonic, but the idea of taking money and putting it into silicon and then using this as the basis for the transfer of value is already (I think) starting to be accepted. There are enormous numbers of problems associated with this, but let me explore this idea for you.

Here's the basic reason why this is going to be so phenomenal. If you think about it, most of the electronic transactions that take place focus on individuals and focus on companies. We carry out financial transactions between ourselves and so on and so forth. If you look at the way things are going, we are going to have literally billions, billions of information devices running just about everything. The question starts to apply that it's not so much about how people are going to transact electronically. The real interesting challenge is how are we going to account for the underlying economy that is going to be generated by all of these information appliances running everything.

It's going to be very, very interesting. If you begin to look, all of these information appliances - and I'm not just talking about personal computers, I'm not just talking about servers on networks - I'm talking about embedded systems as well. What would it be like if each of these embedded systems literally could have money inserted inside of them so they could in actual fact start to pay for services and also receive payment for the services that they generate. I would like to elaborate on this idea.

When I say money, I am talking about real money; money that is issued by the Federal Reserve Bank of the United States. We're not talking about tokens, company money. As people begin to look at money, there is going to be company money beginning to appear. Companies will be tempted to put their company money into silicon chips and then get this to be circulated in the economy. This is of concern to the Federal Reserve system, because there are going to be so many scams here, circulating scams and so on and so forth that you have to become very, very careful because there are two things which drive civilization among others: One is the rule of law; and the other one is we trust the money system. Once the money system is corrupted, that's a big problem for the economy.

What I am talking about here is I am not talking about digital tokens. I am not talking about company money issued by Motorola or Microsoft or Intel or Citibank. I am talking about money issued by the United States Federal Reserve system, the stuff we trust.

I don't know how you feel, but how many of you would like to sit at your computer and transfer $50,000.00 onto the Internet to the First Virtual Bank of Cyberspace? How would you feel? Would you feel comfortable typing at your PC and transferring $50,000.00 into the net? It will go the First Virtual Bank of Cyberspace. Money is different then everything else. We trust it and it's extremely important to us. I am talking about real money here; the stuff that's issued by the Federal Reserve Banking System of the United States.

What we are going to see (this is my view), is we are going to see every silicon chip in the future, every single information appliance will have money embedded in it. It's going to be the basis for the information economy of the future. You have no idea what it takes to account at the moment. It's a total waste of time and energy accounting for all of the underlying economy of the moment through classical accounting systems.

Here it is. This is what's going to happen. We are going to have the silicon chip, which will be the electronic purse, the electronic repository. This will have processing and memory embedded on it. By the way, the challenge is the more memory the better, the more processing the better. We just have an incredible appetite. If I look at what this chip has got to do, we have a voracious appetite for computational capacity and also for memory.

Here's an interesting requirement, and this is not just applying to electronic money. One thing we know a lot about in the banking area is security. Security is something that worries us. You have no idea what is going to be in the future. This is one of the biggest business opportunities going around is security.

We need tamper proof electronics, tamper proof chips, tamper proof coatings on the chips at the kind of volumes which are mass production volumes. I think you need to do it for your own sake in the future. We need it in our business as well. We need tamperproof coatings on the silicon chip so it's very, very difficult for people to get in this chip. This stuff contains real money. Once you put money into this, all of your creative skills will be applied to how can I get at this chip and find out how to get the money out of it. Therefore we have the capacity to say we must protect this. The actual conformal coating, tamperproof electronics, very important in the future.

Then this stuff will have secure and trusted protocols and of course encryption. These chips - and there is going to be an enormous market for it, is my forecast - will contain real money. I'd like to show you how it's going to be used.

Basically this is the problem in Cyberspace. When we are transferring value between each of those, we swap money and we look the other person in the eye and we are willing to shift money for goods and services because we trust the other person. When you start to operate across networks, even if you authenticate, you don't know who you are dealing with. This is the big problem here. Trust is a fundamental one. What we are going to see is any electronic entity, who wish to engage in electronic commerce, moving value between them, the electronic money, will not want to do it unless they have a trusted agent, a money agent, either a silicon chip which will in fact be the basis for transferring value between the two entities. You and I will be very, very reluctant in the future to pass value across networks unless this is done in an extremely trusted and secure way. That's why this is an extremely important opportunity. This applies across networks. It applies across any sort of infrastructure and you can see, and in fact I'll describe this and what's going to happen in companies; you will find the company budget will then be distributed and put inside silicon chips. Each person will have their budget inside their own personal computer. Then you will have to buy and sell your services across the information network of your enterprise in order to, in actual fact, to avoid the normal classical accounting system.

By the way, you'll soon find out whether you're doing productive work or not. Those of you who produce no value, nobody will be interested in buying goods, so you'll find out that soon you'll run out of money in your PC. Those of you who are producing real value, you'll find that you're suddenly in demand. That people will pay for your services. In fact, we'll have an information economy market within the enterprise.

The point about this is there is going to be an enormous opportunity for the trusted money agent here, which has got to be the silicon chip, which will be the basis of transferring real money within companies, within a car, within a home, between the home and the energy suppliers between the home and the telecommunications suppliers between the home and anyone supplying information services or products. This is the nature of what is going on.

In fact, these electronic devices will be the fundamental basis for the information economy. It will be part of the protocol. When silicon chips communicate with each other, I'm sure a lot of you know about communications, there will be a lot of time setting up the communications protocol. The overhead to send some money is part of that protocol is essentially zero. When we are negotiating between these two chips, in addition to all of the communications protocol, why not send some money as well in order to pay for the services each one's providing.

Unless we go to this approach, we will not realize the basis for the information economy we are all building. Building this enormous invoice and billing system is a total waste of time. We are going to go to this. This has got to be the underpinning for the information economy.

What is the future world? The future world consists of this enabling information network, the Internet, a bunch of value based services here, information knowledge. Just imagine if you could start to sell knowledge in very small pieces. Just imagine if you wanted to sell knowledge in the form of a group of pixels, a software object, a line of text, a piece of knowledge, a piece of data. Suppose you could do that at extremely fundable levels, very small levels, essentially zero accounting overhead. You just send the information as part of the protocol, you send them money, ten to the minus 12 cents. It's essentially no overhead to actually transfer the money.

Then we are going to see the electronic devices, the individuals and the enterprise. This is going to be the future world. All of these information entities tied together, moving information, moving knowledge, moving devices which contain value and paying for it as part of cash; real cash, issued by the United States Government, paying for it with an ease which is simply impossible before.

If you look at the way you run your company as I've described, you go through this enormous overhead of building budgets, etc., etc. Suppose instead of this you just got your operating budget inserted into your personal computer. You have a silicon chip, a money chip inside of your PC or your workstation. You get your annual budget loaded into there, $150,000.00; whatever it is. It goes into your money chip and then it's yours. When you want to engage and have a meeting, you go to the meeting with all of your co-workers. You are going to have to do a deal with each other. You are going to have to pay each other for your services. Don't forget: This is no overhead. There is no accounting system. You just pay there and then.

Everybody talks about virtual companies. This is going to be the underlying enabling mechanism for the reality of the virtual company to get together. We will all come together in Cyberspace. We will start working together and we will pay each other in real time, cash. If you are valuable and I want your services and I want you for three hours, I'll pay you $5,000.00. If you have no value I won't want you, or I'll pay you $50.00. This is going to provide the kind of optimizing economy which will provide the virtual enterprise to really appear.

You think this is crazy. You may think this is wacky. Let me tell you something, one thing we know a lot about is money and the way money behaves and technology and how these two are going to fuse together. This is going to be the basis for what's going to happen in the year 2000 and beyond.

It's this issue of microtransactions. You cannot in actual fact send software objects, send small amounts of value and have this fantastic billing system to pay for it. We should know this. It just costs a lot of money to send out an invoice. You look at this and it's the same amount of cost whether we send $1 trillion dollars or 1/trillionth of a dollar. It's essentially the same cost to move ten to the plus 12. or ten to the minus 12. For the first time now we can begin to engage in microtransactions with essentially zero overhead.

You can already see the warning signs. You log onto MSN and you can begin to see also it will cost you $0.05. It will cost you $0.25. You want an image? It will cost you $0.25. You want a piece of information? It will cost you $2.50. Just imagine what it's going to be like when you have your money chip embedded in and the money chip will negotiate for you and it will send the money without any essential overhead. You can engage in microtransactions, so people will be able to achieve a degree of granularity that will be phenomenal.

To finish off, let me describe to you what I think is going to happen beyond the year 2000, in the third millennium. There are going to be billions of electronic devices, which you guys build. All of these will be talking to each other in the home, in the automobile, in information appliances, in entertainment, etc., etc., etc. It won't be people talking to each other, it will be electronic devices talking to each other.

Instead of just sending multimedia; if you look at the whole multimedia industry, you have got to have some payment system built into it. If you don't have it, it's going to be a horrendous nightmare going forward. What you will have is millions, hundreds of millions and billions of information appliances talking to each other. Money will be transferred as part of the process of communicating with each other.

There will be literally trillions of financial transactions taking place without anyone understanding this, but as part of the way that stuff communicates with each other.

The old financial accounting system will ultimately be shown to be obsolete. Arnie Goodfrienders is a financial correspondent in New York and he's a little excessive with this statement, but believes that as we shift to an electronic money economy, it's going to revolutionize capitalism. You may think this is extravagant, hyperbolic and so on and so forth, but I think what I'm trying to give you is a harbinger of things to come. From my experience, and I've spent a lot of time in this technology area, you are looking for fundamental shifts and complexity theory. It is a non-linear world. You look for this. This is one of those shifts. This is a profoundly important shift in the way that it's going to re-shape the economy.

Banking is going to be re-structured. A lot of the old accounting systems simply don't measure to the modern world, we are locked with a lot of the old accounting procedures and so on and so forth. It's the ultimate process. It's the ultimate force for restructuring the economy.

We can see already today the kind of things which are beginning to shape our thinking. I don't think it's too extravagant to say that within the next 20 or 30 years, we are going to see some truly and profoundly revolutionary things.

We have the Smart Card Forum two weeks ago. At Citibank we helped start this about two and a half years ago with three or four companies. The one Smart Card Forum two weeks ago had about 222 companies. It's just grown amazingly. We received the first award for innovation by starting the Smart Card Forum. I pointed out that I first worked on Smart Cards when I was at Motorola in 1975. It's taken 20 years for Smart Cards to reach the level of volumes now round about 400 million units a year. It's taken 20 years.

The issue here is the timing: Whether this is enabling infrastructure to build this business. Let me tell you: My judgment says that we'll see the fusion of silicon and money fused together, and those two things I think will drive a fundamental restructuring of the economy going forward. How long will that take? How the hell do I know? 30 years? 40 years? I don't know. Already today we are running experiments. I have systems up and running which comprehensively implement this. It's not economical because we need more silicon memory processing for cheaper prices. That's just a matter of time. I'll tell you, the whole issue itself (I think) is already rolling along. The question merely is not are we going to do it, it is actually when are we going to do it? My forecast is that in the next ten years we'll see some very substantial changes in the appearance of true electronic money.

Thank you very much.

Questions and answers:

Question: (Inaudible)

Answer: It's going to come out through the market mechanism and through the trusted agents we'll negotiate with each other.

What's going on is really interesting, because what we are finding out in the information economy - and this is work that Brian Hoff has done at Santa Fe Institute - a lot of people in marketing don't understand that marketing in the information world is different. You get increasing returns, not decreasing returns. The market is not always optimal, and people are in fact irrational.

Given those conditions, you will have a market mechanism; we already do this on FX trading at the moment. You can negotiate and trade across the net and set the price and negotiate. That's what will happen here. You'll have a negotiating market mechanism. In fact, there are going to be some very compelling things.

If you look at how Netscape launched, they understood very clearly the fact that you get increasing returns. Give away the software; the first rule. Get it out. Give away the software. Have a distribution system that permits you to have mass distribution in the network and just get it out there very, very quickly.

There are these enabling mechanisms. In the case of negotiations, we'll have a market mechanism to negotiate them. This can be done extremely quickly and it will be trusted agents setting up markets. You'll see markets beginning to appear in the network, which are markets for different types of services. You won't come into the market with no pre-conditions. You will come into a market where there is already some existing sense of value and price.

Question: (Inaudible)

Answer: This is a big problem for them. That really is true. It's a real problem.

The problem is how is the government going to collect taxes on this set up? I talk to the Federal Reserve System quite a bit, because they are trying to struggle with what's going on. This is a big, big problem. Money flows across borders is going to be easy. Everything is going to be a cash base approach. When you want to avoid taxes, what do you do? You engage in tax transactions. This is a real problem.

I work on this Congressional committee on cryptography, and we are already worried about transported data flows. They don't know half of it yet. Just wait till cash starts to transfer across the borders. You don't know what you guys are doing. You are creating an immense amount of problems. That is why this is a big, big worry. Part of the problem the Feds are having is worries about fraud. Just think how easy it is. Printing money is not difficult, but it isn't easy. Just imagine if you put real money in electronic form and turn all you guys loose on breaking into chips, and then just imagine once you've broken into the chip you can then synthesize large amounts of money very quickly. All of you guys will be rich the old fashioned way. I won't earn it, I'll steal it. This is a big worry. If you look at what we're paranoid about, detecting break in and have to contain it and all of this kind of stuff; but a super question. The government is going to be left behind in what's going on here. It's a big problem.

Question: (Inaudible)

Answer: You need a trusted agent to represent you in Cyberspace. The question was that individuals are very nervous they are going to get paid it their electronic salary is paid into their Smart Card, whatever. They go through the doorway and they get pulsed with a little piece of radio frequency that extracts all of his salary in essence. He says what do I do about this? I said you need a good trusted agent to represent you in cyber space.

This is really true by the way. There is going to be enormous business on how to represent yourself in Cyberspace. The so called trusted agent, your digital persona, who is going to represent you? You better trust this chip very, very well. You will not exist except by this chip in cyberspace. The way that you are detectable in the economy in the future, you are in actual fact fairly irrelevant as an individual. It's the way that you are represented in cyber space that counts. You'd better have a good silicon chip to represent you is my advice.

Question: (Inaudible)

Answer: Yes, there are various techniques, and that's one of them. All of this weighting of tolls is an absolutely useless waste of time. The whole issue comes down to crime. People are very clever. The big worry constantly is you set up this stuff. What's it going to do in the way of making it more difficult to extract money out of it. Yes, it's an important way to extract money and so on.

Question: (Inaudible)

Answer: No, I was trying to point out this is not really going to be represented by people in the future. There are going to be hundreds of billions of silicon devices operating. They are going to run the economy. They are going to run the home. They are going to communicate with each other.

In the year 2005, you'll have what? 15, 20, 30 processors in a home. These are going to be working and negotiating, deciding about buying energy, optimizing the house, buying services and so on and so forth. You're not going to be sitting down personally trying to control all of this. I don't think so. You're trust the algorithms are correct and all of this stuff, and these will then start to negotiate with the power company, the telephone company, utilities, with each other buying information and you can negotiate the multimedia channel. You will bid for your favorite program and it will become a market. Of course it will. There is no demand that you'll get it cheap, but there is a big demand that it will jack up the price. All of these devices will be doing it in a way of communicating with each other. It will transcend beyond people. It will be the devices themselves, as part of their total structure, will be communicating with each other and transferring real money beyond the year 2000. This is what I think. Not just individuals, but electronic devices, silicon chips.

Chapter Nineteen: SYSTEM LEVEL INTEGRATION: PROFITS ON A CHIP

Panel Discussion

Moderator

Bryan Lewis
Director and Principal Analyst, ASIC Service
Dataquest Incorporated

Panelists

Brian Halla
Executive Vice President, LSI Products
LSI Logic Corporation

Donald Ciffone
Vice President and General Manager
VLSI Technology

Hirokazu Hashimoto
General Manager, System ASIC Division, LSI Operations Unit
NEC Corporation

Gary Smith
Principal Analyst, Worldwide EDA Service
Dataquest Incorporated

Moderator: Good afternoon and welcome. We are entering a new era of electronic systems design. We at Dataquest are now calling it System Level Integration or SLI. We now have the technology to put 5 million usable gates on a single chip. With such high gate counts, we can no longer work on the gate level, we must be on the block level. We must have solid design re-use in order to achieve these high gate counts. That is the focus of our panel today.

My name is Bryan Lewis and I will be your host today. It is my pleasure to be here. This is my eleventh Dataquest conference, so it's quite interesting and I see a lot of familiar faces out there so thank you all for coming.

System level integration is a new term and a new area of focus for Dataquest. We are using this term because we want to broaden the horizon. We could call it system on a chip or systems on silicon, but we believe that a lot of the functionality will take place in software, as well as in hardware. The definition of system level integration is that it must contain memory on the chip, it must contain logic on the chip, and it must have a compute engine on a single chip and it must exceed 100,000 useable gates.

This is a working definition. Over time we will start pulling in some of the software revenues into our numbers. You heard Mr. Davidow talk this morning about how there are going to be many software and hardware co-designs. That's why we have left our definition a bit broader by calling it system level integration.

The market for silicon today is about a $500 million dollar market. We expect that to exceed $5 billion by the year 2000. Clearly this is a market with a lot of growth and there are a lot of interesting issues involved in this market place. There are many high volume applications emerging that are going to use this technology. Just to name a few: We see the personal electronics, video games, set top boxes, portable computing, portable communications-including cellular phones and multimedia. We heard the presentation from Mr. Patterson on Chromatics about system on a chip going into multimedia, and that is a prime example of putting entire systems on a chip, and also using software to enable some of the functionality.

If designed correctly, system designers can get many benefits from putting systems on a single chip. We can have improved design cycle times and improved flexibility so you can alter your design if it's in VHDL code. You can alter it very quickly. You can get improved performance. In some of the systems in ATM applications we're seeing that you can get as much as 10x performance if you put the entire system on a chip. You can get improved functionality, which is really key. Then you can differentiate your systems in the market place.

When you take the number of chips down, you get a smaller printed circuit board and get reduced costs, if you combine that with the system differentiation, the key to ultimate success is that you have improved system differentiation and you have improved profit margins. We all want improved profit margins. If the system vendors get improved profit margins, so can the chip vendors.

Today we have many distinguished guests on our panel that are leaders in the system level integration market. You can go ahead and read their bio's to find out the details of them, but I wanted today to quickly move into our panel discussion, so I'll introduce the members.

First of all, we have Brian Halla here, from LSI Logic. He is a Vice President at LSI Logic. LSI Logic, as you know, has in the past, had some rocky roads. Over the last couple of years LSI has really become profitable. One of the keys to their success is moving more towards system level integration and coreware design, having large functional blocks on a chip is key to their success. I think that's a good portion of why they are highly profitable today. They are a leader in the market place.

Next we have Don Ciffone from VLSI Technology. VLSI Technology is also a leader in this market place. They too are a public company and you've probably seen that they are very profitable these days. They too have seen the light of system level integration and have really started to push that technology hard.

Next we have Mr. Hiro Hashimoto from NEC. Mr. Hashimoto has been with NEC for many, many years and has worked in the ASIC business for a lot of years. I met him when he was with NEC in Mountain View when he ran their ASIC division in North America, so he is very familiar with North American trends. Now he is General Manager of NEC Corporation on all ASIC technology moving toward system level integration.

Next to him we have Gary Smith. Gary is our EDA analyst. He is on the panel today to give him some views on the EDA industry. Sometimes I joke with Gary and I call him a tree trimmer, and you may wonder what I mean by a tree trimmer. Sometimes he gets out on a limb and I think today he could be out on a limb on many issues. Let's hope he doesn't go to far and break the limb.

Welcome, and please welcome our panel members. The format today; we are going to try a slightly different one then you have seen in a lot of these earlier panels. I am going to ask a series of questions to the different panel members to get things started, but today I really want an interactive panel. I am hoping that you will help me out here and ask some questions, some penetrating questions to stimulate some discussion here. It's okay if you have a particular question, you can go ahead and ask it. We will be on a first name basis here, that's okay. Let's have it interactive and let's have some fun with it.

The first question here: What do you consider - Brian Halla - to be the most critical ingredient for market success for systems level integration players?

Panelist: Thanks, Bryan. It's actually three things and they are all intertwined, no one more important than the other two. The three things are first of all a deep submicron state of the art process technology so that what you can put on a single chip, the system you can represent isn't in any way limited by the technology, but by man's imagination. We are there - as Bryan pointed out - at 5 million usable gates on a chip, and even going beyond that.

The second is a library of intellectual property building blocks which are not cells, but blocks that support standard protocols, algorithms and even instruction set architecture. When you look at some of the systems on a chip that are pervasive today and the data highway that sets up decoder boxes where the elements are not gates or gates, but things like MPEG and Viterbi and Reed Solomon and Qam and QPSK, and maybe even some mixed signal up front to do the clock recovery; a robust library of building blocks to go with that deep submicron technology.

Third - and every bit as important - is the technology and methodology to stitch together those building blocks, such that the resultant final circuit works the first time and insures time to the market to the customer, that it can all be clocked and it can all be tested to make sure that you can do the same thing in terms of time to market and the integrity of the circuit of when it's blocks are stitching together of beyond just cells.

Moderator: Good, thanks Bryan. Don, how about you? What do you think are the most critical ingredients for market success?

Panelist: I think methodology is also a very key attribute, but we look at it from a little different perspective. I think specifically cell based methodology is going to be the defining principle that will decide the winners and loosers in this market place. The degree to which you have a leadership position in bringing cell based products to market is going to determine your success.

You have to tie into that, however, a strong systems understanding of the end application that you are supporting. What we have seen happen in this market place over the last couple of years, and the reason for the turn arounds and success of some of these semiconductor companies is that they have a better appreciation for what systems problems they are trying to solve for our customers. In fact, we understand that how we define products now is much different then it used to be in the past. In the past we provided silicon to our users. Today what we have to do is provide the vehicles which make that silicon usable by the customer. In some cases it's comprehensive application software, development tools, extensive collateral, and maybe multiple elements in a library that play together and applications such as cellular telephony. What we have seen in fact is not only is cell based methodology changing the scope of the market by enabling many applications, but it's also changing and shaping how we define products for the future.

Moderator: Thanks, Don. Hiro, what do you think are the most critical ingredients?

Panelist: A couple of points all of these other people mentioned, but I would like to mention some other points, starting with organization is very important. It used to be that the semiconductor company organized product by product. To talk about systems integration, organizations should be more market oriented, applications oriented. This kind of organization is very important. Another important thing is submicron technology. Already people talk about system books, those books need more medium gate blocks to accomplish this kind of design. This submicron technology is very important. Finally: Even when a design is complete, capacity is also very important. These points are important to participate in this system level integration.

Moderator: Thanks, Hiro. Gary, how about attacking it from an EDA point of view?

Panelist: As an old methodologist, I have to say methodology is obviously number one. That sort of exists today and there are core companies who can really do this and we are lucky enough to have three of them up here. Those methodologies are really starting to come together in at least a handful of companies.

One of the major problems that we have today is in the standards issue in the library world. These system level macros, as we are starting to call them, are very difficult to deal with. One of the mythologies that we have in the industry - some people like to call them smoke and mirrors - is that you can take black boxes, drop them in silicon and route the things and you'll have a system level design block. That just is not true. I have yet to see - and there may be one or two out there - but I have yet to see a successful design done which in essence at some point wasn't done at the source code level, where you really had access to the macro to do some sort of modification to the macro and really integrate that macro into your total silicon design. That's a definite problem today in that obviously the vendors that are doing the work today only trust a handful of companies. This whole system level design issue is now being restricted due to the fact that they have no real good way of developing a system level micro that's modifiable, yet secure, as intellectual property. I think that's a key issue that we have to face today.

Obviously as a EDA guy, although I came out of the ASIC business, it's access to a good process. You don't necessarily have to own it. I think that the last generation of the people who do have the FABs and do know the processes really are doing the work to get to where you need to go to do these designs, but there is no real reason why a FAB has to in fact be owned.

Moderator: Thanks. So clearly design methodology, intellectual property, process, system knowledge are critical ingredients to this. Let's attack a few of these pieces, and then I'll open it up to the audience shortly here.

Bryan, what forms do you think are critical to have your libraries in so that you can have good design re-use?

Panelist: I think you have to have a library of hard macros, where those macros are optimized and tuned to the exact silicon. To pick up from what Gary was saying about the EDA community, if you think about what's happened in the industry over the last five years, whereas the silicon suppliers have advanced gate densities by a factor of 50, going from 100,000 gates on a chip to 5 million gates on a chip in just five years, the EDA community has had the opposite problem with just the tools they have. It used to be okay to just support them on a sun spark station and your job was done. Now they have five standard platforms that they have to support their tools on. In the software business, 70% of the cost happens after you ship the product. Instead of advancing methodology by a factor of 50 - they have actually kind of retreated.

I think that the form the cores need to be in are hard macros tuned to the silicon. For the EDA community, I would recommend that if they want to play in systems on a chip implementation, they should line themselves up with a silicon supplier and work together to provide innovative solutions, instead of yet another VHDL compiler, yet another floor planner, but to do things that are actually linked to the deep submicron technology so that we can advance those together. Things like the coreware methodology that LSI has.

Moderator: Don, how about you? What do you think are the most important forums for the intellectual property?

Panelist: I agree. Certainly you have to be able to have them defined in high level languages. You have to make ease of use the term at issue and also interoperability. I think where the tool guys have fallen down is that they haven't always pushed standards as hard as they should, they haven't always pushed the issue of interoperability. They've left that to be solved by the silicon suppliers with their customers.

I think you'll see some of those folks now moving to a model that tries to put design centers out in the field to patch the holes in the tools relative to interoperability so that they can make the experience more effortless to the customers. I think clearly where they can provide the most value is trying to optimize this interface.

Moderator: Okay. Hiro, what do you think in terms of VHDL code? Is that going to be one of the critical ingredients?

Panelist: I think so. In the past we tried reverse engineering, like the microprocessor - for instance - 1.0 micron technology to .75; this is also a joke.

NEC has a couple of divisions: The ASIC division, the micro division and the system micro division. We use the same sorts of technology, and we force them to use VHDL top down designs.

Moderator: One issue that comes up here is clearly when you are dealing with a lot of standard products, and you have a lot of standard products in your portfolio, a lot of these things are not in VHDL code. It will be interesting to see how different vendors try to get all of this into VHDL code, as well as still play in the standard product market.

Gary, why don't you tell us a little bit about what you think on whether the third party tool vendors will play a major role in distributing intellectual property.

Panelist: There are two groups coming out. Obviously there is a camp, and the EDA industry is split between a camp that thinks they want to control the intellectual property, and then there is the other side of the EDA world that wants to assist the ASIC vendor with handling the intellectual property, which means making the proper libraries, making sure it's hooked to the silicon. We are seeing a split in the EDA industry.

There is this third party group coming up, and basically they are companies that are collecting intellectual property. They collect all of these macros, system level macros, and the idea is that they will then provide these macros to the systems designer and then he would be in some cases, and it depends upon the people you're talking to, he would be then free to go to any FAB TSMC Charter - whoever he wants to go to - and there will be system level systems.

I agree with Bryan that one of the things you have to understand is that once you pass 80 megahertz, if that VHDL description doesn't go down to some sort of silicon implementation, it just ain't going to work. You might get it up to 70 megahertz, you might get it up to 80, but it's going to be a real hard try. There has to be a connection with silicon.

Some of these guys are looking at connecting to various foundries with this thing. I think it's a real hard job. I think they are going to have a hard time getting all of the macros together. They are gathering IP from various consultants and various places, and then trying to get them hooked tight enough into a foundry that they can really make this possible. I think they're something to consider. I think they are a threat to some of the ASIC suppliers. I also see many barriers to try to jump over.

It's going to be interesting. Somebody might come up with a way of making it fly, but so far it's a real hard job.

Moderator: Okay. This is open to any of the panel members. Who do you think will have the most IP in this market place and why; and who will be the distributor?

Panelist: There are two types of intellectual property: There is the cores themselves. We've been banging away at this for five to six years. There's another type of intellectual property, which is the actual methodology to stitch these things together. We have tried to not get ourselves in a position of having to actually evangelize the intellectual property so much as we evangelize the stitching to make it work the first time. All of the cores work the first time. They are all predictable, pre-verified, pre-synthesized, reusable, and then it's the stitching - to us - that's really the key. The building blocks themselves, almost everything in our library you can find somebody in the business of generating that piece of IP as a standard product. It's being able to stitch together half a dozen pieces of those pieces of IP into a single piece of deep submicron silicon and have that work, have that run at not only 80 megahertz, but 100 megahertz, 200 megahertz, and solve the problems of cross-talk and power management and signal integrity and packaging. All of that comes together.

