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1990 SEMICONDUCTOR INDUSTRY CONFERENCE

The Next Decade . . . Where Do the Opportunities Lie?

October 8–9, 1990
Monterey Conference Center
Monterey, California

SUNDAY, October 7

5:00 p.m.	**Registration**	*San Carlos Foyer*
7:00 p.m.	**Cocktail Reception**	*San Carlos Ballroom*

MONDAY, October 8

7:00 a.m.	**Buffet Breakfast**	*San Carlos Ballroom*
7:30 a.m.	**Registration Continues**	*Steinbeck Lobby*
8:30 a.m.	**Semiconductor Industry Forecast** David Angel Group Vice President and Director of Worldwide Research Dataquest Incorporated	*Steinbeck Forum*
9:00 a.m.	**The Next Decade . . . Where Opportunities Lie** Manny Fernandez President Dataquest Incorporated	*Steinbeck Forum*
	Differing Corporate Strategies	
9:30 a.m.	**Pure Play Semiconductor** T. J. Rodgers President and CEO Cypress Semiconductor	*Steinbeck Forum*
10:00 a.m.	**Coffee Break**	*Steinbeck Lobby*
10:30 a.m.	**Building Block Supplier** Frank Gill President Intel Systems Group	*Steinbeck Forum*
11:00 a.m.	**Fabless** Gordon Campbell President and CEO Chips & Technologies	*Steinbeck Forum*
11:30 a.m.	**Group Questions**	*Steinbeck Forum*
12:00 Noon	**Lunch**	*San Carlos Ballroom*
12:45 p.m.	**The Bush Administration's Position on High Technology** Congressman Tom Campbell	*San Carlos Ballroom*
1:45 p.m.	**Wake-Up Call for the US Semiconductor Industry** Carver Mead Gordon and Betty Moore Professor of Computer Science California Institute of Technology	*Steinbeck Forum*
2:15 p.m.	**Packaging for High-Performance Systems: Moving Toward 2000** Mary Olsson Industry Analyst Dataquest Incorporated	*Steinbeck Forum*
2:45 p.m.	**Coffee Break**	*Steinbeck Forum*

(Continued)

3:15 p.m.	**Lithography Strategies: Pushing the Limits**	*Steinbeck Forum*
	Optical Lithography Eugene Fuller Manager, Stepper Programs Sematech	
	X-Ray Lithography Robert Hill Functional Manager, Advanced Lithography Systems IBM Corporation	
	E-Beam Lithography Neil Berglund Assistant to the President and Executive Director of Marketing ETEC Systems, Inc	
	Maskmaking John G. Skinner Director of Advanced Photomask Technology Du Pont	
5:15 p.m.	**Session Concludes**	
6:45 p.m.	**Private Tour and Strolling Buffet Dinner at the Monterey Bay Aquarium**	*Monterey Sheraton Lobby*

TUESDAY, October 9

7:00 a.m.	**Buffet Breakfast**	*San Carlos Ballroom*
8:30 a.m.	**General Announcements**	*Steinbeck Forum*
8:45 a.m.	**Semiconductor Memories in the Coming Decade** Tsugio Makimoto General Manager, Semiconductor Design & Development Center Hitachi Ltd	*Steinbeck Forum*
9:15 a.m.	**Europe: Redrawing the Semiconductor Borders** Jonathan Drazin Senior Industry Analyst Dataquest Incorporated	*Steinbeck Forum*
9:45 a.m.	**Coffee Break**	*Steinbeck Lobby*
10:15 a.m.	**Prices, Profits, Projections: Is This Market Too DRAM Volatile?**	*Steinbeck Forum*
	David Sear Vice President Fujitsu America	
	Robert Brown Vice President and Group Executive Toshiba America Electronic Components	
	William Gsand Vice President and General Manager Hitachi America, Ltd.	
	Joseph Parkinson Chairman and CEO Micron Technology	
	Frank Jelenko Vice President NEC Corporation	
12:00 Noon	**Lunch**	*San Carlos Ballroom*
12:45 p.m.	**The Price of the Future** Fred Zieber Vice President Dataquest Incorporated	*San Carlos Ballroom*
1:45 p.m.	**The Evolving Personal Computer** Roger Johnson Chairman, President, and CEO Western Digital Corporation	*Steinbeck Forum*
2:15 p.m.	**The New Face of Personal Electronics** Hiroyuki Mizuno Executive Vice President and Member of the Board Matsushita Electric Industrial Co., Ltd.	*Steinbeck Forum*
2:45 p.m.	**How User/Supplier Relations Will Change** Irv Abzug GTD Vice President and Director of Corporate Procurement IBM Corporation	*Steinbeck Forum*
3:30 p.m.	**Conference Ends**	

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PRICES, PROFITS, PROJECTIONS: IS THIS MARKET TOO DRAM VOLATILE?

Joseph L. Parkinson
Chairman of the Board
Chief Executive Officer
Micron Technology, Inc.

Joseph Parkinson, a co-founder of Micron Technology, Inc., is Chairman of the Board of Directors and Chief Executive Officer. Previously, he served as the company's president and a director. He is also a board member of SEMATECH and the Semiconductor Industry Association. Prior to Micron, Mr. Parkinson was employed by law firms in New Orleans, New York, and Idaho. He has also been a professor at the law schools of Tulane University and New York University. Mr. Parkinson received a Bachelor's degree from Columbia University, a Juris Doctorate degree from Tulane School of Law, and a Master's degree in taxation from New York University.

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Prices, Profits, Projections: Is this Market Too DRAM Volatile?

Joe Parkinson
Chairman and CEO
Micron Technology

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MICRON

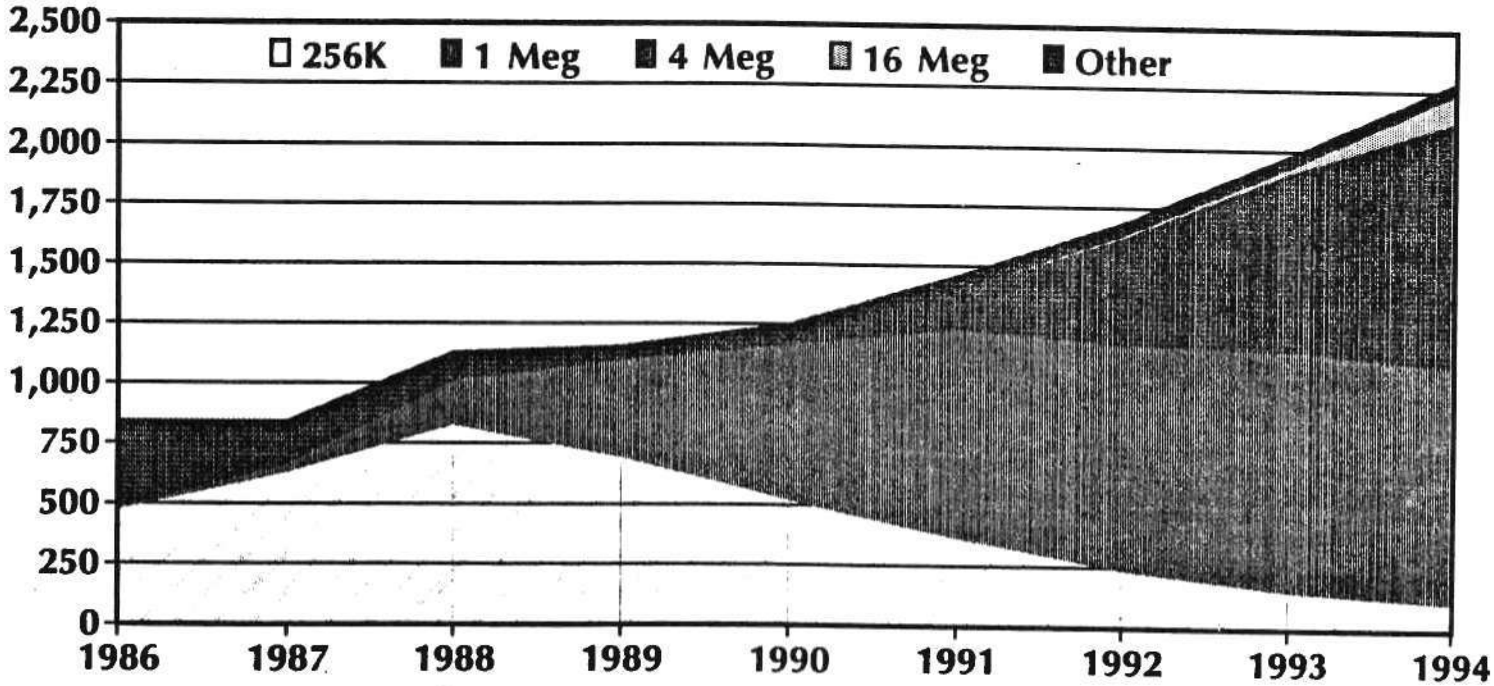
TECHNOLOGY, INC.

Quality • Performance • Service

MICRON

Worldwide DRAM Market

(Units in Millions)

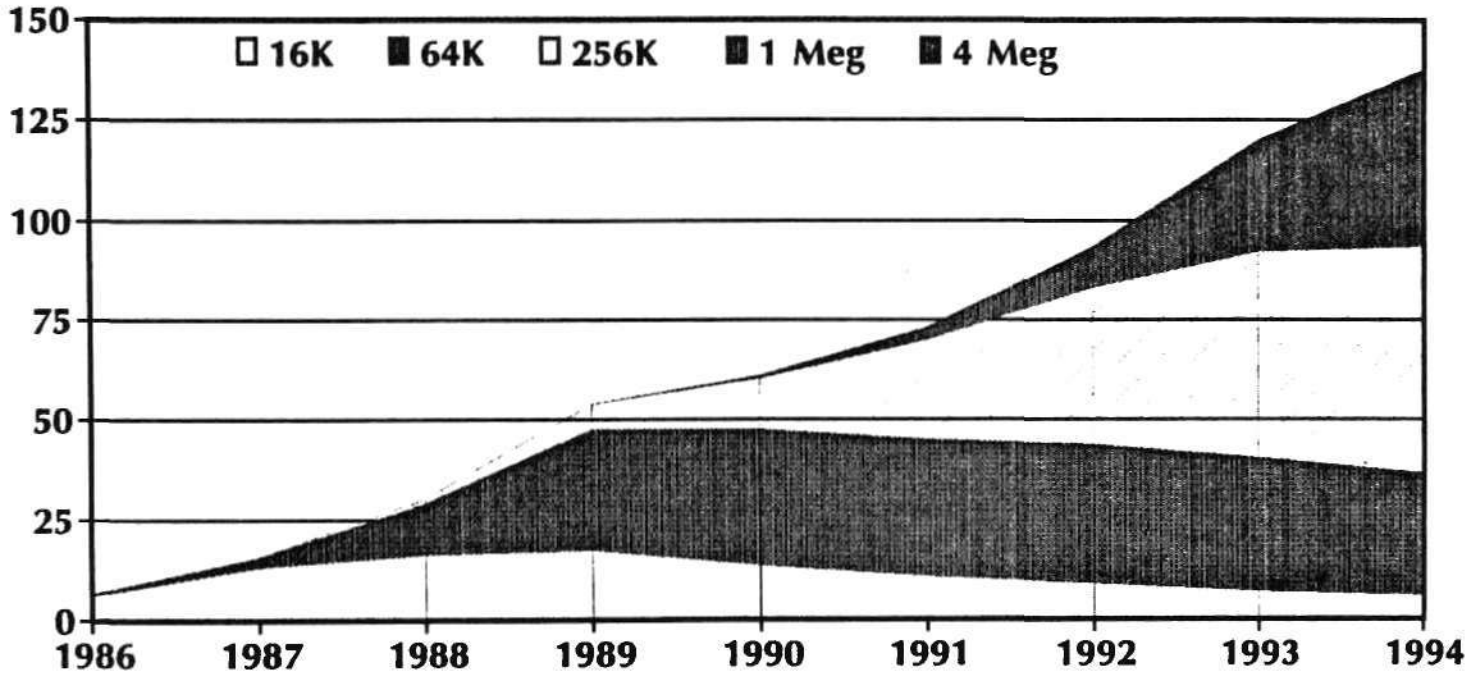


Source: IN-STAT, September 1990

MICRON TECHNOLOGY, INC.

Worldwide Very Fast SRAM Market

(Units in Millions)



Source: IN-STAT, August 1990

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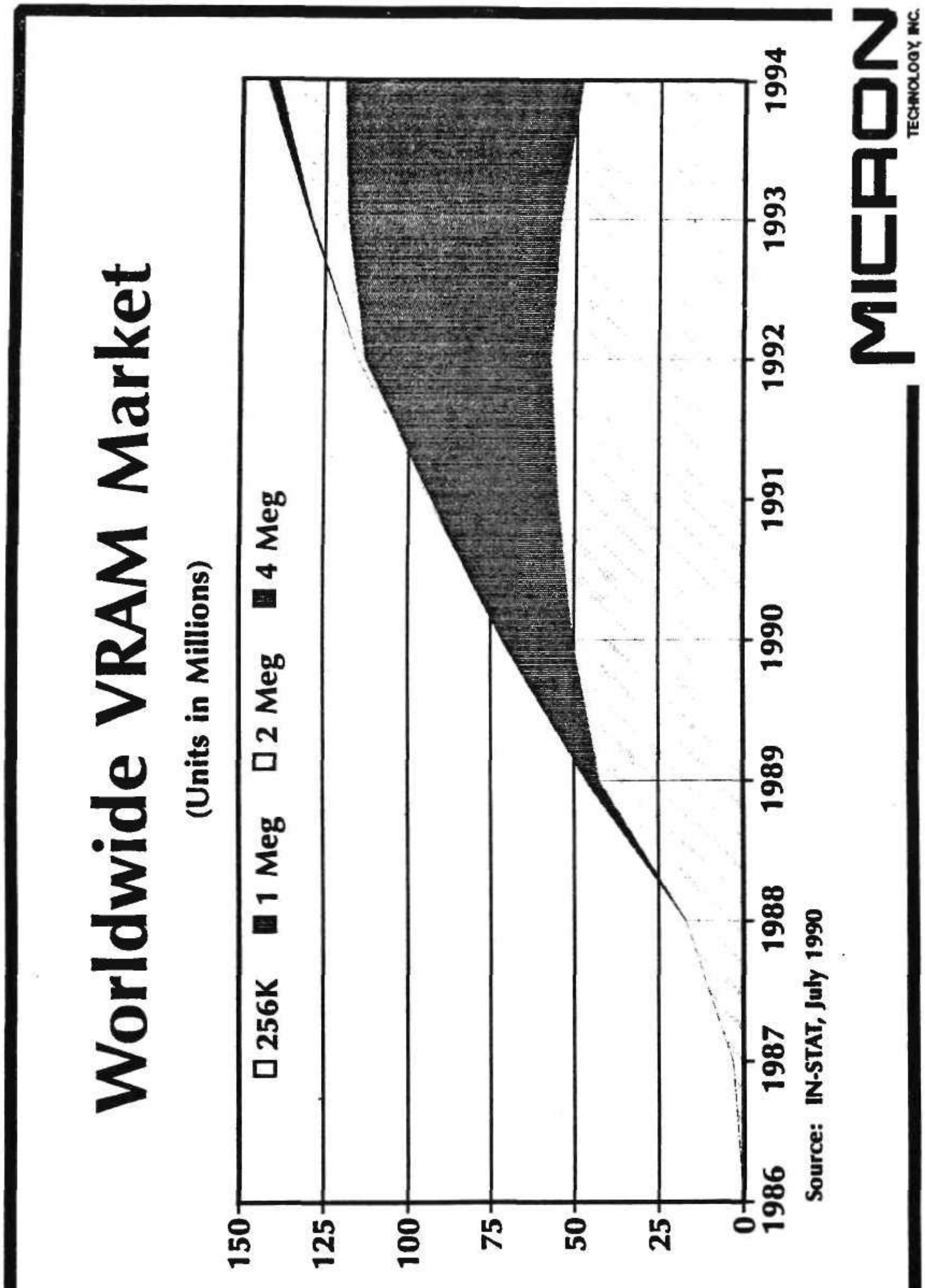


Worldwide VRAM Market
(Units in Millions)
256K
1 Meg
2 Meg
4 Meg
150
125
100
75
50
25
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
Source: IN-STAT, July 1990
MICRON
TECHNOLOGY, INC.

Micron Has Used DRAM Technology and Production Expertise

To expand into

SRAMs
VRAMs

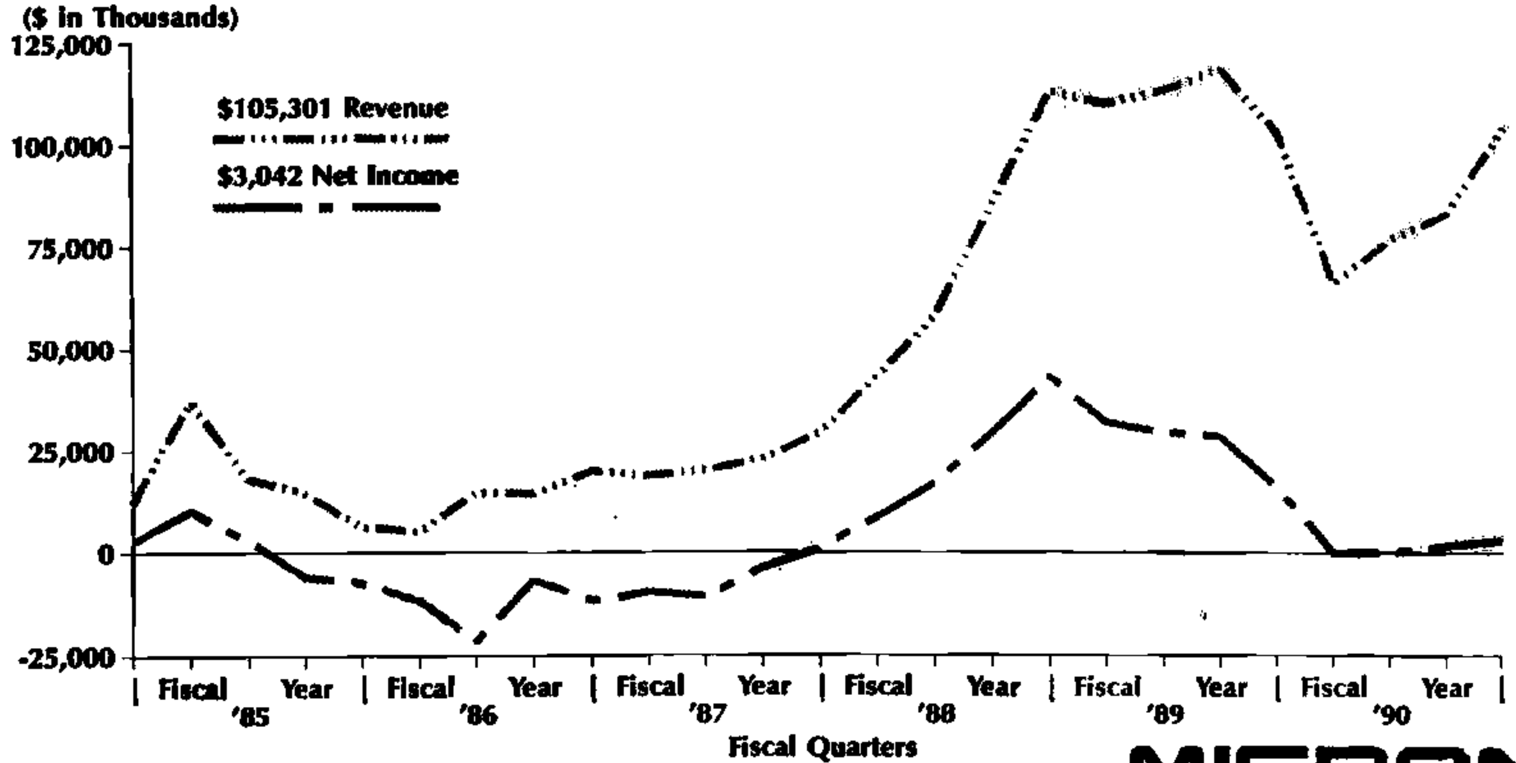
To address emerging markets with derivative products

Triple Port DRAM
64K x 16 DRAM
QUAD CAS DRAM
Cache Data SRAMs

MICRON TECHNOLOGY, INC.

Financial Trends

Q4 1984 to Q4 1990



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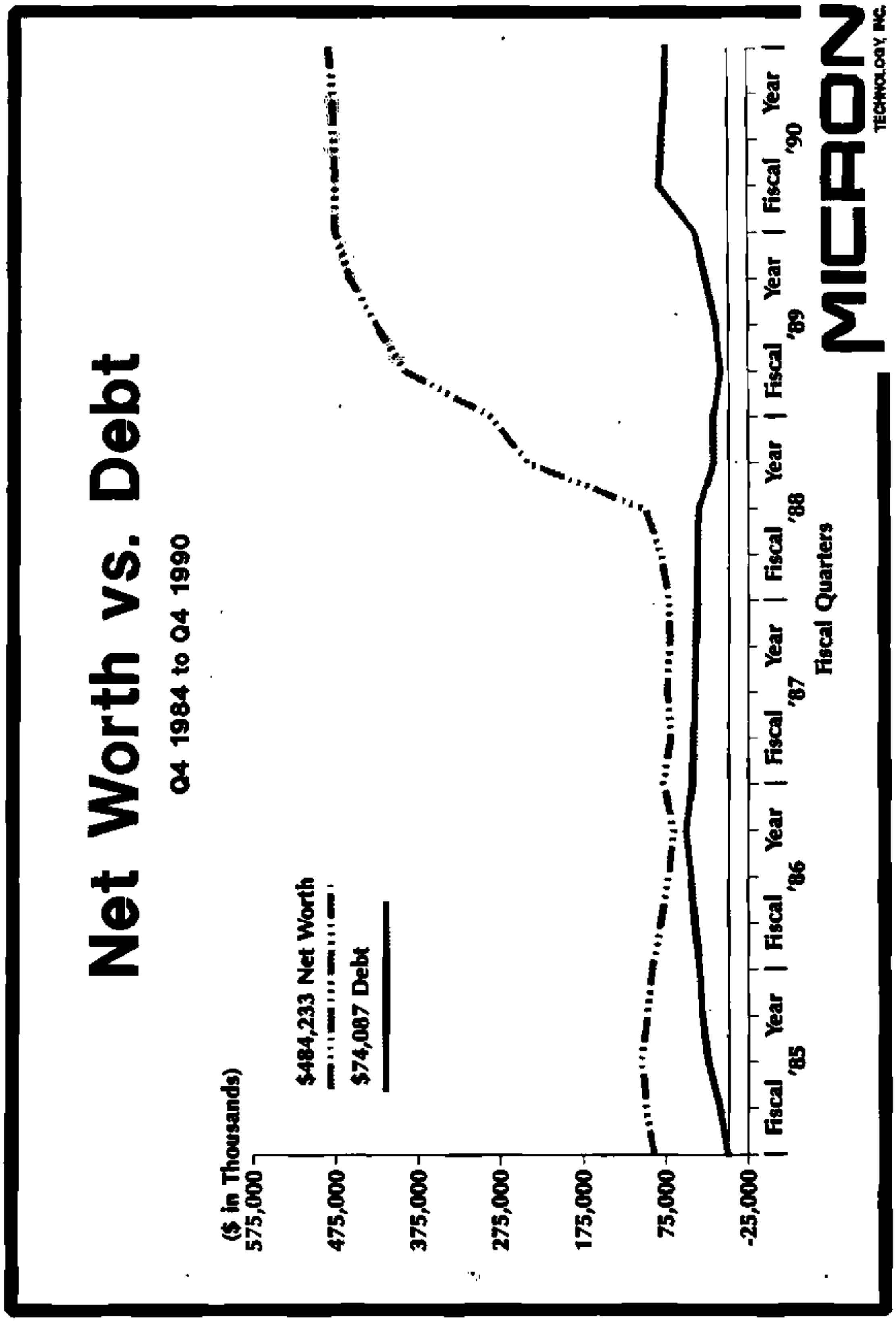
Net Worth vs. Debt
Q4 1984 to Q4 1990
($ in Thousands)
575,000
475,000
375,000
275,000
175,000
75,000
-25,000
$484,233 Net Worth
$74,087 Debt
Fiscal Year '85
Fiscal Year '86
Fiscal Year '87
Fiscal Year '88
Fiscal Year '89
Fiscal Year '90
Fiscal Quarters
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Factors for Endurance in Semiconductor Manufacturing

Smaller die sizes
Reduced mask layers
Equipment selection and automation
Fab configurations and wafer sizes
Continued improvements in product speed
Continually lower manufacturing costs
Excellent quality
Proven reliability
Intelligent burn-in (AMBYX)

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THE PRICE OF THE FUTURE

Fred Zieber
Senior Vice President
Dataquest Incorporated

Fred Zieber is Senior Vice President of Dataquest. Mr. Zieber held positions as General Manager of Research Operations and General Manager of Technology Operations. Technology Operations include all syndicated industry services, consulting activities, and electronic industries information research. He was General Manager and founder of Dataquest's Semiconductor Division. Mr. Zieber has 18 years of experience in market research and consulting. Prior to that, he worked in the semiconductor industry for nine years. He has experience in processing and designing integrated circuits. He holds two patents in the semiconductor processing. Mr. Zieber has a B.S. degree in Electrical Engineering from Stanford University and an M.B.A. degree from the Graduate School of Business at Stanford University.

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The Price of the Future

Fred Zieber
Vice President
Dataquest Incorporated

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THE PRICE OF THE FUTURE

Doing business in the semiconductor industry is expensive, and getting more so every day. Whether we are companies, industries, part of the infrastructure, or--like Silicon Valley--a geography closely alligned with semiconductors the cost of healthy survival is rapidly escalating. I would like to explore some aspects of this cost with an eye to shaping our thinking and our actions for the future—in order to ensure the future: the price we must pay.

To look at the future, please excuse me if I refer to history. But historical developments that have been changing costs in the industry are, with some exceptions, also a resonable guide to the furture. While costs have been rising for a long time it is the magnitude of current and future costs that make a critical difference. They are to the point where the structure and nature of the industry will change. I go back a long way, so history comes easy to me. I joined the semiconductor industry in 1961 as a technician—I was working my way through Stanford—and soon found myself enmeshed in device processing and design. I was paid two dollars an hour. Some things change. But I didn't know anything then; some things never change. For the current discussion, however, I will stay within modern history, the last twenty years, and the foreseeable future, the next five years.

Since, as an industry, we like to pat ourselves on the back, we often hear many impressive numbers regarding the accomplishments of the industry: how density has increased; how tolerences have shrunk; how cost per transistor or gate or bit has plummeted. And we hear how those meritorious figures will improve in the future. Rightly so, the industry should be proud. But those astounding improvements have not, and will not, come free. Let's look at design costs, marketing costs, and wafer fab and processing costs.

Chip density has increased 2000 fold in the last twenty years. Design cost, per bit, transistor, or gate is now about one fortieth the cost of the early 1970's. Truly immense progress. But that means that the design cost per device has gone up, way up. Obviously, there is a lot of variation depending on what figures are used, but that should not detract from the fact that this is a major trend. A good rule thumb is that design and/or development costs go up with the square root of density. While CAD is tremendously beneficial it only partially offsets the tremendous increase in complexity of today's devices, and that trend will continue.

According to Intel, development cost for the 486 microprocessor is

$250 million (a quarter of a billion dollars!) verses $100 million for the 386 microprocessor and $25 million for the 8086 microprocessor more than ten years ago. Big bucks! Of course, other designs (especially design only) are less, a lot less, but for apple to apple, orange to orange comparisons the range of change is similar: by my estimate an increase of 45 times over the last two decades. (As a personal note, I did nineteen designs. The first eighteen worked the first time through fab, and the last convinced me that market research was a better idea. Total development cost, including special processing for several designs, averaged about $25 thousand each.)

Marketing costs have similarly skyrocketed, but for different reasons. In the old days marketing barely existed. More recently, costs have increased because of the increase in market size and the movement to worldwide markets. The former accounts for about an eight times increase and the latter about a three times increase, or about 25 times altogether. Currently, attention and competition at the applications level is rapidly pushing these costs up.

But the sweepstakes winners in costs are wafer fabrication facilities. What price dimension reduction? In the past—my past—the cost of a wafer fabrication facility was in the six figures, i.e. hundreds of thousands of dollars, not hundreds of millions. If anything, the increasing costs of fabs has accelerated recently. What's going on?

Dimension reduction is getting tougher and the advantages of scaling less and less because the physical limits of devices are being approached; that is, the minimum possible size for transistors, resistors, and interconnects. This does not stop progress. But unfortunately, the "cleverness" to continue to increase density is exacting a toll on design, processing, and equipment. Over the next two generations of DRAMs the number of mask levels will reach (in some cases) 27, an increase on the average of about 70 percent. This is necessary in order to provide more interconnect levels, wells, Bi-CMOS, etc.. The number of process steps will double. Routinely, equipment costs for a single station are exceeding $1 million and increasing rapidly.

The demands for control and dimensional tolerance are intense. It is instructive to look at a microcosm of this world—an individual part—to see at that level the efforts being made to meet the demands of the industry,
the quality demands up and down the vertical infrastucture, and the cooperation required both horizontally and vertically in the infrastructure. Five years ago the part cost $50, today it costs $200, and five years from now its cost may exceed $1000. (In certain instances that is the case today in Japan.)

The bad news is clear. More steps; more costs per step; and the more steps the more need for tolerance control in the processing. All of this multiplies costs.

To a certain extent, this is a new phenomenon. While facility costs have been going up steadily for a long time the costs were offset in the seventies by increased throughput and holding the number of mask steps down. More recently, 24 hour operation and higher yields (a basic tripling) have kept cost per good die reasonable. No longer. In the past two decades fab cost have increased 100 fold. They will continue to increase more than 60 percent for each new product generation. Projections are that five years from now state-of-the-art wafer fabs will cost $500 million to $1 billion. This is not penny ante, the stakes required to compete are very high.

Wafer processing costs tend to track capital costs. Future wafers will be hit both with high capital cost and high processing cost, and in some cases major design and development cost.

Let me switch, for a moment, from manufacturing to Silicon Valley. Many of you represent non-manufacturing elements--companies or divisions where the output relies on the creativity or intellectual effort of people. Now, for the record, in the last twenty years the GNP deflator has risen 2.5 times and engineering salaries have risen five times. Engineers are paid significantly better now than in the past. But the price of housing in the Valley is up 15 times; highways are clogged; education is deteriorating; open space is disappearing; and the environment is not getting better. Quality of life is an issue. These problems and these imbalances must be redressed for Silicon Valley to remain a viable location that attracts talent. The piper must be paid; costs will skyrocket.

To summarize these costs, let me put them in the perspective of annual growth rates as best as I can calculate, and please take all the caveats of imprecision into account:

Marketing	14% per annum
Design and development	17%
Wafer fab facility	22%
Processing	20%
Professional salaries	9%

Not a pretty picture.

Given these facts I'd like to draw some conclusions:

1. For a large part of the mainstream of semiconductor products the minimum ante to compete is, or will be, very high, and it is growing faster than the semiconductor market itself. At the SIA Dinner Andy Grove said that scale is important. He is right. The entry fee (or continuation fee) is high enough to endanger a significant segment of the U.S. semiconductor industry and, for that matter, industry worldwide. A corollary: there will be significant attrition.

2. In some product areas success will have as much to do with finance as with technology (assuming technology crosses borders). There appears to be lots of folks willing to pay the bill.

3. The cost, and the complexity, of building a state-of-the-art fab is moving management of fab construction from the company to outside professionals. The fabs are contracted. To a certain extent, aided by suppliers, this has a levelling effect on technology and technological advantage. (The lead times that some companies enjoyed in the past no longer exist.) Both fab financing and fab productivity become critically important. A slow ramp in production will be disasterous both in terms of carrying cost and market prices. If this was true in the past, it will be truer in the future.

4. Because the number of chips per wafer is expected to decline, and wafer capital and processing costs increase, it is clear that chip costs will rise substancially. I believe that a consequence of these costs will be a marked slowdown in the the rate of price/performance improvement, i.e. prices will not fall as fast as in the past, technology change will be slower, the market (in bits or gates, not dollars) will grow slower, and products and fabs will have a longer lifetime. These are all interconnected. The analysis is complex, and murky, but I repeat: price/performance imrpovements will slow. Heresy? Yes! For twenty years I have been a proponent of the industry's experience curve. No longer. That slope is breaking; it will be plainly evident in two to three years.

5. There will be more pressure on mid-sized semiconductor companies, undersized in the big markets and oversized for a protected niche. This began in the 1985 downturn, but it will get much worse. In major product areas there will be fewer boutiques, if any. A corollary: there will exist a large quantum step for small players to become major players.

6. To some extent, companies will choose between competing with dollars or with creativity. Furthermore, but not the same thing, companies will chooze to forgo fabs (as some have done already), or marketing, or design. (Personally, I see a plethora a fabs under construction or in planning. Without a killer application to drive the

market supply is not likely to be endangered for the fabless. Economic generated growth can be supplied adequately.)

7. Lastly, companies must look to new alternatives for reducing costs. These lie outside their corporate walls, but encompass cooperation with suppliers, customers, and other industry participants: shared resources; joint alliance to provide scale; and division of capabilities among companies according to what they do best. The full service company will disappear.

So, what does this mean in terms of the individual manager? Two things.
Firstly, I believe that a large majority of semiconductor (and related) companies will either not survive or not prosper through the next five years. Those that do, either large or small, will have pursued a role that makes long term strategic sense. The time has come to think deeply about that role and act upon it.

Secondly, it is clear that no company is an island. The costs of our technologies and their complexity make that a reality. Survival and prosperity need the help of the government, state and local government, industry consortia or cooperation, alliance, joint efforts, et cetera. There is a long list of items that that can, should, and must be done to affect the level of the competitive playing field or to help reduce costs. I do not mean subsidies or monopolistic conspiracies, but the healthy ground in between. This includes industry concensus and government action on trade, finance, R&D, intellectual property, shared research in industry, and so forth... This is a fundamental, major long term change in industrial organization and operation. It will effect not only the semiconductor industry and other electronics, but eventually all industry.

The point is, there is a need for external action and cooperation that is multiplying tremendously, on the political front, with industry, with other groups with alligned interests, and with suppliers and vendors. The SIA and SEMI have accomplished tremendous things, but those accomplishments are a small drop in the bucket compared to what is needed. And, of course, a concensus on that is a place to start. U.S. industry and government need to get their act together. Corporations need to adapt to the future, changing how they operate. The stakes are huge.

The costs of fabs etc. can be enumerated. But what <u>must</u> be done to ensure healthy companies and industry requires a quantum increase in the efforts outside the walls of our repective corporations. You, me, all of us. That is the real price of the future.

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THE EVOLVING PERSONAL COMPUTER

Roger W. Johnson
Chairman of the Board
President and Chief
Executive Officer
Western Digital Corporation

Roger Johnson is President, Chief Executive Officer, and Chairman of the Board of Western Digital Corporation. He joined Western Digital in 1982 as its President and Chief Operating Officer. Prior to joining Western Digital, Mr. Johnson was President of the Office Systems Group of Burroughs Corporation and Executive Vice President and Chief Operating Officer of Measurex Corporation. He has also held executive positions with Memorex Corporation, the Business Machines Division of Singer Company, and General Electric Company. Mr. Johnson received a B.B.A. degree from Clarkson College of Technology in Potsdam, New York, and an M.B.A. degree in Industrial Management from the University of Massachusetts.

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THIS PRESENTATION WAS NOT AVAILABLE AT

TIME OF PUBLICATION

THE EVOLVING PERSONAL COMPUTER

ROGER JOHNSON
Chairman, President & Chief Executive Officer
Western Digital Corporation

I am always intrigued about how people introduce you? I guess Dr. Mizuno, Irv and I are senior people. At least for me, that must mean that I am old. I know I'm old because my wife, just yesterday, read me something in the paper, and she said "Look at this. It says that old people should not eat health foods anymore because we need all the perservatives we can get."

Someone was asking me how business was. I had just gotten off a plane and saw a mug that depicts how I feel sometimes these days. The mug said: "Since I've run out of sick days, I'm going to call in dead."

I don't know enough to talk 45 minutes. In fact, I'm not going to talk. You have had a long two days of conference. You have heard from wonderful people. You know more about what I am going to talk about than I do. So, I am just going to make observations. Then, if we have some time for discussion, maybe we can do that.

The personal computer, in its evolution, is something that I think we all feel as very real in our everyday lives. The practice of putting more and more into less and less long ago stopped being any type of revolution. It merely is how things are. It is the consistent migration that is driven by the semiconductor industry. The evolution is smaller - which means less weight, more function, less power, lower cost - is the driving force. But, also because of the pervasiveness of computing, which also has, at its core, smaller, more function,less weight, lower cost.

Without acting as an historian or someone who has a crystal glass, I'd like to talk a couple of minutes about some of the technologies behind that, or at least our view of that. I will then talk a couple of minutes on market opportunities. I will conclude with some comments, perhaps controversial, about the atmosphere in which we have to live and grow our business. This is an atmosphere which I think may be more threatening to us than any of the things we normally talk about.

It is hard to believe that the personal computer is less than ten years old. It is hard for me to believe that because I came into this industry in the early 1960s with a company called Friedan that built rotating calculators with a specialized sales force that sold on applications.

So, I can see, just in my short lifetime, quite a parallelism. I think we are seeing a very parallel story between the evolution of the calculator from the 1960s and the 1970s and what we now call the personal computer.

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As products change over time, so must the approach to product development. Desktop computers principally have a predetermined set of parameters for size and functionality. They have become quite standard over time. I think the evolution of the personal computer (which is really a synonym for small things that compute) is and will be, to a greater degree, driven much more by people's needs. This means you need to have a much more flexible view when you are doing the product planning for it.

People's needs change. We don't like to be standard. The only people who like standards are manufacturers. People don't like standards, or else we would all be driving black, square cars.

I think those of us involved in helping to define what the products are and how we contribute to them really have to understand that people want things that do different things that they need, not things that we particularly want to produce in some standard way.

More importantly, the computer that is evolving will be a companion to the way people think. It is going to go with its user everywhere, everyday.

It will be carryable, as opposed to portable. I think that is an important distinction. For the most part, today's laptops, even notebooks are portable: they are not really carryable. They are comparable to a bowling ball. You can get it around, but you don't want to take it to lunch.

I think, by following this path that we are on, this industry - which we, the people who make things smaller tend to drive - will offer personal computers in the next three to five years that provides today's desktop performance and functionality that can be held in your hand. They are commonly called palmtop. I think the palmtop of the next two to three years will have that level of power to it, full function, less that four pounds, all internal circuitry, maybe ten chips or less, fitting in about 3x4 motherboard.

This type of very small computer will replace pad and paper in some instances. It will, for the first time, bring it into the hands of those who are truly noncomputer users. In the 1960s and 1970, we took the calculator out of the specialists hands in accounting and moved it out to people who didn't really understand anything about its insides.

The technologies that enabled that degree of evolution are many. Some basic technologies that enabled the migration from desktops to laptops are the same. Others are new. Among the more driving technical forces are mass storage, computer display, input, connectivity, communications, digital signal processing and power management. All of these rely very heavily on what we do in the semiconductor business.
As designers and manufacturers, we need to find ways of driving higher and higher levels of integration. That, of course, is what drives the size situation.

Battery technologies, some of the technologies that are akin to what we do, will be necessary for us to understand more about. Mass storage is an area that is crucial to the future development of the small computers, because storage requirements for the small computer will vary a great deal more than thy ever have in the past. The days of standard capacities, standard interfaces and form factors are pretty much gone.

In fact, many portable applications cannot take anything mechanical because their size, power and performance will be destroyed as they go into environments that are not very friendly. Therefore, an alternative to rotating storage is absolutely necessary.

I have worked in the rotating storage business and semiconductor business long enough to see every chart predict that every technology will be wiped out by every other technology. It never happens. And I am not predicting that here. However, there is a need for solid-state storage, which will probably come in the form of an EPROM flash. We are working on that, as are several other people.

We have designed a proprietary flash device that can be managed like magnetic media. This is a little different approach. It can interface to a system, just like a disk drive. The catch here is that nothing rotates. This is achieved by marrying existing storage technologies, such as data compression, defect management buffering and error correction, with nonvolatile high density memory. The result is a solution that meets stringent requirements for small computers. It is light, fast, rugged, consumes very little power when compared even to a 2 1/2" Winchester drive. Solid-state storage can be up to 100 times faster and deliver performance using up to 300 times less energy. It is currently too costly. However, those problems, as we all know, are something our industry addresses quite nicely.

Perhaps the most unique feature of this technology is that it is not limited to a specific form factor. It can be configured to look like a very small drive or a memory card. It can be embedded on a motherboard or it can be designed into almost any form factor needed. So, it inherently posses the versatility and the flexibility that are required by emerging small computers.

Flash goes where Winchester technology can't go, and therefore, we feel it will be a major enabling technology for small computers.

In parallel, the natural evolution of the computer will also lead to functional systems that could be operated without a keyboard. We have seen a lot of those things coming along, limited function, stylist-based machines. They are now a reality.

As we move toward the in-your-hand computer, another once-distant technology may come to fruition. Advanced features, such as touch screens, write-on screens, the application of more sophisticated pointing devices, will become commonplace. All of these can benefit from the advance of data signal processing that, basically, is embedding the code information within the sound, pictures or written material the user has at his control.

Digital signal processing in small systems was not feasible a couple of years ago. Today, there are strides being made and we are working in some of these areas. With regard to handwriting, voice recognition, the ability to store condensed written and spoken information efficiently, it is really not that far away. A system could be developed that can recognize and translate information using advanced forms of digital signal processing.

The evolution toward smaller machines will also dictate that we find new ways to communicate and use the information. It does little good to have this hand-held computer if, to access and get at your work, you have to rent a pack horse to bring along your personal printer and fax. Dedicated fax and modem capabilities, realized through a single chip or a mini insertable card, will be one of the ways that tomorrow's small computers can attain true usability. Some of this functionality is already available or in development.

Along with the ability to quickly communicate, connectivity is going to be central to the usefulness of this little computer. The next generation of small computers will need to be dockable. That means that the same physical computer will be used at home, on the road or at the office. Through advanced functionality integrated into the silicon, a hand-held computer could be utilized in this environment and still function quite effectively.

The hardware in these very small computers will need to be totally configurable. For example, when using the computer on the road, the system interfaces with specific video and storage functions and a limited set of peripherals. However, when that same computer is brought and applied to the office environment, those interfaces will change. There will be different keyboards, a larger monitor, higher resolution video. The system may be retrieving data from at tape and interfacing with a laser printer or the fax machine over LAN.

Again, many of the technologies and innovation that make this continued evolution toward small computers possible depend on the engineering ingenuity that we all are familiar with, and our ability to translate that into silicon. The geometries, which we have heard a lot about, are, of course, one of the barriers. To get the levels of integration that we need to drive this functionality, we have to keep making things very much smaller.

Today, many of these disparate functions are working well and are being successfully integrated in themselves. Several of us are, today beginning to merge those functions and physically integrating across functions. More and more of that will be necessary, of course, in the future.

I think one of the successful techniques that must be employed by our industry is that those of us who grew up on the semiconductor side of things and those who grew up on the systems side will have to put those together. It is going to be very difficult for us to succeed unless we have in our originations people who are systems knowledgeable people. We must have people who understand how these generic functions really work in computing.

We need people who can talk with their caps customers at a system design level and understand what the customer is telling us he needs, and then be able to interpret that to our logic designers. I think the day of the technical process driving the product needs in the semiconductor business is pretty well finished, unless you are really moving in the commodity high-volume RAM business.

A lot of these approaches are with us today. There will be a whole variety of new systems introduced at COMDEX. I think, if you look inside some of those, you will find some hints of what may come in the future.

I would like to switch for a second to a discussion of markets, and to a little bit of what might be considered to be impediments to this.

One of the things that can limit us is the lack of market. Right now, we are all going through some difficult times. Yet, if we step back from that and look at market opportunities, we see a variety of things happening.

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The small computer will drive extraordinary market expansion - maybe not this quarter or next quarter, but it certainly will. As we bring this power to people not technically inclined, as with the calculator, the automobile and a variety of other examples, we will observe that people find miraculous additional things to do with it. So, within our existing free world markets, we have a huge growth opportunity ahead of us.

There is a lot of talk about Soviet Russia, East Germany, Eastern Europe. Those are great emerging markets also. There is a lot of debate on how long it will take. But the small computer, for those of you who deal there, is something that is a national objective. They need to manufacture their own computing. They are going to do that, one way or the other. There is a huge market there. I have had some studies done for our company that say that the Eastern market, alone, over the next ten years, represent a doubling of today's free world markets for the things we do. You can argue about when it will evolve.

If you look at the People's Republic of China, and believe that someday they will go, and if the surrounding infrastructure which speaks the language and knows the culture moves in rapidly, that will be third growth market.

So you could take a look and say that in ten years the opportunity exists to grow two times what we know today. To do that will take lots of things. Mostly, it will take a long term view. It will take patience. It will take money. It will take a lot of perseverance. We are, of course, not alone in looking at those markets, speaking now as an American executive looking to the future of our industry. Everyone is there looking at that.

Set that aside for a second. We have heard a lot of discussion on the cost of what we do. Huge numbers, half a billion dollars, a billion dollars, some prediction that there will be a lot of dropout. I agree with that. But I don't think that it has to be necessarily so.

The capital structures of our country have real fundamental flaws in them. I asked about the Tokyo Stock Exchange before I left this morning. After yesterday's close, it had a price/earning ratio of about 40:1 after collapsing. My competitors and myself, whom I watch very carefully, are somewhere around 6:1 to 8:1. That means that we have to earn, depending on the multiple you want to use, five to seven times the earning to raise one dollar of equity.

Why is that? Is that because we are inherently shortsighted? With all due respect to my Japanese friends and associates, is that because of the wine they drink or cultural heritage? No, it's arithmetic.

Let's look at one simple thing. The long-term capital gains tax and the incentive to save, not only in Japan, but in Taiwan and some other countries, is very large. Essentially, there are no long-term capital gains. And there is very high tax on current earnings.

Our country, however, from a capital structure at this point, encourages consuming. From our viewpoint, it not only encourages consuming, but it encourages eating past investments. That is what LBOs are all about. You make more money eating the seed corn than waiting for it to grow something - so, let alone we don not invest in the future, but we eat what somebody did yesterday.

That's why we are sitting and being driven, you and I, by equity markets, for short-term results.

I was in Washington last week, which is one of the more depressing trips you can make. I talked with some people there, and suggested that they raise the capital gains tax. I am a Republican, from Orange County. They almost didn't let me back in. While in Washington, I did get Bob Dole's attention, along with the attention of a couple of other people. They asked me how I could suggest that.

I said, "What is a capital gain? How long do you hold it? What is it, nine months?" There's an interesting definition of investments. So, I said, "What I think we want to do is to raise any taxes on capital gains within one year to 50%, take two years to 35%, leave three years where it is, make three years 15% and five years ago."

All the big hubbub is because we are trying to protect the gains of the traders, people who are churning paper. Those guys don't build anything.

What we need is a structure that allows people to come back and invest in us, the people who when we do earn a dollar will say, "Fine, I'll give you 30," not "what are you going to do next week?"

We talked a little bit earlier about what to do about that. I really think that there are a couple of things we can do.

First of all, in a very practical sense, the notion of working together is something that needs to be taken out of theoretical discussion and brought into practicalities.

Our company has a very good relationship with AT&T. We worked out an arrangement three years ago that was quite unique. We had to build a wafer fab, we had no choice; we were looking at a huge bill. We were ready to do that. At that point the AT&T people came to us. They had a lot of capacity. We didn't work out a foundry relationship,however. We didn't really want a foundry because we can get foundry all over the place. We said, "Let's try to work out an arrangement where your fab looks like ours and we both make out."

Without getting into details, we came within a few dollars of what we thought the cost was. Then we said, "Fine. If I'm going to build a fab, I'm going to incur certain costs. I'm willing to pay you the costs I avoid. If that's enough cost for you to load your fab, we're both okay."

And we did, and we were, and we've lasted for three years doing that.

In addition, the yield data coming off the Orlando fab and the yield data coming out of Madrid now comes in real-time to my engineer. We get the probe data right there now. It looks like our factory. We don't give them purchase orders, we give them forecasts, and we mess them up just like we do our own people.

The point here, I think, is not to go through something we've done, but that we do need to look across our industry and deal at much more strategic levels. I grew up in general Electric Company, and learned there that if I didn't sell or buy from my competitors, I wouldn't sell or buy from anybody, because we built everything but automobiles.

This industry is mature enough now to start looking at some of those things amongst ourselves. It is not unmacho to share some things and figure out joint developments of products, cost of effectiveness of very expensive resources.

Although our current situation is a little like the coffee cup, I think our long-term situation looks pretty good. We have some very creative people in this industry. I look forward to being with you and being in this business for a long time.

I thank you.

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THE NEW FACE OF PERSONAL ELECTRONICS

Hiroyuki Mizuno, Ph.D.
Executive Vice President
Matsushita Electric
Industrial Co., Ltd.

Dr. Mizuno is Executive Vice President and a member of the Board of Directors of the Matsushita Electric Industrial Co., Ltd. (Panasonic/National/Technics/Quasar). Among other responsibilities he is in charge of all engineering and R&D issues for the company. Dr. Mizuno has worked for Matsushita since 1952, specializing in the research and development of silicon and GaAs devices. During his career at Matsushita, he has held a variety of high-level management positions in both Matsushita Electronics Corporation (MEC), a subsidiary company which specializes in producing active electronic components, and Matsushita Electric Industrial Co., Ltd. (MEI). From June 1989 to June 1990, Dr. Mizuno served as Chairman of the Foreign Semiconductor Users' Committee of the Electronics Industry Association of Japan. In this position, he was responsible for finding ways to increase U.S. market share in the Japanese semiconductor market. Dr. Mizuno holds both B.S. and Ph.D. degrees in Physics from the Kyoto University. He also attended the University of Illinois for two years.

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October 8-9, 1990
Monterey, California

Semiconductor Industry Conference

The New Face of Personal Electronics

Hiroyuki Mizuno
Executive Vice President and Member of the Board
Matsushita Electric Industrial Co., Ltd.

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THE NEW FACE OF PERSONAL ELECTRONICS

HIROYUKI MIZUNO

EXECUTIVE VICE PRESIDENT

MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.

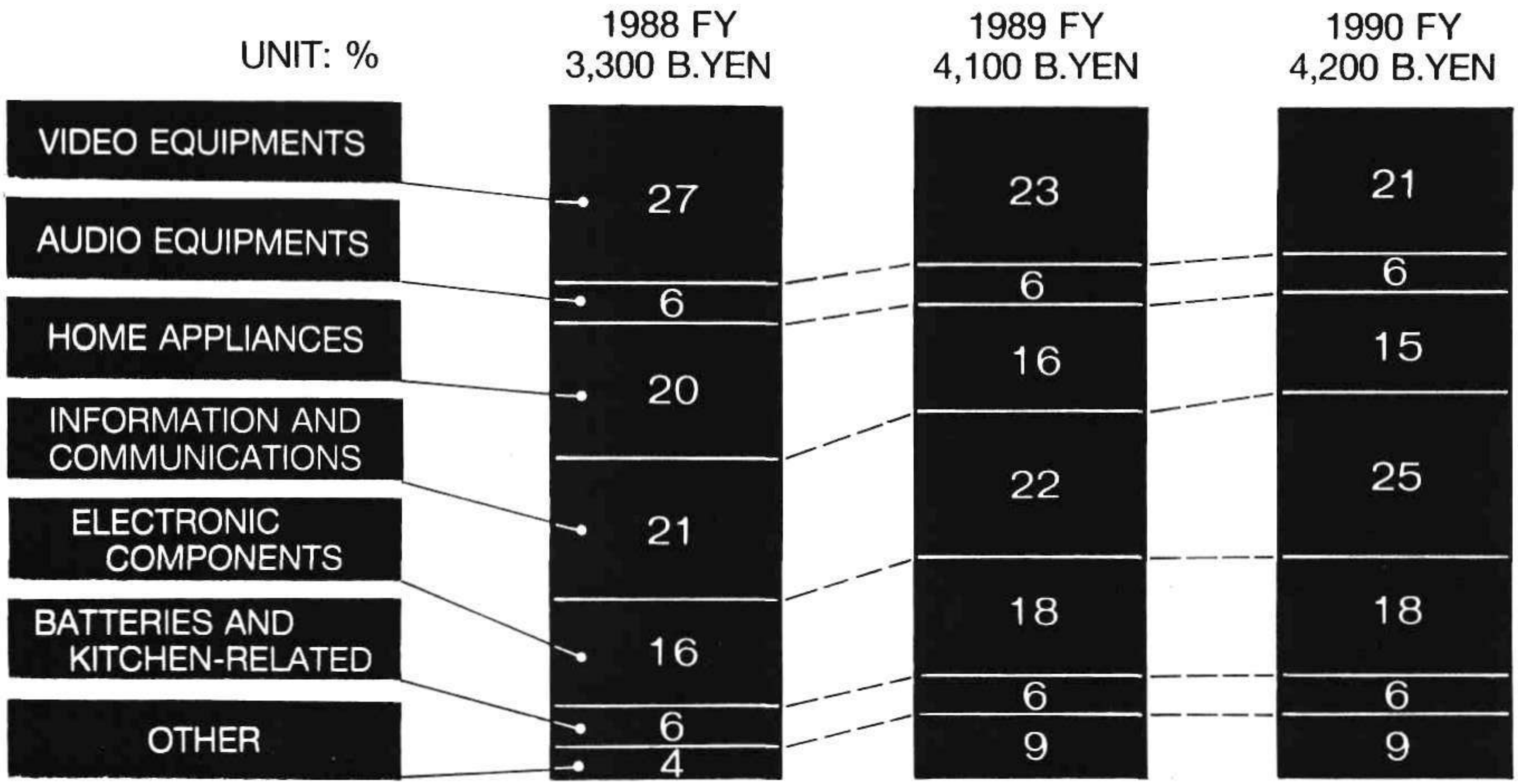
Panasonic

OUTLINE

1. CURRENT STATE OF HOME ELECTRONICS
2. SUPPORTING TECHNOLOGIES
3. FROM HOME TO PERSONAL ELECTRONICS
4. CHANGES IN LIFE STYLE
5. JAPAN AND THE U.S.

Panasonic

MATSUSHITA'S PRODUCT BREAKDOWNS



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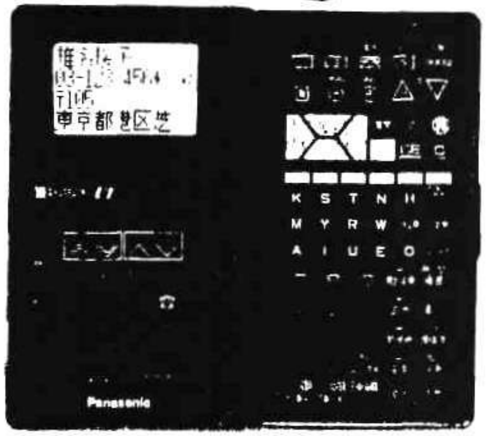
INFORMATION/COMMUNICATION EQUIPMENTS

WORD
PROCESSOR

CORDLESS
TELEPHONE

ELECTRONIC
POCKET-
BOOK



FACSIMILE
MACHINE

Panasonic

INFORMATION PROCESSING TECHNOLOGIES

TV

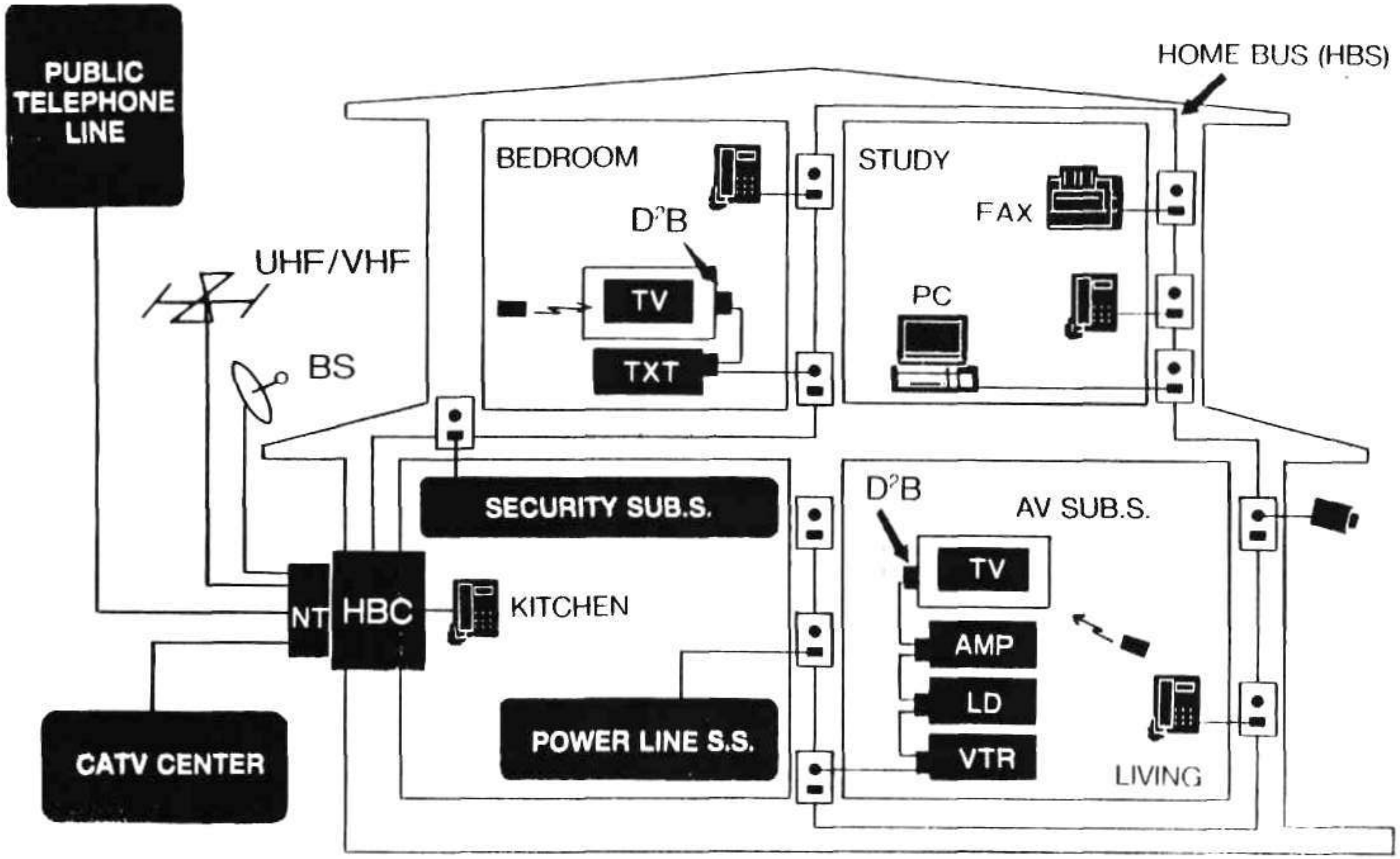
WASHING
MACHINE

VIDEO CAMCORDER

COMPACT DISC PLAYER

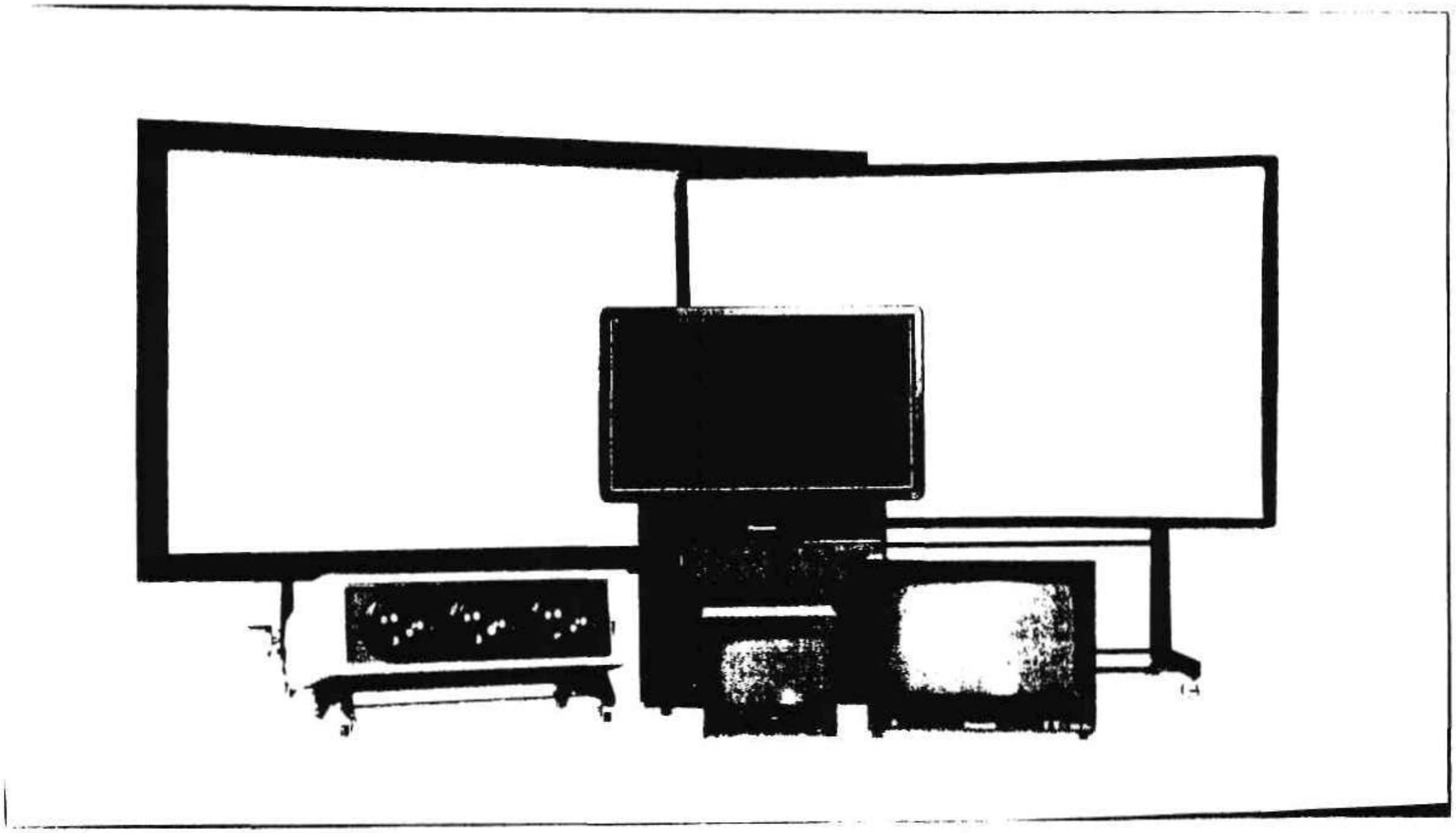
Panasonic

HOME BUS



Panasonic

HDTV



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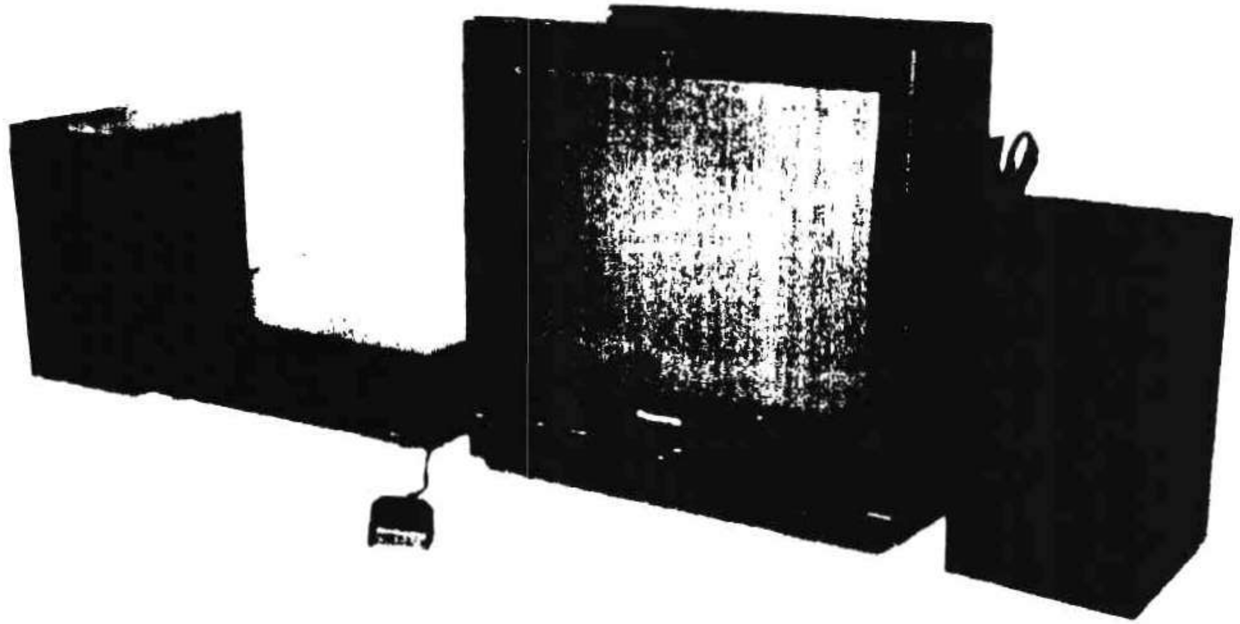
CD-I SYSTEM



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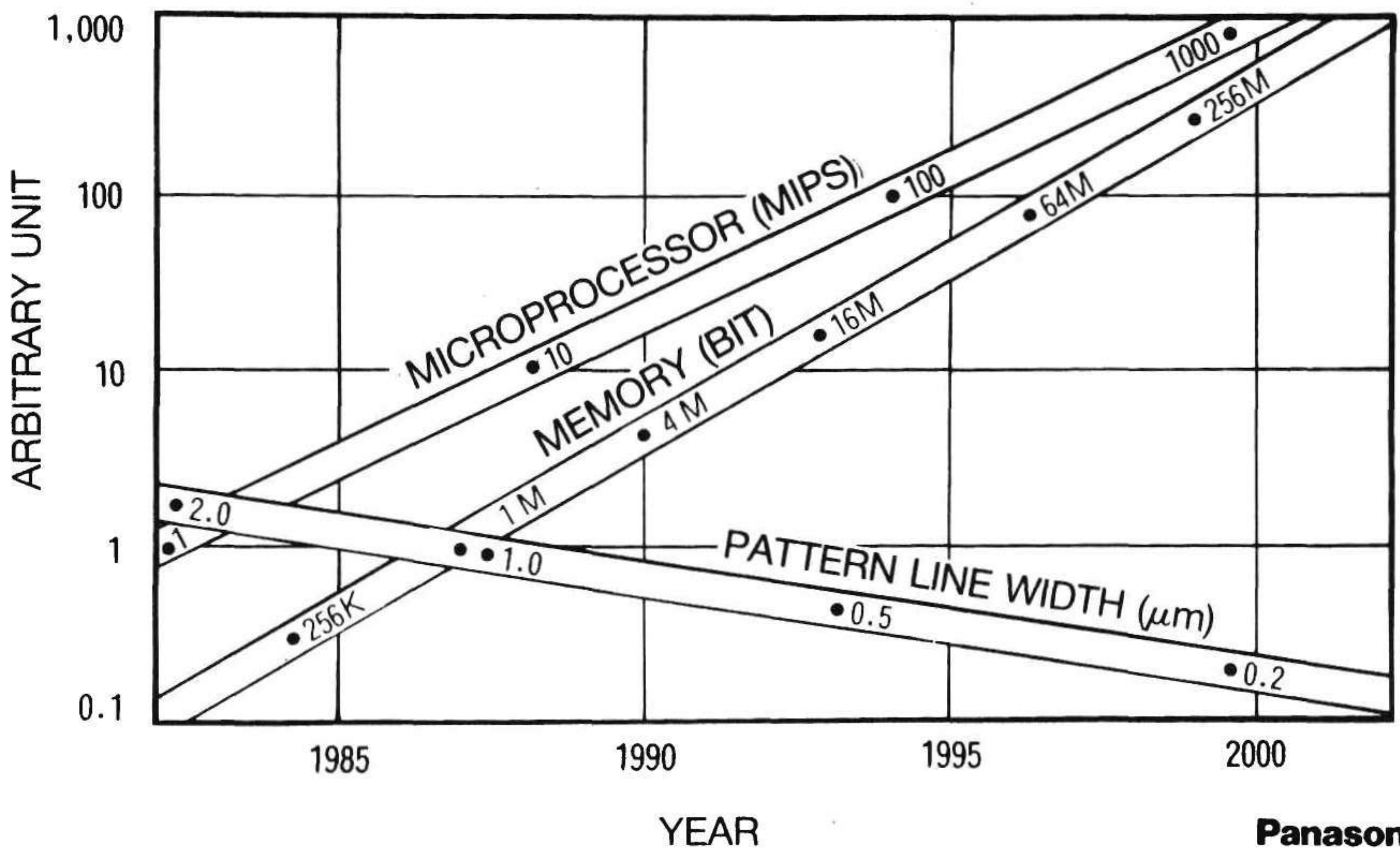
PROGRESS OF SEMICONDUCTOR DEVICES



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ADVANCE IN DIGITAL TECHNOLOGIES

- EVERYTHING (DATA, TEXT, OPERATION) IS REDUCED TO ARRAYS OF BITS (0, 1), AND ARITHMETICALLY MANIPULATED
- TIME IS ALSO DISCRETE. REGARDLESS OF TIME SEQUENCE, ARRAYS OF BITS ARE REARRANGED, PROCESSED, AND RESTORED
- AUDIO AND VIDEO SIGNALS ARE ALSO ABLE TO BE REDUCED TO ARRAYS OF BITS, AND PROCESSED AS WELL

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DRIVING FORCES

- **PEOPLE**

  Basic Needs ➧ Comfort & Convenience ➧ Creativity Differentiation

- **SOCIETY**

  Standard ➧ Diversity

- **TECHNOLOGICAL ADVANCES**

Panasonic

PERSONAL ELECTRONICS-1

Class-1 Low cost, small size

- Audio and Video Equipment:

  POCKET RADIO, HEADPHONE STEREO

  LCD TV, VIDEO CAMCORDER

- Information Processing Equipment:

  CALCULATOR, WP, PC, WS

  desktop → laptop → notebook → card

- Communications Equipment:

  FACSIMILE MACHINES, CELLULAR PHONE

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PERSONAL ELECTRONICS-2

Class-2 Interactive, or person-to-person

- Entertainment & Education:

  VIDEO GAME, CD-ROM, CD-I, DVI

Class-3 For the elderly, children or the handicapped

SPEECH TRAINING SYSTEM

NURSING ROBOT

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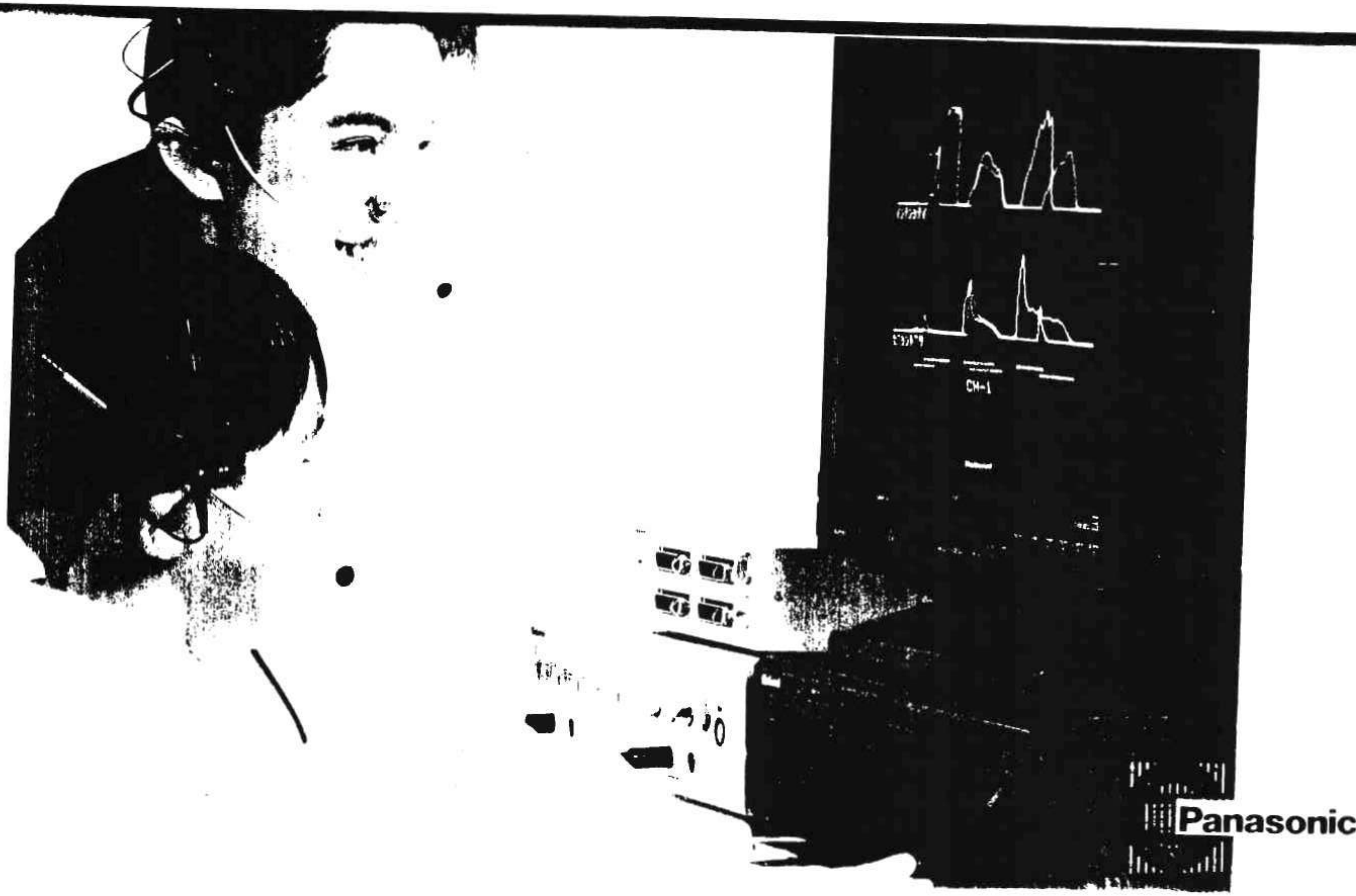
SPEECH TRAINING SYSTEMS



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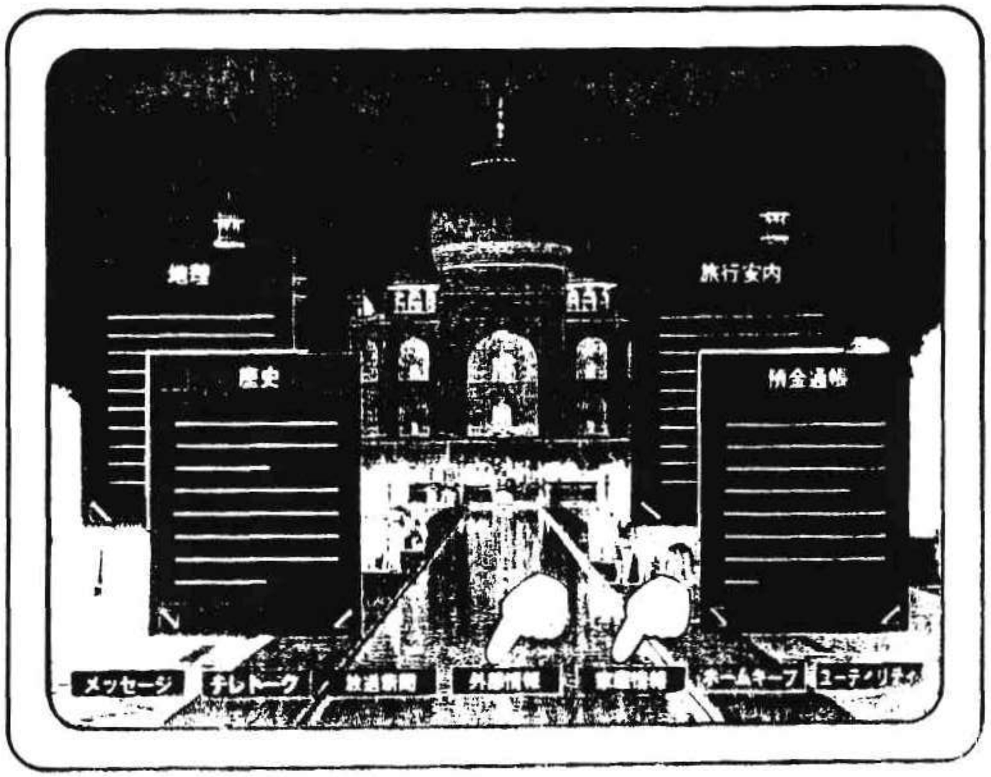
MULTIMEDIA — INFORMATION



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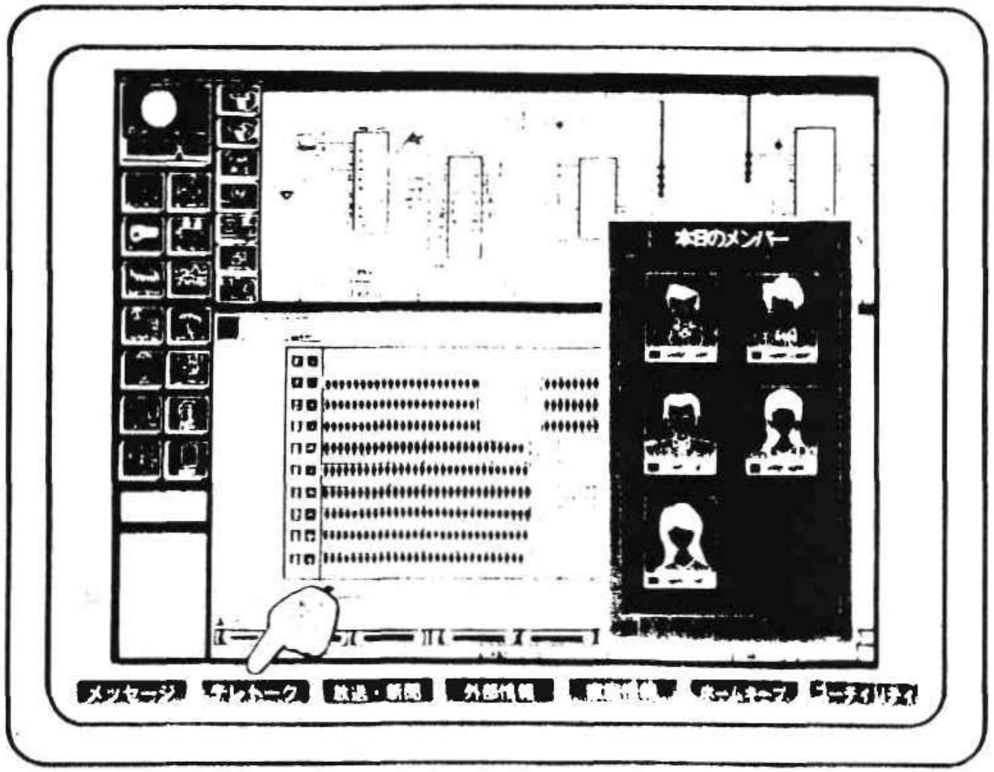
MULTIMEDIA — BUSINESS



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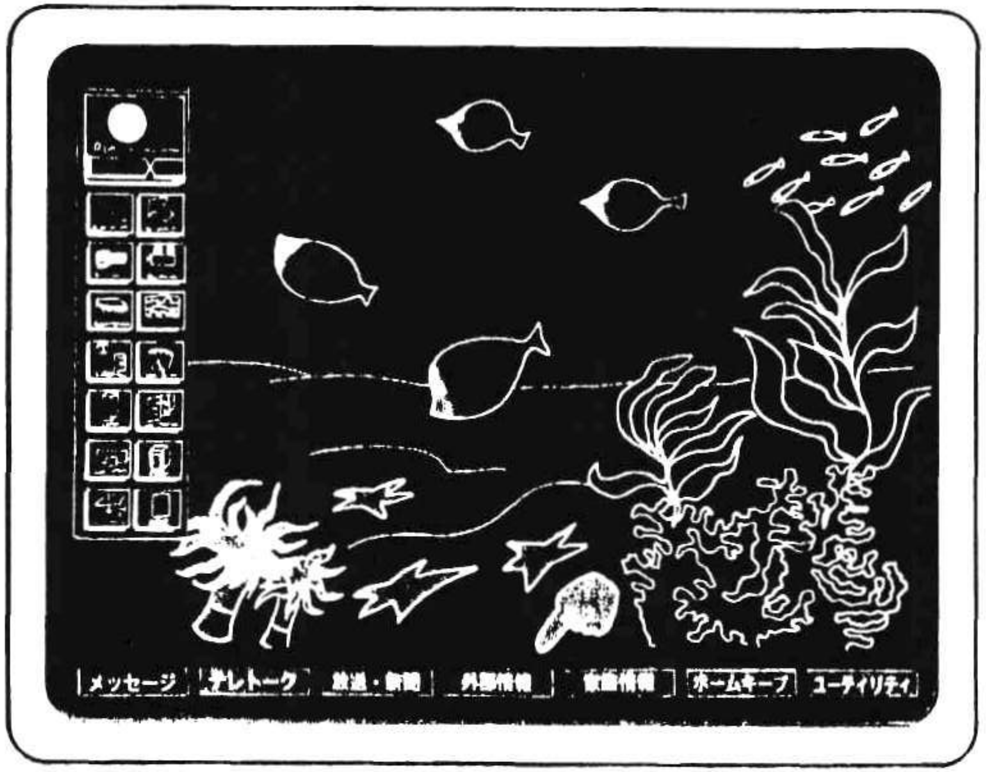
COMPUTER ANIMATION



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CONCLUSION

LESSONS LEARNED FROM MY TENURE AS CHAIRMAN OF THE EIAJ'S FOREIGN SEMICONDUCTOR USER'S COMMITTEE:

- WE'VE MORE IN COMMON
  THAN WE HAVE DIFFERENCES.
- STICKS AND STONES
  ... WORDS CAN INDEED HURT US.
- DON'T UNDERESTIMATE THE POWER OF
  AMERICAN INNOVATION.

