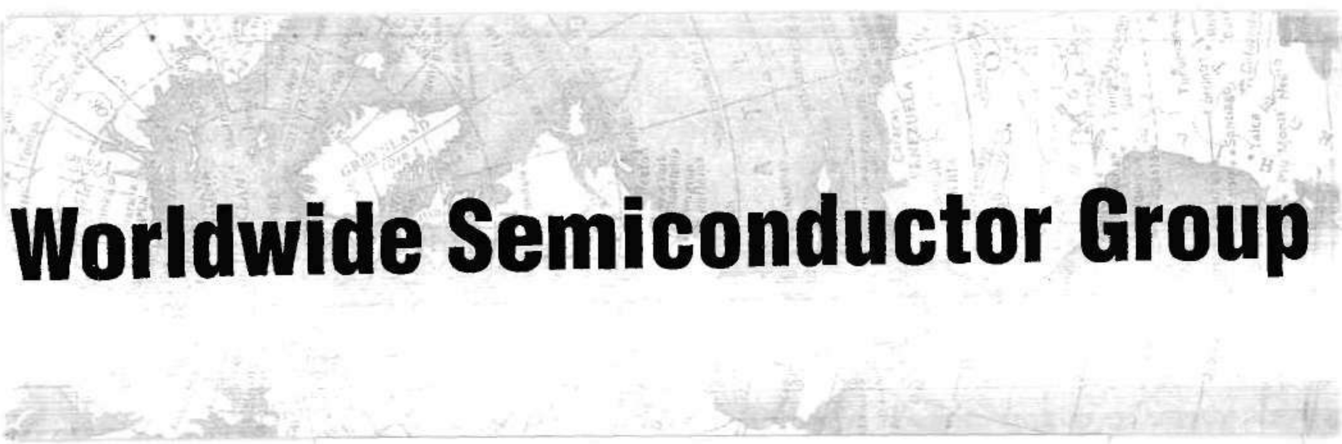
SEMICONDUCTORS '95

The Building Blocks of a New World Order

Executive Summary Report



Worldwide Semiconductor Group

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

Dataquest

a company of
The Dun & Bradstreet Corporation

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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
DataquestIncorporated

Leading edge PC's, which have as much as 40% semiconductor content, are creating the multimedia lifestyle for us and our children. As chip manufacturers move from .35 to .25 micro geometries in the next five years, their factories will put out over 400 billion semiconductor devices. That's 70 for every person on the face of the globe.

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 back logs and capacities maxed out. We hope that over the next two days the experts will provide a real insight into whether this will last.

This year's conference will examine this theme and Building Blocks of a New World Order from a variety of perspectives and presentation styles. You will hear from 13 industry executives who will give 30 minute presentations and their perspective about the dramatic future events in on-line and wireless services, systems, software, semiconductors and 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 it will take in the way of people resources to reach $300 billion dollars or more, to the impact of multimedia on systems and chips and to the inside story on the new DRAM architectures.

These very provocative sessions will be led by eight of our top analysts at Dataquest, and they will also be augmented with a guest moderator, Dan Klesken, a partner with Roberts & Stephens who will be tackling the panel Multimedia Impact on Systems and Chips.

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

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

Chapter Two: PRESIDENT'S REMARKS

Judith H. Hamilton
President and CEO
DataquestIncorporated

WELCOME ADDRESS

If you look back on 1995, from years hence, there are a few things that were significant over this year in information technology. One of them is the PC entering the home in a big way. Our surveys show that 1/3 of all American homes own at least one PC. 1995 is the year that Hollywood met Silicon Valley.

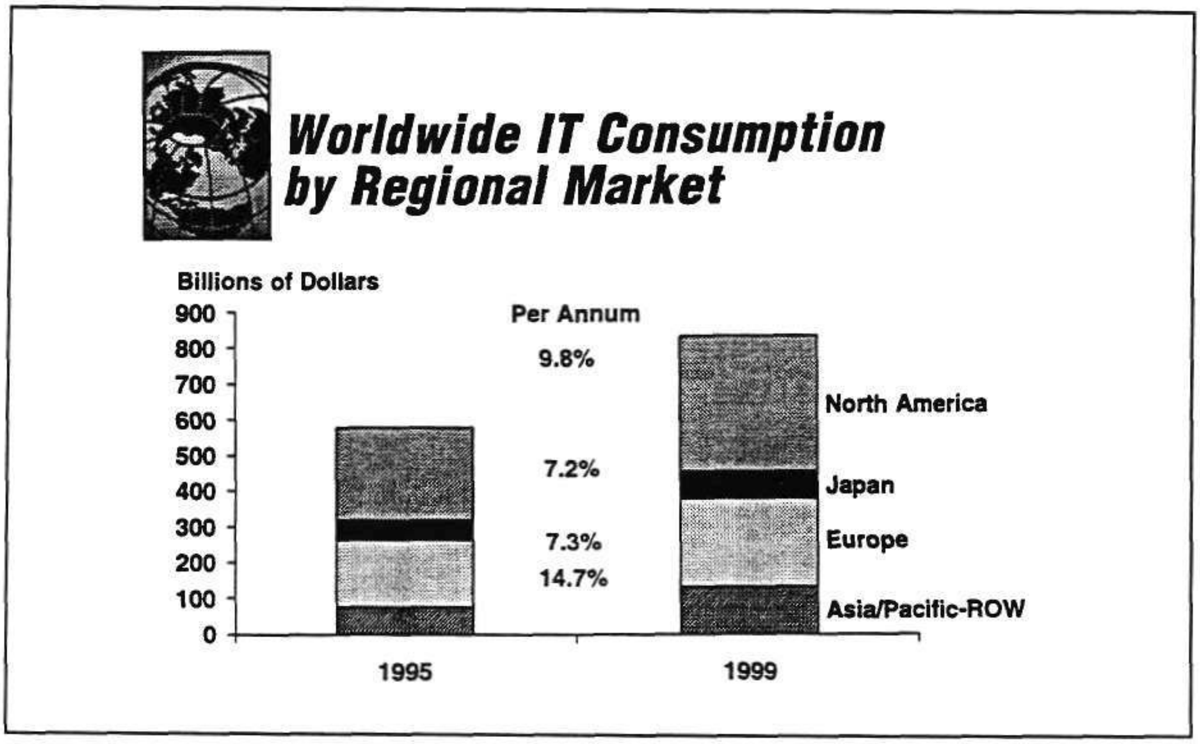
What a Difference a Year Makes!

- **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 . . .)**

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 last year that it's gone international.

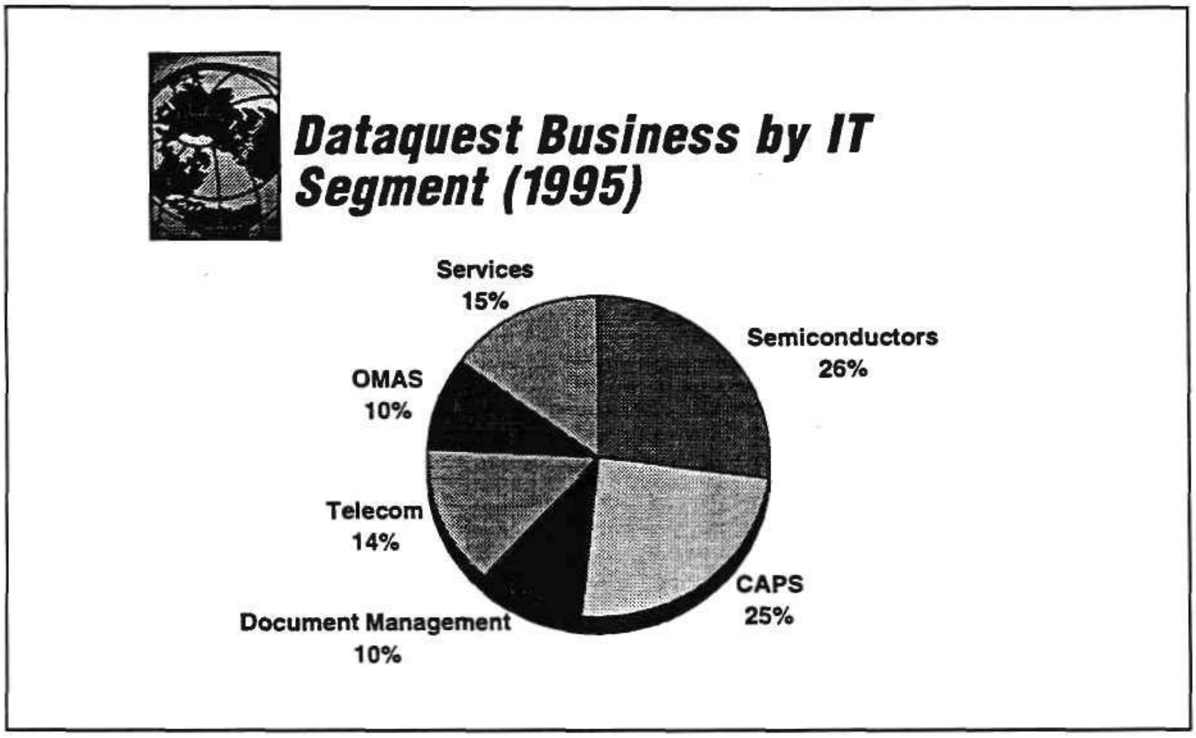
One of the most significant events this year is all the hype around the introduction of Windows 95. None of us have seen anything like it.

We have had many mergers within our industry for a long time and this year was no different. Lotus merged with IBM and Seagate with Conner. But mayber we will remember this year as the beginning of the break up of some really large companies, like with ITT, AT&T and of EDS spinning out of GM.



There is one thing that doesn't change, and that is the robustness and the vitality of the information technology industry as a whole. Some of Dataquest's overall estimates on the growth of the industry and the distribution of it by region has growth projected over the next four years. 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 and is projected to grow about 10% a year.

We have about half of our business in the United States, and the other half is 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. 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, 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, you are sitting in a pretty good position.

The things that fuel that growth are varied and range from multimedia to the automotive industry which are the topics that we will be discussing over the next two days.

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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

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 of what you see and read about. During the election year of 1994, Mexican reserves dropped dramatically. The government didn't report the drop, so it took everybody as a big surprise when the peso was devalued after the election was over and there was a financial crisis. Salinas has been given a lot of criticism for that.

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

The economic impact 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, we know that they are in a recession. The outlook for Mexico, is not an economic issue, it's a political one.

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.

Many U.S. companies are moving to Mexico to take advantage of the cheap labor and from Mexico's point of view, they are going to get out of this recession more than many people are reflecting.

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

Dun & Bradstreet has a database of about 39 million businesses around the globe. We do surveys from within that database and have a 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 study that began in 1947 was designed to gain a business point of view about what the outlook is.

We 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. 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 which correlates very well with the GDP deflator. A new GDP deflator is going to change those but at least until they revise the data it's been a good forecast of that.

For the U.K., it actually led Europe out the recession. They have a close correlation with business expectations and we are going to see steady growth through the end of 1996, in the U.K., based on where its economy is.

France has a new election and a new restructuring in their economy. They will probably have a declining growth pattern there despite the good recovery from the European recessions.

Business expectations in Germany sharply fell when the decision was made to merge East and West Germany. The German economy suffered greatly. The forecast for Germany is some weakening, but still a four percent growth by the end of 1996.

We expect Japan to recover for the last two years. Right now they are on a slow recovery but, by the end of 1996, they will be up to about 3% growth. 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, Asia is clearly the growth part of the world.

Central Europe is beginning to turn around and the former communist block is going to be a plus in world growth. It's a very healthy global environment in terms of our major trading partners, except for Japan.

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%; which is 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.

The information revolution, is just beginning. 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. Growth will slow at times, and that 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 all throughout the way we do things, from buying things in a grocery store to buying things through electronic delivery and on. 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. 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.

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.

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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

The evolution of customer demands and expectations is the evolution of two dominant platforms. Personal computers, servers and the most transforming change of the next decade which is the evolution of the networked world.

A recent MIT study conducted for Information Week concluded that companies that focused their IT investment 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 decisions much closer to their customers. IT gives employees greater access to business critical information in the office or on the road.

Between now and the year 2000, we expect both the personal computer and the server market to grow at a compound annual rate of 16%. Overall, the server market will more than double from $17 million dollars this year to over $40 million dollars in the year 2000.

Most of these platforms will run Intel processors. This is already true for desktop and mobile systems and it is increasingly true for servers. With the Pentium processor today and with the Pentium pro and the P7 to come, Intel is moving further up the performance scale. But there is plenty of room above Intel for high performance platforms.

The PC will continue to be the main engine on information technology for years to come. In the business world, the PC is the primary interaction layer. Customers want the world of enterprise displayed through the PCs as easily and as transparently as possible.

It is the consumer - more so than business - that is driving the evolution of personal computers. While business, education and government still do account for most of the PCs 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.

On the corporate front, ease of use is not so much the issue as ease of entertainment as ease over maintenance. Most businesses are less concerned with bell and whistles than with managing a growing network of PCs 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 PCs from a remote site. With the network management feature now built in to more PCs, software upgrades and other changes can be made over the network, saving time and money.

The most profound change in the corporate environment are in areas such as mobile computers. Portable computers are becoming thinner, lighter and more functional. Users have to make fewer compromises for mobility. Since they are no longer bound to the desktop, they can spend more time with customers and partners.

Today portable PCs account for about 28% of all PC sales. By the year 2000, that number will grow to more than 35%. 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, wire and wireless networks and remote access server forms.

The next decade will be the decade of network connections, servers and distributed information. Some of the most significant growth is going to be in emerging applications such as interactive video, multimedia, Internet concerns, connections and services, electronic publishing, very large databases and very large memory. Each of the areas involves a new way of distributed information and each requires powerful, scaleable, secure and reliable systems.

Two of the key drivers of the server market are the emergence of Windows NT and the acceptance of UNIX as a mission critical computing plan. Over the next five years, these two operating environments will dominate the server market. Today UNIX is about 50% of the market. Other operating systems like Open

VMS and VS, are at 45% and Windows NT is about 5%. By the year 2000, we expect Windows NT and UNIX to have roughly an equal share of the market.

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 in the performance curve, taking over more of the enterprise applications once commanded by mainframe and other large proprietary systems.

Everybody today is talking 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.

The Internet is just one piece of the growing market for inter-enterprise connectivity. We believe that by the year 2000 end user spending on inter-enterprise connectivity will reach $100 billion dollars per year. The business opportunities will fall into four very broad categories. They are, communications, information, transactions and entertainment. That will encompass everything from computer collaboration and electronic commerce for life services and bid on demand.

We believe this is only part of a much larger opportunity. This market will be much like the interstate highway system. The interstates did transform commerce in America. Their biggest impact, however, was in creating vast new business opportunity along the way like, the shopping mall, the service plazas, the gas stations, restaurants and motels. The Internet working will have the same impact. It will create an environment in which new businesses will flourish. 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 for the next few years. By overcoming these challenges, we have a chance to literally re-define computing and the information society.

None of these changes would be possible without the semiconductor industry and the tremendous advances that have been made in the last two decades. 25 years ago the semiconductor accounted for only 4% of worldwide sales of electronic equipment. By 1990, that had grown to over 9%. It will double this year to nearly 19%. The projections are that by the year 2000, the semiconductor will account for 28% of electronic sales. Our appetite for advanced silicon products for microprocessor and D-RAMs to cache RAMS and PCI chips is only going to grow.

Semiconductor companies have been successful because they deliver products that meet the information technology needs of their customers. Nothing is more important than our focus on the customer. Our success as a business ultimately depends not only on our technological excellence, but on our ability to harness that technology to meet customer needs with a continuing partnership between system companies and the semiconductor industry we can deliver the best of both worlds which is great technology and great products for our customers.