Panelist: It is going to be such a big market. There are going to be several people playing at different ends of the market. As Bryan said in his introduction: What's happening is you are starting to see a stratification of participants. Those folks that are still fighting it out at the gate level implementation, those folks that are trying to distance themselves with the methodology and be able to do true systems level integration. While I agree that the way that we integrate that is the predominant way that's going to allow us to differentiate and be successful, I think we also have to somehow take into consideration that a lot of these systems that we're providing solutions for are very complex. They are computer systems. They are also communications systems, which then start to bring in RF issues. There is a whole host of application software associated with development tools for a lot of these applications that we're getting involved in.

I think the companies that are going to be successful are the companies that focus on these vertical markets, leverage the integration technology and the base technology effectively with the thorough understanding of the applications they are going after; a much different model than what was proposed by the ASIC market place over the last decade. That's where you are going to see the difference. The people that can do that at a higher level will be the people that win and the people that are the most profitable. The people that don't will be the want to be's.

Moderator: How about we open it up to the audience. Intellectual property is a critical issue, and there are many issues surrounding intellectual property. Can we take a question from the audience on IP, please?

Question: Bryan, let me address this to you first and then maybe the other panelists. You already have a pretty rich portfolio of IP, but as you go forward now and try to get other cells and other building blocks, other subsystems; how do you acquire that IP from others? Do you license it? Do you buy it? Please give us an idea of how you continue to enrich your library; then any other panelists who want to comment on it.

Panelist: I think that's an excellent question. When we first started this, as Don pointed out, in order to be able to put a system on a chip we either had to pretend we were a systems company or go out and work with vertical systems strategic partners who told us what those building blocks had to be. At that point - and this started (like we said) about five or six years ago - we went out to either develop or acquire those building blocks. What we found over the years is that this has somewhat of a self-propagating kind of a characteristic in that companies like - for example Rambus, that was one of the speakers here - have actually seen our core library as a marketing vehicle for their intellectual properties, so they work with us to put that into our core library. It has a way of self-propagating.

What we didn't do over the years is ever go out and try to develop something and hope that we could sprinkle it out in the market and some industry will grow up around it. In almost every case the intellectual property building blocks that we either developed (and 95% of them we developed), either developed or acquired, were the blocks that our system partners told us to acquire or develop; and our systems partners have typically been the trend setters, because you really don't like to have a trail duster tell you where to invest your R&D dollars. That has worked out very, very well for us. We will continue to do that as we move forward into the vertical segments that are strategic and fast growing.

Another one for us will be wireless. We're busily accumulating and developing those building blocks today for a single chip hand set.

Panelist: We recognized several years ago that we had to compliment our IP design capability with some systems development. Because a lot of times, as Bryan was saying, you do have customers approaching you because of the nature of our business. Some of them are smaller in size and some of them are larger, that want to propagate standards. They want to use this as a vehicle to help propagate standards in the market place.

What you also find is you have to have some level of systems expertise inside of the company that can decide whether that's the right thing to do or the wrong thing to do, and then look at the other elements providing that integrated solution. One of the things we found early on is once you get into this - for example - if you look at the cellular telephony market place, we started off with a base band chip set solution. What we quickly found was when we went to go sell the base band solution, then the next question was what do we do for an RF solution? We tried one business model that says we reference sell it. The next question was what do you do for the software to make the base band and the RF work together, and how can you do that at a price point that allows us to be competitive in the market place? We quickly realized that we had to get enough understanding, either through internal means or collaborations, to encapsulate that total solution of the market place. That was a dramatic change in the way we looked at the market place.

Moderator: We have covered a couple ways of getting intellectual property: Design it with a customer, design it yourself for the market place. What about the third party vendors? The tool vendors as well as the third party library vendors. Hiro, would you like to comment a little bit on that?

Panelist: Yes. Third party vendors are also very important. At this moment a lot of customers are looking for vendor independence. Some customers do not want to come to everything by increments, like Motorola. Customers are not experimenting. They recommend to us third party microcomputer companies and so on. To use the third party vendor is very important to increase attractiveness to some specific customers. Of course, many have CPUs and DSP and MPEG and you have all of these kinds of CPUs. The customers want vendor independence. You have to use some third party labor.

Panelist: One of the things I was going to say about the third party is that we have seen as fast a pace of introducing new technologies. We are introducing a new generation just about every nine to 15 months. Keeping up with the cell library development is almost impossible for our resources as fast as we grow them. At any given point in time we're working with as many as eight to ten different vendors of memory elements and cells. There are a lot of good people out there to do that.

What we have tried to use our resources to do is to advance that beyond cell base, certainly beyond gate array, beyond cell base;

into a core migration capability. We are working on tools today to migrate the entire core. For example: A MIPS processor of 105,000 cells, we want to migrate the entire processor from a .5 micron to a .35 micron. Those are the kinds of tools that we are working on internally.

Panelist: You are seeing application specific tools that are being built. This has just started. We just did the first DST designs last year, so this is a new, new trend. What you are seeing in these application tool sets is that macros are being developed at the very high level, the behavior level, that at some point has to be turned into silicon. I can see that as a source of intellectual property. It is going to be a question of who can control it? Whether that will be passed down to the semiconductor, the ASIC house, whether the system house that does the developing keeps the intellectual property, or whether the EDA companies does the work, keeps the intellectual property. This is going to be a big source of new macros. This is where the new Sans are really being developed more and more is at this real high level, behavioral level of design.

Moderator: How about another question from the audience.

Question: This morning we saw Mike Hackworth present a picture of many incompatible processes on a single chip, D-RAM, flash, RF, ASIC processors; how are you trying to solve bringing these incompatible processes together on a single chip?

Panelist: I think logic processes and D-RAM processes at this moment are different. To combine this sort of thing is not so easy. Of course, we can do it, but you have to pay the extra money. If people really think about combining D-RAM process technology and the logic products within chips, people need to pay extra. If the system takes, okay; but if not, it's very difficult to combine everything on one chip at this moment.

My view is to overcome this kind of thing you need a good year. Memory D-RAM; somebody said 32kb are necessary, somebody said 120kb. The two are very different. People need to spend money to overcome some of these difficulties.

Moderator: Continuing on a little bit, how important do you think having on chip D-RAM is to have a full system on a chip? Don?

Panelist: The thing I was thinking as I was listening to Hiro's answer and the question, because it is one that we wrestle with. You are forced to be in a position where you make trade offs. For example: A lot of the communications products require analog front ends. In the logic processors, you can make a double poly process, but then you trade off: Well, can I do it through design methodology and a single poly rather than double poly? What impact does that have on the performance of the interface? Can I still get what I need? You look at that trade off.

When you look at the D-RAM, when you look at the system partitioning, and you talk about okay, you can do 5 million gates on a chip when you get to .35 micron technology. Really the key thing is what is the most cost effective integration? That is the thing I was thinking of as you were asking your question.

What you look at is in today's world you want to be in the sweet spot of manufacturing, which is probably somewhere between 350 to 400 thousand gates on a chip. Depending on what process, you can get different levels of integration. I think what you are going to see in the area of memory and some of these other technologies is people doing trade offs between pulling that in and not pulling it in. If you look at what's so powerful about .35 microns - for example - that sweet spot of the process then gets you to 1 million gates. The magic thing about 1 million gates, is then you can start looking at doing an integrated set top box. You can look at doing some integrated things relative to computing and high end graphics. It becomes kind of a magic threshold.

If you look at .5 micron technology, that is probably a few hundred thousand gates. It's a very difficult issue that we wrestle with, and I don't know that this notion of complete system integration - as Hiro said - is going to be a reality in the near term. I think what you are going to see is people making system trade offs and trying to understand what the most cost effective answer is. In this euphoria of integration, really what we are trying to do is get the most cost effective solution to our customer.

Panelist: To the extent you can put a whole system on a chip, just because you can, people will ask for that. One of our graphics partners now is trying to figure out how to put two megabytes on a chip for frame buffer applications, and we'll figure out how to do that. We have to do that. Especially if you are a non-PC customer now trying to get D-RAM when there isn't some; it's nice if you can figure out a way to add it to the logic.

In addition to the D-RAM on the chip for high performance frame buffer types of applications, obviously mixed signals reduce some of the front end clock recovery. All of that ends up going on a single chip.

I remember the first single chip implementation we ever did five years ago was the Oki Laser Printer. It really wasn't a single chip implementation. It was one chip to implement the laser printer, and then there was another chip to do the RS 232 and the centron and parallel interface for it because at the time we couldn't mix those two, and now we can. I think just fundamentally, because of the manufacturing economies and because you can put so much more functionality on a chip, people will ask for it, expect it, and it will become a way of life.

Panelist: I think the graphics is a big thing. The D-RAM: If you are just doing the processor, D-RAM doesn't make that much sense. But you start talking about these graphics systems and you start talking about the bandwidth they need to get these things performing properly, to me it makes almost no sense to have any graphics D-RAM not on board with your processor. You just can't get the IO performance that you need.

Moderator: Real quick on the analogs before we take the next question. On the analogs - Gary, real quick - are the design tools there if you want to put analog on chip?

Panelist: The analog isn't a design tool issue. There are design tool solutions for that, but the problem with analog, always has been the problem with analog, until somebody solves it, it will be the problem with analog: You can't test it. Why put it on the chip if you're not going to test it?

What you do with analog - and you all know that we use phase lock loops and analog things in silicon; you build it and then you test the hell out of it until you are sure that the thing is bullet proof. Then you put it into your production process and it's not tested in essence.

The problem with analog is the testability within the manufacturing frame work. You put these IC's, the ASICs are going through the testers and they don't have a whole lot of time to look at the performance. Until we get analog testers perfected, or some sort of a way to start testing analog, no matter what the tools are, no matter what the macros are, you're not going to see a lot of analog on board.

Question: We heard in Bill Davidow's presentation this morning about the possible future where the EDA companies - Synopsis for example - are going directly to a foundry such as TSFC, basically is squeezing out today's ASIC providers. Why do you think that that's not the right model? What's the value added from the ASIC's applies?

Moderator: Any particular person targeted on that one?

Panelist: I think about the time that LSI launched Coreware, Synopsis launched Designware, which has - as far as I'm concerned - become Design Where? I haven't seen one yet. Fundamentally with .25 micron technology, you can't have generic, lowest common denominator kinds of works in any foundry libraries to do gunning transistor logic, pixel, phase lock loops; all of which are just base cases now in some of the more sophisticated courts. You just can't do that without tuning it to the silicon, optimizing it to the silicon, and solving the problems up front - and I mean up front - in the high level language description of power management segmentary, cross talk and so on.

I just don't see this generic, high level approach to these sophisticated circuits and ever come out of it with any kind of high performance circuit or a smallest dye size circuit. I don't think you get that from here. I think the EDA guys - The Synopsis's of the world - are going to be much better off lining up with a silicon supplier, working very closely to solve those deep submicron circuit kind of problems. That's why we've gone out and actually established relationships with some of the leaders in EDA in various areas.

Panelist: I think in my side, the EDA side, I think there are two answers to that: In one way I agree completely with Bryan, but there is the issue of the second tier vendor. In the ASIC world, the gate array world especially, there are the top four or five, or maybe six, it depends on how you count them. Then there are the other guys. I think that the technology available by the EDA vendors, third party vendors today, will in fact eliminate that market. I don't really think there is going to be a second tier group in this next generation of ASIC. There are going to be the guys that are sitting up here on the stage and then a couple of others are going to join them and then there won't be anybody else. You will just take your designs to some other FAB. If you wanted a really high performance, really state of the art stuff, walk up here and ask one of these gentlemen. If you want the other stuff, do design, take it to charter and TSMC.

Panelist: The other thing I think is kind of an interesting spin on that, just to give it to you from a different perspective, is that the foundries that they are talking about to run this material now are charging a lot of FABless guys pretty hefty premiums to ensure that they are going to get supply going forward. I think that one thing that might start to appear more on the horizon as an issue is that the price of entry, in addition to signing up to pay for the silicon for some of these FABless guys, they also need to put their technology on the table. I think the danger really is more to those second tier guys, maybe the FABless companies. What are they going to have to sacrifice in the future in order to be able to support their manufacturing plants. Companies that have captive manufacturing capability have some of the methodology and things we've touched upon, I think have an ability to compete with that model. I think the people really at risk are the people that don't have the manufacturing capability and are going to have to give something up.

If you look at the projections that have circulated around the industry, the foundry companies are still projecting a 20% to 25% delta in demand versus supply going out of this decade. If that's true, there is going to be a real scrambling to try and take available that capacity. People may get fairly desperate in terms of what they are willing to do. I think those are the folks that might be at risk.

Panelist: Back to Bruce's question about Davidow's presentation, I think both of us have always thought that Davidow's one of the best marketing guys that we've ever known, one of the best marketing feats he's ever pulled off was getting two of his start-ups and himself as key note speakers at this conference.

Moderator: If we could take another question from the audience. I'm sure this sounds like a little controversy here.

Question: There is a trend in voltage suppliers going from 5 volt to 3.3. There is a price premium for the chip sets and ASIC on a 3.3 board and kind of preventing industry from making a complete transition as soon as possible. When do you think the price crossover happens between 5 volt and 3.3; and what's the optimum process for a 3.3 ASIC?

Panelist: At least with LSI there is no price differentiation associated with 3.3 volt or 5 volt, and we don't intend to have a price differentiation associated with 2.5 volt and the G-10 technology. Basically you use whatever voltage is optimized for your system and all on the rest of your circuits on your chip. It's typically determined by the end application; whether it's a PC and it's a 5 volt application or it's some kind of a low end powered device, with 2.5 volts.

Except for the fact that some of the newer technologies support the 3.3 and the 2.5, I don't see necessarily any kind of a correlation. By the way, from our standpoint it's the newest technologies, the .35 and .25 micron, that allow us to produce the smallest dye size and get the best cost benefit to our customers.

Panelist: I think one of the things that we are hearing is I agree. Today we don't separate in terms of price or the difference of the power supplies dictated by the application. One thing that is a barrier, however, is analog. There are still some challenges when you take analog down to .35 and .25 micron technology and start running it at the lower voltage levels. Those are things that are being worked through. In terms of the logic portion of it, there is no premium; from our perspective anyway.

Panelist: A price per premium compared to 5 volt and 3.5 volt. Basically what we talk about is 0.8 micron and 0.6 micron. These kinds of things are not ASIC controlled. Memory people still stick with 5 volt. A main use of ASIC is memory control and so on. If memory moves to 3.3, then it's easy to move 3.3 volt with no premium.

Moderator: We at Dataquest in our end user studies are seeing that there is a slower acceptance to the 3 volt technologies. The 5 volt, some people are back filling their 5 volt families because 5 volt is hanging on much longer and we've seeing the 3.3 volt coming in and emerging and doing exactly what Hiro was saying so they can communicate with the 5 volt D-RAM still, because they are cheaper.

Can we take the next question, please?

Question: I think there is obviously no question that core base designs for ASICs are a trend. The question that I have is with respect to really how strong that trend is. If each of you could comment on the percentage of your revenue you are currently generating from core based ASICs, and please disregard just RAM, talk about a logic type core on the device. Also in two to three years, which designs you should have in your sights at this point, what do you think your revenue splits will be? Starting with Bryan in this case.

Panelist: I'm trying to recall the numbers. We're not very secretive about the numbers. We're ramping the coreware portion of our business very dramatically. I think in 1995, we'll do somewhere between 20% to 30% of our revenues. That may be a little bit on the high side of coreware based revenue. We were $900 million last year, that gives you kind of a feel.

One of the things that you should notice, coreware is not necessarily perfect for every industry. Some of the more mature industries, the PCs being a perfect example: We do a lot less coreware in the mother board kind of designs there then we might do in a graphic application for a PC. The reason being is that the chip sets are controlled by relatively small number of suppliers and everything is optimized by the cost of the chip set and to make it possible for a whole bunch of suppliers to offer the same thing.

Where we see coreware, or core based designs really pervasive is in these very, very rapid times to market, where the system supplier needs to put out literally a new generation almost less than each year, where the time to market is so important and to be able to increase the functionality with each generation by re-using what he had in the previous generation, adding more functionality, and then adding a differentiation on top of that. Some of those things, all of the new emerging data highway products like cellular phones, PDAs, video games, visual video disks, set top boxes, interactive set top boxes; all of those things are just relatively, rapidly, dramatically a fast growing market where time to market is very important. Functionality, cost reduction, power management; all of those things really call for the type of solution that coreware or core based designs can offer.

Panelist: We are probably running today somewhere between about 25% to 30% I would expect that next year that will probably grow 5% to 10%.

One other interesting phenomena relative to this core strategy, is that what we see is a lot of these elements we are doing a standard product as well in a modular way that they then can be broken down and embed portions of it. What you are going to see going forward, when we look at our revenue base also, is that some of these will manifest themselves in standard products, even though they are created using an ASIC methodology. What we are seeing today is a blend of those.

That's why when I talked earlier about the cell based methodology, we are actually to the point now where we call them cell based products, rather than cell based ASICS. It's a combination of standard products and cores.

Panelist: For ASICs in 1994, we just exceeded $1 billion dollars. In 1995, we are looking at $1.5. Our goal for the year 2000, we hope to have the majority in core.

Panelist: The core based design is also the fastest growing of our business. In fact, it's growing more than 100% per year. I would say that by the end of 1997, over half of our revenues on a run rate basis will be core based design.

Back to the issue of standard products: There are a variety of different ways that standard products make sense in the equation. One is just to put a standard product out there, like an MPEG, and demonstrate credibility for that technology and ultimately have that at the core.

Another way is if some of our system partners want us to take a coreware or a core based design that we've done with them and go out and take that into the market place and create a standard behind it. The standard products either show up at the beginning or at the end.

Panelist: It's really just a thinned out macro. Then they have to deal with how are they going to sell the soft version versus the hard version.

I think Bill talking about royalties was very interesting, because that has been sort of the bane of the industry ever since I've been in it. The worst thing you want to do is pay royalties to anybody. It's sounding more and more like that's the way it's going to go.

I think there is going to be a strength and weakness issue here, where you will have some of the weaker players with some very attractive cores. Those are the ones that are going to have to make those cores available to generate revenue so that the stronger players, the ones with the methodologies, know how to put these things together and get access to those cores. There are always lawsuits. There's no need for them if we take a look at this as the business proposition it really has to become. Lawsuits take so long, that in essence I think what you are going to find with the speed of the industry is that if you in fact do sue, you will take your product off the market until it's window is closed. There is going to be a great deal of pressure to put a system level macro out there and not get it all messed up with some lawsuit so that you can sell some volumes of it you need to make money.

Moderator: Anybody else want to comment on the lawsuit potential?

Panelist: I don't want to comment on lawsuits at all or even think about them, but litigation associated with a piece of intellectual property at a silicon level probably become less pervasive then intellection property at a system architecture level, where it's a collection of a variety of different kinds of things that will be important. At some point in time hopefully this industry can get moving forward without everything having to be tied up and in some kind of legal protection because then they have to close everything down.

Moderator: Moving forward: You really don't want to let your intellectual property end up in everyone's' hands, because that is how you can attract a high margin. Clearly there are going to be some new technologies that will have to come about to try to at least - if it's not a lawsuit - at least try to slow people down a little bit so they can't figure out exactly what you have in your systems.

I'd like to address this one to Don. What do you think about them? What will the encryption role play in the future of system level integration?

Panelist: We see a real burgeoning opportunity in the area of encryption and security. Basically our vision is that anything that stores or transmits information is going to need security associated with that system. Whether it's compute oriented, entertainment oriented or communications oriented. We see a real opportunity there.

If you look at most of the security solutions in the market place today, they are software based. Yet the demands and bandwidth requirements of many of the applications are becoming much more sensitive to performance.

Also security is becoming much more important. How comfortable are you floating your credit card on the Internet? How comfortable are you having your financial information available to other people through networking? I think we are going to see more and more need for encryption and security going forward. We are making a very heavy investment in this area, because we see that there is a real opportunity in the future.

Moderator: Anyone else want to comment on the encryption?

How about taking it one step further. If it's not encrypted, what role will the Internet play? Can you pull your cell libraries up on the Internet? I would like to address this one to Hiro.

Panelist: At the moment we are using the Internet to transport and also to send libraries. How to protect security we don't think about too much at this moment. We put some scrambling mechanisms in our library.

Moderator: Anybody else want to comment on the Internet?

Panelist: I just got my Internet up and I'm very excited about it, but we don't typically transfer any kind of intellectual property or data across the Internet. The real benefit of the Internet is to allow every man, woman and child to save the long distance call and be able to contact data worldwide on a local call, whereas our customers typically will either install a wide band LAN, A T-1 carrier, whatever, so that they can download their database back and forth.

We've actually as a company gotten to the point that we're not doing tens of thousands of designs. We're doing hundreds of designs and they are so much more complex and we will do whatever it takes to easily transfer data.

In terms of the Internet, our excitement there is we just put up our web page and we had something like 10,000 accesses the first day.

Moderator: Do you think in the future though that we'll see cell libraries actually ending up on the Internet as a vehicle to get widespread acceptance? How about you, Don.

Panelist: With the way it's structured today and the lack of security that exists in the system today, I don't really see that in the near term being a reality. We do have to figure out how to do a better job of electronically making information available to the user community, but I think there are too many security issues at this point that preclude that from being a reality.

Moderator: How about another question from the audience? Has anyone stored one up here?

Question: You touched a little bit on the issue of capacity. As a customer of most of you, .35 micron capacity isn't exactly coming out of all of the orifices today. How would you handle the issue of the customer asking you, the second source, for your designs. I would like all of your reactions to that; if I need a second source, how would you help me?

Moderator: We'll start with Hiro.

Panelist: Our company has a huge capacity for .35. We will ship that product this summer for our customer. Please think about some second sourcing. If a customer has a second sourcing in mind, we would talk to this guy. If a customer wanted to have a GDS 2 tape, we would talk to their GDS 2.

Panelist: We have a little bit of an advantage to second sourcing. As a development partner, we collaborate on libraries and also on process development. We have for about seven years now. We are co-developing the .35 micron process together. We have been working on it for about eight months.

In some cases where we are not able to support our customers, we do exchange customers back and forth to try to make sure that our customers are supported. When we go into this, we go into it with the thought that that is an option that's available, and if customers are interested in that option we help facilitate that process.

Panelist: First of all, just generically on the second source issue, LSI does not have a problem second sourcing if that's the customer's request. I'll take it a step further and say at the other end of the spectrum one thing that we have been trying to do from a management standpoint is manage our business such that the product market and customer portfolio is well diversified across several markets, several products, several customers; such that we're not dependent on the health of any one industry to make sure our company stays healthy. When that's the case, we also don't succumb to the insatiable appetite of any one customer, if they want to put a $400 million dollar order on us, unless then are willing to put the same $400 million dollar order on us every quarter, quarter after quarter, forever. I call that I don't want a home run in one inning that doesn't happen ever inning thereafter.

We actually manage to hold our business at a certain level. That means that we will actually initiate the second sourcing in some cases.

Also in some cases we have customers where we have transferred our process technology - and we will do so going forward - so that they can have an internal source for continuous supply. In those cases there's also a long term win/win relationship built into the contractual agreement.

Second sourcing has become a way of life. It load levels the FAB. It diversifies product portfolio. In many cases it's just a fundamental demand that the customer has to make sure he's got continuous supply.

Moderator: Second sourcing really does require a process compatibility. How do you really handle process compatibility without giving them the process; Don?

Panelist: In the case of Hitachi, we do collaborate on process development. We share information about equipment sets. We do R&D together. It is a process that we can transfer the science back and forth.

However, I would like to qualify that by saying that obviously we find ourselves in situations today where demand far exceeds supply for most of the semiconductor companies. We've had this relationship with Hitachi for a number of years, and had this as an option. But it's only probably in the last six months or so that people have even seriously considered it. I think it's more reaction to a short term delta between the supply demand equation that it's been an ongoing concern historically with our customer base.

Panelist: In some cases you can't. For example: Some of the most advanced deep submicron technologies utilize Tungsten. The industry is just coming up to speed on Tungsten, so you can't just automatically transfer your process and expect that the company will come up to speed. You try to find other ways which is an absolute customer requirement to make that possible. Maybe it's the transfer of a net list, and they figure out how to crank the performance of their own process. It's not always possible to transfer the process technology, although we try to be accommodating when we can.

Panelist: High end product and deep submicron is very difficult. It's actually almost impossible.

Panelist: I think in general the only time that works is if you have basically a vanilla design and extremely large volume. If you don't fit those two categories it just doesn't play. Because if you have low volume, you are in an allocation situation, you have X amount of parts which isn't a high volume, you are number eight on this guy's allocation list. You have to split your orders so you can be number 16 on his list tomorrow and 16 on the guy's list down the block.

Second sourcing is typically - and I can say this because I've been out in the industry for a little while now - it's a really bad idea unless you have a fairly vanilla design or some sort of an exact same process running in each plant, and you have a large volume that keeps the attention of both of the people you are playing with.

Moderator: How about another question from the audience? I've got one more. We're talking about system level strategies, and clearly Intel has its own agenda. We'll hear a couple of statements from our different panel members on how they think SLI will impact Intel's strategy, or any impact at all. Bryan?

Panelist: Back at Comdex in 1994, I think was when Andy Grove announced a native single processing and the CPU or the mainframe on the chip does everything in software. I think they have retreated a little bit from that position to advocate more use of DSP co-processors to do some of the graphics, video and audio functions.

This is part of the way that LSI has been implementing systems on a chip for a long time, putting a distributed network of microcontrollers all on a single chip, all tied together by many channels of DMA. There may be as many as 20 to 30 different S-RAMs to accommodate the various buffering schemes, latches, registers required by each of the microcontrollers and to do the handshakes through the DMA.

To me it's almost like the thought of putting a CPU on a chip is very analogous to the old mainframe days when the mainframe guys believed that everything was a dumb terminal talking to the mainframe that ran everything in software. In reality, those guys became the dinosaurs and the world moved on to distributed processing, helped by the workstation guys at Intel.

That's exactly the philosophy that LSI has applied to putting systems on a chip. We put many microcontrollers all tied together, optimized to the application and never constrained by the technology.

Moderator: Don?

Panelist: I think the key difference there is that the ability to embed the solution independent of what markets it's in, and the flexibility to allow the user to have an input into the control logic that goes around whatever that function is, is the key differentiator. Where we will win in the market place collectively as ASIC suppliers is our ability to embed solutions and offer immediate programmability to the user for those solutions.

A prime example is many people up on this panel have cores. If we were foolish enough to go into the market with a RISC core and do battle with Intel or

Motorola in the microcontroller business, we'd get our heads handed to us. The fact that we can take that core, integrate it into an ASIC solution for our customer, where applications that for us were quite lucrative, but maybe for these other guys they don't want to provide the flexibility. They don't want to have to change. They want to do everything the same way every time. We can carve out a market where we can be successful. I think all of us up here have demonstrated that there is a market for embedded solutions. I think that's where the difference lies.

Panelist: Think about silicon integrated solutions. Market segments are cross-referencing the PC and multimedia and networking and something. We are basically thinking of whole market segments.

On the one hand we have some interest in the PC area. In the PC area we have to take a look at the system logic, graphic accelerators and systems to be combined. The next step would be to combine the CPUs, networking and multimedia and games and so on, I don't think we have too much resistance from Intel.

Panelist: I think system integrations is making a change in that we are now forcing design up to the ES level. I think that's where you are going to see the major change happen. We don't know how to partition software and hardware. We don't have a clue. Basically we decide what's going to be hardware and then the rest we push off on software, and now you have Microsoft is trying to take over some of the DSP function in software and Intel is trying to do it at the CPU. Of course all of the DSP guys - Motorola, TI, AT&T - are saying it's mine, it's mine, it's mine.

Those wars are going on because we have no way of figuring out what's the real optimum implementation of the hardware and software problem. As the systems are becoming built now, at the electronics system level we are developing ways of doing that partitioning, so the answer becomes pretty obvious with the type of system. I think Mentor, as some of you probably heard, bought Microtech research on Tuesday, which shows the EDA world now getting into the software development world. I think the changes will really become evident when you get the tools that will be capable of doing a true electronic system level design, true hardware/software partitioning, and in my mind - and I'm a bigot because I come out of the hardware world - is that I think the demand for hardware is going to grow. I think there are far more problems with designing and developing software then there is in the hardware realm. We are fairly systematic about how we built hardware.

Hardware is faster. It seems to be able to come out actually on time more often then software does. I think the system integration level will drive the tools. It will drive more and more demand for system level integration.

Question: I'd like to maybe ask for a response from the other gentlemen, given the fact that there have been non-trivial challenges from an ASIC perspective embedded in these cores as far as power distribution, blocking, and the overall floor plan and layout. Now what you've done is you've put a controller on the chip and essentially you've caused an opaqueness to the controller from the person who needs software development, who is used to only having emulators, and especially half speed emulation. I guess the question is - especially for the gentlemen with more proprietary type tool sets - how are you addressing the software development issues for the embedded microcontrollers and processors?

Moderator: Bryan, Don?