Panasonic

HOW USER/SUPPLIER RELATIONS WILL CHANGE

Irv Abzug
Vice President
General Technology Division, and
Director of Corporate Procurement
IBM Corporation

Irv Abzug is Vice President of the General Technology Division and Director of Corporate Procurement for IBM Corporation. He has responsibility for worldwide procurement of electronic components for IBM. Mr. Abzug joined IBM's Components Division in 1967, where he played a major role in the initial development of monolithic memories for IBM's System/370. He joined IBM upon graduation from college in 1947 and was involved in the early development of the 7000 series of computers and System/360 display and graphic products. Mr. Abzug received a B.S. in Electrical Engineering from City College of New York.

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October 8-9, 1990
Monterey, California

Semiconductor
Industry
Conference

How User/Supplier Relations Will Change

Irv Abzug

GTD Vice President and Director of Corporate Procurement
IBM Corporation

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THIS PRESENTATION WAS NOT AVAILABLE AT

TIME OF PUBLICATION

DATAQUEST

1990 Semiconductor Industry Conference

Monterey, California

IRV ABZUG

GTD VICE-PRESIDENT & DIRECTOR of
CORPORATE COMPONENT PROCUREMENT

IBM CORPORATION

IBM

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HISTORY
CHANGE
CHALLENGE

THE EVOLUTION OF CUSTOMER/SUPPLIER RELATIONSHIPS

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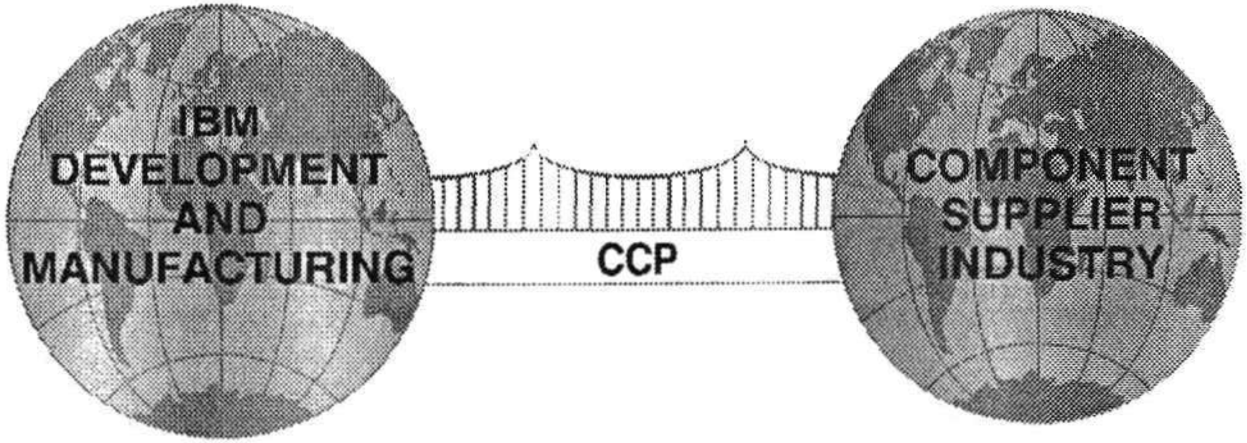
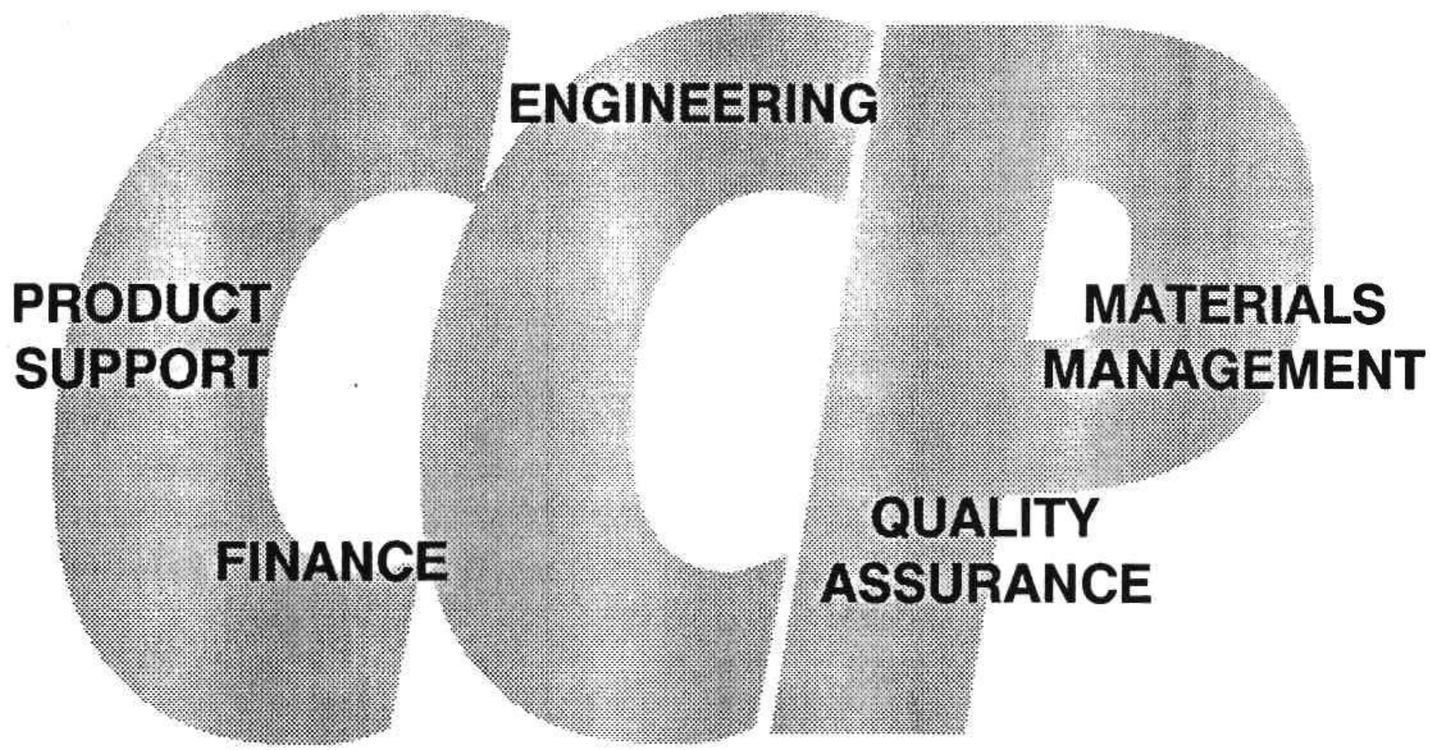
CORPORATE COMPONENT PROCUREMENT



MISSION

Support IBM Product Development and Manufacturing Requirements with Competitively Procured and Technically Qualified Supplier Component Technologies.

CORPORATE COMPONENT PROCUREMENT



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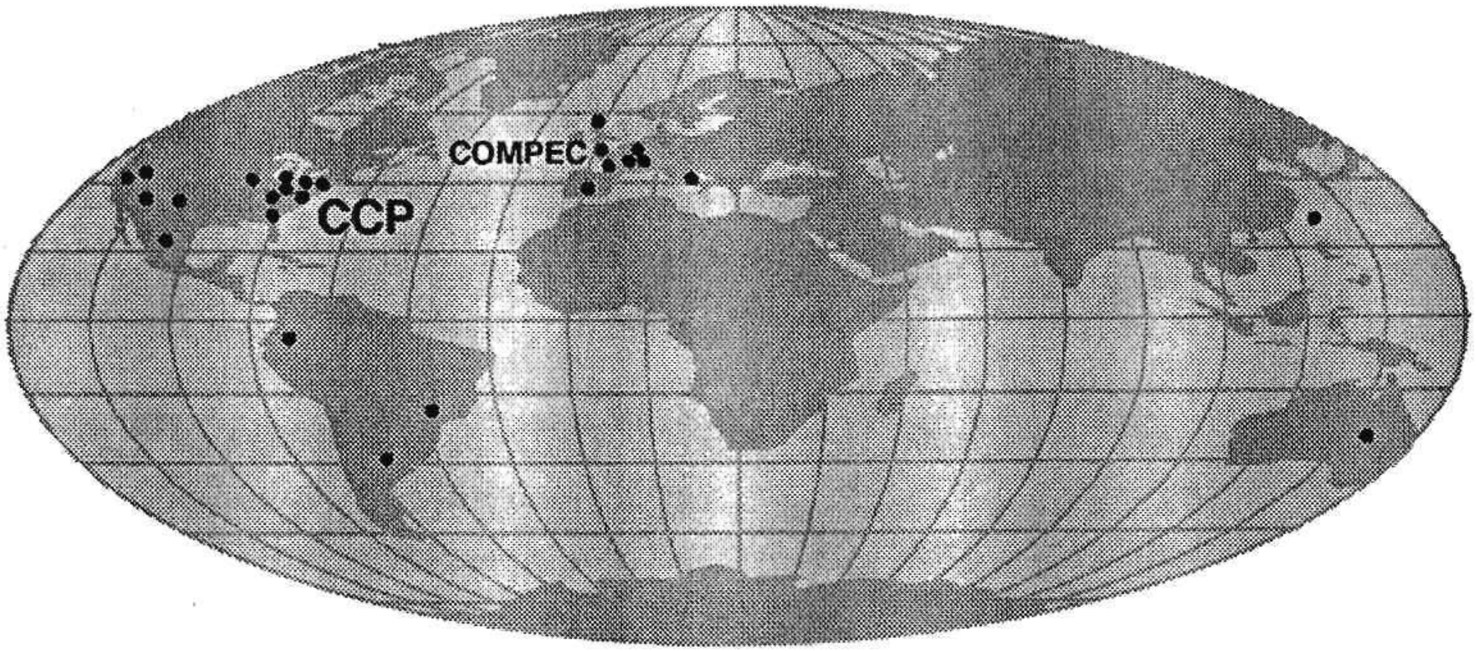
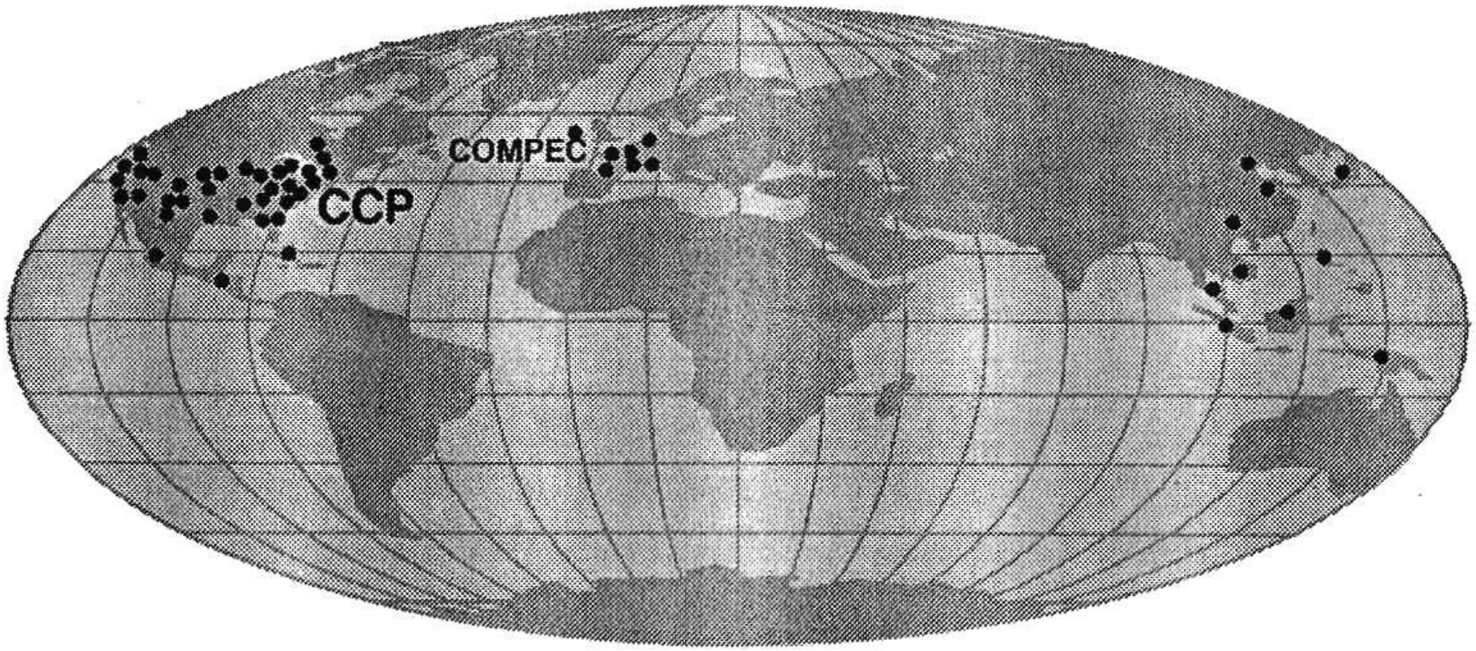
CORPORATE COMPONENT PROCUREMENT



- Supports 38 IBM Sites
- Worldwide Supplier Base
- 20,000 Qualified Part Numbers
- Procures 1.5+ Billion Devices Annually

CORPORATE COMPONENT PROCUREMENT



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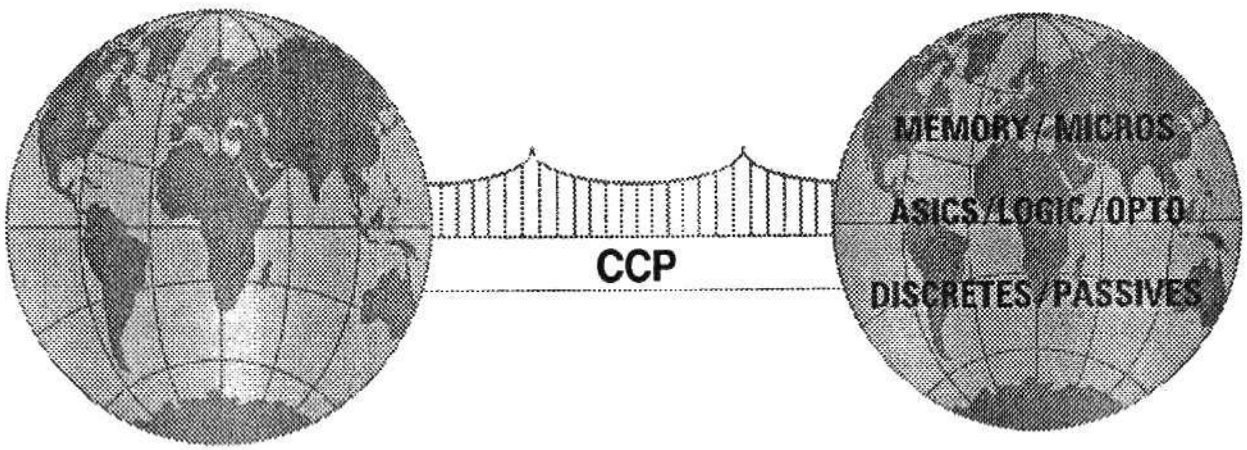
CORPORATE COMPONENT PROCUREMENT



PURCHASE STRATEGY

- Utilize the Unique Capabilities of the Electronic Component Industry
- Worldwide Product Excellence

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1970s

HISTORY
CHANGE
CHALLENGE

THE EVOLUTION OF
CUSTOMER / SUPPLIER
RELATIONSHIPS

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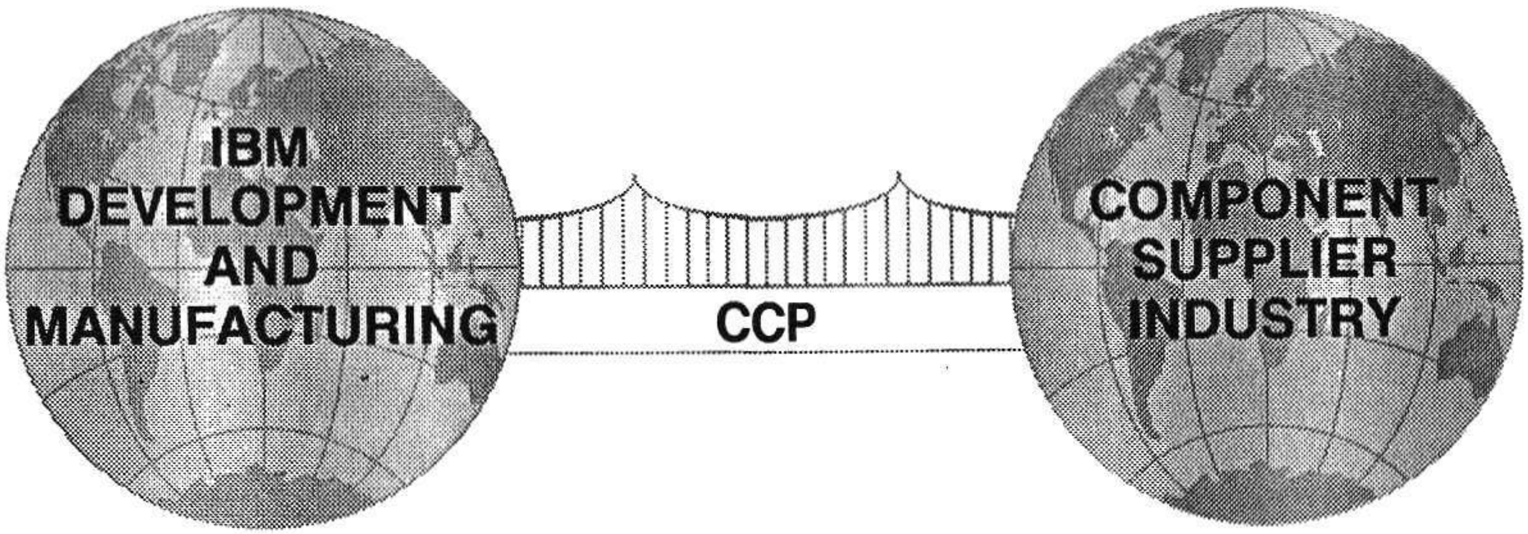
CUSTOMER / SUPPLIER ENVIRONMENT

1970s



"Arms Length" Relationships

CUSTOMER/SUPPLIER ENVIRONMENT

1970s

IBM	SUPPLIER
• REQUIREMENTS MAINFRAME DRIVEN	
• LONG DESIGN CYCLES	
• UNIQUE IBM SPECS	
• HIGH RELIABILITY	

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CUSTOMER/SUPPLIER ENVIRONMENT

1970s

IBM

- REQUIREMENTS MAINFRAME DRIVEN
- LONG DESIGN CYCLES
- UNIQUE IBM SPECS
- HIGH RELIABILITY

SUPPLIER

- SUPPLIER BASE U.S. DOMINATED
- INCONSISTENT DELIVERY AND QUALITY PERFORMANCE
- PREMIUM PRICING FOR COMPUTER GRADE TECHNOLOGY

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1980s

HISTORY CHANGE CHALLENGE

THE EVOLUTION OF CUSTOMER / SUPPLIER RELATIONSHIPS

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AUGUST 12, 1981

FINANCIAL TIMES
LONDON • PARIS • FRANKFURT • NEW YORK • TOKYO

IBM unveils personal computer

THE WALL STREET JOURNAL.

IBM's New Line Likely to Shake Up The Market for Personal Computers

The New York Times

Big I.B.M.'s Little Computer

INTERNATIONAL Herald Tribune

IBM Introduces Home Computer

The Associated Press

NEW YORK – International Business Machines entered the personal computer market.

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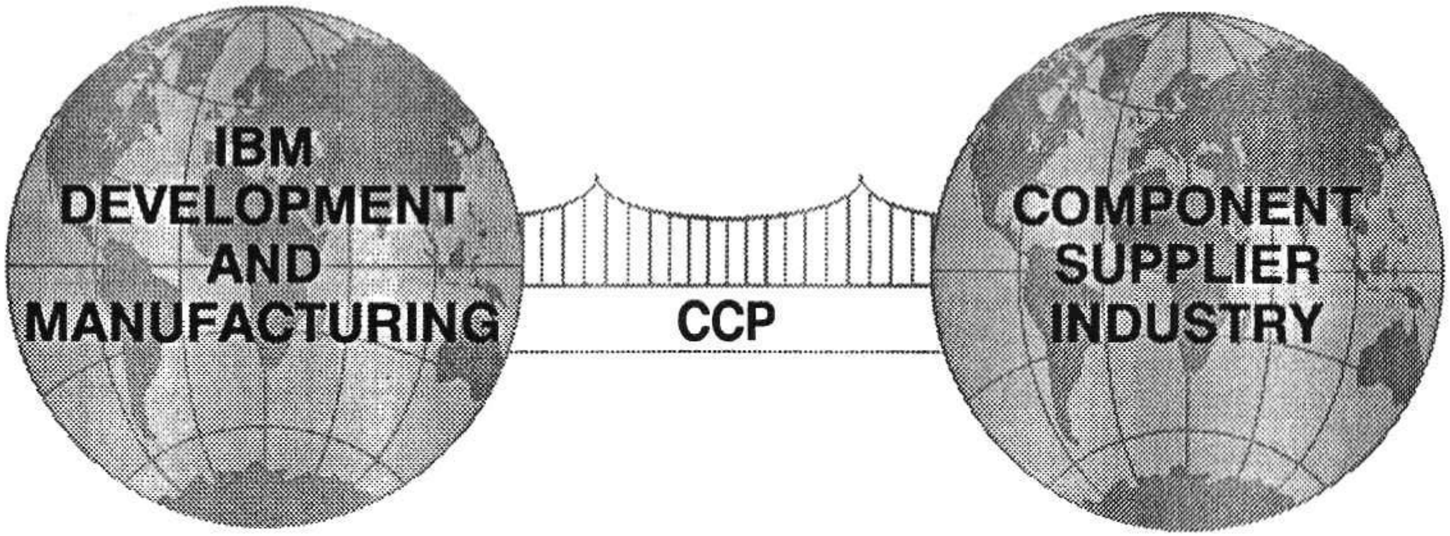
CUSTOMER / SUPPLIER ENVIRONMENT

1980 - 1984



"Transitional" Relationships

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CUSTOMER / SUPPLIER ENVIRONMENT

1980 - 1984

IBM	SUPPLIER
• **PC MAJOR NEW DRIVER** - Short Development Cycles - Reduced Qualification Time - High-Volume Demand • **INDUSTRY STANDARD PARTS**	

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CUSTOMER/SUPPLIER ENVIRONMENT

1980 - 1984

IBM

- PC MAJOR NEW DRIVER
  - Short Development Cycles
  - Reduced Qualification Time
  - High-Volume Demand
- INDUSTRY STANDARD PARTS

SUPPLIER

- UNPRECEDENTED DEMAND
- CAPACITY CONSTRAINTS
- DELIVERY AND QUALITY PERFORMANCE INCONSISTENT
- GLOBAL SUPPLIER BASE

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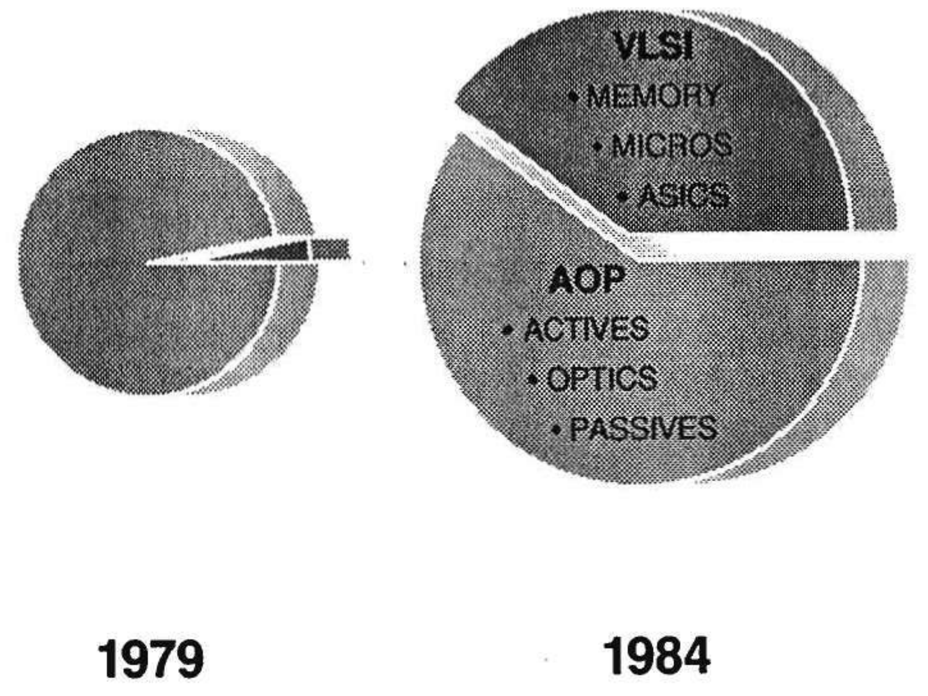
CORPORATE COMPONENT PROCUREMENT

AOP/VLSI TECHNOLOGY DOLLAR DISTRIBUTION



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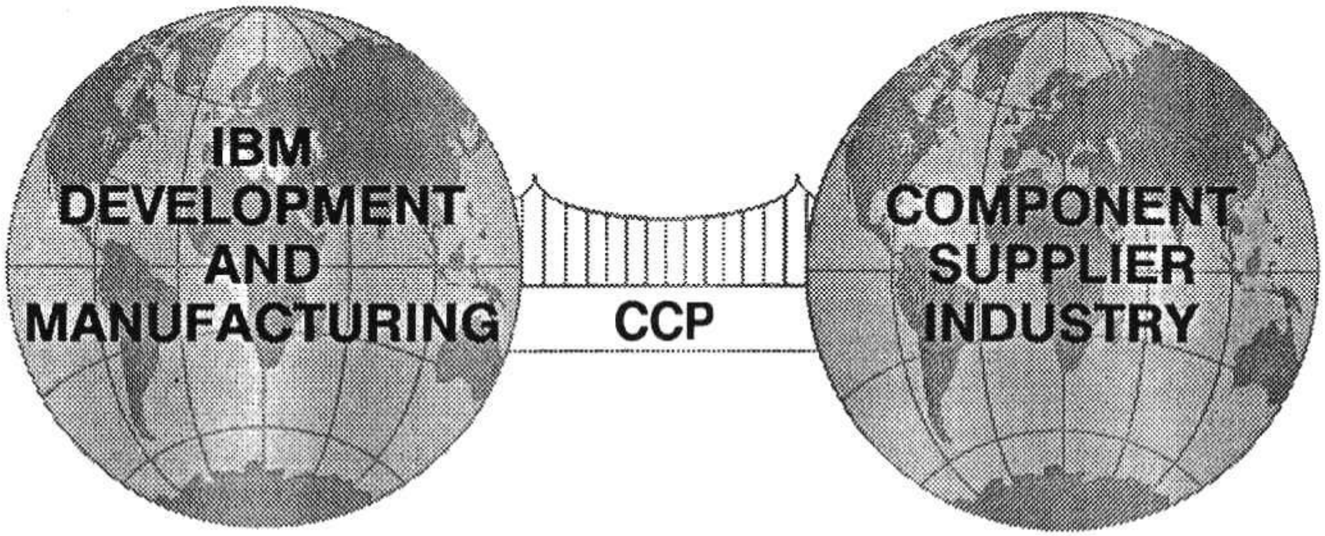
CUSTOMER / SUPPLIER ENVIRONMENT

1985 - 1989



"Closer Working" Relationships

CUSTOMER / SUPPLIER ENVIRONMENT

1985 - 1989

IBM	SUPPLIER

- **INCREASING CUSTOMER DEMANDS**
  - Responsiveness
  - Quality / Reliability
- **CHANGING CCP PROCESSES**
  - Automated Business Placement
  - Electronic Data Interchange
  - Source Acceptance
  - Joint Qualifications

PERSPECTIVE ON DEFECTS

If industry delivers

1.5 Billion Devices per year

at 99.9% DEFECT FREE levels

They will ship to IBM manufacturing

1.5 MILLION DEFECTIVE COMPONENTS

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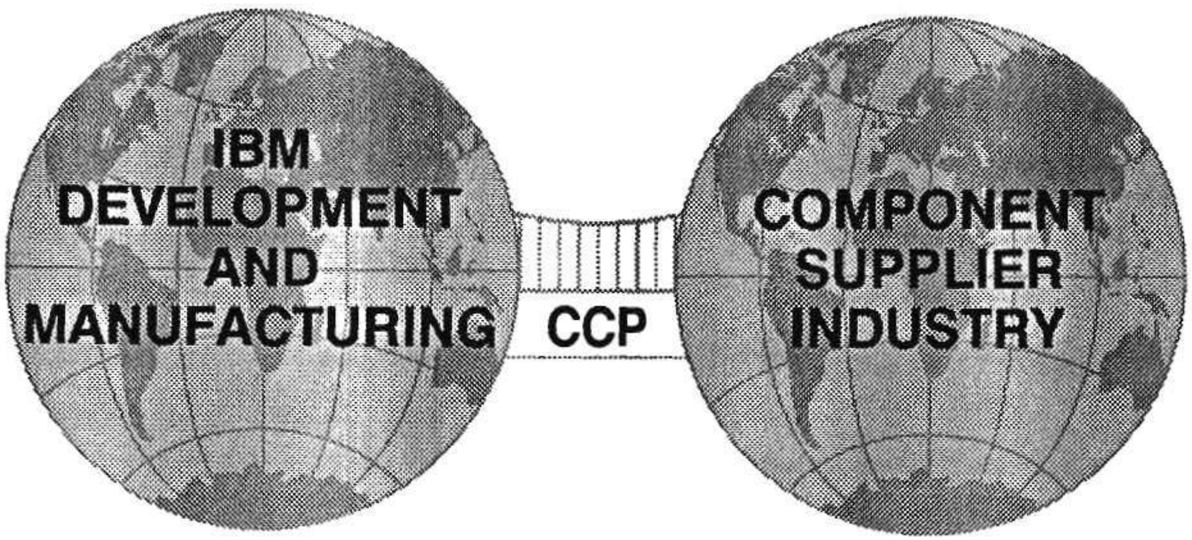
CUSTOMER / SUPPLIER ENVIRONMENT

1990s



"World Class" Relationships

CUSTOMER/SUPPLIER ENVIRONMENT

1990s

IBM — **SUPPLIER**

- **STRENGTHENING PARTNERSHIPS**
  - Early Supplier Involvement
  - Forecast Sharing
  - Performance Feedback

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1985 - 1989

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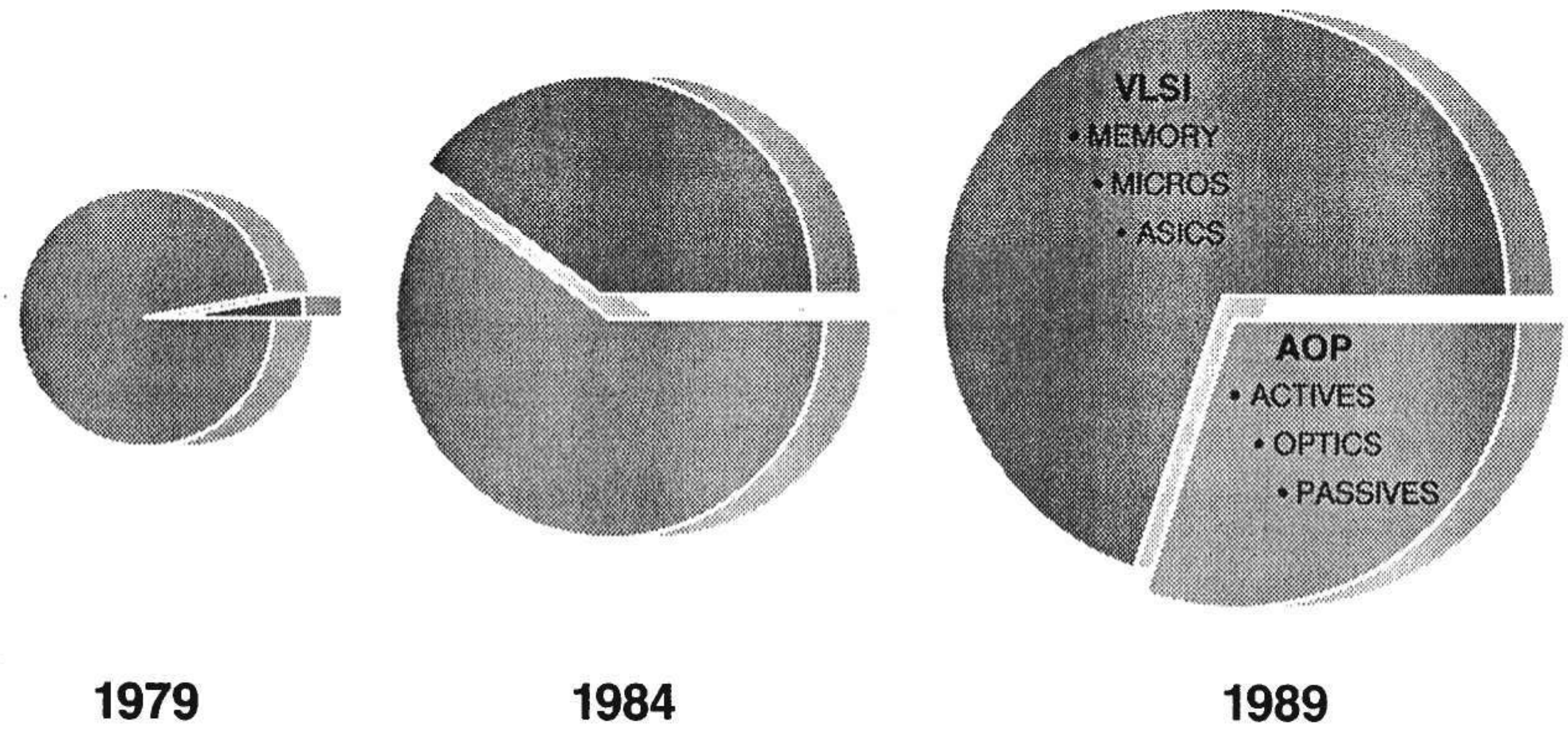
  - Source Acceptance
  - Joint Qualifications

SUPPLIER

- **IMPROVING PERFORMANCE**
  - Delivery
  - Quality
  - Reliability
  - Lead Times
  - Customer Oriented
- **NEW WORLDWIDE SUPPLIERS**

CORPORATE COMPONENT PROCUREMENT

AOP / VLSI TECHNOLOGY DOLLAR DISTRIBUTION



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DECADE OF CHANGE — 1980s

AVERAGE CYCLE TIME REDUCTION 63%

AUTOMATED BUSINESS PLACEMENT 85%

DROP SHIP (VOLUME) 89%

INVENTORY DOLLAR REDUCTION 60%

INCOMING QUALITY IMPROVEMENT 150X

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1990s

HISTORY
CHANGE
CHALLENGE

THE EVOLUTION OF CUSTOMER / SUPPLIER RELATIONSHIPS

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CHALLENGES FOR THE 1990s

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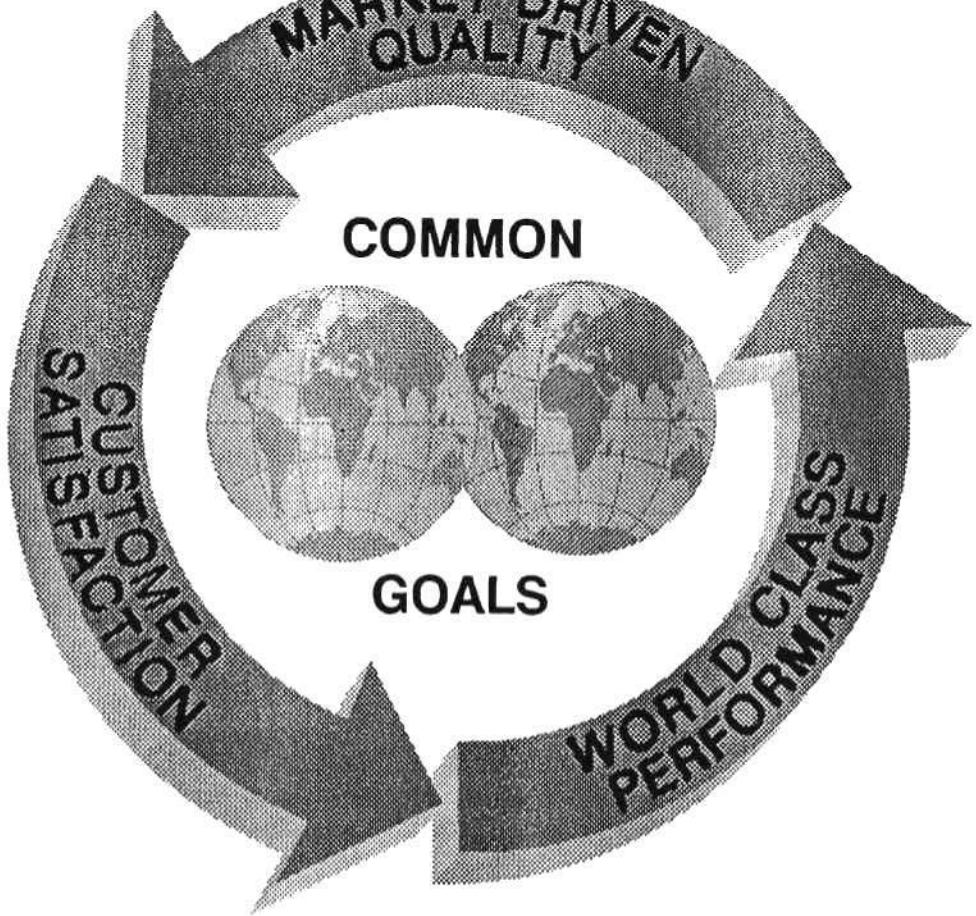
CHALLENGES FOR THE 1990s



IBM MARKET DRIVEN QUALITY

Quality, driven by market needs, that achieves TOTAL CUSTOMER SATISFACTION through the delivery of timely, defect free solutions that offer the best value to customers.

MARKET DRIVEN

"If we can be the best at satisfying the needs and wants of customers in those markets we choose to serve, everything else important will follow."

John Akers
Chairman of the Board
IBM Corporation

"We have to earn our right everyday to do business with our customers."

Donald R. Keough
President & CEO
The Coca-Cola Company

"We have to give customers good reasons to choose us not once, but all the time."

Otto Loefté
President & CEO
Swissair

"A company is market driven when its mission is to satisfy the needs and wants of chosen markets and customers in a profitable and competitively superior way."

Dr. Philip Kotler, Professor
J.L. Kellogg Graduate School of Management
Northwestern University

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CUSTOMER / SUPPLIER ENVIRONMENT

1990s

IBM — **SUPPLIER**

- **STRENGTHENING PARTNERSHIPS**
  - Early Supplier Involvement
  - Forecast Sharing
  - Performance Feedback
- **"WORLD CLASS"**
  - Zero Defects
  - Highest Reliability
  - Statistical Process Control
  - Just-in-Time Delivery
  - Electronic Data Interchange
  - Technology Leadership
  - Lowest Total Cost

Total Customer Satisfaction

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CORPORATE COMPONENT PROCUREMENT

GOALS

- To Grow Consistent with IBM's Demand for Supplier Component Technology.

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- To Provide Component Leadership in the Application of Supplier Technologies in IBM Products.

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- To Provide Component Leadership in the Application of Supplier Technologies in IBM Products.
- To be the Most Competitive Provider of Supplier Components in Terms of Quality, Cost, Technical Support, and Cycle Time.

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- To Enhance Customer and Supplier Relationships.

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- To Enhance Customer and Supplier Relationships.
- To Create an Environment for Creativity, Excellence and Individual Fulfillment.

Semiconductor
Industry
Conference

Lithography Strategies: Pushing the Limits

Optical Lithography Status

Gene Fuller, Ph.D.

Manager, Stepper Programs
Sematech

LITHOGRAPHY STRATEGIES FOR THE 90'S

OPTICAL LITHOGRAPHY

GENE FULLER

SEMATECH / TEXAS INSTRUMENTS

8 OCTOBER 1990

AGENDA

- COMMON LITHOGRAPHY ISSUES
- COMPARISON OF LITHOGRAPHY TECHNOLOGIES
- NEW DIRECTIONS IN OPTICAL LITHOGRAPHY
- OUTLOOK

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KEY LITHOGRAPHY ISSUES

- o TECHNICAL PERFORMANCE
  - RESOLUTION
  - FIELD SIZE
  - ALIGNMENT / REGISTRATION
  - OVERLAY
  - DEPTH OF FOCUS

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ISSUES - 2

- o MANUFACTURING PERFORMANCE
  - RELIABILITY
  - AVAILABILITY / UTILIZATION
  - CAPITAL COST
  - OUTPUT / YIELD / REWORK
  - SEND AHEADS / TEST WAFERS / SETUP
  - COST OF OWNERSHIP

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ISSUES - 3

- o ISSUES FOR THE 90'S
  - AUTOMATION
  - CIM COMPATIBILITY
  - CLUSTERING
  - MANAGING TOPOGRAPHY
  - WAVEFRONT ENGINEERING
    - PHASE SHIFT MASKS
    - DYNAMIC FOCUSING
  - REAL TIME PROCESS CONTROL
  - VERY LARGE FIELD SIZE

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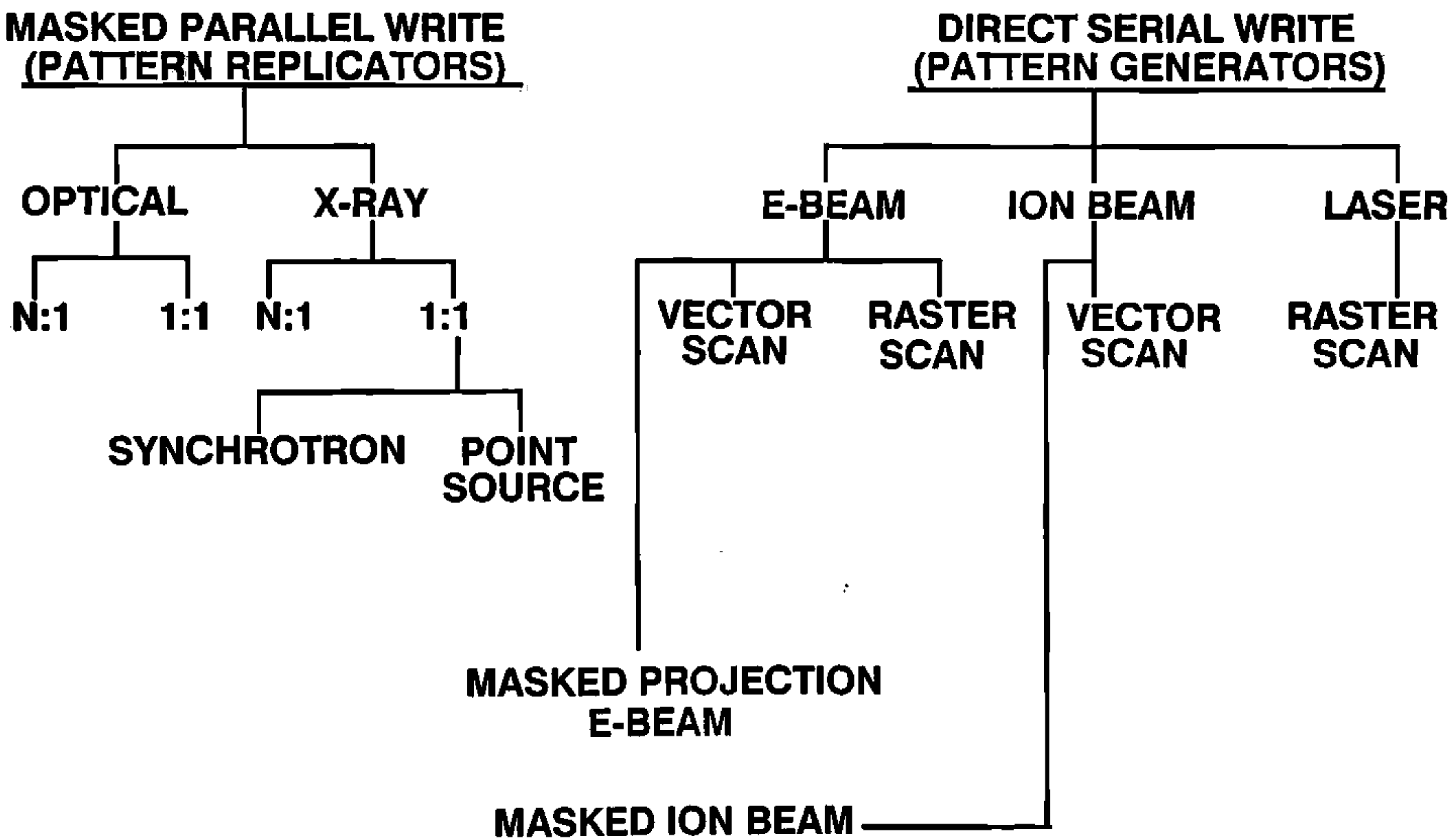
PRINCIPAL LITHOGRAPHY TECHNOLOGIES



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MASKED VS. DIRECT WRITE

	ADVANTAGES	DISADVANTAGES
MASKED PARALLEL WRITE	HIGH THROUGHPUT MACHINE STABILITY "LOW" COST BEST FOR HIGH VOLUME	COST OF MASK MASK ERRORS/DEFECTS OVERLAY PRECISION
DIRECT SERIAL WRITE	RAPID DESIGN TURNAROUND ACCURATE ALIGNMENT FLEXIBILITY NO MASK COST BEST FOR LOW VOLUME	LOW THROUGHPUT HIGH MACHINE COST

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MASKED OPTICAL LITHOGRAPHY

<u>**ADVANTAGES**</u>

VERY MATURE
"LOW" COST
HIGH THROUGHPUT
ROBUST MASKS
MANY SUITABLE RESISTS
NO VACUUM, NO HIGH VOLTAGE

<u>**DISADVANTAGES**</u>

LIMITED DEPTH OF FOCUS
DIFFRACTION LIMITED RESOLUTION
LIMITED FIELD SIZE
OVERLAY PRECISION
LINEWIDTH CONTROL
- REFLECTION FROM SUBSTRATE
- STANDING WAVES
- LIMITED RESIST ASPECT RATIO

STATUS:

- ALMOST ALL LITHOGRAPHY TODAY IS OPTICAL.
- WIDE VARIETY OF EQUIPMENT AVAILABLE.
- STRONG SUPPORTING RESIST TECHNOLOGY.
- LIKELY TO REMAIN AS MOST USED LITHOGRAPHY SYSTEM THROUGHOUT THE 90'S.

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WHATEVER HAPPENED TO ...

- E-BEAM
- X-RAY
- FOCUSED ION BEAMS

  .
  .
  .

MANY TECHNOLOGIES HAVE BEEN PREDICTED TO TAKE OVER FROM "DYING" OPTICAL LITHOGRAPHY DURING THE PAST 10-15 YEARS.

WHY DIDN'T THIS HAPPEN?

- OPTICAL LITHOGRAPHY WAS NOT AT OR EVEN CLOSE TO ITS PHYSICAL LIMITS.

- THE NEW TECHNOLOGIES ENCOUNTERED VARIOUS DIFFICULTIES AND DELAYS AND DID NOT ACHIEVE THE EARLY PREDICTIONS.

- THE TECHNICAL AND MANUFACTURING ENVIRONMENT CONTINUED TO CHANGE.

    - NEW TECHNOLOGY CAPABILITIES
    - REVISED COST REQUIREMENTS

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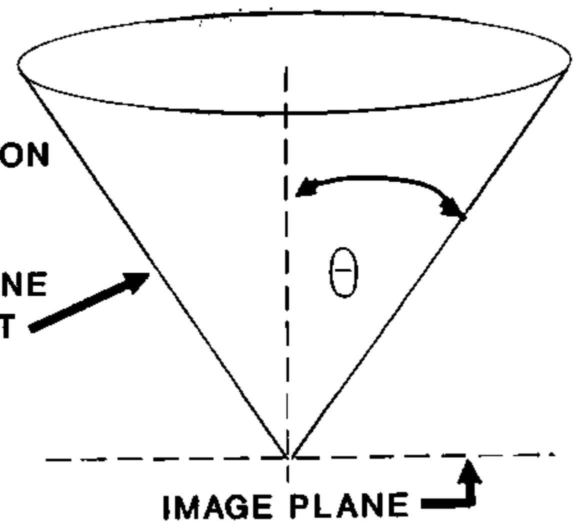
STEPPER PROJECTION OPTICS

- DEFINITIONS
  - -- NUMERICAL APERTURE (NA) = SIN θ
  - -- λ (G-LINE) = 436 nm
  - -- λ (I-LINE) = 365 nm
  - -- λ (DUV) = 250 nm



- RESOLUTION $R = K \frac{\lambda}{NA}$
  - -- PRODUCTION K=0.8→0.7
  - -- LAB K=0.5

- DEPTH OF FOCUS
  - -- THEORETICAL $DOF = \frac{\lambda}{NA^2}$
  - -- ALTERNATE EXPRESSION $DOF = \frac{R^2}{K^2 \lambda}$

- STEPPER COMPARISON (CALCULATED, K = 0.8)

	NA	R (µm)	DOF (µm)
G-LINE	.28	1.25	5.6
G-LINE	.54	0.65	1.5
I-LINE	.45	0.65	1.8
I-LINE	.73	0.40	0.7
DUV	.50	0.40	1.0

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G/I VS. DUV

- o DUE TO IMPROVED GLASS TECHNOLOGY I-LINE LENSES CAN BE MADE AT SAME QUALITY LEVEL AS G-LINE.

  I-LINE WILL RAPIDLY DISPLACE G-LINE FOR NEW SALES.

- o DUV (250 NM) STILL IMMATURE IN:

  - SOURCE, ESPECIALLY LASER
  - RESIST, ESPECIALLY HIGH SENSITIVITY
  - MASK/PELLICLE

- o DUV LENS DESIGN/MANUFACTURING COMPARABLE COMPLEXITY TO G/I.

- o EXCIMER LASERS MAKING STRONG PROGRESS

  - REMAINING CHALLENGES IN OVERALL LITHOGRAPHY INTEGRATION.

  - NARROW BANDWIDTH EXACERBATES REFLECTIVITY AND STANDING WAVE PROBLEMS.

NEW TECHNOLOGY CAPABILITIES

- o OPTICAL MANUFACTURING
  - -LENS DESIGN COMPUTING POWER
  - -SELECTION/QUALITY OF GLASSES
- o CONTROL SYSTEMS
  - -AFFORDABLE WORKSTATIONS
  - -DIGITAL SIGNAL PROCESSING
  - -MODULAR, OBJECT ORIENTED SOFTWARE
- o METROLOGY
  - -LENS INTERFEROMETERS
  - -HIGH PRECISION STAGE INTERFEROMETERS
  - -BUILT-IN OVERLAY/OPTICAL METROLOGY

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KEY ENABLERS

- PHASE SHIFT MASKS
  - DEMONSTRATED APPROXIMATELY 10 YEARS AGO
  - TREMENDOUS INTEREST/ACTIVITY TODAY
  - MOST OF THE COMPLEXITY IN MASK PROCESS
  - VIRTUALLY "FREE" RESOLUTION TO FAB ENGINEER
- SURFACE IMAGING RESISTS
  - SEPARATION OF RESIST FUNCTIONS
  - DECOUPLING OF SUBSTRATE ISSUES
  - WELL SUITED TO DRY PROCESSING
  - PROVEN, BUT COMMERCIALLY IMMATURE
  - COST NO LONGER A MAJOR DIFFERENTIATOR

POTENTIAL PITFALLS

- o FIELD SIZE
  - HOW BIG CAN/WILL CHIPS GROW?
  - MAY NEED DYNAMIC EXPOSURE TECHNIQUES
    - "STEP-AND-SCAN"
    - SUB-FIELD STITCHING
- o DEPTH OF FOCUS LIMITATIONS
  - REQUIRES CIRCUIT TOPOGRAPHY CONTROL
  - STRONGLY FAVORS SURFACE IMAGING RESIST
  - DRIVES WAFER FLATNESS TO SUB-0.25 UM

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POTENTIAL PITFALLS - 2

- o RETICLE ISSUES
  - PHASE SHIFT MASK COMPLEXITY/COST
  - LARGE FIELD SIZE, 5X VS. 1X
- o PROTOTYPING/ASICs
  - LOW VOLUME REMAINS COSTLY DUE TO MASKS
  - MUST ELIMINATE SET-UPS AND SEND AHEADS
  - FAB AUTOMATION/RETICLE MANAGEMENT VITAL

POSSIBLE FUTURE STARS

- o HOLOGRAPHY

  - MANY POTENTIAL ADVANTAGES
    - FIELD SIZE
    - DEFECT IMMUNITY
    - SIMPLE OPTICS

  - SEVERAL RESEARCH DEMONSTRATIONS, STILL SOME YEARS AWAY FROM COMMERCIALIZATION.

- o LASER DIRECT WRITE

  - ADVANTAGES OF E-BEAM, WITH LOWER SYSTEM COMPLEXITY.

  - PROBABLY BEST USED FOR LOW VOLUME APPLICATIONS.

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MICROELECTRONIC MANUFACTURING CHALLENGES IN THE 90'S

HISTORY OF DISCONTINUITIES

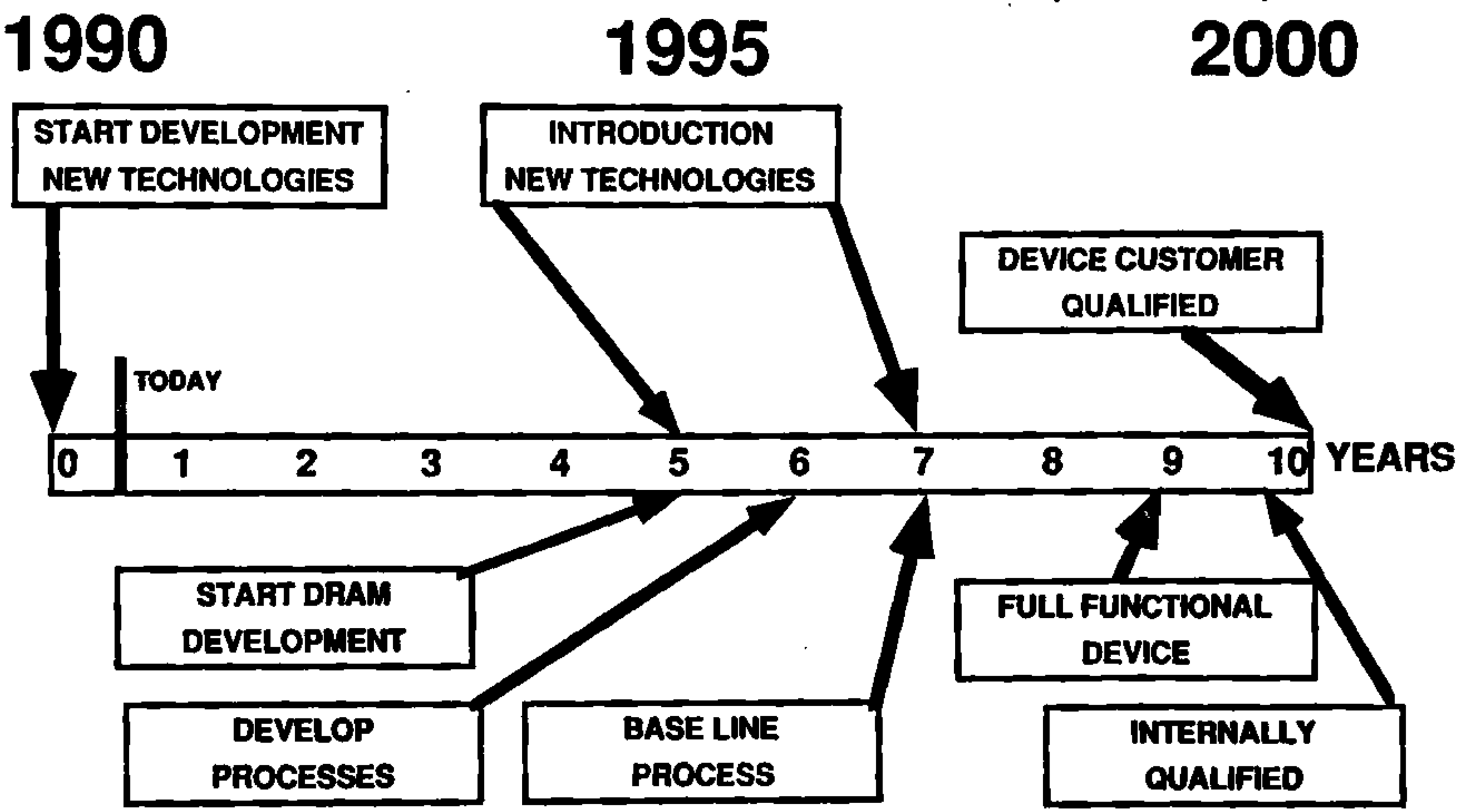
TOOL OR TECHNOLOGY	YEAR DEVELOPED	YEAR IMPLEMENTED IN PRODUCTION	DELTA (YEARS)
SILICON EPITAXY	1960-61	1964	4
SILICON NITRIDE (ATMOS)	1965	1967-68	2
ION IMPLANT	1969	1973	4
TiW METALLIZATION	1969-70	1975-77	6
SCHOTTKY TTL	1970	1974-75	6
CCD'S	1970	1981	11
RIE	1975-76	1980	5
ADVANCED SCHOTTKY (ALS)	1976	1980	4
POLY EMITTER	1976	1984-85	8
REFRACTORY GATE	1976	1983	7
SOI-ION IMPLANT	1978	1989	11
TRENCH	1979	1987	8
SILICIDE	1978	1985	7
LIGHTLY DOPED DRAIN	1980	1986	6
TiN LI	1986	1988	2

MEDIAN TIME FROM DEVELOPMENT TO IMPLEMENTATION -----> 6-7 YEARS

SOURCE: GRAYDON LARRABEE, TEXAS INSTRUMENTS

NEXT GENERATION DEVICE DEVELOPMENT

0.2 - 0.15 MICRON MINIMUM GEOMETRIES (1024 Mbit)



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REQUIREMENTS FOR SUB 0.5 MICRON OPTICAL LITHOGRAPHY

- "PERFECT" IMAGING SYSTEMS
  - DIFFRACTION LIMITED OPTICS
  - FLAT IMAGE SURFACE
- PLANARIZED WAFERS
  - TOPOGRAPHY MUST BE LESS THAN D.O.F.
- SURFACE IMAGING RESISTS
  - MINIMIZED D.O.F. REQUIREMENT
  - REFLECTIVITY CONTROL
- WAVEFRONT TUNING IN THE FAB
  - PHASE SHIFT MASKS
  - ADJUSTABLE FOCUS DURING EXPOSURE

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OUTLOOK FOR OPTICAL LITHOGRAPHY IN THE SUB-0.5 MICRON WORLD

RESOLUTION	DOWN TO AT LEAST 0.25 MICRON
DEPTH OF FOCUS	LIMITED, REQUIRES PLANARIZED PROCESS
C.D. CONTROL	+/- 10% REQUIRED AND ACHIEVABLE
EXPOSURE WAVELENGTH	248 NM CERTAIN, 193 NM POSSIBLE
OVERLAY	DIFFICULT, BUT POSSIBLE TO 50 NM
FIELD SIZE	GREATER THAN 20 MM x 20 MM
RESISTS	SUITABLE RESISTS WILL BE AVAILABLE
MASKS	NX ACHIEVABLE, 1X DIFFICULT

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HOW FAR CAN OPTICAL LITHOGRAPHY TAKE US?

ONE CONCEIVABLE SCENARIO FOR THE MID TO LATE '90'S

WAVELENGTH:	250 NM
NA:	0.65
FIELD SIZE:	30 MM X 30 MM
SUPPORT TECHNOLOGIES:	PHASE SHIFT MASKS SURFACE IMAGING RESIST DYNAMIC FOCUSING PLANAR TOPOGRAPHY
K-FACTOR:	0.5
RESOLUTION:	0.20 MICRON
DEPTH OF FOCUS:	0.5 MICRON

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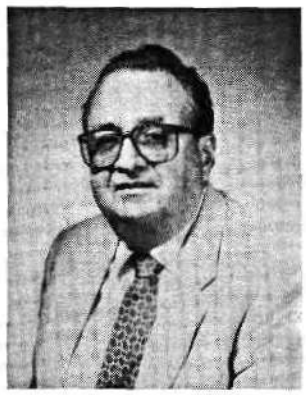
SUMMARY

- OPTICAL LITHOGRAPHY, PREDICTED TO BE DEAD LONG AGO, LIVES!
- DUE TO CHANGING TECHNICAL INFRASTRUCTURE THE FUTURE FOR OPTICAL LITHOGRAPHY CONTINUES TO LOOK STRONG.
- OPTICAL LITHOGRAPHY R&D CONTINUES TO BE STRONG.
- OPTICAL IS NOT THE BEST OR ONLY SOLUTION FOR ALL MARKETS, BUT IT WILL CONTINUE TO DOMINATE HIGH VOLUME SEMICONDUCTOR PRODUCTION THROUGHOUT THE DECADE.

LITHOGRAPHY STRATEGY: PUSHING THE LIMITS
X-RAY LITHOGRAPHY



Robert W. Hill
Functional Manager
Advanced Lithography
Systems Development
IBM Corporation

Bob Hill is the Functional Manager for the Advanced Lithography Systems Development group at IBM's GTD Advanced Technology Center in Fishkill, New York. His responsibilities include metrology, optical lithography, and resist development in addition to IBM's X-ray lithography program and facility. Mr. Hill joined IBM in Burlington in 1960 and has held various engineering management positions in IBM manufacturing and development in Burlington, Vermont; Charlotte, North Carolina; and East Fishkill, New York. Mr. Hill has a B.S.E.E. degree from the University of Vermont.

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SEMICONDUCTOR INDUSTRY CONFERENCE
October 8-9, 1990
Monterey, California

Semiconductor
Industry
Conference

Lithography Strategies: Pushing the Limits

X-Ray Lithography Status

Robert W. Hill

Functional Manager, Advanced Lithography Systems
IBM Corporation

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X-RAY LITHOGRAPHY OVERVIEW

R. Hill and J.R. Maldonado

IBM General Technology Division
Advanced Technology Center
Hopewell Junction, N.Y.