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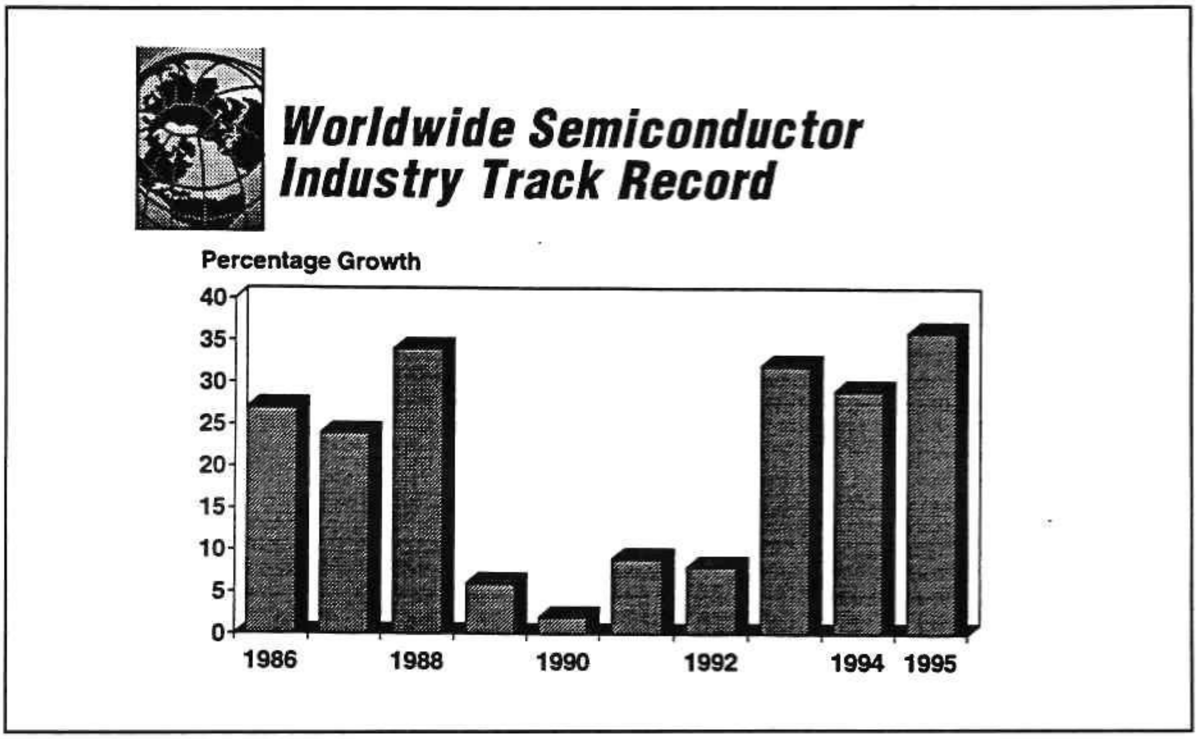
Chapter Five: THE SEMICONDUCTOR OUTLOOK: WILL IT GET ANY BETTER

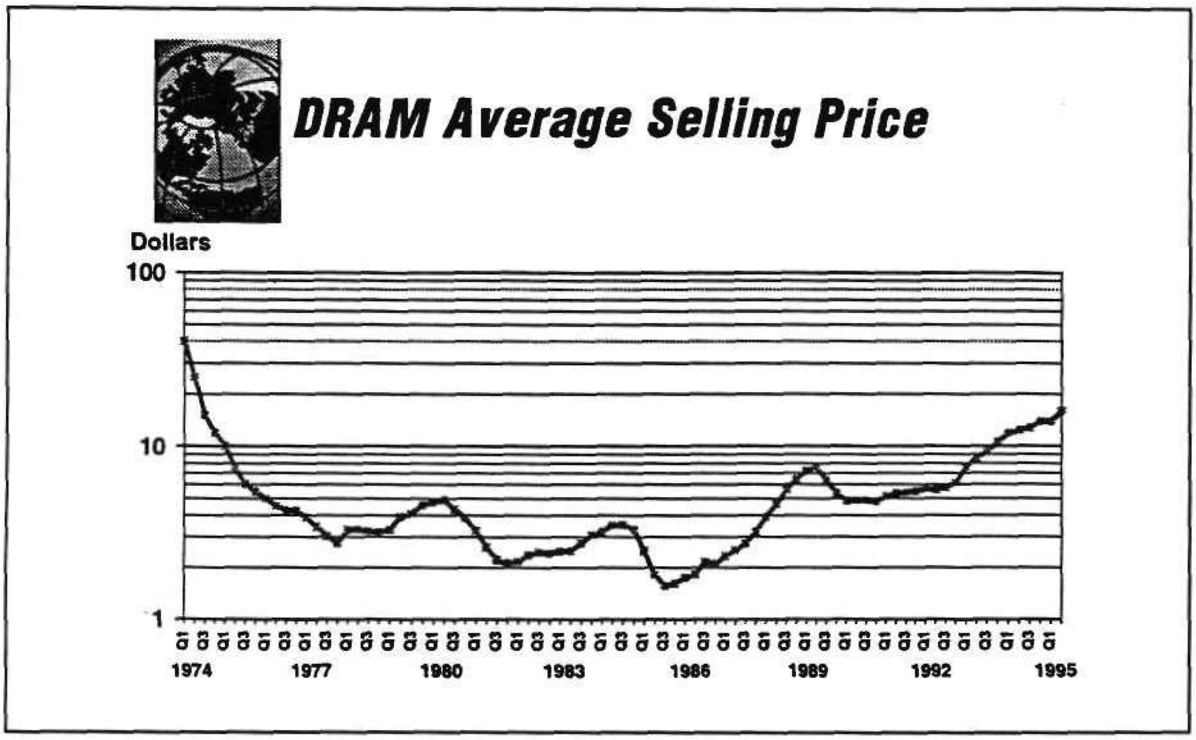
Gene Norrett
Vice President & Director
Worldwide Semiconductor Group
DataquestIncorporated

Agenda: Semiconductor Industry Status, Semiconductor Drivers Forecast, Semiconductor Industry Forecast 2000 and Capital Spending Plans and Implementations

SEMICONDUCTOR INDUSTRY STATUS



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 difficult for your customers and the manufacturers to hold their margins and at the same time keep the price of their products affordable for the global population.

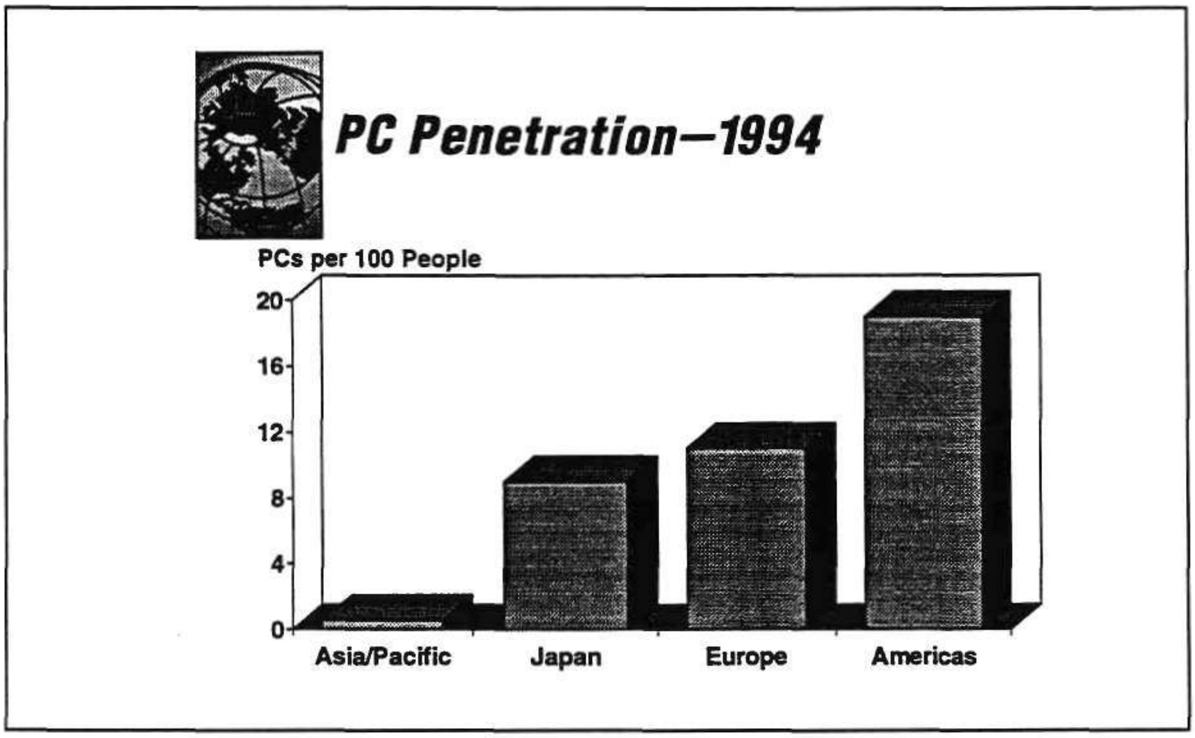


The average selling prices have more than tripled for DRAMs and MPUs. The microperipherals have not increased their prices as much as the DRAMs and MPUs, but they have increased in functionality. Examples include core logic chip sets, graphics controllers and LAN controllers.

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 we still have allocation and the 16 MEG has been slow to ramp up, given the significant manufacturing hurdles to overcome.

We have assumed the average memory configuration increasing in 1996 and 1997 by about 40% to 50% due to Windows 95, as well as other improvements because of increased applications.

Depending upon who is answering the question: The DRAM manufacturer or the DRAM supplier will be the one who will know if it will get better.



For more information on memory prices and availability on a global basis, our current analysis in the DQ Money Report is available.

SEMICONDUCTOR DRIVERS FORECAST

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.

As we look out over five years, we have made the following assumptions associated with the PC industry. The home market throughout the world will be the fastest growing segment of the PC industry, marked by the integration of advanced multimedia functionality.

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%. The DRAMs and processors will be driving this. We also see a large revenue opportunity in integrated controllers and also multimedia engines.

PCs have three multimedia subsystems aside from the MPU that deal with multimedia information. These are the video subsystems which are initially the graphics controllers, but now is evolving to include scaleable video support, as well as soft and hardware based compression technology like MPEG.

There is a second subsystem called 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.

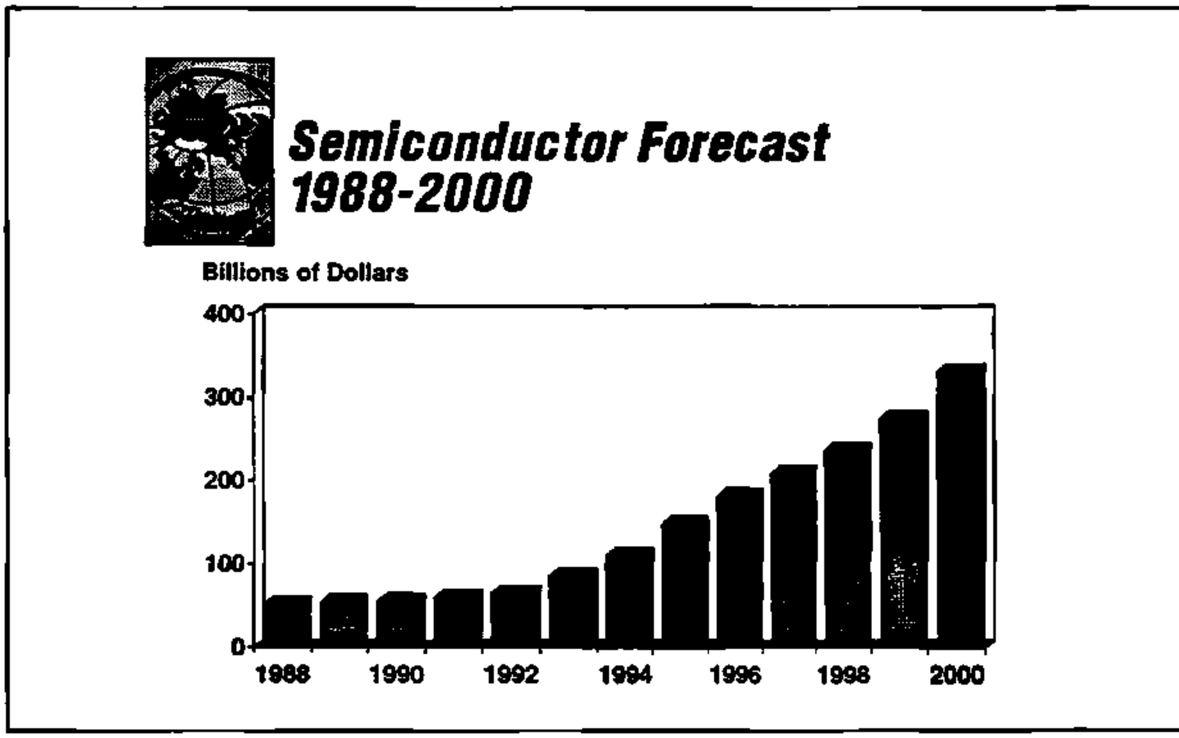
The cellular and broadband PCS market will truly be an explosive one. We estimate 330 million subscribers in the year 2000, up from 77 million this year. This is creating a gold mine for the handset manufacturers. By the year 2000, we forecast 120 million handsets per year shipped, with the semiconductor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

We also 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. We see the following new systems diffusing very quickly across this market place. 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 air bags moving to more than two.

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.

SEMICONDUCTOR INDUSTRY FORECAST TO 2000

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. Economics, population, politics and most importantly technology are providing very positive forces for the electronics growth in the future.



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.

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.

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.

CAPITAL SPENDING PLANS AND IMPLEMENTATIONS

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 look at an average number of FABs built over that period of time of about 30 to 35 FABs, or a total of 200 FABs through the year 2000.

Even with this aggressive forecast we don't get a ratio of capital spending to revenues greater than 23% to 24%, which is a healthy band for a stable market.

We are now living and working in a structural change in our 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%.

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Chapter Six: PANEL: 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

PANEL DISCUSSION

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?

Joseph W. Duncan, Dun & Bradstreet

Answer: 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. In many ways you can look today at the transportation industry and look back over its contribution at the world level up until 1987.

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. The unique part about the current time though is in addition to the economic change, we are in a period of unparalleled social change.

Eric Miller, Donaldson, Lufkin and Jenrette

Answer: 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 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 and more self-feeding than anything we've seen in the past.

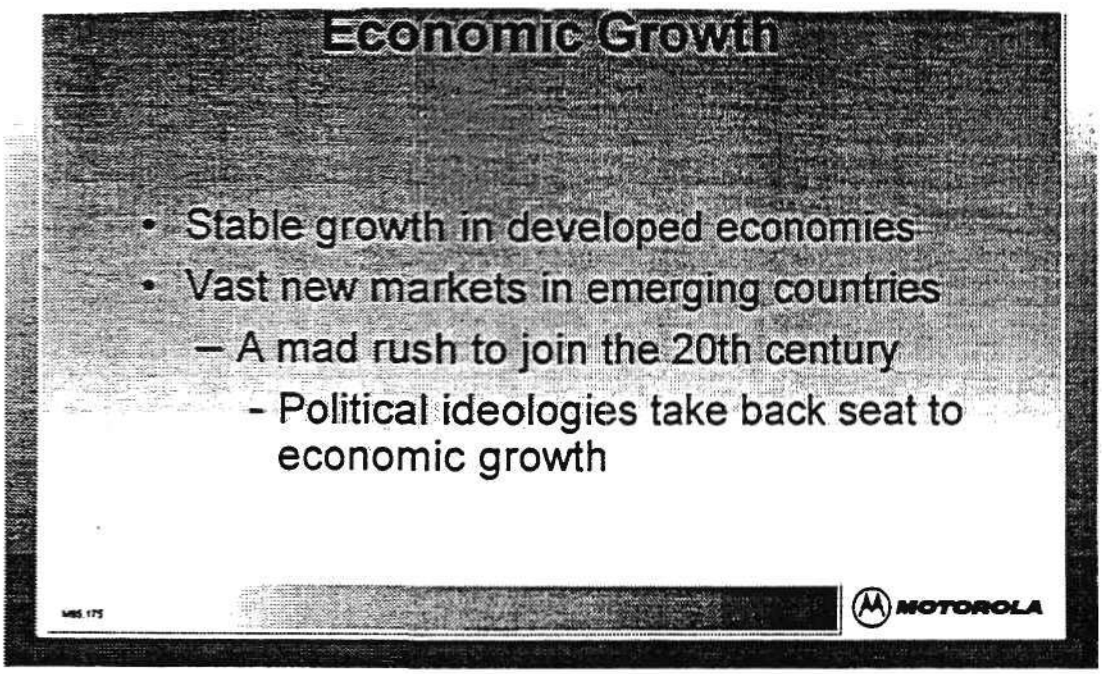
One of the three factors that are contributing to the new complexion of the semiconductor market is the economic growth. One is a more stable growth in the mass economy, and from what was referred to before as the global interconnectedness, and the fact that no one country now can manage its fiscal and 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 new countries like Russia, China, East Europe and India. These counties are coming out of various parlitarian rules. In China right now there is a big struggle to balance the economy that controlled politics.

There is 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.

Panelist: Dr. Chintay Shih, Industrial Technology Research Institute, Taiwan

For the Asia Pacific region, the most important part 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. Their GDP growth rate has been in the area of 15%. In 1965, their total GDP for these four countries was only 1.3% of U.S. GDP in that particular year. In 1995 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.

The production of these countries for 1994 in Taiwan were about 11.6 billion. Singapore: 11.4 billion. Korea: 5 billion. China: 2.1 billion. Total of them producing 14% of the world production. Taiwan and Korea particularly enjoy 28% of gross versus 8.6 percent of the world average over the last decade.

Taiwan and Korean IC industry specifically show a very high growth rate, and also a very high return of 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. The gross rate of the capital investment has been 25% for the last four years.

The waiver consumption between all of this investment completed in 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. Now the return over the exports from the United States has been the major entrepreneur for new businesses in Taiwan..

There are eight companies from this region already in the top 50 of the IC producers. With the success of foundry services provided from TSMC and so on, the IC companies are also able to grow beyond billion dollar companies. There is a good example in Cirrus Logic and Dilink. The foundry business could become the next major growth in this region.

The Asia Pacific region will continue to invest in the semiconductor industry and there will be more significant players from this region in the future.

Panelist:

There are three ways that you pay for communications. With a cable company you pay an access charge, which is a flat rate every month. With Internet you may pay an access charge, which is a flat rate; or you may be measured by how much time you spend. With the telephone company there are tariffs which is like a license to steal.

By telephone, it costs about $8.00 with a 14.4 modem to send a megabyte of data to Europe. If an ISDM is used, it's about $2.00, which is a quarter of the price. On the Internet, it costs about $0.25. If the ISDN Internet is used, it's down to about $0.06. As bandwidth increases, and as things like the Internet become more prevalent, we are going to see a change in the way we pay for data. 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.

With telephony it's about four kilobytes per second, which is pretty easy. You can do that on an analog system. Video conferencing: Maybe 15 kilobytes a second. High quality sound for CD-ROM or 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 is okay. Then for high quality video, you are looking at about one megabyte per second, for really high bandwidth and high quality communications.

What that means is that white collar work starts migrating away. Telepresence, the ability to be performing your function independent of distance becomes a very important feature of the next decade.

You see countries today trying to cut off the Internet. 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.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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Chapter Seven: THE NEXT STEP IN HIGH-SPEED INTERFACES

Geoff Tate
President and CEO
Rambus, Inc.

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. This is because there are some significant trends going on. Processed technology is integrating. It is 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.