Panelist: One of the courses that is quite pervasive in many system on chip designs for us is the MIPS instructed set architecture. Beyond the MIPS instruction set itself, we've provided several bolt-ons that can be turned on and off. One of the internal tools inside the MIPS processor that we offer is a DBX tool or a debugger, which is very similar to the old blue box Intel in circuit emulators, where you can do break points and trace and trap program steps and then dump it and monitor it. We actually can turn that on inside of the silicon, and when we get ready for final production just completely remove that silicon and that's one of the types of things that we're doing.

Another one is with every complex core that we do, we offer a system verification environment where the customer can start literally, immediately, designing to the timing shell and black box representatives of the core and the core timing, almost before the core even sees silicon itself. In many cases the SVE, the silicon verification environment, is really all the tool the customer needs to get the design 95% of the way there before he even commits it to a net list layout.

Panelist: What we realized when we said that we wanted to give ourselves a challenge in embedding these cores a couple years ago, was that if we wanted to really dominate the embedded part of that market place, the goal that we should aspire to would be to offer the level of completeness of a product that an Intel or a Motorola does as a stand alone solution. That would be the measure of whether we had an effective product.

To that end we have developed a graphical debuggers, development tools and boards that go with the processor. We also have operating systems that run in the processor that are offered by third parties. In fact, we use the ARM core and our limit is actually aggressively right now contracted with a couple of different third parties to create operating systems for the core to provide to licensees. We recognize that phenomena and early on we have development tools, operating systems and debugging. We also have emulation capability available for that core.

On the DSP side, both of us license the same DSP core from DSP group. They also provide development tools and software support for the DSP function as well.

I can say that we recognize that's an issue. We've invested in the software, as well as the hardware, on the development side of it. I wouldn't contend that we have as a clean of solution as the stand alone products at this point. That clearly is our goal.

Moderator: We are getting down to about five minutes to go here. We are looking for some closing statements. Why don't we start with Gary for a closing statement. What do you think system level integration will mean to the market place?

Panelist: I think system level integration is changing - is going to - is changing the entire market place. I think the system designers or the system vendors who don't understand its implementation, who don't put together the methodologies necessary to use it, will be going out of business in about five years.

I think there is a lot of work that needs to be done in DBA standards to enable the mainstream designer to use this technology. That is the biggest worry I have, because right now it's an elitist technology. There are only a few people that know how to do it, and those people that know how to do it are gaining major advantages in their market because of this knowledge. It's a major change in the road.

Moderator: Hiro, how about you. Closing comments?

Panelist: System level solutions' are the future direction. The most important thing is again libraries and also to have a very much customer oriented EDA tool.

Moderator: Don?

Panelist: I guess I put a little different perspective on it. I think if I challenge myself and my peers here, the requisite question is, "Can we provide value to you users of this technology?" The degree to which we can demonstrate value and providing integrated systems solutions, are the degree to which we will be financially successful and successful in garnering your business.

What's happened is the definition of a product, the problems that you are trying to solve have changed. We are trying to deliver to you speed flexibility and integration. - to enable solutions in these high volume application markets that you are trying to support. The challenge that we have is to demonstrate value in providing those solutions going forward.

Panelist: One of the problems that we all have is that we tend to be comfortable in the way things were in the past; it's what I call driving down the road by looking in the rear view mirror. I think there are three companies up here that believe you can put entire systems on a chip. The extension to that is when the customer base, when the system partners get educated to the fact that they can now re-define what a system is on a chip, we're going to see something so exciting in our industry that it won't look anything like the past. We won't have system technology that is in any way constrained by the technology. The technology allows you to do anything. You will see in chip systems that are optimized for whatever application you can think of. I think we are just getting to the point where the customers are starting to become educated. They can do just about anything to the limits of their imagination. They are not limited by technology anymore. I think that's when it gets really exciting.

Moderator: My closing comment would be that system level integration is rapidly emerging, as we've heard from our panel members. The time is right. Get ready. Analyze it. Be prepared for the future. System level integration will be here and it's well on its way.

Please join me in thanking our panel members. Thank you, the audience, we really appreciate you coming. Thanks again.

Chapter Twenty: NEW DRAM ARCHITECTURES: WHO NEEDS 'EM?

Panel Discussion

Moderator

Jim Handy
Director and Principal Analyst, MOS Memories Worldwide Service, Semiconductor Group
Dataquest Incorporated

Panelists

Hans Wiggers
Senior Memory Systems Engineer
Hewlett Packard Company

Paul Baker
Director of CPU Engineering
Apple Computer

Jodie Hughes
Vice President of New Business Development
Western Digital Corporation

Max Bouknecht
Manager, Server Systems Development
IBM

Dipankar Bhattacharya
Principal Engineer, Core Logic Business Unit
Opti Inc.

Moderator:

The name of this session is New DRAM Architectures: Who Needs 'Em? My name is Jim Handy. I'm Director and Principal Analyst of Dataquest's MOS Memories Worldwide Service. I just thought I'd give a little bit of an overview of what the different issues are that we plan to address here. Then I'm going to ask for each of our panelists to go through a brief presentation of their company and what the different DRAM I/O structures' impact is on their company. We are going to have a little bit of question and answer here on the podium, and then we'll open it up to the floor for a general questions and answer series.

These are the issues that are forcing us into going with new DRAM architectures. I know that a number of you have heard these before, mostly from different kinds of panels then this one. This is an attempt to be a more refreshing panel. Instead of people who are proponents of different types of DRAM architectures, we have those who are saddled with having to use them.

The Problem: Bandwith!

- CPUs are getting faster
  - 1987: 16 MHz
  - 1995: 175 MHz
- Graphics are getting fancier
  - Was 800x600, 16 colors
  - Now 1024x768, 256 colors
  - Will be 1280x1024, 24-bit color
- Full-motion video is starting to gain acceptance
- Less DRAMs per system ≥ more bandwidth per DRAM

9505850 Dataquest

The reason why this problem exists, the reason why things are happening, is because there is a very large need for increased bandwidth. We have CPUs getting faster. We have, since 1987, about a ten times processor clock speed increase. What's that causing is a lot of thirst for DRAM performance from the CPUs. Graphics are getting far fancier, and while we used to have 800 by 600, 16 color systems which didn't require an awful lot of bandwidth, we are moving now into 1024 by 768, with 256 colors. That requires a whole lot more bandwidth and is a lot more complicated to work around. In the future we will be moving up to very high resolution screens, the 1280 by 1024, 24 bit color. That's really going to attack the bandwidth. It's going to be taking away from the bandwidth of the CPU.

Off in the distance is full motion video. Full motion video requires an awful lot of processing. That's another bandwidth crunch.

The Other Problem: 15 Varieties to Choose from!

Asynchronous	Synchronous	Specialty
Fast Page Mode	JEDEC	Video RAM
EDO	Rambus	Window RAM
Burst EDO	MoSys	Sync Graphics RAM
Enhanced DRAM	RamLink	3D-RAM
Cache DRAM	SyncLink	Sync Video RAM

All of that could be addressed by wider DRAMS built by putting more components onto the bus. You have a granularity issue that we're moving into on the other side, where the number of DRAMs per system, the number of chips per system, is actually being reduced. As a result the bandwidth between any single DRAM chip and the whole rest of the system with all of this increasing thirst for bandwidth; that bandwidth requirement is going up. That's one side of the problem.

The other problem is that there are too many solutions on the table. We count 15. We've vaguely lumped them into three different areas: Asynchronous, synchronous, and specialty versions of the memories. Specialty includes things that are pretty much targeted at a single area. For example: Video RAM and the Window RAM. To get more exotic, you have cache DRAM, Video RAM, things like that. All of these people here are trying to make their decisions about how to run their business and what to chose in their next design out of this very wide range of solutions.

The people on our panel are Jodie Hughes, the VP of New Business Development at Western Digital. Dipankar Bhattacharya. A Principal Engineer at Opti. I like to tease him about his being in the worst position, because he has to pretty much satisfy everybody's needs. Hans Wiggerss, who is with Hewlett Packard. Hewlett Packard's needs are very broad and divergent. Paul Baker is Director of CPU Engineering at Apple Computer. They have their own needs. Finally, Max Bouknecht, and Max is in the file server business. He is the Director of Service and Storage Products at IBM.

Panelist Hans Wiggers:

Memory Components at HP

- Significant user of DRAMS
- Large diversity of needs
  - Low cost printers (< 1 Mega Byte)
  - Personal computers
  - Unix work stations
  - Commercial systems solutions (> 4 Giga Bytes)
- Cost sensitivity
  - Extremely High -> Very High -> High
- Continuous pressure on our systems for better performance at lower cost.
- Assurance of supply (Commodity Components)
- Help drive industry directions.

HEWLETT PACKARD HP Confidential

Memory System Considerations

- Main memory represents large percentage of system cost
- Increased CPU speeds and new architectures require extremely high bandwith. (Super scalar, VLIW)
- Memory system must be expandable by users, with good performance for entry level. (Granularity, Standard Modules)
- Growth in number of bits per chip exceeds growth in required memory size. (Granularity, Bandwidth per component)
- High end systems have long life cycle. Must support three generations of DRAM density.(16M, 64M, 256M)
- Personal Computers have very short life cycle. Must be have latest technology available.

HEWLETT PACKARD HP Confidential

The previous panel dealt predominantly with integration strategies of DRAM and system on a chip. From our perspective, you can't have a system on a chip until you have DRAM on a chip. You really don't have that today. That really is going to be a limiting factor for this type of performance and price in the future. You actually may see disk drive prices begin to go up as opposed to going down. Our big pitch would be to say we must remember that there is a lower end market. PDA - for example - has a similar type problem in that they don't really need 16 megabytes as a base program memory. Focus on the effect of that from a DRAM supplier perspective. Basically, get it embedded and let's go that way. We're kind of at a fork in the road between those two events.

Technology Observations

- Current supply shortage does not encourage production of innovation. (e.g. SDRAM)
- Fewer number of components per system requires new solutions.
  - Wider parts (1Mx4, 1Mx16, 2Mx32, 4Mx64 ???)
  - Faster data rates (33 MHz EDO, 66 MHZ SDRAM, 132 MHz SDRAM, ...)
  - Multiple Banks inside SDRAM (2 banks, 4 banks)
- Revolutionary solutions are being sought.
  - Rambus (Proprietary)
  - Synclink (IEEE P1596.7)
- Graphics often early adopter of new technology.

Conclusion

- Industry still seeking for solutions.
- Any solution must be high volume, standard.
- Price is overriding consideration.
- Impact of new systems (HDTV, Settop Box) is not yet well understood.
- There will continue to be a demand for small memory systems (Integrated in Controller ?)

(Our apologies. Due to technical difficulties the presentations for Jodie Hughes and Paul Baker were not taped. We have included their presentation slides for your reference.)

Panelist Paul Baker:

New DRAM Architectures

- The PC industry is very conservative in adopting new DRAM technology
- In general a new DRAM architecture will only be adopted if there is no cost penalty and no supply risk
- The 64 Mb DRAM may force an architecture change due to the minimum DRAM system that can be produced

DRAM Cost and Availability

- DRAM represents about 20% of total PC system cost
  - Paying a premium for interface to DRAM is a major cost issue
- New OS developments increase DRAM needs
  - Mac System 7.5 - 4 MB min
  - PowerMac systems - 8 MB min
  - Copland - 8 MB min
- The combination of DRAM cost and ever increasing demand mean that PC systems must use commodity DRAM
  - DRAM availability is a major supply issue for PC vendors

4 and 16 Mb organizations

- At the 4 Mb level, the 1Mx4 fast page DRAM is dominant
  - This is the case because the cost is lowest and supply is broad based
  - A 4 MB 32 bit wide system uses 8 parts
  - An 8 MB 64 bit wide system uses 16 parts
- At the 16Mb level, the 1Mx16 part will be very popular
  - 4 ea x16 yields an 8 MB, 64 bit wide memory
  - I believe 2 banks of x16 parts will be the preferred implementation for 16 MB
  - If EDO achieves cost parity with FPM, it will become dominant due to the higher performance provided at no extra cost
  - SDRAM will not be broadly used in main memory applications because of the cost premium

Implications of 64 Mb DRAM

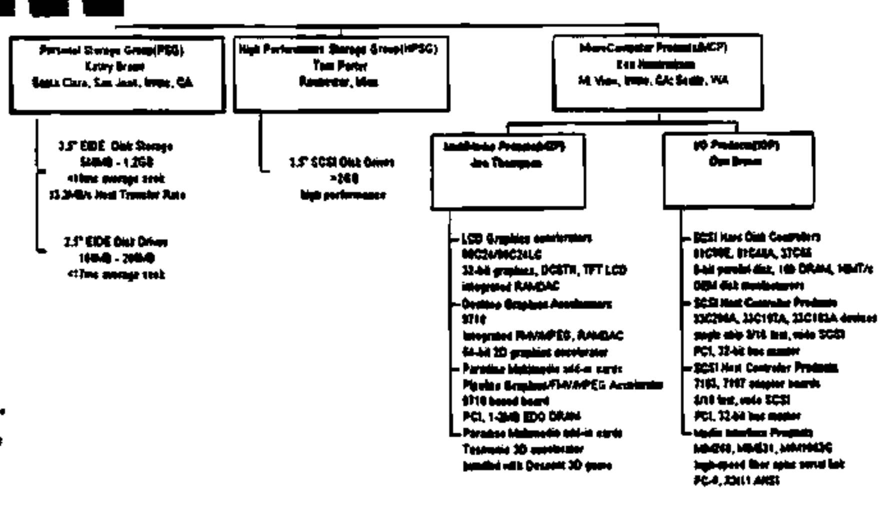
- In the next few years, most PC systems will ship with 16 MB of DRAM and 64 bit processor busses
- Therefore, at the 64 Mbit level, 32 bit wide DRAM will be required to achieve a 16 MB system
- The alternative is to use a new interface that permits a smaller bus width to achieve the same performance
- The die area penalty for 32 bit wide busses may provide enough cost umbrella for a new interface standard to be developed

Panelist Jodie Hughes:

Unique DRAM Requirements

Jodie Hughes

Organizational Structure



DRAM Considerations

- Market is Driven by PC manufacturers
- above drives everything else
  - performance
  - price
  - capacity
  - availability
- Allocated Markets drive conservatism

DRAM Roadmap

PSG

- Cache, table store, overlay
- Thru CY '96
  - 1M, 70 ns
  - EDO Burst Mode
- PRICE!!!
  - 2M?, Embed?
    - vendors
    - cost(<$10)
    - defect density

HPSG

- Cache, tables, overlay, control
- Thru mid CY '96
  - 2M, 70-50 ns
  - EDO Burst Mode
- Fiber(2M?)
  - SDRAM CY '97
    - vendors
    - cost(<$10)
    - defect density

M2P

- Frame Buffer, texture, fonts
- Thru mid CY'96
  - 2M, 45ns
  - EDO Burst Mode
- Shared Frame Buffer
  - SGRAM CY'97
- PCB mixed
  - RAMBUS

Panelist Max Bouknecht:

Of course IBM has a voracious appetite for DRAM of all types. We are also, as you know, a supplier of DRAM. In the interest of focusing on this discussion today, I am going to talk about DRAM as it pertains to PC service. As I look out the next few years, the major alternatives for our designers impact our PC servers, as indicated on the slide. We are surprising no one, I trust.

Over the next few years, the major trends that we see: Densities, of course, moving up to 256 megabits. We see the cost crossover to 3.3 volts occurring sometime probably next year. Clock rates go up and up and up. The 500 megahertz refers to actually a 500 megabyte transfer rate from Rambus.

We see probably some time next year also the four byte SIMM giving way to an eight byte SIMM, probably a 200 pin version. As a server organization, we only look at ECC memories.

When I look at design considerations, first, of course, processor clock speeds are going up and up and up. I would have to caution there that's the clock/ratio scheme from Intel. The bus speeds seem to be at a firewall of about 66 megahertz. I'll talk some more about that in a minute.

Servers now, and even in the PC space, have pretty much become the domain of symmetric multiprocessing. That's an interesting phenomenon, because what it means is that in the ideal world the processor never sees DRAM at all. It sees SRAM out of a cache. Even in today's PC servers under $10,000.00, we are seeing L-1's and L-2's and very soon we will be seeing L-3's. The memory hierarchy is a big part of the processing and design complex. The DRAM basically becomes an old fashioned backing store, just replenishing the caches on misses.

Today's entry level servers at the high end of the PC space are shipping 64 megabytes of memory. Those will go to multigigabyte memories over the next few years. The appetite for main memory is horrendous. There are a number of reasons for that, not the least of which is that the industry standard benchmarks for servers, TPC's D and TPC's C, are almost as dependent on the size of the main memory as they are on processor speed. The size of the memories goes up and up and up in servers.

The main memory bandwidth is the ultimate performance bottleneck that is, provided that you can keep the cache hit ratios up where you like them. There is a tradeoff between processors using DRAMs to backload SRAMs and cache, as well as the I/O which generally (not always), but generally goes directly to the DRAMs.

In a server environment where you are running many, many tasks, multithreads, the main memory then begins to take on some characteristics of the disk system. That is it isn't just the bandwidth from the single backing store we are talking about , but the number of parallel paths into memory, not unlike the number of arms in a disk drive.

We begin to see system design alternatives as the DRAM really becomes the ultimate performance bottleneck where we begin to set up different data paths. For example: Moving data directly from a LAN to a disk, without ever going through main memory. This is some form of distributed processing. (Pick your labels, there are lots of them.) In any event, the bandwidth requirements get so large that there are definitely other alternatives to solving the problem.

Because of all of the characteristics I just mentioned, cost and supply really do remain supreme here for DRAM.

Finally, what concerns us relative to DRAM is granularity and parts on the floor, although this is such an industrywide commodity that we all pretty much face the same problem and customers tend to grin and bear it; or they just buy large memories to begin with and avoid the problem.

We do get concerned over memory controller investments. Designing a state of the art memory controller for today's servers is a non-trivial task. Even though one can try to anticipate if you want to keep costs in control at all, it takes a very clever person to put the programmability into a memory controller without impacting performance in order to handle all of these different types of DRAMs.

Then there is predicting the industry crossover points: This is a crap shoot. It's sort of like the commodities market in Chicago. If you guess wrong you can be in real trouble, either in costs or in supply. We spend a lot of time crystal balling, trying to figure this out, so we can keep our supply definitely flowing; and at the same time remain cost competitive.

That's DRAMs as I see them from the PC server perspective.

Panelist Dipankar Bhattacharya:

OPTi DRAM Architecture for PC

- What does OPTi make?
  - PC Corelogic Chips
  - PC Audio Chips
  - PC Graphics Controllor
- OPTi & DRAM
  - Corelogic : System Memory
  - Graphics Controller: Display Memory

August 22, 1995

OPTi DRAM Architecture for PC

- Why need Faster DRAM
  - Faster CPU: Pentium, P6, etc.
  - Faster Peripherals: Video, Audio, etc.
  - New architecture: Unified Memory
  - New Applications: Games, etc.

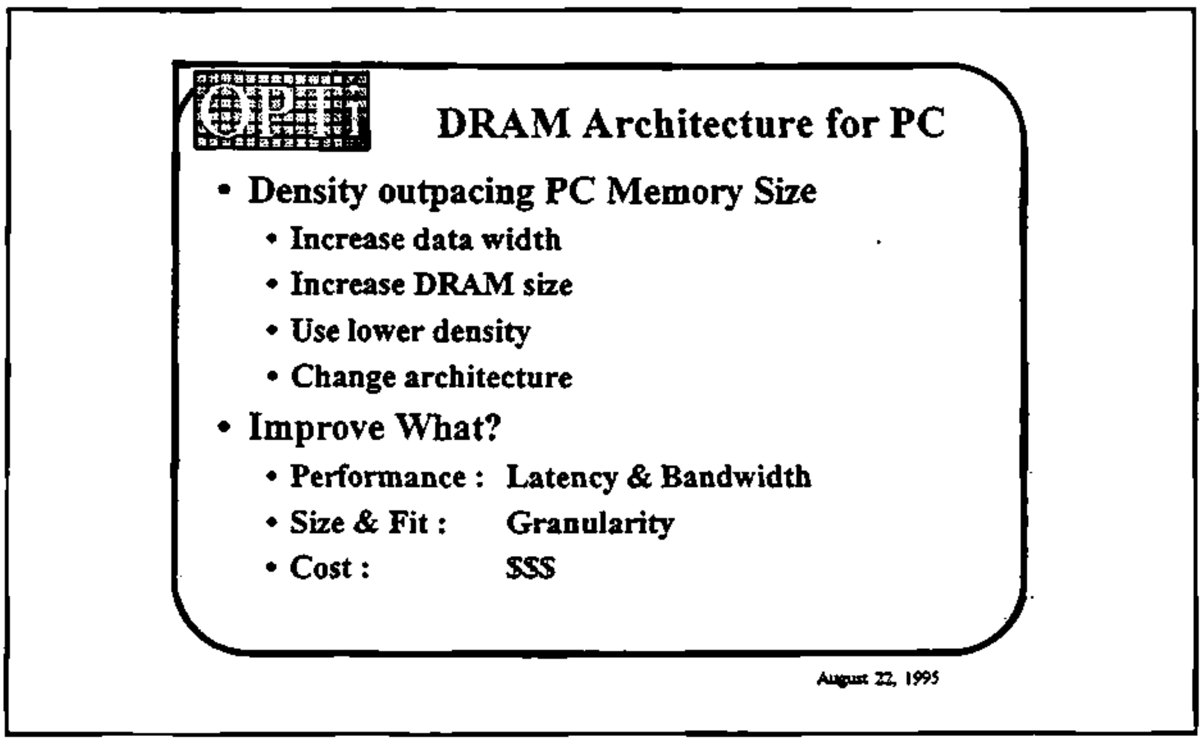
August 22, 1995

We cannot, unfortunately, do as much as what microprocessor people would like. We provide the bridge between the microprocessor and the DRAM to make the large bulk of the compatible IBM systems. Opti also makes graphics controllers for the PC, and audio chips. It is definitely a major factor for us, deciding on next generation products and so on.

For the core logic portion, we have a system memory that uses DRAM.

The PC industry has moved a bit because of the fancier graphics and finally we are moving in the same direction that Apple probably moved some time back, which is unified memory.

Also the new applications, like the games, looking for a lot of bandwidth.



The change in DRAM architecture mainly stems from the large density that we are achieving in DRAMs today. When you go to the 64 megabit density, we are already two steps ahead of what that mainstream PCs of today are shipping. This is four megabit 486.

OPTi

DRAM Architecture for PC

- Improve How?
  - Better Latency
  - Better Bandwidth
  - Fewer pins with faster clock
- Impediments
  - Too many choices !!
  - If you build it they will come: DRAM or Controller?
  - Volume & Cost: Chicken & Egg

August 22, 1995

The reason for the PC industry lagging back is the size of the memory with the old architecture. Hopefully with the larger bandwidth between the individual chips that is coming out today with the new architectures we can move forward a bit faster. Also with the new operating systems, the demand for memory is increasing. The base memory size is going to be increasing.

Our choice has become rather limited. Going into each chip, when we go to the high density DRAMs, we have to either increase the data width into the chip, or use a lower ended chip, or we change the architecture.

What do we want to include in a PC, in the process of doing this? We want to get a larger bandwidth, smaller latency, and a wider, faster bandwidth. The size and fit issue of the granularly is becoming less of an issue today. It is quite desirable, especially if the graphics display memory is to be separated, to have smaller granularies. Of course, one solution there is go to a UMA, which are doing.

The main driving factor is the cost. Cost and availability is really what ties our hands in making a choice of DRAMs.

How do we improve a DRAM? What we want to improve, again, is performance, it's the latency bandwidth. The other thing that can really benefit from in the PC is if we can use few pins with a faster clock. A move in that direction has started with Rambus, and I believe quite a few other companies are coming up.

What prevents us from going forward is one of the major things. It is the many choices that we are faced with. Cost and availability is basically bottlenecked by the fact that everybody is trying to do their own bit. No particular architecture is hitting the critical volume to enable it.

The question remains which one comes first? To enable the DRAM, you need to have a controller that fits into the DRAM and the other way around. The DRAM manufacturers are not necessarily in danger as manufacturers. We need to work hand in hand. With so many choices we are confused, if anything.

The other thing is volume and cost. Unless you hit the volume and don't get the cost and vice versa. The chicken and the egg problem is there too. These are holding us back.

Moderator:

What we really have here, what everybody has outlined, is that we have a technical issue with bandwidth. Where do we go with future designs and all of the bandwidth needs that are there. Also we have a business issue, as Dipankar Bhattacharya just said. Nothing looks promising for reaching critical volume. How is he to decide which memory architecture he is going to support and which ones he is not going to.

Something that struck me as relatively interesting was that Hans was talking about X64 DRAMs on one side, and Max seems to be talking about really deep DRAMs on the other side, which to me would imply that there would be very narrow types of interfaces required in his types of systems.

Dataquest's own interpretation of what's going to happen is that the wider interfaces are going to be supported up to a certain extent. The narrower interfaces are going to be dropped. What impact would that have on your business, Max, if you were suddenly no longer to get anything but X16 and wider architecture DRAMs?

Panelist Max Bouknecht: Just suddenly like that?

Moderator: You could see it coming, I'm sure.

Panelist Max Bouknecht:

In all seriousness, the trick to this whole business is being able to anticipate. It is difficult for me to answer the question you asked, because I can't believe it would ever be like that. As far as we're concerned, the memory controller is the key to the answer to the question, and whether the interface is very wide or very narrow is only of interest in terms of the complexity of the design.

Given the size of the memories that we are using in servers, I don't think I actually care - to be honest with you - in real sense one way or the other as long as I am following what the industry is doing so that I maintain the two critical things I mentioned, the right cost point and the right continuing supply.

Even at high-end servers in the PC space, demand is very perishable. If you can't deliver the product, your competitor will. We are talking 30 days in demand. If you don't fill it in 30 days, your competitor will. That continuity of supply is so simple.

Moderator:

In today's market you don't see an awful lot of drive to compete by changing architectures or anything like that just because of the shortages.

On the other hand, do you - Hans - really seriously believe that you are going to see 64 bit wide DRAMs anytime in the near future?

Panelist Hans Wiggers:

No, I am going to say 32 bit wide DRAMS. They are probably going to be synchronous and it's going to be within a couple of years.

Once you get to 64 megabit technology, because of all of the granularities that we talked about, that is the more sensible part.

I agree with Max in that our high-end systems have the same problem. As I said earlier, we go to our suppliers and we say look, we really need 256 megabit by four. They look at us and say are you serious? Yes, we really need those things. It may not be a big PC market, and everybody seems to be focusing on the PC market, but somehow there are going to be requirements for these other devices as well. But there going to drop them.

Moderator:

Speaking of dropping devices, you were complaining about one megabit DRAMs being hard to get. I'm going to ask each one of the panelists in turn: What is your biggest nightmare right now, Hans?

Panelist Hans Wiggers:

I've got lots of nightmares. That is definitely one of the problems. For the low end things, like our printers, that you will be able to get those. At some point you can just put a four meg in there and just throw away the memory, just like you guys are doing. (indicating IBM)

The other thing, and it's not a topic for this panel, but at some point we expect that this will be integrated within the controllers, the CPU and the whole thing on the chip, including a Megabit of DRAM. That is going to be a specialty market. It is going to be a good market.

Moderator: It doesn't fit too well with a lot of product plans, I'm sure, that a lot of the DRAM manufacturers have.

You were talking about throwing away some of it. What do you look for in DRAM? My understanding of the disk drive market is that it's so price driven that you look for a price point.

Panelist Jodie Hughes:

We look for a price point.

Moderator:

If you are looking for a price point and then it seems like you would use everything that you got within that price point.

Panelist Jodie Hughes:

The unfortunate thing though is that while the price point of the disk drives is going down, if you have to buy the more expensive memory and try to throw away money on the table, then the only thing that you can do is throw away a profit margin. That's the bottom line.

One of our worst nightmares, aside from another disk recession again, is that we have to do this and we don't have any alternatives. We have probably about a six to eight month window whereby we have to decide.

It seems to me that there is kind of a general theme throughout all of this which is that the DRAM market has kind of driven through ubiquity. There are a whole bunch of products out there that could take the same organization. It gets broken down. I don't think the DRAM manufacturers have caught onto that yet. The reality is that there's no such thing anymore as a ubiquitous DRAM market. The server wants different requirements than the workstation, which wants different requirements than the commodity based guys, which wants different requirements than PDAs. I think that if and when - God forbid - the capacity switch turns around, they are going to have to scramble pretty fast to meet the needs of these people to get their capacity in these solutions. I think they maybe want to take that away from this meeting that, at least from the customer perspective - and correct me if I'm wrong - is that we have a real requirement for a specialized (not niche) DRAM for certain applications.

Moderator: A disk drive DRAM, maybe a graphics DRAM?

Panelist Jodie Hughes:

We are going to ship a heck of a lot of disk drives from now to the end of the century, as the DRAMs approach one per system, that is the same as a disk drive. They get to double their volumes by having that part in their disk drive.