IBM

X-RAY LITHOGRAPHY OVERVIEW

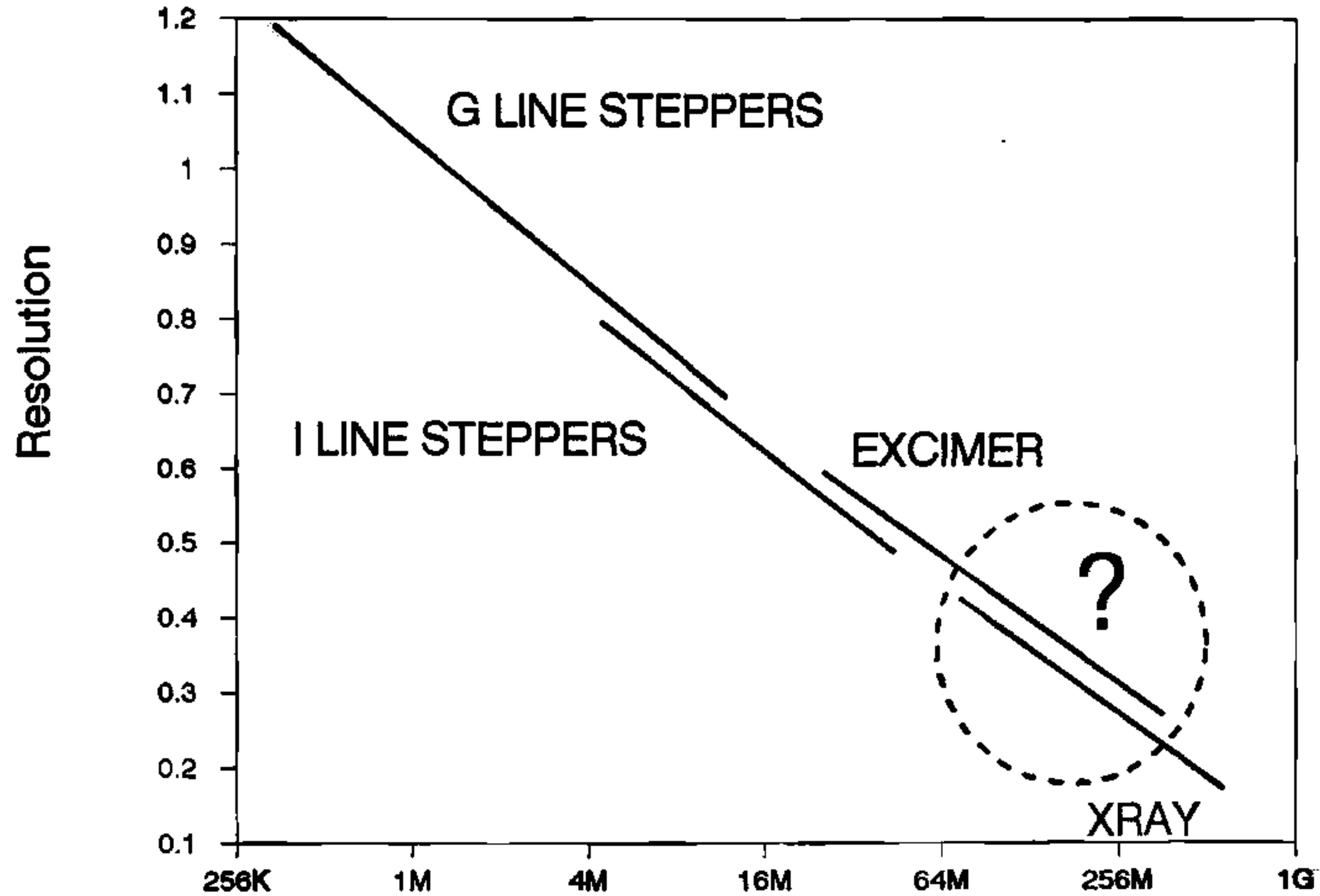
OUTLINE

- WHY X-RAY LITHOGRAPHY?
- SYSTEM APPROACH TO X-RAY LITHOGRAPHY
  - * FACILITY
  - * X-RAY MASKS
  - * X-RAY SOURCES
  - * X-RAY STEPPERS
  - * X-RAY RESISTS
  - * DEVICES
- OTHER PROGRAMS
- EXTENDABILITY OF XRL
- FUTURE

08/90 (R. Hill and J.R. Maldonado)

IBM

Worldwide Lithography Tooling Trends



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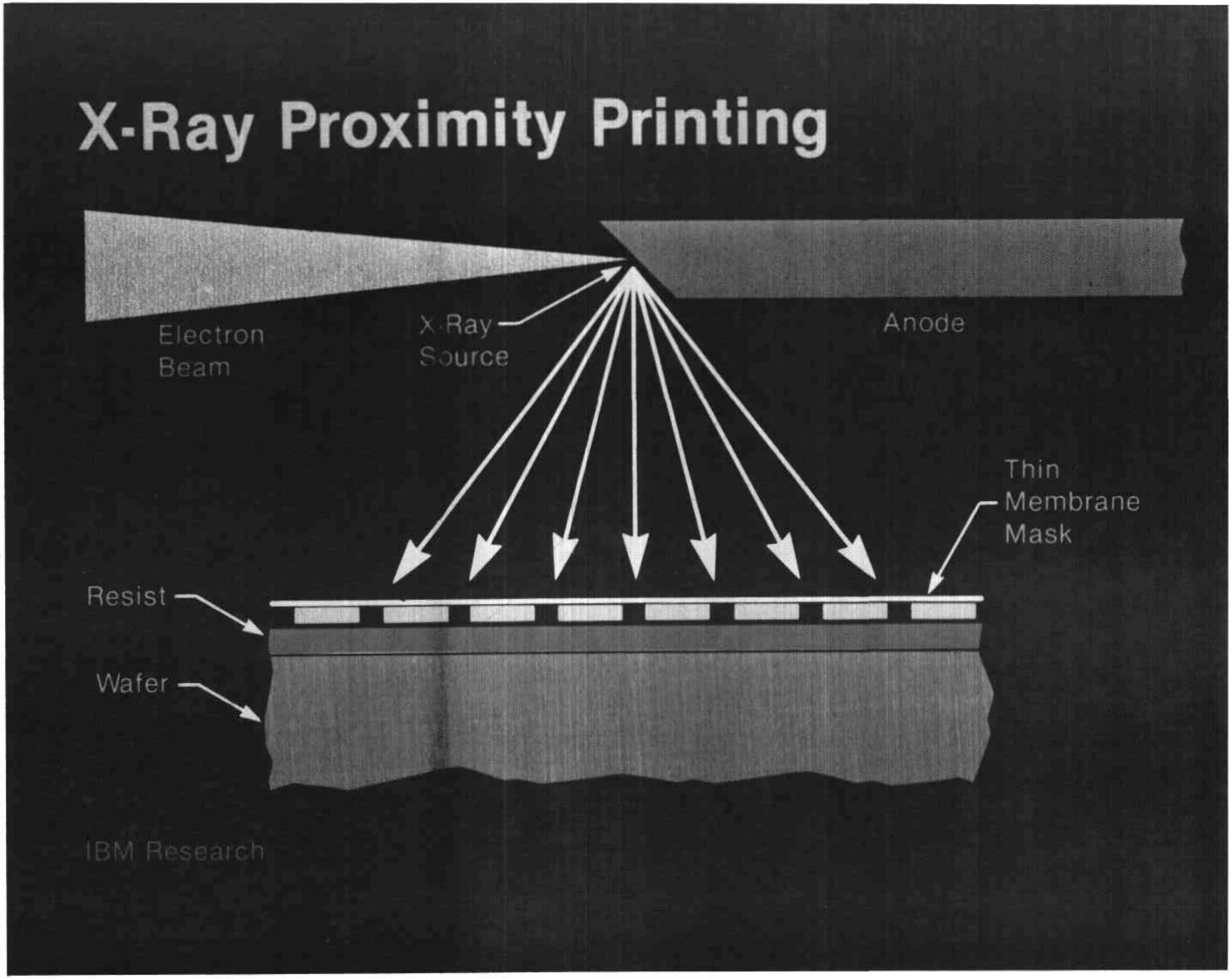
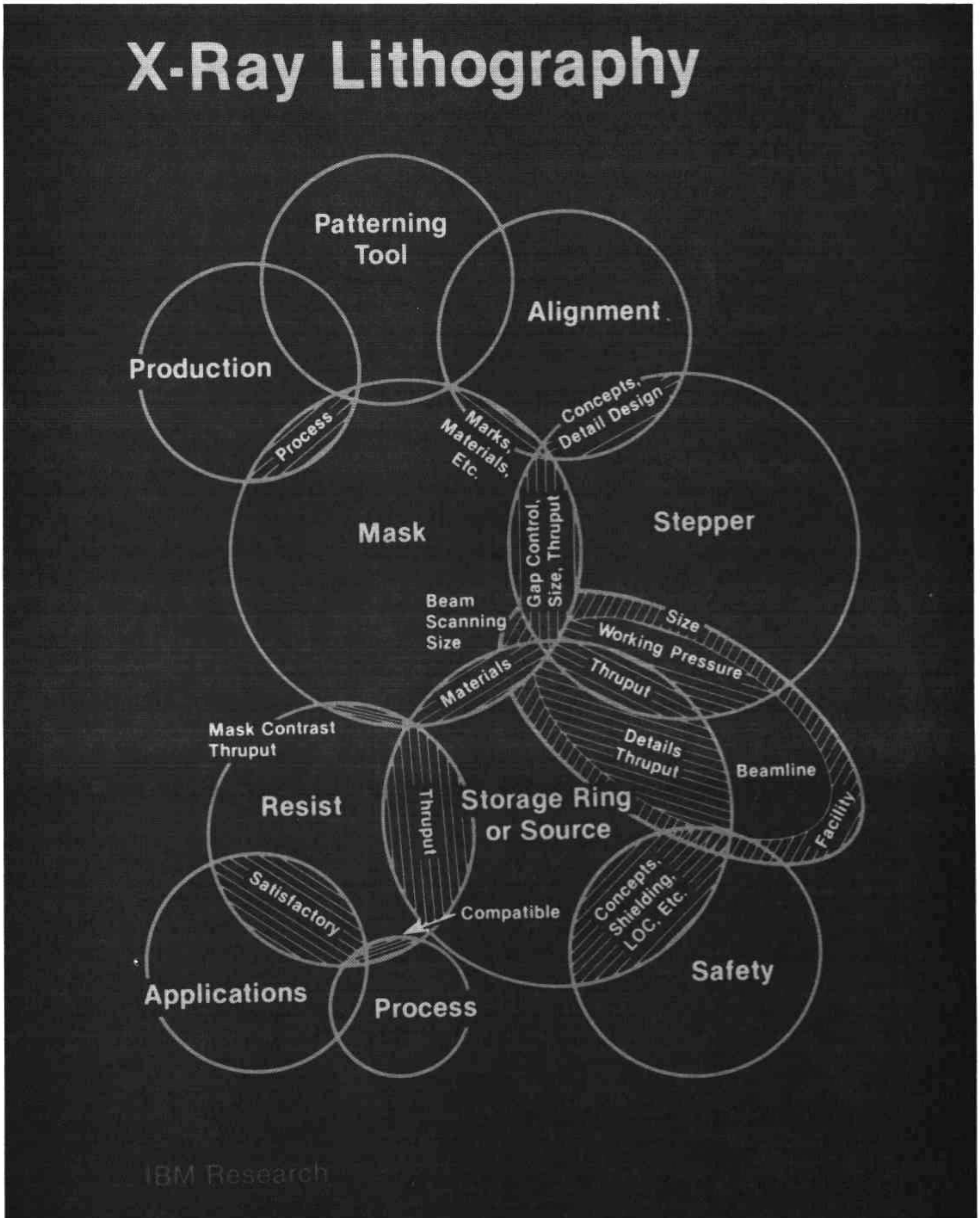

X-Ray Proximity Printing
Electron Beam
X-Ray Source
Anode
Thin Membrane Mask
Resist
Wafer
IBM Research

WHY X-RAY LITHOGRAPHY?

- **ADVANTAGES:**
  - HIGH RESOLUTION AND INCREASED DEPTH OF FOCUS
  - SIMPLER AND MORE ROBUST PHOTO PROCESS STEPS
  - GREATER DEFECT INSENSITIVITY
  - LOWER PROCESSING COSTS
- **DISADVANTAGES:**
  - HIGH INITIAL COST (SYNCHROTRON)
  - MAJOR LITHOGRAPHY TECHNOLOGY CHANGE
  - COMPLEX 1X MASK TECHNOLOGY

RWH/8-8-90/DQC1



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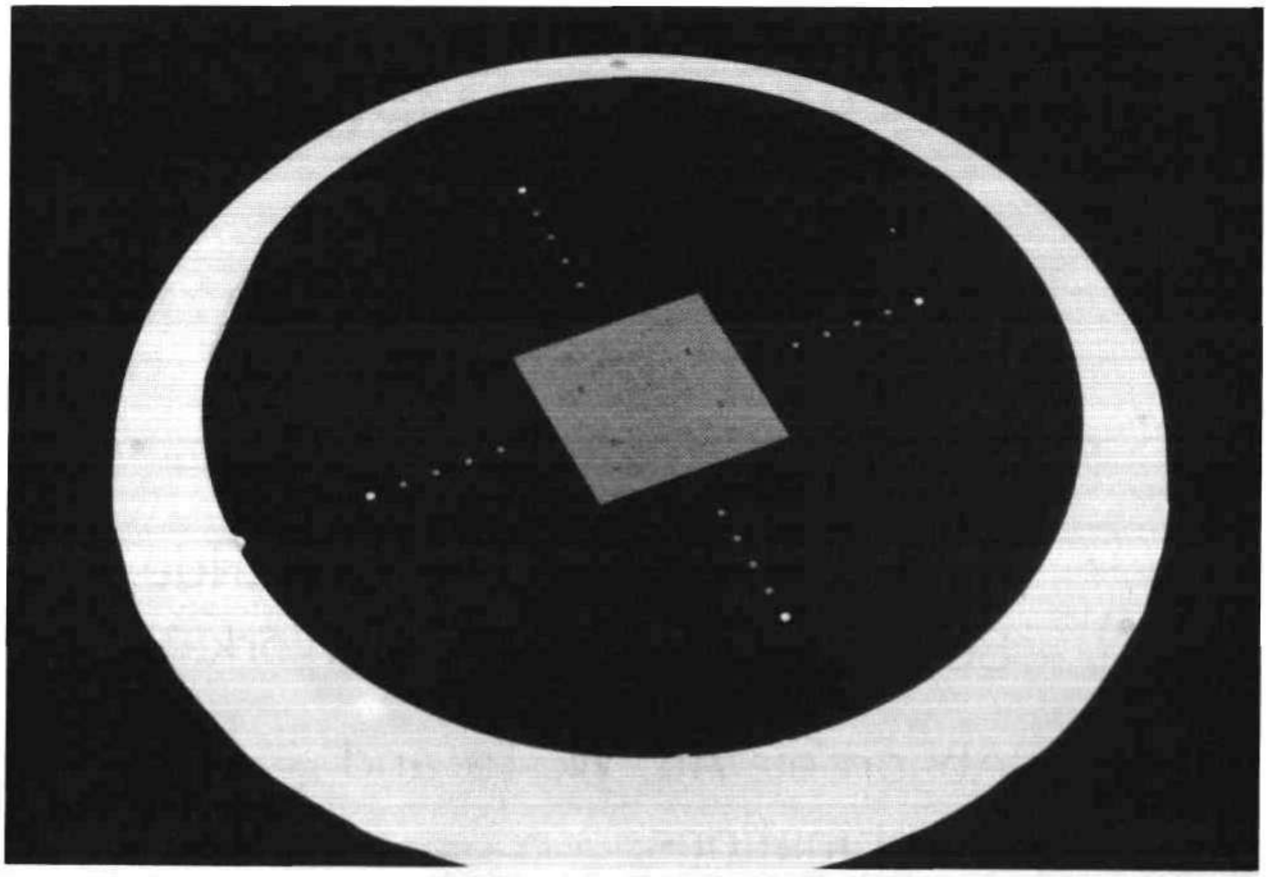
X-RAY SYSTEM COMPONENTS

X-RAY MASK STATUS

- Structure
  - * Substrate: B-doped Si, Si Nitride, Some SiC and Diamond Work.
  - * Absorber: Au, W, Ta and Combinations
  - * Frame: Considered for Standardization (NIST)
- Patterning: E-Beam
- Inspection and Repair: Tools Under Development (Micrion and KLA)

08/90 (R. Hill and J.R. Maldonado)

IBM



X-RAY MASK WITH:

2.4 x 2.4 cm B-Si MEMBRANE 2 μm THICK.

0.5 μm GOLD ABSORBER WITH A DEVICE PATTERN

FREE-STANDING ALIGNMENT MARKS IN WINDOWS

OVERALL MASK SIZE: 10.0 cm.

MOUNTED ON PYREX RING.

X-RAY SYSTEM COMPONENTS

SOURCES

- Electron Impact
- Synchrotron Storage Ring
- Pulsed Plasma
  * Laser Heated Plasma
  * Pinched Gas Plasma
  * Exploding Wire
- Transition Radiation
- X-ray Laser

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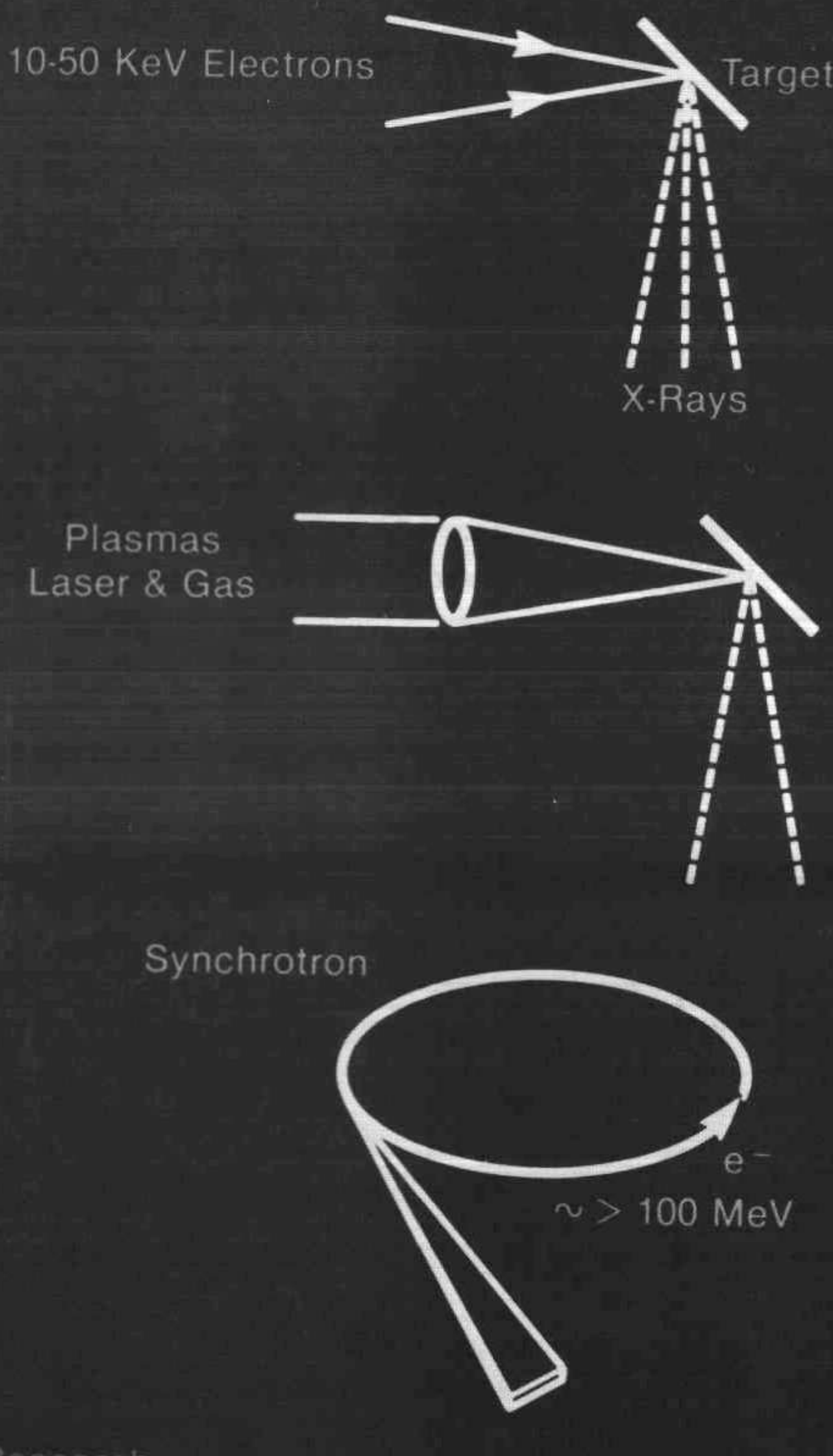
IBM

Sources



IBM Research

X-RAY SYSTEM COMPONENTS

MAIN X-RAY SOURCE CONTENDERS

- SYNCHROTRON SR
    * IBM/Oxford CSOR
    * Japanese SOR?
    * Numerous Warm Rings
- HEATED PLASMA
    * Hampshire's Tool
    * Suss GMBH

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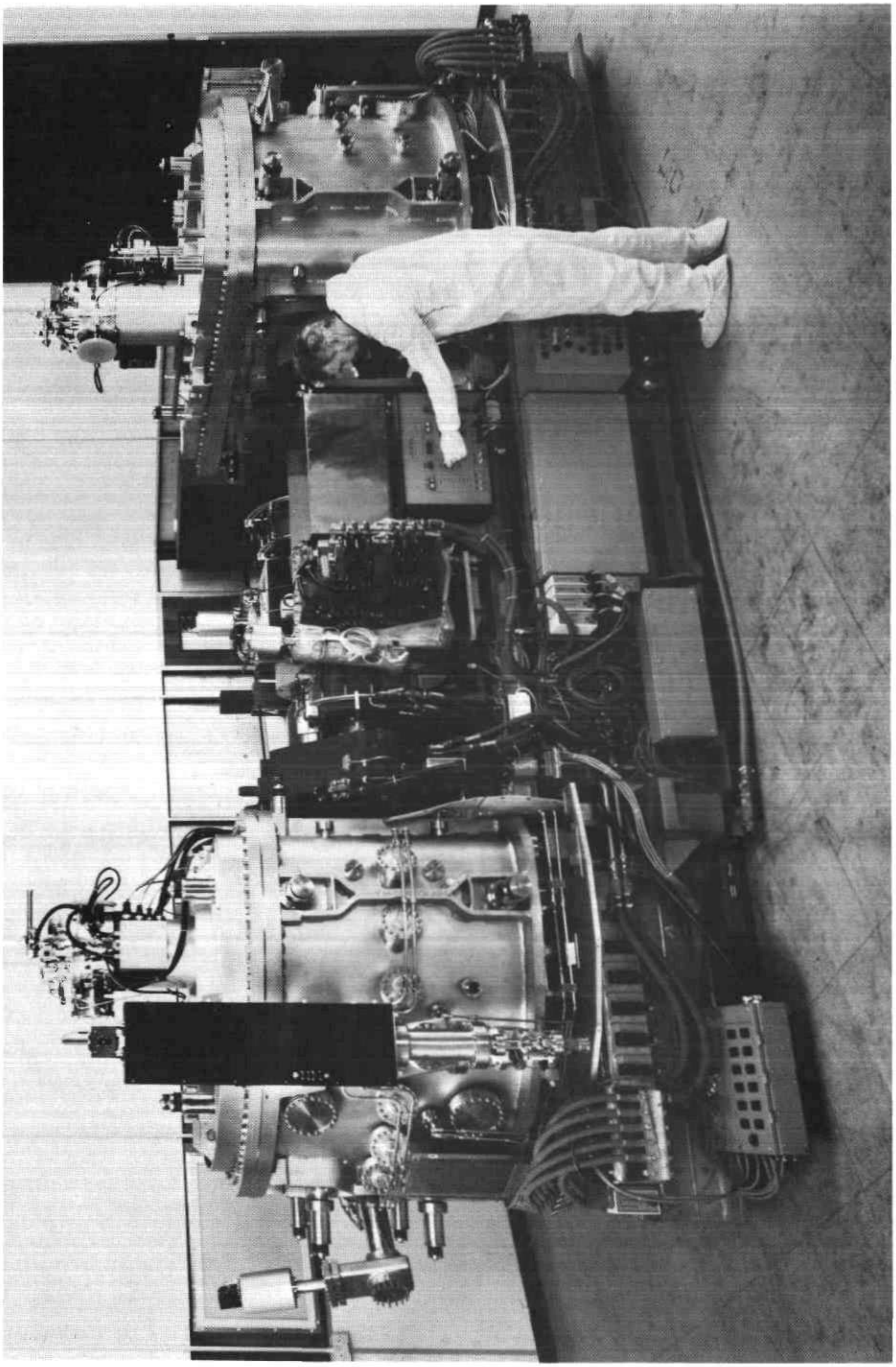
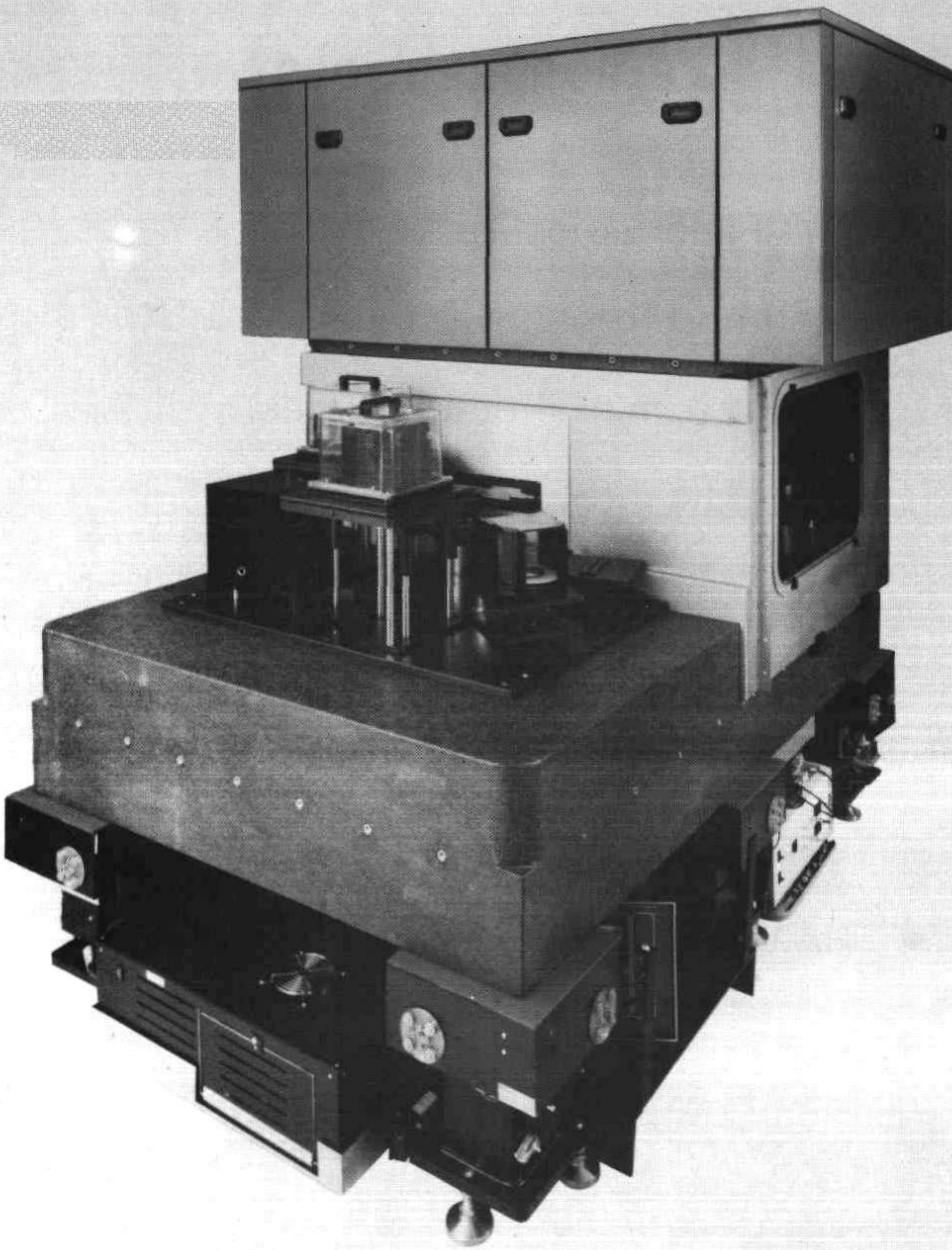
IBM



Series 5000 X-Ray Stepper System



HAMPSHIRE
INSTRUMENTS INC.

X-RAY SYSTEM COMPONENTS

EXPOSURE TOOLS

- Full Field Exposure
- Step and Repeat Systems
  - * Horizontal (Point Sources)
  - * Vertical (SSR)
    - o Beamline
    - o Beam Scanning
      - Mirror
      - Wafer/Mask
- Be Window

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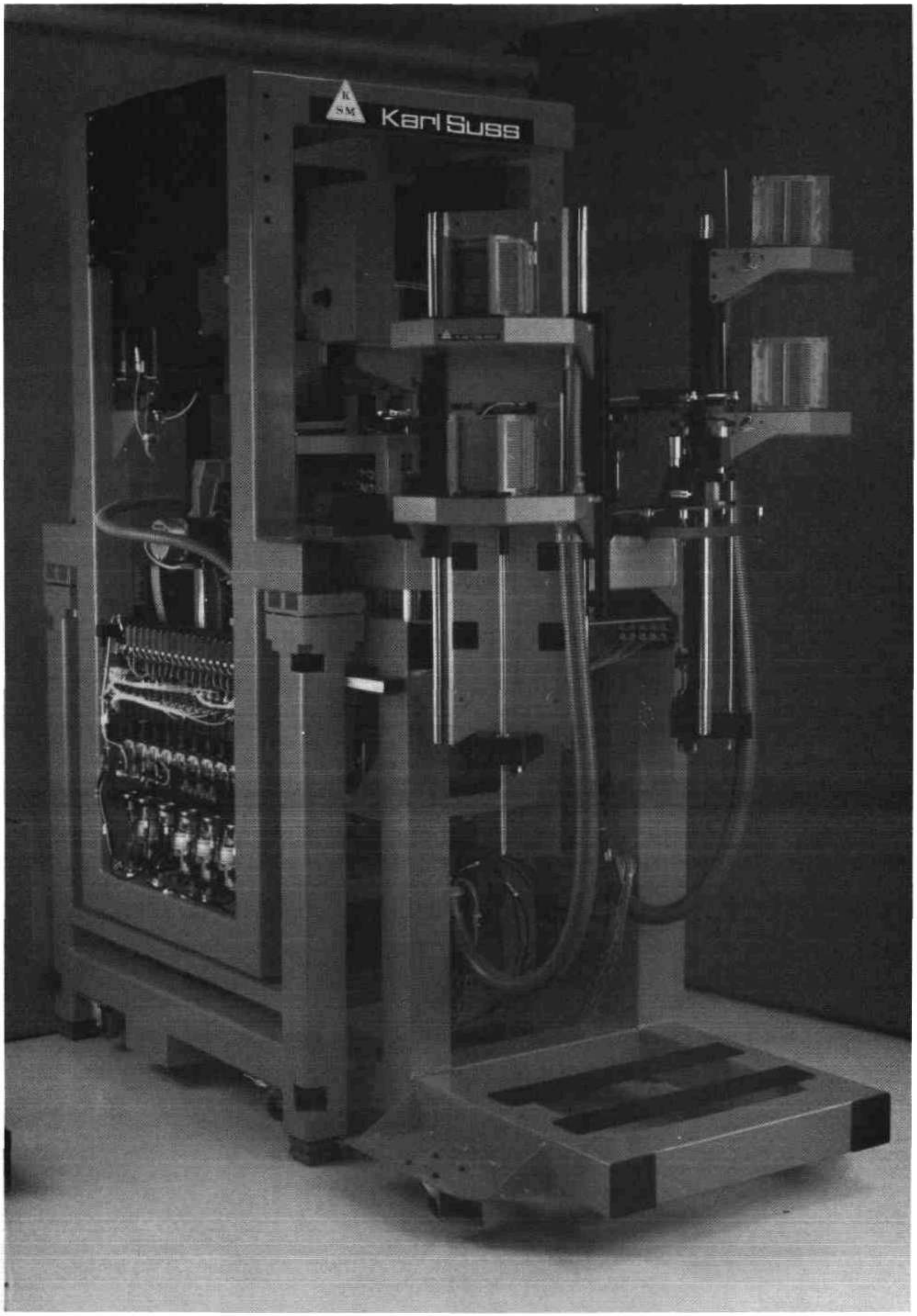
IBM



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X-RAY SYSTEM COMPONENTS

X-RAY RESIST REQUIREMENTS

- Submicron Resolution with Adequate Aspect Ratio
- Thickness Uniformity
- Thermal Stability
- Good Sensitivity

08/90 (R. Hill and J.R. Maldonado)

IBM

MAIN X-RAY LITHOGRAPHY PROGRAMS

- USA
  - * IBM
  - * DARPA
- JAPAN
  - * NTT
  - * SORTEC
- EUROPE
  - * German X-ray Consortium (GCX)

08/90 (R. Hill and J.R. Maldonado)

IBM

XRL ISSUES

- Introduction Point
- High Initial Costs
- 1X Mask Technology
- Extendability

08/90 (R. Hill and J.R. Maldonado)

IBM

EXTENDABILITY OF X-RAY LITHOGRAPHY

- Diffraction Limited (Gap Dependent)
- Less Than 400Å Demonstrated for Isolated Lines
- Believe to Be Under 0.15 μm for Complex Patterns
- More Experiments Needed
- ATT Has Demonstrated Future Potential for Projection XRL

08/90 (R. Hill and J.R. Maldonado)

IBM

X-RAY LITHOGRAPHY OVERVIEW

SUMMARY

- X-Ray Technology is Here
- Shorter Wavelengths Offer Better Resolution and DOF
- DOF Will Be Diffraction Limited
- 1X Mask Technology is the Main Risk
- Will Result in Simpler More Defect Free Processing

08/90 (R. Hill and J.R. Maldonado)

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LITHOGRAPHY STRATEGIES: PUSHING THE LIMITS
MASKMAKING

John G. Skinner, Ph.D.
Director, Advanced Photomask Technology
DuPont Photomask, Inc.

John Skinner joined DuPont Photomask in 1990 to head its Advanced Photomask Technology group. Prior to joining DuPont, Dr. Skinner spent 28 years with Bell Labs in a variety of positions. His initial work with Bell Labs was in the area of solid-state lasers, electro-optic materials, and high speed deflection systems. In 1968, he began work in the area of optical lithography and was involved in the development of a wafer projection exposure tool and a precision step-and-repeat camera. In 1971,he assumed responsibility for the operations of a new mask shop at Bell Labs. Dr. Skinner has worked closely with SEMATECH to help define future photomask requirements, and recently chaired two SEMATECH photomask meetings. Dr. Skinner has undergraduate degrees in Mechanical Engineering and Applied Physics from Northampton Polytechnic, London, and an M.Sc. and Ph.D. in Physics from Oregon State University.

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October 8-9, 1990
Monterey, California

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Industry
Conference

Lithography Strategies: Pushing the Limits

Photomasks Will Never Die, They Won't Even Fade Away

John Skinner, Ph.D.
Director of Advanced Photomask Technology
Dupont Photomask, Inc.

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MASKS

John G Skinner, Ph. D
DuPont Photomasks, Inc.
Gladstone, NJ 07934

The previous talks described three competing lithographic techniques. Optical lithography is the predominant technology for today's IC designs, x-ray lithography is waiting for optics to run out of steam, and e-beam direct-write is nibbling at both technologies to take over the low volume codes, or to share critical levels with one or both technologies. Fortunately for the mask maker, masks can be used with all three technologies. [The use of a stencil mask has been proposed for use with a large diameter electron beam and repeated patterns, to speed up the writing rate.]

The questions facing the mask maker are;
1] When must we replace our present equipment and processes to meet future optical needs ?
2] When must we get ready for x-ray masks ?

Since the advent of a commercial e-beam mask writer [MEBES] in the late 70s, mask making has too often been taken for granted. Fortunately, Sematech, through Dick Clover, recognized that photomasks must be considered as part of IC manufacture and not merely a tool that can be made to any required quality. This interaction has enabled mask makers and equipment vendors to participate in some of the decision making. Jointly we set mask specifications for the next reduction(s) in design rules. However, even with this close connection it is not possible to establish the specifications that will be required five years from now. Mask makers must use their own initiative to plan their future.

The procedure I have used is to:

1] Summarize the probable limits and time schedules for available optical technologies.
2] Estimate the required photo mask specification as a function of time.
3] Use industry's recommendation when x-ray will become a major lithography tool.

[I assume the previous speakers have already described photomasks, including phase shift masks, and x-ray masks.]

Because of the time limit, I will limit my data to 5X reticles.

Table 1 shows a projection of the time schedule for the given minimum wafer feature, and an indication of the applicable lithography. Even though the required resolution can be obtained with conventional masks, it is quite certain that phase shift masks will be used, wherever possible, to obtain a greater wafer processing latitude.

Table 2 shows the tolerance of a number of photomask parameters expressed as a percentage of the minimum wafer dimension. These percentages vary somewhat with different mask users, but the given values serve our present need. Using the data from Table 1 we can project the specifications for 5X retilcles as a function of time.

I will briefly review the different parameters and indicate where it will be difficult to achieve the required specification.

REGISTRATION

This term is used rather loosely. In one sense it means the ability to overlay one level with another. It also means the ability to register any mask level against a specified grid. At this time it is only possible to achieve an overlay accuracy of the order of 0.1 microns on a single machine. I am confident the registration will be improved to the required 0.07 microns for multiple machines before 1992, with either the upgrade of existing pattern generators or the introduction of new machines under development. These upgrades and new machines may require multiwrite to correct inherent machine errors. I believe the 1994 requirement will have to be met with even more multiple writes to further reduce the inherent pattern generator errors. This means new equipment or significant upgrades for 1992 and longer write times for 1994 and beyond. This longer write time to reduce machine errors will be in addition to the extra write time required for the larger pattern data expected in 1994.

CD CONTROL AND MEASUREMENT

We are beginning to see a new era in the measurement of photomask features. With tolerances of the order of one twentieth the wavelength of light, mask makers have to consider the shape of the feature profile, and the straightness of the feature edge. The typical edge profile can contribute as much as the total allowed CD error. The uncertainty of the location of the feature edge, due to the edge roughness, increases this inherent CD error. Materials and processes have to be improved to meet even the near term requirements. Techniques have to be developed to measure the feature edge roughness, and may be even the feature edge slope.

DEFECTS

Leading edge defect detection machines can detect 0.25 micron defects with 95-99% probability. The probability varies with defect shape and size .[Note: the probability is not 100%.] Equipment will be available to detect 0.10 micron defects by 1996, but it will require much development and the new machines will be expensive.
More effort must be put into reducing defects during manufacture. More process automation is needed to minimize defects caused by the presence of operation.

SUBSTRATES

I briefly touched on the subject of possible lithographic techniques because I sincerely hope the actinic wavelength stays above the absorption point of quartz. Quartz is an excellent material for substrates but has an absorption band starting at about 180 nm. [Kr-F is 248 nm.]
Unfortunately we have no domestic source of suitable quartz for photomask substrates. We have developed deposition techniques for putting the opaque film on the substrate, and we are improving our polishing capabilities, but we have no domestic source of suitable quartz for photomask substrates.
The substrate thickness for 1990/91 will no doubt be 90 mils because of its availability. However, the gravitational sag in 90 mil substrates produces a length error of the order of 20% of the allowed tolerance. This error is reduced by using thicker glass. Unfortunately, a thicker substrate makes it more difficult to achieve a uniform temperature during prebake and postbake and this increases the difficulty of achieving a uniform CD.

So far I have only discussed conventional 5x reticles. 4x reticles will have similar mask specifications. 1x reticles will require at least a factor of three tighter specifications. This is not too significant for the registration because the active mask area is twenty-five times smaller. However, the CD control will be a major problem.

Phase shift masks may add life to billions of dollars of existing wafer exposure tools, but they add considerable complexity to the mask. There are many structures being evaluated, and it is evident that the two difficult mask levels, window and metal level, will be relatively straight forward. However, some phase shift designs require sub-half micron features on 5x reticles. Other design involve more complex processing. The difficulties with phase shift masks is not only in the mask fabrication but also the CAD layout.

SUMMARY

The IC industry including mask making is very capital intensive. The difference between wafer and mask fabrication is that wafer throughput is measured in wafers per hour at a given machine, while for masks it is measured in hours per mask. As we approach the mid 90s, the cost per hour for mask making equipment will increase, and so will the required hours per substrate.

Industry must recognize that as design rules go down, mask specs get tighter, and data bases get larger, the cost of masks will increase significantly.

QUESTIONS FACING THE MASK MAKER

1. WHEN MUST WE REPLACE OUR EQUIPMENT AND PROCESSES TO MEET FUTURE OPTICAL NEEDS ?

2. WHEN MUST WE GET READY FOR X-RAY MASKS ?

PROCEEDURE

1. SUMMARIZE THE PROBABLE LIMITS & TIME SCHEDULE FOR AVAILABLE OPTICAL TECHNOLOGIES.

2. ESTIMATE OPTICAL MASK SPECIFICATIONS AS A FUNCTION OF TIME.

3. USE INDUSTRY'S RECOMMENDATION FOR WHEN X-RAY WILL BECOME A MAJOR LITHO TOOL

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LITHOGRAPHY TIME SCHEDULE

MIN. WAFER FEATURE	TIME SCHEDULE	LITHO TECHNOLOGY	DEVICE [DRAM]
0.50 um	1990/1	I-LINE CM*	16 M
0.35 um	1992/3	I-LINE PSM** Kr-F	64 M
0.25 um	1994/5	Kr-F PSM** X-RAY	
0.20 um	1996/7	Kr-F PSM** X-RAY	256 M

*CM CONVENTIONAL MASK
**PSM PHASE SHIFT MASK

TABLE 1

JGS
OCT '90

5X RETICLE SPECIFICATIONS

[CONVENTIONAL MASKS]

MASK PARAMETER	YEAR / MIN. FEATURE TOLERANCE	90/91	92/93	94/95	96/97
		0.50	0.35	0.25	0.20
REGISTRATION	X 20 %	0.10	0.07	0.05	0.04
CD-TO TARGET	X 10 %	0.05	0.035	0.025	0.02
CD-RANGE [3 sigma]	X 8 %	0.04	0.028	0.02	0.016
DEFECT SIZE	X 50 %	0.25	0.18	0.13	0.10
EDGE ROUGHNESS	TO BE SPECIFIED	?	?	?	?
SUBSTRATE	QUARTZ	90 mils	250 mils	250 mils	250 mils
MIN. MASK FEATURE	X 4	2.0	1.4	1.0	0.8

ALL DIMENSIONS IN MICROMETERS, EXCEPT WHERE SPECIFIED.

TABLE 2

JGS
OCT '90

IMPROVEMENTS NEEDED TO MEET

1991 TO 1996 PHOTOMASK NEEDS

YEAR	1990/1	1992/3	1994/5	1996/7
REGISTRATION [PATTERN GEN]	UPGRADE OR NEW	NEW [FASTER]	NEW + MULTIPLE WRITE.	
CD CONTROL	IMPROVED PROCESS	NEW MATERIAL & PROCESSING. MORE AUTOMATION. CONCERN WITH EDGE PROFILE		
	IMPROVED CD STANDARDS NEEDED.			
EDGE ROUGHNESS	ACCEPT - ABLE	IMPROVE. MEASURE EVERY MASK.		
DEFECT DETECTION	AVAIL - ABLE	SIGNIFICANT DEVELOPMENT NEEDED.		
SUBSTRATE	QUARTZ - NO DOMESTIC SOURCE.			
METROLOGY	AVAIL - ABLE	WILL NEED IMPROVED CD & LENGTH MEASURING TOOLS.		
PHASE SHIFT MASKS	DEVELOP TECHNOLOGY	ROUTINE USE		
X-RAY MASKS		PREPARE		

TABLE 3

Second Day

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SEMICONDUCTOR MEMORIES IN THE COMING DECADE

Dr. Tsugio Makimoto
Director and General Manager
Semiconductor Design and
Development Center
Hitachi Limited

Dr. Makimoto is Director and General Manager of the Semiconductor Design and Development Center of Hitachi Limited. His current responsibilities include all MOS and bipolar device development operations, including microprocessors, memories, ASICs, linear, digital LSI, etc. He has been with Hitachi since 1959. Dr. Makimoto received a B.S. degree in Applied Physics from the University of Tokyo, an M.S. degree in Electrical Engineering from Stanford University, and a Ph.D. from the University of Tokyo.

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Semiconductor
Industry
Conference

Semiconductor Memories in the Coming Decade

Tsugio Makimoto
General Manager
Semiconductor Design and Development Center
Hitachi, Ltd.

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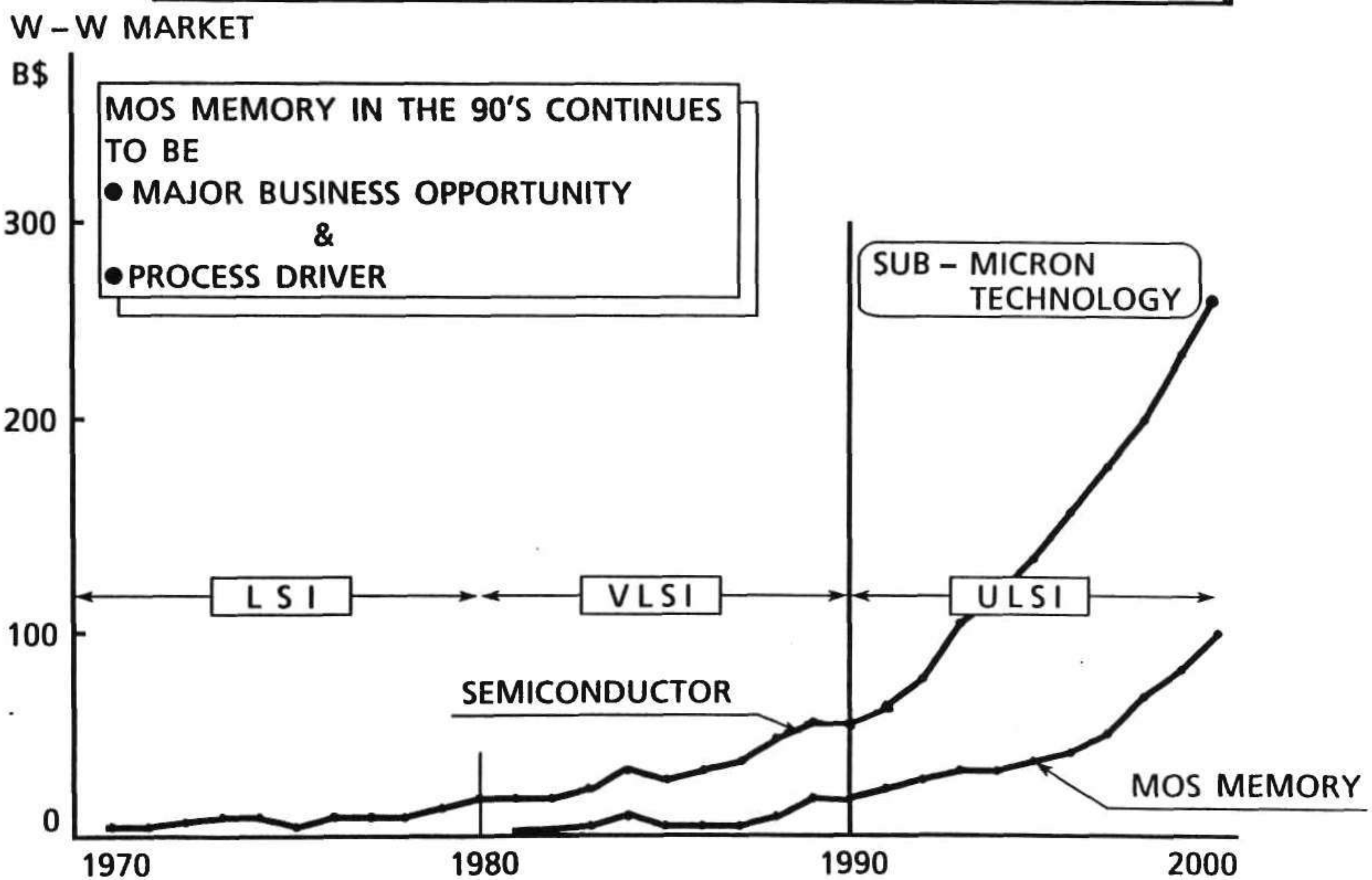
SEMICONDUCTOR MEMORIES IN THE COMING DECADE

TSUGIO MAKIMOTO

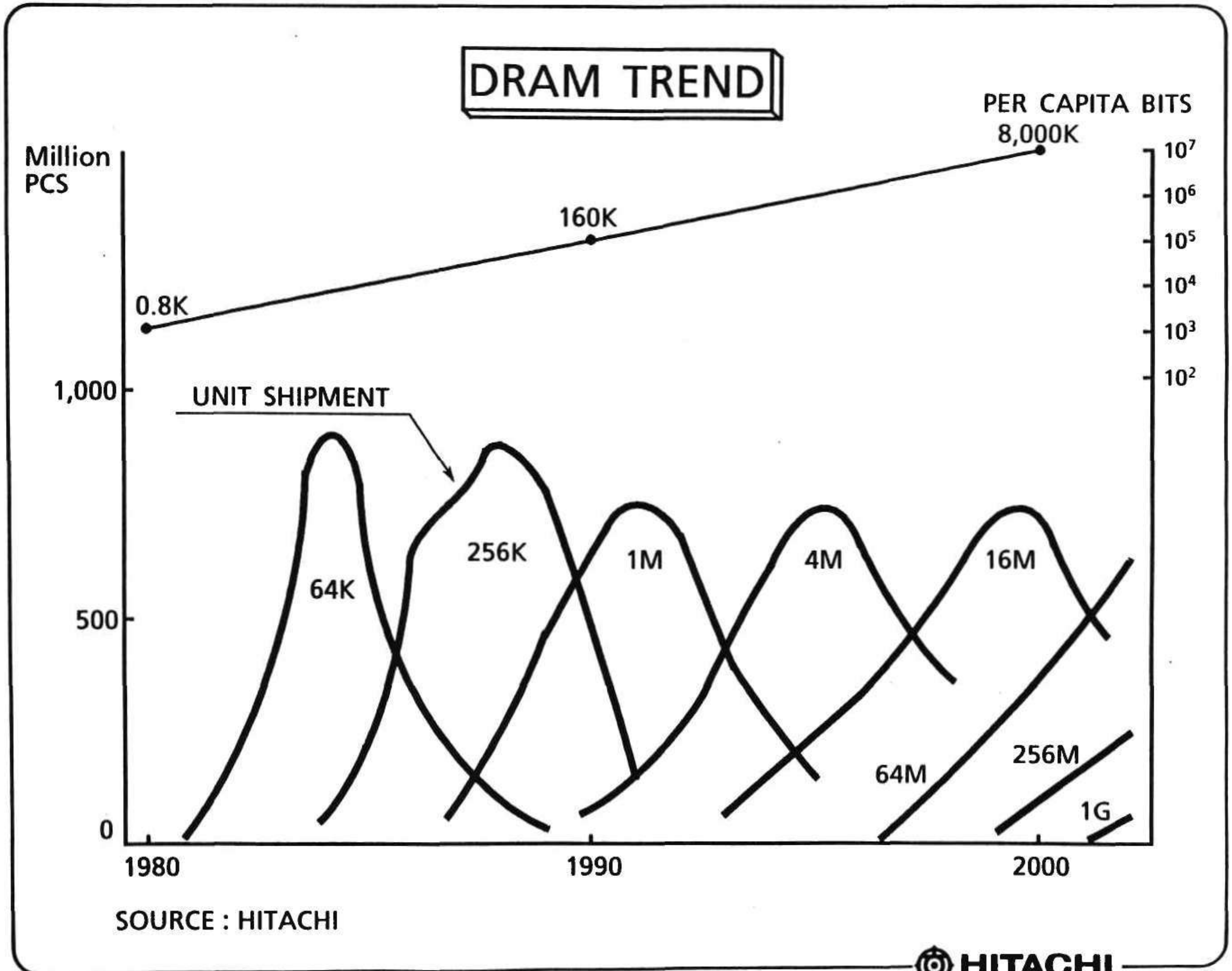
HITACHI

SEMICONDUCTOR AND MOS MEMORY MARKET FORECAST



SOURCE : DATAQUEST, HITACHI

HITACHI



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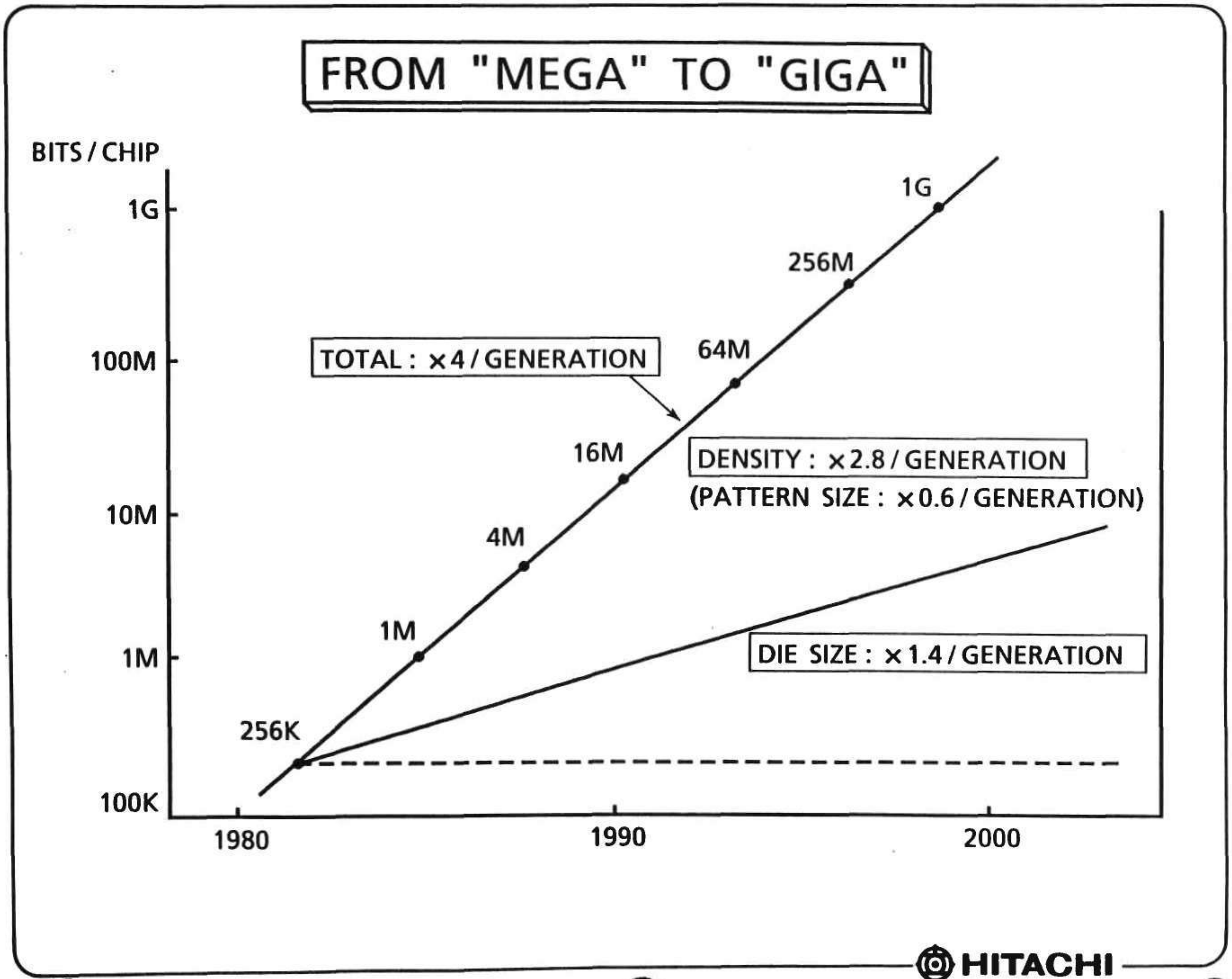

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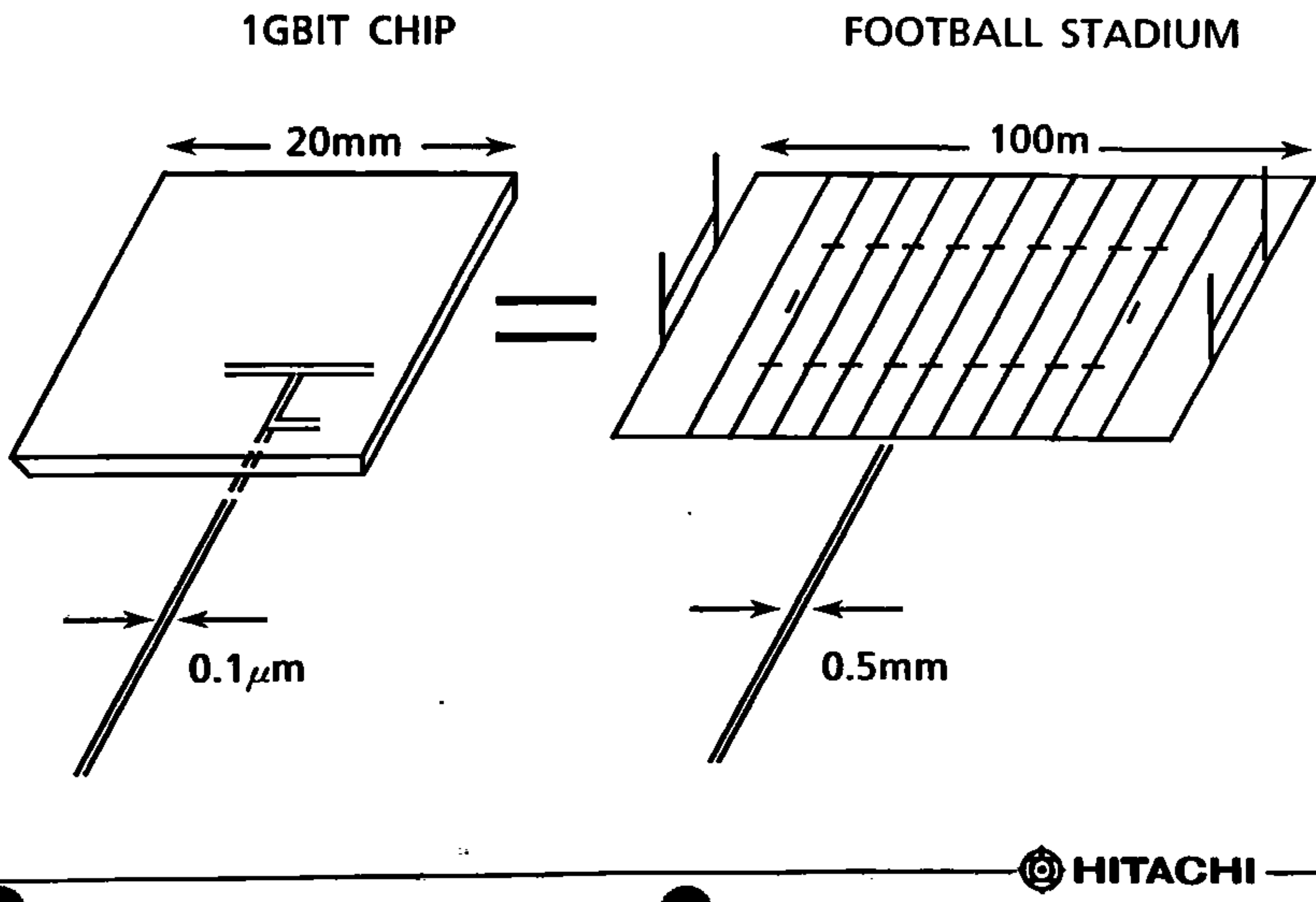
SPACE FACTORS

- SMALLER & LIGHTER -

- DENSITY
- POWER
- PACKAGE

HITACHI

HOW NARROW IS THE LINE WIDTH IN A 1G BIT CHIP?



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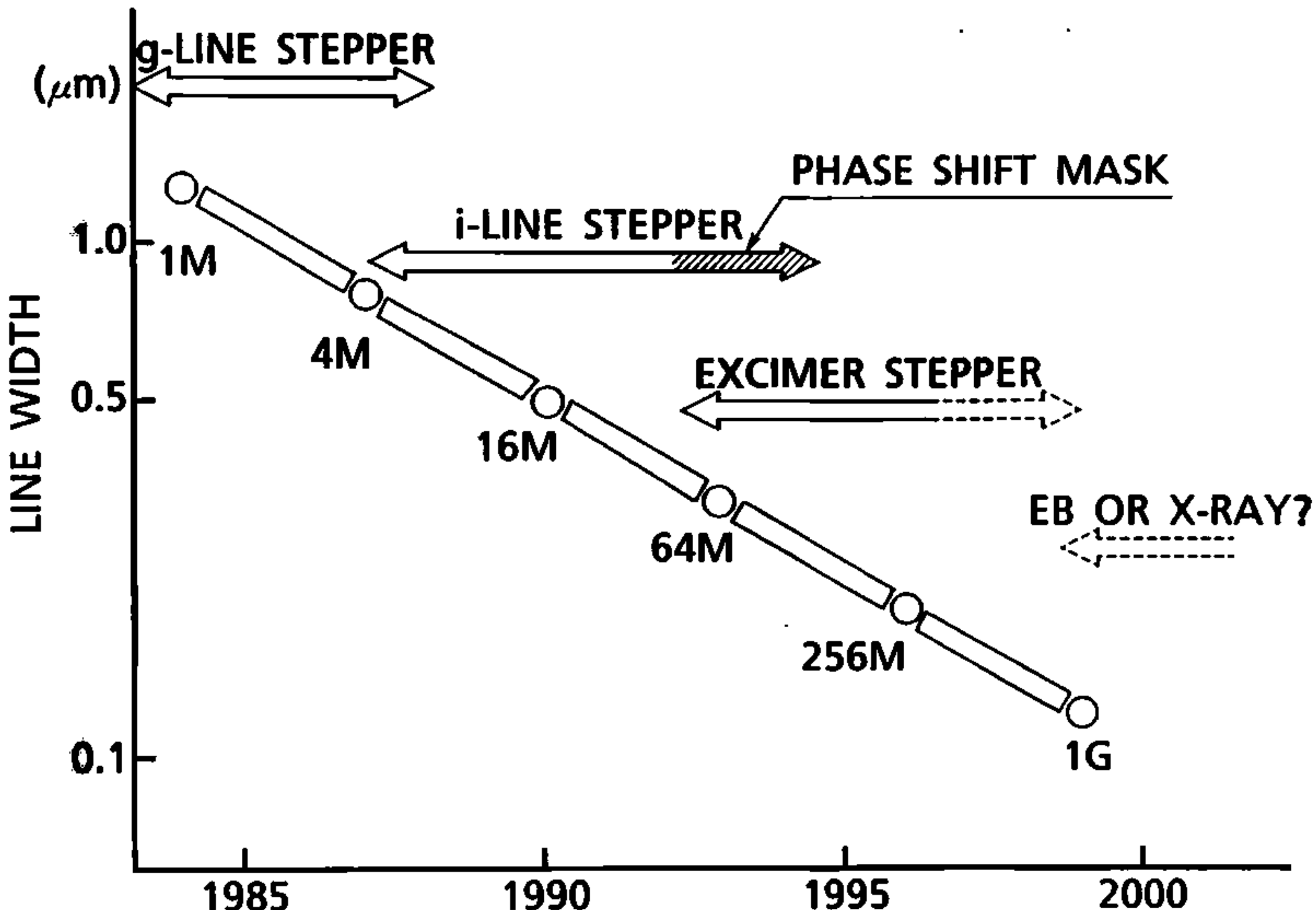
LITHOGRAPHY TECHNOLOGY TREND



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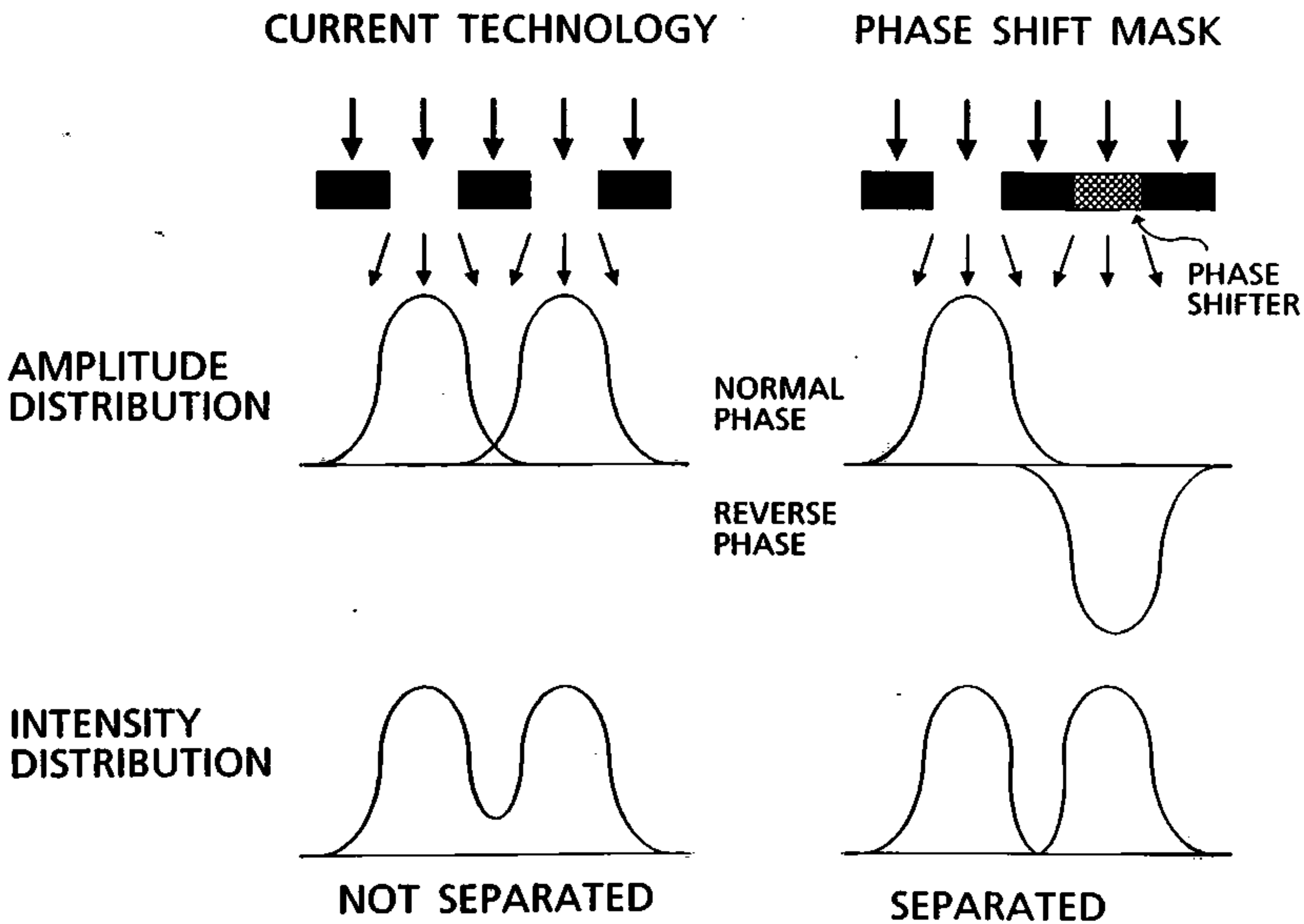
PHASE SHIFT MASK LITHOGRAPHY



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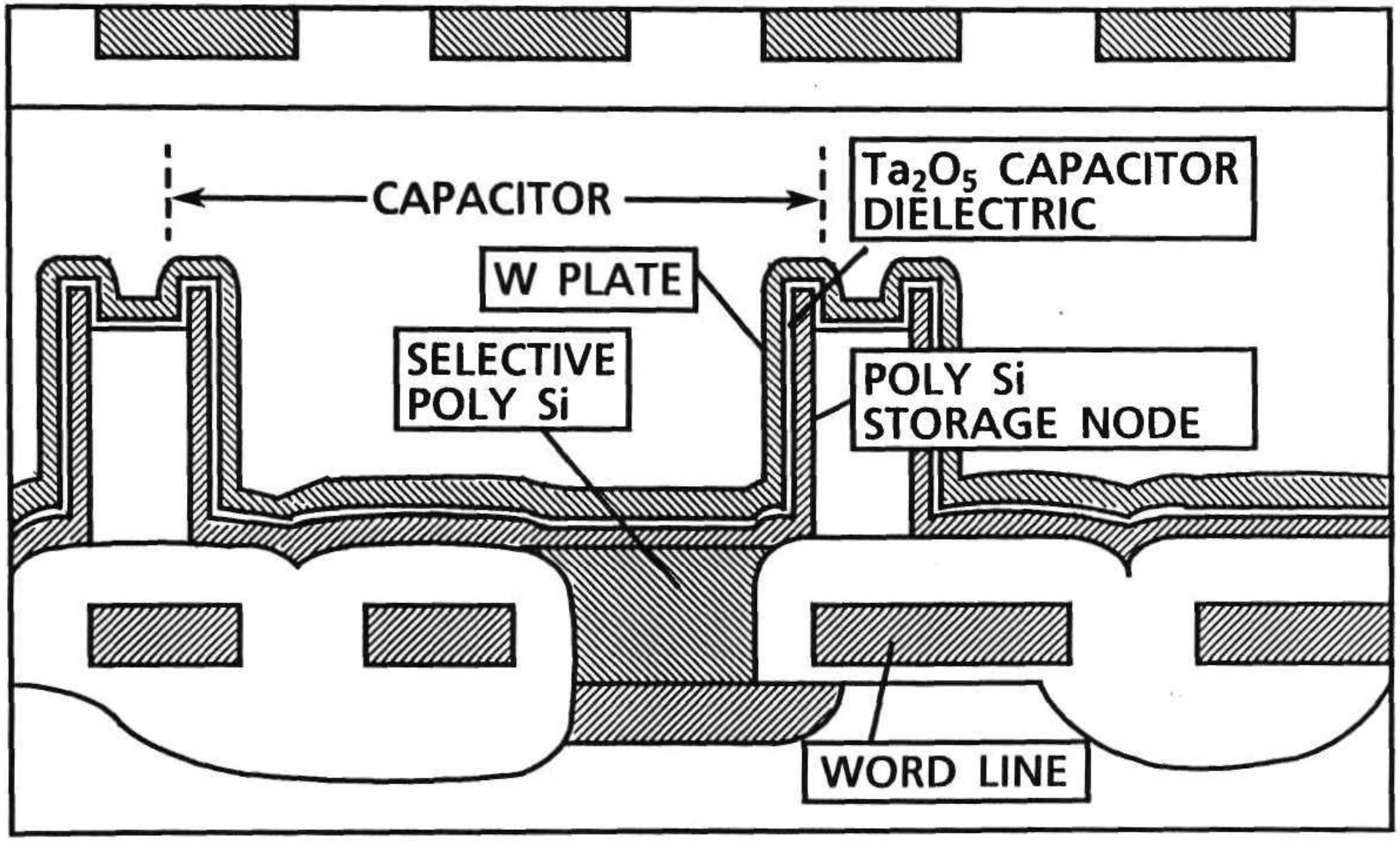
STACKED CAPACITOR CELL FOR 64M DRAM