More Performance at Lower Cost

- Major trends
  - ↘ $0.8\mu \rightarrow 0.5\mu \rightarrow 0.35\mu$
  - ↗ MPU performance
  - ↗ Multimedia performance
  - ↗ PC and consumer multimedia shipments
- More speed from less chips at less cost

As technology is scaled, we are seeing on chip clock speeds gaining 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.

Noise is a big problem running at high speed. It comes from simultaneous switching outputs, cross talk between signals and faster rates that are required for higher frequencies. Skew is another big problem overlooked in the past. Data to data skew, clock to data skew and chip to chip skew.

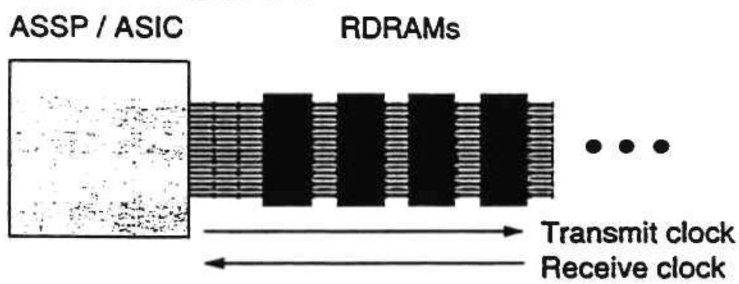
A traditional approach to get higher bandwidth in systems using CMOS IO besides turning up the clock frequency has been to go to wider and wider buses. One of the results of that is bigger packages, but the move to bigger packages means larger lead frames and that brings more capacity and more inductance which makes the whole problem a lot harder.

Some of the problems with CMOS IO, in a package are 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. It is made worse by bigger swings, bigger packages with larger leadframes, faster edge rates and faster clock speeds.

The problems with transmission lines and signaling with CMOS IO are 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.

Minimize Skew



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

Final approach in memory systems and Rambus is a company focused on high bandwidth memory. In traditional memory systems, signal skew is a big problem.

For high speed low cost systems, a new approach is needed for interface, and not just for memory interfacing. Intel with the PCI bus is a good example of the new approach for high speed interface.

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. At Rambus we focused on developing a total solution.

With our approach we have 500 Megahertz data transfer rates using the same technology as today's standard products. That means that every two nanoseconds we're moving a bit over each wire on the bus for 500 megabytes per second.

Besides signal integrity, minimizing skew is critical. In the Rambus approach we just keep things very simple. We have a constrained layout requirement. The bus can be fairly long which 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.

The end result 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 DRAM. The Rambus DRAM 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. This is a tremendously higher bandwidth using the same economics.

The systems that you can see today, set top box systems or game systems you buy in stores, have an architecture where 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, Sega box or a set top box. Each of them has their own separate memory.

With Rambus it's possible to build a system with 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.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

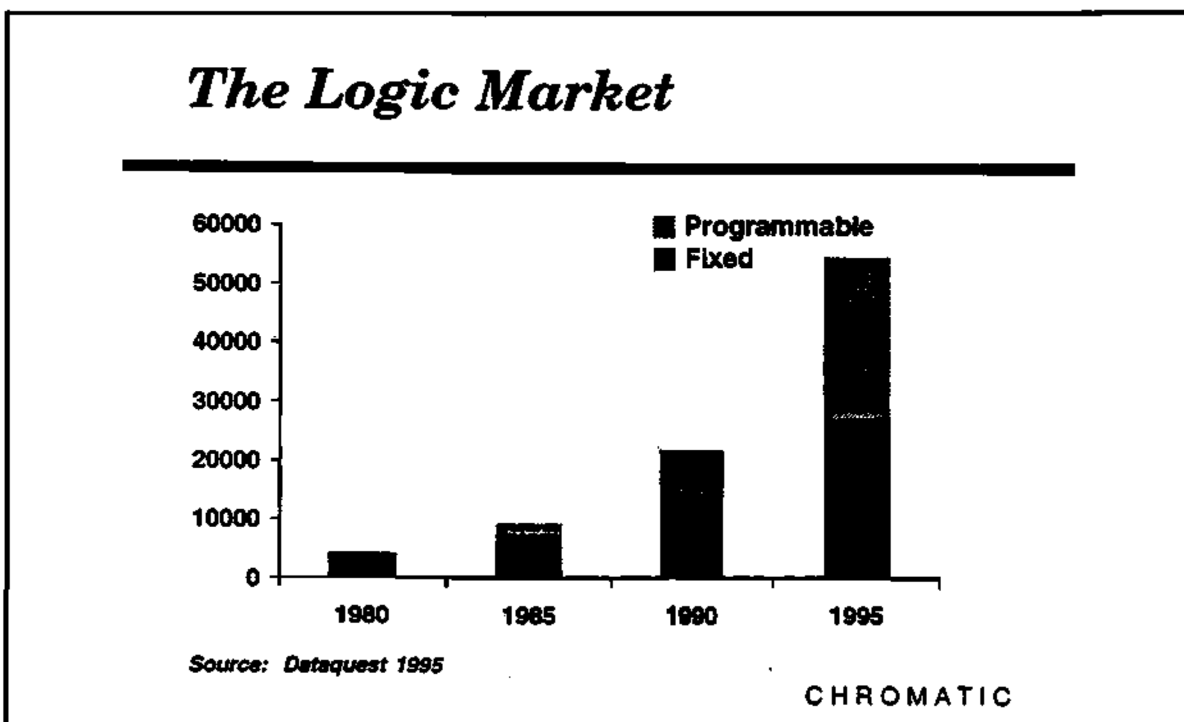
Chapter Eight: PROGRAMMABLE ICs: BEYOND MICROPROCESSORS

Wes Patterson
President
Chromatic Research

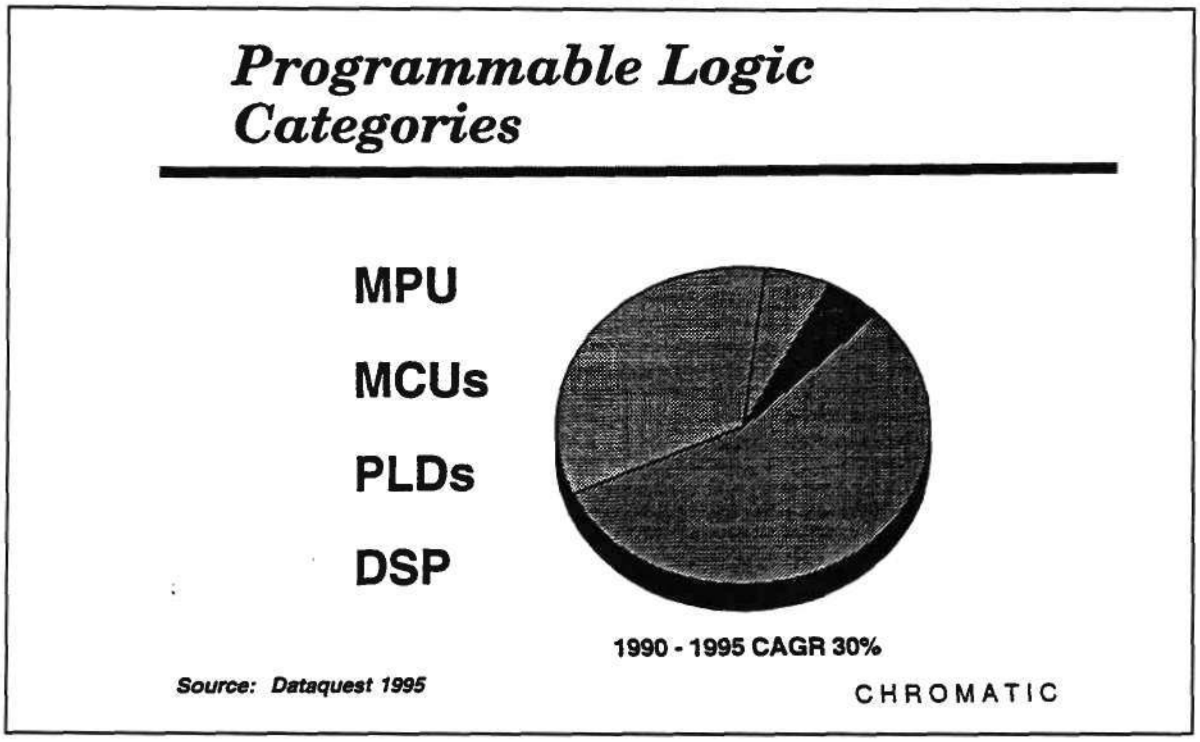
Agenda: The Programmable Logic Market, Extending The Market and Chromatic/Mpact

THE PROGRAMMABLE LOGIC MARKET

There are two kinds of logic IC's. There is fixed logic where what you see is what you get and there is programmable logic where 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 have grown in excess of 30% per year, while fixed logic has grown at less than half that rate.



There are four pieces that make up the area of programmable logic. They are; microprocessors, microcontrollers, programmable logic devices and digital signal processors.

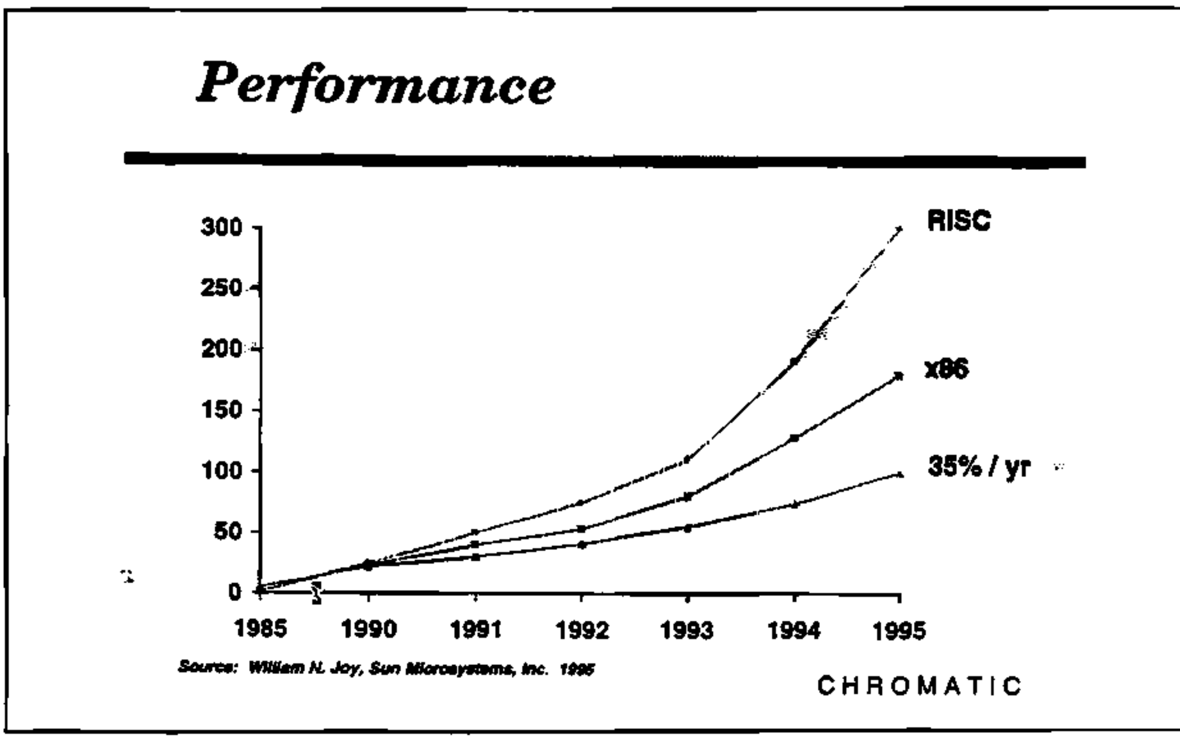
the late 1970's and early 1980's, we began to see the first programmable logic devices or PLDs. The architectural origins on PLD's, come from the ASIC business, either from PLAs that were occurring in ASICs, or somewhat later from gate arrays.

Digital signal processors, also began to appear in the early 1980's. The architectural driving forces for DSPs are signal processing algorithms.

Programmable logic is growing because of performance, price and programmability.

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.

For PLDs, performance is the single most important opportunity for further expansion of that market. Pricing is reaching levels which are compatible with high volumes. Densities 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.



It's architectures that really allow programmable logic to be differentiated. This creates the ability to meet the performance and the cost needs of various markets. It is in the architecture area where new innovation is going to help open up new markets for programmable logic.

Pricing is another consideration. The general trend for all semiconductors is to get to lower cost. 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 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.

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.

EXTENDING THE MARKET

There is a new emerging class of programmable devices that we call application optimized processors. 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 performance, price and programmability.

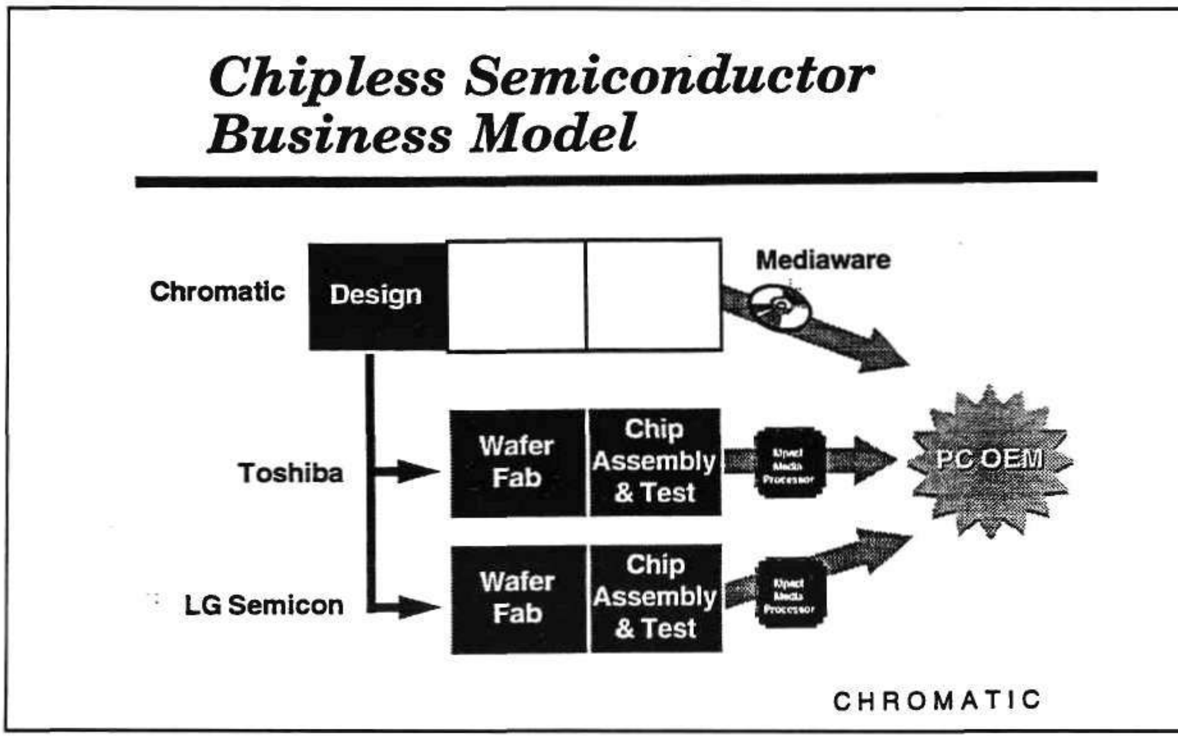
One of the benefits of these application optimized processors is that they can help to simplify complex designs by dealing with higher levels of design abstraction. A highly integrated programmable solution can replace these and give us something that's much easier to understand. Therefore we can reduce costs and we can get to market quicker.

These application optimized processors are not going to apply to every logic problem that we know about. An application optimized processor will probably cost $10 to $20 million dollars to develop, counting cost of defining the architecture, designing the IC, building it and writing the software to go with it.

Some of the potential implications of application optimized processors are 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 may cause some blurring of the distinctions between hardware and software and how people like Dataquest track these revenues. Because of this opportunity to add value through software, we are also going to see a blurring of the manufacturing and design part of the semiconductor business.

CHROMATIC/Mpact

The original intent of Chromatic was not to be an application optimized processor supplier. 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, so the charter of the company was modified and we took on the challenge of defining an architecture that would let us do graphics, video, audio, communications, telephony and 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 high levels of performance to get to a level that would let us run a significant number of these functions concurrently. This processor offers an order of magnitude and 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 because we have singled out the problem we are trying to solve and we've optimized for 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. We've mixed and matched a broad suite of either current acronyms or architectural devices. With a single instruction we can operate on multiple data elements. We can issue more than one instruction per clock and can also process vectors, which occur very frequently in these applications with a single instruction.

We've created an exceptionally effective way of getting the silicon to the customer. We are using advanced process technologies with very high volume, cost effective suppliers.

In today's environment the fact that this device is available from two suppliers is a big benefit.

The drought in the development of new programmable solutions and new programmable architectures is over. We expect to see a number of these application optimized processor solutions coming to market over the next few years. It will become one of the new drivers in this ongoing shift from fixed logic solutions to programmable logic solutions.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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

Jerry Curtis
Vice President and General Manager
Sensor Products Division
Motorola

Micromachine electromechanical structures (MEMS) are a very important new technology which will have a significant impact on the future of electronic devices, products and systems.

The electronics industry has relied on the ability of the semiconductor industry to dramatically increase the number of transistors on a microchip and 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.

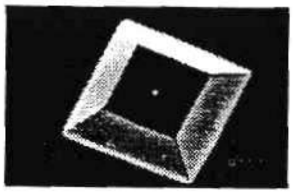
We are continually upgrading and increasing the power of electronic computing and memory circuits. As powerful as they are, they do little more than root and switch electrons through circuits. MEMS devices combine these electronic features with the physical world that will sense emotion, light, sound,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

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)

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.

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 surgery and in quite literally millions of miles into space. MEMS will indeed be the door to a whole new world of electromechanical applications and markets.