Moderator:

However, Dipankar brought up a good point, and that was that as you fracture the market, suddenly nothing has a high enough run rate that the price can go down. Yet everybody is sitting here saying price, price, price, price.

Panelist Jodie Hughes:

Silicon is silicon. To some extent it makes no different other than managing your process flows whether you make X DRAM or Y DRAM. It's just that they haven't had to deal with that infrastructure before.

The semiconductor guys, the ASIC guys, sit there all day and make money. They are under the same price constrains.

Moderator:

It's a different kind of a competitive flow though, because the DRAM market is based on high unit volumes. That's a toughy.

How about Apple? Is there any particular difficulty with DRAM that you guys get?

Panelist Paul Baker:

Our current situation today is that we use a lot of video memory, VRAM, for our high end systems because it offers us the best performance in the graphics intensive applications and such we have today. Really the concern that we have is will we be able to keep that supply going for a long enough time to be able to have a really viable high end alternative?

Even say looking at a synchronous DRAM, even with 128 bit wide bus on S-DRAM, that comparison between the performance of that and the performance of a VRAM with 128 bit wide bus is surprising. VRAM seems to us to be better still. We'll have to even go faster then these pretty high speed synchronous buses to be better than the technology from the 1980's. That's one that is a concern to us.

I do think that in a couple of years a new DRAM technology will have solved that problem. Just for this critical window over the next couple of years, that's a big issue for us.

Moderator:

Getting over the current hurdle. You're talking about that and you're talking about the very high speeds that you need. Max was talking about how the bus speed was somewhat artificially limited by Intel on the processor side of it. I guess that you two are looking at two different sides of the system: The graphics side, which you have very high bandwidth; and then Max is looking mostly at the processor side. Do you think there will be a separation, like what Jodie was talking about? DRAMs with very high bandwidth for graphics and DRAMs that are more matched to the processor?

Panelist Paul Baker:

If the past is a guideline to the future, I guess there will be a separation. There certainly are special graphics memories and graphics is a pretty high volume business, although as the chip set vendors and Apple also, everybody in the PC business is looking for the low end systems to integrate the graphics memory and the main memory in the same chip, or the same bank of memory. Maybe some of the volume demand for specialized graphics memories will be reduced. It could be that we will end up with one in the long run, but I think it is going to take us a long time before there is something for graphics.

Moderator:

Dipankar talked a little bit about unified memory architecture, and I guess something that's a little bit puzzling. This is where you mix the graphics memory and the main memory into the same chips. You no longer might be able to get one megabit DRAM chip for your graphics memory or some low density thing. For example: At the 64 meg density or even a 16 meg density, you might want to use some of your main memory to satisfy your graphics needs.

A big question for this is where does that fit in? Does it fit in with high end systems? Does it fit in with low end systems? Can it be supported with EDO? Does it need to have something like a synchronous DRAM for support? Maybe I'll have Dipankar talk to that first.

Panelist Dipankar:

Actually it seems kind of self defeating. First you ask for a greater bandwidth and then you put more load on the DRAM. On the other hand, you can actually reuse a bunch of bandwidth.

What is driving that though is granularly. The size of video memory required is hard to achieve at a reasonable cost. Here is where the problem is. That's why the UMA is kind of an appealing architecture in that aspect. However, there are some technical hurdles. I think in the long run it's going to come in both the high end and low end. It's going to start at the high end.

Panelist MaxBouknecht:

Even with 3-D requirements, with textures, etc., etc., nobody is going to want to buy a 16 megabyte graphics card.

Panelist Paul Baker:

I think, for us anyway, 3-D is a big driver for needing huge graphics memory. Since you can't afford huge graphics memory you have to go back to unified.

I think that Max's point, and I'm sure in the Intel world as well, it's more and more likely that the CPU adds cache. The CPU bandwidth direct to main memory is actually somewhat mitigated with clever cache designs. If you have a copy of that in cache, you really do reduce the bus bandwidth quite a lot for the DRAM. I think on the one hand DRAM is this big cost thing, so the whole architecture is focused on it. On the other hand, a lot of the work in designing a system today is figuring out a way to enhance the bandwidth while keeping the DRAM the same. It's a two edged sword.

Panelist Hans Wiggers:

I want to make one comment. We talked about diversity and so forth, HP has definitely not given up on having one memory component. We think that the single DRAM can be used both in the high end and all the way down into our laser printers. We are really not eager to split up this market into different categories.

We also think that the synchronous DRAM, because of its multibanked structure, actually is very, very suitable for things like unified memory architecture, because at multiple events you can hide some of the latency.

We are really pushing right now for the synchronous DRAM. We are working very hard (and so are many other companies) in increasing the bandwidth that you can get by working in standard efforts to get fast interfaces. There is really no electrical reason that you couldn't run at 130 or 150 megahertz in the bus if you do it carefully. Rambus has shown us you can do it on a tiny bus of 500 megahertz, you can do an expandable bus up to 160 megahertz.

I think we shouldn't be too eager to wipe that all off and say we are going to have specialty DRAMs for the servers and other specialty DRAMs for the PCs. We wouldn't like to see that.

Moderator:

That actually plays to a couple of business issues; and one of them is one Dipankar Bhattcharya mentioned. If you have low run rates on everything, your prices for everything are going to be high. Something that's more important, and what Hans came out with, was the idea that you would like to kind of unify what kind of parts your company is buying. If you buy a little bit of this and a little bit of that, a little bit of those and a little bit of these, then you are probably going to get really taken advantage of at the negotiating table.

I suspect that is kind of where you were leading with that, and that's something that Jodie and I talked about. Jodie, bless his soul, didn't talk about the graphics arm of Western Digital, which just recently got sold; but apparently was a little bit of a thorny issue by needing different DRAMs than the hard disk drives. I would just like to ask you, Jodie, what kind of problems does it pose to have way different memory needs in different parts of the organization?

Panelist Jodie Hughes:

You would think that normally when you are going into a single vendor like a Toshiba or ACER or whomever, you would be able to leverage one set of requirements against another. When we ran into this we buy one megabit standard DRAMs by the truckload for disk drives, and wanted to ease into the EDO market and found out that the store was basically closed.

It doesn't really matter what other supply you may have garnered before, it's a different commodity and different commodities are allocated. If you're not allocated, then you're not allocated. It can be a severe problem, and it can even almost prevent you from expanding out your business in any one direction if you're not careful.

Moderator:

Max, do you see any difficulties? I don't know whether being with IBM you know, since there are a lot of different things done out of corporate procurement. You probably don't have a lot of visibility as to variety that is being used.

Panelist Max Bouknecht:

Actually we do. I wanted to add about the different types and how that affects your volume and also affects inventory, one of the driving factors in today's business. I don't know about the rest of the gentlemen, but I would not be so pretentious as to say that we know how to predict our product down to the second decimal point. When you don't know how to do that, you better be able to use your parts in different parts of the business.

Panelist Max Bouknecht:

I would agree with Hans in the synchronous DRAM, but it's probably a couple of years away - as near as we can tell - to get the cost where it needs to be, so we'll probably have to make it past through EDO is what we're guessing. I'm going to reiterate again - I hate to sound like a broken record - it's this prognostication factor that is so difficult and yet so, so important to success in any given brief time.

Moderator: I think Opti is in an unique position by having to play to more of a popularity contest.

Panelist Dipankar Bhattacharya: Yes.

Moderator:

You have to go with somebody who you know is going to be a winner because everybody tells you that that's what they plan on buying. Let's just hope that it's the cheapest solution for you and your customers.

Panelist Dipankar Bhattacharya:

I think that's one of the problems that we are facing, is that everybody has the short term focus. We are trying to figure out how can we provide the components in three years if everybody is focusing on today. We are already thinking beyond synchronous DRAM. How can you do something in the future, in the year 2000, because it takes them two years to get used to the idea, two years to quibble about whether it's the right idea, and then two more years to implement it. You are talking about six years before anything else goes anywhere.

Moderator: It's a difficult one. It's about time for me to ask if there are any questions from the floor. Do we have a question over here?

Question:

I am thinking of that chart of Max's, you showed a 3.3 volt DRAM crossover in 1996. I would like to ask the panel who is ready for that? 1996 is next year. I want to find out whether it is for server, for internal IBM, or it's really a commodity PC market.

Moderator:

What if I just share a little point of irony about 3.3 volts: Somewhere, and I don't remember at which line geometry, .35 microns I believe, most DRAMs are built with a three volt core and five volt periphery. They use a five volt power supply and have an internal voltage regulator and bring voltage down to the 3.3 volt core. The reason why they do that is because that's what the market will buy right now. However, the die size would actually be smaller on a straight 3.3 volt part. However, the smaller size die part is commanding a 10% premium right now.

Question:

I'm from Mosel Vitelic. We support Burst EDO DRAMS. Actually, EDO DRAM today is easy to operate at 60 megahertz, no problem; because of improved design technique coupled with improved technology. The second one, I believe, will be B EDO DRAM. EDO burst: EDO burst offers a very small overhead, less than 1%. EDO DRAM offers zero overhead. The cost is so sensitive. EDO burst will be the next one. This will be the bridge between a synchronous DRAM and the EDO DRAM. Synchronous DRAM still has overhead, plus a different type of package. EDO burst has no cost, no port change, same package.

Moderator:

This comment was about the cost considerations that all of us voice and the fact that there are certain generations or I/O structures of DRAMs that are easier for DRAM manufacturers to make than others. Mosel Vitelic appears to be making three volts and five volts on the same part as running options against each other. They are also doing EDO, which is a zero die penalty feature to increase bus speeds up to 60 megahertz the gentleman says, as opposed to the 33 megahertz that Hans brought up. The other interface that he was talking about was burst EDO, which carries an incredibly low penalty.

Dataquest has been talking to Micron about burst EDO. Frankly we've had kind of a problem finding users who are using the interface. What I would like to do is to ask the other panelists whether burst EDO is on the list of DRAM interfaces they do plan on using.

Panelist Hans WIggers:

There are a few problems with burst EDO. The first thing I should talk about with EDO, is it goes up to 60 megahertz. The bus clock rate is 66 megahertz, and you still have two clocks, so it doesn't do you any good. You either have a 1/1 or a 2/2. That doesn't really buy you anything.

Secondly, although the bus is 66 megahertz and everybody may swear up and down that it will not go up, it will go up. It's going to be 75 megahertz, and it's going to be maybe up to 90 megahertz.

With the burst EDO you have a very fundamental problem. There is a short window in which that might be a good solution. Even with today's 66 megahertz bus, maybe if you can 15 nanoseconds or 40 nanosecond devices you can bring it up to 66 megahertz, but it's a short period and then it's going to go away.

The synchronous DRAM is really inherently not that much more expensive then the burst EDO. The die size penalty is in the order of 1%, I think, on the 16 meg. You can actually make up for some of that because, since the device is faster and it doesn't have two banks, it can cut in on your test time.

There are a lot of people who are talking about reducing the test time and making up for some of the costs so that if you add it all up, synchronous DRAM could be actually on a parity with the EDO. Furthermore, the synchronous DRAM has two banks, which is going to be very significant.

We think that the burst EDO is at best a temporary phenomena. We don't think it's going to be around for very long.

Panelist Paul Baker:

As we were discussing, I think EDO is going to be a big winner for us, but burst EDO, because we are not seeing the breadth of supply, it's difficult for us to plan to put that as a feature in all of our processors.

Moderator: You are using video RAMs which are not widely available?

Panelist Paul Baker:

That was a decision that was made long ago. Yes, I agree. That's a problem. Why would we want to get ourselves in that problem again?

Moderator:

Any other comments on burst EDO before we go to the next question?

Panelist Jodie Hughes:

Similarly, yes we could use it. We could probably even saturate the bandwidth that it provides, ironically enough. But because we don't believe it is going to be long term, we're not planning on supporting it.

Panelist Paul Baker:

As Hans alluded to, the question is how long a life does it have? We can all do the analysis of the semiconductor physics to figure these things out, but now we have to keep in mind that fact that we are dealing with an industry commodity. Doing just the analysis of semiconductor physics is not enough. We have to look at all of the other factors that govern an industrywide commodity, and we had questions about the length of life of burst EDO with synchronous DRAM. Are all of the suppliers going to make the investment or not?

Moderator: Just to be repetitive, it's a business decision as well as a technical decision.

Panelist Paul Baker:

One other issue is that we are already talking about so many different solutions and options being available. We would like to limit those to a few. EDO is a no brainer in terms of aspects, that's not really changing. If we are going to do something different, let's do something that makes a different like synchronous DRAM, and let's not fiddle around with something that's in between.

Panelist Dipankar Bhattacharya: Even though Opti may have to in a disk drive, we can't. We have to keep as many people happy as possible. In the same interface it's rather easy to accommodate synchronous DRAM, as well as burst EDO. We have to take the position of supplementing all four kinds to date.

Moderator: You have to please everybody.

Panelist Dipankar Bhattacharya: If there is an availability window of one quarter or two quarters, we cannot afford it.

Moderator: Let's move on to another question.

Question:

Could the panel please comment on where they see the typical megabyte per PC growing over the next three to five years, and what factors would be driving that growth?

Moderator: I know Max isn't going to answer that.

Panelist Paul Baker:

As I mentioned in my slide, where because of the cost, there is a big OS goal to try to stay with eight megabytes as long as possible, but I just don't think it's very realistic that it's going to happen. I think over the next few years we'll probably see the transition from eight megabytes to 16 megabyte systems minimum.

There might be an interesting point: You might say gee, well how about 12? Because of the granularity issues that we talked about, that is probably not going to be a realistic issue. That I think is going to be the case with Max.

Panelist Hans Wiggers: I pretty much agree. Eight to 16 transition is on it's way.

Panelist Dipankar Bhattacharya: I would agree.

Panelist Max Bouknecht:

It's an operating system issue, and I am personally running Windows NT which theoretically can run with 16 megabytes. When I put 32 megabytes in the 3-D stopped working right. It's not going to happen.

Panelist Hans Wiggers:

I think it's already 16 megabytes. You go buy a Windows 95 machine today, and would be hard pressed to find a machine with Windows 95 on the disk drive and eight megabytes.

Panelist Dipankar Bhattacharya:

Under $2,000.00 they are almost all eight megabytes. You just can't afford to put $600.00 worth of memory into a machine that only costs $2,000.00.

Panelist Hans Wiggers:

Your customer gets thoroughly disgusted with the price and buys another piece of memory and puts it in there. That's just a come on at the entry level.

Panelist Jodie Hughes: If you look at Fry's, you will see $1,800.00, 16 megabyte machines.

Moderator:

It's Dataquest's belief that there are price points that are met by the machines, and those machines ship either with four megabyte 486 or eight megabyte Pentium. Then it's the salesperson's job at the computer store to feel around through your wallet and find out how much money you've got to spend and fill that up with memory and software and things like that.

It looks like we've got another question over here.

Question: I represent one of the DRAM manufacturers. It seems to me that the three things that drive costs are yield, die size and volume. SD RAMs have, at least in my opinion, about a 5% die size penalty over page motor EDO. It doesn't appear to me that SD RAM can readily be accepted, at least by people for whom cost is the supreme consideration.

Number two: We, at least Mitsubishi, don't make ECC DRAMS because of the 12% die size penalty. It would seem to me also that many of the DRAM manufacturers wouldn't want to be supporting ECC, at least in terms of a die size penalty. They might want to support something like a checksum, or some other types of CRC checking, but not when it means making bigger DRAM die size.

My third comment is, especially for the one megabit DRAM, those DRAMs are very hard to get. Ultimately embedding the one megabit DRAM in terms of a hard disk controller seems like it makes a lot of sense, but in fact that die size penalty is also severe, and for the hard disk drive industry it is going to take some time to guarantee any assurity of supply to do that for every single supplier. Those are just some comments from DRAMs manufacturers.

Moderator: Nice observations. Something that I was meaning to ask Max about with the ECC thing, I don't believe that he was talking about having the ECC on chip. Were you?

Panelist MaxBouknecht:

I'm not. No. That option is available, but the prevailing ECC that I was referring to is done with memory control or in control of the way the SIMM is organized, not in the DRAM itself.

Moderator:

It adds to the cost of the overall system, but it doesn't really change the parts that are being used in an ECC memory system.

Question:

Max talked about a switch from the SIMM to DIMM format on the server. I'm looking for your thoughts on what you see for SD RAM and other packaging formats next year from a system level.

Panelist Max Bouknecht: By S-DRAM you mean synchronous DRAM?

Question: Yes.

Panelist Max Bouknecht:

I doubt they will be widely accepted next year simply because of cost and the suppliers just haven't made the switch yet. While they are available even now, I don't look for them to be pervasive next year.

My slide said that, at least particularly for servers and 64 meg DRAM and DIMMS and 3.3 volt memory, will become the memory of choice.

Panelist Hans Wiggers:

It's basically the only standard module available right now for synchronous DRAM. We'll see how that plays out. Once you start running it over 100 megahertz, it becomes pretty tough.

Panelist Paul Baker:

Actually in the case of Apple, we've already converted our new products from 72 pin SIMMS to 168 pin DIMMS. The reason we did it was user convenience. It allows you to have a one component upgrade. We are pretty focused on trying to make things easier for our users, so that was our big driver on that.

Question: I have a question about the 64 meg product line. Do you have any comments about what type of packaging you think will be dominant?

Moderator: Was it you, Paul, who was talking about how the 64 meg is going to require several shifts?

Panelist Paul Baker:

Maybe I could just say - at least my opinion on this and the others should say too - I think the whole point of putting DRAM on SIMMS or DIMMS has to do with the fact that no one can make a good answer to that question. What you do is you put an extra layer of packaging so that you can (A): Take anything that anybody can give you; and (B): If somebody comes up with a great idea well, swell. We'll take that too. I think that's our viewpoint.

Panelist Hans Wiggers:

Certainly as a systems supplier, that's the way I feel too. We are pretty much isolated from that these days. We buy at the SIMM or DIMM level, and that way - as you put it Paul - we can take whatever they have to give us.

Panelist Max Bouknecht:

It's funny, because we were talking about cost a lot, and there's no question that it's less expensive, parts count cost, to measure up the price of all of the parts. It's less expensive to put the DRAM on the same mother board with the computer, right? Almost no one does it. The reason is completely wrapped around the suppliers.

Moderator:

Dataquest's viewpoint is that the memory module is a way of erasing several sins. One of those is when you have a vacillation between price per bit, whether the four meg is cheaper than a one meg on a price per bit level, and we saw very high SIMM activity during that point. Once the four meg settled in, we saw more soldering down in the basic memory system.

We are anticipating seeing random use of SIMMS again, once the four meg and the 16 meg in the 1 meg by 16 organization become competitive on a price issue and from day to day the differences between the prices is going to change.

Question:

It sounded like from talking to the panel that there hasn't been much change in DRAMs in the forecast. The key items are cost, cost, cost and supply. Therefore it looks like, I guess my view on the next generation too on synchronous DRAM is a bit different than what was previously expressed here in the audience. It's been my experience that the die size is going to be very comparable to that of the fast page mode. That one of the key items in the cost adder has been This page is intentionally left blank much more than testing time required. With some of the newer testers and new testing methodologies, you will be able to get a much better cost and achieve a maximum of about a 5% die panalty.

I would also suggest that in addition to things like yield and die size, one of things that is going to be crucial for pricing is a standard, so you have several suppliers and manufacturing of parts. There is nothing like competition. Despite today's market, there will again be competition in DRAMs. Competition is what is going to be driving prices.

The people on the panel, who are the end users, should be extremely active - like I know that Hans is - in setting standards, so helping the rest of us that are manufacturing the DRAMs focus our energies on the kinds of products that they are going to be using.

Panelist Hans Wiggers: I certainly agree with what you said.

Moderator: Thank you very much, and thanks to the panelists.

Chapter Twenty-one: THE WIRELESS COMMUNICATIONS ODYSSEY: WHAT ADVENTURES LIE AHEAD?

Panel Discussion

Moderator

Dale Ford
Senior Industry Analyst, Semiconductor Application Markets
Dataquest Incorporated

Panelists

Peter Karsten
Corporate Director, Business Development
Nokia Systems

Dr. Angelo Ugge
Vice President, North American Telecommunications Business Unit
SGS Thomson Microelectronics

Sohail Khan
Vice President, Wireless and Multimedia Business Unit
AT&T Microelectronics IC Group

Toshio Miki
Vice President, Executive Research Engineer
NTT Mobile Communications Network

Ray Millington
Vice President and Director of Engineering, Advanced Products and Technology Division, Cellular Subscriber Group

Motorola

Moderator:

We are privileged to have a group of five panelists today who bring expert knowledge about this industry and who will be sharing that with us today. For our panel I will first briefly introduce our panel members. Following that introduction I will provide brief opening remarks. Then we will hear briefly from each of our five panel members. Our goal is to leave sufficient time for a good question and answer session. I will start off with just a couple of questions, but I want to strongly encourage the audience to participate. One of the strong points of feedback we received last year is the audience had questions they wanted to ask, so I'm going to give you every opportunity to ask those questions today and encourage you to do so. We will have somebody with the microphone. If you will just raise your hand, they will bring a microphone to you. If you will stand up and ask your question we can have some good participation that way.

With that, the title of our section this afternoon is the Wireless Communication Odyssey: What Adventures Lie Ahead? We have come a long way in the world of wireless communications, yet it still seems we are just on the brink of a major explosion in this realm that will have a major impact on our lives and on the semiconductor industry.

Let me introduce first of all Peter Karsten from Nokia. Peter is the Business Development Manager of Nokia Mobile Phones, the second largest cellular phone manufacturer in the world. He is in charge of marketing aspects and negotiations for new concepts, which included two new products from concept to market: One satellite related patent and one new group of ideas implemented in all major phone ranges. His responsibilities also include technology transfer to a new R&D Center in the United Kingdom, and organizing information flow from global sourcing to all R&D centers.

Next we have Angelo Ugge. Dr. Ugge is presently employed with SGS Thomson Microelectronics, holding the position of Vice President of the North American Telecommunications Business Unit. This unit is the vertical integration of sales, marketing and product development. He was the General Manager of the Dedicated Product Group in the American Operations Division which develops, produces, and markets customer application specific chips for different application areas throughout the world.

Next we have Sohail Khan. Mr. Khan is currently the Vice President of the Wireless and Multimedia Business Unit within AT&T Microelectronics IC Group, where he is responsible for P&L, including development, marketing and product engineering for digital signal processors, convergence signal processors, video processors and RF devices.

Next on our panel is Ray Millington. He is the Vice President and Director of Engineering for the Advanced Products and Technology Division of the Cellular Subscriber Group at Motorola. He's been involved in radio and telephone design since 1980, and has played an integral role in development of several key cellular products, including the MMT 450 Nordic Mobile Telephone, the original DynaTAC, and the MicroTAC personal telephone.

Finally, we have Toshio Miki. Mr. Miki is the Vice President and an Executive Research Engineer of NTT Mobile Communications Network. His current research issues are in mobile multimedia design processing techniques, signal processing techniques including speech, audio, video coding and their implementation. He is also taking the role of Chairman of the MPEG4 Committee and Low-Bit-Rate Videophone Expert Group in the Japanese National Body.

As you will see, we have brought in panel members who will give us a good global perspective on the wireless industry. We've had a lot of attention in the United States on recent developments with personal communications. These gentlemen will be able to offer some good perspective on what's happening on a global basis.

Wireless communications will impact our lives in our homes, on the road and in our business place. In our homes we are going through a transition from analog technology to digital technology. Which technology you will use depends on the region you live in. In the United States, we have 900 megahertz ramping up, in Europe they have the Digital European Cordless System, DECT, and in Japan we are seeing the personal handyphone system, PHS.

On the road we see both digital cellular and what is called personal communications services. In the United States they are in the 800 and 1.9 gigahertz bands respectively. We also see pager technology that is being rolled out, satellite technologies that have gained a lot of press attention recently, and also enhanced specialized mobile radio.

In the office place, we see the wireless PBX and the wireless LANs being implemented there.

One thing we have noted is that while many of us are very familiar with the terms and acronyms and jargon of the computer and the PC world, the communications industry has its own set of acronyms and jargon that at times can present a barrier to understanding what is being discussed. I have placed in your binders brief definitions of some of the common terms and acronyms that are used to refer to standards and technologies in this industry.

I point out that there is one correction that needs to be made. On this first page, the standard that's called IS-43 should be IS-54.

NWWA: The New World of Wireless Acronyms

- TDMA: Time Division Multiple Access
  - Air interface access technology
  - Also used to refer to protocol standard (IS-43/IS-136)
- CDMA: Code Division Multiple Access
  - Air interface access technology
  - Also used to refer to protocol standard (IS-95)
- GSM: Global Standard for Mobile Communications
  - Protocol standard using TDMA interface
  - Adopted in European and countries in other regions
  - Basis for DCS-1800 standard in Europe and PCS-1900 standard in U.S.
- PACS: Personal Access Communications System
  - Protocol standard using TDMA interface and time/frequency modes
- Omnipoint
  - Protocol standard using hybrid of TDMA, CDMA, and frequency division technology (IS-661)

9505647 Dataquest

Let me just briefly go down these terms: First of all we have TDMA, time division multiple access, which is an air interface technology. It is also used to refer to a protocol standard, one of the proposed standards in the United States. Both IS-54 and 136, the most recent generation which provides power savings functions use TDMA technology.

There is also CDMA, code division multiple access, again on air interface technology; and again it can also be used to refer to a standard that has been proposed in the United States that is also referred to as IS-95.

GSM: Global standard for mobile communications. This standard uses a TDMA interface. It has been adopted in European and other countries throughout the world. It also forms the basis for the DCS-1800 standard, personal communications standard in Europe, and the PCS-1900 standard in the United States.

PACS: Personal access communications. That is a protocol standard that uses both a TDMA interface and time frequency modes.

Omnipoint is a protocol standard that uses a hybrid of TDMA, CDMA and frequency division technology, and it has been recently designated a standard IS 661 in the United States.

NWWA: The New World of Wireless Acronyms

- DECT: Digital European Cordless Telephone
  - Forms basis for a proposed U.S. PCS standard—uses TDMA
- PDC: Pacific/Personal Digital Cellular
  - Digital cellular air interface standard adopted in Japan—uses TDMA
- PHS: Personal Handyphone System
  - Standard for PCS system adopted in Japan
- SMS: Short Message Service
  - Use of control channels in cellular/PCS transmissions to provide brief pagerlike messages and services
- CDPD: Cellular Digital Packet Data
  - Standard developed for sending packetized data by sharing idle time on voice cellular channels

Dataquest

DECT stands for digital European cordless telephones. It also forms the basis for a PCS standard in the United States, and is based on TDMA technology.

Pacific or personal digital cellular is an air interface that has been adopted in Japan. It uses TDMA technology.

The personal handyphone system, also a PCS system, has been adopted in Japan.

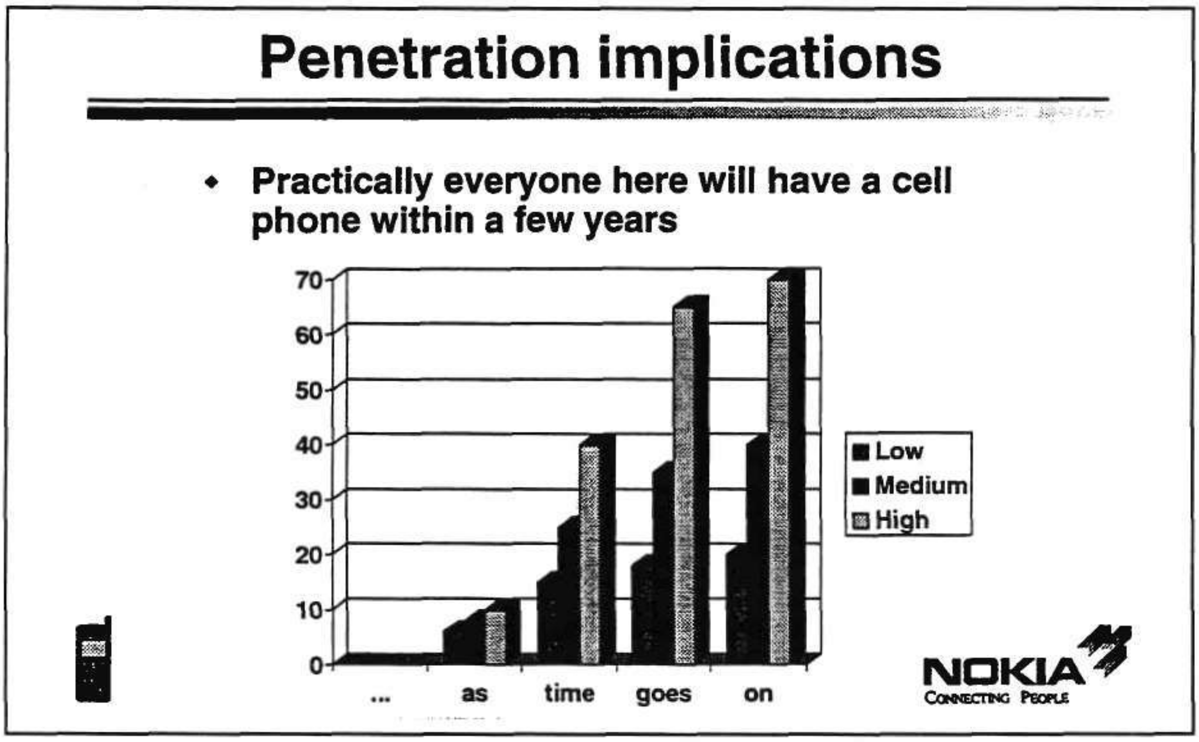
On the data front: Currently we have short messaging service, also referred to as SMS. It uses the control channels in the cellular and PCS transmissions to provide brief pager like messages and services.