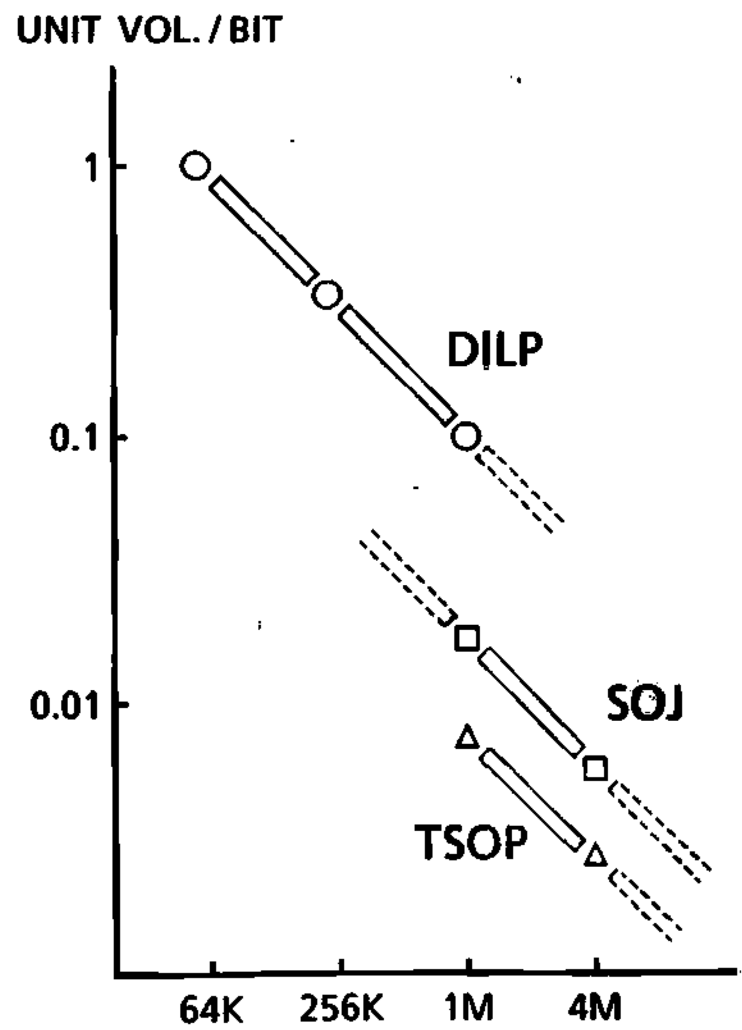


KEY TECHNOLOGIES

- SHIELDED DATALINE
- CROWN CAPACITOR
- Ta_2O_5 DIELECTRIC

HITACHI

MEMORY PACKAGE TECHNOLOGY TREND



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MORE INTELLIGENCE

- FUNCTIONALITY
- PROGRAMMABILITY
- SPEED

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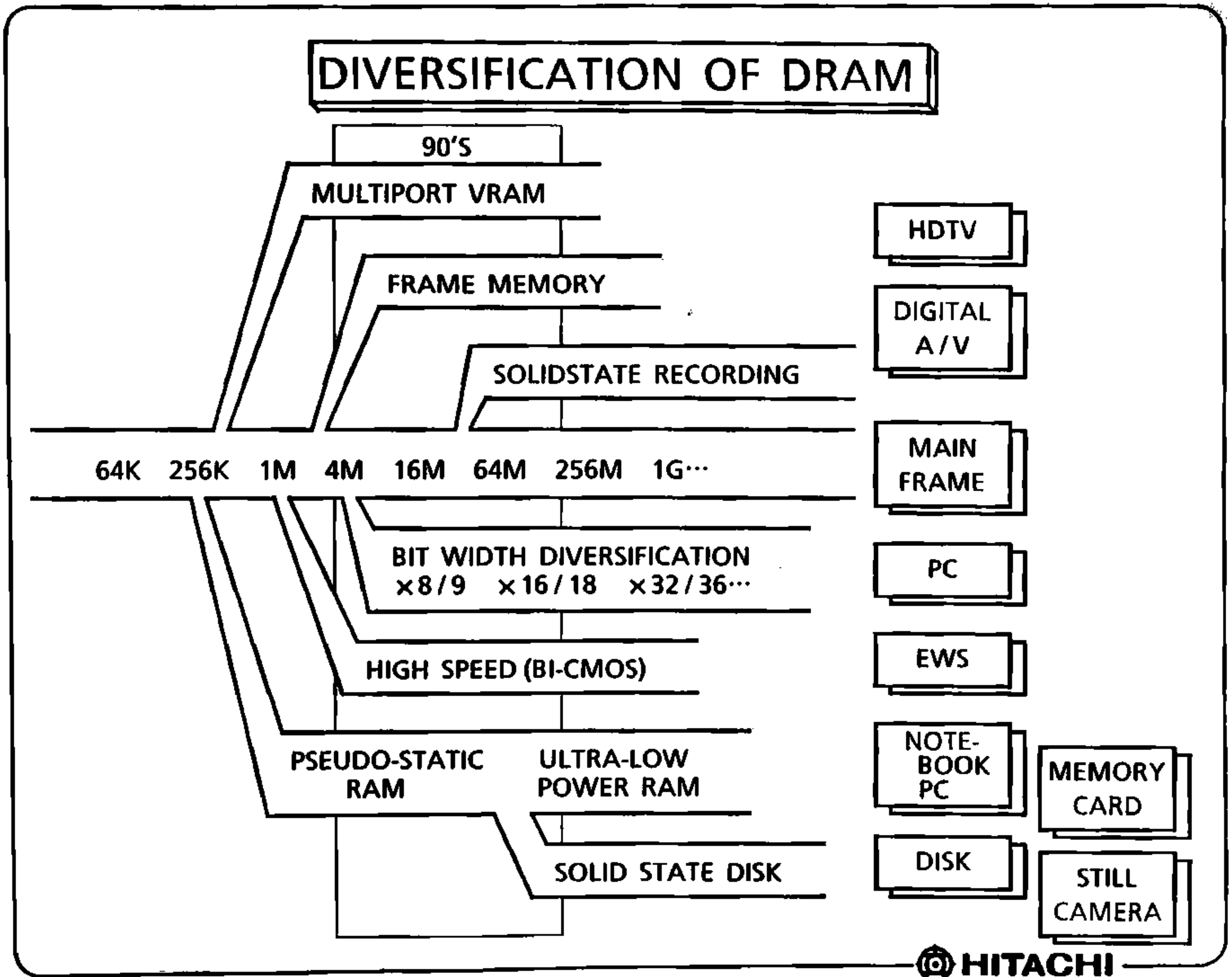
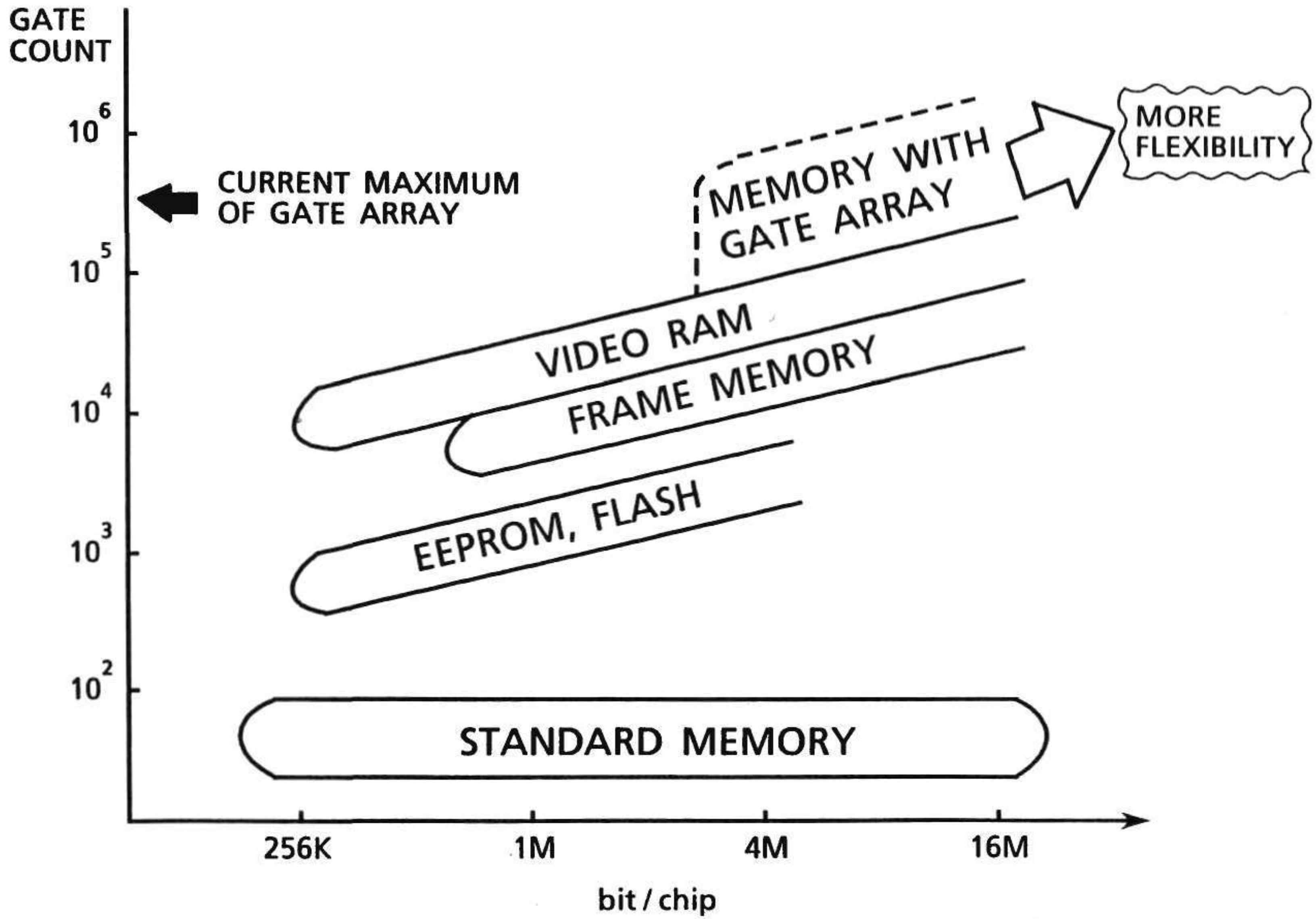

DIVERSIFICATION OF DRAM
90'S
MULTIPORT VRAM
FRAME MEMORY
SOLIDSTATE RECORDING
64K 256K 1M 4M 16M 64M 256M 1G…
BIT WIDTH DIVERSIFICATION
×8/9 ×16/18 ×32/36…
HIGH SPEED (BI-CMOS)
PSEUDO-STATIC RAM
ULTRA-LOW POWER RAM
SOLID STATE DISK
HDTV
DIGITAL A/V
MAIN FRAME
PC
EWS
NOTE-BOOK PC
MEMORY CARD
DISK
STILL CAMERA
HITACHI

LOGIC GATES BUILT IN SPECIAL MEMORIES



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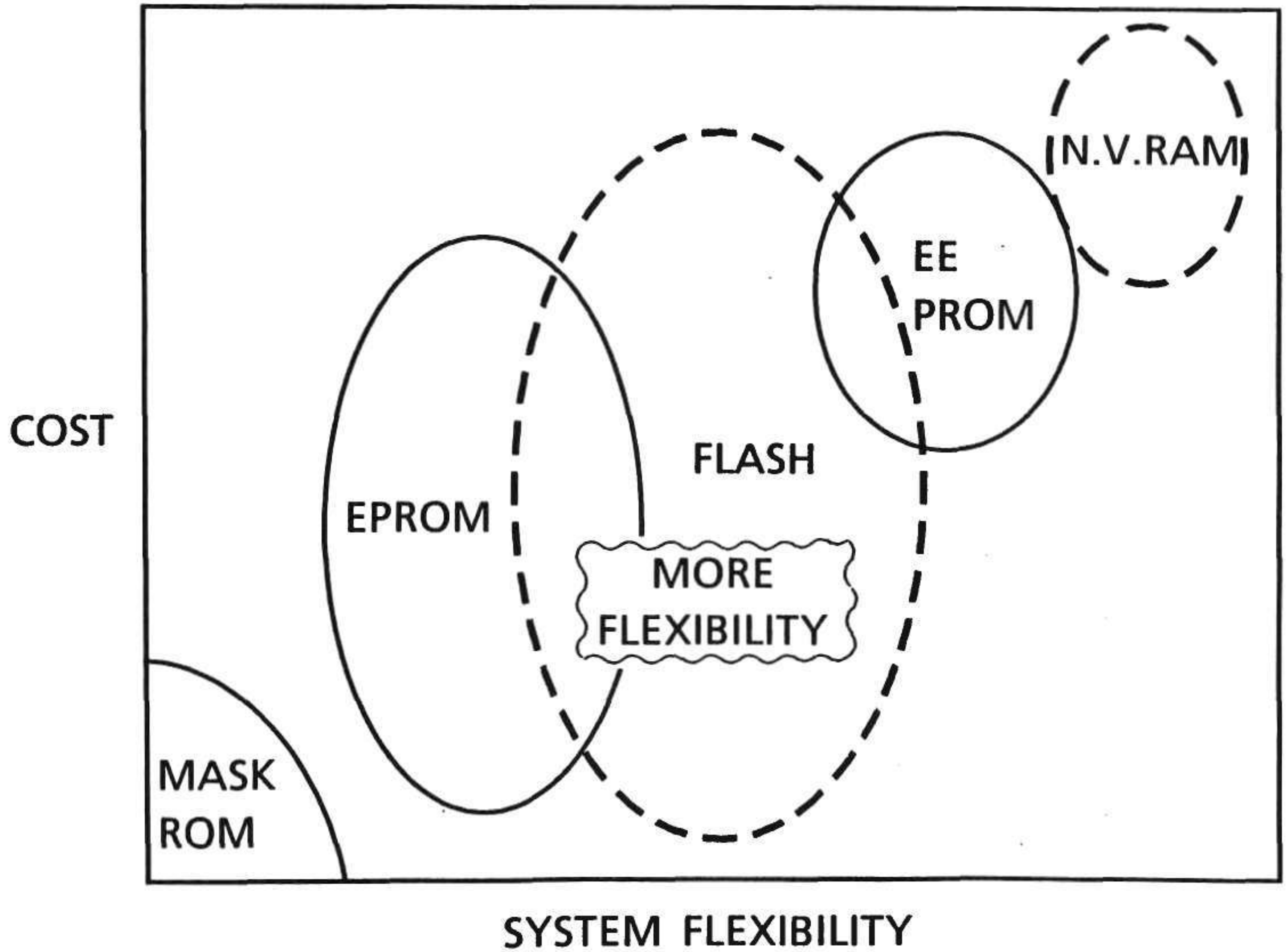
FIELD PROGRAMMABILITY
– NON VOLATILE MEMORIES –



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COST ISSUES

- INVESTMENT
- DIE SIZE
- YIELD

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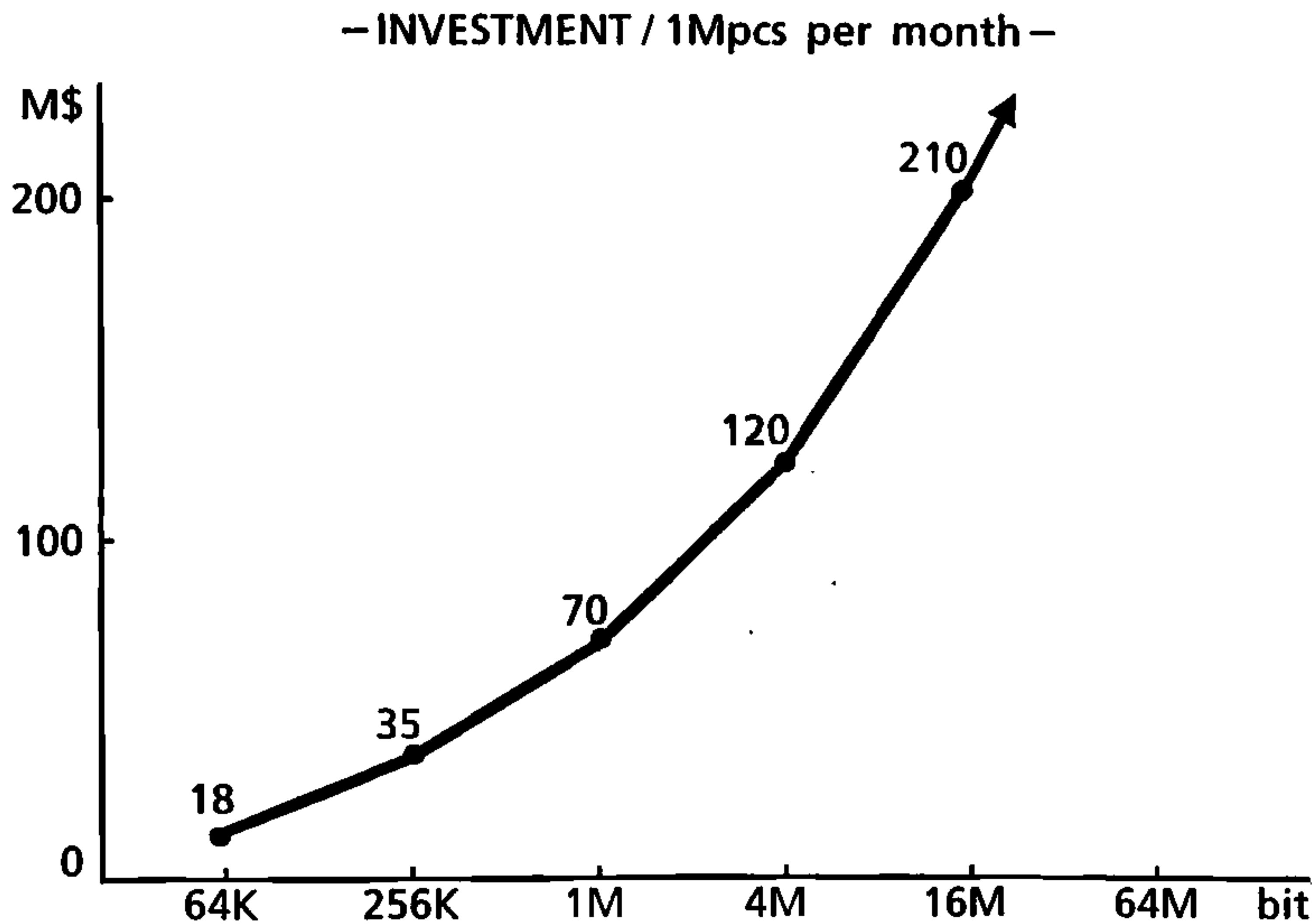
INVESTMENT TREND



SOURCE : NRI

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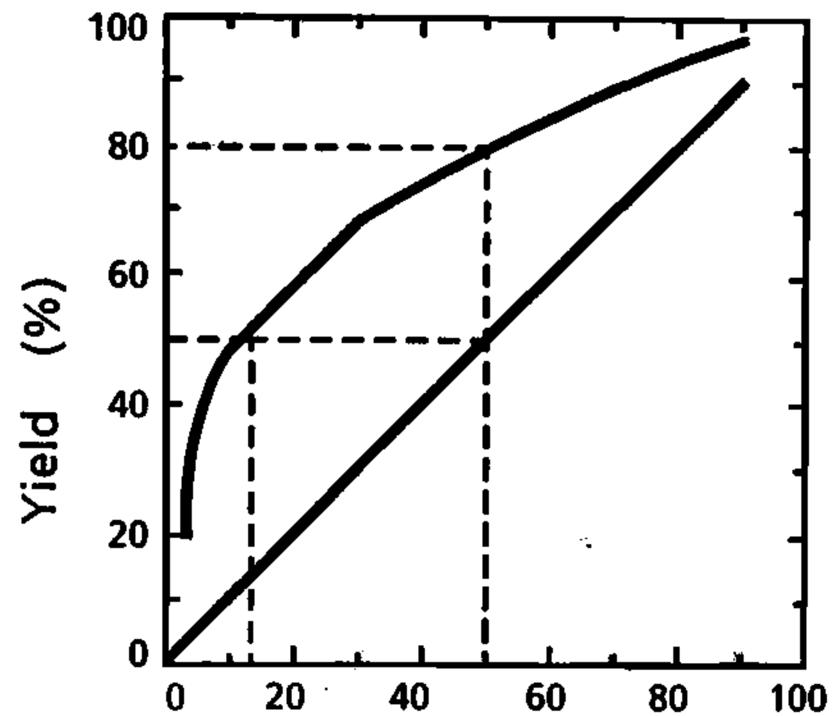
YIELD



$$\text{Yield} = [\text{AUF}] \times \text{EXP}(-A \times D) \times R$$

AUF : Area Usage Factor
D : Defect Density
R : Redundancy

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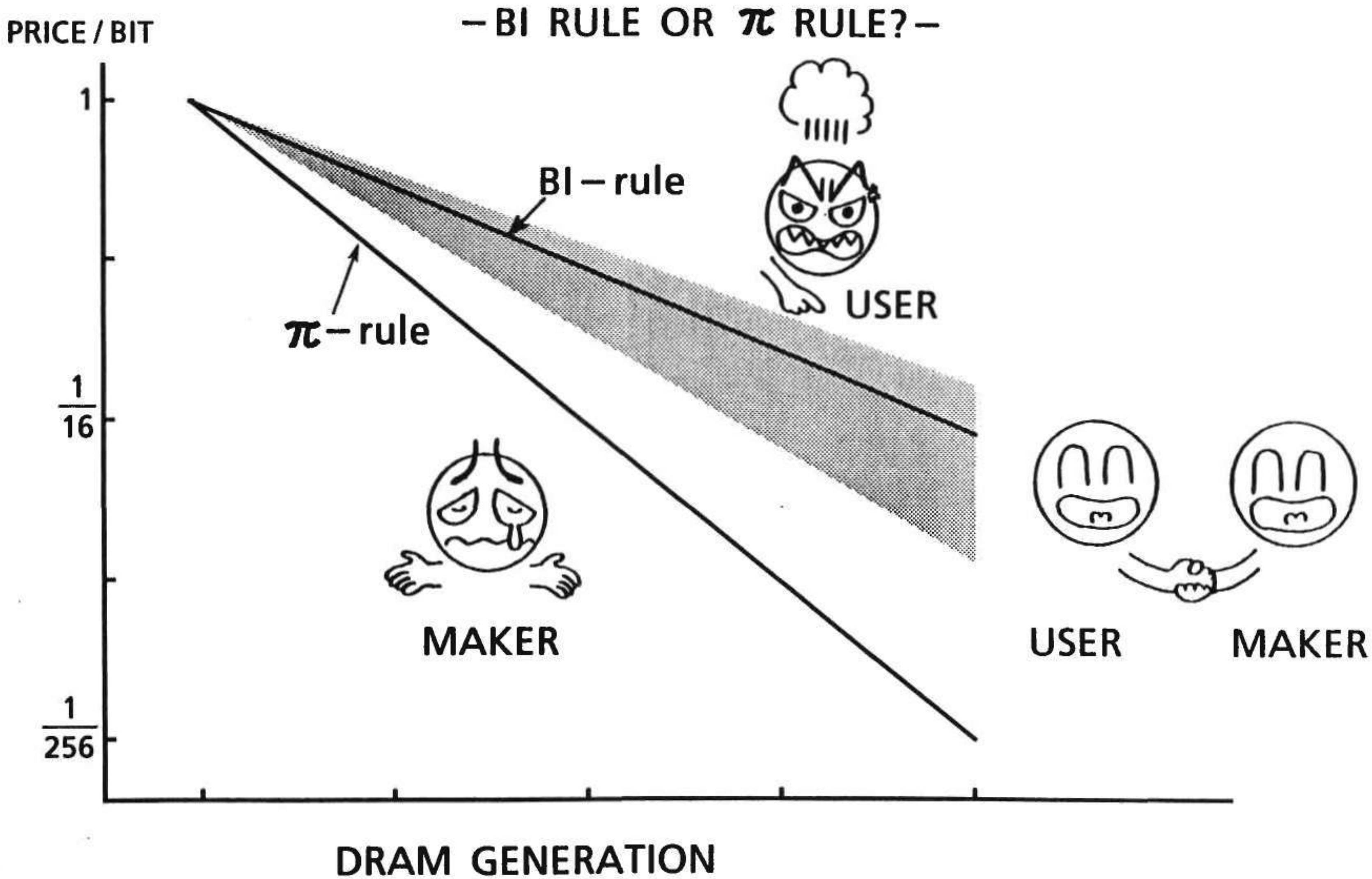
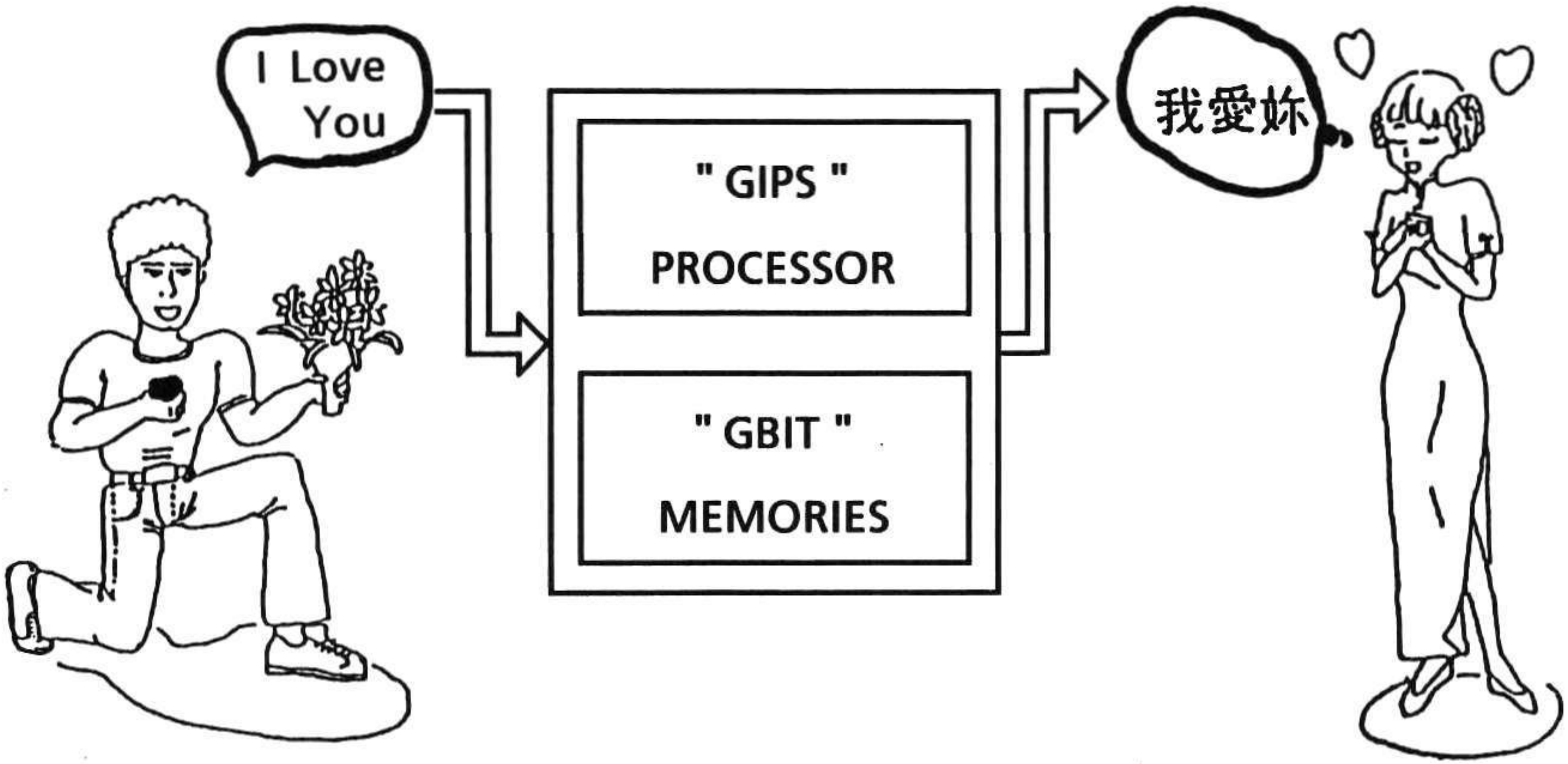
COST TREND



- BI RULE OR π RULE? -
PRICE / BIT
1
1/16
1/256
BI - rule
π - rule
USER
MAKER
USER
MAKER
DRAM GENERATION
HITACHI

EXAMPLE OF " GIGA " ULSI SYSTEM IN 2000

PORTABLE ELECTRONIC TRANSLATOR



HITACHI

CONCLUSION

- ***FIGURE OF MERIT OF SEMICONDUCTOR TECHNOLOGY***

$$\frac{\textit{MORE INTELLIGENCE}}{\textit{SPACE} \times \textit{COST}}$$

- ***HEAVY INVESTMENT FOR R&D AND MANUFACTURING***

  COOPERATION THROUGH PARTNERSHIP

- ***IS THERE PROFITABILITY ?***

  RIGHT MIXING OF π-RULE & BI-RULE IS THE KEY

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EUROPE: REDRAWING THE SEMICONDUCTOR BORDERS

Jonathan P.V. Drazin
Senior Industry Analyst
European Components Group
Dataquest Europe Ltd.

Dr. Drazin is a Senior Industry Analyst for Dataquest's European Components Group, European Semiconductor Application Markets Service, based at Denham, England. Prior to joining Dataquest, Dr. Drazin was a Principal Research Engineer for STC Technology Limited in Harlow, where he worked on VLSI design and semiconductor process characterization. Previously, he was a postdoctoral fellow at Imperial College, London, where he researched e-beam lithography. Dr. Drazin has a B.Sc. degree in Physics and a Ph.D. in Semiconductor Materials from Imperial College, London. He also holds an M.B.A. degree from City Business School, London, and is a Member of the Institution of Electrical Engineers.

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Conference

Europe: Redrawing the Semiconductor Borders

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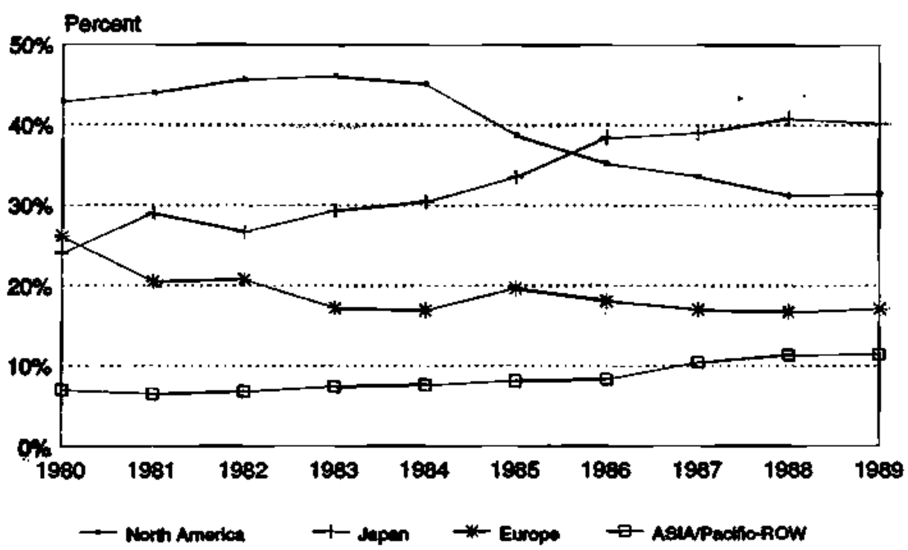
EUROPE'S SEMICONDUCTOR BORDERS

AGENDA

- Europe in worldwide perspective
- 1992 - its impact
- European trade policy
- Standards and applications
- Eastern Europe

WORLDWIDE SEMICONDUCTOR CONSUMPTION BY REGION



Source: Dataquest

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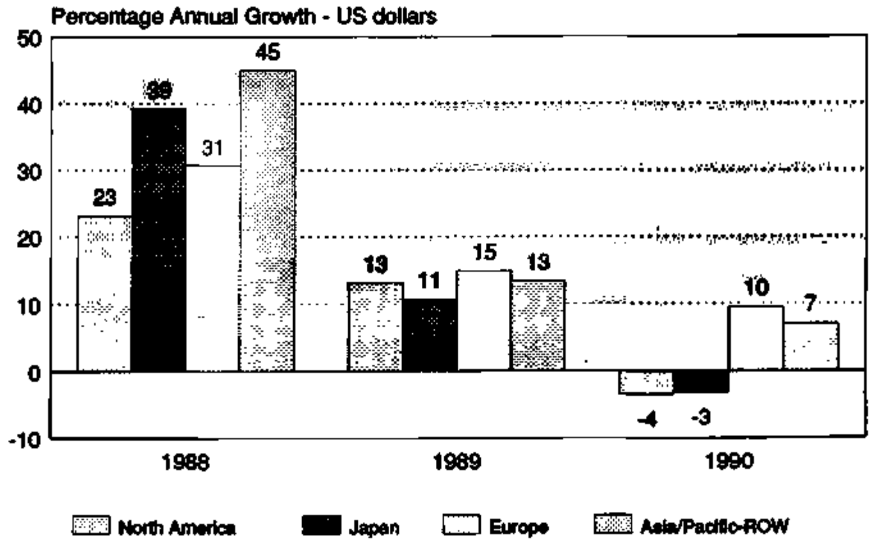
WORLDWIDE SEMICONDUCTOR CONSUMPTION GROWTH BY REGION



Source: Dataquest

RECENT GROWTH - KEY FACTORS

- Foreign investment in production:
  - Just-in time
  - Yen appreciation
  - EC local content
- Strong US operations in computers:
  - IBM (UK, F, I)
  - Compaq (UK)
  - Hewlett-Packard (UK, WG)
  - NCR (WG)
  - Sun (UK)
  - Tandon (Aus)

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JAPANESE PRODUCTION - COMPUTERS

RECENT DEVELOPMENTS

Manufacturer	Product (Location)	Commenced
Toshiba	PCs (WG)	April '90
Mitsubishi (Apricot)	PCs (UK)	March '90
Fujitsu (ICL)	Mainframes (UK)	July '90
NEC	PCs (?)	tba

Source: Dataquest

JAPANESE PRODUCTION (continued)

- Activities not confined to computers alone
- Strong presence in printers, cellular, consumer and facsimile
- Consumer (prod. lines)
  - TV (22)
  - VCR (32)
  - CD (13)
  - microwaves ovens (8)

Source: Dataquest

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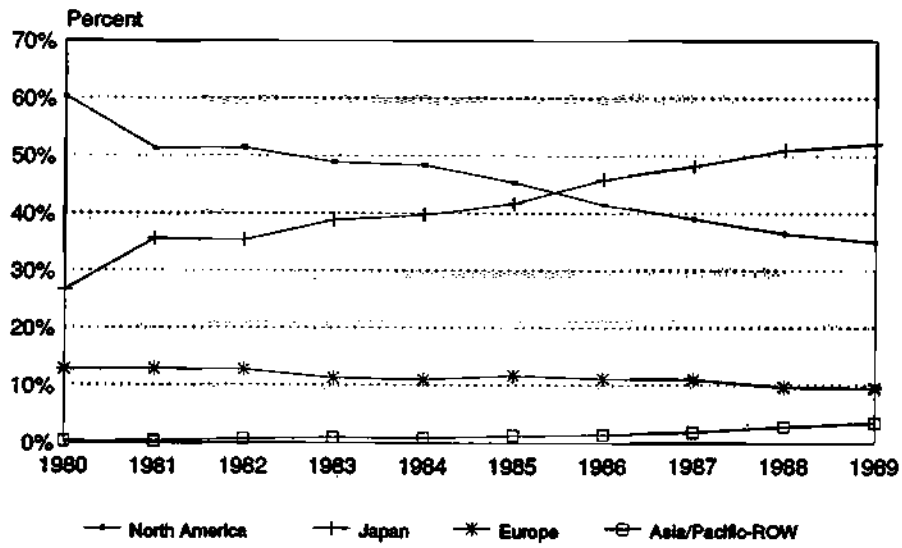
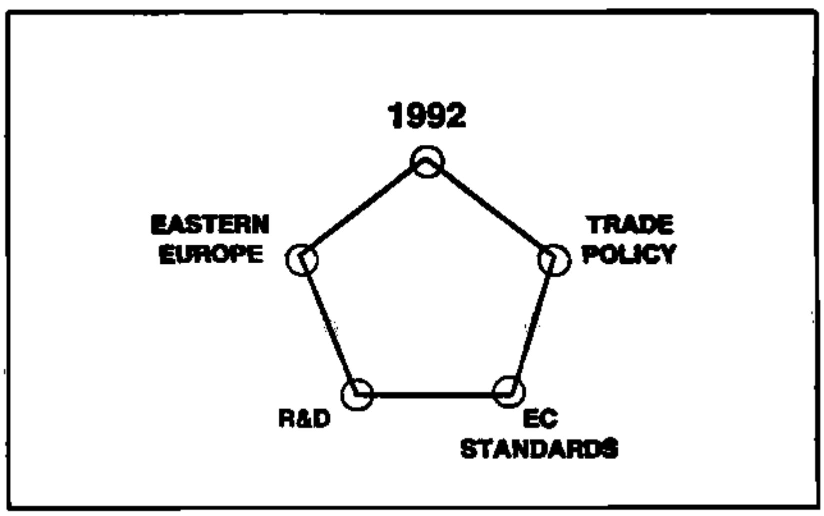
WORLDWIDE SEMICONDUCTOR MARKET SHARE BY VENDOR ORIGIN



Source: Dataquest

THE EUROPEAN PENTAGON



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PRE-1992 PREDICAMENTS

- National protectionism
- Players confined to small markets
- Single Market - 279 measures
- Semiconductors affected by many factors

1992 - TELECOMS POLICY

- Telecoms run by monopolistic PTTs
- 1992 will weaken their hold
- Liberalization of equipment suppliers
- Global companies growing from national ones

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1992 - EUROPE RESTRUCTURING

Siemens/GEC	Plessey
Siemens	Nixdorf
Siemens	Bendix
Bull	Zenith Data
Thomson-CSF	Philips Defense
Aerospatiale/Thomson-CSF	Sextant Avionics
GEC	Ferranti Defense
Philips	Bang & Olufsen

Source: Dataquest

SEMICONDUCTORS - RESTRUCTURING

Waiting for a Bang?

- SGS-Thomson acquires Inmos
- Low activity in MOS memory
- High investment compared to revenues
- Collaboration in production inevitable

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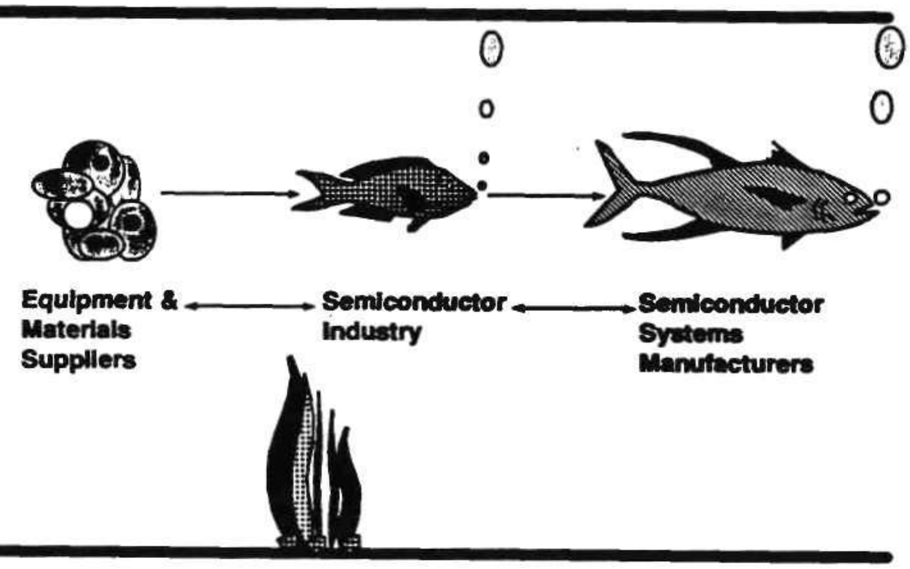
THE EUROPEAN ECOSYSTEM



THE EUROPEAN ECOSYSTEM

MEASURE	Semiconductor Equip./Materials	Semiconductor Manufacturers	Electronic Equip. Manufacturers
TRADE			
Diffusion Rule	○	○	●
Import Duty	●	●	●
Reference Price		●	○
Local Content		○	●
Anti-dumping		○	●
R&D			
JESSI	●	●	○
Eureka		○	●
Esprit	○	●	●
STANDARDS			
ETSI		○	●
CEN		○	●
CENELEC			●

● mainly affected ○ partially affected

Source: Dataquest

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REFERENCE PRICE

- Voluntary DRAM price agreements
- Commenced April 1990
- Preventive measures - preferable to antidumping duties
- Few criticisms (but price fluctuation is a problem)
- EPROM prices to follow

EC DIFFUSION RULE

- Widely misunderstood
- "Made in Europe" if diffusion occurs in EC
- Does not change duties paid
- Targeted at equipment manufacturers faced with local content requirements

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EUROPEAN R&D

- Shift from national to European R&D
- Coordinated across EC and EFTA
- JESSI ($4bn) directed to semiconductors
- JESSI ties into other programs:
  - Eureka
  - Esprit
  - RACE
  - BRITE

EUROPEAN STANDARDS

- ETSI to develop pan-European standards
- Will lead to major semiconductor markets in:
  - digital cellular (GSM)
  - cordless telephony (DECT)
  - personal communications (PCN)
  - high-definition TV (HD-MAC)
- Large single market - good for everyone

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EASTERN EUROPE

- Pillar of least certainty
- Sharply diminished output hampers ability to purchase
- Highest priority: technologies that enable industrial efficiency
- Telecommunications: next after food?

EASTERN EUROPE: A HIERARCHY OF NEEDS

Source: Dataquest

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EAST EUROPEAN JOINT VENTURES AND TRADE AGREEMENTS

(announcements June - August '90)

	Hungary	Poland	Czeck.	Sov. Un.	E. Germ.	Other	TOTAL
Consumer	2			1	4	2	9
Computer				1	3		4
Telecoms	6	3	3	4	4	1	21
Other electronic	1	1		1	1		4
Semiconductor	2			1			3
TOTAL	11	4	3	8	12	3	41

Source: Dataquest

EASTERN EUROPE (continued)

TELESTROIKA

- Very low on infrastructure
- Cannot wait to build own industry - must import
- Contracts going predominantly to Western European firms
- Already driving Western (not Eastern) European semiconductor markets

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CLOSING REMARKS

- Strong market growth in the 1990s
- Semiconductors: close cooperation is the route to success
- Selling into Europe: Borders not Barriers!
- A Single Market, but...
  - over 20 languages
  - many cultures
  - long conflicting holidays

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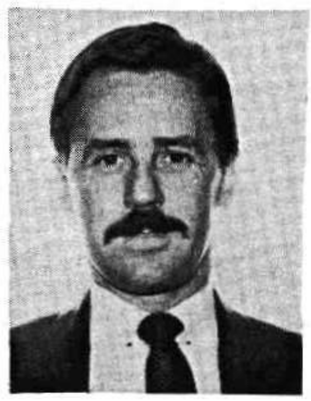
PRICES, PROFITS, PROJECTIONS:
IS THIS MARKET TOO DRAM VOLATILE?



David L. Angel
Vice President and Director
Semiconductor Industry Service
Dataquest Incorporated

David Angel is Vice President and Director of Dataquest's Semiconductor Industry Service. He is responsible for managing and directing all of the company's semiconductor research activities worldwide. Prior to joining Dataquest, Mr. Angel was Managing Director of DQ Alliances, a high-technology investment banking firm affiliated with Dataquest. While at DQ Alliances, he initiated and completed numerous strategic alliances, joint partnerships, acquisitions, and start-up company fundings, the majority of which were related to the worldwide semiconductor industry. Mr. Angel has 25 years of experience in the semiconductor and venture capital fields, having served as President, Executive Vice President, and Chief Operating Officer of several high-technology startup companies. He was founder and senior partner of Almaden Venture, a seed fund and venture capital consultation firm. Earlier, he was founder of Signetics Memory Systems and the Director of American Microsystems Inc.'s (AMI) Image Technology Center. He is considered an expert in semiconductor lithography. Mr. Angel has authored more than 50 publications relating to high technology, funding new businesses, strategies for success in high technology, and management of high-technology companies. Mr. Angel received a B.S. degree in Premedical Studies and Chemistry from Marietta College and did graduate work in Physical Chemistry and Law at Williams College and LaSalle University.

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October 8-9, 1990
Monterey, California

Semiconductor
Industry
Conference

Prices, Profits, Projections: Is this Market Too DRAM Volatile?

David Angel
Group Vice President
and Director of Worldwide Research
Semiconductor Components Group
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THE YEAR WAS 1972

- Richard Nixon was in the White House
- China was opened up
- Supreme Court ruled that the death penalty was unconstitutional
- The Miami Dolphins were the first professional football team to go undefeated in a season
- And . . .

THE YEAR WAS 1972

The memory market was flat

Plan: Assemble the best minds and develop a solution

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SOLUTION

Cut the price!

1,024 bits for $10.24

DRAMs – THE FUTURE

- The news is good
- Memories will increase their pervasiveness throughout all forms of society
  - Personal communicators
  - Nonrotating storage
  - "Smarter" homes, automobiles
  - Custom computers
  - Upper limit may be the memory capacity of the human brain – 1 x 10^{15} bits
  - Information is doubling every four years – all of that information needs to be stored

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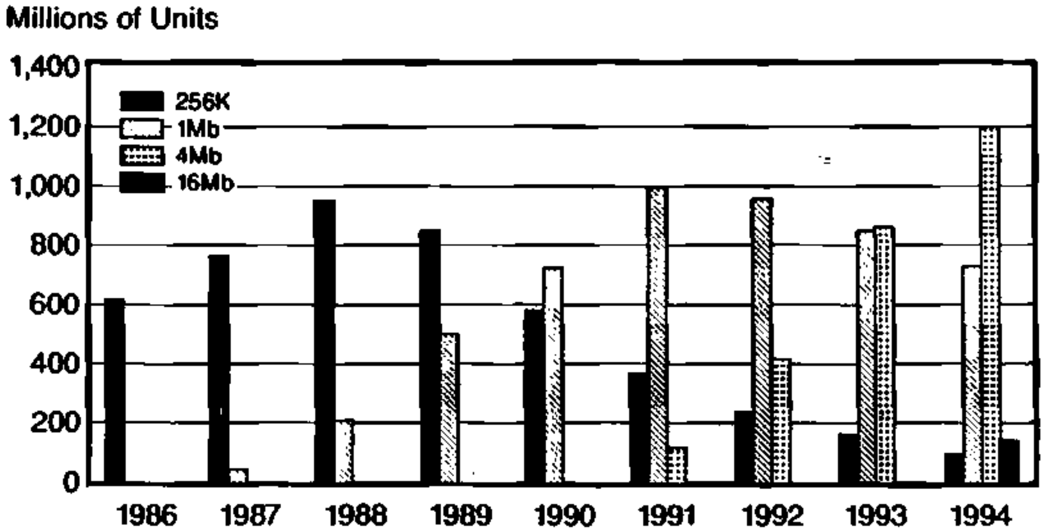
256K, 1Mb AND 4Mb DRAMs

Units Actual/Forecast



Source: Dataquest

	Revenue	Multiple
64K DRAM	$ 1.6B	–
256K DRAM	$ 9.9B	6.2
1Mb DRAM	$24.9B	2.5
4Mb DRAM	$41.8B	1.7
16Mb DRAM		

Source: Dataquest

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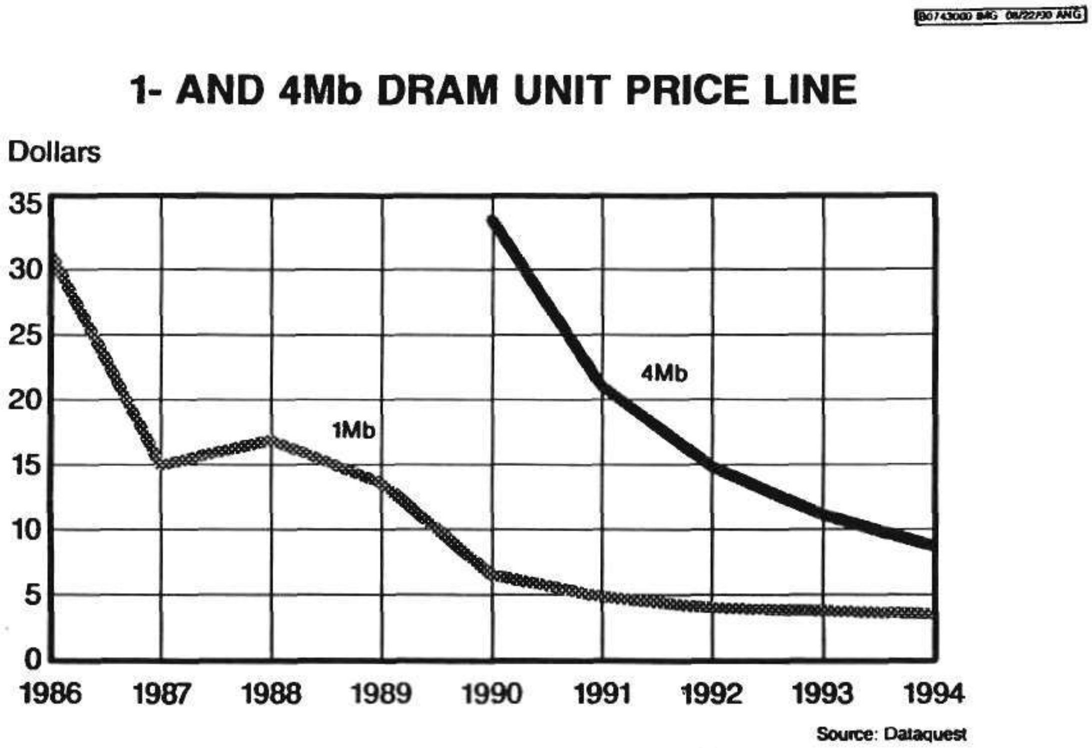
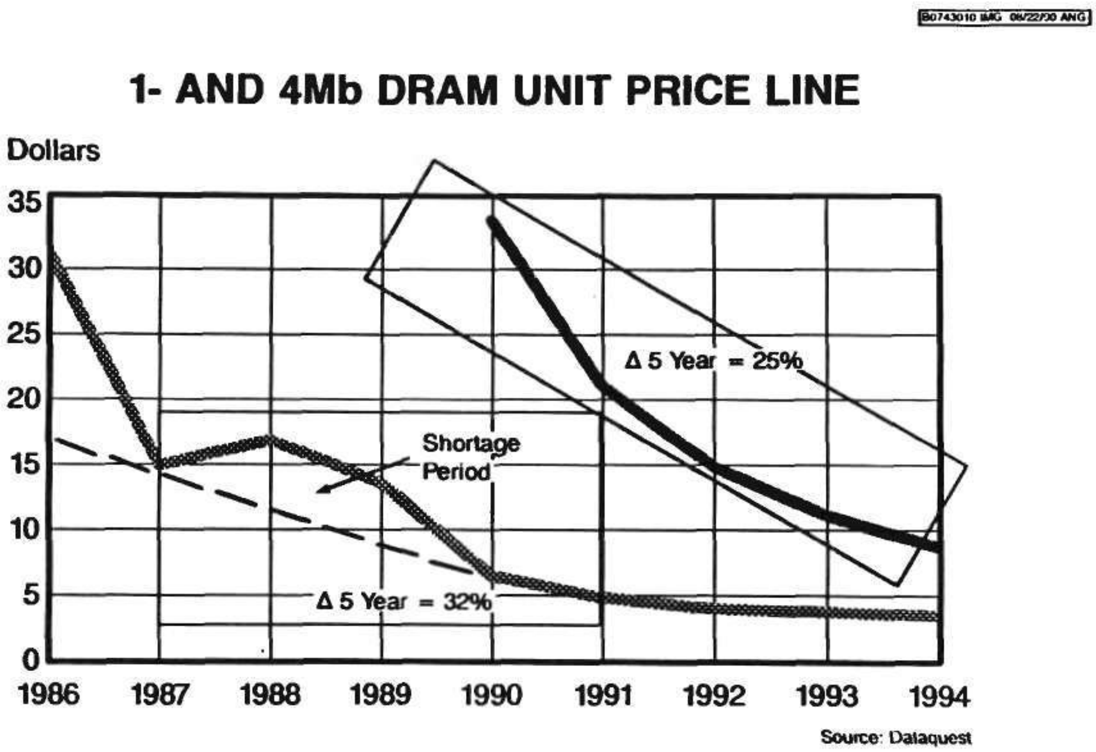
1- AND 4Mb DRAM UNIT PRICE LINE



1- AND 4Mb DRAM UNIT PRICE LINE



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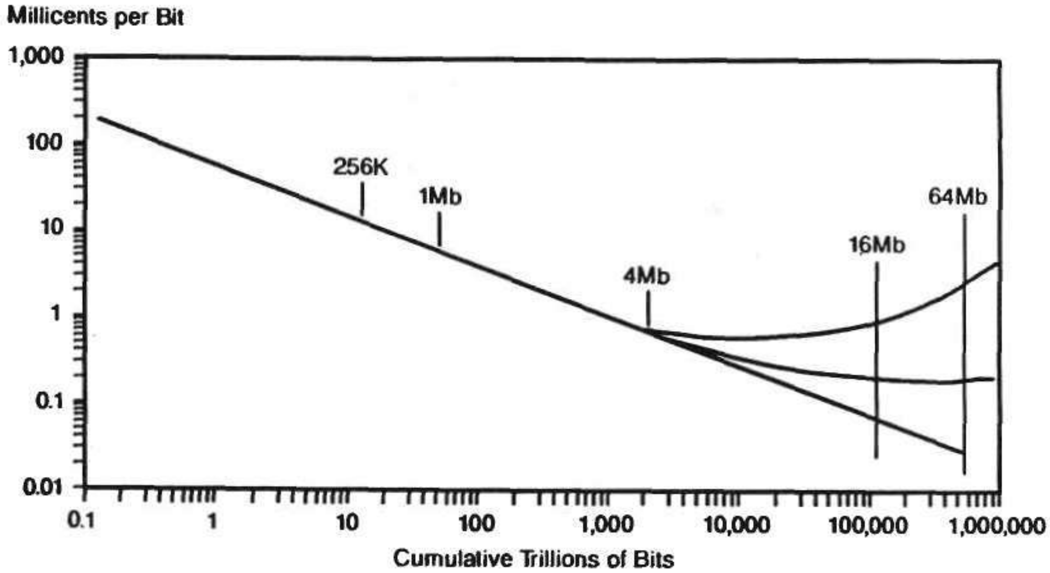
0743011 IMG 08/20/90 ANG

PRICE LEARNING CURVE

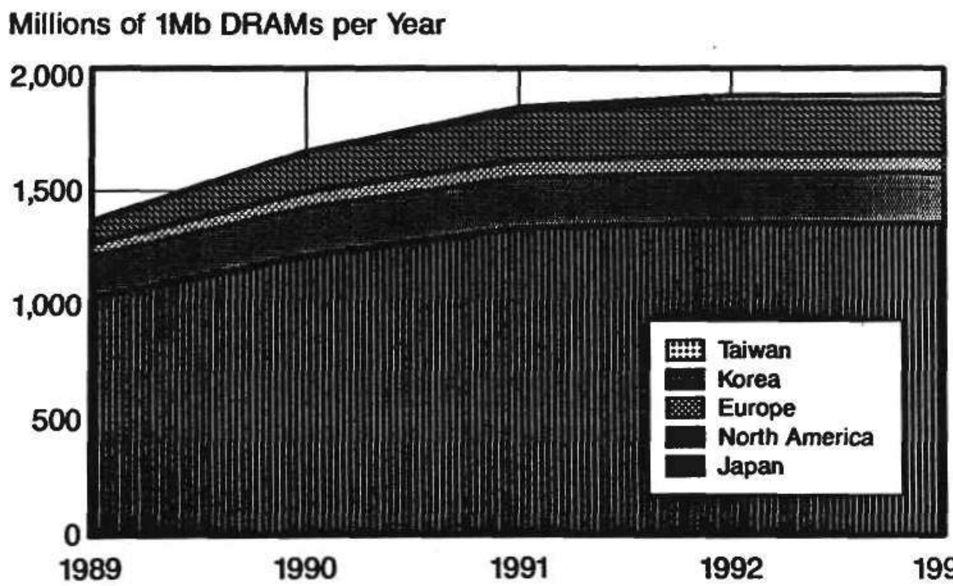
DRAMs



Source: Dataquest

B0743012 IMG 08/22/90 ANG

1Mb DRAM INSTALLED CAPACITY



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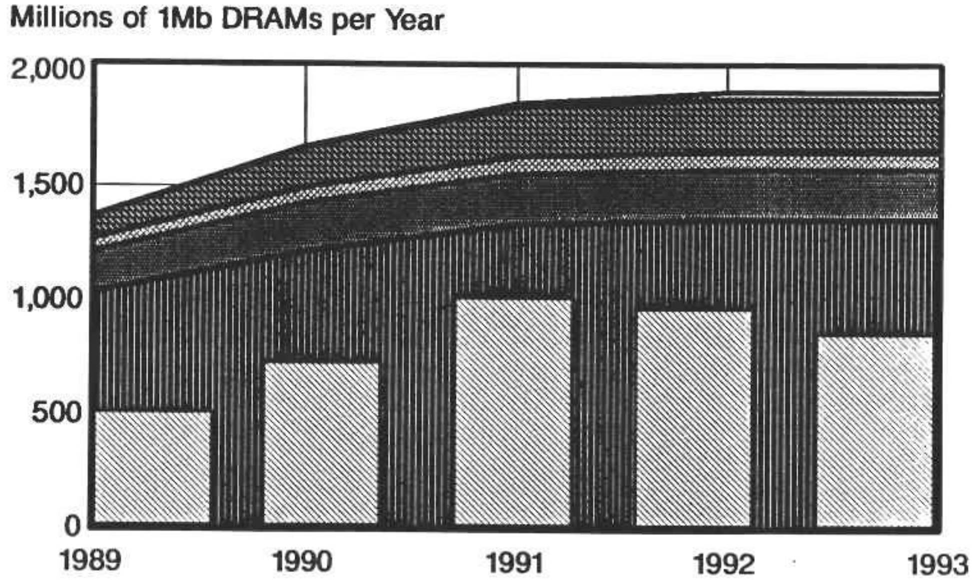
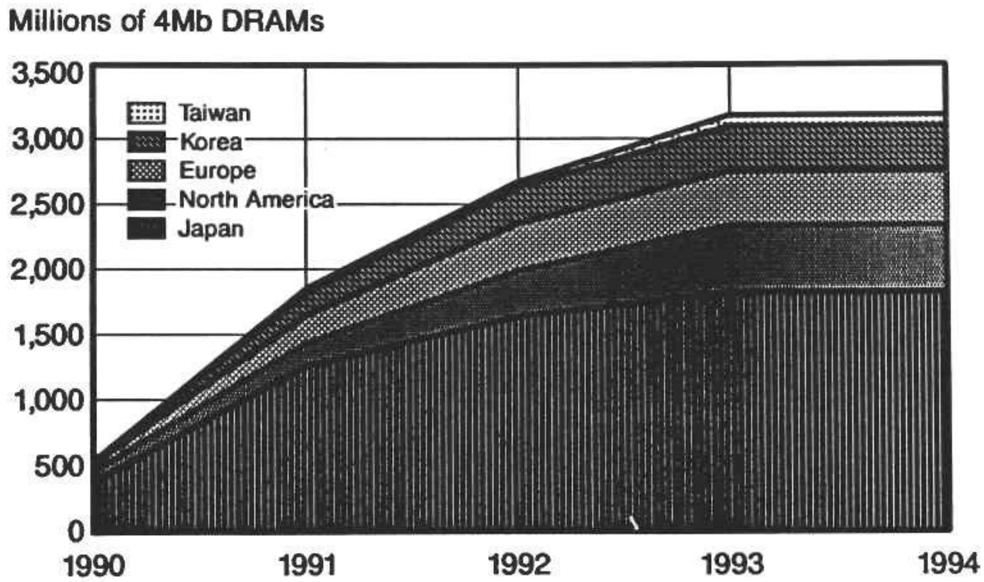


Source: Dataquest

4Mb DRAM INSTALLED CAPACITY



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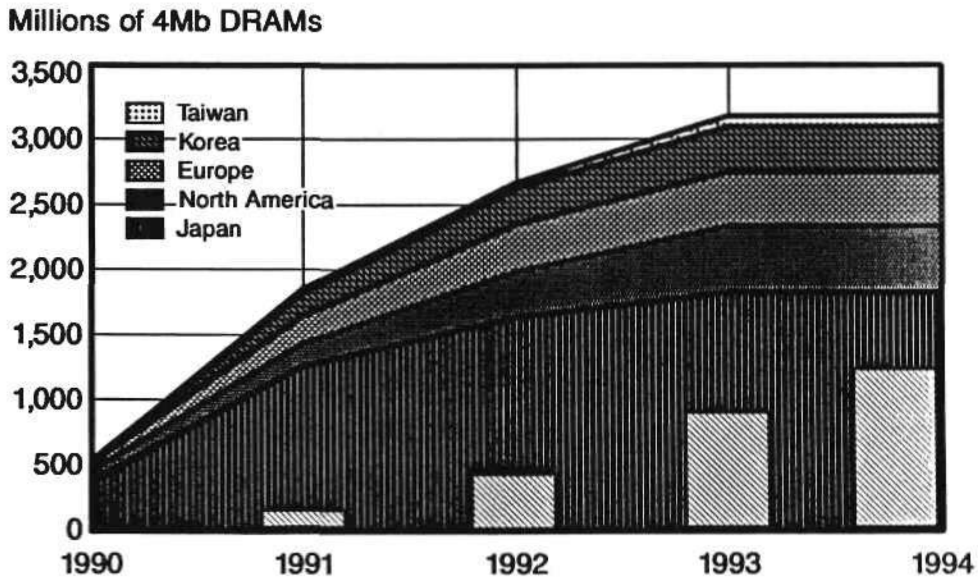
B0743015 IMG 08/22/90 ANG

4Mb DRAM INSTALLED CAPACITY



Source: Dataquest

0743016 IMG 08/22/90 ANG

WHAT ARE THE ISSUES?

- Is it a buyer's market for years to come?
- Can anybody make any money?
- Will the 4Mb part be short-lived in favor of the potentially more profitable 16Mb part?
- Has the industry reached a point where the capital investment cost is so high that the slope of the learning curve will turn upward?

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PRICES, PROFITS, PROJECTIONS:
IS THIS MARKET TOO DRAM VOLATILE?

David Sear
Vice President
Standard Products Operations
Integrated Circuits Division
Fujitsu Microelectronics, Inc.

David Sear is Vice President of Standard Products Operations of the Integrated Circuits Division at Fujitsu Microelectronics, Inc. He is responsible for the division's Standard Products Operations consisting of memory, standard logic, analog, microcomputer, and communication products, memory modules, and IC cards. Prior to joining Fujitsu, Dr. Sear was Vice President of Marketing, and Sales and Engineering for ICI Array Technology. Before this, he founded Perex Inc., a computer peripherals company specializing in tape drives. Dr. Sear received a B.S.E.E. in computer science and a Ph.D. in Physics from the University of London, England.

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Prices, Profits, Projections: Is this Market Too DRAM Volatile?

David Sear
Vice President
Fujitsu America

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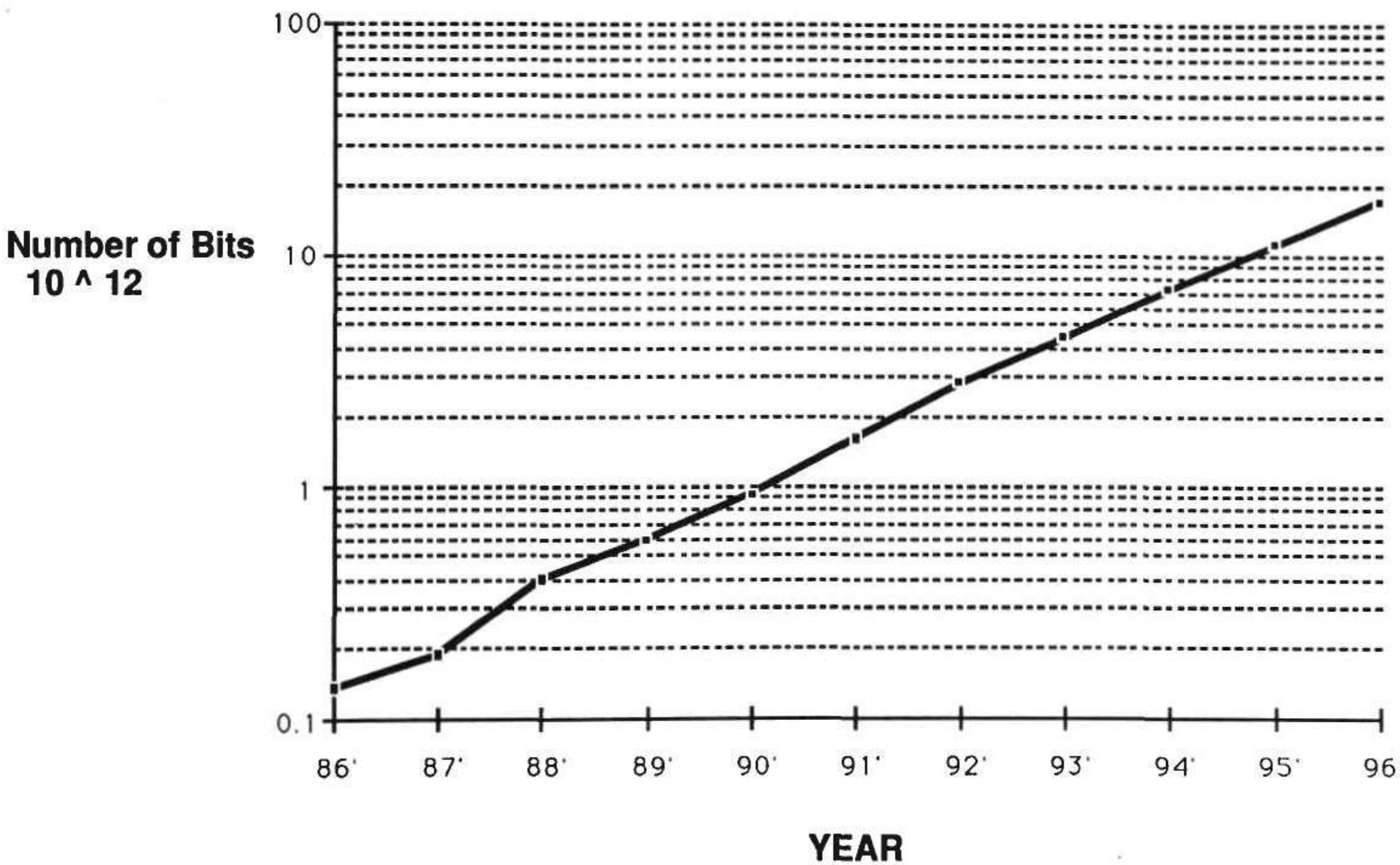
THE CHANGING ECONOMICS OF DRAMs

PRESENTED BY DR. DAVID SEAR
FUJITSU MICROELECTRONICS, INC.

FUJITSU

LONG TERM DRAM DEMAND



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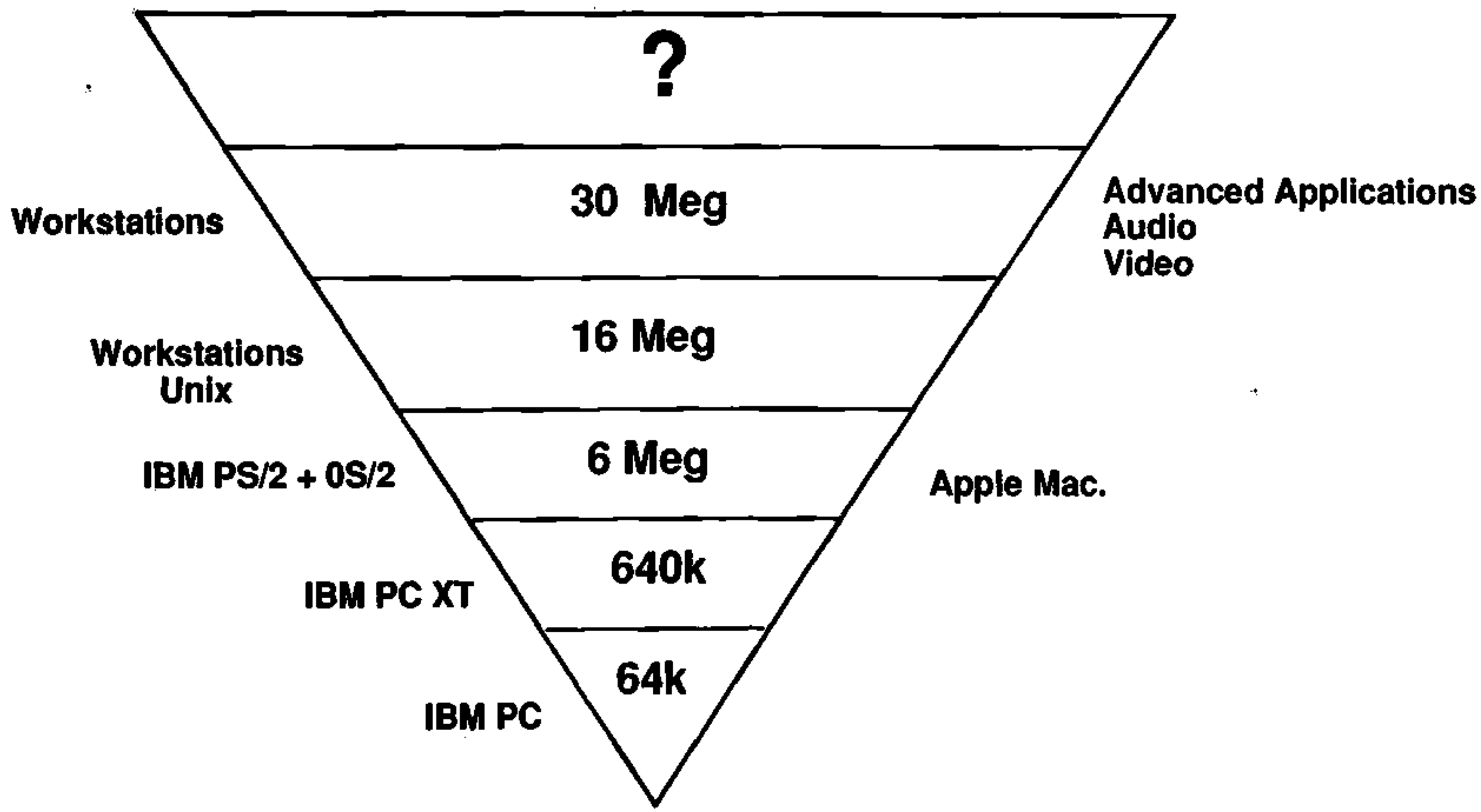
DRIVING FACTORS BEHIND MEMORY USAGE

- Proliferation of personal computers changing the way we perform our day to day tasks
- Evolution from "terse" computer syntax to user friendly interfaces which require complex software thereby driving memory consumption
- High resolution graphics ⟶ Real time graphics ⟶ Color
- Easy to use man machine interface
- Sound and real time NTSC/PAL video
- Dramatic reduction in cost per bit of memory over the last 10 years has resulted in the following statement

> "Software developers treat memory as though it were <u>infinite</u> and <u>zero</u> cost".