Microelectromechanical structures can be divided into three groups which are 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 micrometers, microgears, pin joints, springs and tracks. 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.

Although there are new micromachining processes being developed almost every day, three main processes are currently in place at the commercial level. They are surface micromachining, bulk micromachining and LEGA.

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.

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.

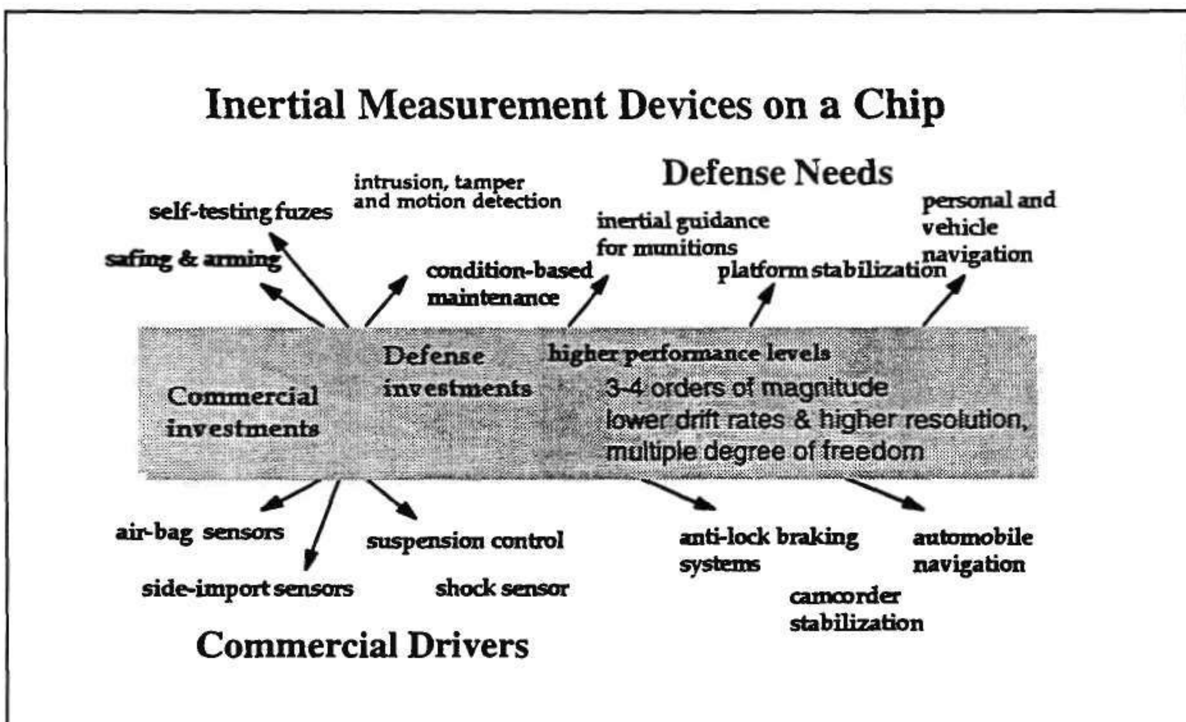
The successful melding of micromachining processes with standard IC fabrication techniques, combined with standard packaging and testing have kept the industry from really developing. Progress is being made, in large part due to aggressive research and development activities of semiconductor companies, universities and research institutions worldwide.

The 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 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. 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 inertial measurement systems on a chip is an excellent example of how ARPA is striving to reach its goals.

INERTIAL MEASUREMENT DEVICES ON A CHIP/PROJECTED GROWTH OF WORLDWIDE MEMS MARKET



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.

We see the MEMS base sensor market experiencing tremendous growth over the next ten years. The total sensor market, which includes non-semiconductor based sensors, will more than double over the next ten years. 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 changing the capacitance which is 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, bulk micromachining and patented processes that allows standard wafer FAB techniques. In addition, we can put it in the plastic package which further reduces costs and makes it a repeatable and reliable product for mass markets.

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.

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 the market. 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.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

Chapter Ten: THE EMERGING MARKET FOR DIGITAL MIRRORS

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

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

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.

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

The march to the digital revolution is occurring. There are areas which have already made the transition from analog to digital, from content to delivery and to user. There are already a number of digital applications, digital tools and digital technologies that are being used.

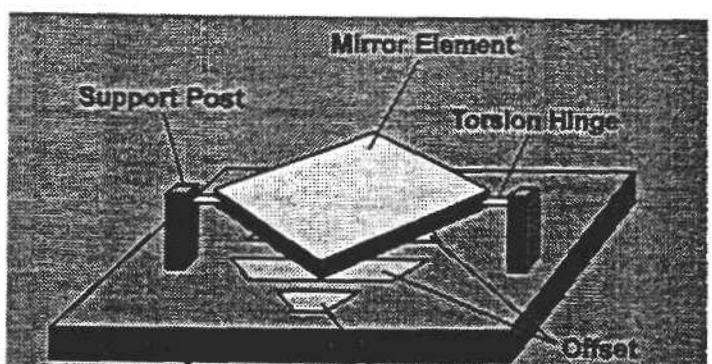
Steven Speilberg films his movies in a digital format. These are transmitted through digital machines, edited on analog machines, and the key right now is that each of these A to D's and DA's represents a filter and those filters represents certain types of information losses at each step.

This is a convergence of semiconductor technologies and micromachines. The DMD is built on top of standard CMOS, on top of S-RAM and eight micron CMOS. It is a true micron machine. 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 which are 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



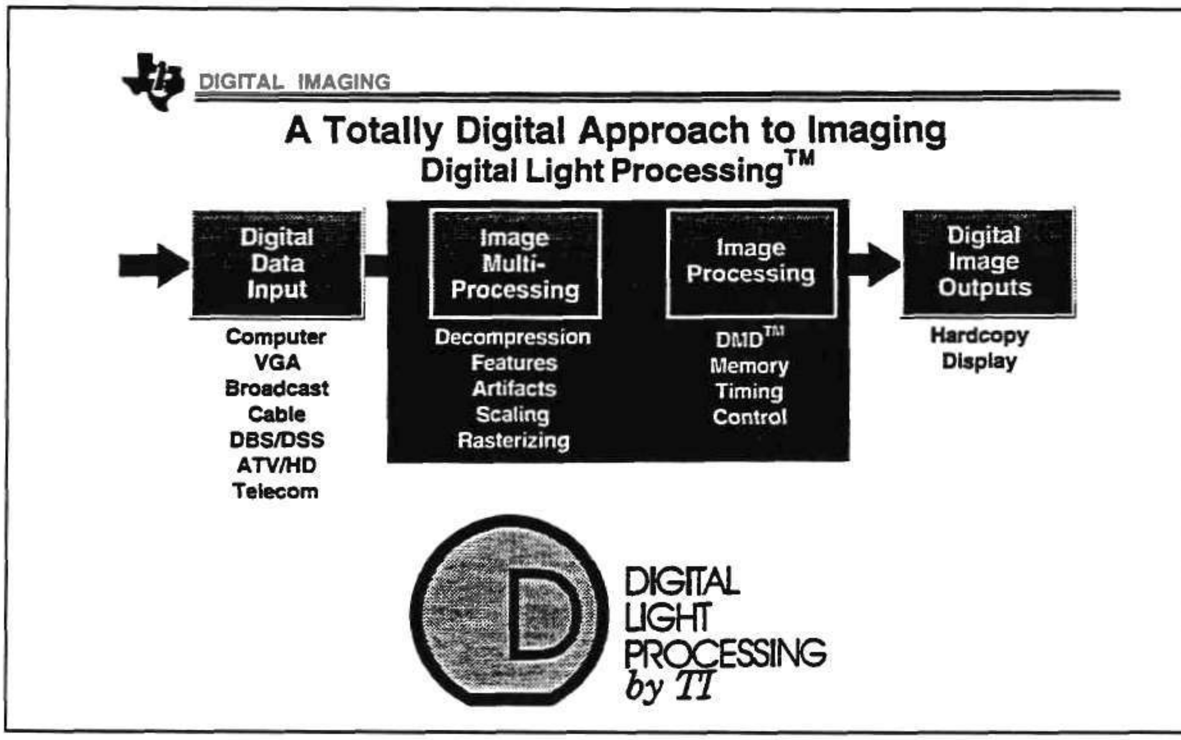
The DMD switch is approximately three orders of magnitude faster, in the neighborhood of 15 microseconds which is able to modulate light very quickly and very crisply, contributing to the resolution.

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.

Currently we are fabricating two specific types of DMD devices for display purposes and one for printers. The linear rate is used for printers, which we also call a hard copy application and it's 7,064 mirrors by 64 mirrors. 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. 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.

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. We use this to image the information, whether it's in a hard copy printer or in a soft copy display, with a minimum of information loss. As the digital information is created, DLP uses a number of microprocessors, specialized DSPs and multimedia video processors to create a truly digital way to display data.



It's TI's intent not to manufacture projectors, printers or TVs. Our intent is to make these DDEs, or digital display engines and to sell them to a number of people.

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 and 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 two, being the display or soft copy and the printing or hard copy, which provides the best opportunity.

Displays can be used 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 and theaters.

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. 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.

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.

Three of the best high end print machines in the world today are from Heidelberg, Chromopress and Indigo. These have a series of common characteristics. They are all in the $300,000.00 to $500,000.00 price range and require at least one full time operator. They require a controlled environment and produce very high quality with very high speed characteristics.

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

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 in a $50,000.00 to $100,000.00 environment producing near quality prints at the same time.

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.

This is a very exciting technology and the market potential for this is measured in billions of dollars. TI is one of the attractive stocks because this technology is viewed as the next major leap in being able to take digital information and display it to greater resolution and brightness than any other technology on the market place today.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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

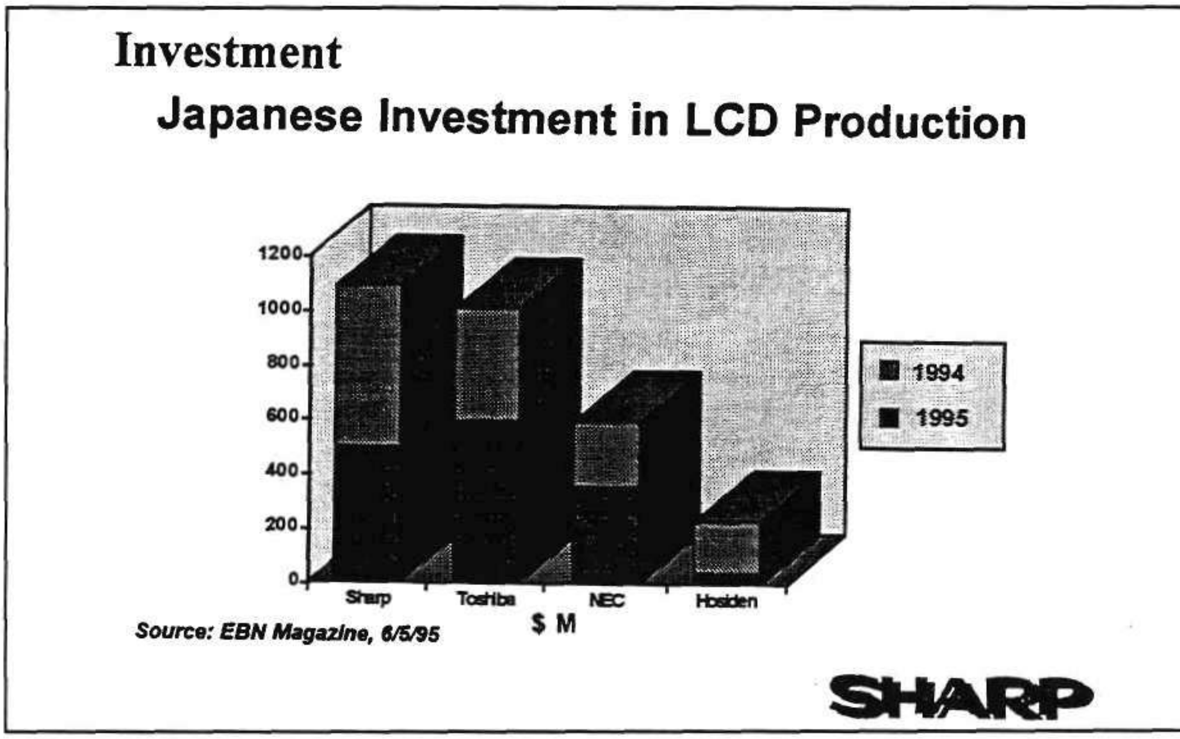
Peter H. Goebel
Executive Vice President and Chief Operating Officer
Ulvac Technologies

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

AGENDA: Investment Issues, and Sharp's Vision

INVESTMENT ISSUES



There has been enormous increase in investments made by the Japanese in the last two years. At Sharp we've invested over $1 billion dollars building the world's largest active matrix FAB, and many other things happening.

Sharp has investments in the Korean side as well: Samsung, Hyundai, Goldstar.

SHARP'S VISION

The home market, the notebook PCs, desktops, more than one per household. Perhaps more vertical applications. A family looking at their flat panel displays, getting customized information coming in from the satellite dish conveniently located outside. 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 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.

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.

Then specialized devices: 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.

We are seeing a conversion happen today from CRT based instrumentation to flat panel displays across the industry of scopes, logic analyzers, etc.

What are some of the enabling things that will bring this about? One thing 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.

Viewing cones. 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.

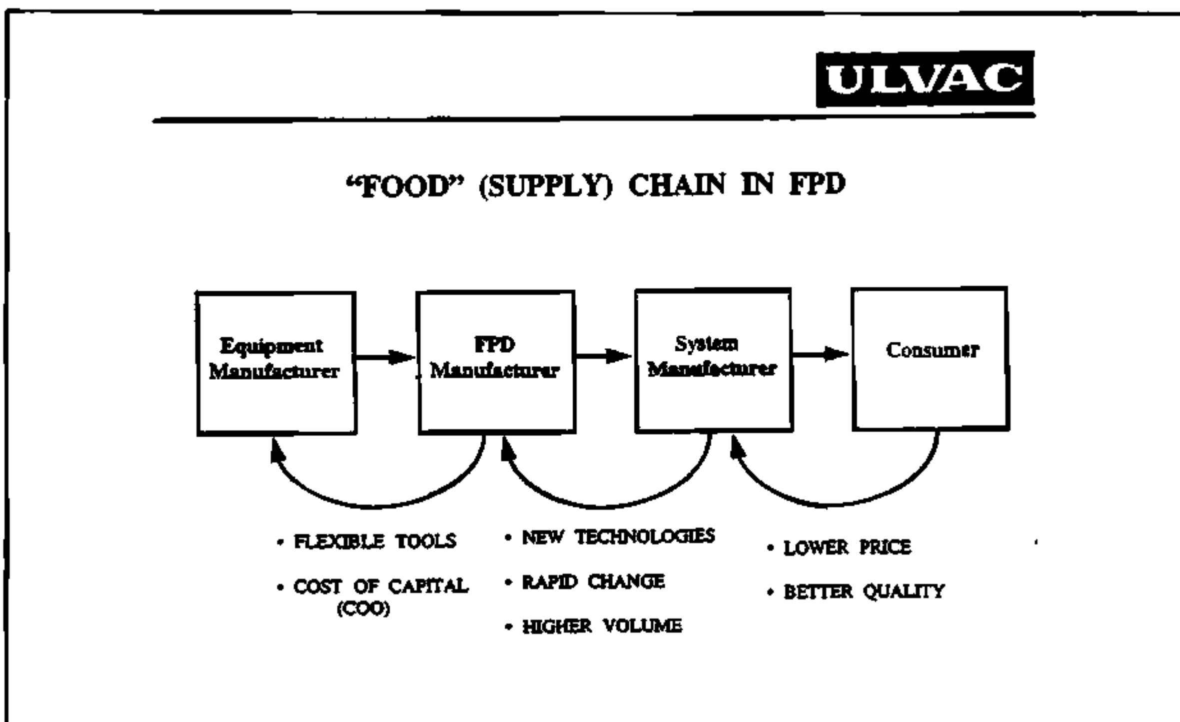
There will be some paradigm shifts that will occur. As these become more portable, usable in greater environments, really good connectivity will have to happen.

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:

AGENDA: Food Chain, Equipment Selection, In-Line Sputtering System and Technology.

What are 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?



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.

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.