CDPD: Cellular digital packet data is a standard developed for sending packetized data by sharing idle time on the voice cellular channels.

I just wanted to run through those quickly to put some foundation in place. I've asked our panel members as they proceed to keep in mind the diverse audience that we have today and we'll attempt to always phrase our discussion in terms that will get us past some of this new terminology.

With that, I would like to thank the participants on our panel today, and I would like to turn over the time now to Peter Karsten from Nokia, who will be our first presenter in the session.

Panelist: My name is Peter Karsten. I am with Nokia Mobile Phones. At Nokia Mobile phones I look at things that we don't do today. I'll show one new product at the end of the presentation as well, which I don't think you've seen before, that we launched a week ago.



I'll be talking in the beginning of the presentation about penetration rates, i.e. the installed user base. One thing to emphasize with the penetration rates in cellular is that the way they're measured is per person, as opposed to per household. That's the difference. Those are just a couple of starting points.

By the way, we have an interesting situation here. We have three here on the Nokia side, and then a good colleague of mine in the industry, Ray, on the other side which has a very similar position to mine in another cellular company. Let's see how different our presentations are.

First of all, as we start off, usage per person is an important thing. A lot of people have begun using cellular phones. The penetration rates in different countries are different, and perhaps the main thing that differentiates between different countries' penetration rates is when the country started, when they deregulated. You've got different countries with different starting points, and then you've got slightly different curves in the different countries on how quick these penetration rates have grown.

Depending on how you measure it, you end up with these penetration rates at the end. If you look at those numbers, those are quite realistic in where we are going for penetrations per person. If you pick any number in the range that you see here, I think you'll see numbers which are quite ambitious. We are going to have a situation which will change our behavior very much. It will have an enormous impact on all of us.

If we look at the impact of cars on people. Most of us here have cars, it's obvious. In the future people like us, all of us here, will have cell phones within five years. Even if we look beyond people who are exactly like us, who fit our sort of cliche, you will see lots of people having cell phones, not only people in our age group, but also older people and younger people. It's going to be absolutely enormous. You haven't seen anything of what's happening yet. There are already countries in the world with more than a 20% penetration rate. Just think about the social impact of this. It's actually quite big.

Assuming current product line

- High volume moving targets require
  - →Flexibility at all stages
    - Upgrades and Customization
    - Modularity
  - →Reliability
    - Low margins do not allow field failures
  - →Tight vertical links
    - Demand > forecast causes immediate shortage
    - Open cards accepting reasonable profits

NOKIA
Connecting People

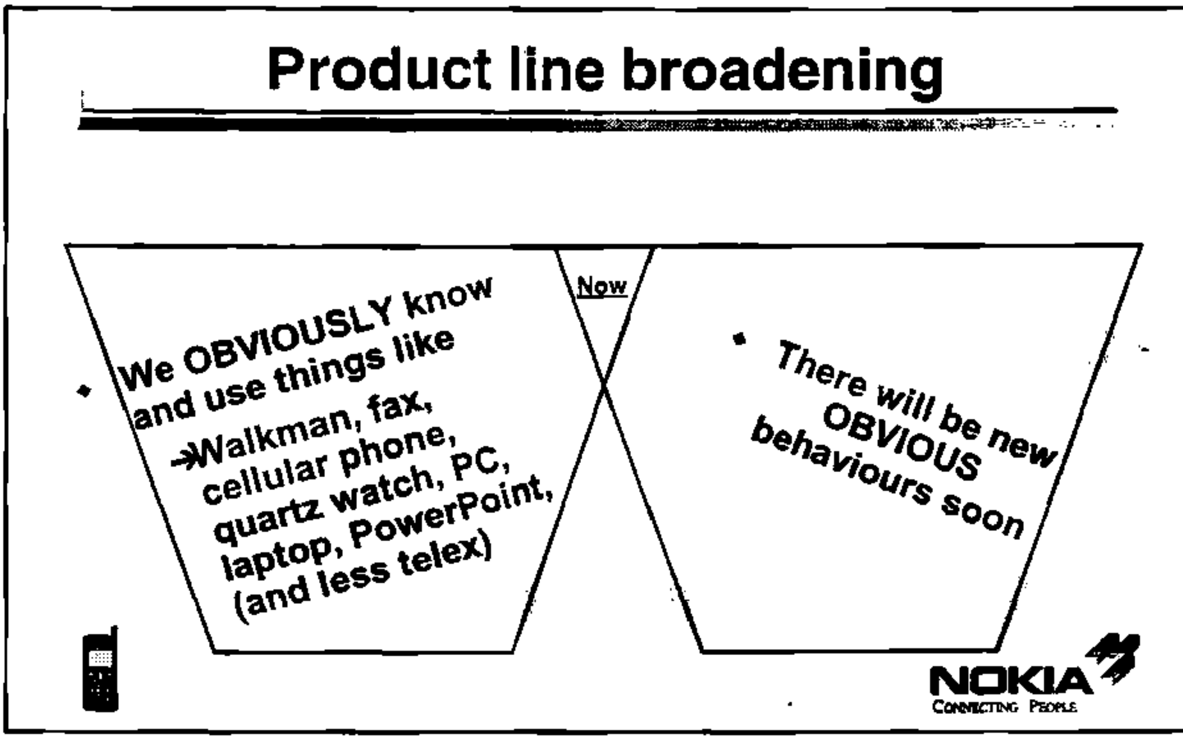
If we now assume for a moment that we continue making phones in our traditional sense, then mass production means that these phones must behave perfectly. If they do not behave perfectly, you have hell in the market place. Reliability, gentlemen, is something that we will ask from you, more than ever before.

I won't go into the actual acronyms, but we will have a total mess out there of different standards. We are going to have a total mess of different concepts as well, so it's going to be terribly confusing. From the point of view of Ray and myself, I am sure that we don't mind, because as long as the standard is big enough, we'll be there. If it's too small then we won't get to be there.

The next comment is on new network roll outs. People will keep talking about how quickly new networks will get rolled out. Take it slow and take it easy. People keep over-emphasizing how quickly these new networks are going to get out there. It's not easy to roll out new networks. Every single network so far has been delayed; no exceptions. Expect new networks, but a little bit later than expected. Just like those children: They do have an enormous impact when they do come along, although they can take a long time coming.

If we look at the implications for the semiconductor industry obviously high volumes means flexibility more than ever before, both within a product and within a total product concept. We mentioned reliability earlier, and it's also got things like tight vertical links. There are more cell phones built this year than PCs. We need very close links with you so that we can estimate how much we are going to be needing.

If we go beyond the traditional cell phones and think about marrying cell phones with other products, or creating absolutely new types of products, then things get much more tricky. I don't think it's obvious that Nokia or Ray's group are going to be the people coming out with these new products, but perhaps it will be. Certainly we are trying to.



We have behavioral aspects to study. If you look at these products here, then it's obvious to people how to behave with these things. It's obvious that we don't come up here with - for instance - a camcorder and film me right now because that's not what you do. Vice versa there are going to be new behavioral codes for cell phones and also new behavioral codes for products that we have yet to see. These products are all products which have turned up over the last 20 years. It's obvious to all of us how you behave if you are the proud owner of one of these objects.

GSM/CDMA95/PDC/PHS/TDMA136/DCS1800/PCS1900/DECT

- GSM based and PDC established
- US will have multiple digital standards
- High penetration
  - → allows room for multiple solutions
  - → means Basic models may dominate
- New concept explosions enabled by
  - →Miniaturization
  - →Convergence
    - Cellular - Intelligent Networks - etc.
    - Cross-standard in a broad sense

NOKIA
CONNECTING PEOPLE

When we look at future objects, we have to look at the total impact of how people are going to behave with these things. Is it going to be considered cool to be a proud owner or what is it going to be considered?

This is something that we launched a week ago. It's a PDA where all the Nokia phones snap in. This is the first time that Ray has ever seen it. The phone snaps in on itself and you can use it for E-mail, for SMS, for fax, for everything. It is a full communicator, plus PDA function is in there.

Roll-out

- Over-estimating the short term impact of change and Under-estimating the long term impact of change are classic mistakes
- Getting a network rolled out is not a trivial task
- => Expect new networks, but later than expected

NOKIA
CONNECTING PEOPLE

Where is it going to go beyond that? Well, obviously we are thinking a little about what our contribution might be, but one thing is for sure: It will not all come down into being a small converged market where everyone is happy and there is only one type of product. It is going to be very, very diverse. Customers demand it. There are so many different individuals out there that we are going to have a situation in the future where goodness knows. I really don't know what's going to come. We have some thoughts and ideas, but let's talk together about where it might be going. Thank you.

Panelist Angelo Ugge: From my accent I believe that you can detect that I am coming from the Mediterranean Sea.

What is the destination of the wireless odyssey? For sure we do not know the how, as was already mentioned, but by my definition wireless has a very clear objective. It is to get rid of umbilical cord of the wire, to give anybody the possibility to communicate anywhere, with anyone around the world. How will we do it? I don't know. What kind of standard will prevail everywhere? Frankly, I don't know. It is not a semiconductor industry proof positive standard.

By the way, I want to congratulate Dale for making my life easier so that you know everything about the standards.

What we will all know, and this seems to be extremely conservative forecast from all of the literature that I have seen and from the data on penetration that are mentioned by the system houses, is that by the year 2000, there will be much more than 250 million cellular or PCS or wireless subscribers around the world. There will be much more than 200 million pager subscribers around the world. There will be more than 100 million new - let's call them wireless terminals - and only God knows if they have cellular, PCS, or what. From now to then it will change dramatically. Even the pager, which seems to be such a tiny portion of our life, we will estimate there will be a market for more than 50 million units per year, every year past the year 2000.

BY THE YEAR 2000 ...

...THERE WILL BE MORE THAN:

> 250 M CELLULAR / PCS SUBSCRIBERS W.W.

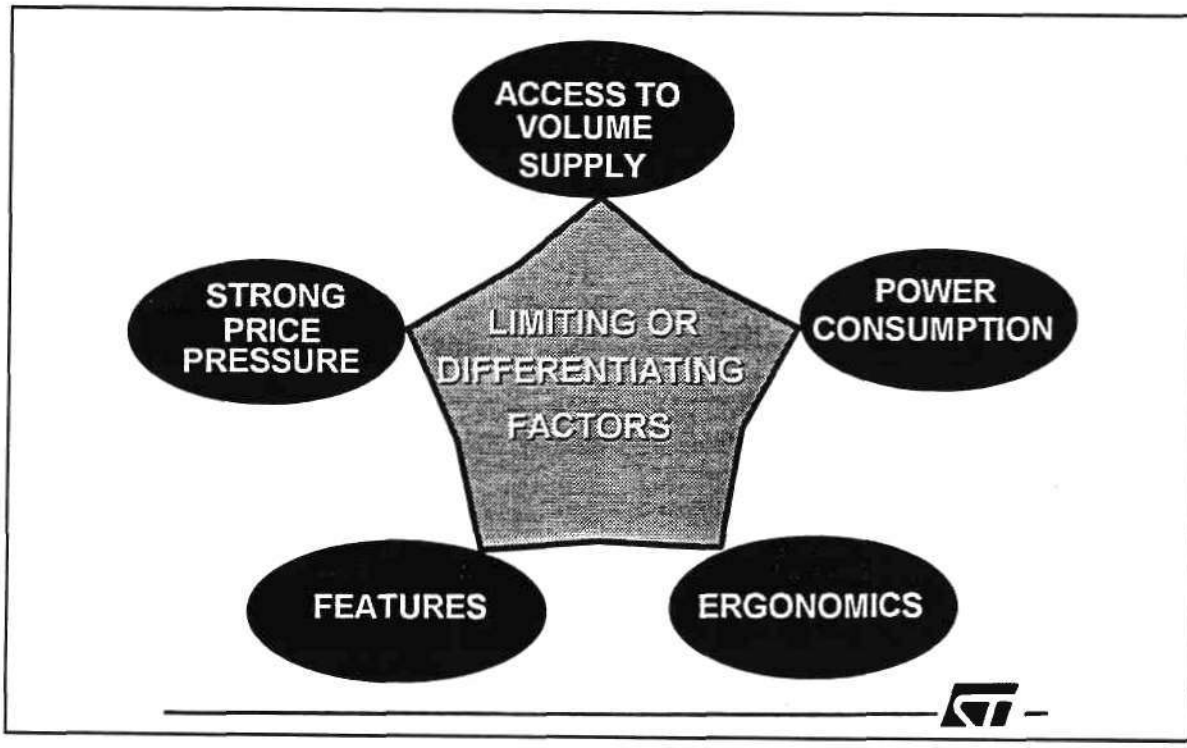
> 200 M PAGERS SUBSCRIBERS W.W.

> 100 M NEW WIRELESS TERMINALS SOLD / YEAR

> 50 M NEW PAGER SOLD / YEAR

I want to make a disclaimer here: All of these numbers are subject to rapid change, and the mix will change. The technology is evolving very fast, and our system integrators here only knows how fast they are produced today. New competition add new challenges on the market.

From our point of view, the semiconductor business people, the people who are dealing with standards and silicon who support our colleagues in the wireless industry; I found five key elements that (from my perspective) we - semiconductor people - need to face to support them and to help them to be successful.



First and foremost, the access to volume supplies. I believe that within quite a few companies in the past few years they lost quite a few million extra dollars because they simply couldn't get as much silicon as they wanted at the time they wanted it.

Challenge number one: Support the volume. It will be growing faster than expected and it will be huge. That implies a lot of capacity to be dedicated to these fellows.

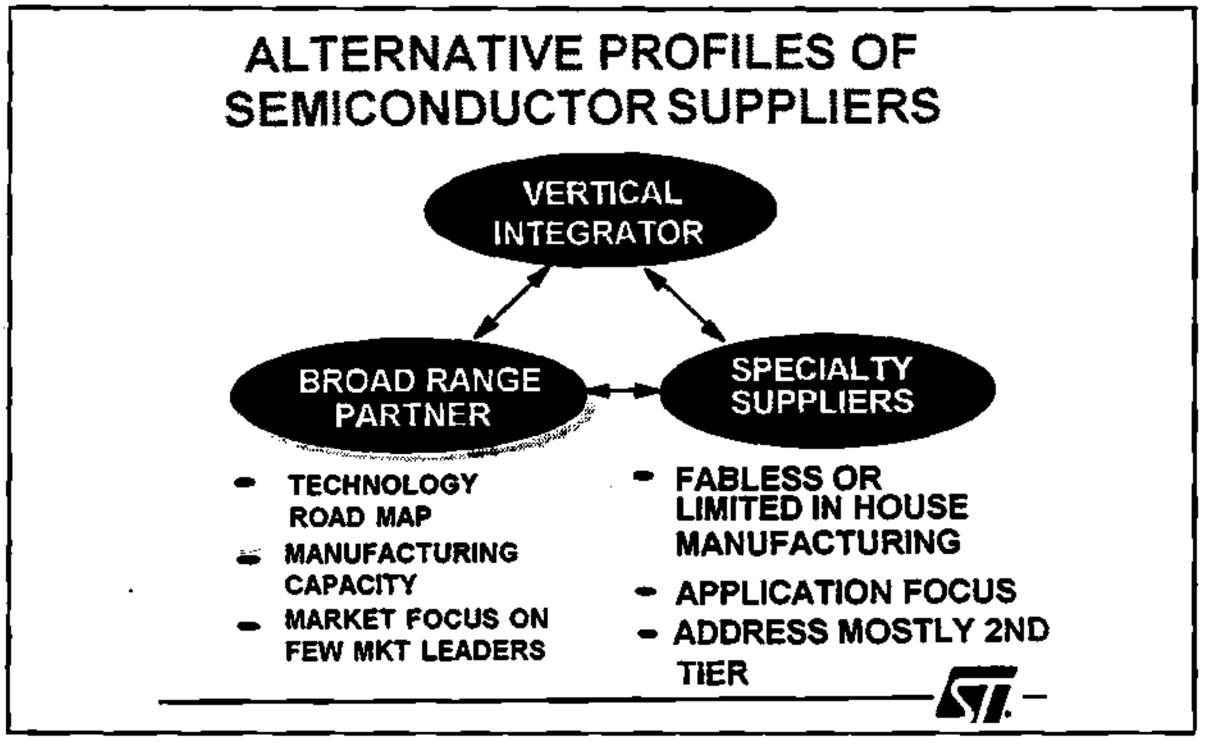
As the markets grow, there will be two equal pressures (I believe). One is I want to have a telephone in my pocket that behaves like a telephone. That means that unless I want to be in a private situation, I want to have it always on. Power consumption will become paramount in the development of the new generation. This will influence the acceptance or the rejection of some portion of the population.

Likewise, a big user volume means that the markt will take on consumer like characteristics. Therefore, if the market is not strong enough there will be further pressure on pricing, which means looking into the cost of materials, the cost of the semiconductors, and economies of scale in producing products.

Then, obviously, the market will demand at least two fundamental features. One is features that sell. What do you want to do with a wireless terminal? If you look at what people wanted to do 50 years ago, it was simply to make a phone call. Now I would like to transmit faxes to my PC while I am on the road, and even further, if my system people would like to listen to me, I would like to have a cellular piece of equipment in my PC so that I don't have to connect the two pieces of hardware together. These are the kinds of features that we are expecting to see from our systems people.

Mass distribution of these handsets will involve ergonomics. What do I mean with ergonomics? Size. Weight. Shape. Color. Form. These will change. These will be imposed on the semiconductor people. Packaging constraints. Thickness constrains and so forth.

Given these limitations on opportunities, what are the models that the semiconductor industry should adopt to serve this market and to be successful with them? In the present, past and still today, you see essentially three major components: One are the vertical integrators. For vertical integrators, I mean Motorola Semiconductor supplies Motorola Cellular or AT&T Micro trying to sell to AT&T.



Obviously they have a big advantage. They have first hand access to the system. They might have other advantages which is access to the volume which is needed to sustain the growth.

The second approach is the one of the growth range of supplier, which is in control of the manufacturing and technology development strategy and can influence both of them to serve this market. This is the role of the huge corporation. SGS Thomson is one of those.

Then there are some suppliers that usually see cellular as a tactical opportunity to increase their market share or market penetration, and they want to seize the opportunity. I see the limitation being not only their access to foundries, but their access to volume. The market is changing so rapidly that it is very difficult to stay in tune with this market opportunity.

My fundamental point is these three motors are not fundamentally, mutually exclusive, and if the industry wants to succeed it will find a way to find the cross-cooperation cross-links to serve a market that is by itself very big.

THE WINNING IC PARTNER

- SYSTEM KNOW HOW INFLUENCES SILICON PRODUCT & TECH. DEVELOPMENT
- CONTROLS THE EVOLUTION OF SPECIFIC & CONVERGING TECHNOLOGIES. (I.E. SUB MICRON, BICMOS + CMOS)
- HAS LARGE INSTALLED BASE OF SUB MICRON VOLUME MANUFACTURING
- WIRELESS IS A CORE CORPORATE STRATEGY
- CAN OFFER FAST TIME TO PRODUCTION

I am trying to come to my conclusion: What is the winning partner for the system integrators in the wireless business? It tends to be somebody who has some level of know how of the wireless system, and not because we want to copy what they are doing, but simply because a minimum level of know how allows us to identify what are the technology needs ahead of time. It also allows us to support the R&D investment and eventually the many special investments needed by the system integrators.

Obviously, this partner must control their own technology, their own strategy. It is easy to say that you cannot acquire the technology, but the fundamental point here, if you accept the partnering of high volume, lower cost, then sooner or later we have to integrate those things into very few numbers. That means that you have to have a set of converging technologies that are tailored for a productive market.

Finally: Volume manufacturing. This goes without saying. If this is going to be a volume market, where do you make these things? The density, the complication of this processor by far is such that they fall in the category of being a submicron technology. Today we are talking about .8 micron BiCMOS technology and 0.5 micron CMOS technology. In the near future we will talk about 0.5 micron Bi CMOS, and 0.4 micron CMOS and so on. Not only do you need to add high volume capacity, but you have to have high volume capacity in the submicron arena, which today is a domain of the PC market. The PC market is hungry for this integrated technology.

That means that the corporations that want to be present in the wireless business need to make it a corporate strategy. It is to be seen as one of the fundamental strategies and not just a tactic of the corporation in order to survive in the year 2000.

Finally - and I think here I am overstepping my boundary - time to market is the key. Time to market will be the key from conception of an idea to turning it into huge volume production. This is where the two industries need to work together to make it sooner, to make it bigger, to make it better. Thank you.

Panelist Sohail Khan: Good afternoon. I think some of you think that I am going to be the repetition of what you heard from Peter and Angelo, a similar theme.

One of the things which you heard a lot about is standards and the various different standards which are applicable to various markets. What I have tried to do here is to summarize on one page, the opportunity that is available to us in the wireless area, both in the area of wireless voice and data and how it spans every single aspect of life from a home use to a business use. Maybe this is the opportunity which Davidow missed this morning when he showed $700 billion and he couldn't identify the rest of the $1 trillion market he was talking about. The other $300 billion will come from this opportunity which is available to all of us.

One good thing in this area is that there are standards. In PC the de facto standards came in to place. Standards help, but on the other hand standards can also slow down the growth of the market.

One thing that has happened because of diverse standards is that it has slowed the growth of the market. Diverse standards have caused more confusion. As Peter mentioned, the industry market is big enough for Nokia and Motorola to find a way to be a player in that market.

It applies in the same way to the semiconductor vendor. There are huge investments which take place from the semiconductor side. The paradigm has changed from the old paradigm where the semiconductor guys only had to worry about providing a very general device. I will show you in a few graphs what things we have done to help our system partners, like Motorola, Nokia and other people, who play in this makret.

The standards are good, but at the same time we hear that wireless has taken off, but we are still seeing slow development on the wireless data side. The different standards and confusion is one of the reasons wireless data has not taken off. The same is true of the overall U.S. market.

On the other hand, if you look at the standards which are pervasive, this pervasiveness enables commoditization The key issue here is the standard has to be a pervasive standard for everyone to make an investment. The options become very simple. Do I need it and which is the best supplier who will fulfill my needs? The same thing will happen to the system suppliers. The same thing will happen to the silicon suppliers. See what happened to the data fax market? See what's happening in the GSM area. Maybe Peter and Ray can say more about it.

If we go and look at what the market trends are we see that because of pervasiveness and commoditization we are seeing the wireless terminal really becoming a consumer product. You are seeing a typical requirement which comes along with a consumer product. It is quite different from the PC world. You can try to debate whether you need to have a PC or not. But everyone needs to communicate. Think of the number of people who are available who still have never made a phone call. One of the data points that I was told is that in China still 200 million people have never made a phone call. The trend in wireless voice is that it is going to be a real consumer product. The cost is going to be the key driving factor.

When we look at the data side, we see a lot of different standards. It may be a little bit controversial what I am going to say, but this is how we see it. People believe in getting incremental value and having the existing things which are available to them provide additional capability. We see the biggest pull in the data market coming from the paging side. This demand comes from the users, because the users' need is to receive data. The paging network and infrastructure is very well suited to provide the asymmetrical version of the wireless data. As the infrastructure and the availability is available, you are seeing that many services are being added to the paging network.

Digital Wireless Domain

Home Cordless	Commercial Cordless	Public Cordless	Microcellular	Macrocellular	Terrestrial Communication	Satellite Communication
Cordless telephone (CT3, PHP)	Wireless PBX (DECT)	CT2, CT3 PHP	DCS1800 DCS1900 DECT PACS	IS136, GSM PDC, CDMA	Private Mobile Radio IDEN	Iridium
44-48MHz 900MHz	Toll-quality In/out building	900MHz Outgoing Metropolitan	Metropolitan In & out Paging	Full roaming		
	Wireless LANs		CDPD Circuit switched	CDPD Circuit switched	Paging MOBITEX ARDIS N-PCS ESMR	GPS

Voice

Data

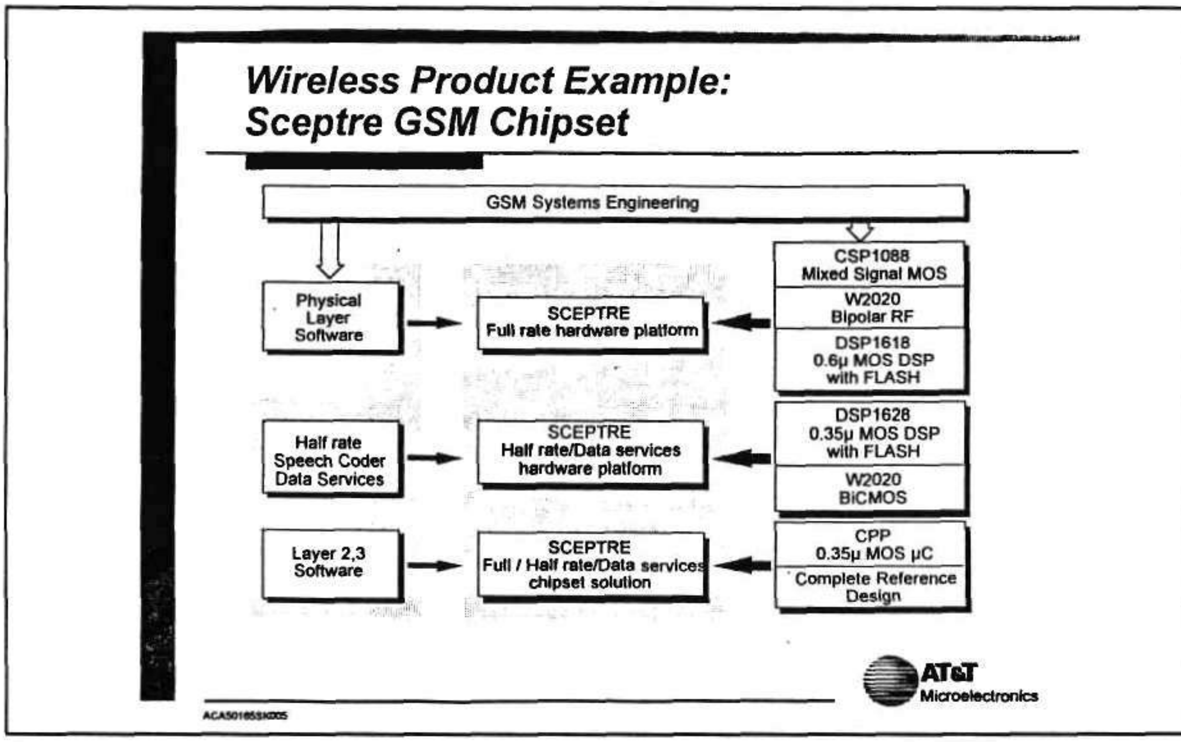
AT&T Microelectronics

ACA501855K001

Another key point which we are seeing in the market or the infrastructure is that the same paradigm is happening in the wireless domain which happened in the computer domain when things moved from the mainframe to the servers. We are seeing that these big base stations will become micro base stations. As the growth of PCS comes, maybe there will be a base station in every attic of the house. It gives them the flexibility to add and provide different functionality that is needed in a different area and what they can afford.

We see a phenomena in the wireless area, where like what happened in the PC area, the R&D of specific companies is moving to the semiconductor people. There will be similar phenomena happening in the wireless area. The key technology which the system vendors we are looking for in semiconductor suppliers is a system level expertise. Dont' just give us the chip. They cannot afford to take a device and build the system and then later on find out that something was missed and they have to go back and reconfigure the whole system, or add additional chips to make the whole system work.

What we at AT&T have done is to look at the complete problem, not just from a silicon standpoint. We look at a higher level, doing a complete system simulation and model right up front to really determine what are the right trade-offs between hardware and software. From there, you work with the system vendors, in defining what the right partitioning and the functionality is without changing the basic system. Then you can let them add more value, like going from full rate to half rate to data services, and I'll show you the examples of how we did it for GSM.