INCREASE OF MEMORY USEAGE IN COMPUTERS



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DRAM PRICE EXPERIENCE CURVE

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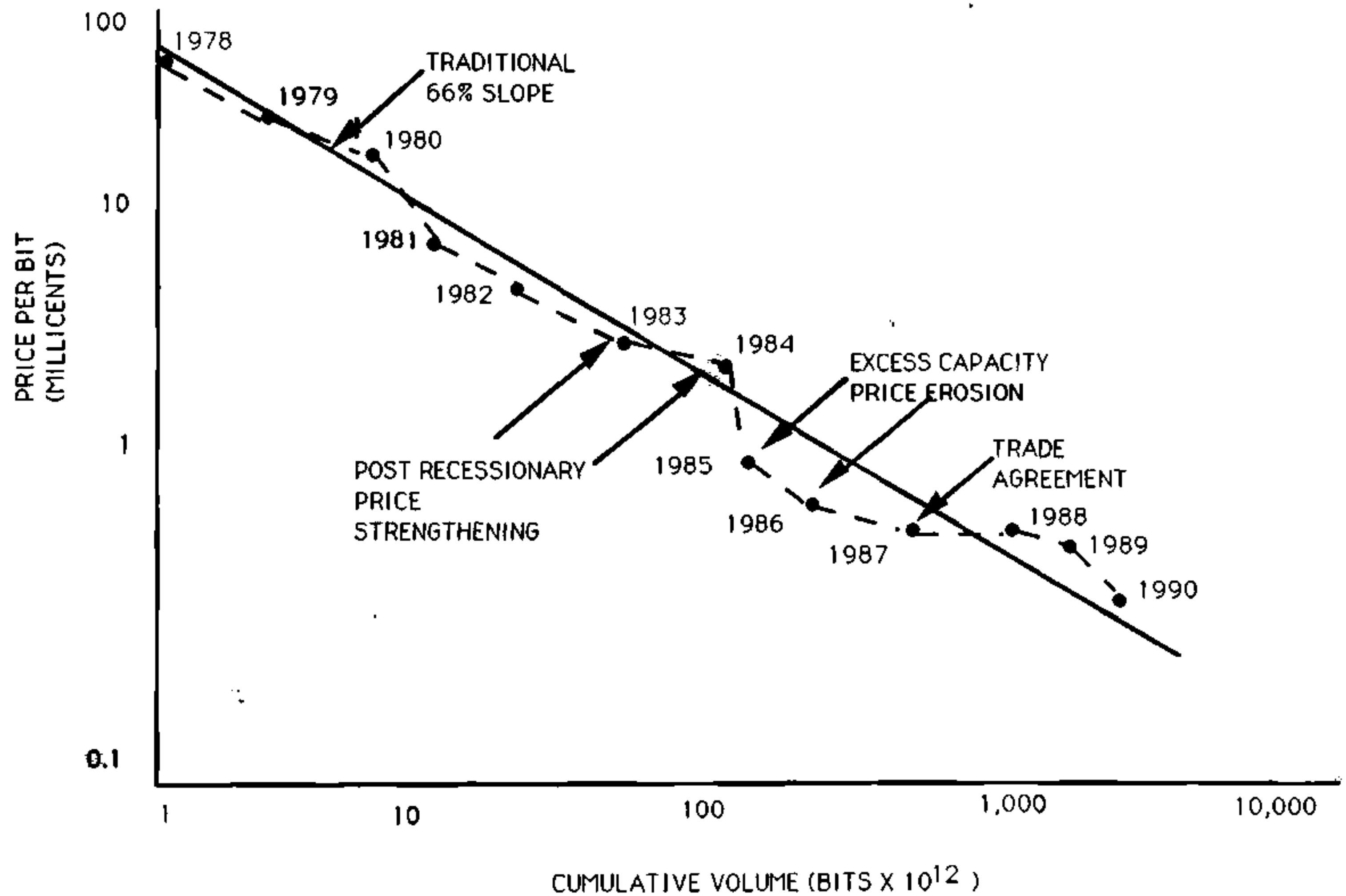

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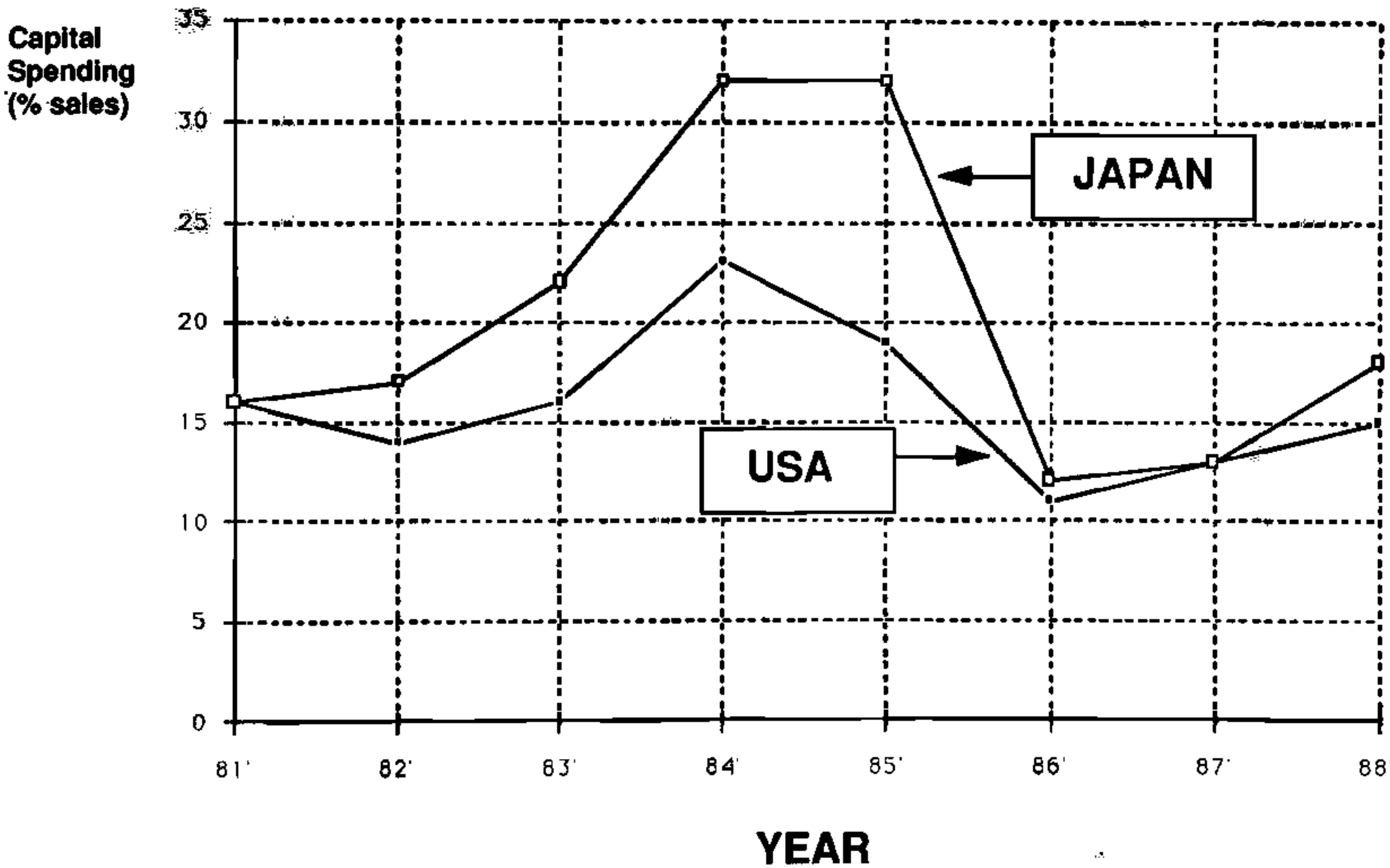
SEMICONDUCTOR INDUSTRY CAPITAL SPENDING



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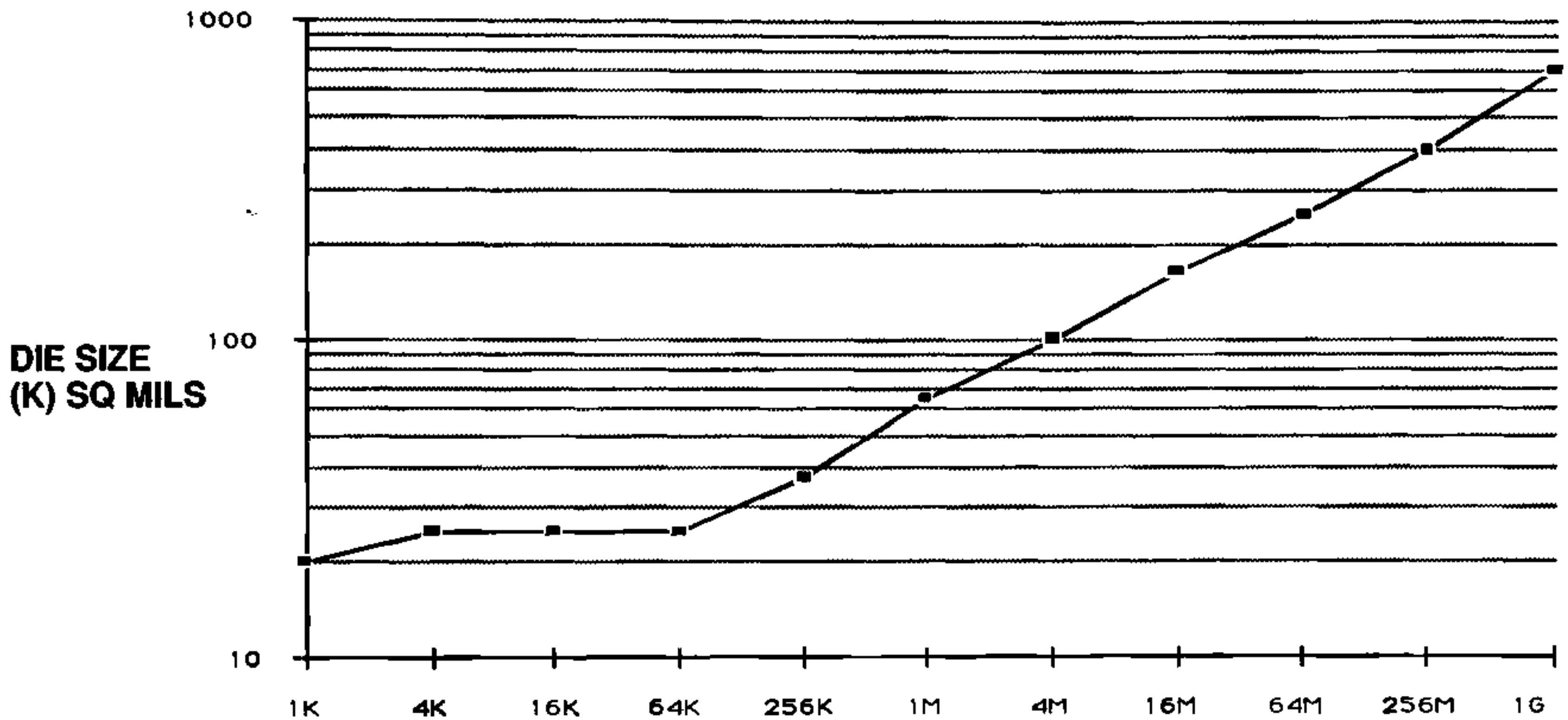
DRAM SIZE TRENDS

FIGURE 2: ACTUAL PLUS PROJECTED DIE SIZES OF EACH DRAM GENERATION



- During the transition from the 1K to the 64K, the die size has been relatively constant at 25,000 sq. mils

- Since the 256K, the die size has been increasing at an ever expanding rate

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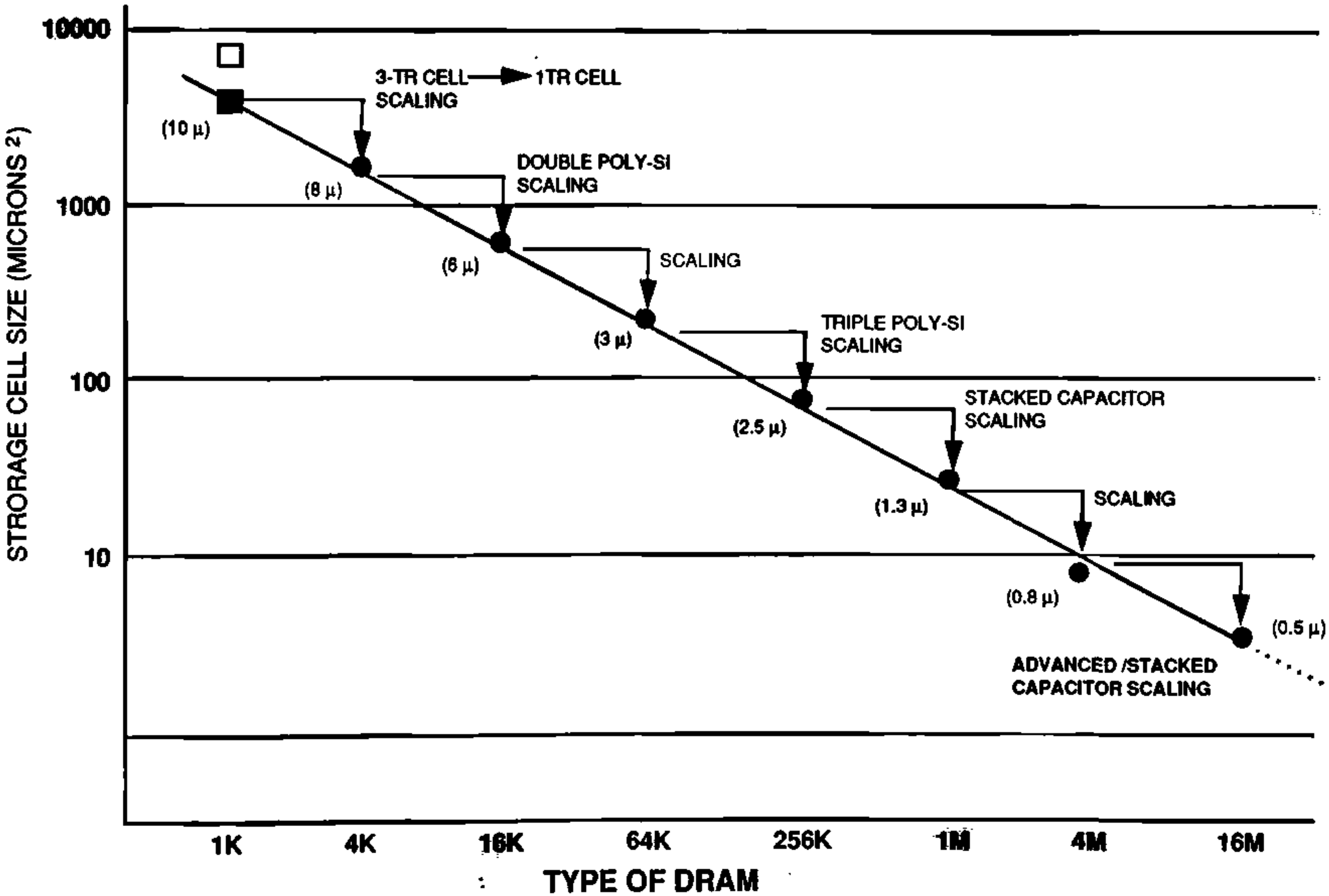
DRAM SCALING HISTORY



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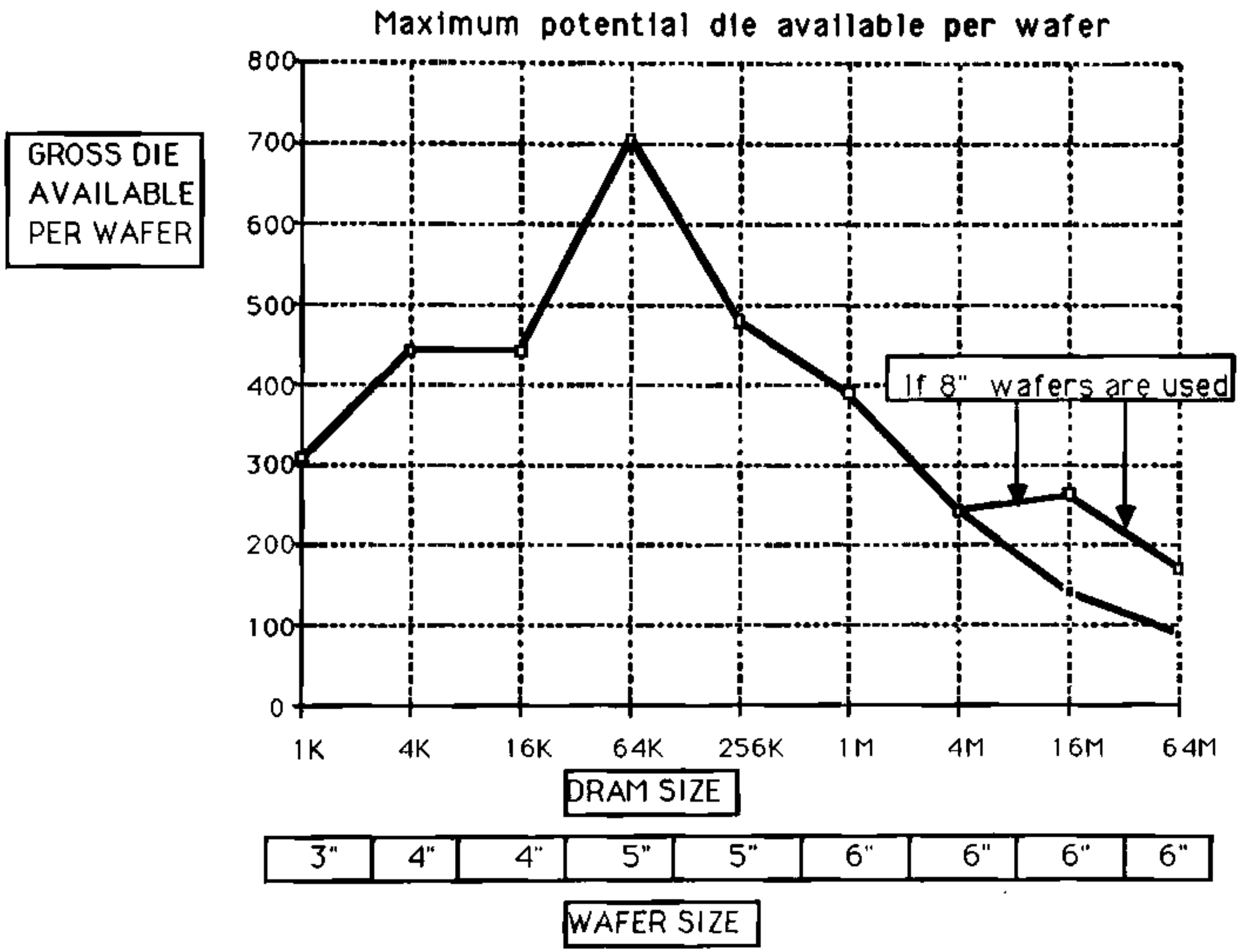
AVAILABLE DIE PER WAFER



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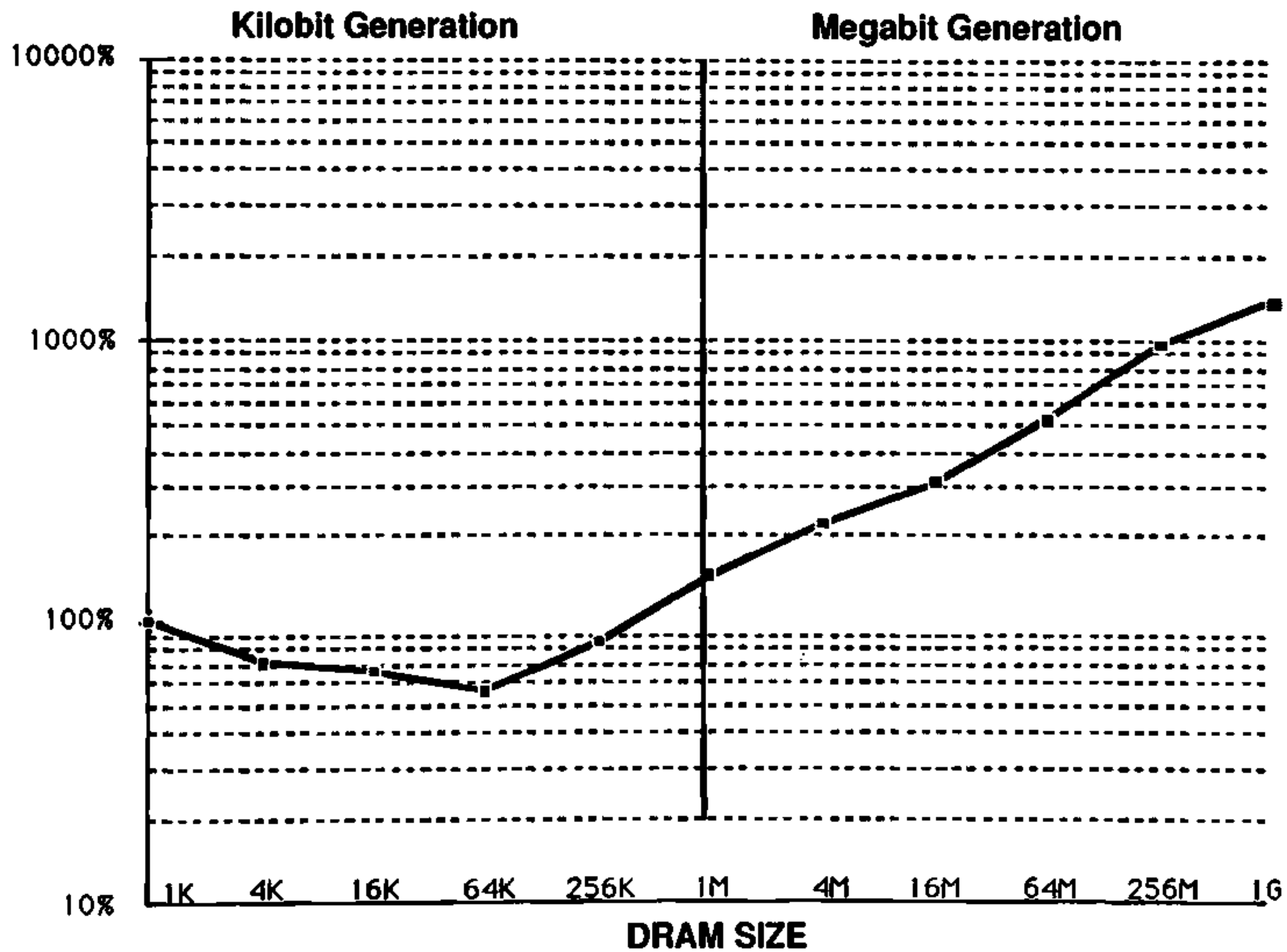
DIE COST

FIGURE 3: COST PROJECTIONS NORMALIZED TO THE 1K DRAM



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CHANGING TIMES

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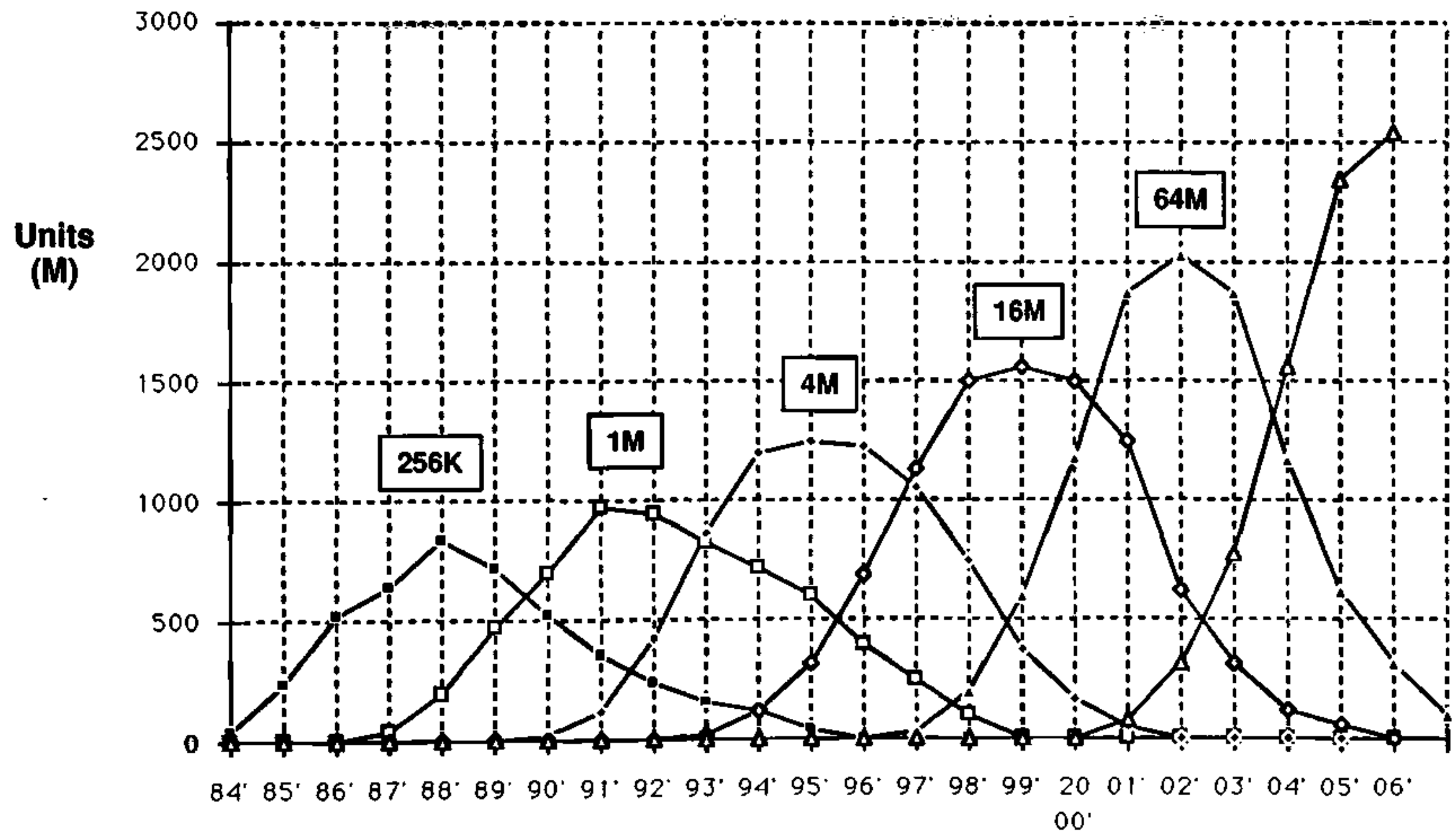
PROJECTED DRAM LIFE CYCLE



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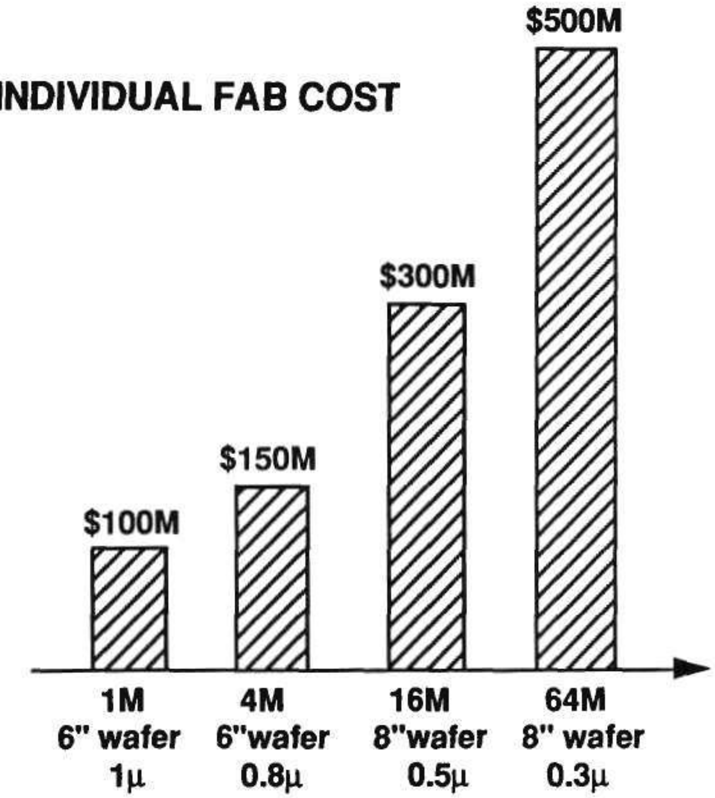
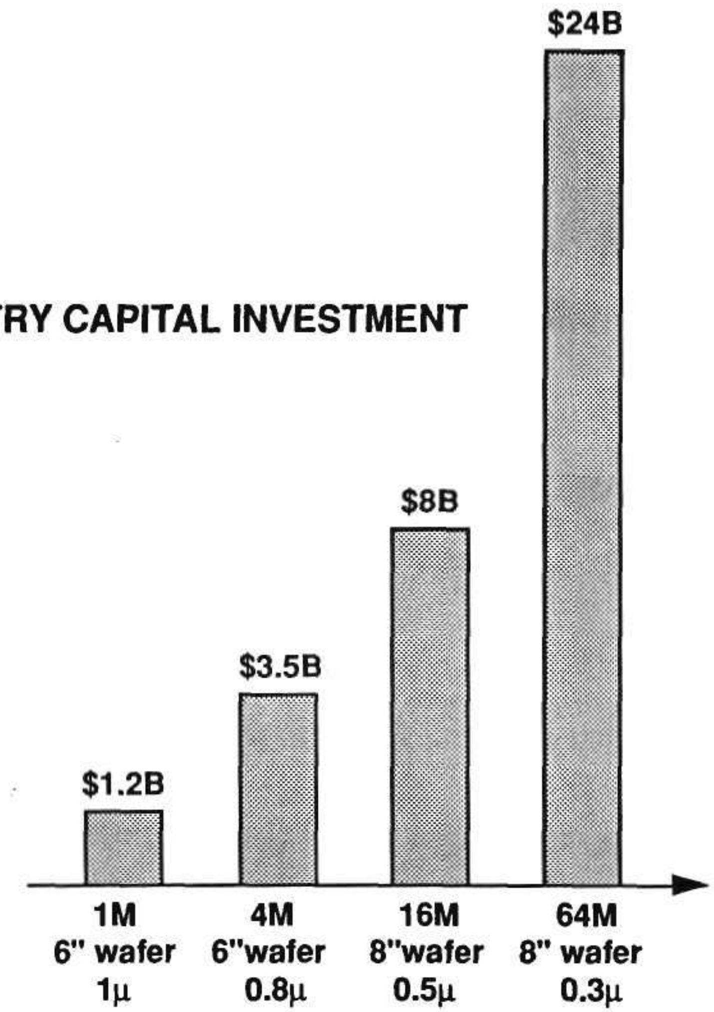
PROJECTED WAFER FAB CAPITAL EQUIPMENT COSTS

INDIVIDUAL FAB COST



INDUSTRY CAPITAL INVESTMENT



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CLOSING COMMENTS

CONCLUSION

- The long term demand for memory appears to be insatiable
- The economics of the megabit generation have changed from the kilobit generation
- Price/bit will continue to fall but at a slower pace, i.e., 80% - 90% curve instead of 60% - 70% curve
- Wafer fab costs are projected to increase causing the DRAM business to be extremely capital intensive
- The ante has been raised, but DRAMs are still an excellent business to be in
- DRAMS have now become almost as important to the world economy as a barrel of OIL!!

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PRICES, PROFITS, PROJECTIONS:
IS THIS MARKET TOO DRAM VOLATILE?

Robert J. Brown
Senior Vice President and Group Executive
Semiconductor Operations Group
Toshiba America Electronic Components, Inc.

Robert Brown is Senior Vice President and Group Executive of the Semiconductor Group for Toshiba America Electronic Components, Inc. Mr. Brown has held several managerial positions with Toshiba. He was Vice President and General Manager, MOS IC; Director of Sales, MOS IC; and National Sales Manager, MOS IC. He was recently elected as the first American to serve on the Toshiba America Electronic Components Board of Directors. Prior to joining Toshiba, Mr. Brown served in various regional sales managerial positions with Signetics Corporation and also as their Telecommunications Marketing Manager. Before his association with Signetics, Mr. Brown was District Sales Manager with Transitron Electronic Corporation, Discrete Semiconductors and Bipolar ICs. He also worked for Westinghouse Electric Corporation as Distributor Manager, IC Division; District Manager, Electric Components; Sales Engineer and product Specialist, Electron Tubes. Mr. Brown received a B.S.E.E. degree from Fairleigh Dickinson University.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 8-9, 1990
Monterey, California

Semiconductor
Industry
Conference

Prices, Profits, Projections: Is this Market Too DRAM Volatile?

Bob Brown

Vice President and Group Executive
Toshiba America Electronic Components

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DYNAMIC RAM MARKET

TOO DRAM VOLATILE ? ? ? ?

Bob Brown
TAEC
Dataquest Conference
October 9, 1990

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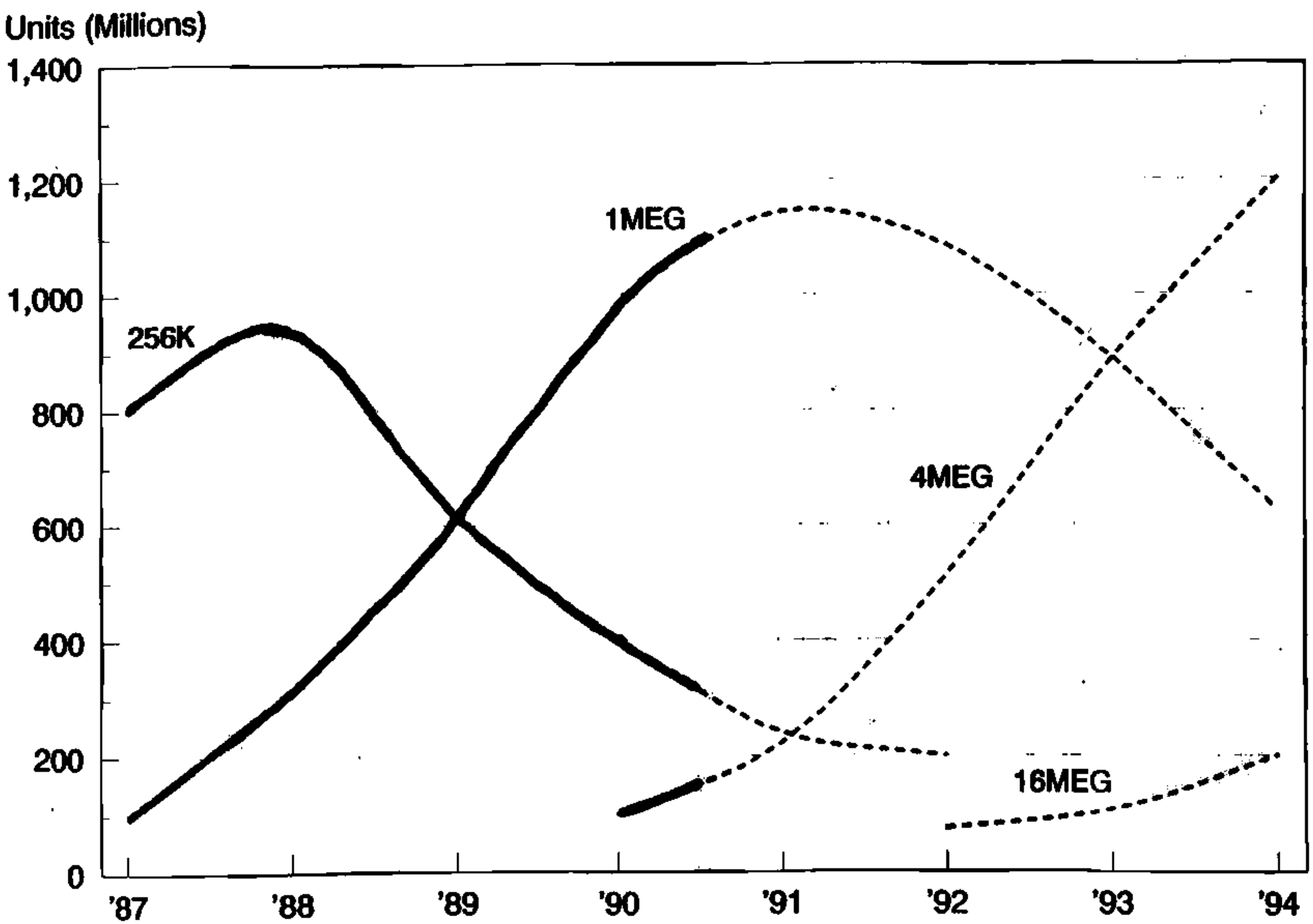
TOSHIBA DRAM MARKET FORECAST



TOSHIBA

DRAM TRENDS

- PACKAGING
- DEVICE ORGANIZATION
- MODULE ORGANIZATION
- APPLICATION SPECIFIC MEMORY
- POWER SUPPLY VOLTAGE
- PROCESS
- SPEED

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PACKAGING TRENDS

	DIP	PLCC	SOJ	ZIP	TSOP	MODULES	CARDS
256K	0	0	X	0	X	0	X
1MEG	0	X	0	0	0	0	0
4MEG	0	X	0	0	0	0	0
16MEG	X	X	0	0	0	0	0

Toshiba America

DEVICE ORGANIZATION

	X1	X4	X8	X9	X16	X18
256K	0	0				
1MEG	0	0			0	
4MEG	0	0	0	0	0	0
16MEG	0	0	0	0	0	0

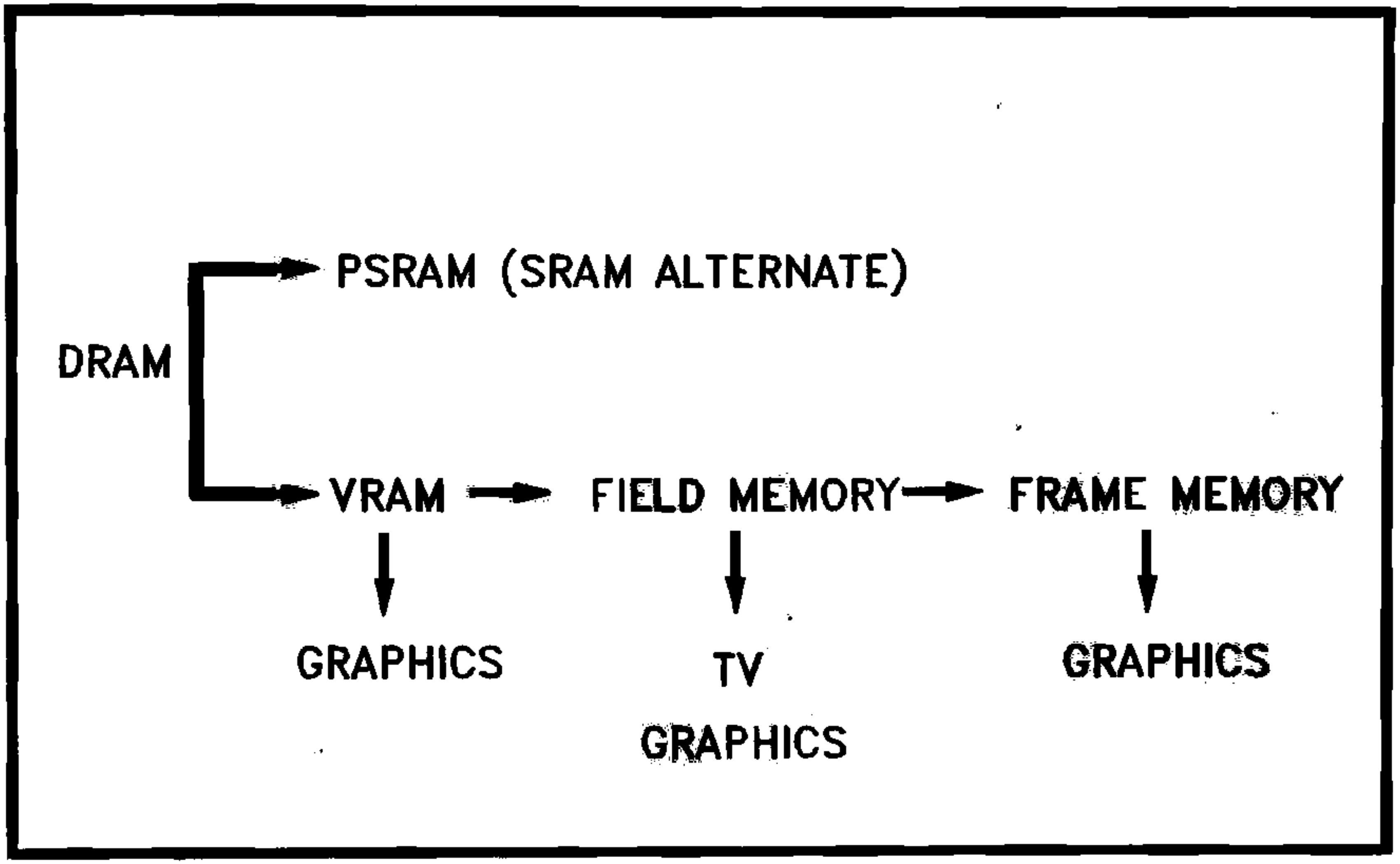
Toshiba America

MODULE ORGANIZATION TREND

	X8	X9	X18	X32	X33	X36	X40	X72
256K	0	0						
1MEG	0	0		0	(0)	0	0	
4MEG	0	0	0	0	(0)	0	0	
16MEG	(0)	(0)	(0)	0	(0)	0	0	(0)

Toshiba America

DRAM ASM TREND



Toshiba America

DRAM POWER SUPPLY TREND

	5.5V EXT 5.5V INTERNAL	5.5V EXT 3.3V INTERNAL	3.3V EXT 3.3V INTERNAL
256K	0		
1MEG	0		
4MEG	0		
16MEG		0	(0)
64MEG			0

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TECHNOLOGY TRENDS

	DIE SIZE	PROCESS TECHNOLOGY	CELL
256k (SMALLEST)	18mm²	1.8u → 1.5u → 1.2u → 1.0u	PLANAR
1MEG (SMALLEST)	39.4mm²	1.2u → 1.0u → 0.8u	PLANAR
4MEG	81.5mm²	0.8u → 0.7u	3-D TRENCH OR STACK
16M	~130mm²	~ 0.55u	3-D

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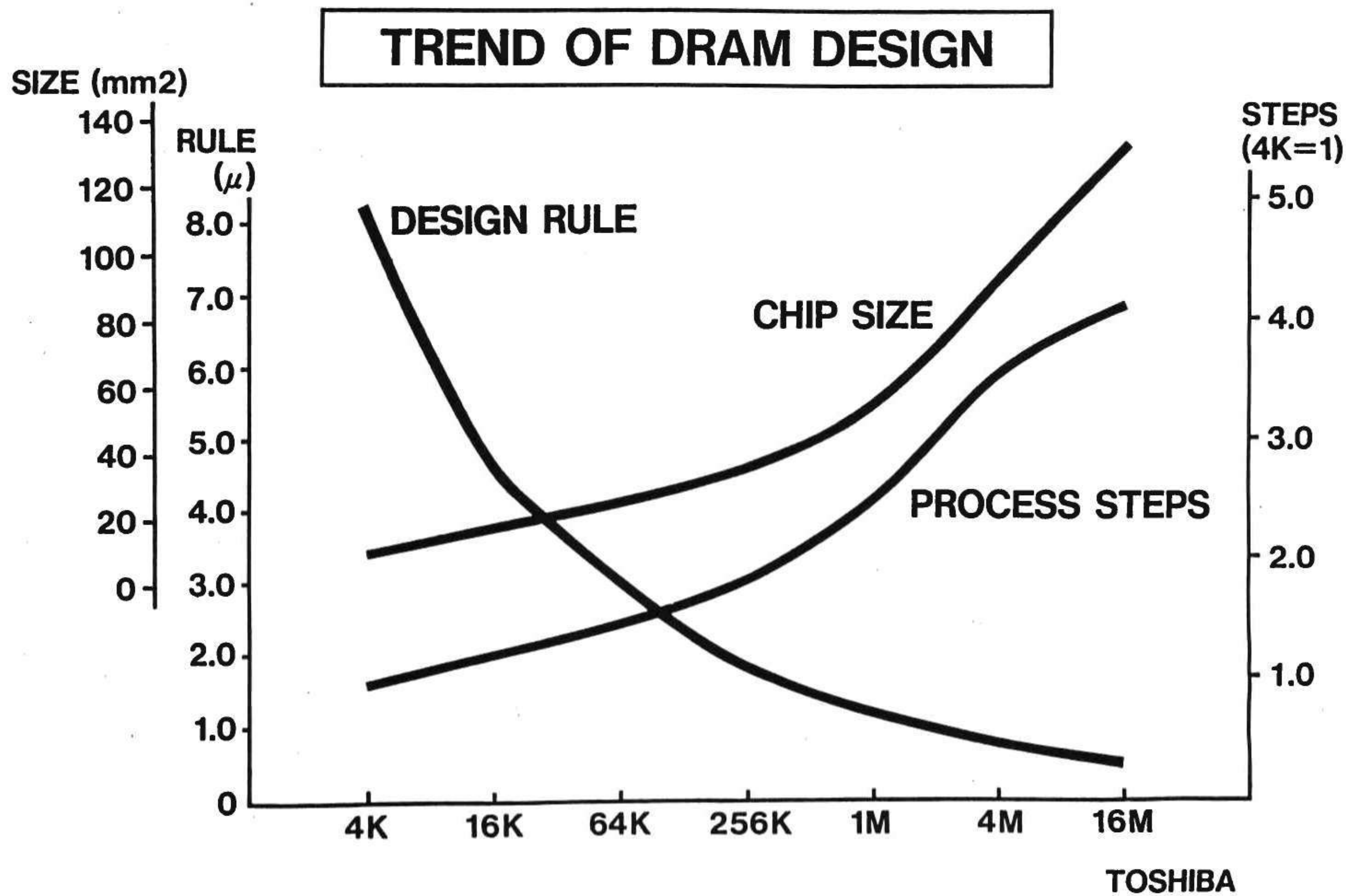
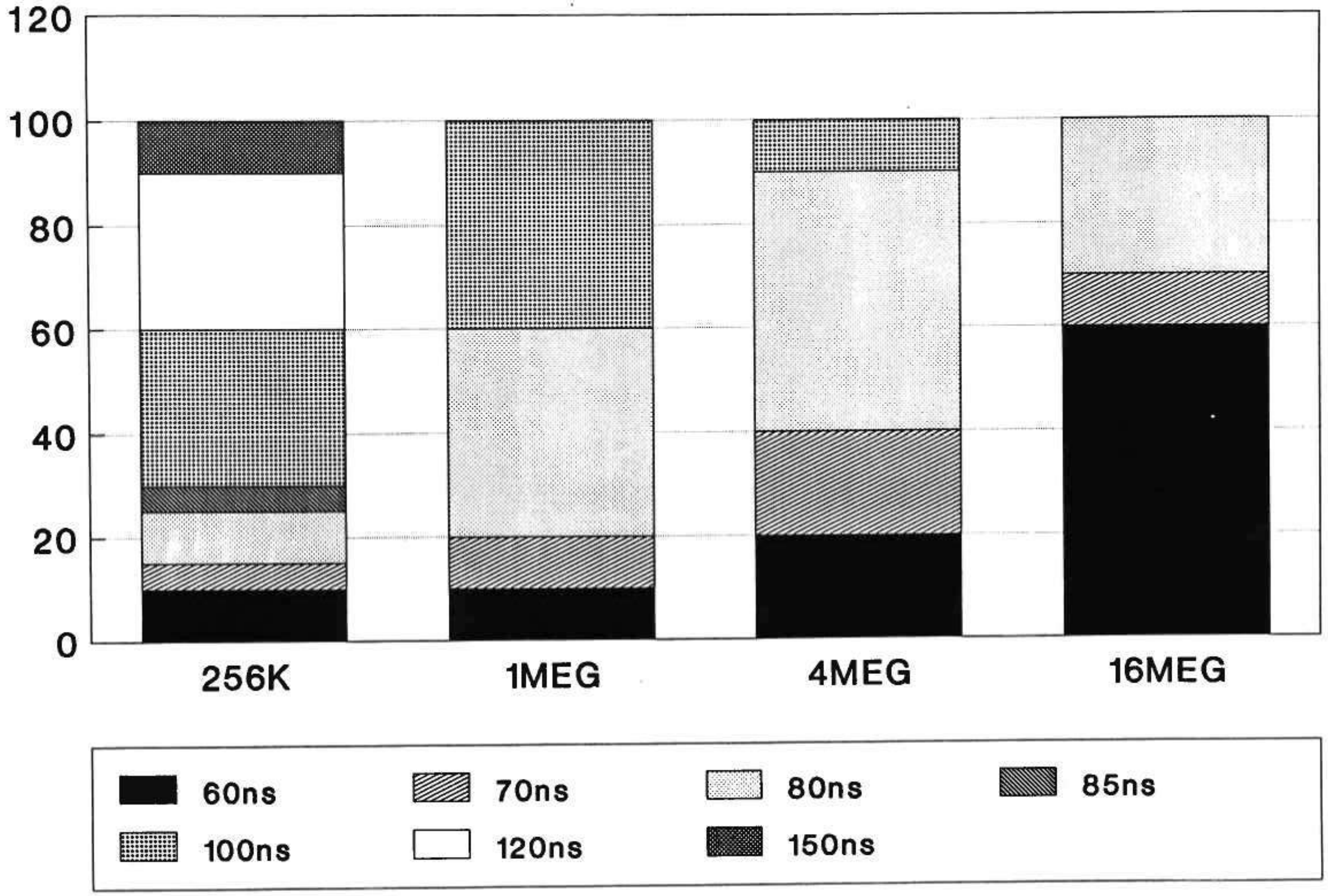

TREND OF DRAM DESIGN
SIZE (mm2)
140
120
100
80
60
40
20
0
RULE (μ)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
STEPS (4K=1)
5.0
4.0
3.0
2.0
1.0
DESIGN RULE
CHIP SIZE
PROCESS STEPS
4K
16K
64K
256K
1M
4M
16M
TOSHIBA

APPLICATION SPEED TREND



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DRAM APPLICATIONS

256K	1MEG	4MEG	16MEG
MAINFRAME	PC	FILESERVER	FILE SERVER
TELECOM	EWS	LAPTOP	LAPTOP
IND CNTRLS	MNFRM	EWS	(HDTV)
PRINTERS	TELECOM	MNFRM	(AUDIO)
PC	PRINTERS	IND CNTRL	SSD
EWS	IND CNTRL	SSD	EWS
	SSD	PC	MNFRM
	PRINTERS	TELECOM	IND CNTRLS
	LAPTOP	PRINTERS	PC
	HAND HELD	INSTRUMENTS	TELECOM
			PRINTERS
			INSTRUMENTS

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PRICES, PROFITS, PROJECTIONS:
IS THIS MARKET TOO DRAM VOLATILE?

William L. Gsand
Executive Vice President
Hitachi America, Ltd.

William L. Gsand is Executive Vice President of Hitachi America, Ltd. and General Manager of its Semiconductor and I.C. Division. Previously, he was Vice President of Marketing and Sales. Prior to joining Hitachi, Mr. Gsand was Vice President for Worldwide Sales and Marketing at General Instrument Microelectronics. He has held sales management positions with both Intel Corporation and Texas Instruments, Inc. Mr. Gsand received a B.S. in Engineering from the U.S. Naval Academy and an M.B.A. equivalent from Stanford University.

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Semiconductor
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Conference

Prices, Profits, Projections: Is this Market Too DRAM Volatile?

Bill Gsand
Vice President and General Manager
Hitachi America, Ltd.

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Prices, Profits, Projections: Is This Market too DRAM-volatile?

William L. Gsand
Executive Vice President

Prices, profits and projections - allow me to be prophetic! **DRAM: Prices will go down. Profits will go up. Growth and diversification are inevitable projections.** Beyond that, there are important parallels that relate to technology, to competition and to customer needs. These 3 areas all hold unique relationships to prices, profits and any supportable projections for DRAMs.

TECHNOLOGY

Let's first look at technology. Traditional wisdom says that the way to reap the big rewards in Memory (or any semiconductor for that matter) is to invest in R&D, arrive early, grab the gold ring and get off of the merry go-round into the next attraction well ahead of the crowd. Make your profits up front and do it with premium prices and moderate volumes. Leave the mature market to the "leaders in trailing edge technology."

That theory may not hold true in today's environment. As the time to market and price erosion curves compress, the "comfort of leadership" of the past threatens to become the "cost of leadership" in the future. How then, can development and ramp-up costs be offset if not by the "early entry theory"? These alternatives should provide at least a partial solution.

1. **Longer periods of price stability** (supply / demand balance).
2. Longer periods of market involvement **(Fabless phase downs).**
3. **In-house semiconductor equipment technology.**
4. **Larger and more extended "return" on technology** (royalties / alliances).

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U.S. Patent Awards - 1989

This list of patent awards is an indication that DRAM leaders will continue their emphasis on protecting intellectual property in the nineties.

COMPETITION

There are now more than a dozen DRAM suppliers worldwide - all scurrying around trying to develop a differential advantage in order to be successful as an innovative competitor.

The market has told us that it will no longer go along with a loner as a strategically preferred DRAM supplier. The user risks have proven to be too high and the success ratios too low. A viable competitor has to find its alliance within three classifications to expect a warm reception from the DRAM customer base.

Supplier Classifications: **Mainstream Supplier**
Alliance
Benevolence

The mainstream suppliers will number less than five worldwide. Alliances will represent a similar number and will need to draw resources and technology either from benevolent sources (Sematech, IBM, AT&T, universities) or from the mainstream suppliers.

Unless a supplier fits into two of these categories, it might want to reconsider its viability as an independent competitor in the DRAM market.

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CUSTOMER

The analysis of prices, profits and projections cannot be substantiated without an ability to respond to the market needs. Increased DRAM complexity and specialization will see a growing future as evidenced by cache memories and video RAMS. These will expand to multiple

configurations **(Hitachi will manufacture over 500 configurations of the 4MB DRAMs)** and ultimately to integrated modules containing "common process" application-specific DRAMS and logic products to support the likes of 80486, SPARC, MIPS and HP Precision Architecture systems.

SUMMARY

Only companies with extensive financial resources and staying power can command a share greater than 10% of this massive market. For them, the prices can be volatile and they will still prosper. The profits can be maintained in the long run with a multi-generation, integrated business structure as described earlier. And the projections should be bright.

The DRAM market is a jewel, but its brilliance will be enjoyed only by those who make the total commitment from R&D to mature production and who have the wherewithal to withstand the violent swings and intensive competition inherent in this business.

The DRAM business will not be: easy, dominated or predictable.
But it will be profitable, big and exciting. Hitachi will be a major factor! And we're looking forward to the opportunity to compete.

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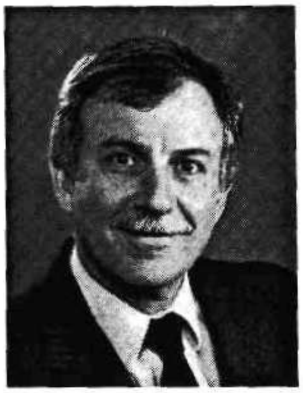
**PRICES, PROFITS, PROJECTIONS:
IS THIS MARKET TOO DRAM VOLATILE?**



Frank Jelenko
Vice President
Strategic Planning
NEC Electronics, Inc.

Frank Jelenko is Vice President of Strategic Planning for NEC Electronics. He is responsible for identifying, developing, and maintaining key markets for NEC products in the United States. Previously, he was Vice President of Marketing and later served as Vice President/General Manager for the ASIC and microprocessor business units. He joined NEC as manager of strategic account management programs. Mr. Jelenko also worked for ADL Management Consulting, General Instrument Microelectronics, Motorola, and Signetics. Mr. Jelenko received a B.S.E.E. degree from the Massachusetts Institute of Technology.

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October 8-9, 1990
Monterey, California

Semiconductor
Industry
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Prices, Profits, Projections: Is this Market Too DRAM Volatile?

Frank Jelenko
Vice President
Strategic Planning
NEC Corporation

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Prices, Profits, Projections

Is this market too DRAM volatile?

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DRAM Business Is...

Key product	Largest volume Technology driver
Problem product	Volatile Severe competition
Changing	Commodity => - Application-specific - Customized Glo-calization Capital intensity

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Why It Is Volatile

- Poor demand visibility
- Capital intensity
  - Timing of decision
- Increasing number of competitors
  - Critical industry
  - Low barriers to entry

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To Reduce Volatility
Suppliers should

- Improve visibility for demand
  - Customers
  - Vendors
- Support market trend for increasing diversity
  - Develop application-specific memory
- Establish flexible manufacturing

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To Reduce Volatility
Customers should

- **Improve future demand visibility**
- **Develop closer relationships with global technology companies**
  - **Ensure product supply**
  - **Develop customized memory**
- **Glo-calized purchasing**

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NEC

DRAM Future

Growth	Memory requirements New applications
Customer support	Total competitive solution
Value-added memory	Application-specific memory - CAD support - Foundry support

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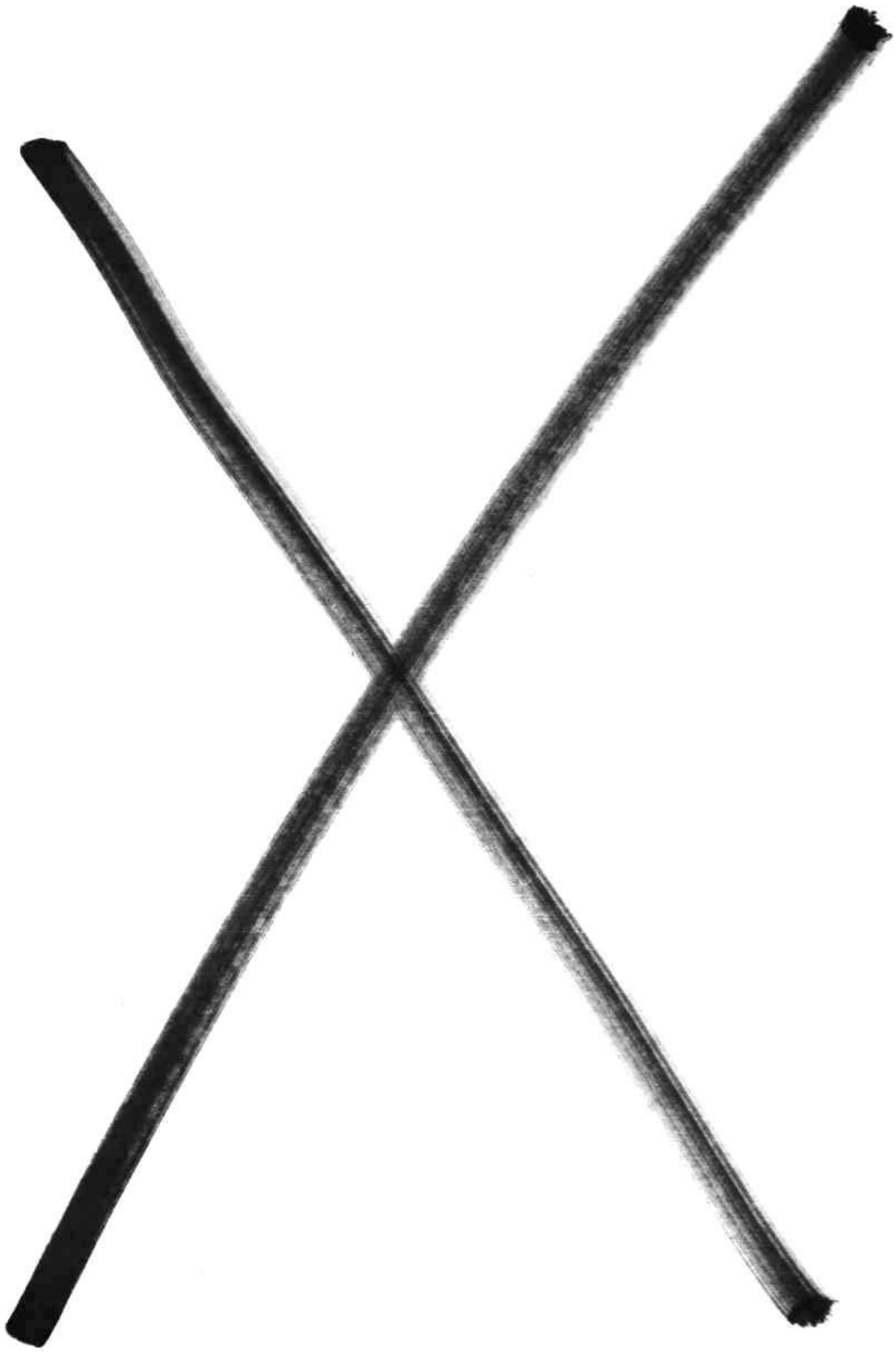

1990 SEMICONDUCTOR INDUSTRY CONFERENCE

The Next Decade . . . Where Do the Opportunities Lie?

October 8-9, 1990
Monterey Conference Center
Monterey, California

SUNDAY, October 7

5:00 p.m.	**Registration**	*San Carlos Foyer*
7:00 p.m.	**Cocktail Reception**	*San Carlos Ballroom*

MONDAY, October 8

7:00 a.m.	**Buffet Breakfast**	*San Carlos Ballroom*
7:30 a.m.	**Registration Continues**	*Steinbeck Lobby*
8:30 a.m.	**Semiconductor Industry Forecast** David Angel Group Vice President and Director of Worldwide Research Dataquest Incorporated	*Steinbeck Forum*
9:00 a.m.	**The Next Decade . . . Where Opportunities Lie** Manny Fernandez President Dataquest Incorporated	*Steinbeck Forum*
	Differing Corporate Strategies	
9:30 a.m.	**Pure Play Semiconductor** T. J. Rodgers President and CEO Cypress Semiconductor	*Steinbeck Forum*
10:00 a.m.	**Coffee Break**	*Steinbeck Lobby*
10:30 a.m.	**Building Block Supplier** Frank Gill President Intel Systems Group	*Steinbeck Forum*
11:00 a.m.	**Fabless** Gordon Campbell President and CEO Chips & Technologies	*Steinbeck Forum*
11:30 a.m.	**Group Questions**	*Steinbeck Forum*
12:00 Noon	**Lunch**	*San Carlos Ballroom*
12:45 p.m.	**The Bush Administration's Position on High Technology** Congressman Tom Campbell	*San Carlos Ballroom*
1:45 p.m.	**Wake-Up Call for the US Semiconductor Industry** Carver Mead Gordon and Betty Moore Professor of Computer Science California Institute of Technology	*Steinbeck Forum*
2:15 p.m.	**Packaging for High-Performance Systems: Moving Toward 2000** Mary Olsson Industry Analyst Dataquest Incorporated	*Steinbeck Forum*
2:45 p.m.	**Coffee Break**	*Steinbeck Forum*

(Continued)

3:15 p.m.	**Lithography Strategies: Pushing the Limits**	*Steinbeck Forum*
	Optical Lithography Eugene Fuller Manager, Stepper Programs Sematech	
	X-Ray Lithography Robert Hill Functional Manager, Advanced Lithography Systems IBM Corporation	
	E-Beam Lithography Neil Berglund Assistant to the President and Executive Director of Marketing ETEC Systems, Inc.	
	Maskmaking John G. Skinner Director of Advanced Photomask Technology Du Pont	
5:15 p.m.	**Session Concludes**	
6:45 p.m.	**Private Tour and Strolling** **Buffet Dinner at the Monterey Bay Aquarium**	*Monterey Sheraton Lobby*

TUESDAY, October 9

7:00 a.m.	**Buffet Breakfast**	*San Carlos Ballroom*
8:30 a.m.	**General Announcements**	*Steinbeck Forum*
8:45 a.m.	**Semiconductor Memories in the Coming Decade** Tsugio Makimoto General Manager, Semiconductor Design & Development Center Hitachi Ltd.	*Steinbeck Forum*
9:15 a.m.	**Europe: Redrawing the Semiconductor Borders** Jonathan Drazin Senior Industry Analyst Dataquest Incorporated	*Steinbeck Forum*
9:45 a.m.	**Coffee Break**	*Steinbeck Lobby*
10:15 a.m.	**Prices, Profits, Projections: Is This Market Too DRAM Volatile?** David Sear Vice President Fujitsu America	*Steinbeck Forum*
	Robert Brown Vice President and Group Executive Toshiba America Electronic Components	
	William Gsand Vice President and General Manager Hitachi America, Ltd.	
	Joseph Parkinson Chairman and CEO Micron Technology	
	Frank Jelenko Vice President NEC Corporation	
12:00 Noon	**Lunch**	*San Carlos Ballroom*

(Continued)

12:45 p.m.	**The Price of the Future** .... *San Carlos Ballroom* Fred Zieber Vice President Dataquest Incorporated	
1:45 p.m.	**The Evolving Personal Computer** .... *Steinbeck Forum* Roger Johnson Chairman, President, and CEO Western Digital Corporation	
2:15 p.m.	**The New Face of Personal Electronics** .... *Steinbeck Forum* Hiroyuki Mizuno Executive Vice President and Member of the Board Matsushita Electric Industrial Co., Ltd.	
2:45 p.m.	**How User/Supplier Relations Will Change** .... *Steinbeck Forum* Irv Abzug GTD Vice President and Director of Corporate Procurement IBM Corporation	
3:30 p.m.	**Conference Ends**	

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1990 Semiconductor Industry Conference
Market Research Survey

In order to continually improve the types of products and services Dataquest provides for the semiconductor industry, we need to better understand your information needs. Please help us by completing the following questionnaire.

1. Is your company a Dataquest client? ___ Yes ___ No

2. Which of the following best describes your company's primary activities? Choose only one.

___ Semiconductor manufacturer

Type:

___ Standard Logic ___ ASIC ___ DSP ___ Smart Power
___ Microcomponents ___ Memory ___ Telecom ___ All Types
___ Linear-Analog ___ Opto-Discrete ___ Gallium Arsenide

___ Supplier to semiconductor industry

Type:

___ Test equipment ___ Design equipment/software
___ Manufacturing equipment ___ Materials
___ Services

___ User of semiconductor products
___ Distributor, government agency, consultant, investment advisor
___ Other ______________________________
(Please specify)

3. Which of the following best describes your position/title?

___ CEO, President, Vice President
___ Strategic Planning/Business Development
___ Sales and Marketing Management
___ Product Development/R&D/ Engineering Management
___ Product Management
___ Market Research/Analyst
___ Operations Management
___ Purchasing/Vendor Selection
___ Other ______________

4. How did you learn about this conference?

___ The brochure was mailed directly to me.
___ Someone in my company gave me the brochure.
___ I saw the announcement in a newspaper or magazine.
___ I heard an announcement at a previous Dataquest meeting.
___ Someone from Dataquest called me.
___ Other ______________________________

(over)

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5. Rank the reasons you attended this conference in order of importance (1 being the most important). Circle only those applicable to you.

	Most				Least
To hear Dataquest's forecasts	1	2	3	4	5
To hear Dataquest's market analysis and predictions	1	2	3	4	5
To hear industry leaders	1	2	3	4	5
To meet my customers	1	2	3	4	5
To talk with Dataquest analysts	1	2	3	4	5
To meet my counterparts	1	2	3	4	5
To hear about and discuss critical industry issues	1	2	3	4	5
To help evaluate our investment portfolio	1	2	3	4	5
To meet my suppliers	1	2	3	4	5
To learn about my competition	1	2	3	4	5
To examine new Dataquest products I've heard about	1	2	3	4	5
To learn about new markets and sales leads for my company's products or services	1	2	3	4	5

	Highest				Lowest
6. How well did the conference meet these objectives?	1	2	3	4	5

	Highest				Lowest
7. How would you rate the conference facilities and location?					
Guest rooms	1	2	3	4	5
Meeting rooms	1	2	3	4	5
Meals	1	2	3	4	5
Location (City)	1	2	3	4	5

8. In the future, should the length of this conference be: ____ Shorter ____ Longer ____ The same?

9. Would you prefer ____ more ____ fewer or ____ the same number of Dataquest speakers?

10. Topics/speakers you would like to hear at next year's conference:

____

____

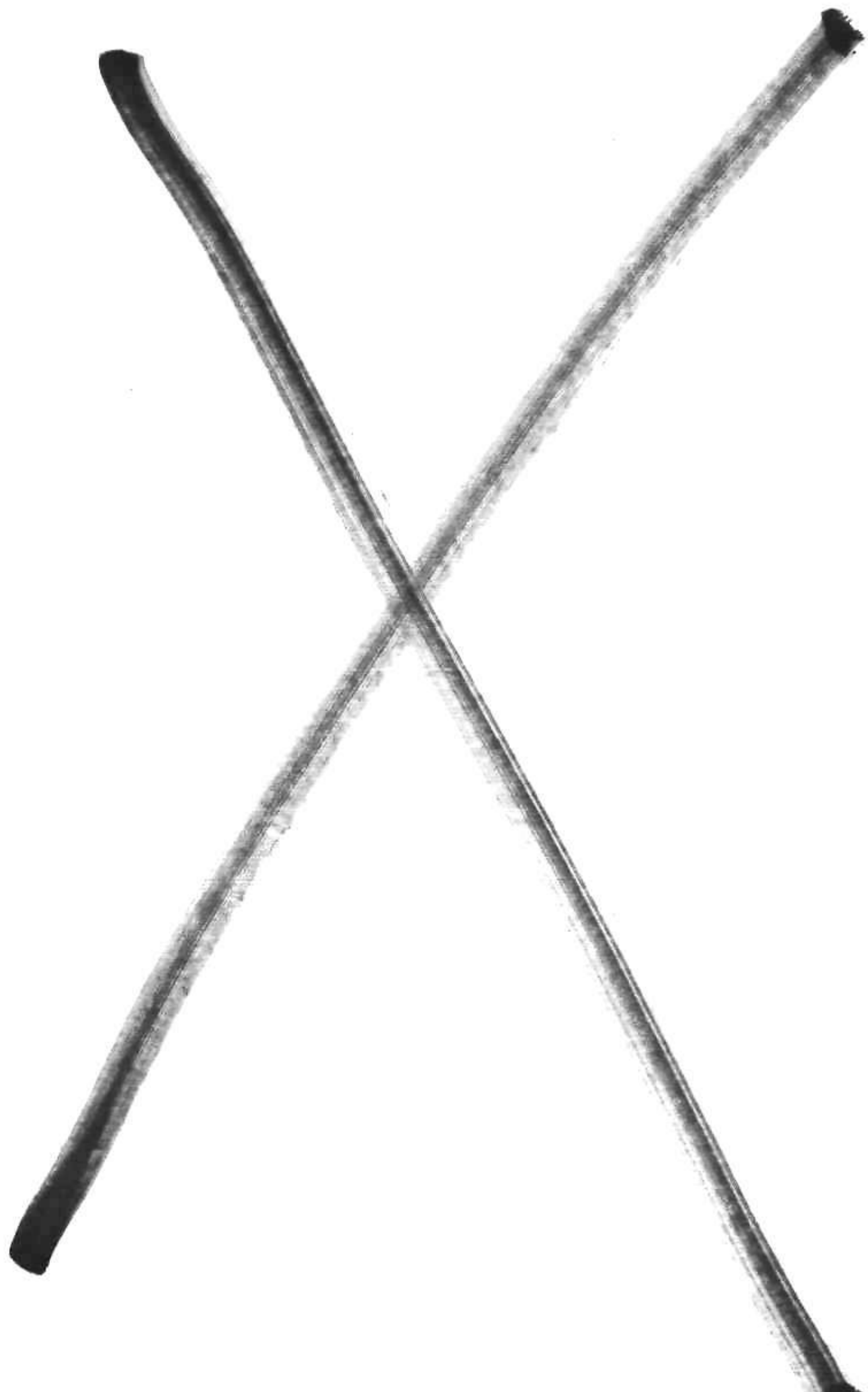
11. Please use this space for your comments on any aspect of our conference:

____

____

____

Name ______________________
(Optional)



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October 08 through 09, 1990
Monterey, California

List of Attendees

Irv Abzug	IBM Corporation
Alan Allan	SEMATECH
Eric Alling	Shipley Company, Inc.
David Angel	Dataquest Incorporated
David M. Antos	Eastman Kodak Company
Ed Armstrong	Hughes Aircraft Company
Bernard Aronson	Zoran Corporation
Joseph Arruda	Kawasaki Wafer Technology
Willi W. Bacher	First Components GmbH
David Bagby	Hitachi America, Ltd.
Chris Bajorek	IBM Corporation
Stan Baker	Electronic Engineering Times
Jerry Banks	Dataquest Incorporated
James Barnett	Xilinx Inc.
Brent Bartlett	Dewey, Ballantine, Bushby, Palmer & Wood
Rheba J. Bass	Fujitsu Microelectronics, Inc.
Greg Bauer	Ashland Chemical Company
Ron Benham	Dexter Electronic Materials
C. Neil Berglund	ETEC Systems Inc.
John Berryman	National Semiconductor Corporation
Michael J. Bill	AT&T

Chris Billat	Insystems, Inc.
Susan Billat	Insystems, Inc.
Jeff Billinger	Alcoa Electronic Packaging, Inc.
Robert Blair	LSI Logic Corporation
Philip Blakey	Airco/BOC
Victor Blatt	SID Microelectronica S.A.
Albert Blodgett	IBM Corporation
Dorothea Blouin	U. S. Department of Commerce
Robert Boehlke	KLA Instruments Corporation
Steve Bogart	National Semiconductor Corporation
Howard Bogert	Dataquest Incorporated
Peter Bonney	Eastman Kodak Company
Robert Boole	Analog Devices, Inc.
H. J. Bosch	Netherland Centres for Microelectronics
Charles M. Bosnos	Lumonics Corporation
Michael Boss	Dataquest Incorporated
Everett Boswell	Western Digital Corporation
Thomas Bowers	Advanced Micro Devices, Inc.
Frank Brem	Sundstrand Data Control
Nathan Brookwood	Intergraph Corporation
Robert J. Brown	Toshiba Amer. Electronic Components, Inc
Stan Bruederle	Dataquest Incorporated
Bradley Bryan	Dean Whitter Reynolds
Ellery Buchanan	General Signal/Xynetics

George Burns	Dataquest Incorporated
Dan Butler	Bechtel Corporation
Mark Caisse	Dataquest Incorporated
Gordon A. Campbell	Chips and Technologies, Inc.
Ray Campbell	
Tom Campbell	U.S. House of Representatives
George Canavan	Applied Materials, Inc.
Michael Canning	Cirrus Logic, Inc.
Jim Cantore	Oki Semiconductor
Tom Cate	Analog Devices, Inc.
Lori Chance	Dell Computer Corporation
Chi-Ping Chang	Industrial Technology Research Institute
Bill Chastain	NCR Corporation
Stephen Chiao	Mosel Corporation
Jade Chien	Taiwan Semiconductor Mfg. Co., Ltd.
Paul Chien	Taiwan Semiconductor Mfg. Co., Ltd.
S. L. Choi	Samsung Semiconductor, Inc.
Chae Kyun Chung	Hyundai Electronics Industries Co., Ltd.
Cindy Clover	SEMATECH
Richmond Clover	SEMATECH
Vernon Coleman	Chartered Semiconductor
Murray Collette	Oak Technical Inc.
Ray Colline	Xerox Corporation

Bill Cornwell	Electroglas
Michael Cowan	IBM Corporation
Bill Cronquist	Fujitsu Microelectronics, Inc.
Paul Crosby	Coherent Lazer Group
James Crosskill	Varian Associates
Gordon Cumming	Oki Semiconductor
Rob David	IBM Corporation
Richard C. Davis	Intel Corporation
Bob Derby	Weitek Corporation
Stephen L. Diamond	Sun Microsystems, Inc.
Steve Domenik	Weitek Corporation
Dan Domingo	NEC Electronics Inc.
Bill Douglass	AMP Incorporated
Jonathan Drazin	Dataquest Europe Ltd.
Roger F. Dunbar	Ernst & Young
James E. Dykes	Signetics Corporation
John East	Actel Corporation
Kermit Eaton	Air Products & Chemicals, Inc.
Linda Ebaugh	Barclays Bank
Will Eckert	Shinko Electric America, Inc.
Tom Egan	AT&T
Tom Eichenberg	Dynachem
Dolores Elderd	Dataproducts Corporation
Robert Elderd	Dataproducts Corporation

Marc Elliot	Dataquest Incorporated
Mark Ellsberry	Samsung Semiconductor, Inc.
Roger D. Emerick	Lam Research Corporation
Raymond Epes	Bank of America
William Ergas	Imperial Bank
Douglas G. Fairbairn	VLSI Technology, Inc.
Dennis Fandel	IBM Corporation
Chet Farris	Hughes Aircraft Company
Manny Fernandez	Dataquest Incorporated
Mark FitzGerald	Dataquest Incorporated
Donald Fletcher	Hong Kong Government
Jim Fleury	MIPS Computer Systems, Inc.
Claes Y. Flodmark	Ericsson Telecom AB
Debbie Folsom	Intel Corporation
Paul Forster	International CMOS Technology
Jorge Freyer	ETEC Systems Inc.
Deborah Friedemann	Bank of America
Ohitoshi Fujimoto	Marubeni International Electronics
Gene Fuller	SEMATECH
Patricia Galligan	Dataquest Incorporated
Paul Gardner	Bank of America
Robert Gardner	Hamilton/Avnet Electronics
Tracy Garnier	NKK America Inc.
Clark Gerhardt	Montgomery Securities

Bernard Gilbride	Pall Process Filtration Co.
Frank Gill	Intel Corporation
Bob Goedjen	Raytheon Company
Lawrence H. Goldstein	Standard Microsystems Corporation
Nelson Goncalves	SID Microelectronica S.A.
Gary Grandbois	Dataquest Incorporated
Larry W. Grange	Xerox Corporation
Mark Grant	Marshall Industries
Joseph Grenier	Dataquest Incorporated
Ron Gridley	First Interstate Bank
Kerry Grimes	Dynachem
David Grooms	Kyocera America, Inc.
Jack Grucza	SEMATECH
Skip Grzanka	Raytheon Company
William Gsand	Hitachi America, Ltd.
Bharat Gupte	Oki Semiconductor
Leslie T. Guttadauro	VLSI Technology, Inc.
Chuck Gwyn	Sandia National Laboratories
Takaaki Hagiwara	Hitachi, Ltd.
H. Glen Haney	Dataquest Incorporated
William Hanna	W. L. Gore & Associates, Inc.
Ronald Hardin	Edwards-Temescal Corporation
Byron Harding	Dataquest Europe Ltd.
Koji Hasegawa	Mitsubishi Kasei America Inc.
Christopher Hayden	Hampshire Instruments, Inc.