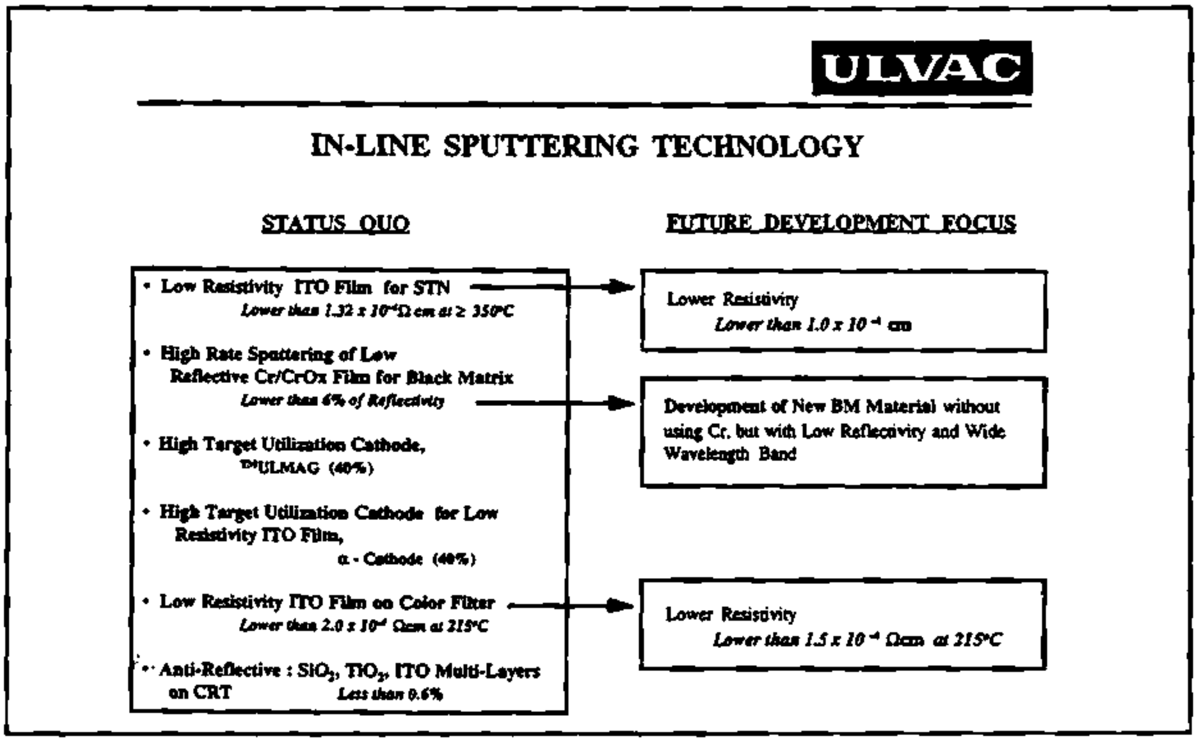
We are not only looking at a technology variableness in this market, but we are also looking at a market that is ever changing. There has been a tremendous build up in Japan, Korea and Taiwan in manufacturing capacity, and as a matter of fact at this time demand is less than supply capability.

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.

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. Over time we have been in 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.

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.

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.



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.

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.

Multichamber vs. 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.

Equipment suppliers to the flat panel market have to live by the theme: Remain flexible.

Harry Marshall:

AGENDA: Strategy: New Class of Display, How Do You Do It?, Keys to Success.

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.

STRATEGY

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. 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 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.

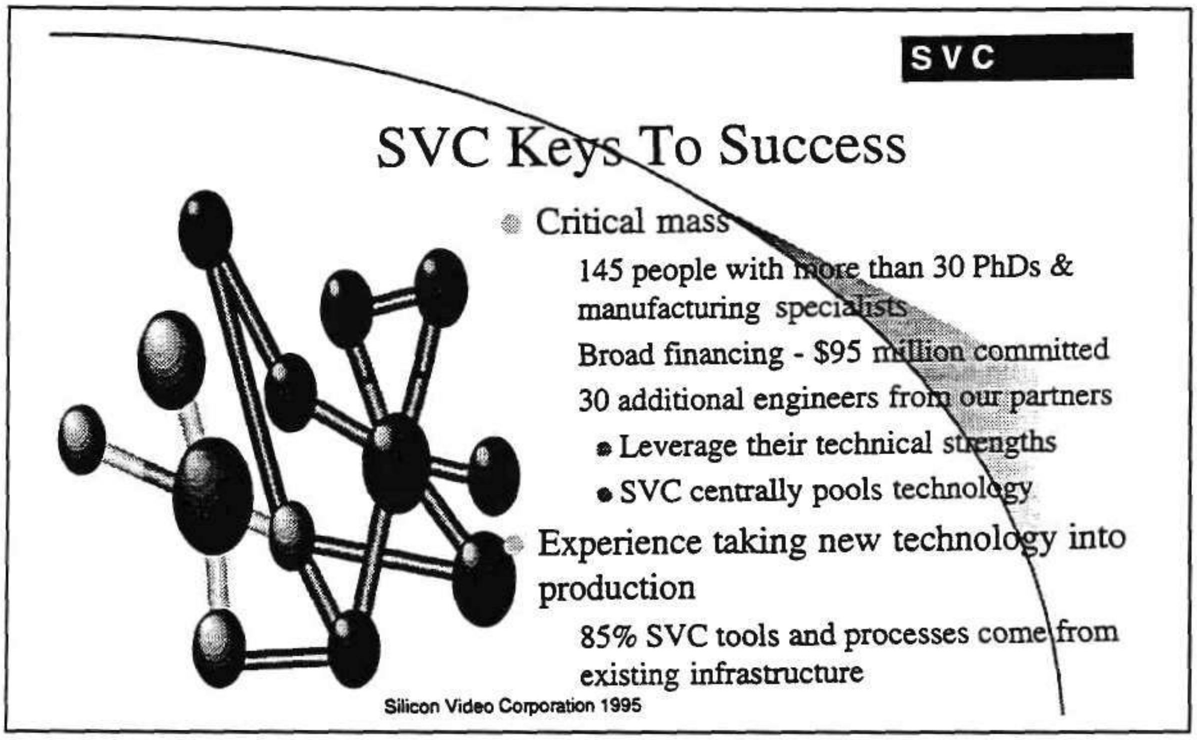
HOW DO YOU DO IT?

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. You better depend on broad sources.

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.

KEYS TO SUCCESS

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. 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. 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.

SVC

SVC Keys To Success

- Committed customer-partners
  - H-P drives product requirements
    - Forces you to address system architecture issues early
    - Keeps you from falling in love with your technology
  - Partners provide equity, patents, engineers
  - Dilemma - 1 yr design-in vs. 1 yr factory build - solved
- Target mainstream, high volume segment
  - HP & Compaq driving notebook Thin CRT definition
  - Single path to real cost reduction and a secure beachhead

Silicon Video Corporation 1995

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.

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. 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.

Conclusion: 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.

There are huge markets that will be tapable by a different technology, a bit of a paradigm shift if you will.

There are 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.

While we have very strong customer partners who want notebooks, they want to have a differentiated product. 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.

Douglas J. Bartek:

AGENDA: Opportunities, Semiconductor Influence, and Advances in Technology

OPPORTUNITIES

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.

SEMICONDUCTOR INFLUENCE

Semiconductors directly influence and enable flat panel technology to be useful, like graphics controllers and video controllers and panel drivers and those types of circuits.

ADVANCES IN TECHNOLOGY

Advanced graphics and video controllers and advanced display technologies, advanced applications, all of these have to move forward simultaneously to be accepted in the market place.

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

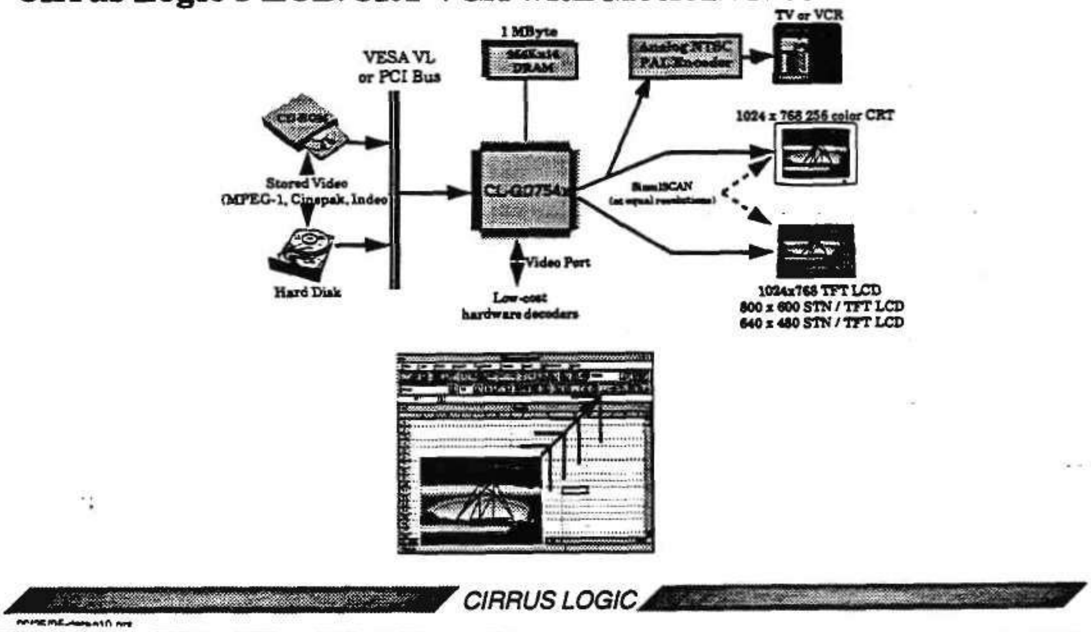
- **Superior display quality**
  - 256K colors
  - Excellent color uniformity
- **Cost-effective**
  - 201 --> 240 >> 309 outputs per driver
  - 10 --> 8 drivers for 640x480 LCD
  - 12 --> 10 --> 8 drivers for 800x600 LCD
  - 16 --> 14 --> 10 drivers for 1024x768 LCD
- **Increased display: module area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

CIRRUS LOGIC

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.

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.

Example of New Semiconductor Controller Technology
Cirrus Logic's LCD/CRT VGA with MotionVideo Acceleration



Hardware Codecs for MPEG 1 are available today in different form factors.

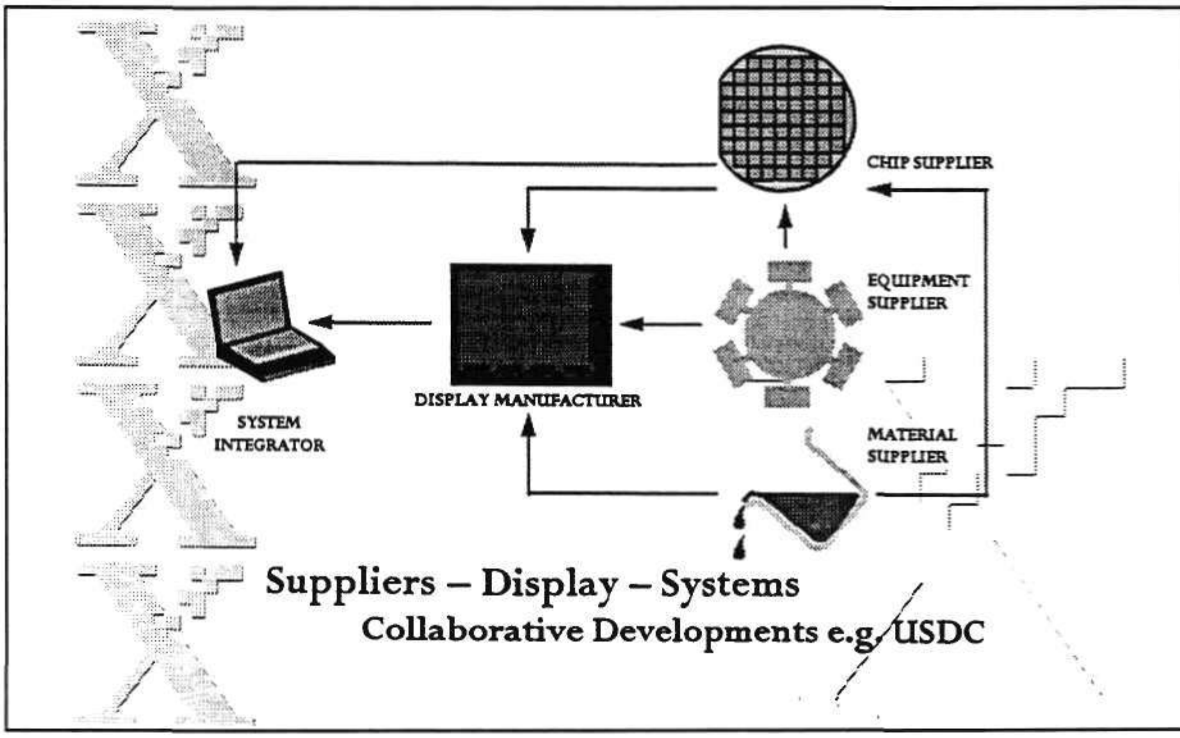
A full MPEG add in card subsystem costs about $100.00 to $150.00 retail.

This is driver technology that again is enabling the acceptance of these newer types of panels with higher resolution, more colors, etc.

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.

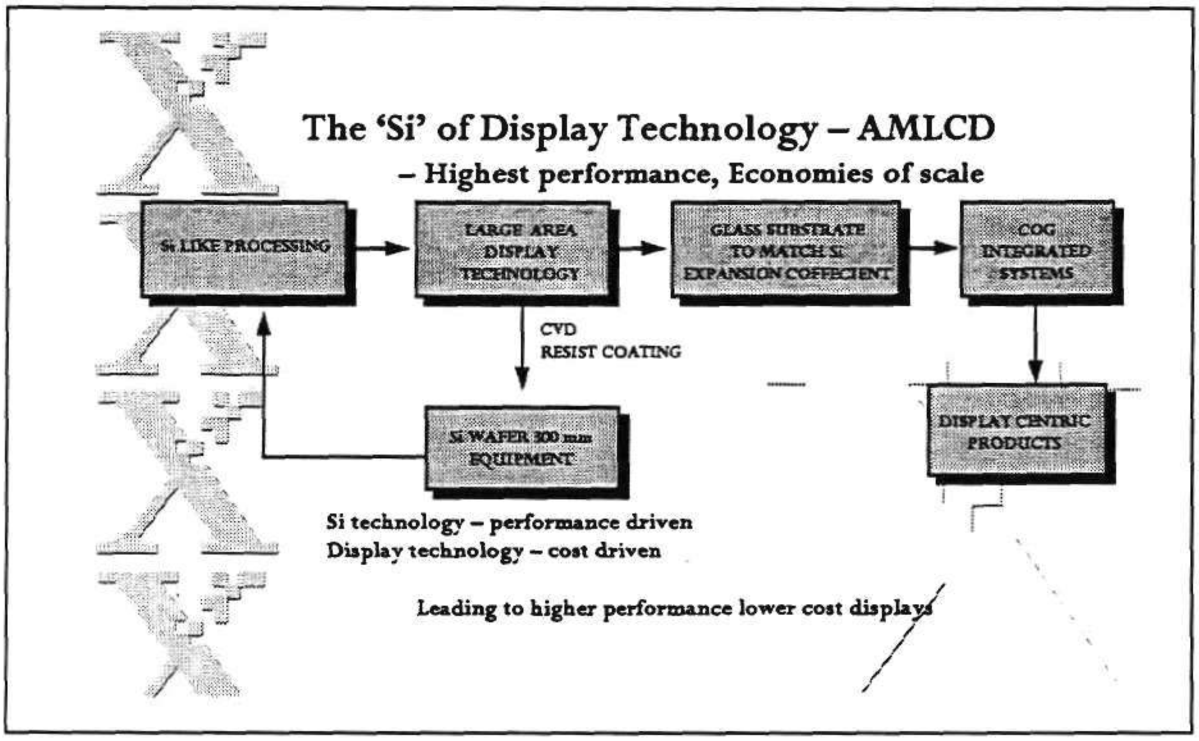
Dr. Malcom Thompson:

AGENDA: Inter-relations Between Systems,



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. 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.

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 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.

As you go to very large substrates we are looking at different coding techniques for photoresist. We are consuming a large amount of material because of these large sizes.

You have a combination. Silicon technology has driven performance for a long period of time. What display technology will drive is cost.

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.

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.

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.

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.

Standards Versus Differentiation

– are they mutually exclusive or can you have both?

Substrate	**- Substrate size has been used as Manufacturing differentiator** **- Equipment cost of multiple sizes**
Displays	**- Commodity standard display (VGA)** **- Display differentiated products**
Systems Interfaces	**- Plug & play to commodity display** **- Systems Intergration**

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.

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

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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

Wai 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. In 1995 we expect the industry to achieve $150 billion. Is it possible to do this?

The PC market is the industry that is driving the semiconductor industry today. This is 1/3, and what we are proposing is four cycles. The market assumptions are that the PC is driving industry growth. The PC is a unique product. It's a high volume product.

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. 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.

About 2,400 MSI, that stands for million square inches of silicon a year of new capacity has to be added at the silicon level, silicon wafer level. We estimate that will cost about $6 billion dollars in capitalization of the silicon wafer industry.

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.

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.

With those assumptions we will begin to hear about some of the issues from our panel speakers.

Panelist Wai Shin Lin:

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.

Taiwan's IC production value. In 1989, it was only $400 million. Global IC production value in 1989 was $46 billion. This original projection of about $250 billion.

The global growth rate from 1994 to 2000, is about 17.5%. Taiwan's growth rate is about 34%, which is somewhat higher.

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 waiting to expand into the so called billion dollar FAB, the eight inch FAB.

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.

Japan being competitive in notebooks. Korea is a somewhat more particular market. The production weight in Taiwan is shifting more to notebooks, PCs.

The figures and facts indicate 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 this worldwide demand, the Pentium is driving the PC speed faster and faster. It certainly requires more memories and more high end CPUs. By the year 2000 production will increase to probably 8% to 10%, which is the country's mission.

Panelist Marcus T. Wilson:

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. What we are concerned about is developing new uses and new user for semiconductor products, for products in the area of intelligent machines, and artificial creatures, if you will.

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.

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.

Networks: Microprocessor growth in networking will continue to grow as they enable the network ease of use and increased data throughput.

Embedded microprocessors will also enable rich image processing by linking digital cameras, faxes, scanners, printers, digital copiers to PCs.

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.

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.

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.

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.

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.

Can others grow and if they can, will they invest in the semiconductor business? 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: 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? The people that have the skills that we need to participate in the engineering and get us there are really our greatest concern.

Panelist James J. Kim:

The industry is beginning to recognize the importance of packaging as the chips are becoming more complex.

How to support it? We believe the factories' productivity will increase roughly about 7% per year based on improvements 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.

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.

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 VGAs, 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. The global infrastructure to support more than 150 new semiconductor FABs will need to recruit and develop human resources.

We need to establish global information data sharing networks. For example: Most global semiconductor companies, like Texas Instruments, they have joined ventures and subsidiaries all over the world: They call it a hominization of the equipment and the technology.