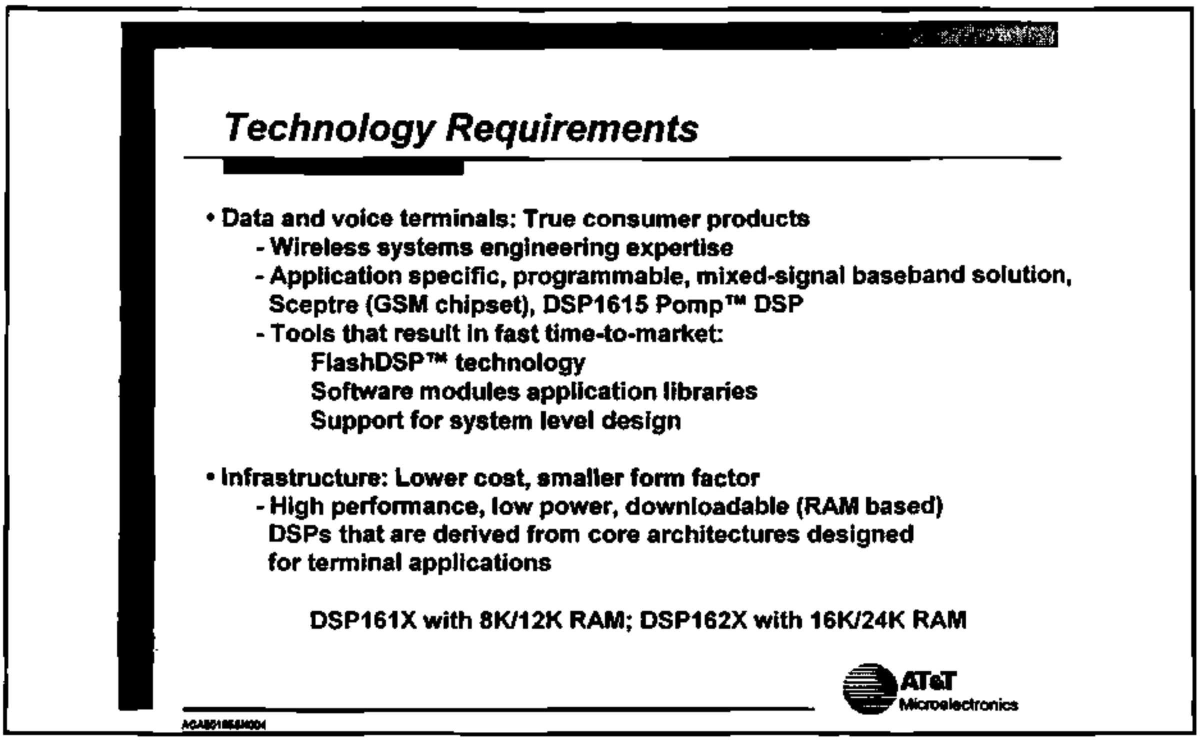


Another thing which is extremely critical is time to market. One of the things that we have done is to provide our partners with a flash memory capability. The DSPs we provide them with have flash memory on chip. Think of how much benefit they get from reducing a typical week of development to eight seconds of programming right in the field. You can also do the testing with this part.

As I mentioned that the infrastructure is also going to move, in the same way to support these consumer type needs, you cannot afford to provide technology for the infrastructure which is very expensive.

You have to drive the same technology which you are developing for the terminals to be applicable to the infrastructure, but at the same time give them the flexibility that they can upgrade their systems by just changing the software and not changing the hardware. We have different flash memory products and solutions in this area.

The example of the GSM solution: What I mentioned is that the focus was not on the devices, the focus was on the total GSM system. From there, we develop the right products and technologies which our system partners can use to add different value and a different software function without changing the whole basic system design.



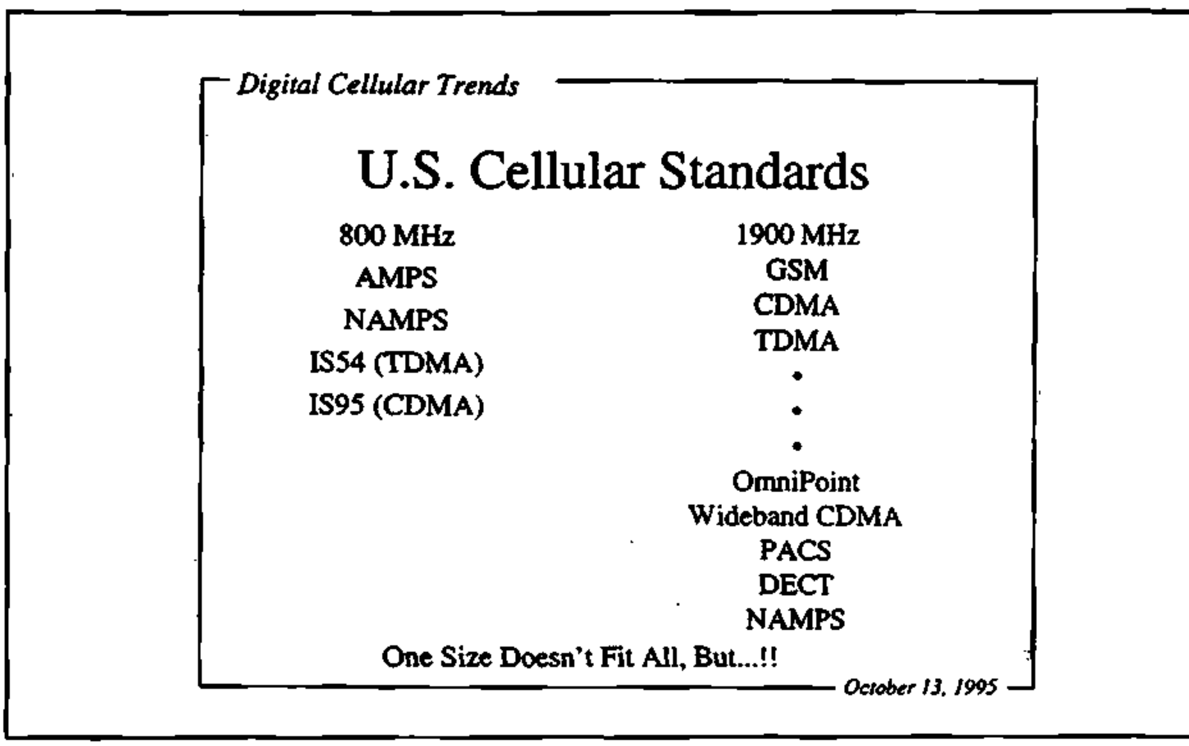
What we see ahead is that what we will be working to provide this market place with the capability to produce a real consumer product. A product that lets a consumer afford to be anywhere, and have the capability to be connected anytime. We are driving this technology where we can enable future companies to build terminals which will cost less than $50.00. The only way you can do it is to bring all of this capability and integration together.

One of the things which we are doing at AT&T is building very modular processors, which will enable us to bring these capabilities together. What we do is we have the CMOS process, which is pure digital. You go add more steps.

You get the linear CMOS capability. You add more steps. You have the flash capability. You add more steps. You have the bi-CMOS capability. With the cost trade offs, that has enabled us to provide solutions to system guys with the cost trade offs, and let them integrate all of those solutions and enable the industry so that there will be one phone for every individual, which will make all of us happy.

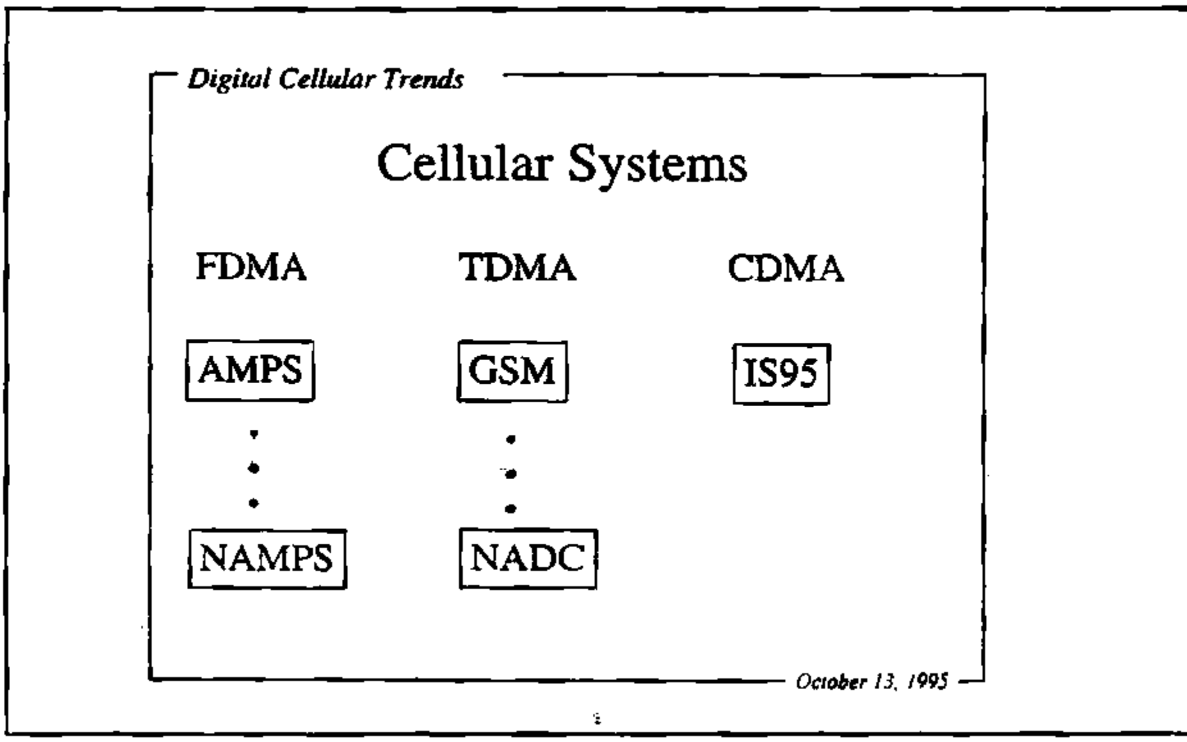
Panelist: I am Ray Millington. I am with Motorola. Good afternoon. You will hear a different accent now. You get to hear a good old Chicago accent.

The first thing I wanted to do was look at the list. Dale did a good job of explaining some of the standards that are being developed or are in use here in the United States. One thing you get, at least I walk away from this chart feeling, is that it's the un-standard. We have so many different specifications in existence, that it's really gotten to the point where you have a hard time putting your finger on something that is a standard. It's really reflective of the fact that to me there's no silver bullet. There's no one single answer to provide the end user with all of the applications and services that are needed. I think this is getting carried a little too far when we fragment the market and the standards as much as we have.



When I look at it, I think there are really two basic classes of users: We have the power user, the power cellular user who uses a lot of air time, needs the features, needs all of the full functionality that cellular can provide. We also have the casual user, the user who is looking at having a cellular phone to provide safety or convenience for their application.

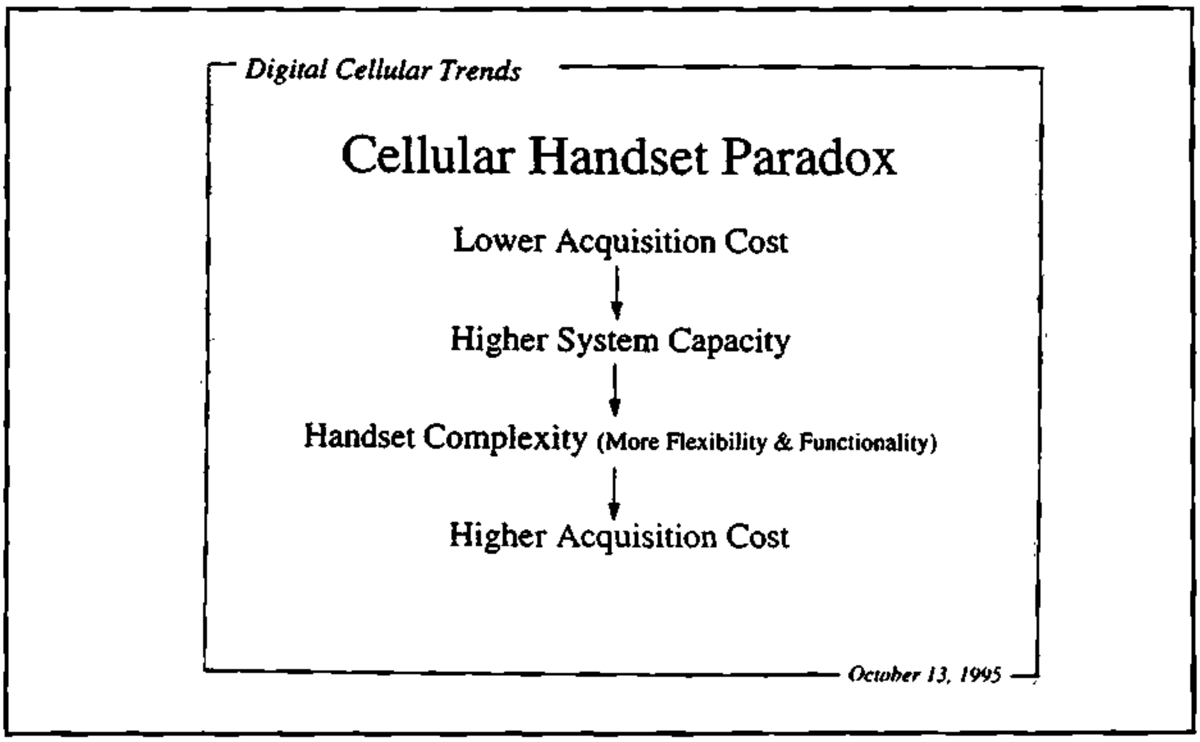
I think we can do a better job developing fewer standards. I think that's what's going to happen. I wish I had a way to fast forward and then look back and say what the winners going to be. Time is going to tell. Peter and I, being in the subscriber side of the business -a subscriber is just another name for handsets. We have to be able to provide equipment for all of the different products because we don't know what systems will provide the ultimate usage and become the "standards" going into the 21st century.



We do know that the importance of the standards are that we build up a good volume base. Peter is right. There is room for more than one standard and still provide a good volume base to drive our costs down. We're not going to be able to do it with ten or 15 standards. We need to minimize. We need to shrink that down.

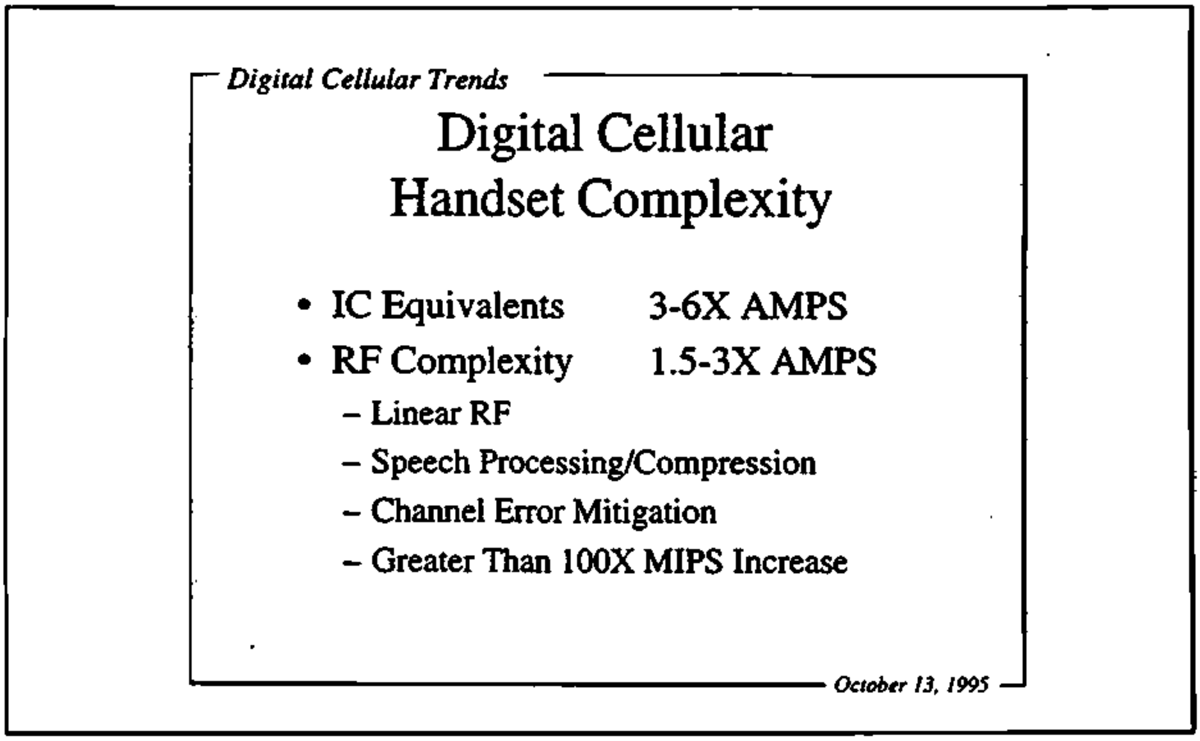
The other thing that helps is the quality of the product, the end service that's delivered. These services are becoming very complex. The ability to work the bugs out of the system - so to speak - and also enhance the services within the systems is going to be difficult if we don't home in and train and work in two or three different standards. Working on a standard as we have, on the AMP system here in the United States, I think we have been able to develop a very good quality, a very high quality cellular service. It's taken time. Here it is 1995, we've been in operation for almost 12 years on cellular, and we still find things from time to time that are surprises. We are still uncovering many surprises in GSM, in TDMA, the IS 54 standard here in the United States; and I think it's going to be more of the norm going forward. We need to be able to work together as an industry to help find solutions to problems and enhance the services.

The other thing that's obviously important about standards is interoperability between different networks. People roam from one city to another city and you need to make sure that the services are compatible.



I just wanted to spend one minute just giving you a little bit more information about what's involved in the different cellular systems. To my left - your right - we have FDMA (as Dale said), that's frequency division multiple access. Basically what's happening there is we have one user per RF channel. In the case of AMPS, that's a system that's been in service for over a decade. That's one user per 30 kilohertz. We also have a narrow AMP standard, that's the NAMPS, and that's a ten kilohertz channel per user. We can handle roughly three times as many users in the RF spectrum with narrow AMPS as we can with AMPS, and that's a service that's been in operation since 1991.

TDMA, time division multiple access: You have one RF channel that's shared by several different users. In the case of GSM, we have a 200 kilohertz channel, shared by eight different users simultaneously. NADC, North American Digital Cellular, we have a 30 kilohertz channel with three users simultaneously. CDMA, Code-Division Multiple Access, we have a 1 1/4 megahertz channel that's shared by many users, 40 to 50 users.



RF complexity, that's another thing that not too many people really think about. You think that digital, you go to digital to make it simpler from an RF standpoint, and that's not true in the case of digital cellular. We have to go to a linear RF modulation scheme, and that impacts both the transmitter, as well as the receiver. In order to manage many users per channel or many users in different time slots, we have to go to speech processing compression. Channel error mitigation is done. That's how we get more efficient use of the spectrum. The handset gets involved and on a real time basis we have a lot of processing that's being done in the subscriber handset.

The original AMPS units were fairly dumb. The processing load that was handled by the AMPS handsets were less than a half a MIP. Units in the digital cellular arena are in excess of somewhere around 50 MIPs and above. You have quite an engine in that little cellular handset. It's a pretty good workstation.

My closing statement would be that again there is no one answer and there is no one situation that you can look at that will predict what is going to happen. I can point to two different markets and what's happened there over the last couple of years.

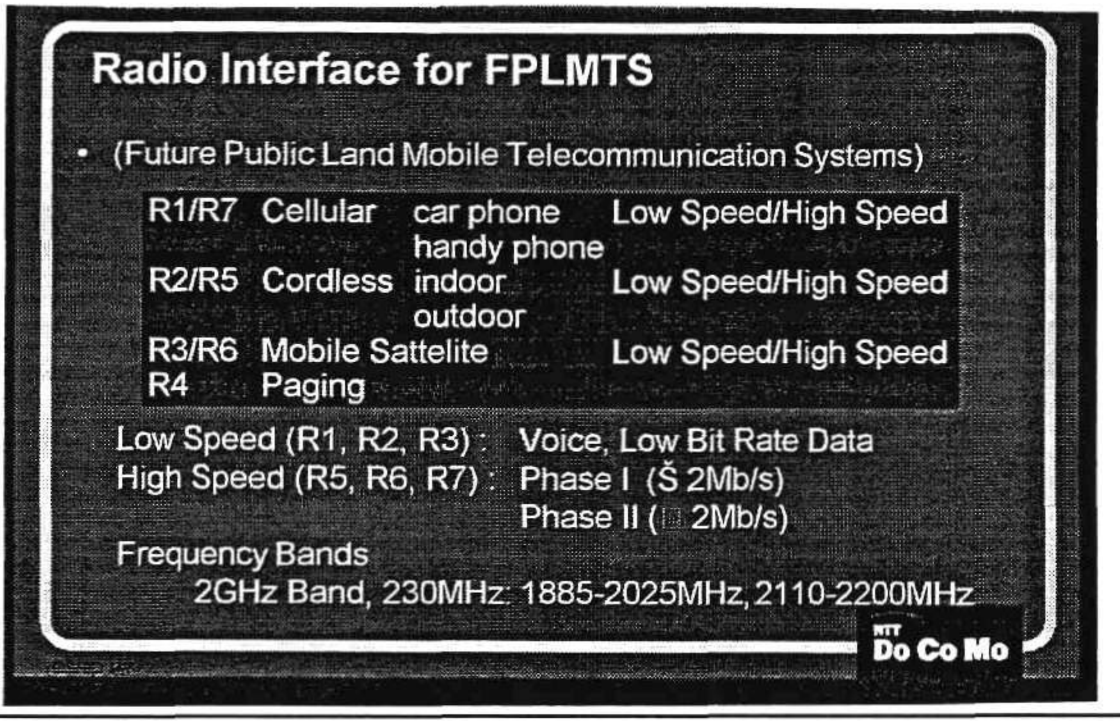
Take Germany: Germany started out without a very good analog cellular system and GSM was introduced. GSM provided handsets the previous German system could not provide. In Germany we've gotten to a point where digital is the dominant technology. About 75% of the cellular penetration in Germany is digital, 25% is analog.

The U.K. on the other hand had a very vibrant, very robust analog system, and digital was introduced at about the same as it was in Germany. What's happened is both markets have continued to grow. Digital or GSM is about a 16% penetration in the U.K., and the analog is at about an 84% penetration. Again, I think that kind of reinforces what I said, that there's not one size that fits all. There's not one answer. You are going to have different classes in a market that will go to digital and there are other classes in the market that will continue to be served by analog.

THE WIRELESS COMMUNICATIONS ODYSSEY: WHAT ADVENTURES LIE AHEAD?

Panelist: Good afternoon. I am Toshio Miki from NTT Mobile. Probably you know that NTT Mobile is a nationwide pager operator in Japan. We divided from the NTT main body three years ago. We are now working independently from the NTT main body and that's why my company's logo, the NTT is in small fonts.

The current situation and the problems in the near term or medium term were covered by the former speakers, so I would like to talk about the long range activities, especially in standardization in international organizations.



This slide shows the radio interface for FPLMTS. It's a revision of future public land mobile telecommunication systems. This is recognized as the first generation of radio. You will find from the graph there are four categories. The first one is well known, the serial radio. The second one is a cordless for indoor use or outdoor use. The third one is a mobile satellite, and the last one is paging. Except in the paging case, there are two classes based on a transmission bit rate.

First from R1 to R3, it is low speed transmission, probably used for voice or low bit rate data.

The second class is a high speed class from R5 to R7, which has two phases in the development. The first phase, the phase one, is less than two megabits per second. Phase two is a future one, higher than the two megabits per second. In any case, the high speed have a very high bit rate as compared with the current cellular radio use.

The FPLMTS will be assigned to the frequency bands of two gigahertz, with 230 megahertz bandwidth.

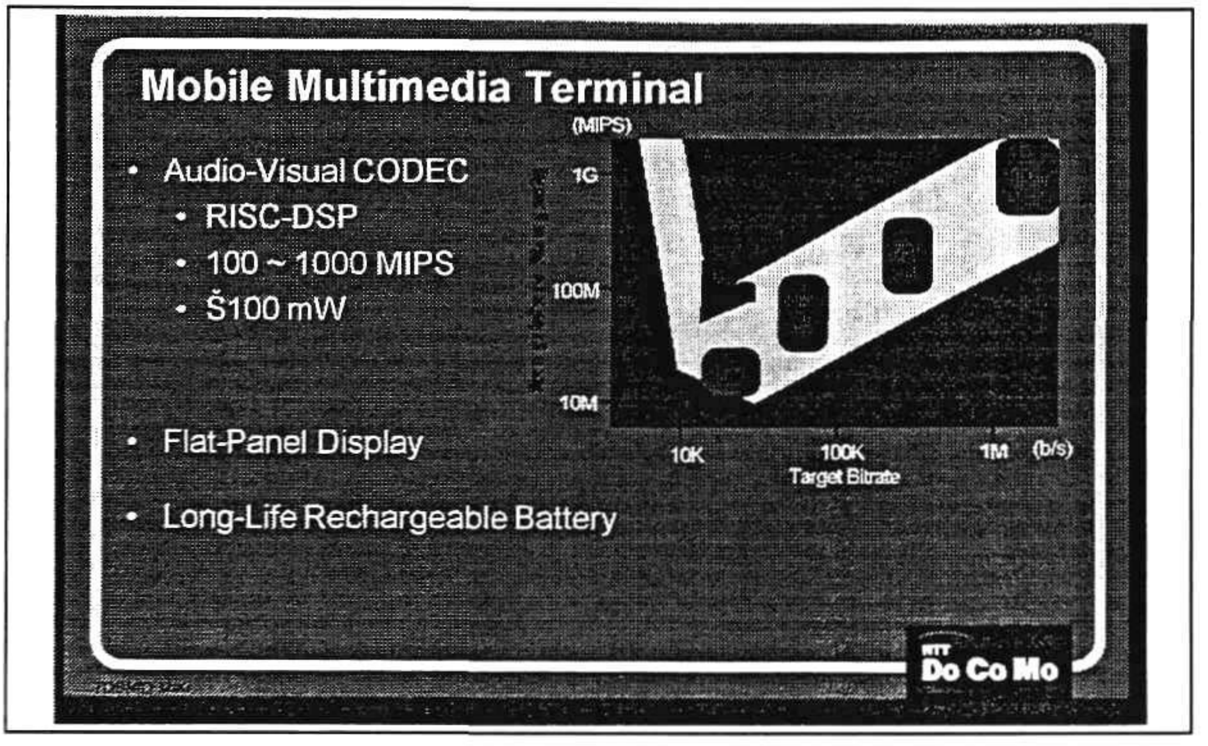
We can use such a very high bit rate radio interface, and what we want to do in this system is mobile multimedia. In the case of mobile multimedia, there are three important things we have to consider. The first one is audio/visual codec, which requires very high calculations and resources, as shown in the view graph.

We need various kinds of functionality for the codec, for example the downloading for updating a new voice. It's not a high MIPS DSP, but a DSP type processor will be required.

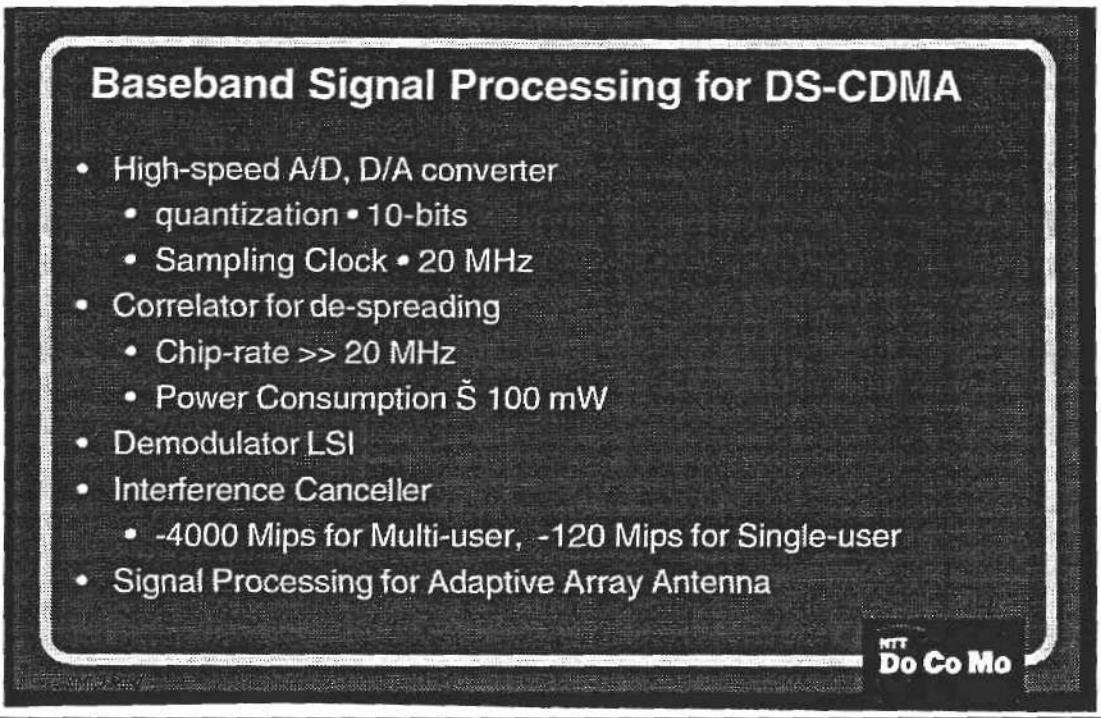
It's power consumption is a problem. The current video and speech codec requires some tens watts in equipment, but in the mobile handyphone it needs less than 100 milliwatts; also a flat panel display and long lasting batteries.