Jim Healy	LTX Trillium
Heidi Hedlund	Apple Computer, Inc.
John Hein	Union Bank
Stephen Hensler	Air Products & Chemicals, Inc.
Mike Hildreth	Ernst & Young
Robert W. Hill	IBM Corporation
Len Hills	Dataquest Incorporated
William E. Hinch	Canadian Imperial Bank of Commerce
Eugene R. Hnatek	Viking Labs/Honeywell
Larry C. Hollatz	NCR Microelectronics
Richard Hunt	National Semiconductor Corporation
Dennis Hunter	Applied Materials, Inc.
Richard Hunter	Ashland Chemical Company
Mi Jeong Hwang	Samsung Electronics Co., Ltd.
Pat Hyek	Ernst & Young
John F. Imbalzano	DuPont Company
Ron Iscoff	Semiconductor International
Ione Ishii	Dataquest Incorporated
John Ishimaru	Dataquest Incorporated
Errol Ives	Zitel Corporation
John B. Jackson	Dataquest Incorporated
Susan James	Ernst & Young
Frank M. Jelenko	NEC Electronics Inc.
Richard Jelinek	Chicago Board of Trade

Alan Jepsen	Bank of America
Bill Jewell	Texas Instruments, Inc.
Kris M. Johnson	Intel Corporation
Richard Johnson	NCR Corporation
Roger Johnson	Western Digital Corporation
Joanie Jones	IBM Corporation
Tom Jones	Rockwell International Corporation
Jonathan Joseph	Montgomery Securities
Richard Joy	Unisys Corporation
Walter F. Kalin	FSI International
Arun Kamat	GoldStar Technology, Inc.
Walter Kameta	Standard Microsystems Corporation
Kohei Kamigane	JETRO
Hisao Kanamaru	Kokusai Electric Co., Ltd.
Yu Sig Kang	GoldStar Electron Co., Ltd.
Chen Kao	Olin Hunt Specialty Products, Inc.
Jack S. Kasahara	Hoechst Celanese Corporation
Terry Kaspar	Apple Computer, Inc.
Jeff Katz	Atmel Corporation
Chad Keck	Prudential-Bache Capital Funding
Craig Keever	Scott Specialty Gases
Mark R. Kent	Bank of the West
Dae Soo Kim	Hyundai Electronics Industries Co., Ltd.
Iksu Kim	Hyundai Electronics America
Kyung Kim	Hoya Electronics Corporation

Dan Klesken	Prudential-Bache Capital Funding
Hideo Kobayashi	Kokusai Electric Co., Ltd.
Richard Konrad	Siemens Components, Inc.
Niels Krabbe	Security Pacific Venture Capital
Lee Krueger	Dun & Bradstreet Bus. Credit Services
David Krug	Mentor Graphics Corporation
Bruce Kubicka	Intel Corporation
Lori Kulvin	Dataquest Incorporated
Hidehiro Kunitomo	NEC Electronics Inc.
Daniel Kunstler	J.P. Morgan Investment
Susumu Kurama	Dataquest Japan, Ltd.
Noella Kwan	Applied Materials, Inc.
Anthony Kwee	Union Bank
Rick L. La France	Nikon Precision, Inc.
Peter Lablans	Netherlands Foreign Investment Agency
Burt Lancaster	Veriflo Corporation
Jean-Pierre Laussade	Sony Corporation of America
Ilbok Lee	Samsung Semiconductor, Inc.
Jimmy Lee	Integrated Silicon Solutions
Keith Lee	Advantest America, Inc.
Seong-Ku Lee	Electronics & Tele. Research Institute
Yongo Lee	Samsung Electronics Co., Ltd.
Alice Leeper	Dataquest Incorporated
Marc Letraon	Schlumberger Technologies
Bryan Lewis	Dataquest Incorporated

Peggy L. Lewis	Tektronix, Inc.
John Lezotte	Advanced Packaging Systems
Voon Kheong Liow	Singapore Economic Development Board
Samuel S. Liu	Silicon Integrated Systems Company
David Locke	Gould AMI Semiconductors
Lois Long	Dataquest Incorporated
C. Y. Lu	ERSO/ITRI
John Luke	Taiwan Semiconductor Manufacturing Co.
Eric Lutkin	Hewlett-Packard Company
Dennis Lyden	Standard Microsystems Corporation
Dennis Lyftogt	Dataquest Incorporated
Phillip Lyman	Ma Laboratories
Jong-Son Lyu	E.T.R.I.
Abraham Ma	Ma Laboratories
Rod MacDonald	Branson International Plasma Corporation
Bob Machado	DuPont Photomasks, Inc.
Tsugio Makimoto	Hitachi, Ltd.
Azmat Malik	Mitsubishi Electronics America, Inc.
Gabriel A. Marao	Itausa Export North America
Michael Mardesich	The Source/GE Capital
Doug Marsh	ASM Lithography, Inc.
Frank T. Martin	IBM Corporation
Junko Matsubara	Dataquest Incorporated

Gunter E. Matthai	Robert Bosch GmbH
Michael W. McCann	Genus, Inc.
Mike McCarver	KLA Instruments Corporation
J. Daniel McCranie	SEEQ Technology, Inc.
Keith McDonald	Samsung Semiconductor, Inc.
James B. McElwee	Security Pacific Venture Capital
Gregory F. McHugh	Analog Devices, Inc.
Jonah McLeod	Electronics
Stephen E. McMinn	Vertex Semiconductor Corporation
Carver A. Mead	California Institute of Technology
Dave Mees	Credence Systems
Joe Megginson	DuPont Photomasks, Inc.
John I. Melgalvis	IBM Corporation
Jean Pierre Melia	Fiat Semelco
Paulo Mendes	International Finance Corporation
John E. Meyer	Fujitsu Microelectronics, Inc.
George E. Miller	Mill-Bern Associates, Inc.
Neil Mimatsu	Ryosan USA, Inc.
Chung Yun Min	Electronics & Tele. Research Institute
Akira Minamikawa	Dataquest Japan, Ltd.
S. Mizumachi	Anelva Corporation
Hiroyuki Mizuno	Matsushita Electric Industrial Co., Ltd.

Masa Mizuno	Sony Corporation of America
Susan Mooney	DAW Technology
James M. Moriarity	Applied Materials, Inc.
Yasuhiko Morita	Marubeni International Electronics
Tony Moroyan	Hitachi America, Ltd.
Larry Morrell	Data I/O Corporation
Mike W. Morrissey	NCR Microelectronics
Phil Mosakowski	Dataquest Incorporated
Laurence W. Nagel	AT&T
Suresh Natarajan	Singapore Economic Development Board
Nick Nazarenko	E.I. DuPont de Nemours & Company
Andre Neumann-Loreck	Quantum Corporation
Sakushi Nishioka	Hitachi Research Institute
Carl Noblitt	Eaton Corporation
Joanne Nolan	GE Capital ELLCO
Jan Noordhoff	Weiss Scientific Glass
Gene Norrett	Dataquest Incorporated
Mark H. Norwood	Intel Corporation
Chris P. Nugent	U.S. Leasing Corporation
Joe O'Neill	Samsung Semiconductor, Inc.
Katsuhiko Ohara	Crestronics Company, Ltd.
Daniel Oleiski	Orbot Instruments, Ltd.
Arnie Olson	Bank of the West
Mary Olsson	Dataquest Incorporated
David Orgill	Applied Materials, Inc.

John Osborne	Lam Research Corporation
Lawrence T. Osborne	Amsterdam-Rotterdam Bank N.V.
Todd Oseth	Ramtron Corporation
James Osmun	Advanced Micro Devices, Inc.
Drew Allen Osterman	International CMOS Technology
Rick Oyama	Tokyo Electron, Ltd.
Robert Ozarski	Edwards High Vacuum International
C. Y. Pae	Samsung Electronics, Inc.
David Palmer	Texas Instruments, Inc.
Joseph Parkinson	Micron Technology, Inc.
Ken Pearlman	Dataquest Incorporated
Dennis Petrich	LTX Trillium
Bill Pfeifer	Bechtel Corporation
Michael Pippins	Varian/Extrion
Riccardo Poggi	Italtel
Philip Pollok	Plessey Semiconductors, Ltd.
Alan Portnoy	Goldstar Technology, Inc.
Doug L. Powell	Motorola, Inc.
Frank Powell	Advanced Technology Laboratories
Michael W. Powell	Nikon Precision, Inc.
Betty Prince	Texas Instruments, Inc.
Andy Prophet	Dataquest Incorporated

Chet Purcell	Ciba-Geigy Corporation
Frank Ramsay	Toshiba America, Inc.
Vivek Rao	J.P. Morgan Investment
John Raszcewski	IBM Corporation
Dave Raulino	Hitachi America, Ltd.
Mark Reagan	Intel Corporation
Ron Richard	Matsushita Electric Industrial Co., Ltd.
Peter Richmond	Advanced Micro Devices, Inc.
T. J. Rodgers	Cypress Semiconductor Corporation
Carol Rosen	Electronics Purchasing
Nathan Rosenberg	Pitney Bowes, Inc.
Judee Rowan	Apple Computer, Inc.
David Rowe	Intel Corporation
Meg Rumpf	Bank of America
Elizabeth Rutherford	Bank of Boston
Tom Rutherford	J. C. Schumacher Company
Bernadette Ryan	Advanced Micro Devices, Inc.
Jaggi Sabherwal	Amdahl Corporation
Kunishiro Saito	NEC Electronics, Inc.
Carl Salanitro	Hughes Aircraft Company
Jan Salsgiver	Arrow Electronics, Inc.
Frank Sammann	Dataquest Incorporated
Leonard Sanders	Manufacturers Hanover Trust Company
Cathryn Sandstrom	Intel Corporation
Steve Sanghi	Microchip Technology Inc.

Richard Sanquini	National Semiconductor Corporation
Vimal Sarna	Northern Telecom Electronics Inc.
Rene Savelsberg	Netherlands Foreign Investment Agency
John Scheer	Northern Telecom
Russ Schlager	Electro Scientific Industries, Inc.
Gary Schmitt	American Speciality Gas Technology, Inc.
Ron Schwarer	Hitachi America, Ltd.
Ted Schwarzbach	Scott Specialty Gases
Dave Sealer	Siemens Components, Inc.
David C. Sear	Fujitsu Microelectronics, Inc.
Uday K. Sengupta	Cymer Laser Technologies
Krishna Shankar	Dataquest Incorporated
Alex Shaw	Nikon Precision, Inc.
Mike W. Shea	DAW Technology
Russell Sheppard	Northern Telecom
Koichiro Shoda	Matsushita Electric Industrial Co., Ltd.
Joseph Siderine	Intel Corporation
Mark Siegel	Semiconductor Systems
Michael A. Silverstein	Advantest America, Inc.
Chet Silvestri	MIPS Computer Systems, Inc.
David M. Simko	Swagelok Company
Thomas L. Singman	Union Carbide Industrial Gases Inc.
Mikes Sisois	Atmel Corporation
John G. Skinner	DuPont Photomasks, Inc.

David Smith	EMPAK Inc.
Steve Sparks	AT&T Microelectronics
Teri Sprackland	Electronic Business News
Frank Stamatatos	Pall Process Filtration Co.
Beej Stoeckeler	Paradox Domain's Inc.
Mark Stott	Motorola, Inc.
Rodney Stubbs	PlanTek
Hee S. Sul	Samsung Electronics, Inc.
Richard Sulpizio	Unisys Corporation
Daniel Sun	Integrated Silicon Solutions
Nabil Takla	Matra Design Semiconductor
Takeo Tanaka	Kobe Development Corporation
Yoichi Tanaka	Narumi America, Inc.
John Tchiang	Wyse Technology, Inc.
Paul B. Tenseldam	Sequent Computer Systems, Inc.
Tom Thornhill	Montgomery Securities
Colin Tierney	Lam Research Corporation
Kazuhiro Todokoro	NEC Corporation
Roy Towlen	IBM Corporation
Phillip Truckle	Electroglas
Paul Turner	Price Waterhouse Technology
Cliff Vaughan	Oki Semiconductor
Mark J. Verissimo	First Interstate Bank

Mike Villott	SEEQ Technology, Inc.
Jan Visser	Houtstra Polimero
Andy Vouloukos	IBM Corporation
Haskell Waddle	Plessey Semiconductors, Ltd.
Robert Wajda	Intel Corporation
Tadashi Wakayama	Toshiba Amer. Electronic Components, Inc
David Walker	U.S. Leasing Corporation
Richard Walker	ATEQ Corporation
Susan G. Warrens	Intel Corporation
Akira Watanabe	Okura Electronics Co., Ltd.
Gordon C. Westwood	General Signal/Xynetics
James Williams	Tegal Corporation
Lou Williams	ZyMOS Corporation
Rufus Williams	Union Carbide Industrial Gases Inc.
Eric Winkler	Electronic News
Hoon Won	Memory Clearing Corporation
Fred Wong	Rapro Technology, Inc.
Ting Wong	Mosel Corporation
Peggy Marie Wood	Dataquest Incorporated
William C. Woodruff	Sharp Electronics Corporation
Larry Woodson	Texas Instruments, Inc.
Michael W. Wright	GCA Corporation

Tony Wutka	IBM Corporation
Ding-Yuan Yang	Winbond Electronics Corporation
Won Yang	Samsung Semiconductor, Inc.
Richard Yen	Wearnes Technology Corp.
Tony Yu	United Microelectronics Corporation
Denise Zertuche	Dataquest Incorporated

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SEMICONDUCTOR INDUSTRY CONFERENCE
October 08 through 09, 1990
Monterey, California

List of Attendees

AMP Incorporated	Bill Douglass, Manager, Systems Packaging
ASM Lithography, Inc.	Doug Marsh, Vice President, Worldwide Sales
AT&T	Michael J. Bill, Intellectual Property Manager Tom Egan, Intellectual Property Manager Laurence W. Nagel, Intellectual Property Division
AT&T Microelectronics	Steve Sparks, Vice President, MOS Memory, Marketing and Development
ATEQ Corporation	Richard Walker, Senior Vice President, Customer Operations
Actel Corporation	John East, President and Chief Executive Officer
Advanced Micro Devices, Inc.	Thomas Bowers, AMD/SEMATECH Technology Transfer Coordinator James Osmun, Engineer Peter Richmond, Manager, Corporate Product Marketing Bernadette Ryan, Senior Market Research Analyst
Advanced Packaging Systems	John Lezotte, General Manager

Advanced Technology Laboratories	Frank Powell, Purchasing Agent
Advantest America, Inc.	Keith Lee, Manager, Corporate Systems and Applications Engineering Michael A. Silverstein, Senior Sales Engineer
Air Products & Chemicals, Inc.	Kermit Eaton, IGD Western Region Manager Stephen Hensler, Commercial Manager
Airco/BOC	Philip Blakey, Vice President, Electronics
Alcoa Electronic Packaging, Inc.	Jeff Billinger, Business Development Analyst
Amdahl Corporation	Jaggi Sabherwal, Staff Buyer
American Speciality Gas Technology, Inc.	Gary Schmitt, Vice President Sales and Marketing
Amsterdam-Rotterdam Bank N.V.	Lawrence T. Osborne, Vice President
Analog Devices, Inc.	Robert Boole, Director, Market Research Tom Cate, Director, Strategic Development Gregory F. McHugh, Director, Information Services
Anelva Corporation	S. Mizumachi, General Manager
Apple Computer, Inc.	Heidi Hedlund, Commodity Team Leader Terry Kaspar, Supply Based Manager, Memory Judee Rowan, Supply Base Manager - ASICs

Applied Materials, Inc.	George Canavan, Marketing and Business Manager Dennis Hunter, Director, Corporate Development Noella Kwan, Market Industry Analyst James M. Moriarity, Director of Marketing David Orgill, Manager, Investor Relations
Arrow Electronics, Inc.	Jan Salsgiver, Vice President, Semiconductor Marketing
Ashland Chemical Company	Greg Bauer, Regional Sales Manager Richard Hunter, Vice President and General Manager, E&LP Division
Atmel Corporation	Jeff Katz, Vice President, Marketing Mikes Sisois, Vice President, Planning Systems
Bank of America	Raymond Epes, Vice President Deborah Friedemann, Vice President Paul Gardner, Vice President and Manager Alan Jepsen, Assistant Vice President Meg Rumpf, Vice President
Bank of Boston	Elizabeth Rutherford, Loan Officer
Bank of the West	Mark R. Kent, Assistant Vice President Arnie Olson, Vice President
Barclays Bank	Linda Ebaugh, Associate
Bechtel Corporation	Dan Butler, Manager, Conceptual Designs Bill Pfeifer, Vice President, Marketing

Branson International Plasma Corporation	Rod MacDonald, Vice President, Finance and Administration
California Institute of Technology	Carver A. Mead, Gordon & Betty Moore Professor of Computer Science
Canadian Imperial Bank of Commerce	William E. Hinch, Vice President
Chartered Semiconductor	Vernon Coleman, Director, Product Planning and Business Development
Chicago Board of Trade	Richard Jelinek, Education and Marketing Manager
Chips and Technologies, Inc.	Gordon A. Campbell, President and Chief Executive Officer
Ciba-Geigy Corporation	Chet Purcell, Product Manager
Cirrus Logic, Inc.	Mike Canning, Executive Vice President
Coherent Lazer Group	Paul Crosby, Director of Sales and Marketing
Credence Systems	Dave Mees, Chairman and Chief Executive Officer
Crestronics Company, Ltd.	Katsuhiko Ohara, President
Cymer Laser Technologies	Uday K. Sengupta, Vice President, Marketing

Cypress Semiconductor Corporation	T. J. Rodgers, President and Chief Executive Officer
DAW Technology	Susan Mooney, President and Chief Operating Officer Mike W. Shea, Vice President, Marketing and Sales
Data I/O Corporation	Larry Morrell, Marketing Operations
Dataproducts Corporation	Dolores Elderd, Purchasing Manager, Agreements
Dean Whitter Reynolds	Bradley Bryan, Investment Banker
Dell Computer Corporation	Lori Chance, Memory Products Buyer
Dewey, Ballantine, Bushby, Palmer and Wood	Brent Bartlett, Economist
Dexter Electronic Materials	Ron Benham, President
DuPont Company	John F. Imbalzano, Market Program Manager
DuPont Photomasks, Inc.	Bob Machado, Technical Service Manager Joe Megginson, General Manager John G. Skinner, Director, Advanced Photomask Technology
Dun & Bradstreet Bus. Credit Services	Lee Krueger, Electronics Industry Specialist

Dynachem	Tom Eichenberg, Product Manager Kerry Grimes, Director of Marketing Sales (SMG)
E.I. DuPont de Nemours & Company	Nick Nazarenko, Product Manager
E.T.R.I.	Jong-Son Lyu, Senior Engineer
EMPAK Inc.	David Smith, Executive Vice President
ERSO/ITRI	C. Y. Lu, Deputy General Director
ETEC Systems Inc.	C. Neil Berglund, Executive Director of Marketing Jorge Freyer, Assistant Director of Marketing
Eastman Kodak Company	David M. Antos, Buyer Peter Bonney, Materials Engineer
Eaton Corporation	Carl Noblitt, Director, Marketing
Edwards High Vacuum International	Robert Ozarski, Director of Engineering
Edwards-Temescal Corporation	Ronald Hardin, Vice President, Technical Operations
Electro Scientific Industries, Inc.	Russ Schlager, Product Manager
Electroglas	Bill Cornwell, President Phillip Truckle, Director of Marketing

Electronics & Telecommunications Research Institute	Seong-Ku Lee, Head of Project Management Section Chung Yun Min, Senior Member, Administrative Staff
Ericsson Telecom AB	Claes Y. Flodmark, Manager, Corporate Coordination
Ernst & Young	Roger F. Dunbar, Partner in Charge Mike Hildreth, Senior Manager Pat Hyek, Senior Manager Susan James, Partner
FSI International	Walter F. Kalin, Director of Marketing
Fiat Semelco	Jean Pierre Melia, Fiat Semelco Member of the Board
First Components GmbH	Willi W. Bacher
First Interstate Bank	Ron Gridley, Vice President, Regional Corporate Management Mark J. Verissimo, Vice President
Fujitsu Microelectronics, Inc.	Rheba J. Bass, Analyst Bill Cronquist, Business Planning Manager John E. Meyer, Vice President, Assistant General Manager David C. Sear, Vice President, Standard Products Operations
GCA Corporation	Michael W. Wright, Vice President, Marketing

GE Capital ELLCO	Joanne Nolan, Assistant Vice President, Market Research
General Signal/Xynetics	Ellery Buchanan, Vice President, Lithography Service Gordon C. Westwood, Vice President, Marketing
Genus, Inc.	Michael W. McCann, Vice President, Marketing and Sales
GoldStar Electron Co., Ltd.	Yu Sig Kang, Executive Director
GoldStar Technology, Inc.	Arun Kamat, Marketing Manager
Goldstar Technology, Inc.	Alan Portnoy, Executive Vice President
Gould AMI Semiconductors	David Locke, Military Product Marketing Engineer
Hamilton/Avnet Electronics	Robert Gardner, General Manager, Vice President, ASIC Operations
Hampshire Instruments, Inc.	Christopher Hayden, Director, Customer Operations
Hewlett-Packard Company	Eric Lutkin, Marketing Analyst
Hitachi America, Ltd.	David Bagby, Marketing William Gsand, Executive Vice President

Hitachi America, Ltd.	Tony Moroyan, Product Marketing and Engineering Manager Dave Raulino, Market Research Engineer Ron Schwarer, Marketing and Planning Manager
Hitachi Research Institute	Sakushi Nishioka, Researcher, Management Systems Group
Hitachi, Ltd.	Takaaki Hagiwara Tsugio Makimoto, General Manager, Semiconductor Design & Development Cente
Hoechst Celanese Corporation	Jack S. Kasahara, Product Specialist
Hong Kong Government	Donald Fletcher, Principal Consultant
Houtstra Polimero	Jan Visser, Manager, Sales and Marketing
Hoya Electronics Corporation	Kyung Kim, Executive Vice President and Chief Operating Officer
Hughes Aircraft Company	Ed Armstrong, Semiconductor Product Line Manager Chet Farris, Associate Manager Semiconductor Products Ceneter Carl Salanitro, Materials Manager
Hyundai Electronics America	Iksu Kim, Director, Strategic Marketing
Hyundai Electronics Industries Company, Ltd.	Chae Kyun Chung, Assistant Manager Dae Soo Kim, Manager

IBM Corporation	Irv Abzug, Vice President and Director, General Technology Division Chris Bajorek, Director, Technical Strategy Development Albert Blodgett, Manager of Strategic Analysis Michael Cowan, Program Manager Rob David, Product Program Office Manager Cheryl Fandel, Dennis Fandel, Senior Business Planner Robert W. Hill, Functional Manager, Advanced Lithography Systems Joanie Jones, Project Technology Office Frank T. Martin, Program Manager, Industry Operations John I. Melgalvis, Industrial Engineer John Raszcewski, Advisory Engineer Roy Towlen, Business Planner Andy Vouloukos, Senior Engineer Tony Wutka, Advisory Engineer
Imperial Bank	William Ergas, Vice President
Industrial Technology Research Institute	Chi-Ping Chang, Director, Division Planning and Technical Marketing
Insystems, Inc.	Chris Billat, President Susan Billat, Senior Vice President
Integrated Silicon Solutions	Jimmy Lee, President Daniel Sun
Intel Corporation	Richard C. Davis, Supplier Quality Engineer Debbie Folsom, Memory Commodity Manager

Intel Corporation	Frank Gill, Senior Vice President, Director,Sales and Marketing Kris M. Johnson, High Density EPROM Marketing Manager Bruce Kubicka, Manager of U.S. Market Research
Intel Corporation	Mark H. Norwood, Manager, Corporate Market Research Mark Reagan, Marketing Analyst David Rowe, Strategic Planning Cathryn Sandstrom, Commodity Manager Joseph Siderine, Program Manager Robert Wajda, Senior Engineer Susan G. Warrens, Qualification Engineer
Intergraph Corporation	Nathan Brookwood, Strategy Marketing Manager
International CMOS Technology	Paul Forster, Vice President, Sales and Marketing Drew Allen Osterman, President
International Finance Corporation	Paulo Mendes, Senior Engineer
Italtel	Riccardo Poggi, Advanced Procurement
Itausa Export North America	Gabriel A. Marao, Vice President
J. C. Schumacher Company	Tom Rutherford, President
J.P. Morgan Investment	Daniel Kunstler, Managing Director Vivek Rao, Vice President
JETRO	Kohei Kamigane, Director

KLA Instruments Corporation	Robert Boehlke, Chief Financial Officer Mike McCarver, Vice President, General Manager, Rapid Division
Kawasaki Wafer Technology	Joseph Arruda, Director of Marketing
Kobe Development Corporation	Takeo Tanaka, General Manager
Kokusai Electric Co., Ltd.	Hisao Kanamaru, General Manager Hideo Kobayashi, Manager
Kyocera America, Inc.	David Grooms, Product Manager, Microelectronics Group
LSI Logic Corporation	Robert Blair, Senior Vice President, ASIC Group
LTX Trillium	Jim Healy, President Dennis Petrich, Director of Marketing
Lam Research Corporation	Roger D. Emerick, Chief Executive Officer, Chairman of the Board John Osborne, Senior Vice President, Strategic Develop Colin Tierney, Vice President of Operations
Lumonics Corporation	Charles M. Bosnos, Product Manager
MIPS Computer Systems, Inc.	Jim Fleury, Director, Strategic Marketing Chet Silvestri, Vice President, Technology Products Group

Ma Laboratories	Phillip Lyman, Vice President, Sales and Marketing Abraham Ma, President
Manufacturers Hanover Trust Company	Leonard Sanders, Vice President
Marshall Industries	Mark Grant, Semiconductor Marketing Manager
Marubeni International Electronics	Ohitoshi Fujimoto, Manager Yashuhiko Morita, Director
Matra Design Semiconductor	Nabil Takla, Vice President
Matsushita Electric Industrial Co., Ltd.	Hiroyuki Mizuno, Executive Vice President and Member of the Board Ron Richard, Consultant Koichiro Shoda, General Manager, Strategic Operations, Corporate Technology
Memory Clearing Corporation	Hoon Won, Chief Executive Officer
Mentor Graphics Corporation	David Krug, ASIC Program Manager
Microchip Technology Inc.	Steve Sanghi, President and Chief Operating Officer
Micron Technology, Inc.	Joseph Parkinson, Chairman of the Board
Mill-Bern Associates, Inc.	George E. Miller, President

Mitsubishi Electronics America, Inc.	Azmat Malik, Business Development Manager
Mitsubishi Kasei America Inc.	Koji Hasegawa, Manager
Montgomery Securities	Clark Gerhardt, Partner Jonathan Joseph, Analyst Tom Thornhill, Vice President
Mosel Corporation	Stephen Chiao, Vice President Ting Wong, Vice President, Research and Development
Motorola, Inc.	Doug L. Powell, Vice President and Director, Technology Planning and Development Mark Stott, Manager, Strategic Research
NCR Corporation	Bill Chastain, Applications Engineer, MPD World Sales Richard Johnson, Assistant Vice President Microelectronics Products Division
NCR Microelectronics	Larry C. Hollatz, General Manager, Colorado Springs Mike W. Morrissey, General Manager, Fort Collins
NEC Corporation	Kazuhiro Todokoro, Market Research and Planning Manager, Semiconductor Group, Group Planning Office
NEC Electronics Inc.	Dan Domingo, Corporate Strategic Marketing Manager Kunishiro Saito, President

NEC Electronics Inc.	Frank M. Jelenko, Vice President, Strategic Planning Hidehiro Kunitomo, Director
NKK America Inc.	Tracy Garnier, Business Advisor
Narumi America, Inc.	Yoichi Tanaka, President
National Semiconductor Corporation	John Berryman, Group Director, Volume Products Business Center Steve Bogart, Senior Product Marketing Engineer Richard Hunt, Vice President, Computer Industry Marketing Richard Sanquini, Vice President, Dynacraft and Corporate Strategic Project
Netherland Centres for Microelectronics	H. J. Bosch, Managing Director
Netherlands Foreign Investment Agency	Peter Lablans, Area Director Rene Savelsberg, Area Director
Nikon Precision, Inc.	Rick L. La France, Director, Marketing Michael W. Powell, Vice President, Marketing Alex Shaw, Director, Measurement Technology
Northern Telecom	John Scheer, Director of Market Development Russell Sheppard, Director, Strategic Semiconductor Components
Northern Telecom Electronics Inc.	Vimal Sarna, Product Manager

Oak Technical Inc.	Murray Collette, President
Oki Semiconductor	Jim Cantore, Manager, Strategic Marketing Gordon Cumming, Corporate Chief Technologist Bharat Gupte, Marketing Manager, Standard Products Cliff Vaughan, Marketing Manager, ASIC Products
Okura Electronics Co., Ltd.	Akira Watanabe, Manager
Olin Hunt Specialty Products, Inc.	Chen Kao, Director, Planning
Orbot Instruments, Ltd.	Daniel Oleiski, Sales and Marketing Executive
Pall Process Filtration Co.	Bernard Gilbride, Marketing Manager, Electronics Frank Stamatatos, Senior Sales Specialist
Paradox Domain's Inc.	Beej Stoeckeler, President and Chief Executive Officer
Pitney Bowes, Inc.	Nathan Rosenberg, Manager, Custom Integrated Circuit Design
PlanTek	Rodney Stubbs, President

Plessey Semiconductors, Ltd.	Philip Pollok, Director, Marketing and Sales Haskell Waddle, President
Price Waterhouse Technology	Paul Turner, Executive Director of Research
Prudential-Bache Capital Funding	Chad Keck, Managing Director Dan Klesken, Senior Semiconductor Analyst and Vice President
Quantum Corporation	Andre Neumann-Loreck, Commodity Manager
Ramtron Corporation	Todd Oseth, MASIC Business Manager
Rapro Technology, Inc.	Fred Wong, Vice President, Technology and Marketing
Raytheon Company	Bob Goedjen, Director, Strategic Accounts Skip Grzanka, Product Marketing Engineer
Robert Bosch Gmb	Gunter E. Matthai, Manager, Technical Planning
Rockwell International Corporation	Tom Jones, Planning Manager
Ryosan USA, Inc.	Neil Mimatsu, Regional Manager

SEEQ Technology, Inc.	J. Daniel McCranie, Chairman & Chief Executive Officer Mike Villott, Vice President, General Manager, Logic Division
SEMATECH	Alan Allan, Competitive Analyst Richmond Clover, Lithography Systems Manager Gene Fuller, Manager, Stepper Programs Jack Grucza, Business Analyst
SID Microelectronica S.A.	Victor Blatt, Managing Director Nelson Goncalves, Managing Director
Samsung Electronics Co., Ltd.	Mi Jeong Hwang, Assistant Manager Yongo Lee
Samsung Electronics, Inc.	C. Y. Pae, Senior Managing Director Hee S. Sul, Vice President, Sales and
Samsung Semiconductor, Inc.	S. L. Choi, Senior Planning Manager Mark Ellsberry, Director of Marketing, Memory Products Ilbok Lee, President Keith McDonald, Vice President, Sales and Marketing Joe O'Neill, Vice President, Sales and Marketing, Micro Products Won Yang, Vice President, Finance and Administration
Sandia National Laboratories	Chuck Gwyn, Department Manager, Microelectronic Programs
Schlumberger Technologies	Marc Letraon, Manager of Corporate Communication

Scott Specialty Gases	Craig Keever, Sales and Marketing Manager Ted Schwarzbach, Region AL Vice President
Security Pacific Venture Capital	Niels Krabbe, Analyst James B. McElvee, Senior Vice President
Semiconductor Systems	Mark Siegel, President
Sequent Computer Systems, Inc.	Paul B. Tenseldam, Staff Engineer
Sharp Electronics Corporation	William C. Woodruff, Director, Integrated Circuits
Shinko Electric America, Inc.	Will Eckert, Vice Presiden, Sales and Marketing
Shipley Company, Inc.	Eric Alling, Director, Technical Marketing
Siemens Components, Inc.	Richard Konrad, Vice President of Sales Dave Sealer, Vice President
Signetics Corporation	James E. Dykes, President
Silicon Integrated Systems Company	Samuel S. Liu, President
Singapore Economic Development Board	Voon Kheong Liow, Deputy Director, Electronic Components Industry Suresh Natarajan, Director, Chicago Center

Soft Silicon Devices	Michael D'Agostino, Vice President, Marketing Hesh Khajezadeh, President and Chief Executive Officer
Sony Corporation of America	Jean-Pierre Laussade, Vice President of Semiconductors Masa Mizuno, Enginmeering Monitor
Standard Microsystems Corporation	Lawrence H. Goldstein, Vice President, Engineering Walter Kameta, Sr. Vice President Dennis Lyden, Marketing Manager, Memory Products
Sun Microsystems, Inc.	Stephen L. Diamond, Director, Strategic Technology Marketing
Sundstrand Data Control	Frank Brem, Advanced Product Manager
Swagelok Company	David M. Simko, Manager, Marketing
Taiwan Semiconductor Manufacturing Company, Ltd.	Paul Chien, Engineering Director John Luke, Vice President, Marketing
Tegal Corporation	James Williams, Vice President of Finance, Chief Financial Officer
Tektronix, Inc.	Peggy L. Lewis, Procurement Manager
Texas Instruments, Inc.	Bill Jewell, Market Analyst David Palmer Betty Prince, Strategic Marketing Manager Larry Woodson, Manager, WW Strategic Marketing

The Source/GE Capital	Michael Mardesich, Appraiser
Tokyo Electron, Ltd.	Rick Oyama, Marketing Coordinator
Toshiba America Electronic Components, Inc.	Robert J. Brown, Senior Vice President and Group Executive Tadashi Wakayama, President
Toshiba America, Inc.	Frank Ramsay, Strategic Marketing Manager
U. S. Department of Commerce	Dorothea Blouin, Semiconductor Industry Specialist
U.S. House of Representatives	Tom Campbell, Congressman, California 12th District
U.S. Leasing Corporation	Chris P. Nugent, Asset Management David Walker, Manager, New Market Development
Union Bank	John Hein, Senior Vice President Anthony Kwee, Vice President
Union Carbide Industrial Gases Inc.	Thomas L. Singman, Marketing Manager, Electronics Rufus Williams, National Sales Manager, Specialty Electronic Products
Unisys Corporation	Richard Joy, Vice President and General Manager Richard Sulpizio, Vice President and General Manager

United Microelectronics Corporation	Tony Yu, Manager, U.S. Operations
VLSI Technology, Inc.	Douglas G. Fairbairn, Senior Vice President, Corporate Strategy and Development Leslie T. Guttadauro, Manager, Strategic Programs
Varian Associates	James Crosskill, Planning Specialist
Varian/Extrion	Michael Pippins, Product Manager, Extrion 220, Beverly Operations
Veriflo Corporation	Burt Lancaster, Vice President
Vertex Semiconductor Corporation	Stephen E. McMinn, Vice President, Marketing and Sales
Viking Labs/Honeywell	Eugene R. Hnatek, Research and Development Engineering Manager
W. L. Gore & Associates, Inc.	William Hanna, Associate
Wearnes Technology Corp.	Richard Yen, President
Weiss Scientific Glass	Jan Noordhoff, Vice President, Finance/Administration
Weitek Corporation	Bob Derby, Senior Vice President Steve Domenik, Vice President, Marketing
Western Digital Corporation	Everett Boswell, Vice President Roger Johnson, Chairman, President, and Chief Executive Officer

Winbond Electronics Corporation	Ding-Yuan Yang, President
Wyse Technology, Inc.	John Tchiang, Corporate Purchasing Manager
Xerox Corporation	Ray Colline, Commodity Manager Larry W. Grange, Manager, Electronic Commodity
Xilinx Inc.	James Barnett, Vice President, Strategic Planning
Zitel Corporation	Errol Ives, Director of Materials
Zoran Corporation	Bernard Aronson, Executive Vice President
ZyMOS Corporation	Lou Williams, Director of Marketing
	Ray Campbell, Consultant

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Semiconductor Industry Conference

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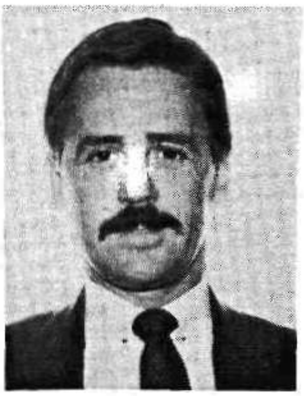
SEMICONDUCTOR INDUSTRY FORECAST



David L. Angel
Vice President and Director
Semiconductor Industry Service
Dataquest Incorporated

David Angel is Vice President and Director of Dataquest's Semiconductor Industry Service. He is responsible for managing and directing all of the company's semiconductor research activities worldwide. Prior to joining Dataquest, Mr. Angel was Managing Director of DQ Alliances, a high-technology investment banking firm affiliated with Dataquest. While at DQ Alliances, he initiated and completed numerous strategic alliances, joint partnerships, acquisitions, and start-up company fundings, the majority of which were related to the worldwide semiconductor industry. Mr. Angel has 25 years of experience in the semiconductor and venture capital fields, having served as President, Executive Vice President, and Chief Operating Officer of several high-technology startup companies. He was founder and senior partner of Almaden Venture, a seed fund and venture capital consultation firm. Earlier, he was founder of Signetics Memory Systems and the Director of American Microsystems Inc.'s (AMI) Image Technology Center. He is considered an expert in semiconductor lithography. Mr. Angel has authored more than 50 publications relating to high technology, funding new businesses, strategies for success in high technology, and management of high-technology companies. Mr. Angel received a B.S. degree in Premedical Studies and Chemistry from Marietta College and did graduate work in Physical Chemistry and Law at Williams College and LaSalle University.

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Monterey, California

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Semiconductor
Industry
Conference

Semiconductor Industry Forecast

David Angel
Group Vice President
and Director of Worldwide Research
Semiconductor Components Group
Dataquest Incorporated

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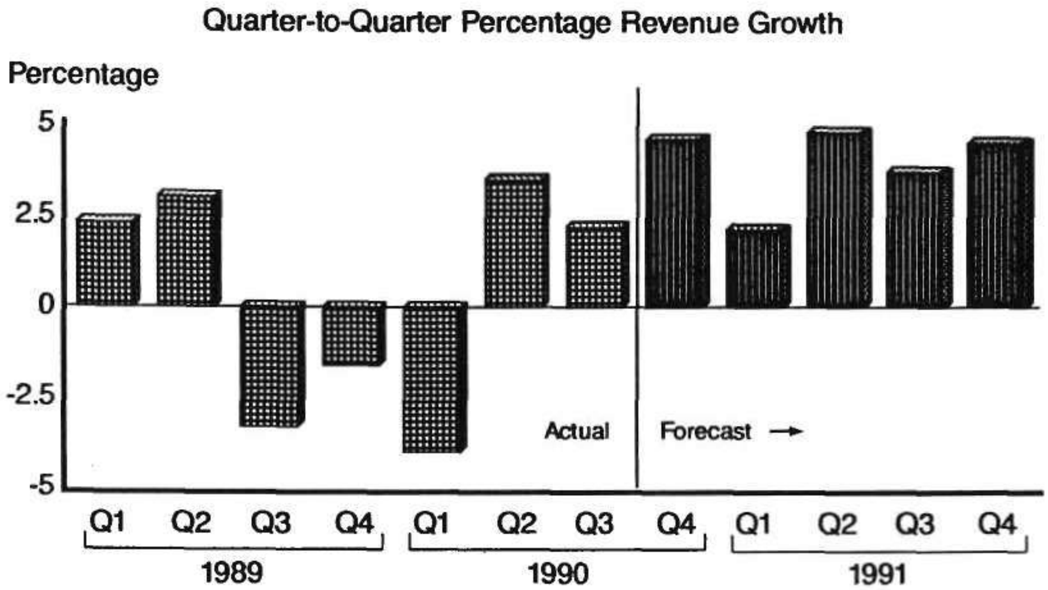
WORLD SEMICONDUCTOR INDUSTRY FORECAST



Source: Dataquest

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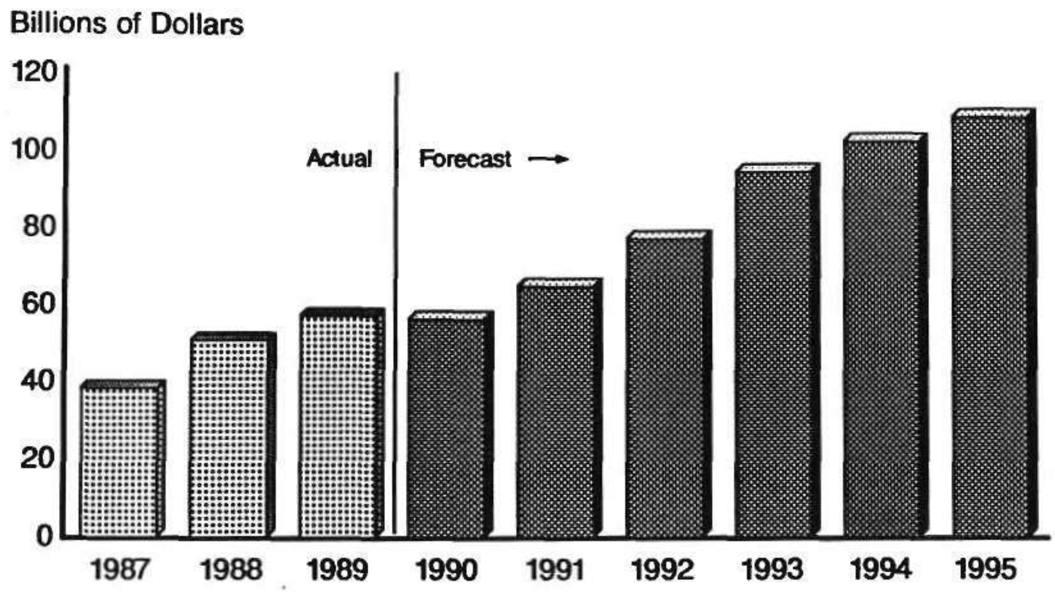
WORLD SEMICONDUCTOR INDUSTRY FORECAST



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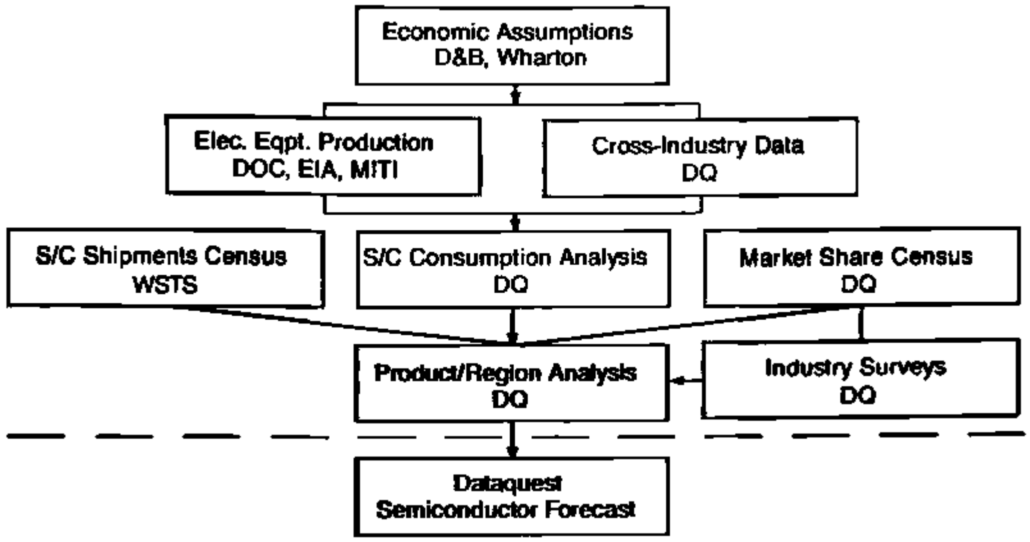
DATAQUEST FORECASTING SYSTEM

Quarterly Semiconductor Forecasting Cycle



Why?

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ISSUES THAT COULD AFFECT THE FORECAST

- War in the Middle East
- German reunification
- Rising cost of Japanese capital
- Slowdown becoming broad-based recession

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THE NEXT DECADE . . . WHERE OPPORTUNITIES LIE

Manny Fernandez
President
Dataquest Incorporated

Manny Fernandez is President and Chief Executive Officer of Dataquest. Since he became President in October 1985, Dataquest has increased its products and services, expanded its overseas coverage, and earned record revenue and profits. Under Mr. Fernandez's leadership, Dataquest has introduced low-priced products that include directories, focus reports, and newsletters; tripled its resources for primary research; and launched additional industry services in the areas of semiconductors, information systems, peripherals, and office equipment. Also under his direction, Dataquest has established research and marketing activities in Boston and Seoul and has greatly enlarged its offices in London and Tokyo. Mr. Fernandez's management of the acquisitions of Intelligent Electronics Europe and Invitational Computer Conferences and the merger of Focus Research Systems has enabled Dataquest to broaden its research capabilities and product offerings worldwide. Mr. Fernandez has been involved in high-technology industries for the past 21 years. Prior to assuming the presidency of Dataquest, he founded the company's Strategic Executive Service, which provides vital decision-making support for CEOs of high-technology companies. Before joining Dataquest, Mr. Fernandez was President and CEO of Gavilan Computer Corporation, President and CEO of Zilog, Inc., and Group Vice President of Fairchild Camera & Instrument Corporation. Mr. Fernandez received B.S. and M.S. degrees in Electrical Engineering from the University of Florida.

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Semiconductor Industry Conference

The Next Decade . . . Where Opportunities Lie

Manny Fernandez
President
Dataquest Incorporated

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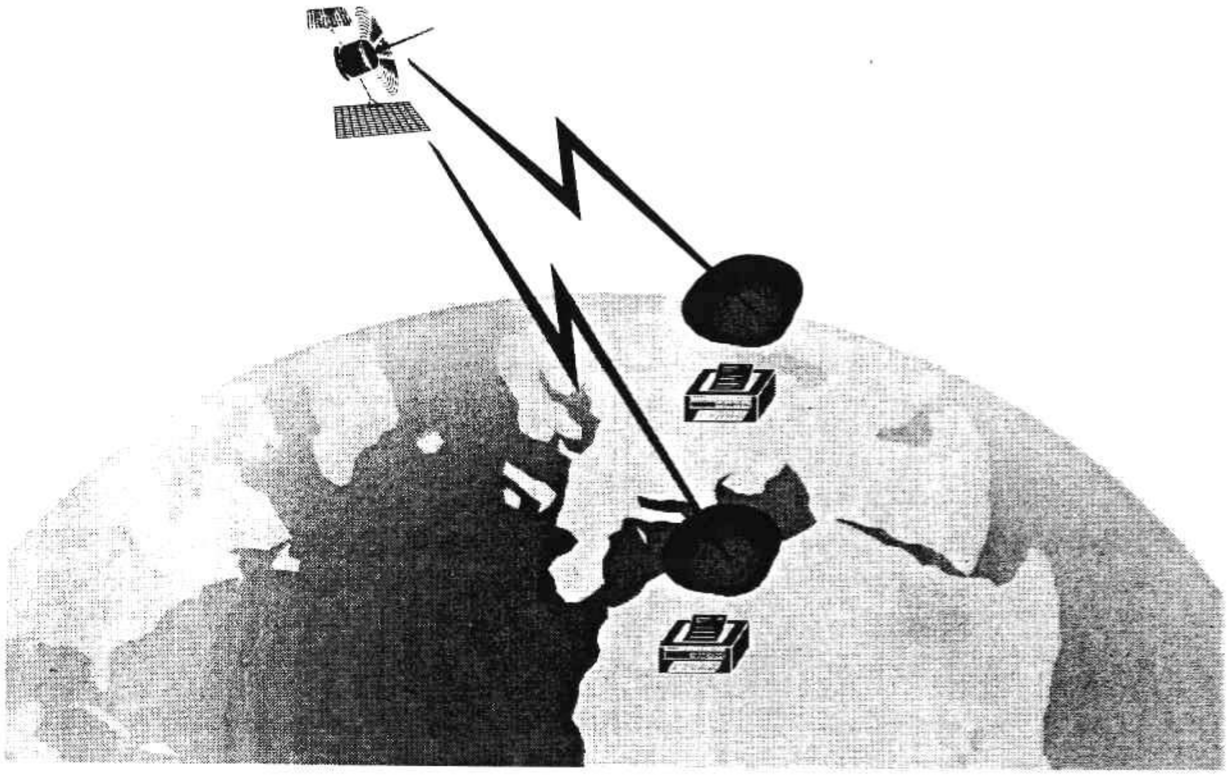

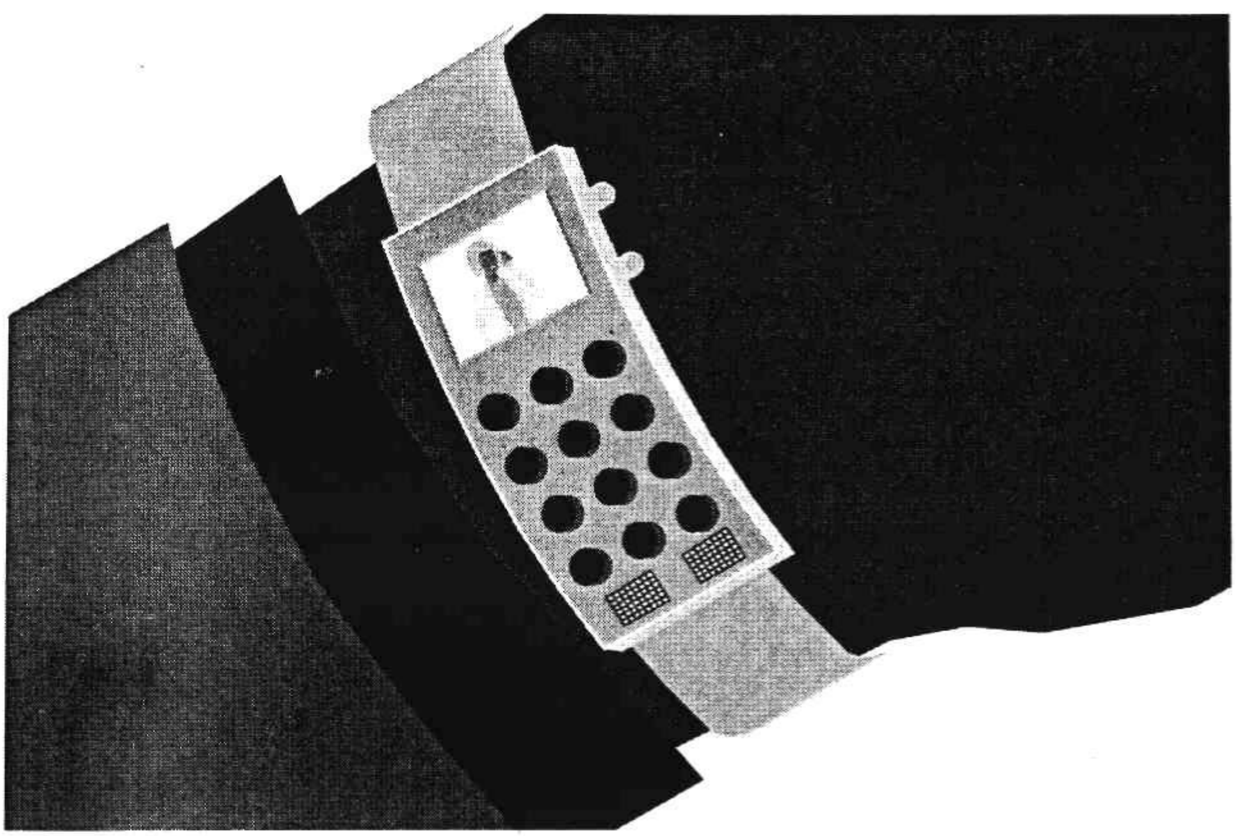

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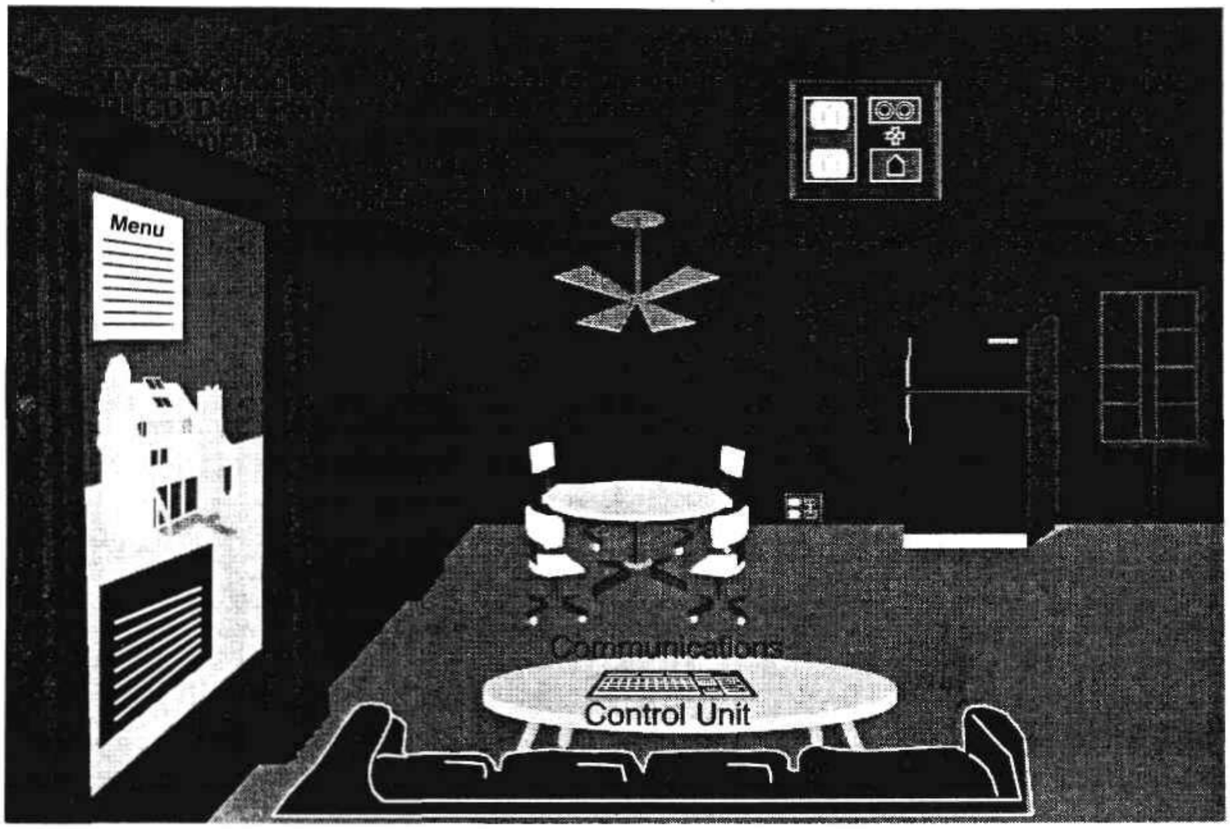

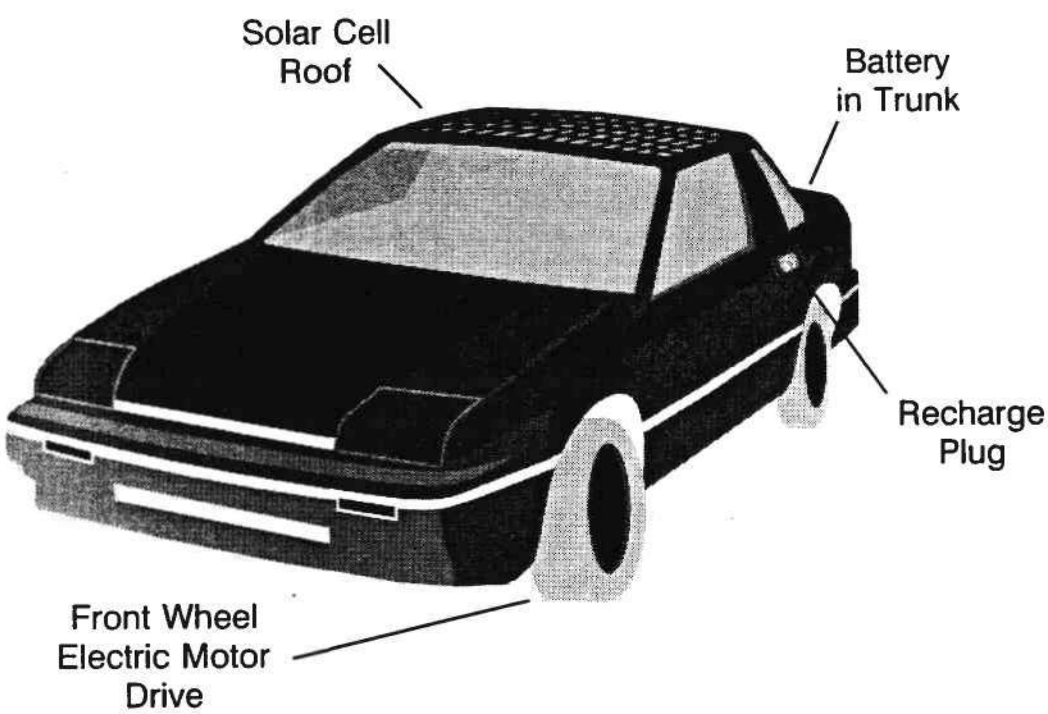

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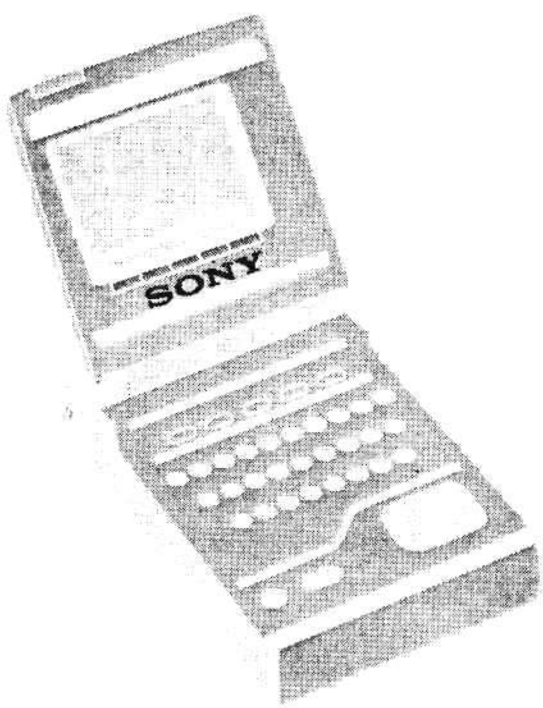

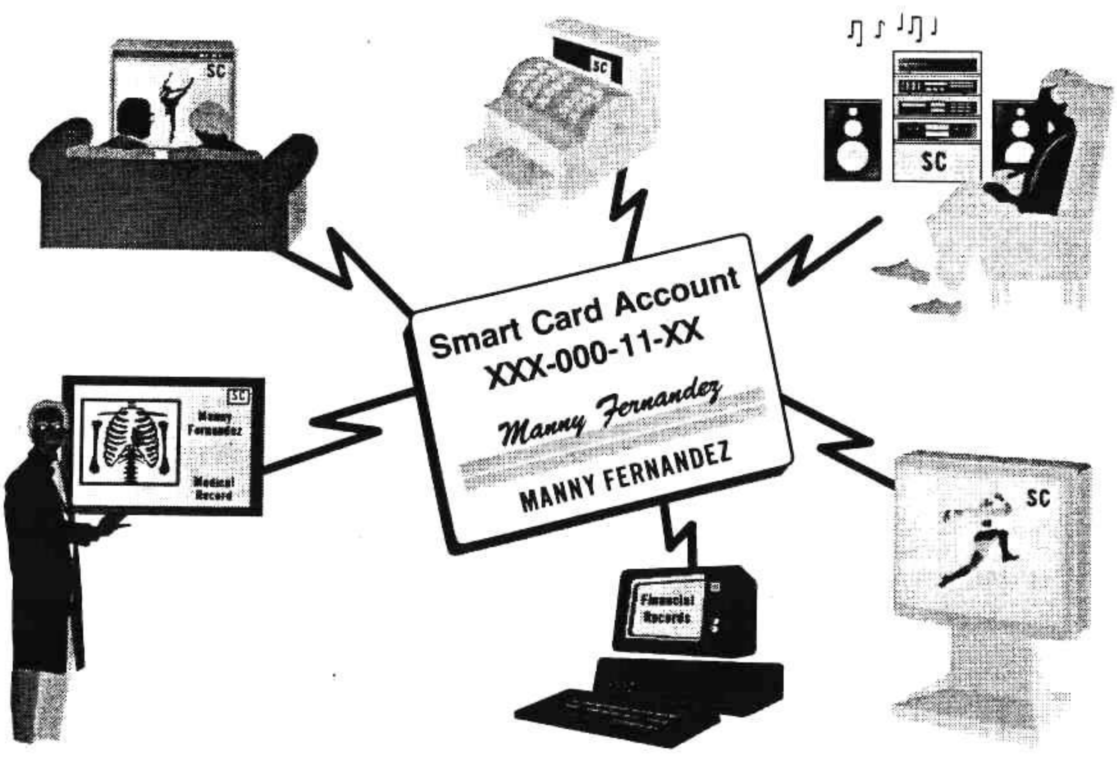

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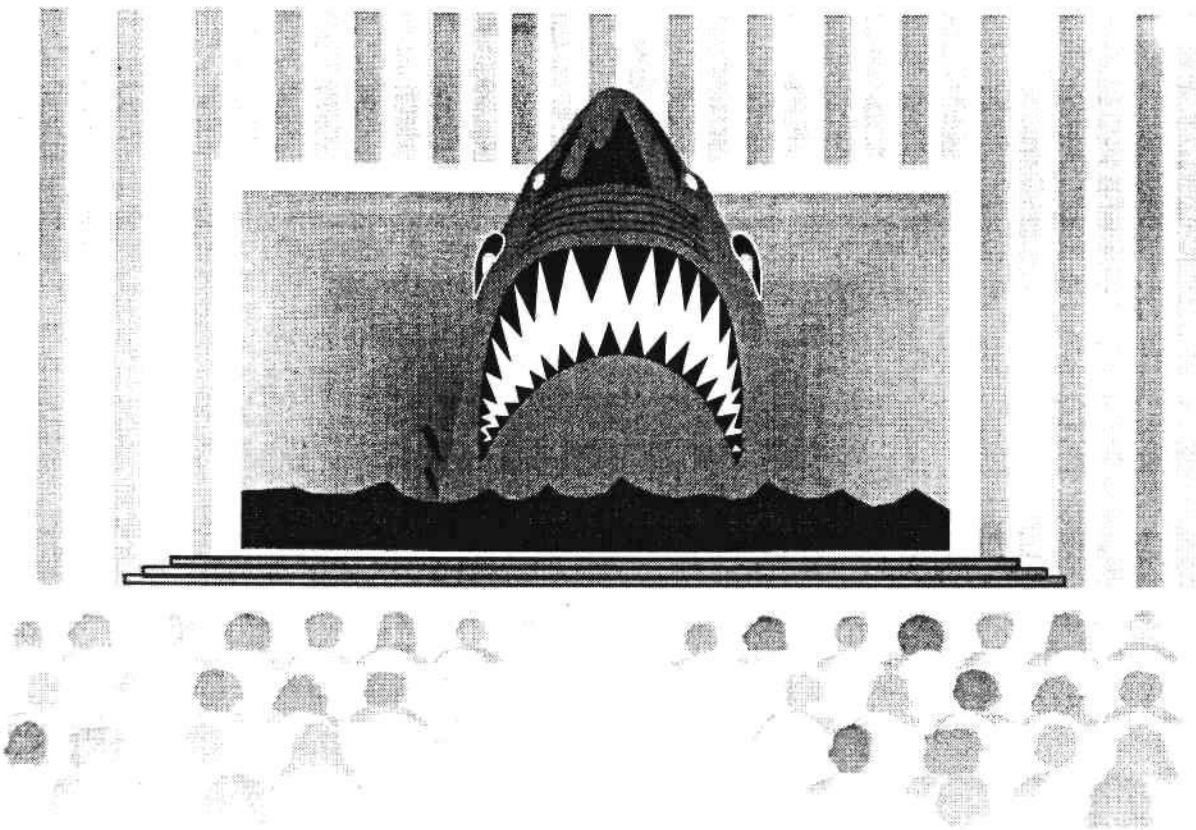

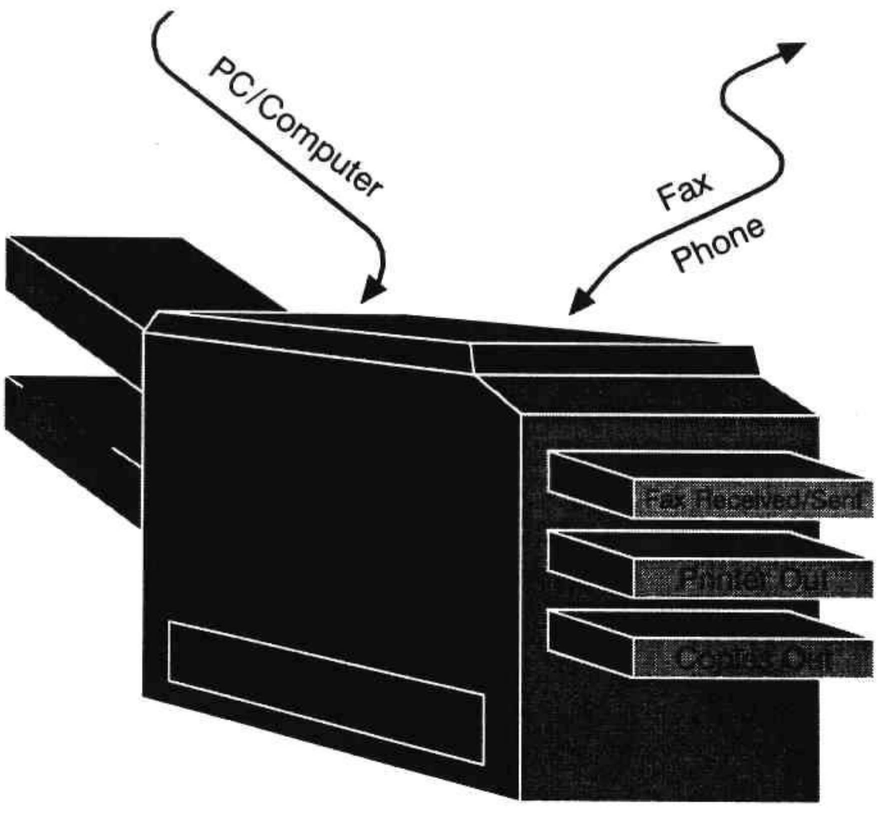

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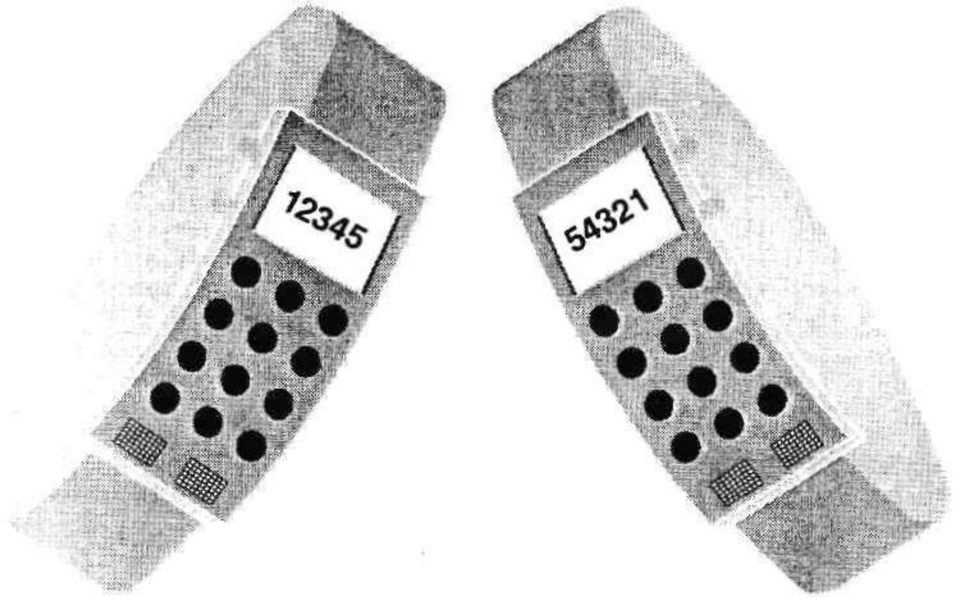

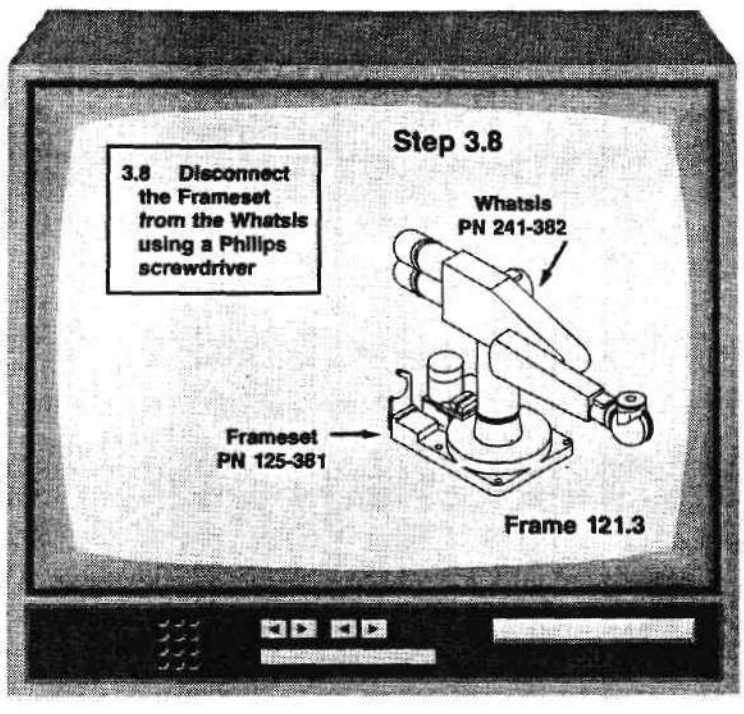

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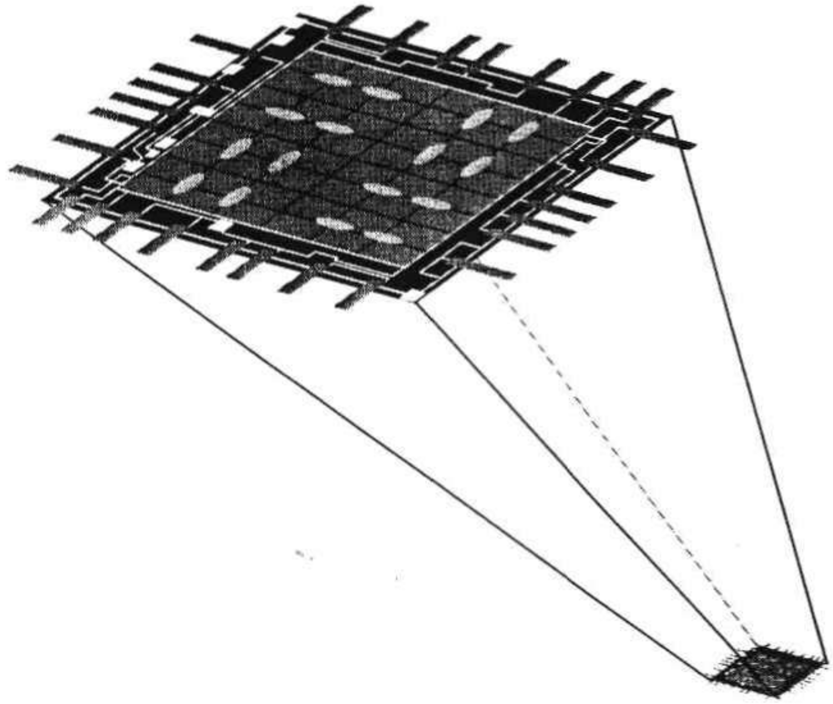
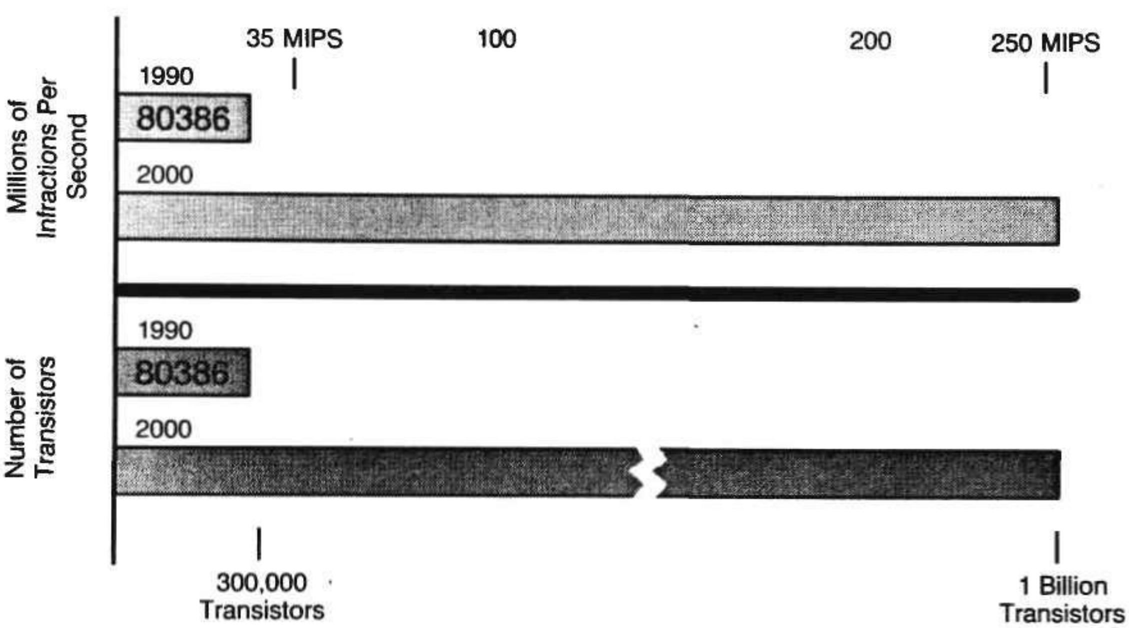