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 productivity's. 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 walk in together. The partnership can help to reduce the cycle time, cut down the learning curve of starting a new FAB, and increase the productivity's and help to deliver on time, help to train the customers, the engineer operators, to make this $300 billion dollars become reality.

Panelist Roger D. McDaniel:

Is the issue 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 year?

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.

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. 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.

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.

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.

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.

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.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

equally loaded, equally short, and keep skew into the hundreds of picoseconds as opposed as into the nanoseconds, like in traditional solutions.

The end result 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 DRAM. The Rambus DRAM 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. This is a tremendously higher bandwidth using the same economics.

The systems that you can see today, set top box systems or game systems you buy in stores, have an architecture where 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, Sega box or a set top box. Each of them has their own separate memory.

With Rambus it's possible to build a system with 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.

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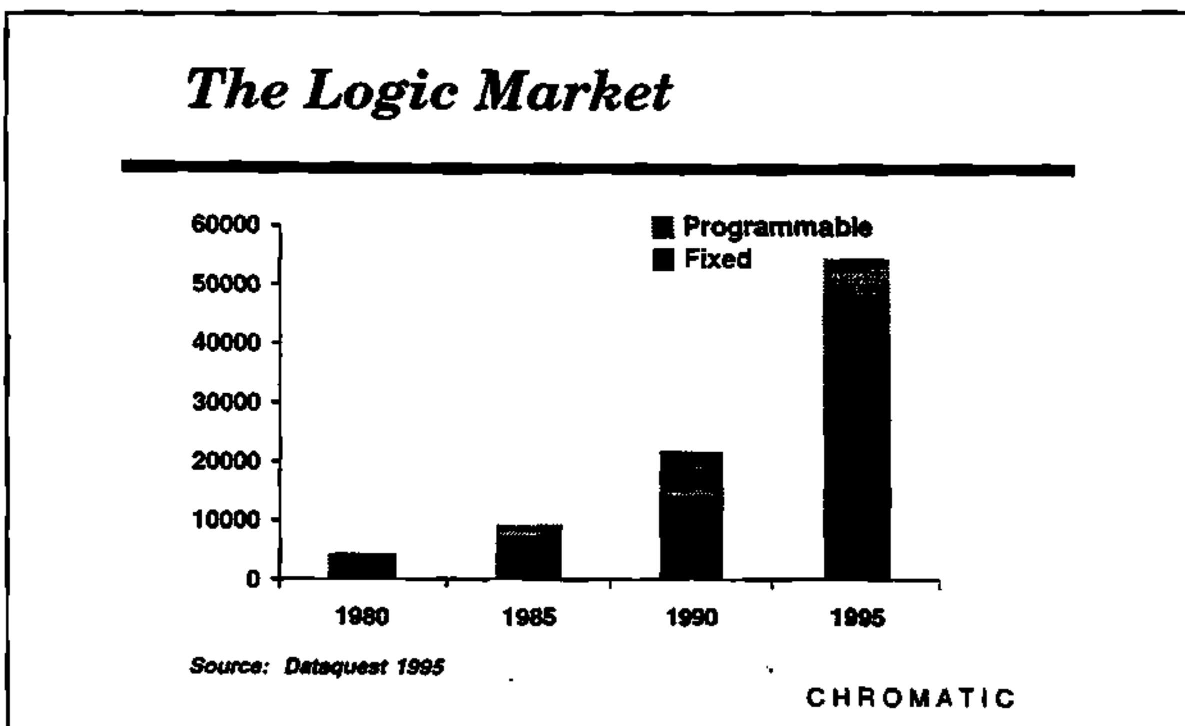
Chapter Eight: PROGRAMMABLE ICs: BEYOND MICROPROCESSORS

Wes Patterson
President
Chromatic Research

Agenda: The Programmable Logic Market, Extending The Market and Chromatic/Mpact

THE PROGRAMMABLE LOGIC MARKET

There are two kinds of logic IC's. There is fixed logic where what you see is what you get and there is programmable logic where 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 have grown in excess of 30% per year, while fixed logic has grown at less than half that rate.

Chapter Thirteen: WELCOME ADDRESS

Joe Grenier
Vice President
Semiconductor Device and Applications Group
Dataquest Incorporated

(Slides not available at printing)

AGENDA: Interesting Applications

The continuing pervasion of electronics in our lives; and a matter of creativity which prevents further pervasiveness of electronics in our lives. Collectively we sum them up and the other ideas are going to come. They are going to help very much in reaching that $300 billion dollar market.

By the year 2000 Motorola expects 222 MCUs to be found in the home, 35 in the car, 42 in the office and four on our person.

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 and 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.

How about a model train with an intelligent wireless control system that eliminates conventional wiring and switching of conventional train layouts? The base unit also provides the necessary collision avoidance and arbitration between contending transmissions from the handheld unit. A sound module, called Railsounds, provides 12 bit, digital audio playback for up to six channels simultaneously for an almost unlimited accommodation of effects. Each of the units, the handheld unit, the base unit, the receiver module and the sound module, all contain microchip technology MCUs. The system will soon be available at a price between $1,000.00 and $1,500.00.

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.

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.

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. Smartscore contains a course encyclopedia, stored in a two megabyte PCMCIA card, which contains detailed information on over 6,000 U.S. golf courses.

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 GPS 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 order entries into the computer by voice command.

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 from the satellite receiver, combined into a talking laptop computer. 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.

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.

Trimble Navigation provides the GPS receiver used in the Strider product and the 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 Scout Master, 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, cab interior companies use GPS; 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.

Other applications: Heavy equipment; machine guidance, shovels and loaders are guided to precise design grades, aerial guidance system that allows one to three meter accuracy for application of agricultural materials.

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. (Tape: The Raven) The Raven is the first project of the Peugeot 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. 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.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

Chapter Fourteen: ACHIEVING 0.1 MICRON TECHNOLOGY: WHAT WILL IT TAKE?

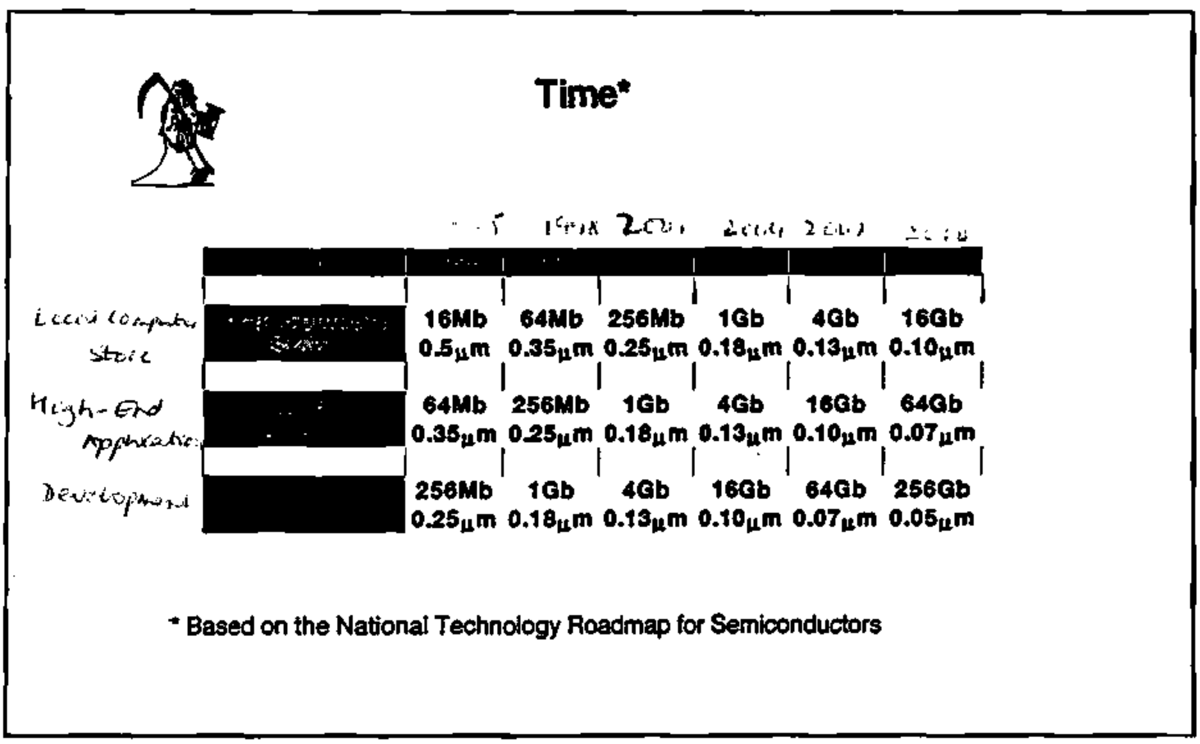
Jim Owens
Chief Operating Officer
SEMATECH Inc.

AGENDA:

Introduction: What Really is .10 Micron?, The Future, Engineering, Hot Topics, Interconnect, Models, The Money, and People.

WHAT REALLY IS .10 MICRON ANYWAY?

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.



THE FUTURE

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 and microprocessors that are using 1/4 micron technologies. 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.

ENGINEERING

The engineering is full of challenges. 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.

Engineering

- Full of challenges
  - Device functionality
  - Lithography
  - Interconnect
  - Modeling
  - Design
  - Etc.

HOT TOPICS

Let's go into one of the hot topics: Lithography. The first one 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. DUV: It stands for 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 geometry's. 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.

Let's talk about optical lithography. Historically we keep predicting the demise of optical lithography. I'm here to predict that we are actually going to be using optical down to .10 micron.

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.

Silver is somewhere between copper and gold in some of its properties. Aluminum, of course, is what we use today.

LDR stands for low dielectric reconstant. This is the oxide in between all of those metals.

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 think it was visually made very clear, interconnect really is the biggest problem. Interconnect is going to be the performance limiter.

MODELS

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. We really need to start looking at all of our models from a molecular point of view. Right now our models are all macroscopic.

Computing power continues to increase. 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.

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.

THE MONEY

Is the money going to be there? I think that's the tougher question. This industry has seen a 25% to 30% improvement in cost per function every single year since it existed.

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. 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.

PEOPLE

People: Right now that's a big issue. People are wondering are we going to have enough people out there in the future?

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 then what we did in 1984.

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. 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.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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Chapter Fifteen: DECONSTRUCTING THE SEMICONDUCTOR INDUSTRY

William H. Davidow, Ph.D.
General Partner
Mohr, Davidow Ventures

AGENDA: Vertical Suppliers, and Forecast.

What is going on in the semiconductor industry today is similar to what happened to the computer industry in the past. The vertically integrated suppliers have been de-constructed and, as a result, the industry has been reconstructed.

As industry size increases, and as the number of companies participating in the industry grows, it becomes more logical for horizontal suppliers to enter the marketplace due to the economies of scale.

VERTICAL SUPPLIERS

The vertical suppliers who are integrated have become less and less efficient, relative to the horizontal suppliers. Texas Instruments, at one time the model of the industry, built its own process equipment, its own packaging equipment, made its own silicon, its own semiconductors, and packaged and shipped its product to customers. Today, all of us are interested in buying tools.

As the complexity of what we are able to build has vastly increased, our understanding as semiconductor companies of what the end-use application is, has continually decreased. Application specialists who understand subjects like ATM or graphics or multimedia applications have grown up. Thus, more and more opportunities are going to arise for horizontal suppliers to enter the marketplace and supply services that fill horizontal niches.

The pattern of company de-construction is the direct result of vertically integrated suppliers losing key competencies in important areas. What happens is in periods of rapid change, companies fail to leverage the competencies of others. Those that fall prey to this are, more often than not, the losers.

The FABless semiconductor business has added tremendous value for customers. They have accomplished this by subcontracting assembly, adding algorithms and software, designing methodology to silicon foundries, and utilizing unique marketing skills. The result has been companies with billions of dollars in sales, achieved by exploiting niches in applications expertise that vertically integrated semiconductor suppliers lacked.

Assembly houses are going to add more and more value in the future and, indeed, much of the packaging that goes on inside IC manufacturers is going to move to the assembly houses. This is going to be a very capital-intensive and skill-intensive business.

The role of royalties is also going to change. In the past, royalties were a penalty. They were a penalty for having to either intentionally or unintentionally violate someone else's patent. They were a toll. In the future, as R&D costs continue to escalate, there is going to be an advantage to pooling some of the commodity processes.

Vertical suppliers will continue to dominate the industry. They will continue to grow. As a result, they will increasingly purchase outside services from small, tightly focused companies.

Intel is an example of a vertically integrated supplier that will continue to climb. They have massive volume requirements. It's hard for them to plan on available foundries. They gain time to market by having the ability to integrate process and design, and they have optimized their process for products that they deliver.

The industry is going to begin de-constructing into a series of horizontal layers and, in time, there will be no one model for semiconductor businesses in the future. The business models are going to become more varied, and that is going to create tremendous opportunities as the industry continues to grow.

FORECAST

The forecast-- from Robertson, Stephens, Dan Klesken-- shows how the semiconductor industry is expected to grow: $300 billion in business by the year 2000; $700 billion by the year 2005. To drive the point home, $1 trillion in business is the equivalent of selling $150.00 in semiconductors to every man, woman and child on the planet.

Inevitably, the semiconductor business is going to become a trillion dollar market. At that point, a billion dollar company would seem relatively insignificant. But the truth is, there are going to be hundreds and hundreds of opportunities for $100 million and $1 billion companies to fill the leftover niches. And as they say in Texas... "We spill more than that every day."

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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Chapter Sixteen: MULTIMEDIA 2000

Michael L. Hackworth
President and Chief Executive Officer
Cirrus Logic, Inc.

AGENDA: Vision, Today, Drivers, Microns and Survival

VISION

Alan Kay, a fellow at Apple Computer, said his vision for multimedia would be realized when his six year old daughter could sit down on a Saturday morning and create her own 3-D interactive cartoons on a machine that cost less than $1000.00.

That definition captured, in a very simple concept, the interface, price point, human interface, and friendliness required to create a truly rich multimedia experience. On the current trajectory, Alan Kay's vision will probably be realized by the year 2000.

TODAY

Multimedia today is fundamentally in a playback mode. That's where all of the investment and technology at the present time is headed. Video game developers deserve a lot of credit for stimulating the demand for multimedia and PC's and, in fact, are probably the "engine" for a home PC at this moment in time.

Today we are seeing arcade-quality video games migrate to the PC, replete with full-motion video, 3-D graphics and surround sound, all making for a very rich multimedia experience.

As we near the 21st century, we can expect multiple drivers of growth in this interactive age. These drivers will set in motion changes that will create new realities for chip makers.

DRIVERS

The list of drivers is headed by humanistic interfaces, or more natural ways to interact with the computer. In the late 1970's, the federal government legislated emission requirements on the American automobile industry. Unbeknownst to the general public, the equipment of the PDP8 was inserted into virtually every automobile. It was a completely natural interface that brought tremendous technology and advancement to the auto industry. It is that kind of interface that will dramatically expand the marketplace.

Growth Drivers In The Interactive Age

- **Humanistic Interfaces**
- **Internet & Broadband Communications**
- **Multimedia Applications & Content**
- **Unprecedented Affordability**

The next tremendous "engine" of growth will be communications; specifically, the Internet and broadband communications.

The Internet is the killer application for bringing high speed communication into the home and office. 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 will most certainly create and stimulate turnover and demand for new hardware.

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.

MICRONS

As the microns continue their inevitable shrink toward the .10 micron, the tendency will be to put all information on one chip. This is even more profound for the test equipment industry, where there are specialized testers for D-RAM, Pro Logic and analog continuous time signal processing. This will all have to be combined into single test equipments.

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 has 150 million transistors, with about one-third less the components found in that original XT machine.

The implication of these realities is that R&D is being forced down the value added chain. R&D activity has shifted from the semiconductor industry to the semiconductor capital equipment industry. 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 OEM's. Years ago, PC manufacturers spent 6% on R&D. Today, it is not uncommon to see leaders in the industry 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.

In biology, there is a phenomena called the S-curve of life. The bottom of the "S" is germination. The right seed in the right orientation takes root and, hopefully, grows. In a new company, the bottom of the "S" is the start-up phase, or the start-up phase of a new technology. Eventually, the right company or technology in the right orientation takes root and, hopefully, grows.

SURVIVAL

The chip makers' survival will depend not only on feature size reduction and integration of more components, but on innovation as well.

Once we are over the hurdle of survival and practicing in this new paradigm, the chip makers can thrive on change, leading to the innovation of even more new system architectures like the Chromatic multimedia engine and the Phillips Trimedia engine. And if this can be accomplished with the current R&D burden, the value in the food chain can be increased as well.

The bottom line? Seize the opportunity or miss the boat.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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

Question: 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. We are beginning to see the impact of multimedia as more and more people have multimedia PCs.

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.

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.

Panelist Bruce Ryon:

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.

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? 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.

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.

Panelist: 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.

We see a significant drop in margins for the software developers. 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.

Question: Thoughts about delivering value in the home or in the business?

Panelist Rob Enderle:

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.

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.

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.

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. 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.

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?

Panelist: 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.

Moderator: Let me address the idea of education. I've got college aged kids. I also have an eight and a seven year old at home. We use Score in Menlo 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 in Menlo Park. 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.

Question: Is there a way that we can use computers to stimulate learning?

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.

Panelist: It's an interesting issue. 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.

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.

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.

Question: 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?

Panelist: In the office place the biggest bottleneck right now is the network. The other side is hardware.

Question: How about communications? Talk about it both for the office, as well as the home; talk about both aspects.

Panelist: 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.

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.

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: 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 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.

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.

Question: Where do you see semiconductors helping to resolve some of these bottlenecks, some of these costs issues we talked about.

Panelist: Certainly we are seeing that Intel's concept - and perhaps the trend setters - are bringing the technology down into the chip. 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.

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. 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.

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.

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.

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.