Another thing we have to consider are radio sockets. You know that to achieve such a high speed interface, the one problem encountered is employing the high speed CDMA case. In order to realize CDMA, we have to give up various radio sockets. On the front end, high speed analog to data and data to analog compatibility is required. It's ratio is about 10 bits. The sampling properties are 20 megahertz, considering the two megabits per second transmission.

If we want to have a very high capacity for many subscribers, the interference canceller will be indispensable. In the base stations that will handle the multi users, in that case we need 4,000 MIPs for multi user radio receivers. In the case for single users, it's around 120 MIPs.



Another promising way to handle the high capacity is employing the adaptive array antenna.. It also requires the high signal processing performance. That's why we need a very high speed DSP with RISC type and a general CPU. We need the high speed front end, and converter, and very low power consumption.



This shows one example for the mobile multimedia terminal. It is very likely that the PDA terminal will have - for example - a portable video phone in it's window. This application should be affordable, usable bye even children, and also pocket sized. In Japan, it's very important that multimedia have color capability. I do want to have that and they are now developing this.

Thank you very much.

Moderator:

With that we would like to begin our question and answer segment. We have a few minutes for questions and answers.

Question:

My question is how is the Motorola Iridium System going to affect your business, and also Loral's low earth orbiting system called Global Star?

Moderator: Let's start off with Ray.

Panelist:

I'll try and answer that. I don't think that the Iridium or Loral Global Star systems are going to be direct competitors for cellular. They are going to provide services that are ancillary to cellular. They provide the fill in areas where there isn't cellular coverage and it's going to be the strength of those systems to provide that. I hope that answers your question.

Question:

I'd like to ask you a follow up question, Ray. The financial community sees a lot of risk in these satellites. What are the critical risks that you see and what can be done to reduce those risks in implementing a satellite system.

Panelist:

I don't have all of the answers for all of the risks, but I think that the key thing is that we go through the right validation processes and the right steps and that we provide a system that's robust as far as link margin between subscriber units and satellite, and also that we make sure that we build in the right expectations for the end user. It's not a cellular replacement.

Panelist:

From Nokia's point of view, I would like to agree that head to head satellite vs. cellular: No chance. Cellular wins every time. If cellular chooses not to go head to head, that's when satellites can have a success rate. If you have a few percent here and a few percent there and so forth in a large area where cellular has chosen not to go head to head, and then you have a system which can wipe up all of these few percents here and there and add up so as to make it a total system viable, that's where satellite has a chance.

Panelist:

A satellite system does have the opportunity to provide really the first world wide communications standard. That's another big plus for it.

Question:

One of the panelists earlier on said that there is going to be a big market for pagers over the next several years. Why would anyone want a pager in the year 2000, when you can get that nice cheap PDA, which I thought Japan was talking about?

Panelist:

There are a couple of reasons. Number one: It is extremely cheap compared to owning a telephone. Number two: The area of growth for pagers today, from the data we have collected and seen, in the modernized countries where there is an infrastructure that would allow you to (A): Use a cellular; or (B): go from a pager to the nearest phone to answer your call. The biggest data growth indeed is in an area where there is no telephone infrastructure and it is not foreseeable for the next X years. The pager therefore becomes not only a way of accessing the remote person, but it is envisioned also as a way to transmit bidirectional messages of a very simple nature.

Panelist:

I would like to comment. Nelson Mandella said a week ago at his speech at Telecom 95, he said that communications in the 21st century will be a basic human right. That means that everyone in the world in the future will assume the right to communicate with devices. Again, if we just look at the broad groups of people in the world, there are people who are so terribly different from each other, that even though cellular might grow very quickly, it means tons of room for entirely other approaches - such as pagers - to continue growing.

I think it would be very radical to say that pagers would disappear; at least in the short term.

Question:

There has been some discussion about the phone number per person and intelligent phone that knows whether you're in your office or your house or your car or wherever. To what extent do you see that?

Panelist:

Cost service: It acts like a cordless telephone when you're at home. As you move away from the house it reverts back to the macro cellular system. There is a network protocol that's required to transfer the incoming calls and route the calls to your correct system. Whether that's your home base station or the macrocellular system. There is a lot of work to be done and it is being done with networks to provide intelligent location registers and to work within the ISDN framework. I think that will be an important development going forward and the industry is grappling with how to develop standards and network protocols to do that.

Question:

Do you have any idea of the time frame when we might start to see the one personal number in the market?

Panelist:

I would think within the next couple of years there will be several different solution sets.

Panelist:

May I add one comment to that. I am about to subscribe to one of the systems developed. The system is available as described. Obviously I don't expect it to be available on a gross scale, but it is starting now.

Panelist:

If I look at the way that I use my cellular phone at home at the moment. I get all of my phone calls onto my cell phone, regardless of where I am in the far east or in Europe; then when I get home I just go to call divert, what I think it's 1-2-3-4 key presses to do a call divert onto my home phone and I just chuck it in the bin and leave it there until I leave the house the next time.

From the point of view of my friends and colleagues, they always call the same number. It's de facto for me today.

Question:

Does the panel feel comfortable talking about the economics of billing in the future? Do you see the practice of virtually giving away the phone and billing on a per use basis being the direction; and is that cost going to decrease in the future with basically the amtorizing of the capitalization of the new technology? The second question: The speaker over lunch was very provocative in his projections about the potential use for billing with semiconductor cash. Do you see that as a technology that you are factoring into the system design of the portable phone of the future?

Panelist:

The question has to do with billing systems. I think service operators have more control over that type of thing than I do.

Panelist:

This thing about giving away phones for free. I don't think we'll do that at this point. Somebody else does that. That's different market by market. Some markets don't do that at all. For instance: I think in Japan phones are not given away for free.

Panelist: There is a subsidy, but they are not free yet.

Panelist: It's not like one cent and that sort of thing.

Panelist:

The follow up question was interesting on the electronic cash. I think GSM has a system in place with Smart Card that enables that type of thing.

Panelist: Technically it's not difficult. The question is do people really want it?

Panelist:

As this technology is proven and becomes reliable, then an incorporated feature that the speaker was addressing during lunch; I strongly believe that we can definitely look into something happening. The trend is there; obviously the time frame is unknown. I am not able to tell you whether or not in ten years or in 50 years; I don't know.

Question:

Maybe I could ask you a quick question. You brought up the interesting point of time to market being very critical. Today most of the cellular services are rolling out new PCS services that have the voice capability in place, but data is definitely in lag. You have touched on a number of different things that have impacted data rolling out. How quickly do you see it before we can start having data implemented in these PCS technologies?

Panelist:

I think if you look at the current systems, you can always do it separately; and that is what people are using. If you look at the other area which I touched upon - paging - the infrastructure in paging is in place and it is nationwide. Most of the capability and need is for on-way data. People want to get small messages and be available.

If you want to know what your stock is doing, you want your New York stock broker to send you the information, not necessarily for you to send back. Some of these capabilities are already being made available on a lot of paging networks.

Panelist:

I would like to just re-emphasize that one of the new paging networks that's being introduced in the United States is a two way paging network, and the reason it is two way is to help the system provider locate the pager so that rather than broadcasting these large text message throughout an entire system, they use the two way paging device to locate the pager within a specific cell so that they can minimize the amount of air time and the amount of traffic that they have to use in order to get that message to that end user. It is going to become an application that becomes more and more prevalent.

Panelist:

When people talk about circuit switched data, I think it's important to remember four factors. The first thing is circuit switch data in analog means that you get about one bit wrong per 1,000, 10 to the minus three. That's not very good. On E-mail applications and so forth it's not very fun.

If you look at the digital world, then you can have two flavors: There's either digital transparent, which is very much like the analog situation; or you can have digital nontransparent, which is very much better. Instead of ten to the minus three, you get ten to the minus nine. You can't compare those two in the same sentence because they are very difficult.

The fourth aspect with circuit switched is that it is possible without any problems to link directly from a digital side of the network into things like the Internet, which means that it's possible to go from your mobile unit into your local area network without ever touching the PSDN, without ever modulating your signal. We've demo'd this. It's quite easy. You can have a log in time from scratch. When you open your machine you go boom, you can have a log in time onto your local area network, which is below six seconds.

Therefore, these aspects (I think) should be remembered when you think about circuit switched cellular data. It's not just one thing like this. It's split out. It's got different flavors.

This page is intentionally left blank

Chapter Twenty-two: HOW TO SUCCEED IN THE MULTIMEDIA CONSUMER SYSTEMS MARKETPLACE

Panel Discussion

Moderator

Greg Sheppard
Director and Principal Analyst
Semiconductor Applications Markets
Dataquest Incorporated

Panelists

Kazuaki Mayumi
Director Applications Labs
Matsushita Electronics Corporation

Dr. Takashi Kubota
Director, Senior Chief Engineer,
Consumer Products and Information Media Systems
Hitachi

Kenji Hori
President and Chief Technology Officer
Research Laboratories
Sony Corporation of America

Dr. Klaus Vokholz
Senior Director,
Corporate Planning and Strategy
Philips Electronics

Moderator:

Dataquest is excited to be hosting this panel on Opportunities in Consumer Electronics Systems. We have just embarked on a new program, the Multimedia Semiconductor Application Markets Consumer Program. We hope to be hosting more forums like this for you in the future, delving into more detail for what we think is a very exciting area, with lots of growth opportunity.

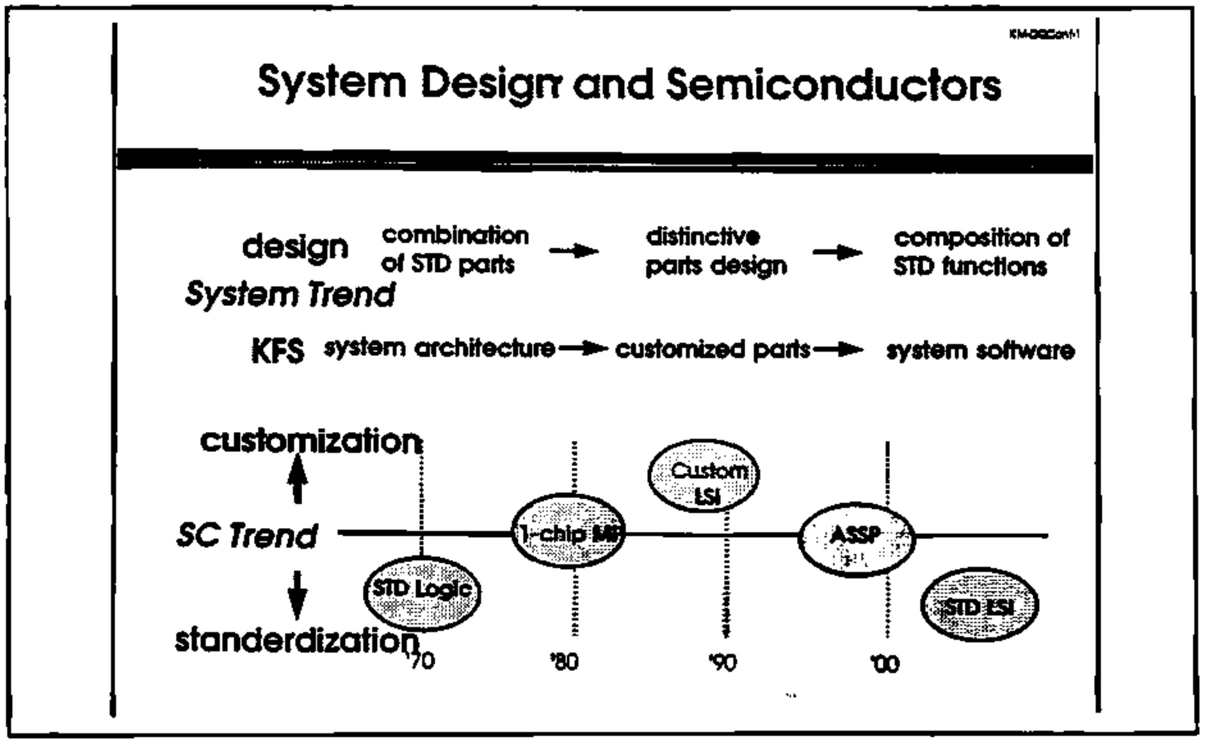
HOW TO SUCCEED IN THE MULTIMEDIA CONSUMER SYSTEMS MARKETPLACE

Our first speaker today is Kazuaki Mayumi. He is Director of the Applications Laboratory at Matsushita Electronics, responsible for developing LSI architectures for advanced electronics systems, as well as semiconductor applications technology for managing intellectual property rights at the semiconductor group. Mr. Mayumi has a degree from Kioto University and joined Matsushita in 1963. I think without further adieu we'll jump right on in.

Panelist Kazuaki Mayumi: Thank you. I am Kazuaki Mayumi from Panasonic, and I represent multimedia in the consumer field and semiconductors. From the customization standpoint, the semiconductor begins the standard logic.

At this stage, designers design by combination of standards first. For instance: Standard Logic CMOS.

At first the parts exist. Then systems are designed. After that, single chip microprocessor appeared. Finally, the custom LSI is available.

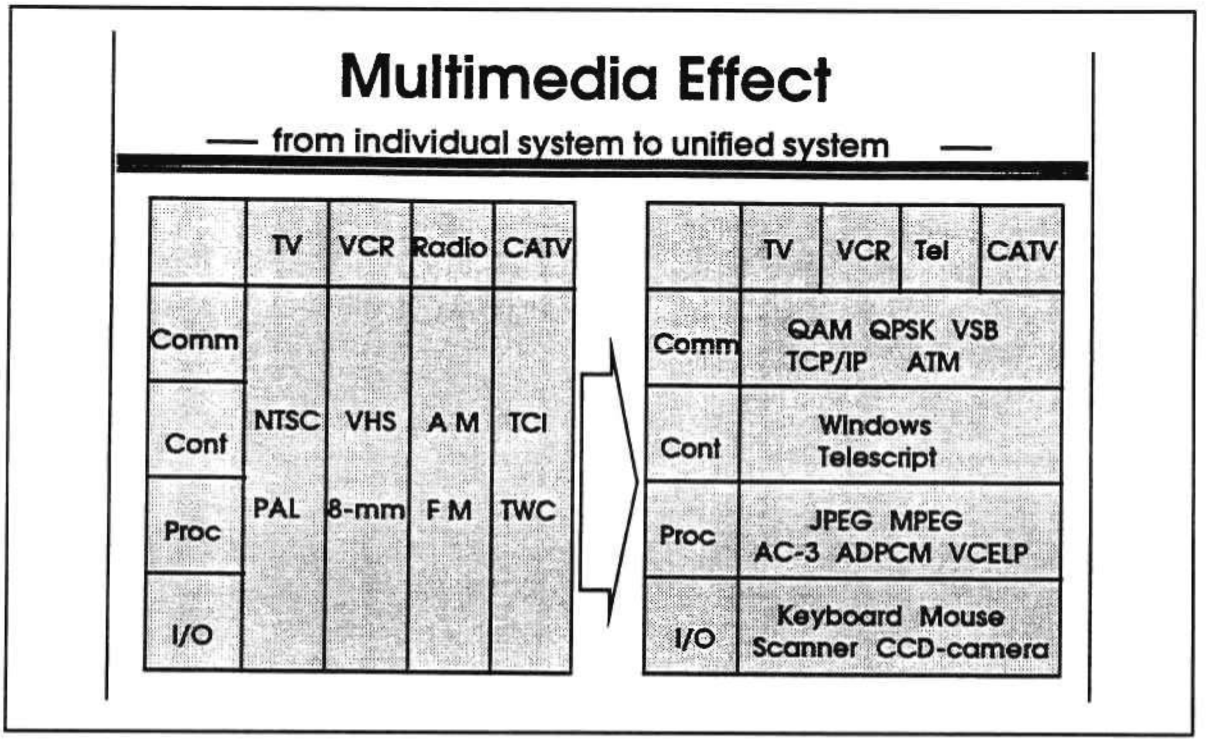


At this stage, the system was at first fixed. Then LSI is designed in the video area. The key for success for designers: How you can get the customer to customize his own parts. Custom LSI has flexibility. It becomes ASSP, Applications Specific Semiconductor Products.

The ASSP will become the standard LSI. Semiconductors start from the standardization and go through the customization, then go back to the standard state.

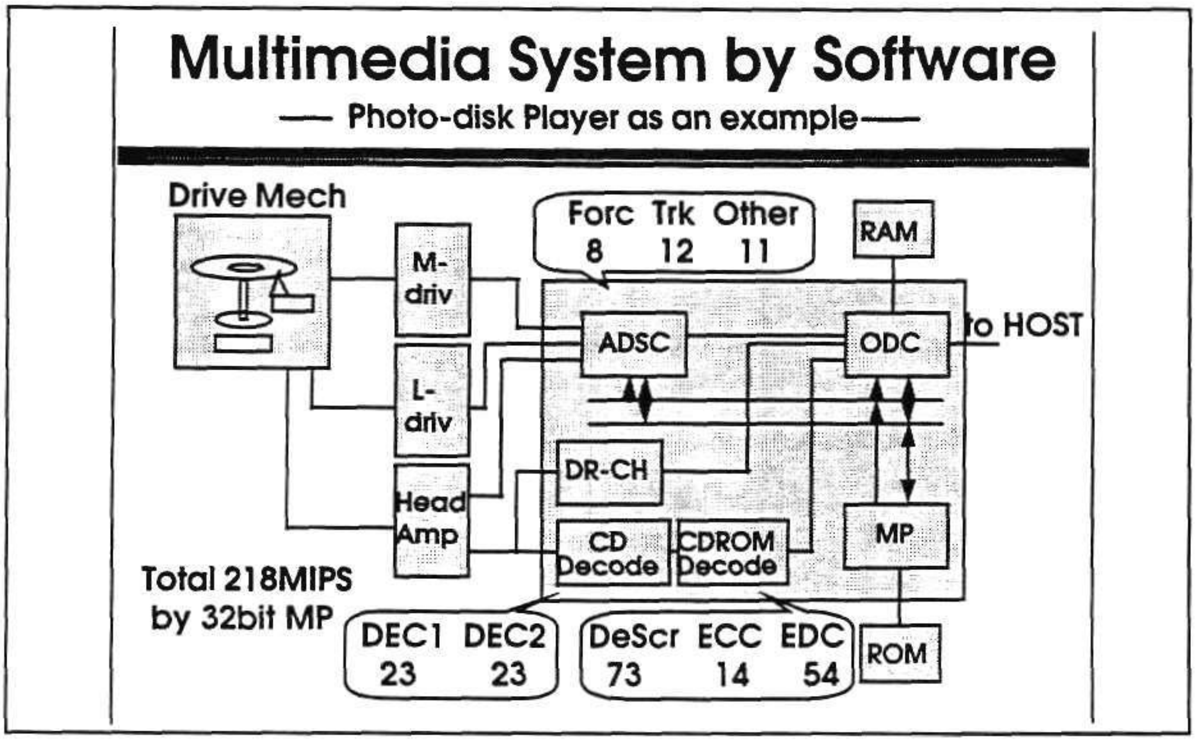
The final stage system design by completion of standard functions.

Previous stage: All systems are specified in the video area. For instance: NTSC system - or TV - completion of sound or voice processing, modulations and transmissions are specified individually. It is the same for VCRs.



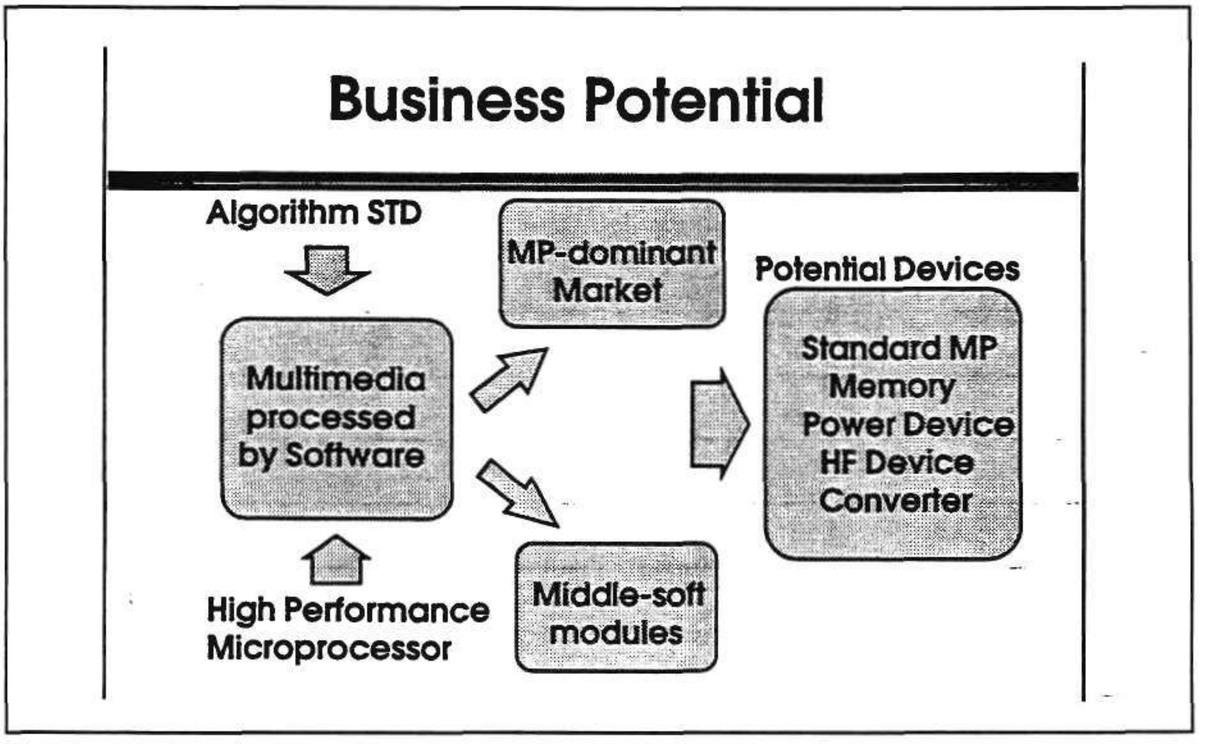
For instance: VHS defined single processing itself. No variations between TV and VCR. That we call multimedia effect makes the right hand side of the channel.

Algorithms themselves are specified for method, not for applications. For instance: Co-communications, QAM or QPSK and so on are specified. It becomes standard algorithm.



For instance: Windows or telescript will be specified. These algorithms are used for TV or VCR with telephones or CATV. These vertical specifications become the horizontal specifications. These specifications are processed by software. We don't need hardware anymore.

This is an example of the CD-ROM with quadruple speed. If we have enough CPU power for 80 SC's, this is 80 system control, focusing, tracking MIPs and other controls, 11 MIPs. CD recording, 46 MIPs will be consumed. CD-ROM decoding, this scrambling takes much MIPs, 73; error correcting, 14; error detecting, 54. Totally, if we have 218 MIPs by 32 MIPs microprocessors, we don't need any hardwares. We can process by software.



By those backgrounds, this final chart shows conclusions. Algorithms become standard and microprocessors have higher and higher performance. As a result, as indicated in the chart, multimedia processing by software. It means a market dominated by microprocessors and so-called parts ware, middle soft module, will be dominant.

In these circumstances, potential devices are indicated in the light brown. A standard microprocessor are top survival devices; and memory itself. Software is only memory. Standard microprocessor and memory makes computer system. Another potential device is power device or high frequency devices or combators, A/D converters. Those three devices cannot be depressed by software.

Another chance for semiconductor manufacturers in software modules: If semiconductor manufacturers can offer the standard soft modules, he can get the opportunity to get single chip microprocessor MCU or DSP as a container of the standard software. If he has no software, container has no meaning. Semiconductor manufacturers should have the devices which cannot be depressed by software, and software with single chip programmable devices.

HOW TO SUCCEED IN THE MULTIMEDIA CONSUMER SYSTEMS MARKETPLACE

It's just a joke: Standard microprocessors and memory and middle software makes the United Kingdom of the IDM, not IBM. 20 years ago for computer systems, IBM is the empire of the systems. In the multimedia era, IDM makes the United Kingdom. I for Intel, because they have standard microprocessors. M for Microsoft, because he has standard soft modules. D, D is not decided. This is standard for D-RAM. The quite strong competition in the D-RAM field. If manufacturers dominate the D-RAM field, he can be a member of the IDM Kingdom. Thank you.

Moderator: Thank you, Mr. Mayumi.

Our next speaker is Kenji Hori. He is with Sony Corporation, where he is President and Chief Technology Officer of the Research Laboratories located here in the United States. He is also a Director of Sony Corporation. He's been with Sony since 1961, and he's held various positions in R&D in the personal computer group, consumer video, as well as advanced TV development; I think a very well rounded background. The facilities in the U.S., in case you aren't aware, are in Montvale, New Jersey; San Jose and San Diego, California.

Mr. Hori has a degree from Tokyo University, as well as a graduate degree from Stanford University.

Panelist Kenji Hori: Thank you, Mr. Sheppard. Good afternoon ladies and gentlemen. How to Succeed in the Multimedia Consumer Systems Marketplace is a very difficult question. A lot of strategies and trials have been proposed for the future multimedia consumer systems. A number of equipment has been developed for so called multimedia.

How to succeed in
The Multimedia Consumer Systems Market Place

- **Broadcast/Network:** Satellite, Cable, Terrestrial, Telephone, ISDN
- **New Interactive Service** VOD, NVOD, Home Shopping
- **Computer:** Mulitimedia PC, Home Server
- **TV:** Digital STB, Large Screen, Wide Screen, Multiscan, HDTV, Flat Screen
- **Video:** Multimedia CD, Digital VCR, Digital Video Camera
- **Audio:** CD PLUS, MD, CD Changer
- **Home Network:** IEEE 1394

I just list up here some of those categories and equipment which could have a big difference on the multimedia consumer systems. Today nobody knows the possibility of their success and the degree of their impact.

Here broadcasts and networks already will change their market share very much in the future. Near interactive services will come, but not so soon.

Computers: It is a fact that computers and new video games are getting into homes and we say more important tasks of home equipment. It is a fact.

TV, video and other equipment are already in every home, and do not look to change evolutionary in the future of consumer multimedia systems. However, they are changing and we'll still be the most important equipment among the multimedia systems at home.

I would like to briefly touch on flat screen TVs and DVDs, VCRs, because these new things are used a lot with semiconductors. Also I would like to touch on other key devices for the future of multimedia at home.

Sony recently announced a flat TV. Flat screen development has been our dream. A lot of engineers have tried to develop various kinds of flat screens. Every CD is on the successful device, but they are not treated to bigger screens for living rooms. Recently Sony has developed a new display device, which is active metric flat display, plasma addressed liquid crystal technology. The thickness over the panel is just less than four millimeters, 1/6 inch for 25 inch screen. Picture quality is very nice, and we cannot see any significant problem in the prototypes.

I don't say that our flat screen TV will come to all of our living rooms soon, but CRT will soon be the major display for TV. Flat screen TVs are becoming more realistic then we thought a couple of years ago. Recently the many major companies investing a huge amount of monies to develop the flat screen; more money than before. I'm not sure when it will be available. I can say just very soon. This is one of the very important new devices. It is not a new one, but large screen flat TVs will come in a couple of years to the home. It uses a lot of semiconductors.

Next is DVD. Last month the Sony and several other companies came to a basic agreement on the single format of the next generation of high density optical disks. The new format combines the best features of super density chromatic, as proposed by the SD Alliance. The multimedia CD format proposed by Sony. The basic specification of the single format are backward compatibility with current CD and CD-ROM media, and .6 millimeter substrate thickness, a bonded disk and 4.7 gigabyte data capacity per layer. We are now discussing to get finer specifications in detail, and I think very soon we'll have an answer to our specifications.