MICROPROCESSOR



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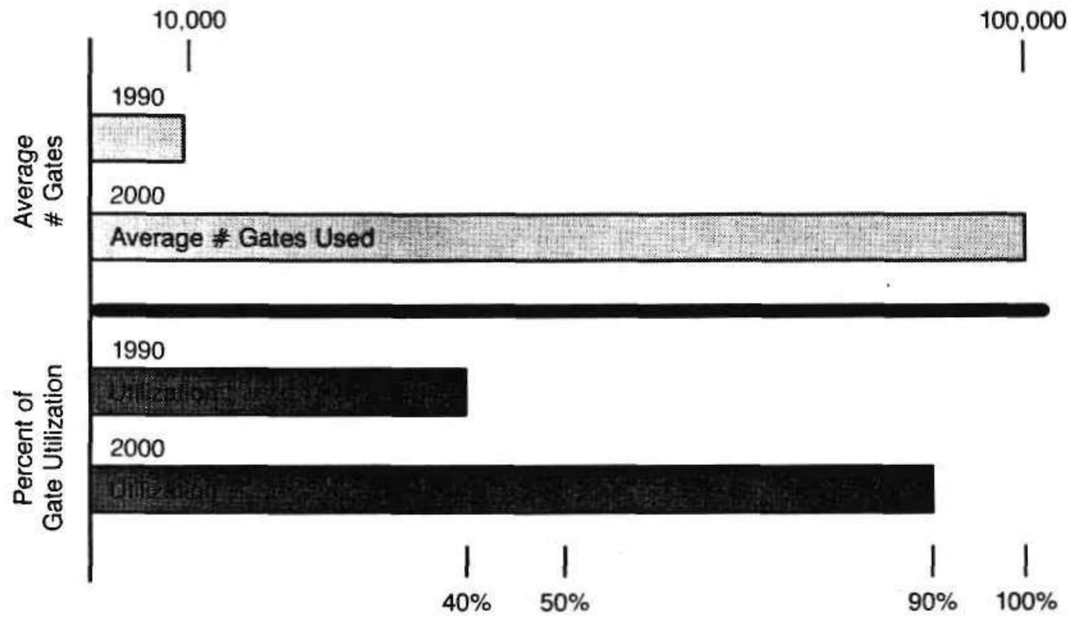
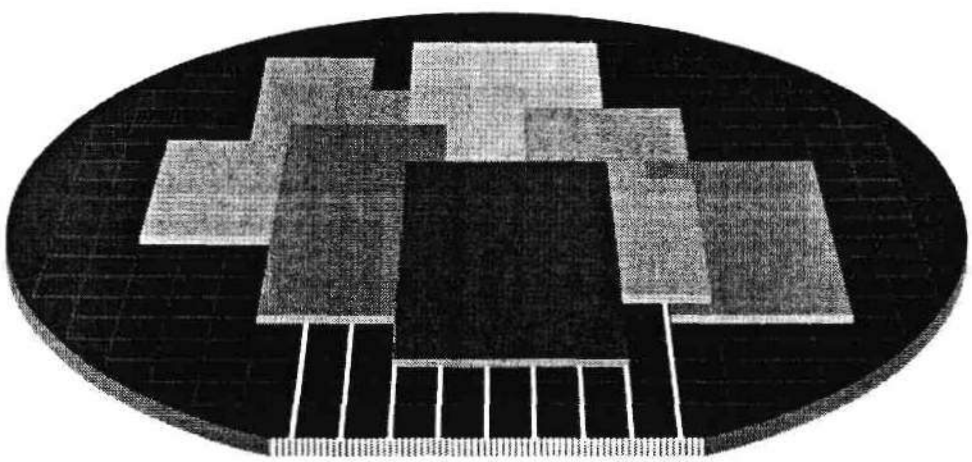
ASIC





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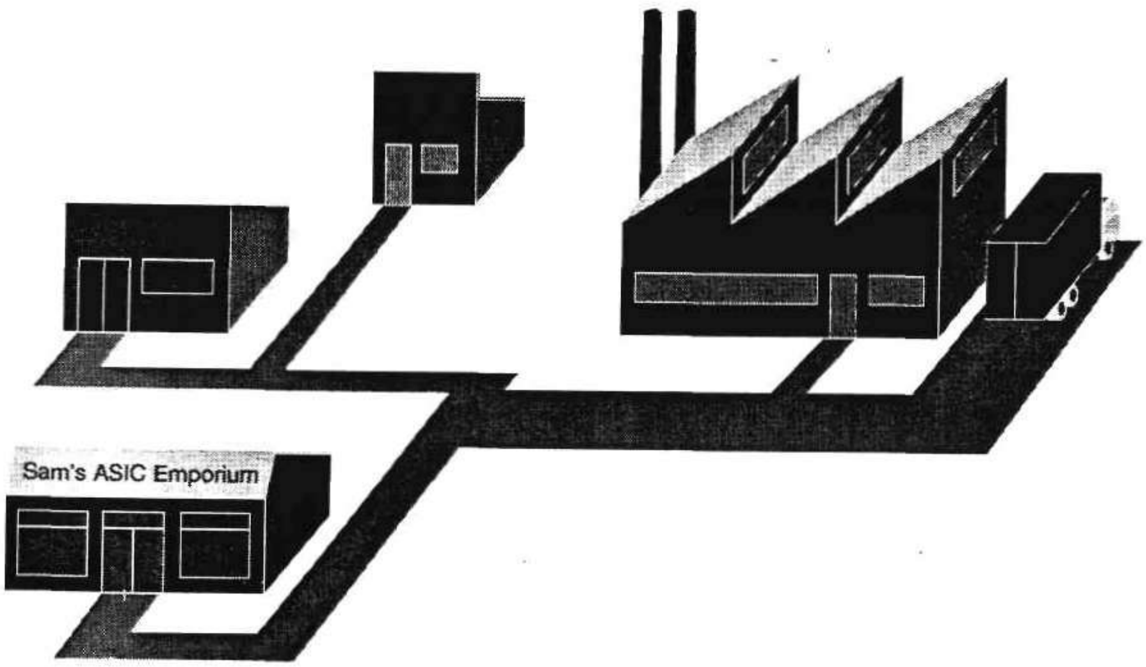

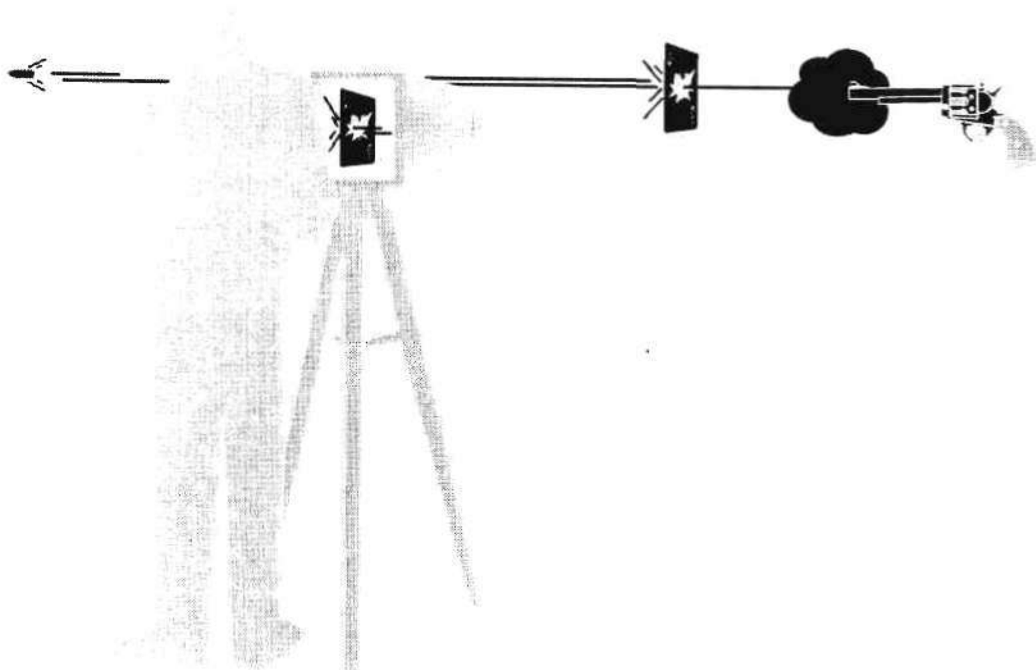

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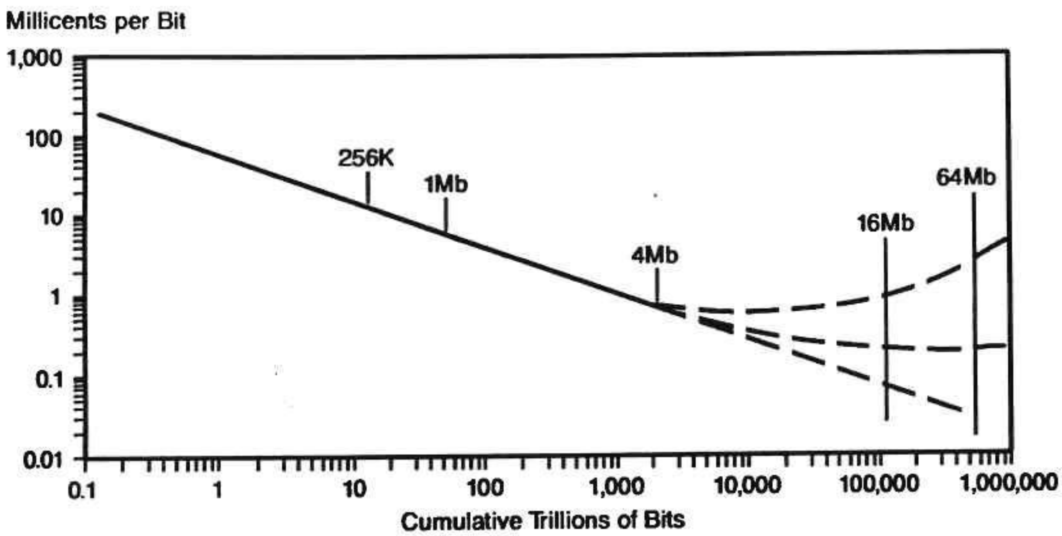
"MOORE'S LAW"
PRICE LEARNING CURVE
DRAMs



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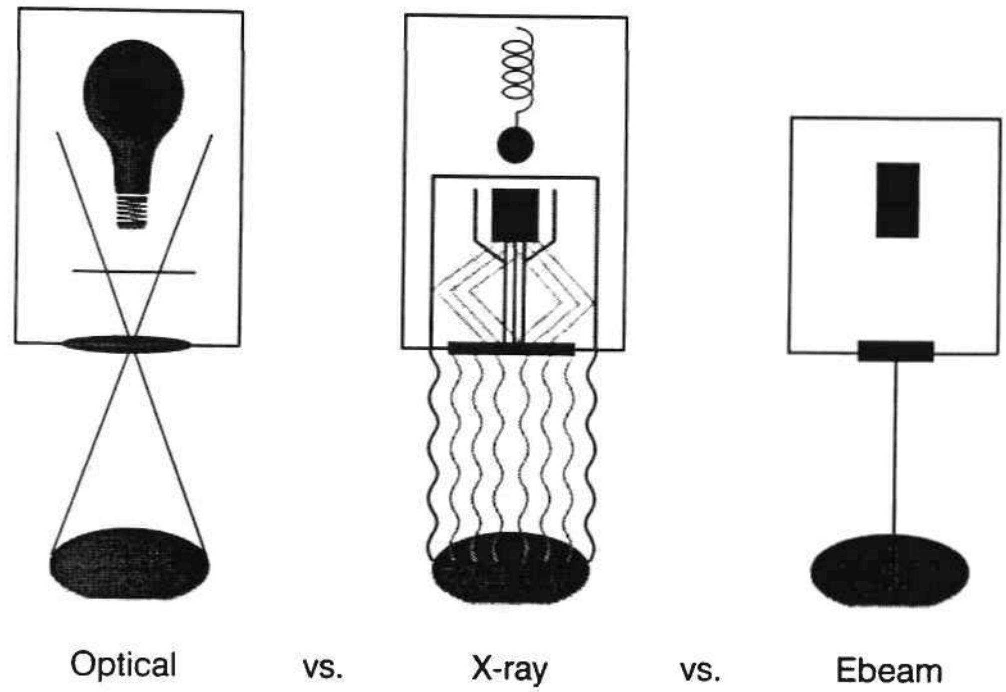

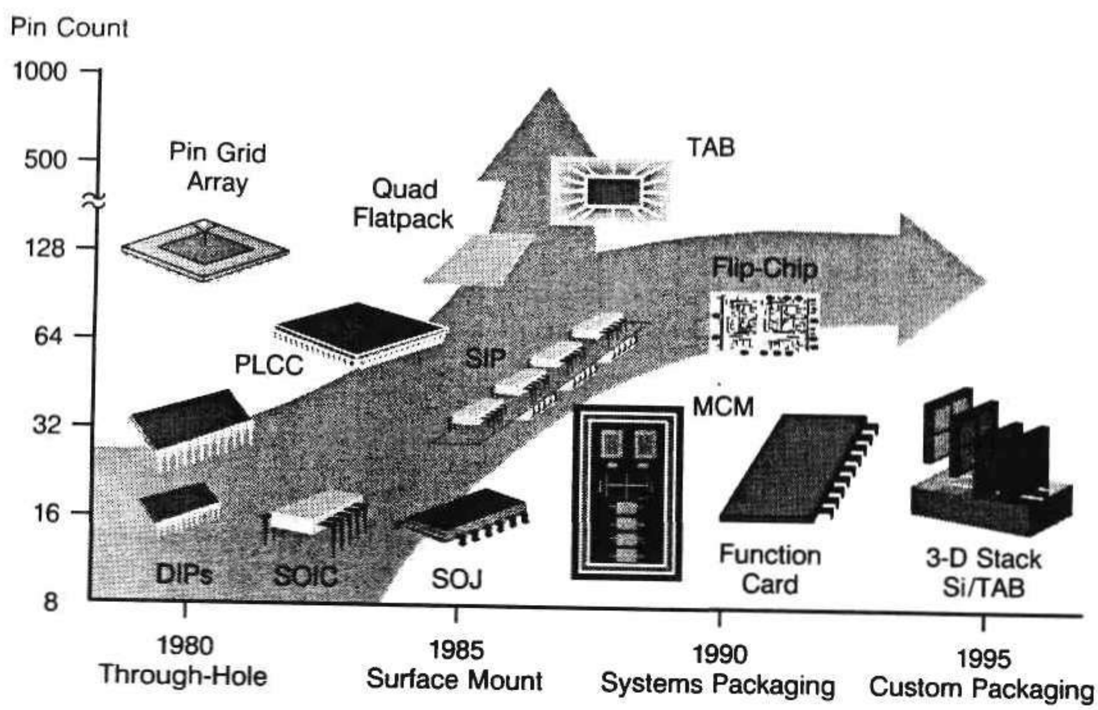

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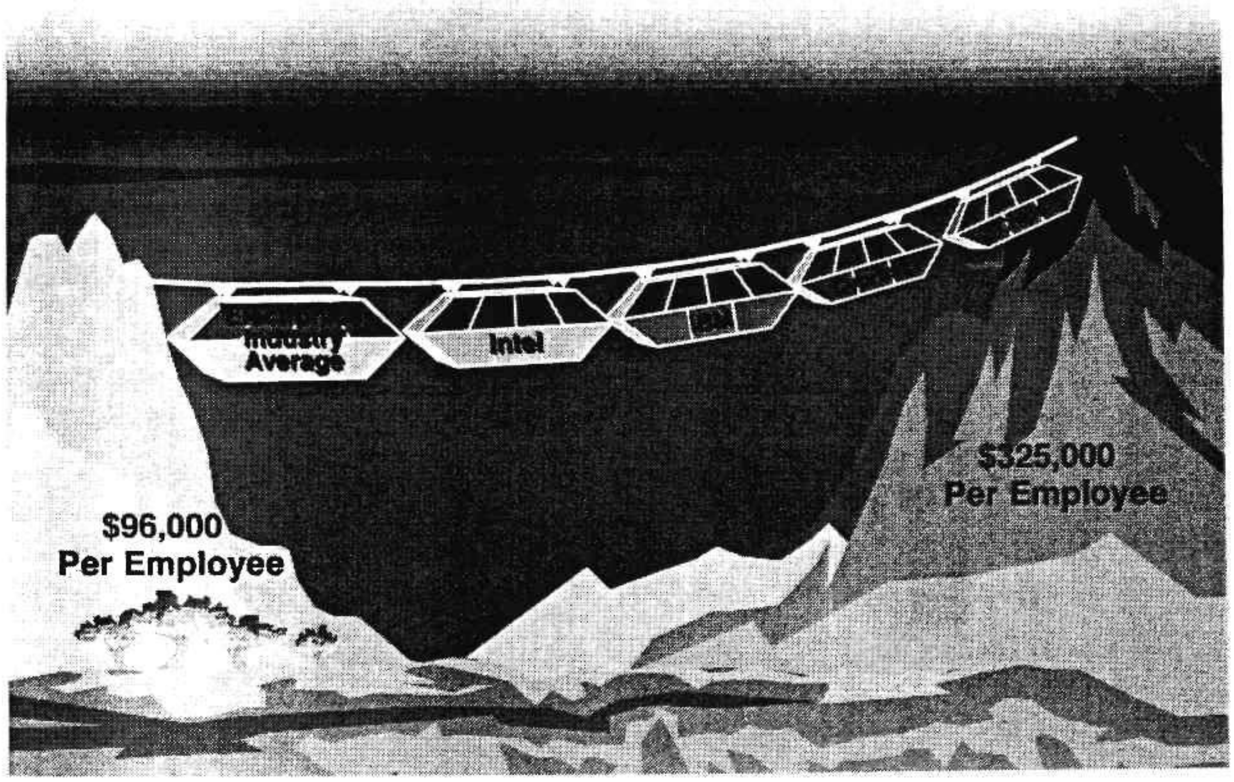

MAJOR TECHNOLOGY OPPORTUNITIES IN THE 1990s

- Widespread use of Smart Cards
- Tremendous advances in medical imaging
- Proliferation of wireless communication
- Integration of office functions
- Major strides toward paperless society
- Breakthroughs in harnessing solar energy
- Expanding use of environmental sensing

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Semiconductor
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Differing Corporate Strategies: Fabless Semiconductor Supplier

Gordon Campbell
President and CEO
Chips & Technologies

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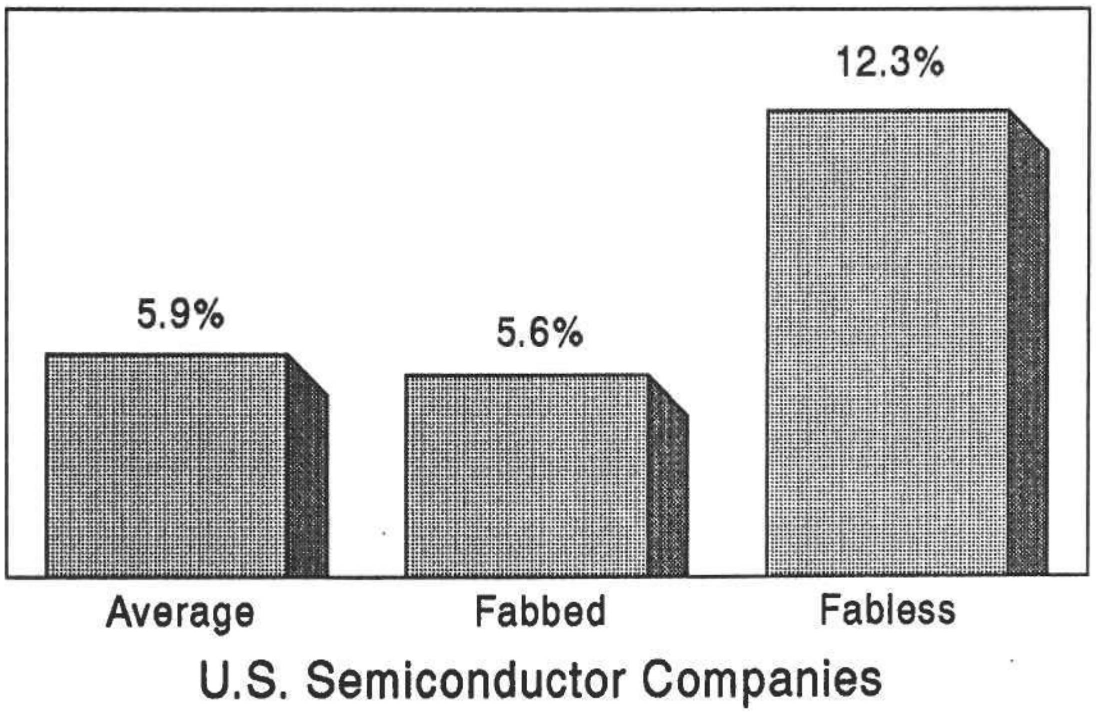
Fabless Companies Are More Profitable
1989 Net Income as Percent of Sales



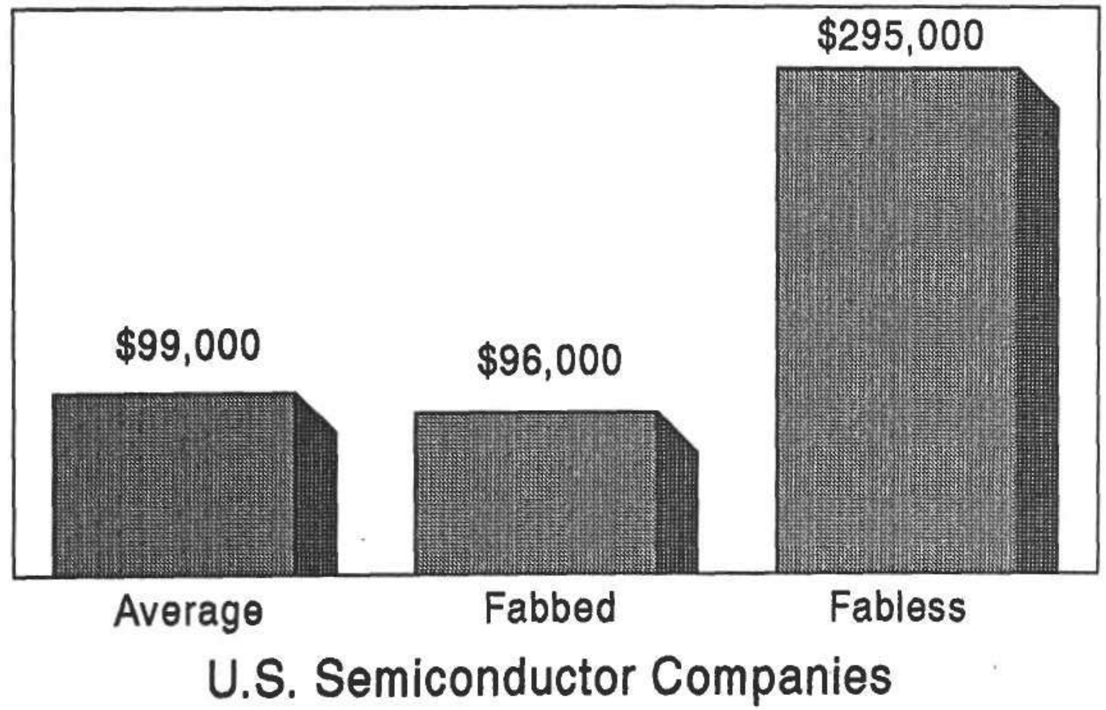
Source: Dataquest

fab003

CHIPS
Solutions for a Changing World

Fabless Companies Have Higher Sales

1989 Sales Per Employee



Source: Dataquest

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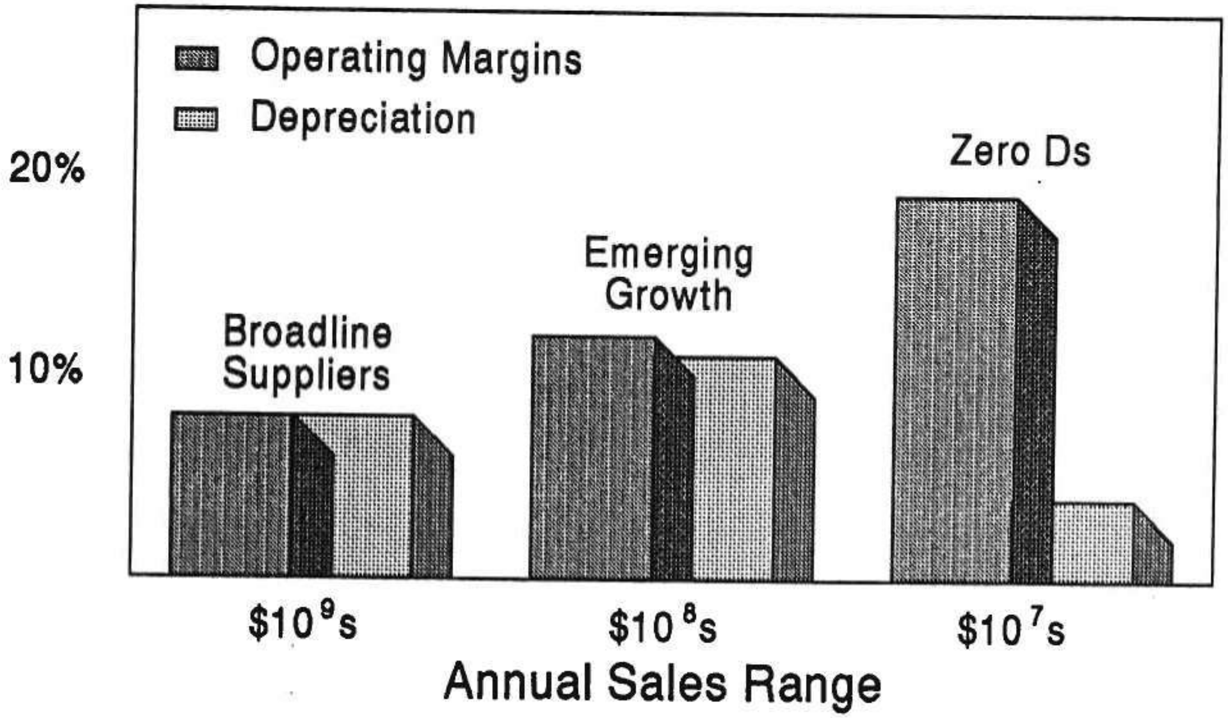
Fabless Companies Bear Less Risk
3 Strategies Deal with Capital Intensity



Source: Hambrecht & Quist, Inc.

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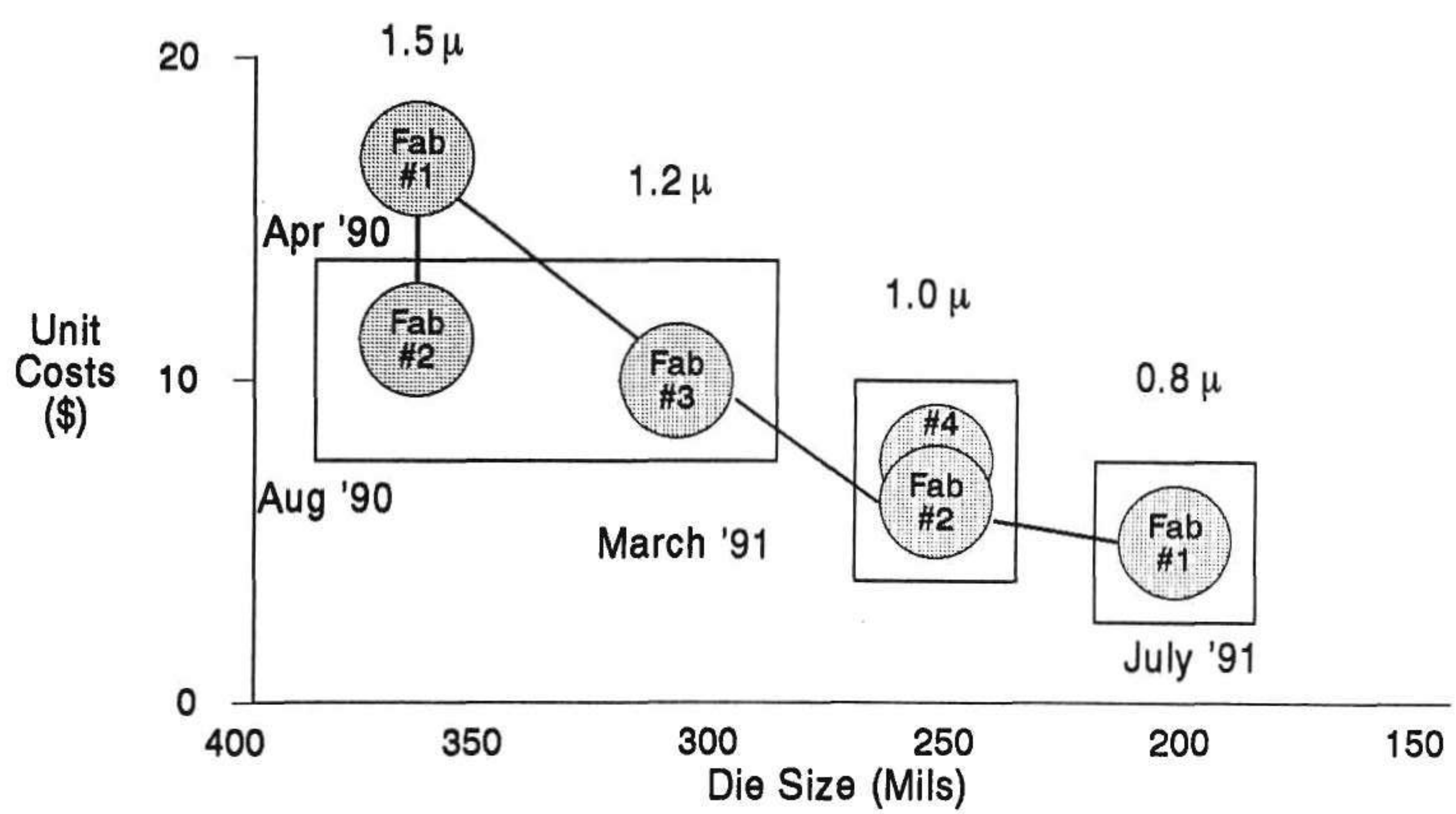
Multiple Fab Cost Reduction Plan



fab006

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The Key to Successful Fabless Operation Is ASP

- Average Multiple on Wafer Costs Is 5x the Wafer Price

- Fabless Margins Average 20% vs 12%

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Fabless Companies Must Deliver a Clearly Value Added Product

- Products
  - CHIPSets
  - Co-Processors
  - DSP
  - Field Programmable Logic

- Benefit
  - Reduce Computer Systems to Chips
  - Performance
  - Software Content
  - Flexibility

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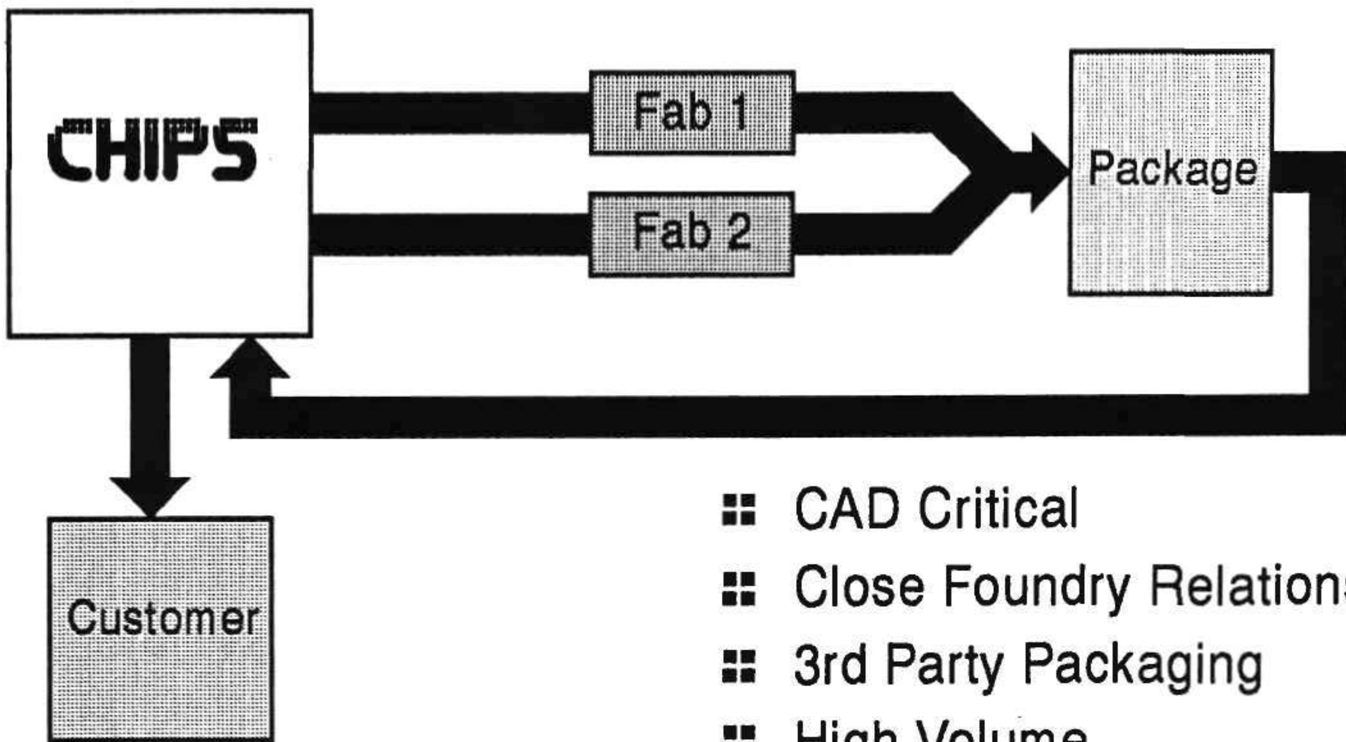
The Fabless Manufacturing Flow



- CAD Critical
- Close Foundry Relationships
- 3rd Party Packaging
- High Volume

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Typical $100M Revenue Based Company

	Fabless		Fabbed	
Capital Costs				
Building/Land	0		$28M	
Equipment	0		54M	
		$0		$82M
Operating Costs				
Material	0		$ 5M	
Direct Labor	0		5M	
Indirect Labor	0		12M	
Indirect Materials	0		1M	
Building Depreciation	0		1M	
Equipment Depreciation	0		13M	
		$0		$37M

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Typical $100M Revenue Based Company

Wafer Costs

Capacity Utilization	Fabless	Fabbed
100%	$600	$422
75%	$600	$633
50%	$600	$844

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Fabbed Companies Are Turning Fabless

Company	Product	Foundry
Intel	Memories	Japan, Korea, Taiwan
LSI Logic	ASICS	Japan
VLSI Tech	ASICS	Japan, Europe
National Semi	Memories	Japan
AMD	Memories	Japan
Sierra Semi	Mixed Signal	Singapore
SEEQ	Memories	Japan
Texas Instruments	Memories	Korea

fab012

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To Fab or Not to Fab?
That Is the Question

CHIPS

Solutions for a Changing World

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DIFFERING CORPORATE STRATEGIES:
THE ROLE OF THE BUILDING BLOCK SUPPLIER

Frank C. Gill
Senior Vice President
President, Systems Group
Intel Corporation

Frank Gill is a Senior Vice President of Intel Corporation and President of Intel's Systems Group. Mr. Gill joined Intel in 1975 as District Sales Manager in the Edison, New Jersey office. He has served as Midwest Regional Sales Manager, Western Area Sales Manager, and Director of North American Sales. In January 1986, Mr. Gill was named head of the North American Sales Force including Applications, Sales Training, Sales Administration, and the Corporate Strategic Account Group. In September 1987, he assumed responsibility for Europe, Japan, Asia Pacific, and Intercontinental Marketing. Prior to joining Intel, Mr. Gill spent six years at Signetics in marketing, sales, and field management positions. Mr. Gill received a B.S.E.E degree from the University of California at Davis.

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Semiconductor
Industry
Conference

Differing Corporate Strategies: Building Block Supplier

Frank Gill
President
Intel Systems Group

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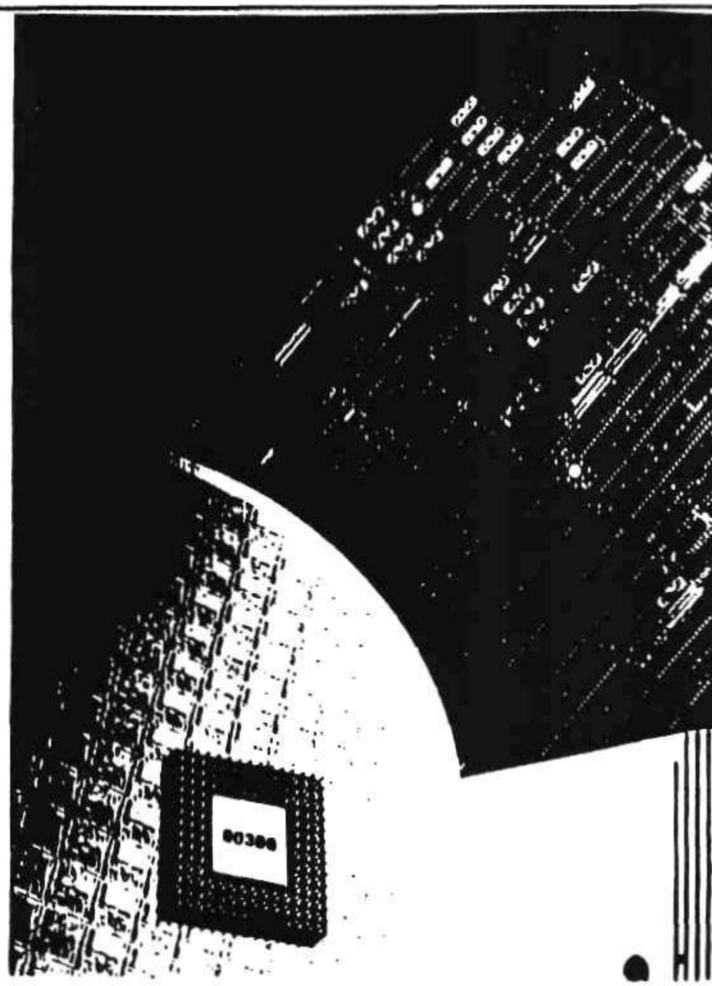
Frank Gill
Senior Vice President, Intel
President, Intel Systems Group

BUILDING BLOCKS SUPPLIER FROM CHIPS TO BOXES



Controllers

Memory Chips

Microprocessors

Subsystems

PC Platforms

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THE TREND TO BUILDING BLOCKS

- Technology Treadmill
- **Market Opportunities**
- Move to Standards
- Cost of Technology Development

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MARKET OPPORTUNITY: EARLY BUILDING BLOCK ENTREPRENEURS

► **Chips and Technologies**	*Chip Sets*
► **Western Digital Disk Controller Modules**	*Cards*
► **Intel Multibus Single Board Computers**	*SBC*
► **PC**	*PC*

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OLD WORLD COMPUTING VERSUS NEW WORLD COMPUTING

DATA GENERAL CIRCA 1980	*COMPAQ TODAY*
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Proprietary Operating System	**Microsoft DOS, Windows**
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RESTRUCTURING COST

Wang Loses $496.7M in Quarter

DG Loses $21M in Quarter

Unisys Net Off 78%

Bull Posts $347M Loss

Operating Profit Off At Philips

DEC set for $400M cutback

Olivetti Net Declines 43%

HP Quarter Earnings Drop 5%

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COST OF TECHNOLOGY

Silicon Fab Trends

	Wafer Size	Characteristic Dimension	Typical Product	Capital Cost
1973	3"	6 Micron	1K RAM	$10M
1980	4"	3 Micron	16K RAM	$60M
1990	6"	0.8 Micron	4M RAM	$>500M
2000	10"	0.3 Micron	256M RAM	$>1B

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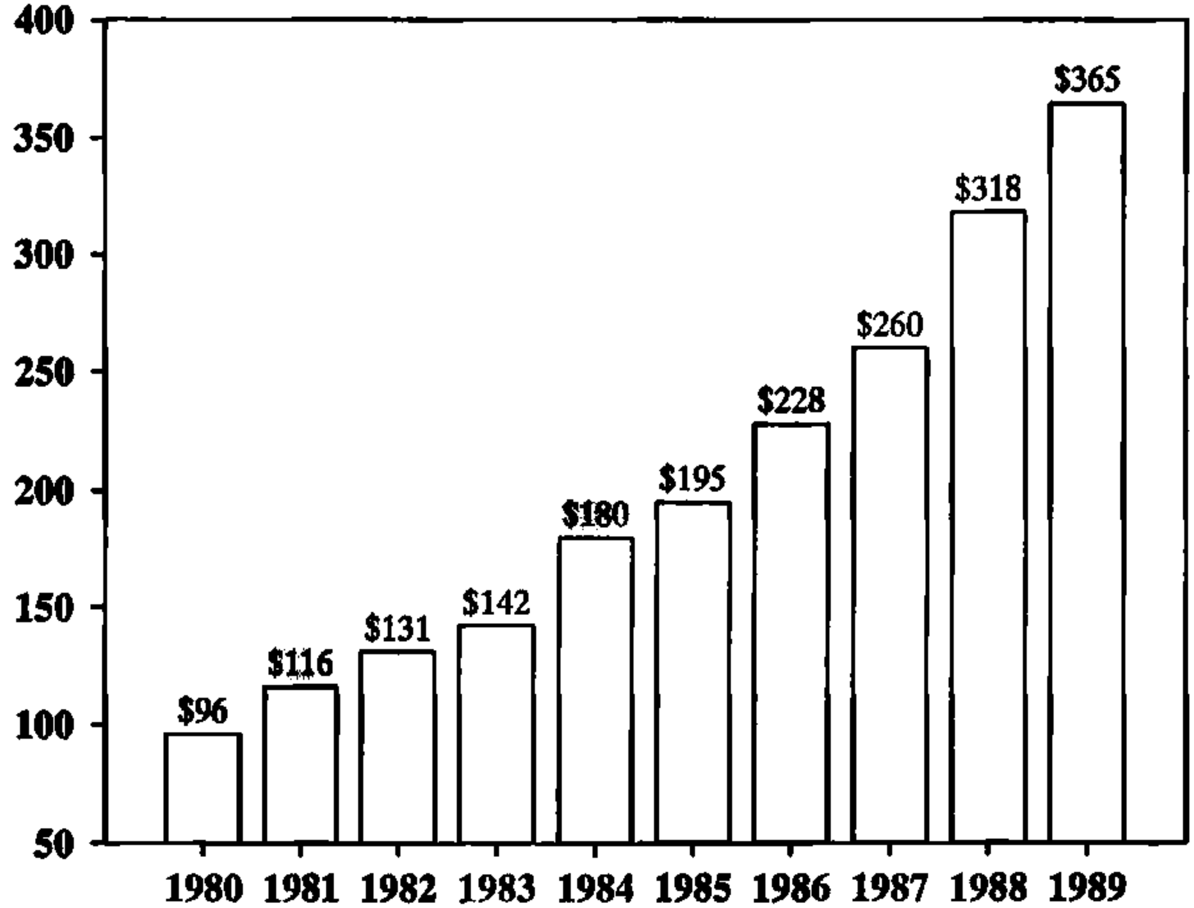
RESEARCH AND DEVELOPMENT

(Dollars in Millions)



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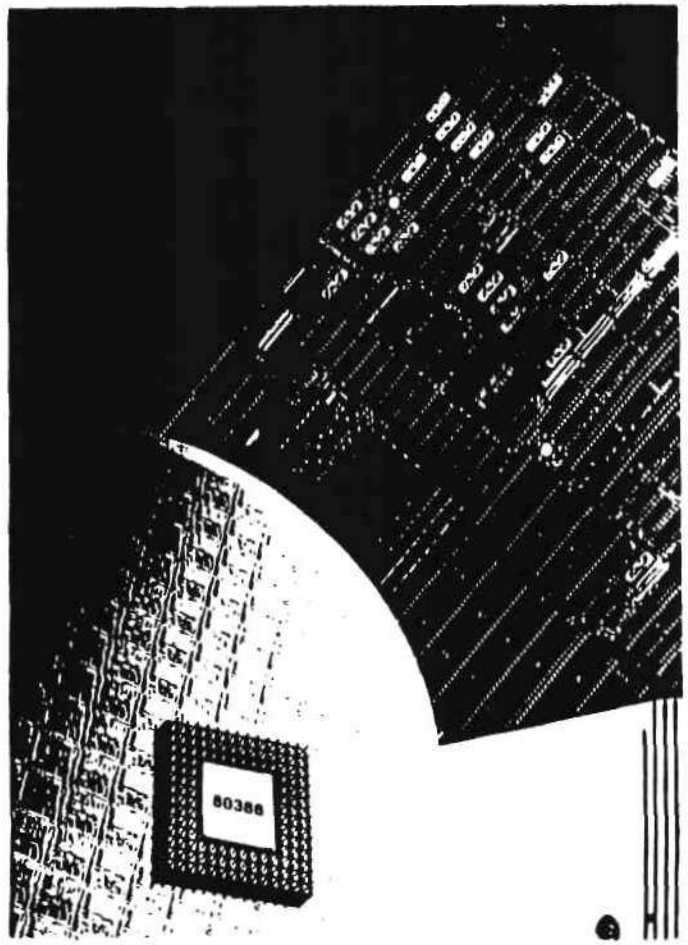
INTEL STRATEGY
SELL AT ALL LEVELS OF INTEGRATION



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BUILDING BLOCKS FULFILL A MARKET DEMAND

	Make	*Buy*
IBM	X	X
DEC	X	X
Unisys	X	X
HP	X	
Apple	X	
Compaq	X	X
AT&T	X	X
Siemens	X	X
Olivetti	X	X
Bull	X	X
Nixdorf	X	X
Philips	X	X
STC/ICL	X	X

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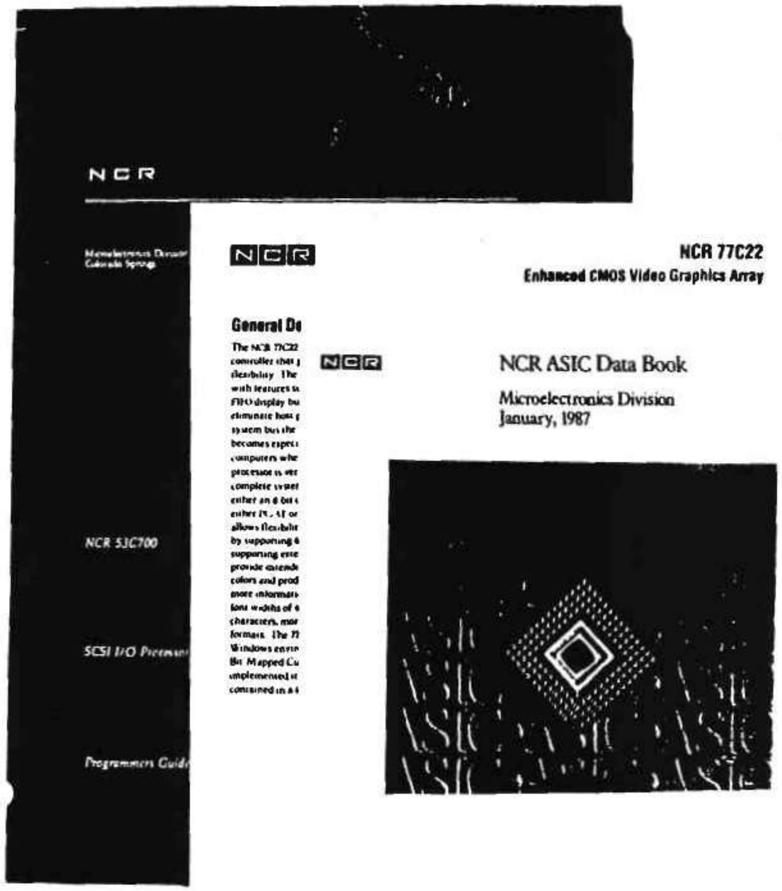
NCR



NCR to map whole new course
COMPUTERWORLD

NCR Opens Wide, Users Say Ah
Information Week

NCR Debuts New Systems
ELECTRONIC BUYERS' NEWS

NCR Adds Desktop, Multiprocessor CPUs
ELECTRONIC NEWS

NCR Shucks Closed Systems
CSN

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NEC

Top Ten Worldwide Semiconductor Manufacturers for 1989

1989 Rank	Company	1989 Revenue
1	NEC	5,015
2	Toshiba	4,930
3	Hitachi	3,974
4	Motorola	3,319
5	Fujitsu	2,963
6	Texas Instruments	2,787
7	Mitsubishi	2,579
8	Intel	2,430
9	Matsushita	1,882
10	Philips	1,716
	North American Companies	19,978
	Japanese Companies	29,809
	European Companies	5,443
	Asia/ROW Companies	1,983
	Total World Companies	57,213

Source: Dataquest

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STANDARD BUILDING BLOCKS ARE THE FOUNDATION OF THE NEW COMPUTER INDUSTRY

- **Technology Marches On**

- **Market Speaks in Favor of New Computer Industry**

- **Cost of Development Drives Everyone to Building Blocks**

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DIFFERING CORPORATE STRATEGIES:
PURE PLAY SEMICONDUCTOR SUPPLIER

T. J. Rodgers
President and Chief
Executive Officer
Cypress Semiconductor Corporation

T. J. Rodgers is Founder, President, Chief Executive Officer, and Director of Cypress Semiconductor Corporation. Dr. Rodgers and the management team at Cypress have received numerous awards for excellence in financial management. In its seven years of growth, Cypress has posted consistent, outstanding financial results even during the industry's various ups and downs. Prior to founding Cypress, Dr. Rodgers was with Advanced Micro Devices (AMD), charged with running its static RAM product group, a 74-person production and development organization which, at that time, accounted for ten percent of AMD's sales. Previously, he managed the MOS memory design group at American Microsystems, Inc. (AMI). Dr. Rodgers graduated as a Sloan scholar with a double major in physics and chemistry from Dartmouth College. He attended Stanford University on a Hertz fellowship, where he earned a masters degree and a Ph.D. in electrical engineering. While attending Stanford, Dr. Rodgers invented, developed, and patented the VMOS technology, which he sold for cash and royalties to AMI.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 8-9, 1990
Monterey, California

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Semiconductor
Industry
Conference

Differing Corporate Strategies: Pure Play Semiconductor Supplier

T.J. Rodgers
President and CEO
Cypress Semiconductor

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THIS PRESENTATION WAS NOT AVAILABLE AT

TIME OF PUBLICATION

DIFFERING CORPORATE STRATEGIES: PURE PLAY SEMICONDUCTOR SUPPLIER

T. J. RODGERS
PRESIDENT and CEO, CYPRESS SEMICONDUCTOR

If you ever want a lesson in humility which I had, I used to drive by AMI every now and then, remember having worked there, having worked hours every bit as hard as the hours I work at Cypress right now. About three years ago I drove by the old homestead - literally, on Homestead Road - one day and I drove by what used to be Fab #3 and Fab #4 where we worked, and it was ploughed, there was nothing left but a field full of grass. It's more economical to go back to fruit orchards in the Silicon Valley in that case than to make semiconductors.

That is a lesson about running scared that I have never forgotten. It is one of the most important lessons that I think our industry needs to learn.

Having heard from the last speaker our obituary, it is difficult to discuss how a pure play semiconductor company can survive. But I guess I am a throwback, so I'll give it a chance.

I don't like going to Washington to see if my appropriation came through. I don't like complaining about the Japanese as though they were the root cause of problems that I have in my company - and I do have some. I hate subsidies, and that includes Sematech money to our industry. I just like to fight fair and open on a flat field.

Can we survive? After all, the sky is falling.

All you have to do is look at the statistics. Take the SIA statistics 1982 and 1989. In 1982 the American Semiconductor industry held 51% of the market the Japanese 35%. In 1989 the numbers had reversed, 51% for the Japanese 35% for the American - 16 points up 16 points down, 32 points of relative change. The sky has fallen.

Sandy Kane tells us that it takes $1 billion dollars - as a matter of fact, your numbers from $400 million to $700 million to $2.5 billion in the last talk - to build a fab. How are we going to do that? Who will have the money?

Gordon Moore has told us its going to take $200 to $400 hundred million to get in the microprocessor business. How many companies will be able to roll the dice for a quarter of a billion dollars to find out if their architecture makes it in somebodys computer company.

Now that sky has fallen a little bit, lets go back to about 1980 and consider about two hypothetical semiconductor companies both with $200 million dollars in sales, one Japanese and one American. The Japanese company, lets say,

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had a single $100 million dollar fab to support its $200 million dollar business. That fab had a yield of 75%, meaning for every wafer coming out of the fab, 75% of the chips in that wafer were good, 25% bad. That is 1980.

In the United States our $200 million semiconductor company had 25% yield - trust me, I was there; that is part of the field story - and 25% means that instead of needing one fab to support the business it needed three fabs.

So we had two $200 million companies, one needing a single hundred million fab at an interest rate of 3% and the other needing three hundred million dollars, three fabs at an interest rate of 9%. Three times more money, three times higher interest rate, nine times higher cost of capital. That is the recipe for doom and gloom. That is what happened in the period of 1975 to 1985. If I could give one example that said why we lost market share that would be the example.

But you have to remember that's yesterday's news. I will say later why it is yesterday's news. The industry is no longer like that, and we can no longer continue to use decade old models to say what we have to do going forward.

If you look a little bit more carefully, the sky isn't falling nearly as badly as the subsidy lobbyists would have you believe. Of course, the worse the sky is falling, the harder Congress gets prodded to give money out.

For example, if you take those same SIA statistics and look at them a different way, you get a totally different picture.

One thing I didn't say about that 32 point relative drop was that in 1982 the yen/dollar ratio assumed in statistics was 248:1, where as in 1989 the yen/dollar ratio was 139:1. In 1982, the Japanese were driving up the yen/dollar artificially to make their products cheap to gain market share. Just to prove that we were fair in 1989 we were driving the dollar down to 139 yen to the dollar, artificially low, to gain market share. If you take out that aberration, if you use the number of 139, which makes the American statistic worse and use that over the entire period you find out that at a constant yen-dollar ratio of 139 that 32 points of relative market change, 27 of those 32 points are due to the exchange rate and the other five not.

I often give a quiz at talks like this. Some of you have probably heard it before so I won't go through the formality of giving the quiz, but let me give a few questions and answers which pretty much everybody flunks.

First, which foreign country owns the most American assets? The urge is to jump on Japan actually owning a golf course right around here and the Rockefeller Center. But the fact is the British own twice as much of American assets as do the Japanese. We always complain about the Japanese taking over this and that, yet there was not even a whimper when the Mobil Oil sign came down on all the gas stations on the west coast and the British Petroleum sign went up.

From which country do we import the most? Everybody lunges, "That one has to be the Japanese." But the fact is we import more from the Canadians then we do from the Japanese.

Which country has the largest economy? Half the people get that wrong. I think it is fairly obvious, but the fact is the United States economy is 2.5 times larger than the Japanese economy. If you take the data from the Hoover Institute from Dr. Thomas Moore, and extrapolate the slightly larger growth rate of the Japanese economy and ours, you get a crossover point 189 years from now - not exactly the kind of number that requires panic action.

Which country has the most engineers? We all know we have more lawyers and doctors and the Japanese have more engineers. Wrong again. The United States although on a per capita basis has fewer engineers than Japan, on an absolute basis it has twice as many engineers. I hope one of the biggest values of the "Peace Dividend" will not be whatever 2savings in the defense budget, but that we will be liberating some of those very brilliant engineers to start working on commercial and sellable things rather than things we bury in the ground and hope we never have to use.

Which country has the best balance of trade? "That's got to be Japan." Wrong again. Germany, which has an economy like ours relying on many small companies, not mega-companies and not MITIs, has a better balance of trade than Japan.

Which country is most productive? "Aha! He has finally thrown one down the center slow so I can knock it out o the park." Wrong again. The most productive country in the world is the United States, with estimated productivity 30% higher than Japan.

So, as we are listening to "the sky is falling" rhetoric we should remember in the back of minds that we have the best and strongest economy in the world and what we need to do is guide it in the right direction, not panic with stopgap measures.

Sure, we have lost ground in static RAMs. Intel invented the static RAM and now, in effect, it is not part of the business. National Semiconductor just exited static RAMs, and Advanced Micro Devices has just set the record by leaving the static Ram business three times in the last five years.

But that does not mean that only the Japanese are left. If you look at last year's statistics, the largest static RAM company in the U.S. was Integrated Device Technology; we were second, both of us with more that $100 million in business; and Micron Technology, closer on our tails than we would like - three entrepreneurial companies taking the place and holding the fort against the Japanese attack in static RAMs. Where would we be without those entrepreneurial companies?

We keep hearing about the invincible force, MITI. Ask yourself, "Where was MITI most effective?" DRAMs would be the answer. What company was the most successful in DRAMs? Toshiba. When did Toshiba take over? The megabit.

You would have to ask the guy who did the megabit program at Toshiba under the aegis of MITI, who is here today. His name is Dr. Yoshio Nishi. He runs the integrated circuits division for Hewlett Packard. I had DR. Nishi come to

Cypress to give a second go at an IEEE seminar he presented on MITI and what it meant and what it didn't mean. Dr. Nishi says that never were technical secrets exchanged in MITI, that the intense competitors would only deal in the most global generalizations, and really no collaboration generated technology that propagated to the companies, that was a myth in the United States; that all that MITI did to really make things better in Japan was to extract a public commitment from all the companies that they would fund the MITI project regardless of whether or not the economy was good or bad. So, MITI, in essence, forced long-term thinking, that which we have ascribed to the Japanese forever, on the Japanese semiconductor industry. Dr. Nishi said it was MITI's greatest accomplishment.

By the way, when we are talking about the "unstoppable force" MITI, let's not forget their screw-ups. The DRAM success is getting a decade old, and continuing to talk about it is getting a bit old. How about TRON? When is the last time you had to worry about TRON?

And how about the Fifth Generation Computer? That is the one that was so scary, they were going to take over the supercomputer industry. It is caused us to form the MCC in order to compete with them on a giant vs. giant basis. They have admitted that the Fifth Generation Computer wasn't that good.

Then, of course, the last statement in these speeches is, "The United States is going to be third. We have MITI in Japan, we have JESSI in Europe, and we've got nothing, so we better get with it." Of course, we can all look at Jessi's strategy for SRAMs with Philips in Europe and see that has also been a great success.

So, let's just rush headlong into having the government give us money and think that is going to make things better. It is not.

In the recent AMD quarterly report, after excusing poor earning, Jerry Sanders said that they were due to investing in the future to become part of the "oligopoly that will emerge in the semiconductor industry in the future, to invest to be part of the companies that survive" - sort of the "Big Three," if you will, of the semiconductor industry. I think if you ask Ford, General Motors and Chrysler, "Are oligopolies competitive and can they hold the line against foreign competition?" the answer is "No."

I was in the library looking over notes which I wrote last night and read braced on the steering wheel of my Honda on the way down. (My Honda was made in Marysville, Ohio, by the way, by those workers who weren't good enough to build good quality in General Motors cars.)

This says "the decade of semiconductor start-ups," and then on the bottom it says in big red letters "Library copy. Do not remove!" Having been someone who never liked rules, I started paging through it. I have to admit it's a pretty good book.

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With all this consolidation you hear about, the facts ought to square with the religion. If we are consolidating toward the "Big Three," then we ought to look at a graph that says we have 100 semiconductors, then 25, then 15, and now we're down to 12, and you can see the curve.

If you look on page 3, you see a graph that shows the semiconductor companies that started in 1981 through 1985. If you count those up, you find there are 114. 1981 through 1985 was the period when Cypress was started, Bernie Vanderschmidt's company, Xilinx, was started, and Gordy Campbell's company [Chips and Technologies] was started.

Then I took the data from the other part of the book and integrated from 1980 all the way back to 1960, so I took and entire two decades before that five year period. Guess what? Fewer companies started in the two decades before 1981 through 1985 than in that short period. So, somehow, we are not consolidating. Somehow, there are more and more companies.

Dataquest, in its wisdom, laid that our for us on page 11: "The third wave of start-ups share many common characteristics. In general, the more successful companies tend to be as follows:

- highly focused, flexible, able to move quickly out of stagnant markets into high growth markets;
- willing to develop new markets and educate users about their products and design services;
- positioned at the leading edge because of their advanced process technology and proprietary CAD software;
- resourceful in attracting venture capital from U.S. and foreign capitalists;
- aggressive in building strategic alliances to develop new applications jointly and secure wafer fab capacity."

That is correct. As a matter of fact, what I just read you wiped out the middle section of my talk.

If we look at Porter's new book on "The Competitiveness of Nations," he talks about countries which are successful in given industries being successful not because of capital, or labor resource, or cheap coal, or cheap oil, but being successful because of many companies competing in a given area in a given country making that country successful, an example being Italy in the shoe industry.

Tom Peters tells us, when he testified against U.S. Memories in Congress, that we shouldn't use the MITI model, which is wrong, and lunge after it, because we will land where the Japanese were, as the Japanese are scrambling to become more entrepreneurial, knowing that is the way of the future.

George Guilder, in what I consider to be a landmark book, "In the Microcosm," which I also reviewed in the Harvard Business Review, tells us that smaller is better, more computer on a desktop means that amazing things will come from small groups of people in a garage.

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If you look at the statistic I gave you earlier, the 9X statistic, that has changed as well. Whereas the yield used to be 75% in Japan and 25% in America, our yields at Cypress are now up to 75%. The Japanese are now are 90% or better; they are still ahead of us. But what used to be a 75%-to-25% gap (200%) is now a 90%-to-75% gap (20%), and that is a big deal. And that cost of capital that used to be 3:1 is now closing and is now nearly 1:1. So, the next disadvantage we used to suffer of 9X is now down to somewhere around 2X, and therefore that huge capital formation disadvantage is really going down. That is a big part of the change in statistics to where, I believe, if you take the yen/dollar out of the statistics, you will see flat market shares for the United States from 1985 through 1989.

The main reason I don't like complaining about unmovable things like the government and foreign competitors is that it takes away individual responsibility. That is what really bothers me about our industry right now, that we have become a bunch of whiners. You can work three days a week, your company can be in trouble, but it's not your fault, it's the Japanese problem. You can lay off your research and development and have your products end up selling for 43 cents on the average, but that's not your fault, it's the fault of your Congressman in Washington who didn't lobby hard enough. You can declare your obsolete architecture still to be as good as the other guy's new architecture because you have to protect a cash cow, and then whine later on that you haven't got the appropriate protection from the government.

I think, if we need to look at the fault for the falling of the market share of the United States semiconductor industry to a two-thirds approximation, we ought to be looking in the mirror, and that includes me.

Welfare doesn't work. I saw Lyndon Johnson in 1969 get up and talk about spending a few million dollars to wipe out hunger in the United States. After two decades of spending, there are more hungry people in the United States then there ever were.

We are not going to get bailed out by the government. We will not double or triple up in Sematech. Our government can't even afford to keep the museum open where people can view the Liberty Bell today!

I think entrepreneurs continue to represent the value in the future of the United States. Let me give three quick examples.

First, the billion dollar fab. Cypress is now, on an annualized rate, about a quarter-billion-dollar company. You may or may not believe it, but the total investment in both of our fabs, Fab #1 in San Jose and Fab #2 in Texas, which do all of our research and development and all of our production, is $73 million; $35 million in Fab #1, and $38 million in Fab #2. I don't know how the $400-$700 million fab came around, but if any of you need to build one I will guarantee to build it for you for $200 million, as long as I can keep half of the difference between the budget your people propose to you and what I actually spend doing it.

Let me tell you about a little company called Ross Technologies. It is a subsidiary of Cypress. We thought we were too big to get into the microprocessor business. We had 1,500 people, we were $200 million, and there was an alarming outbreak of bureaucracy throughout the company. We founded Ross Technologies with an entrepreneur named Roger Ross who came out of Motorola.

Ross Technologies, for a total investment o $7 million - not the $200-$400 million you hear about elsewhere - brought out SPARC chipset which is the top of the line Sun machine, the 490 that you can buy today, and the top of the line machine from Solborn and other companies. The head count when the project was complete was 36.

So, I don't know where it came from that you need buildings full of hundreds of engineers and you need $200-$400 million to get into the microprocessor business, but we surely didn't need it, and we couldn't have afforded it.

Guess what? What I'm worried about is we did it on the old Suns to build the new Suns. We've now got new Suns which are our workstations to build the next generation Suns. Our competitors will start with better machines than we did. I'm worried about the guys coming up behind me that will do if for $3.5 million and have 15 people. What am I going to do about them?

Finally, Toshiba is going to make a SPARC laptop machine. They have two choices for vendors, Ross Technologies (a 50-man operation in Round Rock, Texas, with no fab) and Fujitsu, both of whom make SPARC. Which will Toshiba pick to design into their laptop? The answer is, of course, Ross. That is a fact. We got that one.

It shows two things: (1) that the Japanese are making a serious effort to buy our products, which they are not given a lot of credit for right now; and (2) that small, agile companies can do things that big companies cannot, and that includes Japanese companies, not just American companies.

The final example is another start-up called Asmin Semiconductor Corporation. They just had a party celebrating their first million-dollar quarter. They are one of only two companies in the world from whom you can buy a 3-nanosecond 4-K SRAM. We have a big companies, like Unisys and AT&T, buying those SRAMs. The only company we have to worry about taking the business away from us is Synergy, another company you have also never heard of, a start-up, and the only other company shipping 3-nanosecond static RAMs.

Cooperation between companies will be the future. It is inherent in Japan, you have vertical organization. One of the most important aspects of it isn't the capital formation, it is the cooperation. Instead of being at war with the people that you sell things to, you cooperate with them. I think a good example is Sun and Cypress. Cypress never could have brought that chip to market for $7 million without the cooperation of Sun laying an architecture on us and saying, "This is what we want, and if you make it we'll allow you to take it to the public domain. And, by the way, here's an operating system." It counts. That kind of cooperation has big value. we have to find more of it.

Unfortunately, our arch rival, IDT, has found that kind of cooperation with MIPS. I only wish we had that weapon.

Altera and Cypress. Altera is one of those fabless semiconductor companies you will hear Gordy Campbell talk about later. Altera has a value-added component in what they ship. The technology counts for them. They knew they needed a fab. We have teamed up. They bought 9% of our Fab #2 in Round Rock, Texas. It is making them more competitive. They are putting technologies into our fab in return for wafers at cost.

Here are some examples of companies not cooperating. Let me pick one that you might be familiar with, Intel and Advanced Micro Devices. It makes for good reading in the San Jose Mercury News. Every day I get up and read my paper. Did you read the last one? There are two guys both named Webb. A package was sent to one and the other one got it. They set it to the wrong company. AMD read it and is going to use the 386 for their new clone machine. They were sued right away for that. Of course, AMD had to sue Intel back right away because, after all, they obviously stole that package and stole proprietary information. That is the latest little battle going on in corporation. I'm sure the Japanese were doing something like making dynamic RAMs and getting their yields better during that same period of time.

Moving past even Intel and AMD, in the first place in useless litigation goes to Texas Instruments which is suing virtually everybody in the semiconductor industry and, for the first time ever, suing its own customers, a new record, suing Dell and Tandy.

Can pure play semiconductor companies survive? I don't think that is the real question. I think the question is can the dinosaurs survive? It is getting cold out there. You better get small, get fast and grow hair real quick if you want to stay around - and a bigger brain wouldn't hurt either. Congress can pass the Ice Age Prevention Act of 1990, but it won't do any good.

As I look to the future, it is the small companies that will bring on what we need. The entrepreneurs will bring on the new technologies, the new architectures, the new products. They will do it with every characteristic capital efficiency, which is extremely important in an era of tight capital. And I have just heard that is going to be a global problem, meaning start-ups will be more well-positioned than ever in any country to make use of scarce capital.

They won't just survive. Small companies and pure play entrepreneurial semiconductor companies are our hope for the future. Thank you very much.

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THE BUSH ADMINISTRATION'S POSITION ON HIGH TECHNOLOGY

Tom Campbell
Congressman
U.S. House of Representatives

Congressman Tom Campbell represents California's 12th District, which includes the heart of Silicon Valley. In his first term in Congress, Congressman Campbell has focused on improving American high-tech competitiveness in international markets. He has co-authored the Hose Republican Competitiveness Package, a 12-point plan designed to stimulate capital formation and reform America's tax, trade, antitrust, and liability laws. Congressman Campbell serves on the Science and Technology Committee and the Judiciary Committee. Before serving in Congress, Congressman Campbell headed the FTC Bureau of Competition and was a tenured professor at Stanford University, teaching courses in economics, antitrust, corporate law, and international law. Congressman Campbell graduated magna cum laude from Harvard Law School and received a Ph.D. in Economics from the University of Chicago.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 8-9, 1990
Monterey, California

Semiconductor
Industry
Conference

The Bush Administration's Position on High Technology

Tom Campbell
Congressman
US House of Representatives

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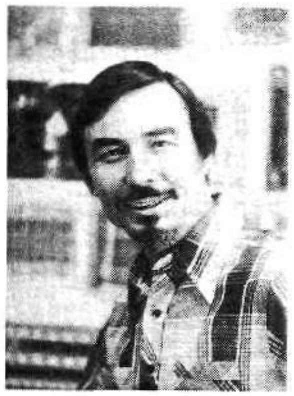
WAKE UP CALL FOR THE U.S. SEMICONDUCTOR INDUSTRY



Carver A. Mead
Gordon and Betty Moore Professor
of Computer Science
California Institute of Technology

Carver Mead, the Gordon and Betty Moore Professor of Computer Science has taught at the California Institute of Technology for more than 30 years. He has contributed in the fields of solid-state electronics and the management of complexity in the design of very large scale integrated circuits, and has been active in the development of innovative design methodologies for VLSI. He has written with Lynn Conway, the standard text for VLSI design, "Introduction to VLSI Systems." His recent work is concerned with modeling neuronal structures, such as the retina and cochlea using analog VLSI systems. His new book on this topic, "Analog VLSI and Neural Systems" has recently been published by Addison-Wesley. Professor Mead is a member of the National Academy of Sciences, the National Academy of Engineering, a foreign member of the Royal Swedish Academy of Engineering Sciences, a Fellow of the American Physical Society, and a Life Fellow of the Franklin Institute. He is also the recipient of a number of awards including the centennial medal of the IEEE.

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A Wake-Up Call for the US Semiconductor Industry

Carver Mead
Gordon and Betty Moore Professor of Computer Science
California Institute of Technology

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WAKE-UP CALL FOR THE U.S. SEMICONDUCTOR INDUSTRY

Dr. Carver Mead
Gordon and Betty Moore Professor of Computer Science
California Institute of Technology

You are hearing from all the leaders of our great industry at this conference and the last thing in the world you need is to have an academic stand up here and tell you how the industry works. But what I might be able to do is stand back a little bit and, in the context of the theme of this conference, "Looking Into the Next Decade," look back a decade or two and see where we have come from, and think forward into the future a little to what might be coming up on a longer time scale than battling it out over the next generation of microprocessors.