Panelist: If you partner from strengths you're smart; and that's what really needs to happen here.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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Chapter Eighteen: E-MONEY: ANOTHER HOT ENGINE FOR SEMICONDUCTORS

Colin Crook
Senior Technology Officer
Citibank

AGENDA: Financial Transactions, Experiments, The Underlying Economy, Security, The Future, The Cost,

Citibank is a very large consumer company. We have around 70 million customers globally. We are a global operation.

FINANCIAL TRANSACTIONS

Around the world's telecommunications industry, there are approximately over 500 billion 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.

$1 trillion dollars within Citibank's flow through art systems, our networks, through our silicon chips onto disks, across communications network.

EXPERIMENTS

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. 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.

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.

THE UNDERLYING ECONOMY

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. 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.

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.

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? 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.

SECURITY

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.

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.

THE COST

It's this issue of microtransactions. 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 $12.00 or ten to the minus $12.00. 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.

THE FUTURE

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. Then we are going to see the electronic devices, the individuals and the enterprise. This is going to be the future world. This is going to be the basis for what's going to happen in the year 2000 and beyond.

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 cyber space.

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.

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 revolutionalize capitalism. Banking is going to be re-structured.

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? 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.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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:

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. The functionality will take place in software, as well as in hardware.

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.

Modertor: What do you consider to be the most critical ingredient for market success for systems level integration fliers?

Panelist Brian Halla:

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. The second is a library of intellectual property building blocks which are not cells. Third - and every bit as important - is the technology and methodology to stitch together those building blocks.

Panelist Don Ciffone:

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. You have to tie into that, however, a strong systems understanding of the end application that you are supporting.

Panelist Hirokazu Hashimoto:

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.

Panelist Gary Smith:

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.

Moderator:

This is open to any of the panel members. Who do you think will have the most IP and why 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. There's another type of intellectual property, which is the actual methodology to stitch these things 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.

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 Hirokazu Hashimoto:

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.

Panelist:

One of the things I was going to say about the third party is that we have seen as fast of pace of introducing new technologies. We are introducing a new generation just about every nine to 15 months.

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.

Moderator: How important do you think having on chip D-RAM is to have a full system on a chip?

Panelist Don Ciffone:

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.

Panelist:

To the extent you can put a whole system on a chip, just because you can, people will ask for that.

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.

Moderator: On the analogs are the design tools there if you want to put analog on chip?

Panelist Gary Smith:

The analog isn't a design tool issue. There are design tool problems and that, but the problem with analog is you can't test it. Why put it on the chip if you're not going to test it?

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?

Panelist Brian Halla:

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 gunny transistor logic pixel, phase lock loops; all of which are just base case now in some of the more sophisticated courts.

Panelist:

I think in my side, the EDA side, I think there are two answers to that: In one way I agree completely with Brian, but there is the issue of the second tier vendor. In the ASIC world, the Gatorade world especially, there are the top X four or five, or maybe six, it depends on how you count them. Then there are the other guys.

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.

Moderator: If we could take another question from the audience.

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 of the rest of your circuits on your chip.

Panelist:

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.

Panelist:

A price per premium compared to 5 volt and 3.5 volt. Basically what we talk about is 8.8 micron and 10.6 micron. These kinds of things are not ASIC controlled. Memory people still stick with 5 volt.

Question:

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?

Panelist Brian Halla:

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.

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%.

Panelist:

The ASICs in 1994, just exceed $1 billion dollars. In 1995, we are looking at $1.5. Our goal for the year 2000, we hope to have about 17,000 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.

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?

Panelist Don Ciffone:

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.

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?

Panelist Hirokazu Hashimoto:

Our company has a huge capacity for .35. We will ship that product this summer for our customer. Please think about some second sourcing.

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.

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. Second sourcing has become a way of life. It load levels the FAB. It diversifies product portfolio.

Moderator:

Second sourcing really does require a process compatibility. How do you really handle process compatibility without giving them the process.

Panelist Don Ciffone:

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.

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.

Moderator:

How do you think SLI will impact Intel's strategy, or will there be any impact at all?

Panelist Brian Halla:

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.

Panelist Don Ciffone:

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.

Panelist: Think about silicon integrated solutions. Market segment is cross-referencing to the PC and multimedia and networking and something. We are basically thinking of whole market segment.

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.

Moderator:

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 Gary Smith:

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, don't put together the methodologies necessary to use it, will be going out of box business in about five years.

Panelist Hirokazmu Hashimoto:

System level solutions' future direction. The most important thing is again libraries and also to have a very much customized rendering of CMA 2.

Panelist Don Ciffone:

I think if I challenge myself and my peers here, the request 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.

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 look.

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.

Thank you, the audience, we really appreciate you coming.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

Chapter Twenty: NEW DRAM ARCHITECTURES: WHO NEEDS 'EM?

Panel Discussion

Moderator

Jim Handy
Director and Principal Analyst, MOS Memories Worldwide Services 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 them? My name is Jim Handy. I'm Director and Principal Analyst of Dataquest's MOS Memories Worldwide Service.

All of that could be addressed by wider DRAMS built out of 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 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

Dataquest

Panelist Hans Wiggers:

The previous panel dealt with predominantly 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.

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 ?)

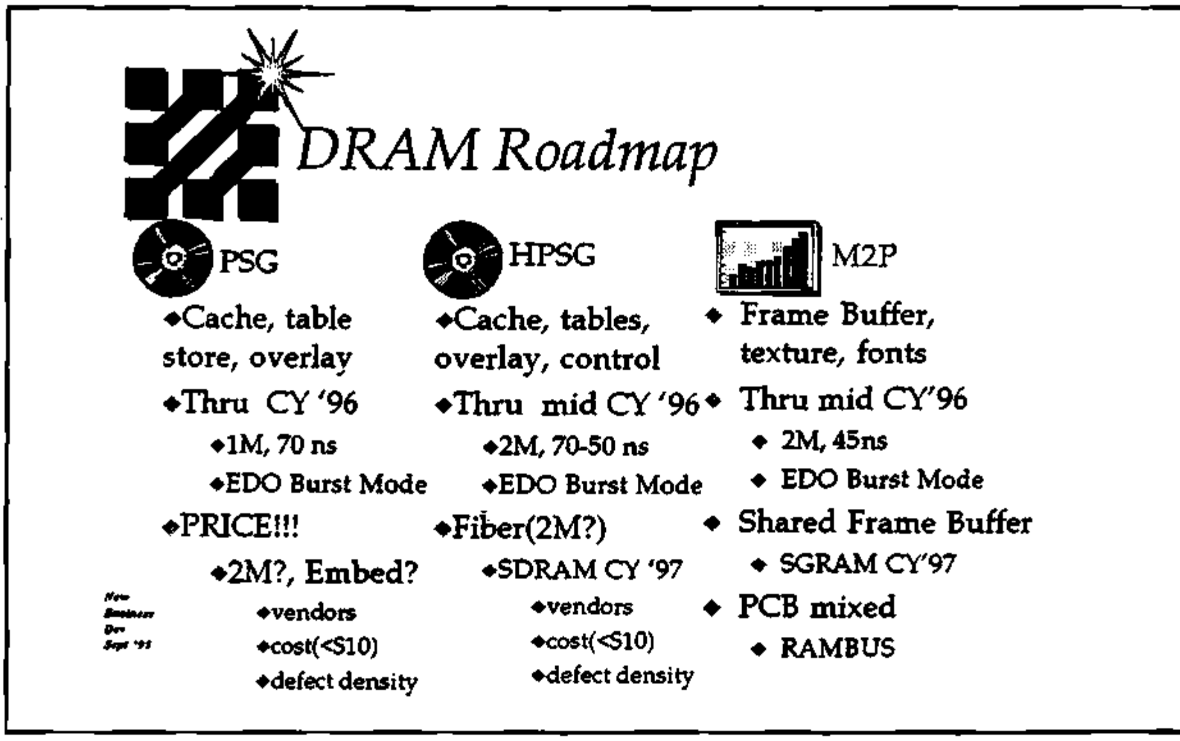
HEWLETT PACKARD HP Confidential

Panelist Paul Baker: *(Due to technical difficultites the audio presentation is not available)*

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**

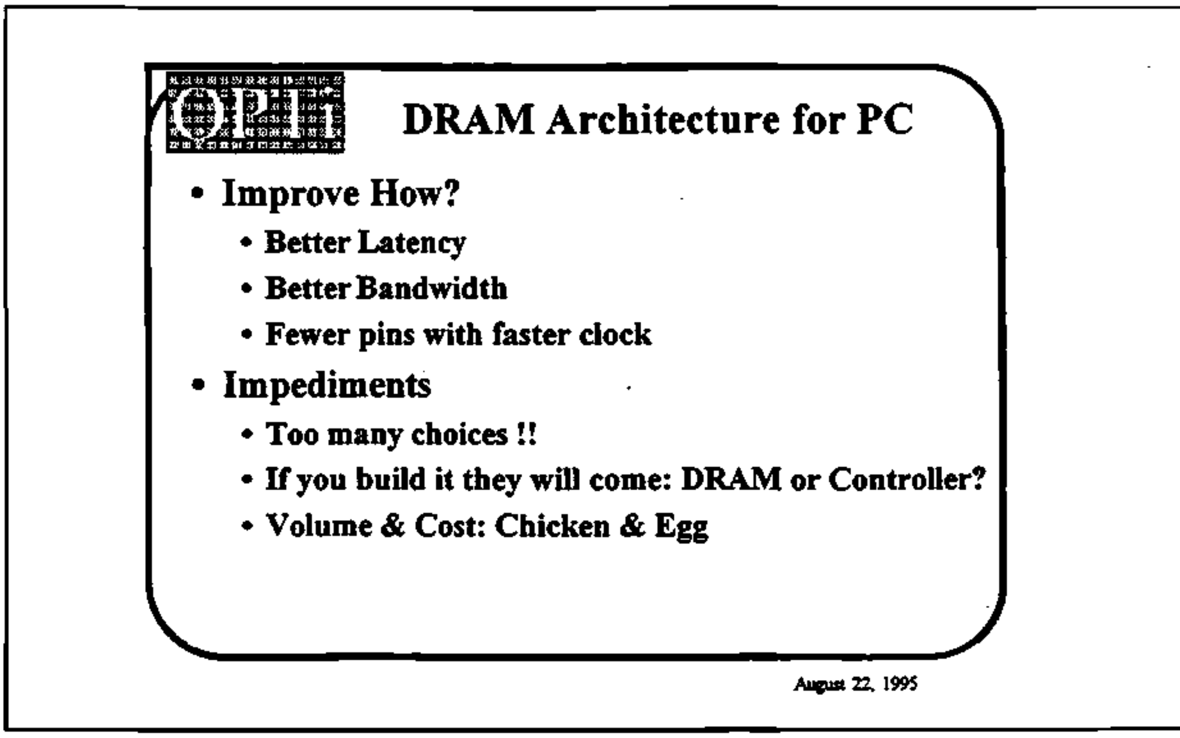
Panelist Jodie Hughes: *(Due to technical difficultites the audio presentation is not available)*



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. Over the next few years, the major trends that we see: Densities, of course, moving up to 256 megabyte. Cost and supply really do remain supreme here for DRAM.

Panelist Dipankar Bhattachara:



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.

Panelist Max Bouknecht:

The trick to this whole business is being able to anticipate. It is difficult for me to answer the question 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.

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.

Moderator:

Speaking of dropping devices, you were complaining about one meg 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. 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.

Moderator:

It doesn't fit too well with a lot of product lines, 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:

The unfortunate thing though is that while the price point of the disk drives are 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.

Moderator: A disk drive DRAM, maybe a graphics DRAM?

Panelist:

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.

Panelist:

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.

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 for such we have today.

Moderator:

Getting over the current hurdle. You're talking about that and you're talking about the very high speeds that you need. 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:

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.

Moderator:

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 asynchronous 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.

Panelist:

The 3-D requirements, with textures, etc., etc., nobody is going to want to buy a 16 megabyte graphics card.

Panelist:

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.

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.

Moderator:

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, and be able to leverage one set of requirements against another. When we ran into this we buy one megabit standard DRAMs by the truck load for disk drives, and wanted to ease into the EDO market and found out that the store was basically closed.

Moderator:

Do you see any difficulties? I don't know whether being with IBM you know that 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 also affects inventory, one of the driving factors in today's business.

Panelist:

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.

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.

Moderator:

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:

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.

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 available?

Panelist:

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?

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?

Panelist:

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.

Panelist:

It's an operating system issue, and I am personally running Windows MT 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:

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:

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:

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.

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 reach 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.

Comment:

I represent one of the DRAM manufacturers. It seems to me that the three things that drive costs are yield, die size and volume. S-DRAMs have, at least in my opinion, about a 5% die size penalty over page motor EDO. 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.

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 S-DRAM and other packaging formats next year from a system level.

Panelist: By S-DRAM you mean synchronous DRAM?

Question: Yes.

Panelist:

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.

Panelist:

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:

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.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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

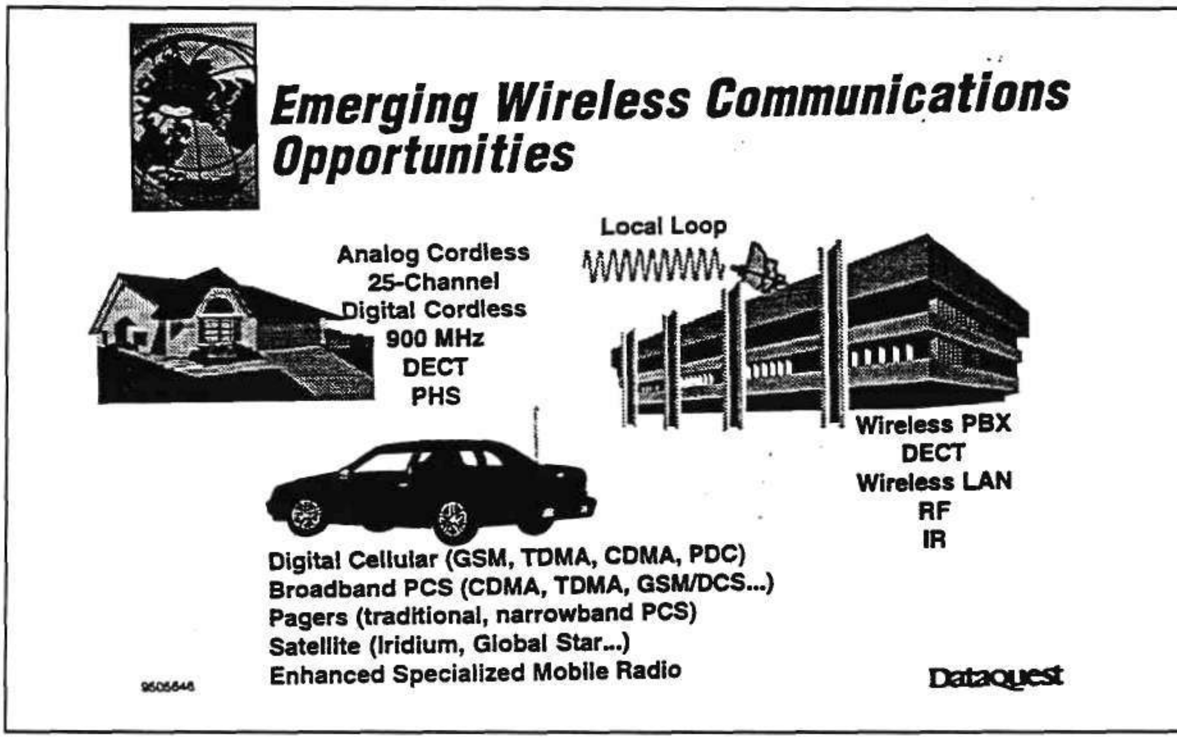
Dr. Angelo Ugge
Vice President, North American Telecommunications Business Unit
SGS Thomson Microelectronics

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



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. Depending on what 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.

Panelist Peter Karsten:

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 company started, when they deregulated. Depending on how you measure it, you end up with very penetration rates at the end.

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

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.

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.

If we look at the implications for the semiconductor industry's obvious high volumes it 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.

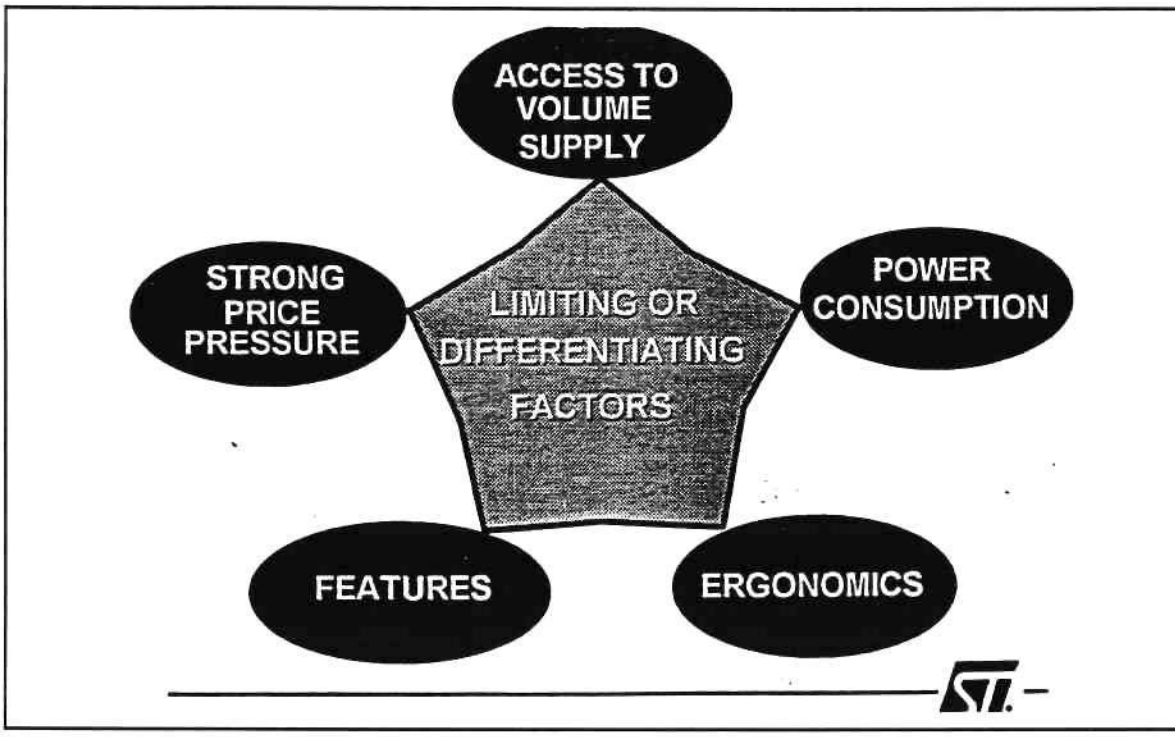
When we look at future objects, we have to look at the total impact of how people are going to behave with these things. Is it going to be considered cool to be a proud owner or what is it going to be considered?