PLASMATRON

High-Resolution, High-Contrast, Large-Screen, Active Matrix Flat Display, utilising Plasma Addressed Liquid Crystal Technology

Specifications:

• Address System:	Plasma Address Type Active Matrix
• Liquid Crystal:	90-degree TN
• Color Filter:	RGB Vertical Stripes
• Scanning Method:	Non-interlace
• Display Range:	Diagonal 25 inches (16 : 9)
• Pixel Number:	768 (trio) x 448 (line)
• Pixel Size:	0.72 (trio) x 0.69 (line) mm
• Brightness/Contrast:	250 cd/m^2 / 50:1
• Color Scale:	260,000 colors
• Panel Dimensions:	602 (W) x 380 (H) x 3.7 (D) mm
• Panel Weight:	1.7 Kg

This is just an example of the profile for the new DVD. It looks very similar to the CD. This is just an example of the CD. It contains the movies inside. It can have 140 minutes per side.

Next-Generation High-Density Optional Disc Format

- Backward compatible with current CD media
- 0.6 mm substrate thickness, bonded disc (single - layer / dual layer) and 4.7GB data capacity per layer
- EFM Plus signal modulation
- RS-PC eror correction code

We announced a new consumer video camcorder based on consumer detailed format, so called DV format. There are two different types of cassettes. This is the ordinary DV concept. This is the smaller than original audio cassette. It can record four hours and 30 minutes of video programs, with its 25 milli bps video signal. 25 milli bps video rate.

If we record into the video signal, it can record 28 hours of video programming.

Consumer Digital VCR

- Cassette Size: 125(W)x78(H)x14.6(D) mm (DV Cassette)
  66(W)x 48(H)x 12.2(D) mm (Mini DVCassette)
- Tape Width: 6.35 mm (1/4 inch)
- Recording Time: 4 hour 30min (DV Cassette)
  1 hour (Mini DV Cassette)

  Digital Compoment Recording (4:1:1)

Luminance:	13.5 MHZ, 8 bits
Chrominance:	R-Y 3.375 MHZ, 8 bits
	B-Y 3.375 MHZ, 8 bits

  Video Rate: 24.948 Mbps

  Recording Rate: 41.85 Mbps
- Tape Capacity (Unformatted): 85GB (DV Cassette)
  19GB (Mini DV Cassette)

Mini DV cassette is developed mainly for this style of camcorder and still can contain high memories. The important thing is we can have more than 70 gigabytes memory in such a small cassette. If we have just a 10 DV cassette, then you have a 700 gigabyte memory. DV cassette is already available in the market, and now just for the video camcorder. Thank you very much.

Moderator: That you, Mr. Hori.

HOW TO SUCCEED IN THE MULTIMEDIA CONSUMER SYSTEMS MARKETPLACE

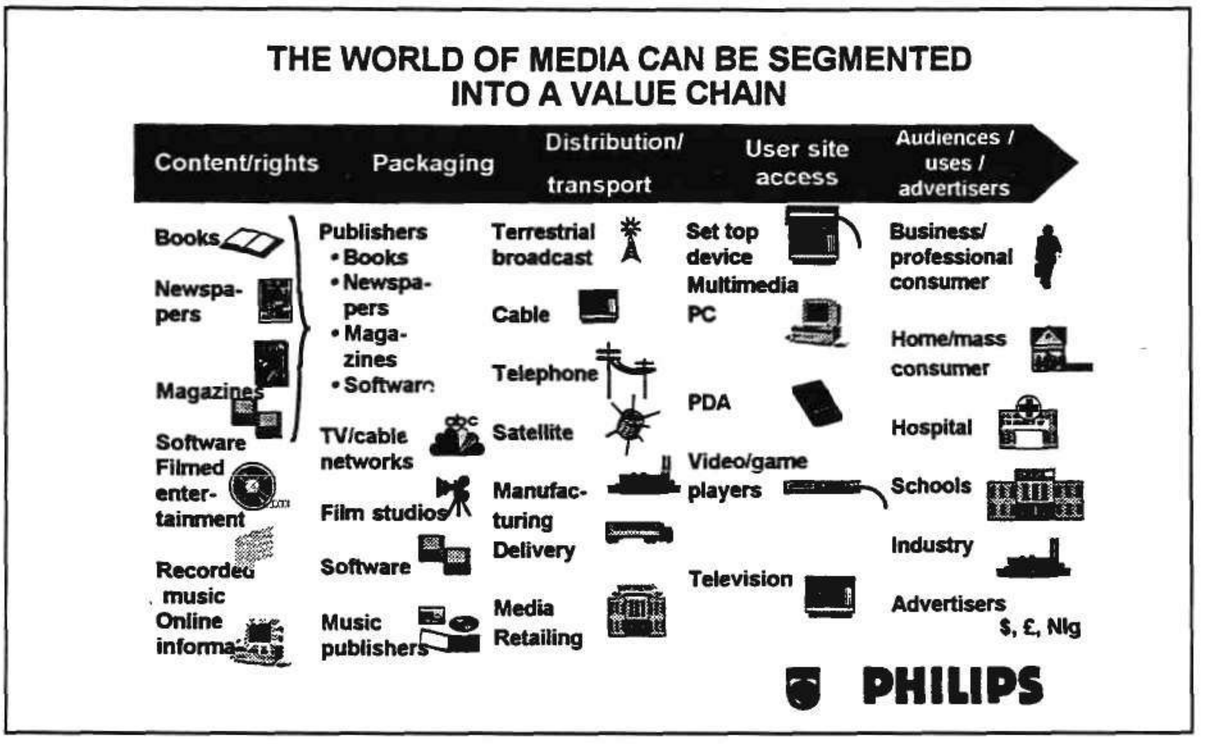
Our last speaker is Klaus Volkholz, who is a Senior Director of Corporate Strategy with Philips Electronics. He is based in the Netherlands. He's been primarily involved with helping re-direct and change a $35 billion dollar business, as noted here on his bio; certainly quite a challenge. He's been in this role for the last nine or so years.

Previously he had been in strategic planning and business development for Philips in Germany, and prior to that working with Philips here in California.

He has a Ph.D. in Electrical Engineering from the University of Michigan, and not a bad football team sometimes; not that I'm biased. With that, Dr. Volkholz.

Dr. Klaus Volkholz: Good afternoon. I would like to give a perspective of the migration of the industry from media to multimedia and address some of the major issues that we see as prerequisites for success of multimedia. With that I will be continuing somewhat along the vein of the discussion that we had at the end of the morning.

You can think of the world of media, and we have thought of it that way in the last couple of years, as a value added chain where really multiple options exist along the various stages of the chain. Several industries have been participants in these various stages over time and have established strong positions in generating content and providing services and as publishers or carriers or content, and ultimately as suppliers of hardware.



You can think of the industries of music and motion picture, prints and software publishing, broadcasters, cable and satellite providers, telecom operators, media retailers, electronics manufacturers and not in the least advertisers. All of these played their respective roles, and in moving from what we clearly see as the world of media into multimedia, the first observation I would like to make is that really we have had multimedia with us for a long time in the medium of television, where certainly video and audio - and in Europe with the use of Teletext, certain text data - have been combined and delivered to the consumer.

What is new is that interactivity has been added through things like media players and video game players, and on the other hand video and audio has been added to the PC, which by definition an interactive device, and thereby these two worlds are converging.

In order to advance from media to multimedia and to interactive multimedia, on the one hand you have to observe that several industries compete. The cable, the telco's for example; and we heard about that this morning to some extent. On the other hand, a number of industries have to play together, publishers of content, broadcasters, hardware manufacturers, to implant new applications.

This has certainly been observed by our company in the past when we played a role through our Polygram music publishing business, and on the other hand our consumer hardware business in establishing the CD standards 12, 13 years ago with Sony and others for music CD. This required the participation of two industries at least, and a few more as we progressed.

We see this more recently in a discussion like about the digital TV standards in the United States, which has been under development by first several consortiums and then the Grand Alliance over the past four or five years, and where all of a sudden very recently, despite the participation of the hardware and the broadcasters, Hollywood comes along and says gee, how did you ever think of 16 by 9 as the aspect ratio for digital TV? We use wide screens as wide as 10 by 24. All of a sudden there is a big surprise.

The media value chain

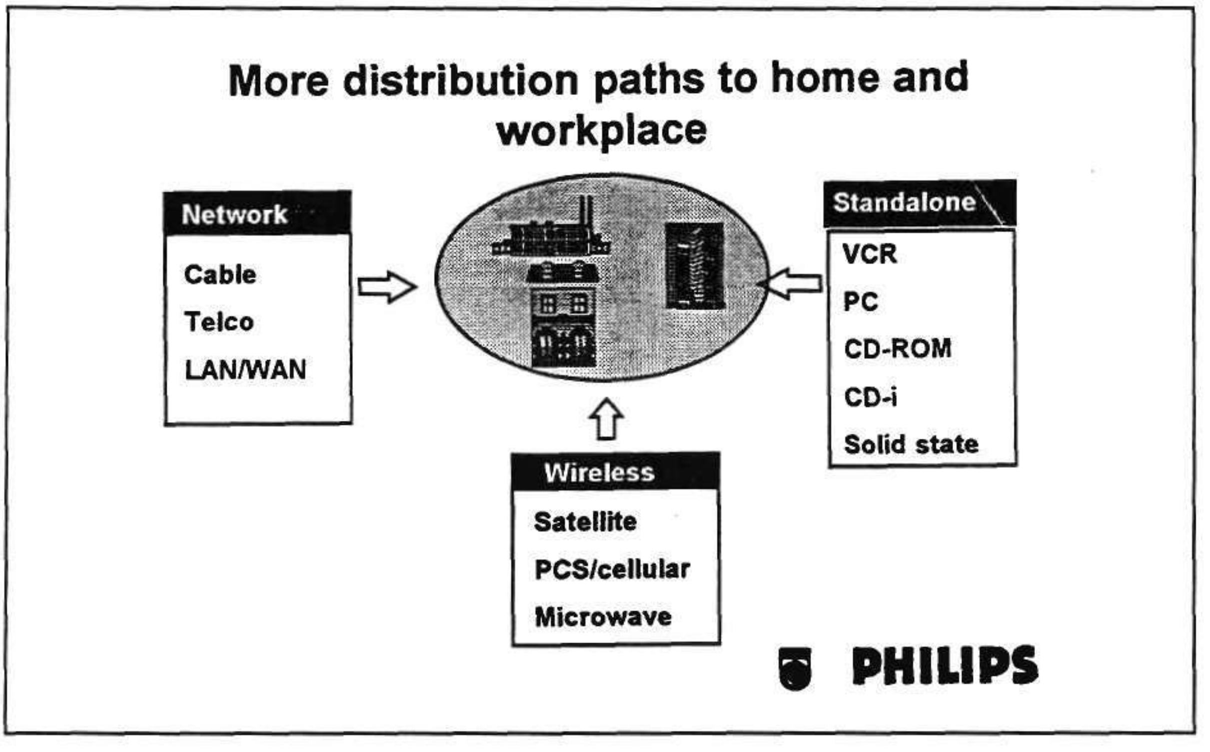
1993 market size (US$,B)	Content/rights	Packaging	Distribution/ transport	User site access	Audiences / uses / advertisers	Total
USA	50	70	265	30	Advertising pays 130	415
Europe	41	55	239	20	Advertising pays 67	355
China, Taiwan, Hong Kong Japan	24	28	131	27	Advertising pays 57	210

PHILIPS

My company certainly, as a participant in a number of the stages of the value added chain, has tried to understand and also be instrumental in bringing about the working together of the various parts of the industries and the value added chain.

This second slide shows some of the numbers that can be attached to the world of media, and we've fairly carefully researched those during the last year, year and a half, to gain a better understanding of the different participants and the markets of those participants along that chain. Purposely I am not showing numbers from multimedia, because again I have the difficulty of just what is the definition of that as a subset of that total chain, as we go from content through end user.

What you observe is that these are very sizeable markets, certainly also measured by the large sizes we've been hearing about during the last day and a half, $150 billion to $330 billion growth of this industry of semiconductors. Here we talk about $415 billion in the United States, $355 in Europe, and $210 in just four countries of Asia. In addition to that, you have advertising, which facilitates bringing a certain part of media content - and multimedia content in the future - to the end user.



Some of these segments are growing rapidly. We know the segments of multimedia computers; wireless we just heard about; interactive software that are growing explosively to some extent. Others are more static and even declining. The big question is will multimedia mobilize additional spending by the consumer out of his discretionary dollar? That was debated to some extent this morning, and the answer to that is that I see yes, but certainly - if you look at history - you see the VCR, video rental, you see cable and pay TV, you see satellite TV more recently; the PC and the multimedia PC; but nonetheless much of this happened gradually over periods of five and ten years. We have to examine the benefits that the user sees in relation to the cost of providing that benefit.

For example: Several years ago high definition TV was very much the hype of the day, both in all three regions really of Japan, Europe and the United States. We've all had programs on high definition TV. What we've seen is that in practice the incremental benefit of having higher definition is very difficult to provide along the total chain, especially the last part of the chain, the end user device was very expensive. The consumer has voted - I think - that having greater choice in programming is much more valuable to him then to having greater definition, more pixels on the program that is being displayed.

The same thing about interactive TV. This is something that is certainly coming, yet video on demand, home shopping, home banking, multimedia on-line information certainly will come very gradually. It will take a number of years to materialize.

There are many methods of delivery through wire line, wireless and through various forms of carriers that are purchased by the consumer. You certainly have to realize that a number of these compete with each other. For example: Video on demand competes with video rental; and video rental is a pretty cheap way of having say a Blockbuster store's 8,000 programs at your disposal that you can chose from, and before you have that kind of choice in the video on demand system, we are going to be quite a few years down the road.

Telephone service is being touted by cable companies as an option to add more value to their cable systems, and yet as we heard this morning, this is difficult to provide and difficult to upgrade those systems to make them two way and to provide that. Nonetheless, with the newer systems it's happening. In the U.K., for example, where cable coverage has been very low and just (I think) 3% of households are connected today, in those areas where there are connections, almost 1/4 of subscribers have taken advantage of also subscribing to telephone service, and switching away from British Telecom or Mercury, which is a very interesting development.

Another one is direct broadcast satellite, and that has just come in recently in this country. It came somewhat earlier in the U.K. It was probably the first country where you had several million subscribers of broadcast satellite, because they didn't have the cable systems.

Nonetheless, you have to realize that those dollars that go to the direct broadcast satellite providers - and they're not small dollars - probably aren't going to be spent again by the same consumers on providing or buying cable service. You're going to see a great proliferation of satellite channels.

For example: In Europe, Astra is in the process of launching three more satellites, providing another 500 digital channels in Europe, or part digital, part analog. EUTEL SAT is going to launch another five satellites in the next two or three years, providing over 1,000 channels. You're going to have 1,500 channels available by satellite in Europe.

Digital video broadcast is another option that has been developed in Europe over the past several years, and is probably going to be first supplied to the terrestrial broadcast in the U.K. by 1997. Recent decisions in that direction have been taken and a number of people have banded together - I believe including Sony - to make that possible.

Another option that you have is wireless cable. It's been more used as a fill in in the United States in areas where cable was too uneconomical to put into the ground. You see a development to move that into the higher microspectrum. There is now experimental service at 28 gigahertz, in Europe at 40 gigahertz, and that again is going to be another alternative that is going to compete with the likes of satellite delivery, traditional cable delivery, etc. It may be more economical - for example - in Latin America. We see quite some interest in this mode of delivery because the cable hasn't been laid into the ground and it's much quicker in a large city like Safalo to provide that service through microwave.

Where does all of that leave interactivity? All of these channels more or less are one way. What we have found, and we are participants at Philips and some joint ventures that provide that service is that you can set up narrowband channels that allow the response of consumers for program selection; for example game show responses, shopping responses, etc. That doesn't require a lot of bandwidth, so it's fairly easy to provide that.

Let me move on to the issue of what does it take to be successful? I'd like to make a point that it really takes two things. One is that we're all very familiar with the semiconductor industry, which is technology. The three major items here, of course, are optical storage, our broadband networks and our compression that make both of these more powerful in delivering multimedia content.

You've heard about the optical storage side. We are going to see a major advance there in the next several years. We're also going to see movement to erasable and recordable storage at the same densities in the next several years. All of that is going to be of major significance.

What has been the most difficult advance has been the one with broadband networks. It has become very expensive and people recognize this; to think about providing broadband capability to the home. All of the great schemes that have existed, things like the French Frontable, ten years ago never came to fruition. Germany's similar schemes have existed. What you see indeed is that hybrid fiber coax is probably the most economical solution to this problem.

On the other hand, the telco's have looked at providing wideband capability through technology like ADSL, Asymmetric Digital Subscriber Line, but yet this is also very expensive technology, where you have to spend in excess of $1,000.00 per subscriber to provide - for example - 1 1/2 megabit per second capability.

The industry faces some challenges that are going to be key in making multimedia happen. I'd like to draw your attention to three. One is what I call open systems. Open systems architecture is very familiar to us from the computer industry. I would say that as long as the industry here in multimedia is at odds and you see Ellis and Gate's debates that argue whether the intelligence is going to be in the network or in the terminal; as long as people haven't agreed on how to provide conditional access through encryption and each cable or satellite provider insists on placing his own proprietary set top box, it is going to be very difficult for consumers to really become very enthusiastic about all of this. Also when formats for software haven't been sufficiently defined to allow a migration from one hardware generation to the next, in other words the backward compatibility which was just referred to in the Sony presentation.

The second one is the issue of standards. Things like a common publishing format would be very necessary for interactive content. It is a very important item. Things like digital broadcast standards, the referred to DVB. There is now a group called DAVC, Digital Audio Video Counsel. That group is quite a bit of the industry worldwide that is making a very important effort to bring various standards under one global umbrella. Digital broadcasting over all media, satellite, cable, terrestrial, etc.; but also interactivity, which will allow you to integrate in an interactive carrier devices, multimedia players, etc.

Development of "Multimedia"

Challenges for the enabling technology:

- evolution of optical storage
- extension of compression capability
- evolution of broadband network and user access capability

Challenges for the Industry:

- "open" system architectures
- common formats
- Transparent, international rules on content-related Intellectual Property Rights

PHILIPS

Finally, the point of IPR is very important when you go to the capability. You go through digital VCR or through erasable disks to record all of that good digital, high quality stuff that comes to us over satellites or cable or whatever. The content industry, generally referred to as Hollywood, is going to insist that proper safeguards are implemented in terms of a single copy limitation, just like we had the discussion when the digital audio tape was introduced ten years ago and the content industry didn't really acquiesce in this until a single copy mechanism was adopted.

The point is that on the one hand technology advances require great competition and the greater the competition the more rapid the advances. On the other hand, the companies of the industry cooperating across the value added chain really require a much greater degree of cooperation then many like to admit or realize. This is something that we see as very important as a prerequisite for this industry. Thank you.

Moderator: Thank you, Klaus. I would like to now move into a question and answer phase of our session here, and I'll start by kicking out a couple of questions, so all of you be thinking of your questions and we'll rush a mike over to you to get those up to the panel here.

I'd like to explore the area of digital video disk a little bit more. That's certainly a big area in terms of the agreement that just has come through. I was wondering if perhaps we could get some clarification on the agreements, like how licensing will work, maybe a little idea of the timing as to when the market could emerge, and perhaps Mr. Hori you could start with that.

Panelist:

As soon as possible in order for other companies to start development for their first product. I hope this isn't just a personal admission, that in a couple of months they will come to the final arena.

Moderator:

Many of the people in the audience are from emerging semiconductor companies. There will be an opportunity for them to get access to license, perhaps develop a chip set let's say; develop more of these devices?

Panelist: Yes.

Moderator: It looks like there's an emerging opportunity there.

Just to clarify a little bit, there's the digital video disk, there's the digital VCR, and there are also things like the set top box which can bring in on demand movies. It seems like the consumer is faced with a plethora of different alternatives that are digital in nature. This is a somewhat general question, but any thoughts as to how the market place is going to settle out as far as where the volume is going to go? Perhaps Mr. Volkholz has some ideas there?

Panelist:

I think you're going to see all of it, but again the consumer is only going to be gradually induced to be spending more and more dollars on that. I think the digital set top box of the future is also going to have recording capability worked right into it hopefully. They will provide the consumer with the ability to record that high quality programming that he can receive over satellite channels or microwave distribution, whatever. I think that will stimulate both markets.

Moderator: Mr. Hori?

Panelist:

I don't think the video on demand or the near video on demand comes. I don't think so. The people will buy the books or CDs, but never videoware. The people want to buy, sometimes by the books or CDs, something they can listen to.

If the people think that at any time that he wants he can see the movies, he can listen to the audio, why would he like to buy the movies or CDs?

If people think that at any time he wants he can get a book, then he will never buy the book until he believes that he really wants the book. That means the business of video on demand will not become a big business (I think). Maybe someone doesn't agree, but I believe that the video on demand center was not the best from the business point of view.

Panelist:

If I may just add to that, I think what you are going to indeed see is near video on demand when you have something like 1,000 satellite channels available, then you can provide certain programs at 10 or 15 minute intervals and people can switch in almost any time they like; but it isn't quite video on demand. That, again, is one step more expensive to provide and I agree with you that that isn't going to come very soon.

Moderator:

I would like to open it up to the floor at this point if there's any questions out there. If not, I'll continue on with what I have.

Question:

I'd like you to address some of the intellectual property issues, because I think they're very serious ones. Once you can record things digitally, then you can manipulate them, you can interact with them and all of that. Do you see that the content providers are going to permit that to occur when you have a set top box that can record or DC? Kind of a two tiered pricing of play only and archival? How do you guys see that playing out as that manipulability comes forward?

Panelist:

I think the content industry hasn't really thought about all of that totally through. They are definitely very leery of doing anything to disturb their present streams of income. They have essentially, over time, seen that they were able to multiple their streams of income because of different delivery mechanisms. First they only had the movie houses, the cinemas. Then they had television. Then in the last 15 years they've had video rental as a third channel, and that has added greatly to the revenue stream also in time. I think they are going to be very leery to disturb that picture. They will indeed make sure that whatever you do, you do it in your own home. If you manipulate the video in your own home, I don't think they have much objection to that or are going to do very much about it. But they want to make sure that you're not going to be making multiple copies and distributing it to your neighbors or even semi-commercially beyond that. That's the significance of the single copy inhibition that has to be incorporated into the algorithms of these devices. Here, again, is a semiconductor opportunity to bake that into silicon, just like we did in the DAT case.

Panelist:

The owner of the TV program should be maybe copied. But the pay per view or the rentals either should not be copied. We can do that.

Question:

This is for all of the panelists. Each of you are a manufacturer of traditional consumer equipment, TVs and VCRs and so forth. This week in the microprocessor forum up north and of course down here we've heard a lot about interactive multimedia. Each of you primarily spoke about the final delivery being on a television type of a set. I'm wondering what your view is of the media ending up on a personal computer and how that might affect your business, being primarily consumer type of companies rather than PC type companies?

Moderator:

I guess to paraphrase, really what's the threat of the PC to the traditional consumer electronics companies? Would one of you care to tackle that one?

Panelist:

Certainly some of the content provided by media companies is going to end up on the PCs. I think there is nothing wrong with that as such. I think though that in practice, people - most families - are going to find it more enjoyable to watch say a movie at some distance of ten feet or more and some screen size which makes it a device that one would normally call a TV; while in some cases think of a student in a room. He may want to combine the two devices and have both the PC and the TV capability in that device. I think there's nothing wrong with that.

You may also find as these architectures advance that there's going to be kind of a LAN in the home, that will allow you to display the same information on either screen. We see a convergence of the two worlds, and yet we see both worlds continuing to serve their separate purposes.

Panelist:

In Japan, of course in the United States also, but in Japan the PC which has the TV capabilities are becoming more and more popular now. Also it really isn't we started to sell the living room TVs which has a multiscan function. This break can be connected to the PC. Yes, my son has a TV, PC, audio sets in his room. Maybe the individual uses will be combined.

Moderator:

If I can throw out kind of a semiconductor industry structure question: Each of you work for vertically integrated companies where a lot of your semiconductors are supplied by your semiconductor divisions. As we move into this new age of digital systems, do you see that changing? Should we expect more supply of technology from independent Silicon Valley start ups - if you will - other types of companies or do you expect it to stay more traditional? I guess it's kind of a loaded question, but I am just interested in an opinion. Mr. Mayumi, any thoughts there?

Panelist:

There are many surprises here. There are algorithms for intelligent properties, so he can make - for instance - one system. Another surprise, a different type, is set top makers collecting the functions to make his own system. For instance: For MPEG 2, there are many event holders. We cannot afford to make all of the chips. For that reason they make some associations. It will be quite dangerous for makers.

Moderator:

Yes. There certainly is a matter of economics involved. If you can source those, which certainly makes sense.

A question I had is in HDTV, we heard some views that it's struggling. What is the consensus of HDTV? It does exist in Japan currently now with the Hughes system. The U.S. has the Grand Alliance Specification, and Europe is going to the Digital Video Broadcast approach. Is HDDB dead? Is it going to take longer to emerge? Any views there?

Panelist:

In Japan, we don't have so much excitement as we have in the past. The source of the new systems or HDDB TVs is growing steadily. I don't have any definite figure, but we have sold (I think) more than 500,00 units, or something like that. 300,000. It's growing. We have 11 or 14 hours of programs a day now, from 10:00 in the morning to the midnight.

The funny thing, the wide screen TVs are becoming more preferred. Wide screen with standard definitions has become more preferred. More than 50% of the TVs sold are now the wide screen in Japan.

Moderator: This is of the 16 by 9?

Panelist: The 16 by 9 has now become very popular in Japan.

Moderator: How about standard definition television? We are hearing words of employing MPEG digital transmission techniques; what is the standard definition? Any thoughts on how that market is going to roll out?

Panelist:

Yes. In Japan, the little satellites will start very soon. Now that we have the analog data satellite broadcasts, JSAT will start a digital satellite program I think next year.

Moderator:

Any other questions that we jarred out there in the audience so far?

I just wanted to talk a little bit about geographic opportunities. We have roughly 1/3 or so of the world population that's bought TVs, VCRs and camcorders; and now we are reaching into the rest of the world. What do you see as the opportunities to help there and what's the best way to go about it. Any thoughts there, Mr. Volkholz?

Panelist:

Certainly what we see is the major opportunity in terms of market size is in Asia Pacific today, in China, in the Pacific Rim. This is advancing very rapidly. Of course, at first it was conventional TV, but certainly in the more affluent areas of Southern China and Hong Kong, Taiwan, Greater China, you see a very rapid movement toward cable systems. As a matter of fact, Hong Kong seems to be pretty much in the forefront of this development, because I understand that in terms of hours of viewing per inhabitant, Hong Kong by far exceeds the United States and other countries. Hong Kong Telecom also is very determined to bring Hong Kong into the age of video on demand. They have a very ambitious program, which goes far beyond the 2,000 test subscribers, which will have tens of thousands and hundreds of thousands in their plans in the next couple of years. That's where we see the greatest degree of action at this point.

I've also mentioned briefly the interests of Latin America and things like using microwave distribution - wireless cable if you like - to leapfrog the establishment of cable systems in their cities. I think you are going to see that in other third world countries as well as a need.

Moderator:

I think as we draw towards a conclusion here, one last question that I had was really what does it take to be a successful semiconductor supplier to the consumer electronics community? As we look forward towards the year 2000, what will it take to be successful? Maybe if I could get all three of you to perhaps comment on that. I know our audience would appreciate it. Mr. Mayumi?

Panelist:

Semiconductor suppliers should move to these areas. We need much more higher technology devices.

Panelist:

Sony has a semiconductor group. We started in the very early stage of the semiconductors to develop the first portable radio. Until 15 years ago, our semiconductor group just supplied the semiconductors to inside of Sony, internally. Now they have started to sell the semiconductors outside of the company. In my company, the semiconductor group is just a separate company.

In order to develop the new set products, the semiconductors are very, very important. From the very early stage, we are committed, we are semiconductor people. I have a laboratory here in the United States to work with companies in the United States.

Panelist:

Maybe I can inject another aspect, which you will appreciate coming from the consumer perspective, but which you may not like as much as semiconductor suppliers, which is the aspect of price. Certainly when you think of devices such as set top boxes of multimedia players, which architecturally are very related; then we are looking at the need to really proliferate these devices to go from a consumer/end user prices of say $500.00, $400.00, down to $300.00 to $200.00. In order to accomplish that, you certainly cannot incorporate $100.00 or a multi $100.00 dollar processors into these. You have to look for solutions that are more in the vein of say a $20.00 processor, and maybe another $20.00 co-processor for video or something like this. Solutions like the Magic Carpet for example from Silicon Graphics are (I think) quite amenable to this sort of approach, which is different from the PC. There I also see the difference between the PC world and the consumer world to some extent. The PC - by definition - if you want to run Windows, etc., you have to have a certain level of processing power, and thereby you are bound to the more expensive semiconductor devices by definition. I think that's an important aspect to keep in mind to bring forward the multimedia age for the consumer.

Moderator: We would like to thank our panelists for coming today and sharing with us insight in their industry.

1

2

A

B

C

C

D

E

F

G

H

I

N

O

P

R

S

S

T

U

U

V

W

Z

This page is intentionally left blank

Produced and edited by Market Makers