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:

What is the destination of the wireless odyssey? For sure we do not know the how, as was already mentioned, but by my definition the wireless has a very clear objective. It is 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?

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 if they have cellular, PCS, or what. From now to then it will change dramatically.



First and foremost, the access to volume supplies. 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.

Likewise, a big user volume means that it will be a consumer-like tendency, therefore if it is not strong enough there will be a further pressure on pricing, which means looking into cost of material, cost of the semiconductor, and economy of scale in producing it.

Then, obviously, the market will demand at least two fundamental features. One is the features that sell. What do you want to do with a wireless terminal? If you look at what the 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.

Mass distribution of these sets will involve ergonomics. What do I mean with ergonomics? Size. Weight. Shape. Color. Form. These will adapt. 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 from Motorola Cellular or AT&T Microeconomics trying to sell to AT&T.

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.

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 or we want to try to active the mishmarket of productivity, but simply because a minimum level of know how allows us to identify what are the technology needs ahead of time to support the R&D investment.

Finally - time to market is the key. Time to market will be the key from conception of an idea to turning out of huge volume productions. 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:

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 concise them, try to put it on one page, that the opportunity which is available to us in the wireless area, both in the area of wireless and data, and how it spans from every single aspect of life from a home use to a business use, and maybe this is the opportunity which Davidow missed this morning when he showed $700 billion and he couldn't identify the other $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 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.

The paradigm has changed from the old paradigm to where the semiconductor guys only had to worry about providing a very general device. I will show you what things we have done to help our system partners, like Motorola, Nokia and other people, who play in this thing.

The standards are good, but at the same time we heard about the wireless has taken off, but we are still seeing quite a slowness in the data side.

On the other hand, if you look at the standards which were pervasive, it's pervasiveness will commoditize. The key issue here is the standard has to be a pervasive standard for everyone to make an investment.

Market Trends

- Wireless voice moving to ubiquitous service with a consumer orientation
  - Lower cost terminals and service
  - Smaller, more stylish design with longer battery life
- Largest market pull for wireless data is from enhanced paging and narrowband PCS messaging (2 way text and voice)
  - Incremental service based on widely accepted paging standard
  - Economically satisfies the asymmetrical data communication requirements of most mobile data users
  - Many broadcast services being established in anticipation (stock quotes, sports, headlines, etc.)
- Infrastructure moving from a centralized wireless communication mainframe to a distributed wireless communications server
  - Specialized service needs required micro-cellular & pico-cellular architectures
  - Success of PCS vision dependent on flexible and low cost infrastructure deployment

AT&T Microelectronics

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 more like micro. As the growth of PCS comes, maybe there will be a base station in every attic of the house.

These market trends that you have to have the technology which will support that. One of the things when you look at the technology, that the technology and the whole market is moving towards the consumer. You need to have the technology and the support, a similar infrastructure to what you see in a consumer application.

Another thing which is extremely critical is time to market. One of the things that we have done, we have provided to our partners a flash capability that the devices, the DSPs we provide them with has a flash on chip.

Besides the system capability, having the ability to integrate, you have to bring a lot of other capabilities, high level tools, different software capability, and technologies like flash.

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.

What we see ahead is that what we will be working to provide this market place with is a capability where you can really achieve a real consumer product and you can see that you can afford to be any time, any where, and have the capability to be connected.

Panelist Ray Millington:

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.

Digital Cellular Trends

Standards Needed

- Volume
- Quality
- Interoperability

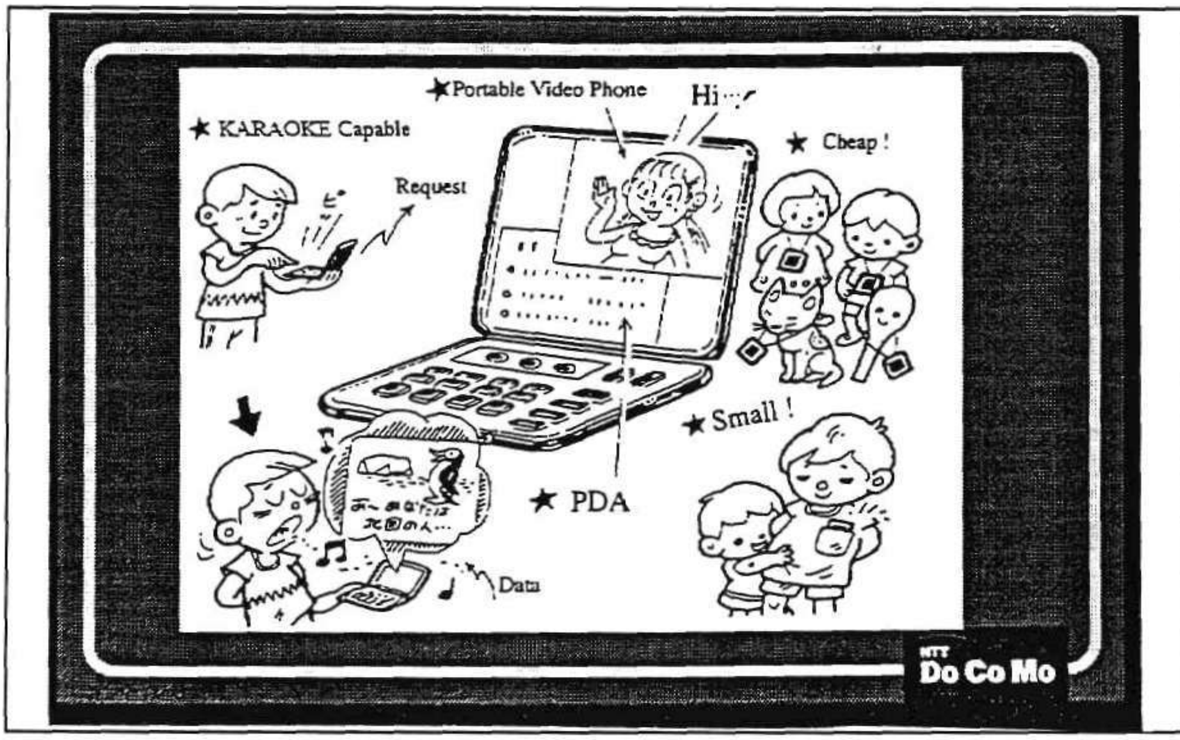
October 13, 1995

There are really two basic classes of users: We have the power user, and the casual user.

We do know that the importance of the standards are that we build up a good volume base. The other thing that's obviously important about standards is interoperability between different networks.

RF complexity, that's another thing that not too many people really think about, but you think at digital, you go to digital to make it simpler than 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.

Panelist Toshio Miki:



This will show that one example for the mobile multimedia dominoes. It is very likely that the PDA domino, with - for example - the portable video phone and it's window. One thing in this application is that the price should be cheap, which can be used by even the children, and also the pocket sized small one. In Japan, it's a very important application of the multimedia, the color allocation. I do want to have that and they are now developing this.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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

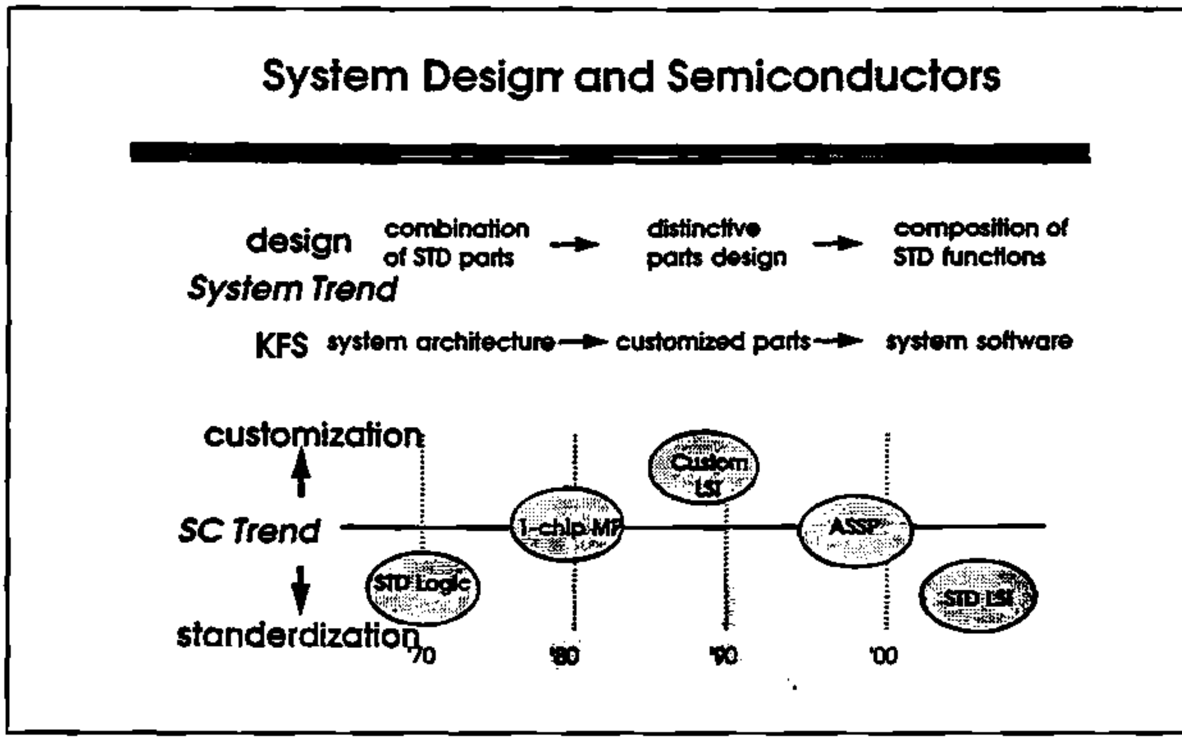
Dr. Takashi Kubota
Director, Senior Chief Engineer
Consumer Products and Information Media Systems
Hitachi

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

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

Panelist Kazuaki Mayumi:

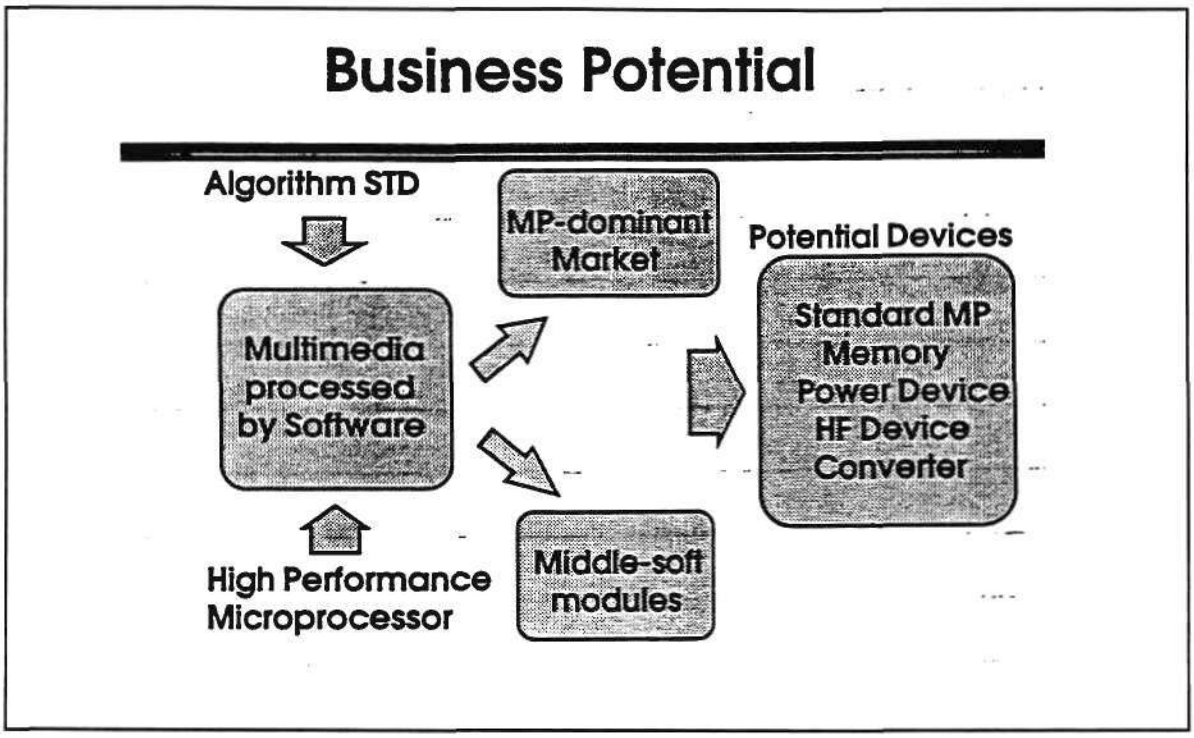
At this stage, designers design by combination of standards first. For instance: Standard Logic. At first the parts exist. Then systems are designed. After that, single chip microprocessor appeared. Finally, the custom LSI is available.



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.



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.

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.

Panelist Kenji Hori:

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.

Some 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.

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.

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.

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.

Dr. Klaus Vokholz:

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.

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

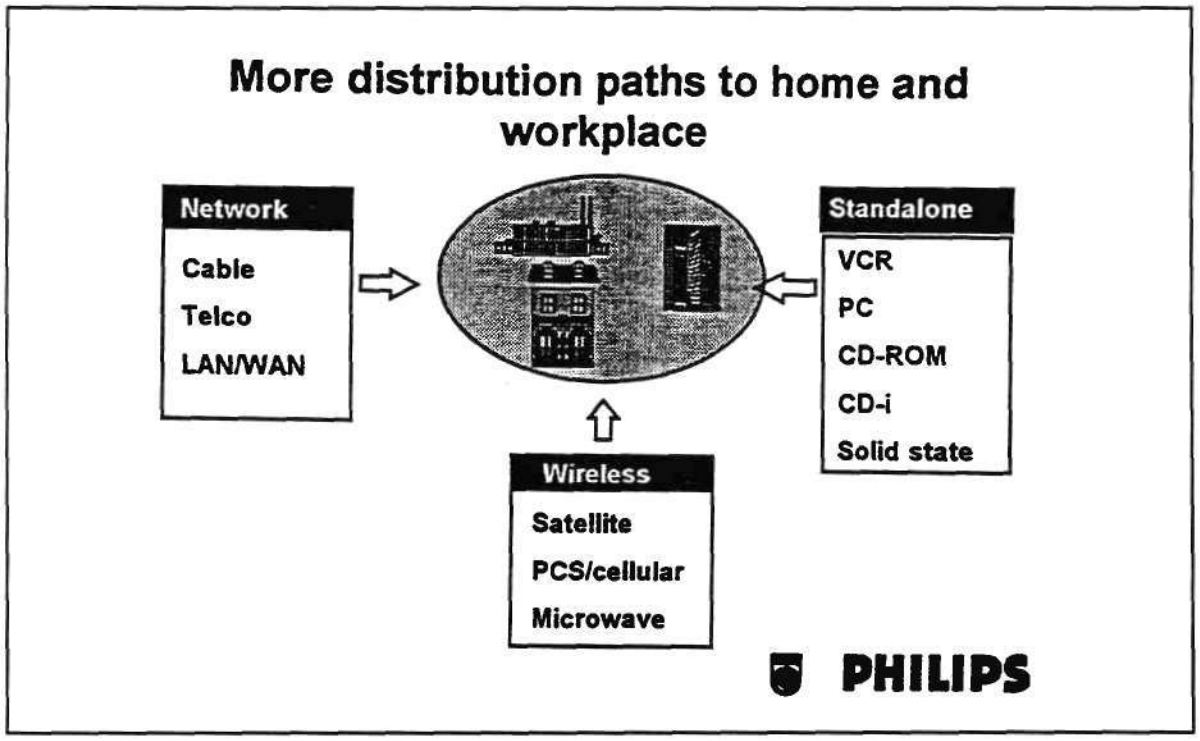
PHILIPS

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.

There are very sizable 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.



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.

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. Another one is direct broadcast satellite, and that has just come in recently in this country.

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.

Let me move on to the issue of what does it take to be successful? 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.

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.

The industry faces some challenges that are going to be key in making multimedia happen.

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:

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.

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 manipulation 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.

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.

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 makers collecting the functions to make his own system.

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 (I think) is going to the Digital Video Broadcast approach. Is HDTV 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 HDTVs is growing steadily. Wide screen with standard definitions has become more preferred. More than 50% of the TVs sold are now the wide screen in Japan.

Moderator: 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. 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.

Panelist:

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.

Moderator: We would like to thank our panelists for coming today and sharing with us insight in their industry.

Note: Refer to the "Verbatim Transcript Documents" for the Full in-depth discussions, explanations, charts, graphs and audience Questions and Answers.

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