I will go back a fair ways here, all the way back to when there were vacuum tubes. The term "dinosaur" was used today. It is funny hearing that term used with respect to semiconductor companies. I always think of it with regard to this kind of technology which was commonplace when I started designing electronics.

We have come a long way, down through the vacuum tubes, smaller vacuum tubes, printed circuit boards, discrete transistors, and then the big transition, in 1959, between the discrete transistor and the integrated circuit.

I am indebted to Gordon Moore, whom I am named after, for some of these slides.

These are the early integrated circuits. These are sort of the "missing link" in the evolutionary chain. When they dig everything up a million years from now, they won't find any of these. They will find the big microprocessors that are in these hulks of PCs that are buried under the layers and layers of civilization, but they won't find these things, because that was the early one, the "missing link."

Then we got microprocessors. There is Federico Fegines's first 4004.

Early memory.

This is the very first Gordon Moore plot of Moore's Law. When he gave me this slide he apologized, saying, "Intel is a small company and we can't afford fancy graphics."

Then, as time went on, Moore's Law developed further. This is 1979, at a talk on the Cal Tech campus.

We heard about Moore's Law earlier today. There was a little hesitance there at the end, but that's okay.

Here is another Moore's Law from last year. You can see, as Intel has grown and prospered, the quality of the graphics has come to match.

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When I first learned about Moore's Law, I was very excited about it. I was talking to a friend of mine, Tom Perkins, from the Kleiner, Perkins venture capital firm, about this great exponential explosion in our microelectronics capability with time. He said, "Aw, Carver, it's just a learning curve.

Bruce Henderson, at the Boston Consulting Group, has studied learning curves a lot. All you have to do is to plot the log of the cost as a function of the log of the cumulative volume of any product or service, and you get one of these straight lines on this kind of a plot. That's really all that's going on there."

It was actually discovered in World War II. It is true, if you do this for many different products and services, you get fractional power law on a plot like this over a very large range of volume. This applies to everything - from the electric power industry, to oil, to anything you care to name.

It is a really interesting phenomenon, that as we produce more things, we learn how to do it better. There is a lot of learning that goes into one of these learning curves.

The semiconductor industry has sort of made an institution out of that and often prices things according to where the learning curve is going, instead of where it has been. But you all know much more about that than I do.

It seems to me there is something missing in this view of our industry. I think of it as sort of a featureless landscape on one of these curves. Here you are out in that landscape and there is no signpost that really tells you with any exactness where you are. I know many of you feel this way sometimes.

It seems to me that doesn't exactly capture the roller coaster we have been on in our industry. Here we are in an industry where the transistor was invented, the integrated circuit, the microprocessor, and so forth; there have been these major inventions which punctuate our industry at rather regular intervals. I call it the 12-year cycle. It is actually about 13 years, but that doesn't sound quite as good so I use 12 as a nice round number.

I spent a lot of time thinking about how you might conceptualize what really goes on in response to one of these major inventions. I want to share with you a set of thoughts which I have put together and modestly called Mead's Laws of the Economics of Innovations.

There is a problem with economics that is summarized in a story about Professor Jones, a professor of economics, in a talk at a professional society meeting. Professor Jones drones on and on for about an hour. At the end of his discussion of his new theory of economics, someone in the back of the room raises their hand and says, "Professor Jones, How does your theory apply to the crisis in Silicon Valley?" Jones scratched his head a little bit and said, "Well, my theory applies more in general than in any specific case." That's a problem with theories like that.

I think there is a lot of innovation in the semiconductor industry, in particular in electronics, the information industry in general. I think there are some things we can say about it. I would like to share those things with you today.

The first thing is, if you think of Henderson Law here, skating down a Henderson learning curve, it had to start somewhere. Essentially, all of your are with companies that were started in the last 20 years or so. That is where most of the action is in the information industry today. Things got started with some kind of innovation.

What happens when there is this step function of innovation, when there is a new thing discovered, a transistor or an integrated circuit?

Usually, the thing you can do with a new technology has value. If it doesn't, it will not last long, so those aren't the ones we will talk about. That value allows you to charge a price in excess of your cost. And for something that is really new, and you and only you can do it, and it creates a lot of value for other people, the premium of price over cost can be substantial.

With time, other people will learn how to do that, too. They will learn how to make the integrated circuits or they will learn how to copy your latest microprocessor - "second source" I guess is the proper term - and so the price will no longer be something that you have free reign to set however you like, and it will come down.

Eventually, the price will get set by a manufacturing cost. You get to charge a little premium, which we have always called in our economics classes the "return on investment." In general, economics, as a field and as a theory, gets taught about this part of the curve down here where we are well along on the learning curve, where we are not near any break point in the invention sense, and we are able to charge a premium over our cost of production. That gives us a return on investment.

I don't have to tell you that this is a game that can be played worldwide and there are countries like Japan that play it much better than we do. But the other thing that we need to realize is that the information technology is not, by and large, a technology that is dominated by this steady-state learning curve and steady-state return on investment, because, in the presence of these step functions of major innovations, there is a premium of price over cost that is considerably larger than that dictated by the return on investment. That area under that part of the curve I have termed the return on innovation. That is what makes venture capital work, that is what makes start-up firms with new ideas do very well, and that is what is really fueling the information economy that we line in today.

So, we are really not living down on this part of the curve except in old, sort of buggy whip style products. Gordy Campbell mentioned TTL products earlier today, products that are very well evolved. The newer products are well up on this curve and there is a lot of value to be added, both for the customer and for the supplier, early on in this evolution.

A succinct summary of that: The price comes down to the cost level only asymptotically, and, in the meantime, there is a notion of return on innovation which is separate from the age-old concept of return on investment.

A second idea that I would like to share with you is that usually the new idea, the new technology, is replacing some existing technology. For example, the transistor replaced the vacuum tube, the integrated circuit replaced circuit boards with discrete transistors on them, and so forth. So, there is usually an old way of doing things, and the old way is skating down its Henderson curve, its own learning curve. Then you introduce a new technology, and it you are careful, the new method will have some headroom. This is what I call the Headroom Principle.

If the learning curve, once you get to steady-state for the new way, isn't well below the learning curve for the old way, you really don't have any headroom here, you don't have any place where you get a return on innovation, and it is very, very hard to get a new technology started that way. That is what happened to bubble memories, fore example; there just wasn't any headroom.

There was narrowly enough headroom for semiconductor memories. We take them for granted today, but, for those of us who lived through that transition, the core memory people put up a really significant fight because they were on their own learning curve. In fact, there was a period there where there was alot going on in the marketplace.

In summary, the Headroom Principle is that the price that you can charge for the new way is going to be below the cost of doing it the old way.

If you don't have that kind of headroom , my own personal rule of thumb is you've got to have a factor of 10; if you don't, the old way is going to dominate. And, even if the new way is "better," it won't survive if you only have a factor of two, because you are skating down the Henderson curve for the old technology faster than you can ever catch up and you are behind the power curve on this.

The most important thing I have to say to you today is the third observation: We live in an industry where there are repeated major innovations. We went from tubes, to transistors, to integrated circuits, to microprocessor, and we are now in an era where computer-aided design of the solutions, as Gordy Campbell calls them, are a major part of what is happening in the marketplace. Each of these innovations has made a big difference in the cost of arriving at a solution in a new way.

For that reason, the marketplace never got into a steady-state Henderson curve. Each of these, like the discrete transistors, would skate out on a Henderson curve that looked like this. But, before they ever really got to steady-state we had an integrated circuit. And SSI was sort of skating out on its Henderson curve, and then the microprocessor came along, and so forth.

So, in an industry punctuated by these major, major innovations you never get to where the raw return on investment is really the dominant factor in the economics. We are always sort of dominated by the next major innovation that is coming along.

As a country, the United States has thrived in this turmoil. It is the kind of thing that creates a lot of opportunity for entrepreneurs, and it is certainly the kind of thing we are still doing very well, and it is certainly the kind of thing the next decade is all about. Information technology above any technology we have ever seen is driven by this repeated punctuation with major innovation.

If you stand back and defocus this slide a little bit and put a box around it, like that original slide of the learning curve, you notice that we have what looks like a learning curve, but it is much steeper than any of the manufacturing learning curves. That is because of major innovations. So, we have an industry which is growing exponentially faster - in terms of the capability it is delivering to the marketplace - than any individual manufacturing learning curve.

That is my third observation: Given these major innovations, the composite learning curve is exponentially steeper than any individual Henderson curve.

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There is a fourth observation: What makes an innovation a "major innovation, a breakthrough technology if you like? You can always argue about the fringes, but my definition of that is you weren't looking for it there. Most of these innovations I was standing right there looking, and I was looking the wrong way.

When we were all trying to make better higher-performance discrete transistors, Bob Noyce came along and said, "Why don't you just use the aluminum that is there already to hook up the transistors that are there already and then you don't have to cut them all off and put them on circuit boards to do that?" So, it was an innovation in the interconnect technology, not an innovation in the transistor itself.

And so it has gone. We were all making standard products, and then the microprocessor made a product that we could configure to a particular use. Then, just about the time everyone was looking at how to make more programmable devices, the design technology came along that allowed us to make better dedicated solutions to large system problems.

The major innovations are always the ones in a different direction than everybody is going. For that reason they are not things you can plan, and they are often contrary to the corporate cultures that have been so effective in producing a stream of products, given the last generation. Few companies have been able to transition from one generation to the next. It is very hard to do, given that the technology takes these right-angle turns, but it is the strength of our industry.

One example of this phenomenon of looking in a different direction I can show you in particular. In 1979, Gordon Moore gave a talk at Cal Tech where he showed the middle of the three Moore's Law slides. He also showed this slide of the design cost of producing a VLSI kind of chip as a function of the year.

You can see the data points and you can see Gordon Moore's extrapolation as to where design costs were going. This was, of course, predicated upon doing design the way it had always been done.

Ten years later, Gordon came back and gave another talk at Cal Tech and he showed this slide. This is the design time as a function of the year. You notice it carries quite a different story. That story had to do with the development of computer-aided techniques for doing the design of complex chips that had happened during the 1980's. It has made a big difference to our industry, that we can design very complex chips with far less human effort than we used to design, for example, the first microprocessor.

That is an example of an innovation that happened that wasn't about semiconductor processing, it wasn't about device physics, it wasn't about interconnect; it was about human effort in the design process.

Gordy Campbell made some comments this morning about what happens in complex systems. The semiconductor industry today is really about providing a base technology for the information age. Silicon really is a medium for realizing information technology. a silicon wafer is really like an unpainted canvas to an artist. It is an undedicated medium in which you can realize systems of any kind. The process for realizing those systems in not dependent upon the particular design. So, it shares with printing and film processing the property that the particular image determines the functionality, not the process by which that realization of that silicon wafer is accomplished.

That notion, that silicon processing is by and large pattern independent and that the design process really is quite a different matter from the fabrication process, leads us to an interesting line of thought. It has been mentioned in this morning's session and I just want to say a few words about it this afternoon.

As the chips have gotten more and more complex and the design techniques and design tools have become more and more sophisticated, more and more of the effort in a complex chip design goes into managing the complexity itself and less and less of it, a smaller and smaller fraction, is silicon specific. Thus, much of the expertise required to design a modern silicon system (a system on silicon) is involved with the system level trade-offs and the system level design, and less and less of it specific to the individual 8888888888888888888888transistors and techniques down on the silicon itself. For that reason silicon design has gotten more and more like software and less and less like, for example, laying out highways, designing a particular bridge, or something which is specific to the particular medium.

There is an interesting parallel with the personal computer business which I would like to point out. It used to be that the computer companies not only built the big tin boxes with all the heat generating electronics inside, but also made the operating systems, and often, the application programs as well. During that era there wasn't much software, and what software there was wasn't very good.

The personal computer has given us basically a medium into which software applications can be plugged (or mapped, if you like). We have an enormous wave of innovation in software development, although it is still difficult for that software to keep up with the hardware development. There is a reason for that: Most of the complexity in modern systems has been relegated to the software side of things.

How come we get any of it done at all if that's where all the complexity is, and we can go out and buy all of that complexity for a few hundred bucks? The reason is there is a whole industry out there providing software, and that software gives us the application specificity to what is otherwise a pretty prosaic product, the personal computer. So, there is a whole new industry, a whole new way of doing business, and a whole new wave of innovation that has come about because of the personal computer.

We are just now seeing, in companies like Gordy Campbell's (Chips & Technologies), Weitek, Brooktree, Actel and many others, companies that have chosen to make their contribution by concentrating on the design process, putting the expertise into the design and leaving the manufacturing process to those who are good at silicon manufacturing. We heard a whole debate about that this morning which I won't go into. Gordy defends that turf much better than I do.

We are noticing that there is a lot of value-added in the design process. And there are whole companies - a whole industry now - now taking advantage of the fact that people are expert at manufacturing silicon. One can work with them and deal with them on the silicon manufacturing and put one's energy into the design process, where there is a lot of value to be added. From the corporate perspective, that means there is money to be made there.

The industry that we are looking at today has quite a different structure than it did 20 years ago. Twenty years ago, really, semiconductor meant standard product, nobody did silicon foundry, and there wasn't really a design tools industry as such.

Since then, we have seen the semiconductor foundry service come on as a full-fledged partner in this business world and we have seen a blossoming of the design tools business. That rate at which design tools are evolving has not slowed down; we are seeing innovations on that front all the time.

So, it is an exciting world we are living in because the result of this structure is really just now being felt - the fact that there are advanced computer-aided design techniques, there are people who spend their energy doing specific applications without having to provide all of these other elements, and we have the infrastructure in the form of the silicon foundries and the design tool suppliers.

The fact that Gordy's company has been such a resounding success has helped a lot, but there are a lot more behind him providing solutions for various problems - opportunities - in our information age.

We hear about the woes of the software industry and the fact that everybody can copy software. We are beginning to see a lot of information technology delivered on silicon instead of on floppy disk. I predict that there will be a lot more of that in the future.

Because silicon ends up being the substrate for the information in any case, it is sort of silly to have it on a floppy disk. Putting it on a chip that will also execute the intellectual property that is there, not just provide it for execution by a general-purpose computer, is often a more rewarding way to go.

More and more people are figuring that out. There are more and more chips being supplied that are full solutions to certain applications. I predict that we are going to see much more of that in the 1990s.

How about beyond the 1990s? Are there going to be more major innovations? I don't see any slackening in the pace of innovation, major or minor, in Silicon Valley. I find a very healthy atmosphere. I see a lot of innovation, a lot of entrepreneurship, and a lot of health in the information industry. I am absolutely sure that in the next decade we will see major innovations happening.

I am working on a technology which I believe will be one such major innovation, using silicon to build systems that mimic the operation of the brains of animals. The brains of animals are about a billion times more effective at processing information than our most advanced semiconductor technology. There are a lot of lessons we can learn from studying biology as to how information is processed in those brains. Most of the lessons we learn teach us that the principles used in the brains of animals can also be implemented in our silicon medium. That's the good news.

The bad news is a lot of the processing that goes on in the brain in analog. So, just now that the universities have stopped teaching analog courses and none of the books have any analog circuits in them anymore, we are going to have to go back and learn all that stuff again. Like I say, the breakthrough technologies always come in the direction you're not expecting. This one is not exception.

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PACKAGING FOR HIGH PERFORMANCE SYSTEMS: MOVING TOWARD 2000

Mary A. Olsson
Industry Analyst
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Dataquest Incorporated

Mary Olsson is an Industry Analyst for Dataquest's Semiconductor Industry Service. She has been with Dataquest for eight years and is responsible for coverage of the worldwide packaging and nonvolatile memory markets. She has worked in technology assessment, market research, and consulting for ten years. Prior to joining Dataquest, Ms. Olsson worked for the Technology Analysis Group. Ms. Olsson holds a B.A. degree from San Jose State University.

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Packaging for High-Performance Systems: Moving toward 2000

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AGENDA

- Worldwide IC package market
- Emerging technologies analysis
- Applications and materials analysis
- Strategic issues and opportunities
- Summary

AGENDA

- Worldwide IC package market

1990 WORLDWIDE PACKAGE MARKET

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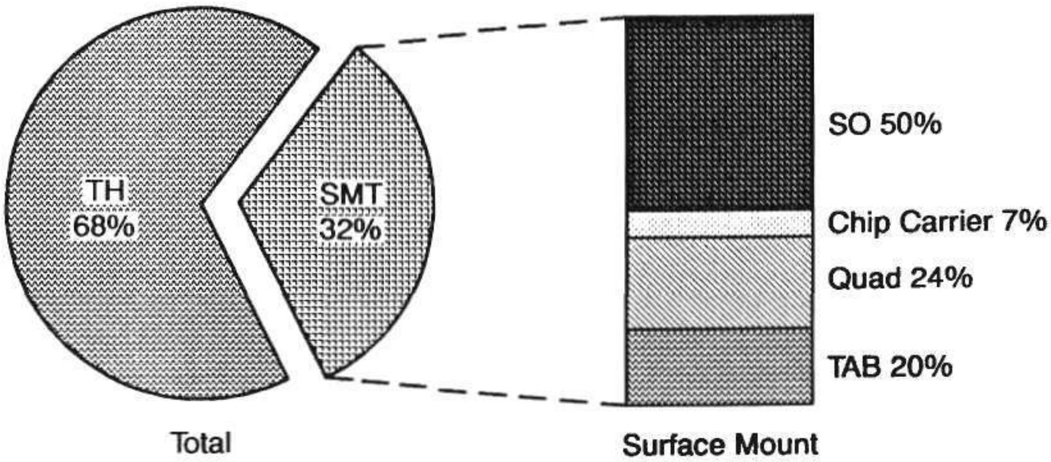

Source: Dataquest

PACKAGE TECHNOLOGY TRENDS

	Current	Near Term 1993-1995	Long Term 1997-2000
DIP	Declining	Declining	End of life
SMT	Evolving	Lead space/cost	Dominance
Quad	ASIC	10,000-20,000 gates	190-600 leads
TAB	Emerging	>200 leads/QFP	Performance 80-800 leads
Flip Chip	Emerging	Density driven	Interconnect
Multichip	Emerging	High-end driven	1,000 mips

Source: Dataquest

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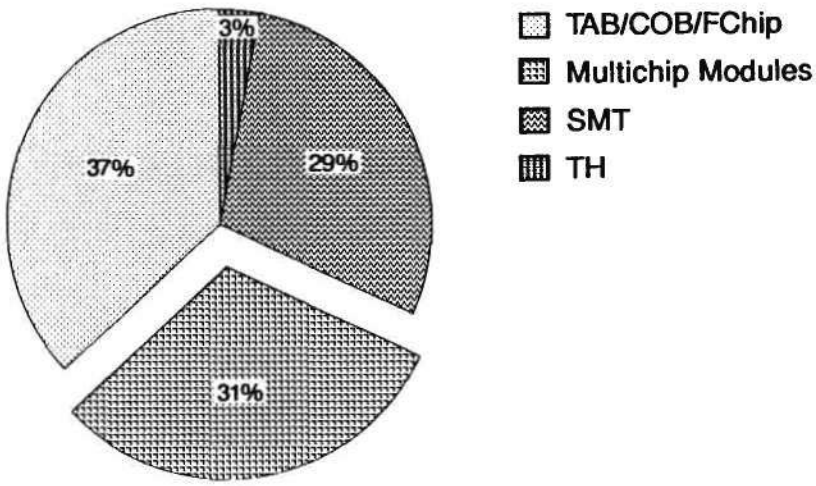
SYSTEM PACKAGING -- 2000



Source: Dataquest

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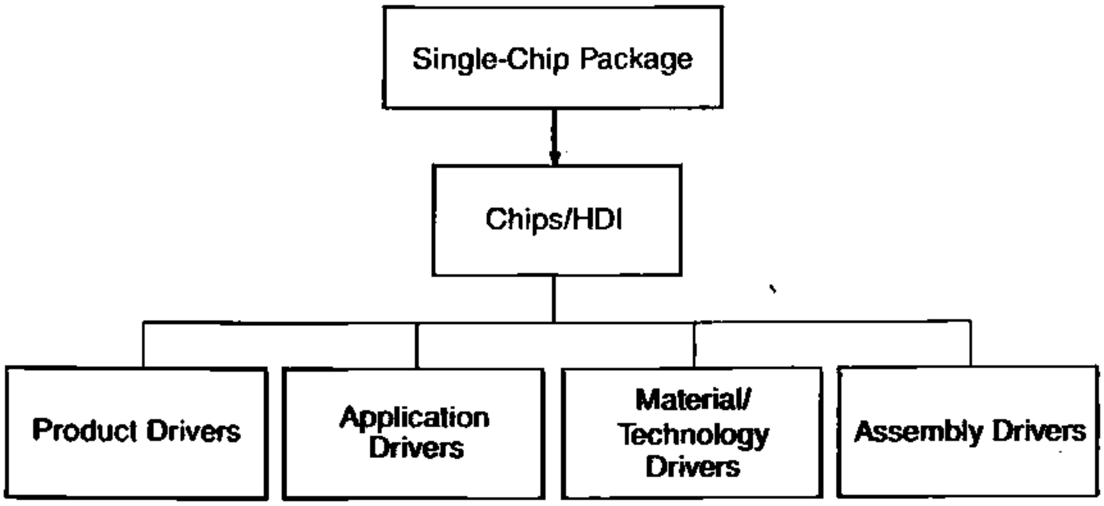
AGENDA

- Worldwide IC package market
- Emerging technologies analysis

HDI MARKET DEVELOPMENT STRUCTURE



Source: Dataquest

MCM DRIVERS

	Products		
	Current	Near Term 1993-1995	Long Term 1997-2000
MPU Speed	20 MHz	100 MHz	300 MHz
ECL			Photonic logic
Logic/ASIC	150-400ps	50-150ps	1.5-2.0ps
Memory	CMOS	BiCMOS	BiCMOS/FERRAM
PC	1MB	16MB	128MB
Workstation	8MB	128MB	512MB
Speed	20-80ns	9-60ns	<25ns
GaAs			
Logic/ASIC	50-80ps	20-60ps	<5-10ps?
Memory	16K/3ns	>60K/3ns	>100K/3ns

Source: Dataquest

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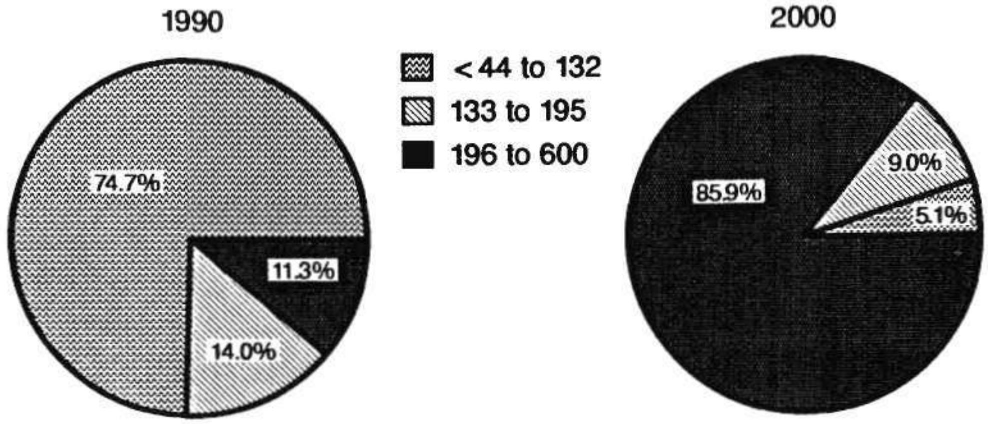
ASIC LEAD COUNT TRENDS

(Percent of Units)



Source: Dataquest

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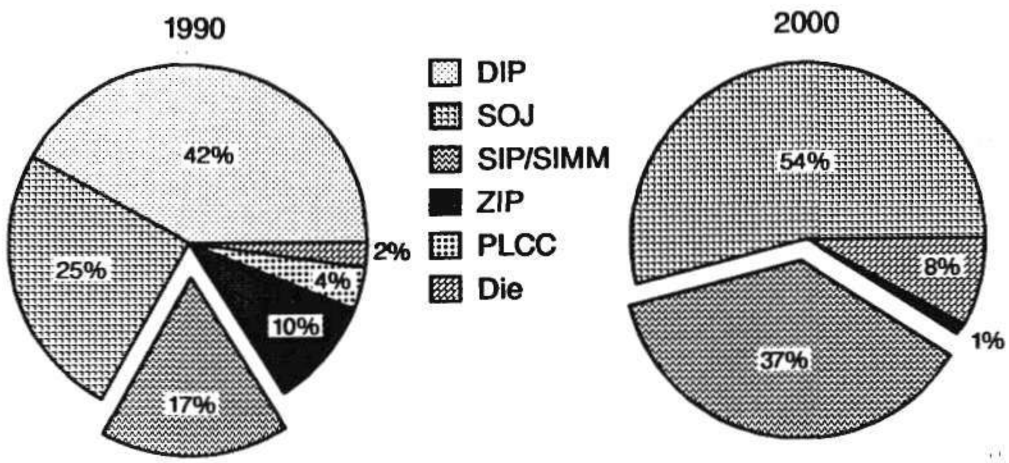
MOS DRAM PACKAGE PRODUCTION

(Percent of Units)



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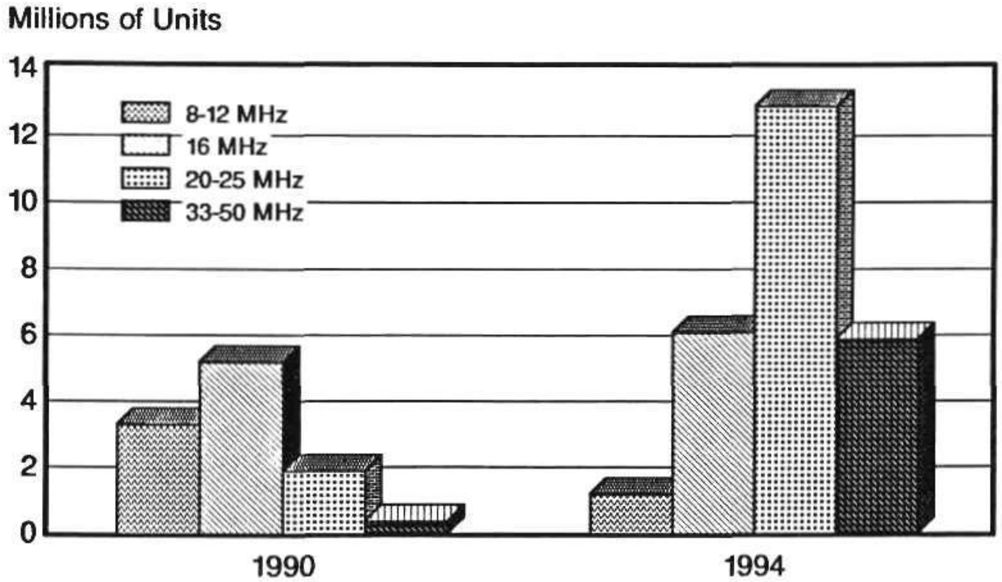
ESTIMATED MPU SPEEDS



Source: Dataquest

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AGENDA

- Worldwide IC package market
- Emerging technologies analysis
- Applications and materials analysis

MCM DRIVERS

Materials/Technology

Company	Substrate
Advanced Packaging Systems	Silicon/ceramic
AT&T	Silicon
Boeing	Silicon
CNET	Silicon
DEC	Copper
Dow Chemical	Silicon
Fujitsu	Glass-ceramic
General Electric	Alumina
Hewlett-Packard	Alumina
Hitachi	SiC/alumina
Holz Industries	Silicon/alumina

Source: Dataquest

MCM SUPPLIERS

Alcoa	MCNC	Polylithics
HDI Integration	Midway	Rockwell
Honeywell	Mitsubishi	Rogers
Hughes	Mosaic Systems	Siemens
Ibiden	nChip	Sumitomo
IBM	NEC	Texas Instruments
Irvine Sensors	NTK	Thorn-EMI
Kawasaki Steel	NTT	Toshiba
Kyocera	Oki	Unistructure
MCC	Polycon	Unisys

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AGENDA

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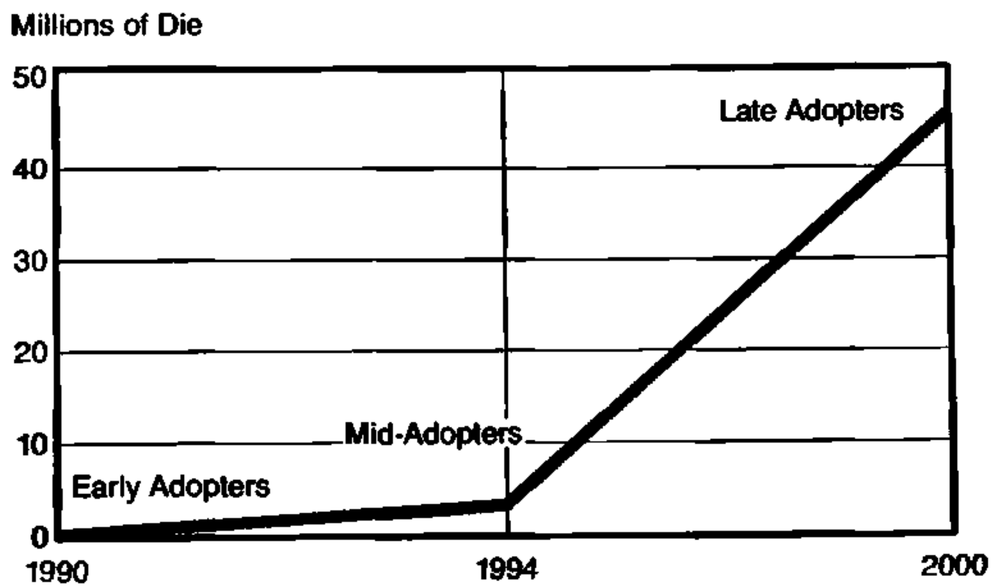
MULTICHIP OPPORTUNITIES



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MCM DRIVERS

Assembly

- Semiconductor and PCB assembly -- combine efforts
- Semiconductor manufacturers -- sell technology and modules
- Systems houses -- license technology

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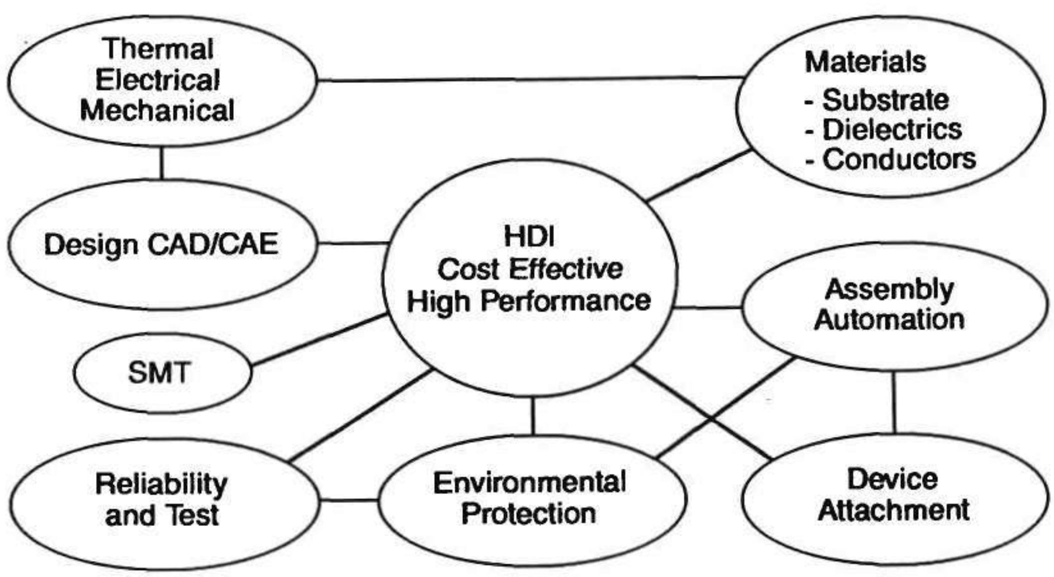
IC PACKAGING -- 2000



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MCM MARKET TRENDS

Benchmarks

- Performance/density
- Computer market growth
- Chip-space reduction
- New PC applications

Barriers

- Slow market momentum
- North American start-up mentality
- Lack of CAE/test tools

Source: Dataquest

SUMMARY

- Device clock rates will exceed 50 MHz
- Market price premiums will support development of MCM technology
- Surface-mount technology has prepared the systems market to accept HDI interconnect structures – MCM, WSI, etc.
- HDI packaging technology will change the industry

Source: Dataquest

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LITHOGRAPHY STRATEGIES: PUSHING THE LIMITS

Moderator

Peggy Marie Wood
Senior Industry Analyst
Semiconductor Equipment, Manufacturing, and Materials Service
Dataquest Incorporated

Peggy Wood is a Senior Industry Analyst for Dataquest's Semiconductor Equipment, Manufacturing, and Materials Service. Her responsibilities include research and analysis of the semiconductor industry with respect to wafer fabrication equipment, electronic materials for semiconductor processing, and the technology trends of semiconductor manufacturing. Prior to joining Dataquest, Ms. Wood was a postdoctoral research affiliate in the Department of Chemistry at Stanford University. While at Stanford, she supervised the installation of new research facilities and was responsible for the purchase of optical, electronic, and laser equipment. In addition to pursuing hew own research in nonlinear chemical dynamics, Ms. Wood taught undergraduate laboratory courses and supervised graduate student research. Ms. Wood received a B.S. degree in Chemistry from California State University at Sacramento and a Ph.D. in Chemistry from Stanford University.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 8-9, 1990
Monterey, California

Semiconductor Industry Conference

Lithography Strategies: Pushing the Limits

Peggy Marie Wood, Ph.D.

Semiconductor Equipment, Manufacturing, and Materials Service
Dataquest Incorporated

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LITHOGRAPHY STRATEGIES: PUSHING THE LIMITS
E-BEAM LITHOGRAPHY

C. Neil Berglund, Ph.D.
Special Assistant to the President and
Executive Director of Marketing
Etec Systems, Inc.

Dr. Berglund is Special Assistant to the President and the Executive Director of Marketing of Etec Systems, Inc. Etec is an independent U.S. equipment company supported by a recently formed strategic working alliance, which includes IBM, DuPont, Micron Technologies, Grumman Aerospace Electronic Systems Division, and Zitel. Etec manufactures advanced electron beam lithography tools used by the semiconductor industry for production maskmaking and direct-write-on-wafer pattern generation. Dr. Berglund is a recognized international leader in microelectronics technology with more than 26 years of experience in the semiconductor industry and has managed every aspect of IC design and production. He served for five years as Director of Technology at Intel Corporation in Aloha, Oregon, where he pioneered CHMOS technology. In 1983 he founded Ateq Corporation, an equipment company that designs and manufactures laser-based lithography systems. Dr. Berglund received his B.Sc. from Queen's University, Kingston, Canada, his M.S. from the Massachusetts Institute of Technology, Cambridge, Massachusetts, and his Ph.D. from Stanford University, California, all in Electrical Engineering. He is an elected Fellow of the IEEE for his contributions to MOS device characterization activities. Dr. Berglund holds may patents and has chaired many conferences and advisory boards. He is currently a Consulting Professor of Electrical Engineering at Stanford University.

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Semiconductor
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Conference

Lithography Strategies: Pushing the Limits

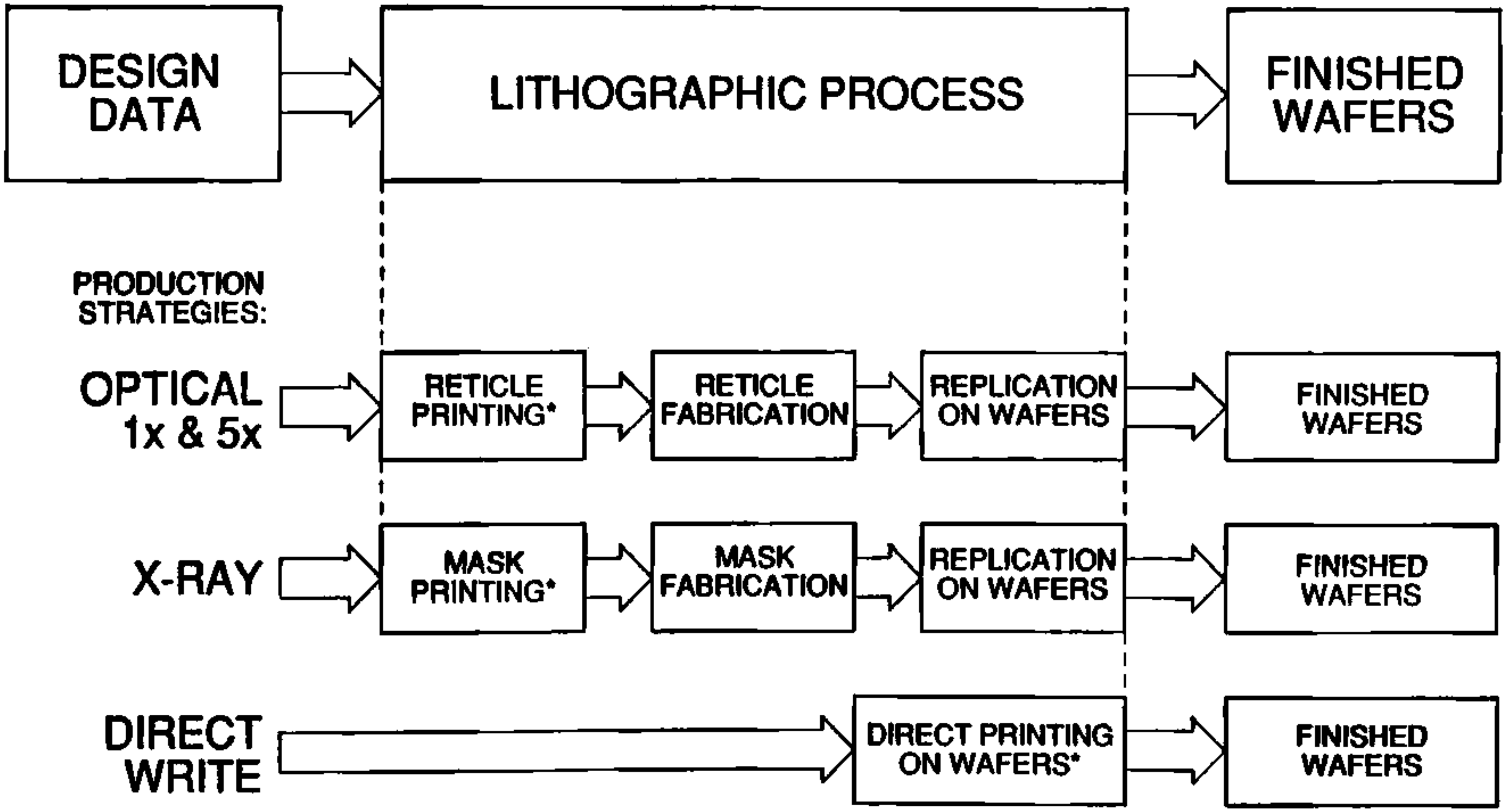
E-Beam Lithography Status

Neil Berglund, Ph.D.
Assistant to the President
and Executive Director of Marketing
Etec Systems, Inc.

Electron Beam Lithography Status

- Device Patterning Flow
- Maskmaking
- Direct Write
- Summary

Device Patterning Flow



*REQUIRES ADVANCED E-BEAM TECHNOLOGY

5X Reticle Specifications

1987 - 1996

Year	1987	1990	1993	1996
DRAM Generation	4 Mb	16 Mb	64 Mb	256 Mb
Minimum Feature Size (wafer)	0.8 µm	0.5 µm	0.35 µm	0.25 µm
Pattern Address Grid (5X reticle)	0.25 µm	0.10 µm	0.05 µm	0.025 µm
Layer Data Size	30 MB	120 MB	200 MB*	300 MB*
Registration (two-point align)	0.20 µm	0.12 µm	0.08 µm	0.05 µm
Throughput	<1 hr	<1 hr	<1 hr	<1 hr
Maximum Corner Radius	0.25 µm	0.15 µm	0.10 µm	0.05 µm

* Assumes data compaction

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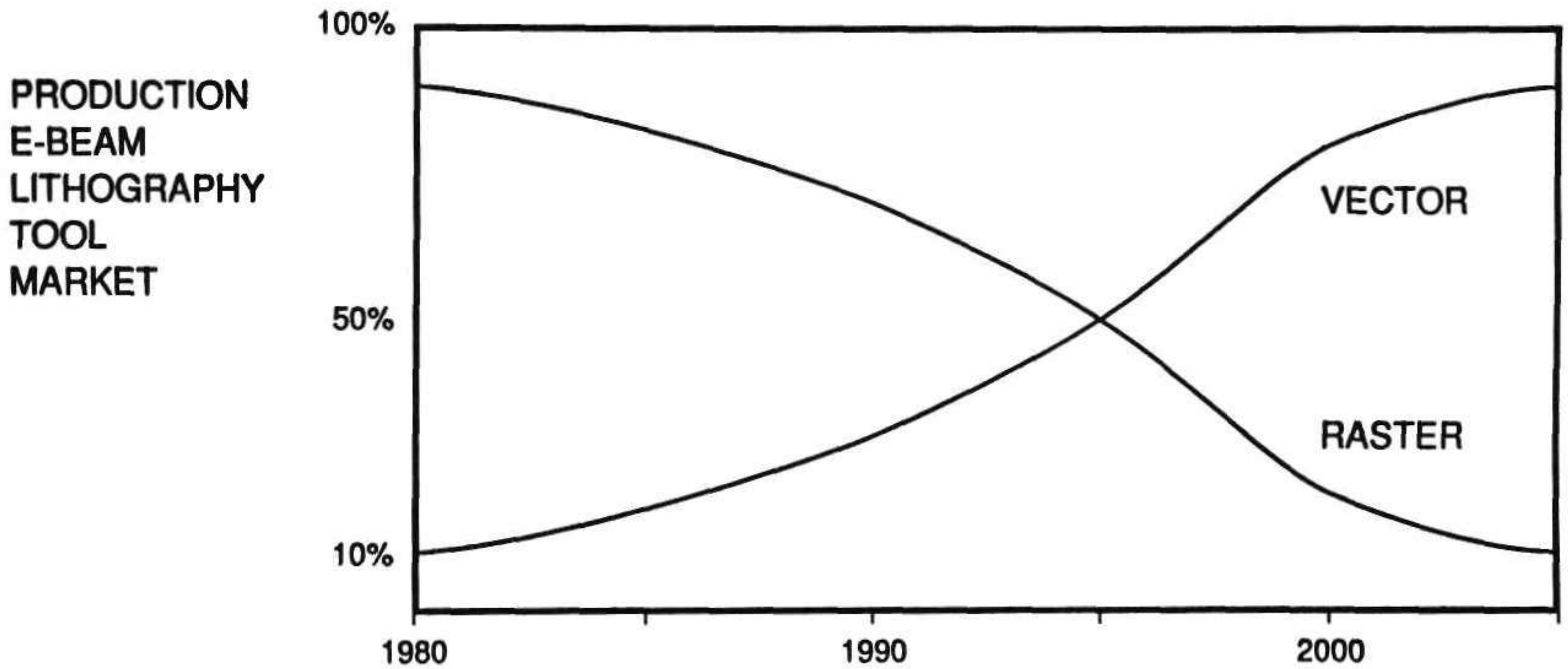
Integration of Maskmaking Technology with Wafer Fab Process

Year	1987	1990	1993	1996
DRAM Generation	4 Mb	16 Mb	64 Mb	256 Mb
Compensate Stepper Distortion	No	Maybe	Yes	Yes
Localized Sizing	No	Maybe	Yes	Yes
Phase Shift Masks	No	Maybe	Yes	Yes
Proximity Effect Correction	No	No	Maybe	Yes

E-Beam Lithography Market
Raster vs. Vector



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System Architecture: Raster vs. Vector

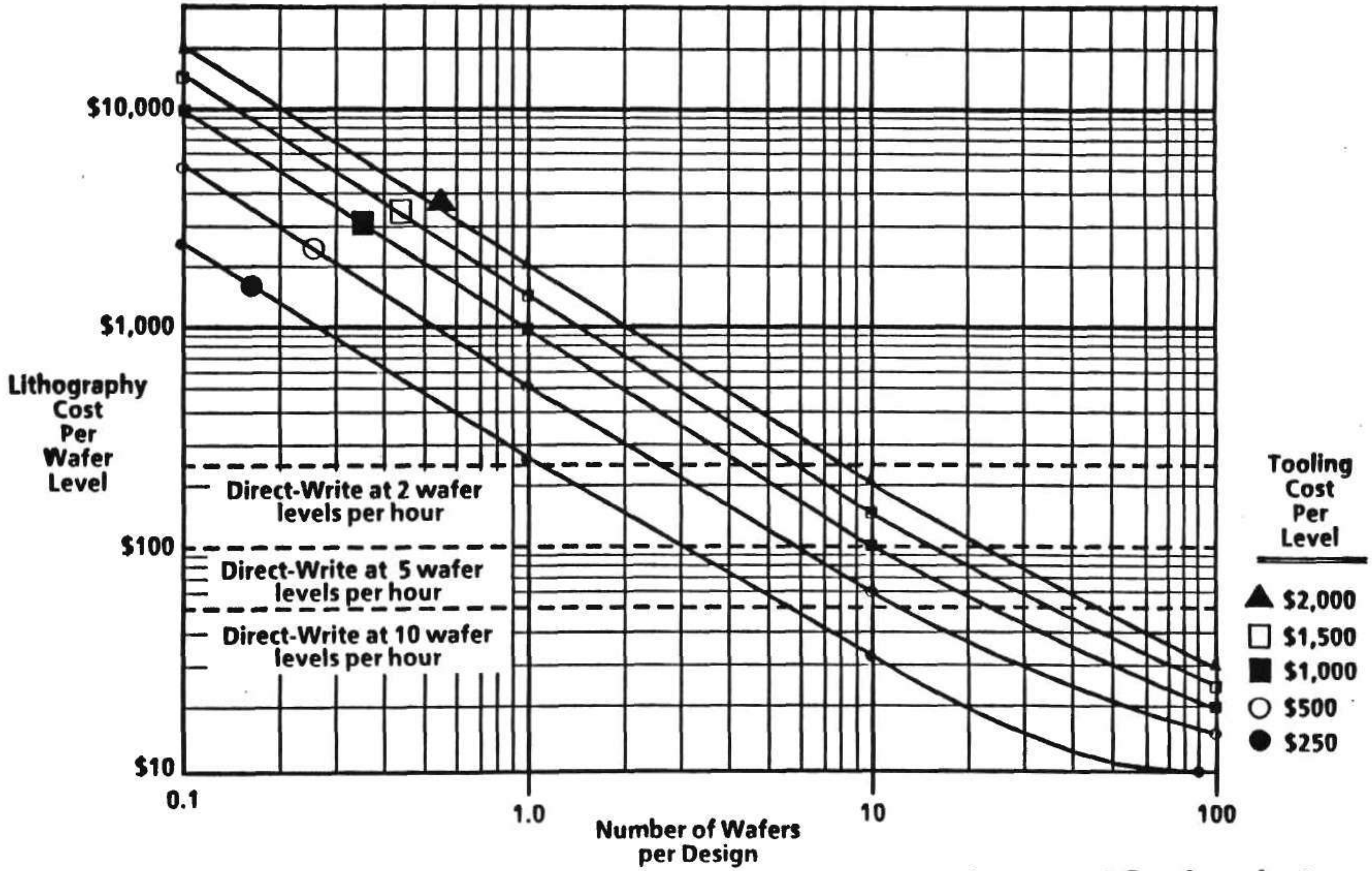
- Maskmaking lithography tools will tend toward a vector scan architecture for the following reasons:
  - economics
  - data file size
  - edge placement decoupled from address grid
  - elimination of corner rounding
- However, maskmakers will be able to extend their existing raster scan tool base at least to 64 Mb DRAM generation

Direct Write

Market Segments:

- Research & development requirement
  - Advanced prototyping
  - Very high resolution, very low volume
- Low volume production
  - ASIC, Gate Array, GaAs
  - Medium to high resolution
- High volume production
  - DRAM production
  - High resolution Mix & Match

A Comparison of Direct Write and Optical Lithography Costs as a Function of Total Wafers Processed



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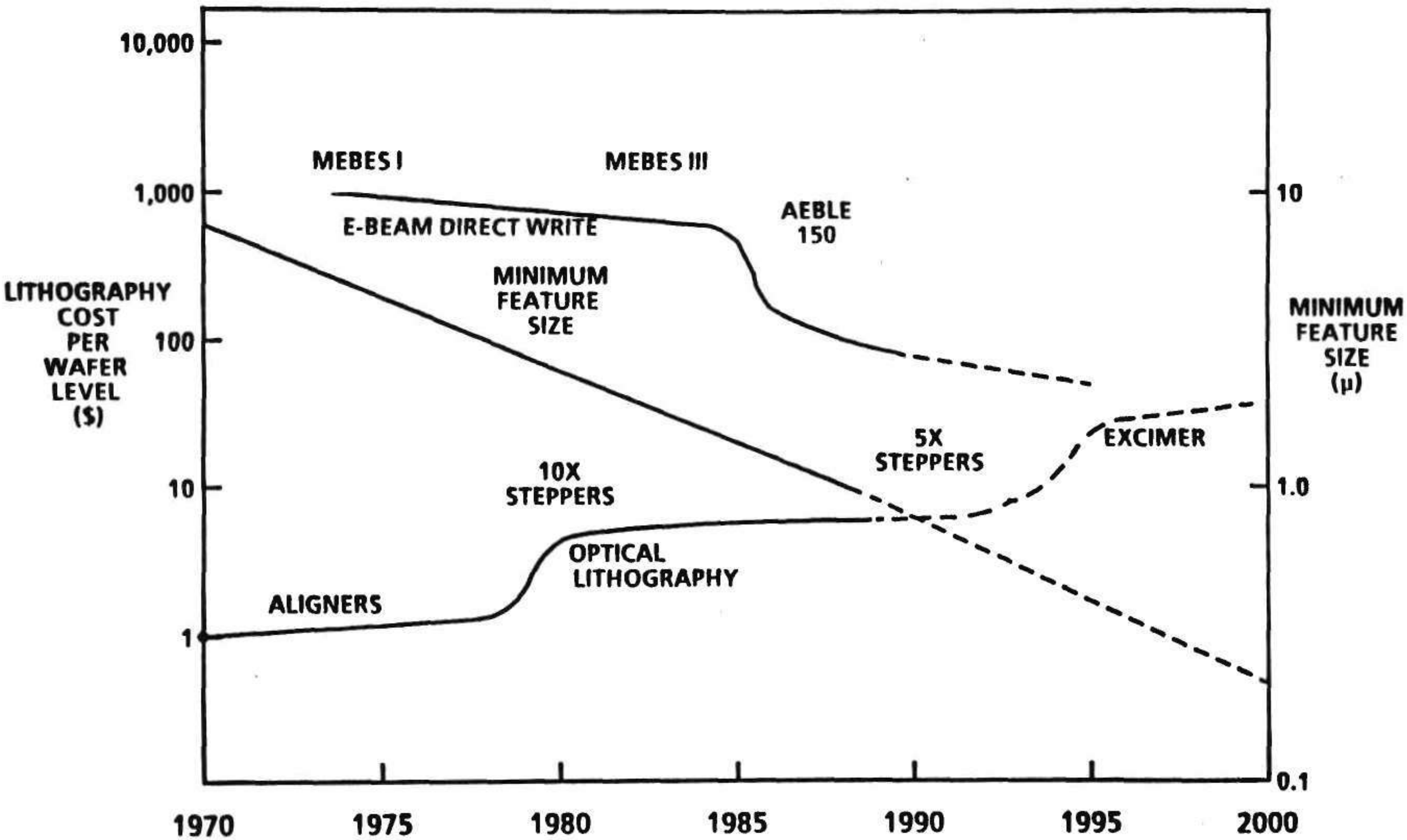
ETEC

Electron Beam Lithography Status
C. Neil Berglund, Ph.D.

Lithography Cost Trends for Direct Write and Optical



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Summary

- E-Beam will remain a key technology for maskmaking and direct write.
- Vector scan will dominate raster scan in the long term for maskmaking as well as direct write.
- Direct write is economical for low volume production today.
- Direct write will be cost competitive for selected production layers by the mid - 1990's.

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LITHOGRAPHY STRATEGIES: PUSHING THE LIMITS
OPTICAL LITHOGRAPHY

Gene E. Fuller, Ph.D.
Manager, Lithography Modules
SEMATECH

Gene Fuller is the department manager for lithography at SEMATECH. Prior to his assignment to SEMATECH Dr. Fuller was the Director of Manufacturing Science and Technology Project at Texas Instruments. He began his work with TI in 1979 as a Member of the Technical Staff in the Houston Process Development Laboratory. In 1982 he moved to Dallas to join TI's Semiconductor Process and Design Center, where he was the Branch Manager for Advanced Lithography, responsible for development programs in X-ray lithography, e-beam, and optical lithography. Prior to his joining Texas Instruments, Dr. Fuller was a member of the scientific staff at Brookhaven National Laboratory, where he worked on radiation damage and defect spectroscopy in crystalline materials and silicon dioxide. Dr. Fuller received a B.S. in Physics from Michigan State University and both M.S. and Ph.D. degrees in Solid State Physics from the University of Wisconsin.

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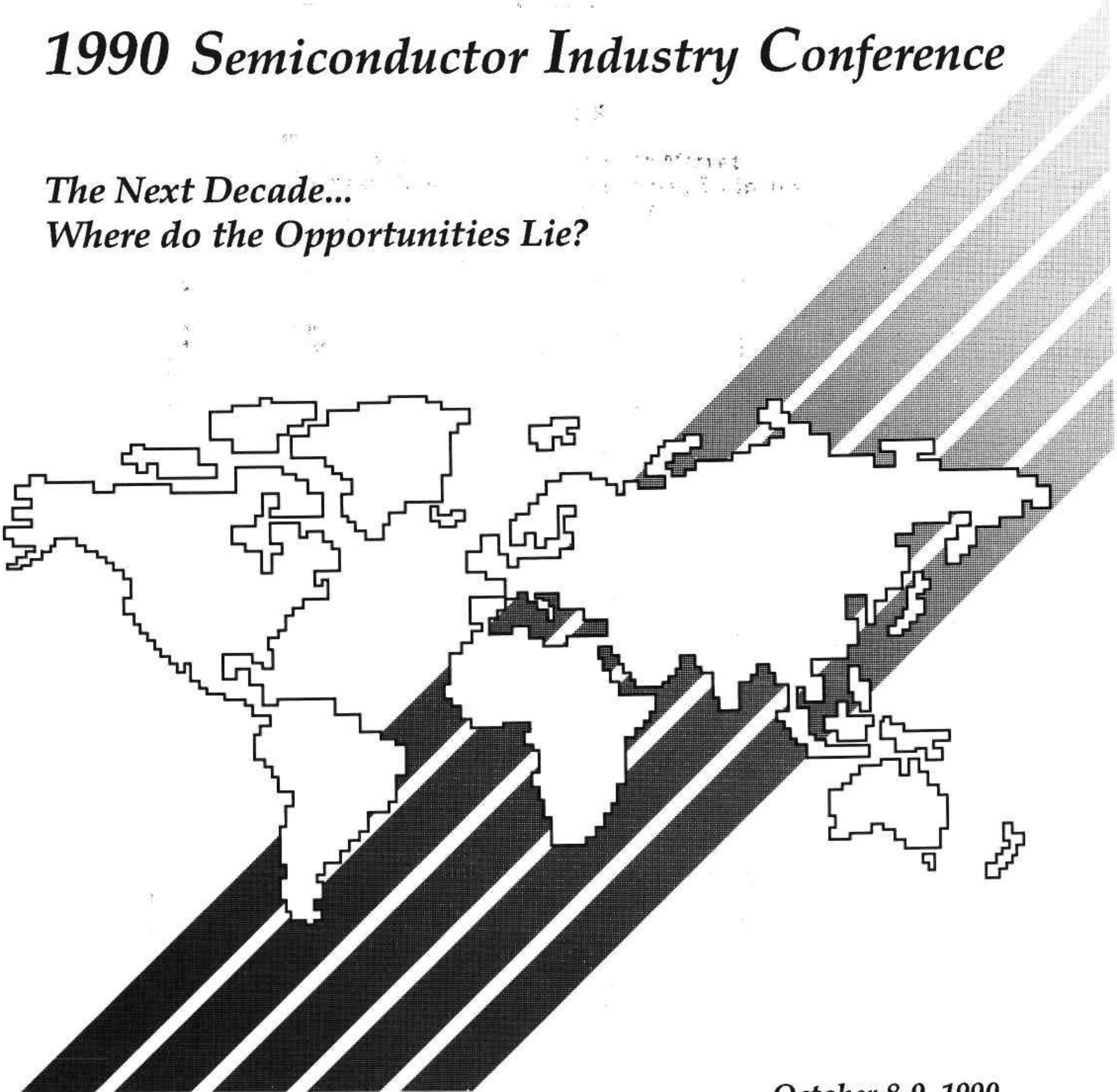
1990 Semiconductor Industry Conference

The Next Decade...
Where do the Opportunities Lie?



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Jenny Williams
Semiconductor Components Group

1990 Semiconductor Industry Conference

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SEMICONDUCTOR INDUSTRY FORECAST

David Angel

Group Vice President and Director of Worldwide Research
Dataquest Incorporated

Welcome. This is Dataquest's Sixteenth Annual Semiconductor Conference. This conference is the largest conference that Dataquest has ever had. Thank you for coming. Thank you for your business. We appreciate it. Rest assured, we never forget that you are the reason that we are here.

This year we had quite a challenge given to us for this conference, based upon the success of last year's conference. In the year that has ensued, we have received many private comments that last year's conference, particularly the late Tuesday session, was quite a "moving" experience for many of you.

Dataquest Forecasting System

Let's take a look at our most recent forecast.

Illustration #1 shows our forecast methodology. It is probably far too complicated for all but the most devout of industry analysts to understand, so I will try to simplify the process for you.

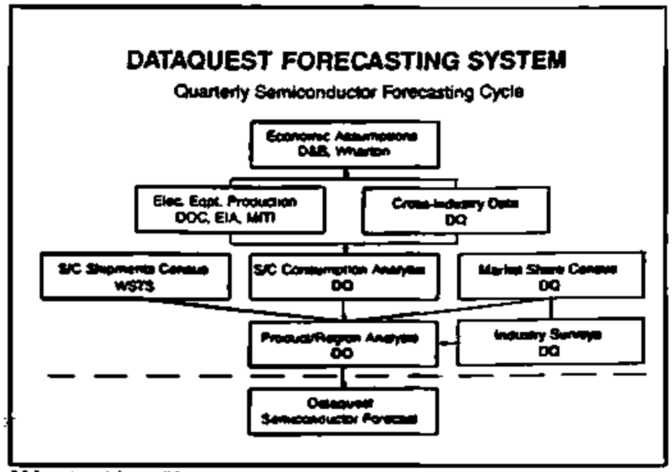


Illustration #1

- We begin by examining basic economic assumptions: potential and actual economic growth, availability of capital, interest rates, employment, productivity, and all of those mysterious things that young, incredibly bright MBAs like to talk about.

- We then combine that with actual production statistics from organizations, such as the Department of Commerce and MITI, as well as our own very comprehensive industry data bases.

- Having done that, the fun begins. All of this is fed into Dataquest's state-of-the-art bank of biochemical computers, with gigabytes of memory, whom we just happen to call Pat, Terry, Ken, Mark, Alice, Patricia, and many, many more — namely, our very best analysts. They are sequestered in a room until they arrive at a verdict.

The rules are simple: The governing rules are parliamentary procedure and the Marquis of Queensberry. It gets tough in there. Lesser mortals have to wait outside until a puff of white smoke goes up Dataquest's chimney.

Basically, the supply-side analysts present the forecast from the standpoint of the chip producers. This forecast is challenged by our user-side analysts. At the end of the day, if the supply side proposes that their clients, surveys and industry consensus state that a million microprocessors are going to be shipped next year, then the user-side analysts must agree that their surveys, industry contacts and consensus conclude that the users plan to buy a million microprocessors. Basically, it is just that simple. That's the check and balance. We do not allow a discontinuity.

Now, in some respects, in thinking about this, one could look at Dataquest as somewhat of a bridge between the supply side and the user side of the industry: "If the supply side proposes that a million DRAMs are going to be produced next year, do you, the user side, agree that you will buy a million DRAMs? And, if not, what is the number?" So, it becomes a process of iteration, back and forth, until we finally arrive at an agreement.

We then modulate that forecast with the same type of input from all of our regional offices throughout the world.

Let me again use memories as the example. We typically operate with four memory analysts in our San Jose office. We have three memory analysts in our Japanese office (two supply side, one user side) who very carefully follow the heart of the DRAM industry. We have full-time analysts in Korea, as well as Europe. And we have just announced that next year we plan to add on-site research capability in Southeast Asia. These eight to 10 worldwide memory experts all participate with their counterparts in ASICs, analog and micro components to arrive at a forecast.

Just when everybody is almost exhausted, we introduce yet another dimension: We bring in Dataquest's other industry services. For example, can the data processing industry absorb the chips that the producers intend to make? Do growth rates for the telecommunications industry support the forecast? Will enough personal computers be absorbed to consume the output of the microprocessor and the memory chip companies?

The "Why" and the "What"

The forecast that you finally receive, if I must use a highly overworked cliché, is really just the tip of the iceberg. It is what we like to think of, or what I have a tendency to call, the "What."

But, I think, an equal value of what Dataquest may provide may lie also in the "Why?" of the forecast. Why do we think that there will be growth or shrinkage in the industry? Why do we assume certain events? Why have we arrived at our conclusions? It is this knowledge — the "Why?" side of it — that you need to run your business. The "What" alone is no longer sufficient.

However, having said that, let's look at the "What" for just a few moments.

World Semiconductor Industry Forecast

We now believe that 1990 will be down 1.3% compared to 1989, on the basis of worldwide semiconductor revenues. As I mentioned, we will tell you the "Why?" in just a few moments.

We forecast that 1991 will show growth of 15% over 1990 — but, to be honest with you, it is

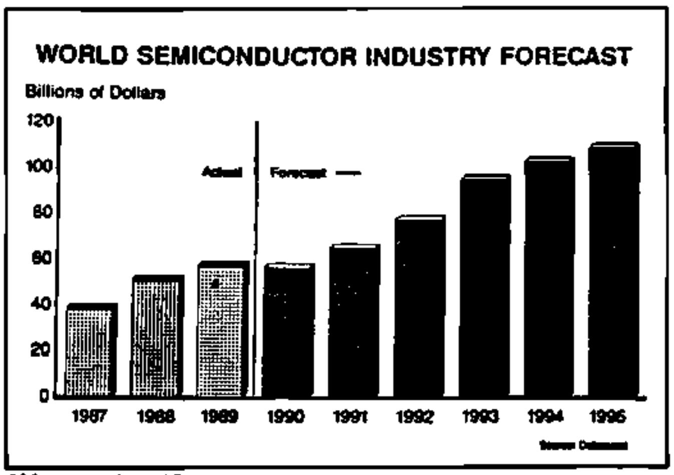


Illustration #2

one of the toughest forecasts we have ever prepared. There are an awful lot of things that could go wrong.

The peak of the cycle will occur in 1993, with growth of over 22%. By 1994, the industry will double in size, so the opportunities absolutely abound.

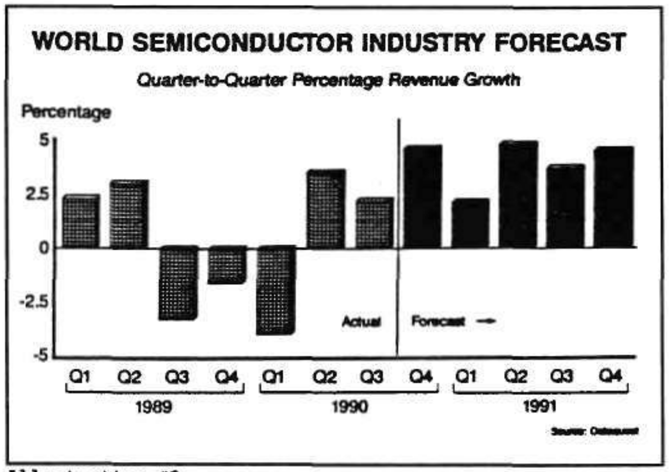


Illustration #3

The first quarter of 1990 was poor, down over 4%.

Quarter 2, on the other hand, was up 3.5%. Production of personal computers, particularly in Europe, was strong. We experienced a mini-shortage of DRAMs, just as those very same memory experts I mentioned a few moments ago had predicted. Lead times of 80386-type devices were beginning to be measured in light-years.

The third quarter, the current period, will be soft — worldwide growth, we believe, of about 2%. A serious erosion of DRAM prices is bringing down an otherwise fairly positive quarter.

1990 Total Industry Performance

Let us for a moment look at total industry performance for 1990 from a different perspective. Analog chips will be up 7% in 1990 compared to 1989. Nevertheless, microcomponents will be up over 12%; MOS logic will be up; discretes will be up; opto-electronics will be up. However — and here is the killer — MOS memory (essentially DRAMs) will be down 18%. MOS memories will be down approximately $3 billion in 1990 compared to 1989. DRAM consumption in Japan will be down almost 25%. Bit growth in 1990, overall, will only be about 14%.

If DRAM revenues in 1990 were only the same as they were in 1989 — that is, zero growth — then the worldwide semiconductor industry would have grown about 5% this year. Now, I realize you cannot run your businesses on "if's," but I wanted to give you some idea of the enormous effect that DRAMs are having on the health of the worldwide semiconductor industry.

What Can go Wrong in 1991?

Let's move on to the "Why?" for 1991. When I first saw a 15% growth projection for 1991, I had some problems. I want to caution that the list of things that could go wrong is extensive. Let's look at some issues.

First, I think, contrary to what you and I are feeling, the sky is not falling.

• The unemployment rate is at 5.7%. That is lower than this rate was for any year from 1974 to 1987.

• Factory utilization of capacity is at 83%. That exceeds only six years in the past 20 years.

• The rise in oil prices is not likely to push the economy into a recession. If the price of a barrel of oil settles to around $27 during the next 12 months — and we think that is a likely scenario — then Gross National Product would decrease by only 0.5%.

David Angel

• In discussions which I have had with several of you last night and today, many people have reported — quietly, almost secretly — that the month of September actually is a pretty good month. One of the chief concerns that we are facing right now is consumer confidence. The same types of decisions that we make in fore-stalling investments and acquisitions in our homes have a tendency to move over into our businesses. It is that lack of confidence right now, more than anything else, that has us concerned.

Positive Issues for 1991

Let's now talk about some of the positive issues for 1991.

• The market for telecommunication chips and related devices is expected to be good, and particularly so in Europe. Let me give you an example. It has been reported to us that ALCATEL is installing a quarter-of-a-million new telephone lines in the Soviet Union, and Siemens is installing one million new lines in Poland. The demand for cellular telephone in Germany, France, and the United Kingdom is explosive. We also believe this is a solution in Eastern Europe for the lack of hard lines in those countries.

The book-to-bill ratio for telecom chips at two major European companies is running between 1.5 and 2.0. So, the telecom side of the business and its pull-through business, with analog devices and other things, is extremely good right now.

Growth in Memory Consumption

Let's look at some growth rates for items which are heavy consumers of chips:

• Workstations are expected to grow 36% in 1990 on a revenue basis.

• Personal computer growth next year will be up 18%. Now, I will be the first to admit that is mostly notebooks and laptop computers, but that is good news for the 4 Mb DRAM suppliers.

• Again, Europe is reporting surprisingly strong growth in mid-range computers. One of the effects of 1992 is that the financial institutions will be able to do cross-border business. We are observing extensive replacement of old computing systems with modern mid-range systems. For example, one source last night told us that the IBM AS\400 mid-range system is suddenly selling very well in Europe.

• Local area networks and file servers are also being installed at a brisk rate. That represents a lot of memory consumption.

• While the clone personal computer makers clearly are taking heavy weather, the brand-name manufacturers are experiencing growth. These suppliers depend heavily upon ASICs for product differentiation.

• Data processing, we think, will continue to be a major driver of the ASIC market. We are looking for growth in the data processing area of over 10% in 1991. That is a $121 billion industry. About 50% of all IC chips and over 70% of all memory chips go into the DP business. Data processing growth in 1990 appears to be only half of what we expect the growth to be for next year. Consequently, we think there is substantial up-side for chip suppliers to that industry next year.

Memory Forecast

This brings us to the subject of memories. Our Japanese office forecasts that DRAM consumption in 1991 will be up 22% with mid-growth close to 60% — remember, it is only 14% this year.

Revenues for MOS memory are expected to be up more than 19% worldwide. However, a substantially improved DRAM scenario is critical to meeting the forecast total industry growth rate for 1991. Consequently, I urge you to stand by for our panel on DRAMs tomorrow. I am hoping they will give us substantial insight into what that market looks like next year.

There are obviously many more "Why's" to our forecast, but I hope this begins to give you a flavor for all of the thinking that goes into a Dataquest forecast.

What Can Go Wrong?

The ancient Chinese wished upon their enemies that they may live in interesting times. These, my friends, are interesting times.

• The Middle East situation obviously overshadows almost all other events, at least for the moment.

• A capital drain on Germany as a result of the reunification could certainly hamper European growth.

• Rising cost of Japanese capital. Last week I was in Japan when the long-term credit bank of Japan raised its interest rates to 8.9%. That is the third raise in those rates in three months.

• Slowdown becoming broad-based recession.

If you would like a copy of our latest forecast, it is available in the library.

Program Introduction

We have an impressive list of speakers who will be with us for the next two days. I think this is a good time to hear what they have to say.

What better way to do that than to introduce our President, Manny Fernandez, who has a unique perspective of what this industry and our business will look like in this next decade.

THE NEXT DECADE . . .
WHERE THE OPPORTUNITIES LIE

Manny Fernandez

President and Chief Executive Officer
Dataquest Incorporated

Good morning. It is great to see all of you here — a lot of old friends and, I'm sure, some new friends to be made over the next couple of days here.

This is like a homecoming for some of us. I have been at Dataquest for six years, but I have been in the audience with you for the last 15 years, beginning with the second Dataquest conference. This is really a homecoming for me, as I am sure it is for many of you.

For those of you who have not been at the conference for the last few years, this has been an eventful place.

When David asked me to speak to you at this conference I was very pleased to be asked back. But then he told me there was some good news and some bad news. The good news was that I don't have to worry about what I am going to say for about 10 years. The bad news was that I have to look ahead and give you a forecast of the semiconductor business 10 years from now.

As I was getting prepared for this opportunity last night, I was watching TV. One of the local channels had a satellite weather forecast of different parts of the world. Because of what has been happening in the Middle East, they even had a satellite photograph of the weather patterns there. It dawned on me that those satellite pictures of Kuwait and Saudi Arabia looked the same as they looked six or eight months ago — or, for that matter, 10 years ago — but, interestingly, as you move from that satellite perch down to earth, you can see that the action on the ground is significantly different.

I think that, in a way, is analogous to the semiconductor business. If you take a look today at the semiconductor industry compared to 10 years ago, from way up in the sky, it looks as though there has been pretty steady growth, a very successful industry which has grown very nicely over the last 10 years. But, as you come down to the ground, you see some changes that are dramatic and permanent. We have all gone through some changes. Some of them have been very painful.

The 1980 Forecasts

My task is to look ahead at the next 10 years. To do that appropriately, I want to go back and take a look at October 22, 1980, in Scottsdale Arizona. I was in the audience with many of you when some of the speakers presented their forecasts for the next few years.

The opening speaker of that conference is also speaking tomorrow, Fred Zieber. In his speech, Fred forecast that the semiconductor business was to grow at an unbelievable 20% compounded over the forecast period from the 1980 base of $11.1 billion. The results are absolutely amazing. I think that Fred, in 1980, did not present as rigorous a forecast as David just presented, but today, in 1990, the semiconductor business represents a $66.4 billion market and the compounded annual growth from 1980 was 19.7% — a 0.3% difference.

That same day, Gordon Moore told us that the biggest concern for the 1980s was software. Gordon said that growth in the 1980s and 1990s would be limited if we did not have enough software engineers to program the microprocessor revolution that was anticipated to explode in the 1980s. Boy, was he ever right! If you look at it today, software is unquestionably the limiting factor. I believe that the personal computer business is tremendously under-penetrated because of software.

Dataquest follows the personal computer business — and that is just one of the many markets that software is impacting, of course. We have seen that it has reached the highest level of lag time between software and hardware ever. There is now a four-and-a-half-year lag between the software side and the hardware side in the personal computer business. That is absolutely dwarfing the ability to penetrate the personal computer side of the market.

K.K. Iwata (then from NEC, now with LSI Logic) also spoke at that conference. K.K. told us in 1980 that there was already a major gap in technical education between Japan and the United States, and that gap could be significant in the 1980s if something were not done about it. That also was true, of course. At the end of my speech I will highlight technical education as one of the major issues that this industry will face by the year 2000.

Charlie Sporck also spoke. He told us that the U.S. was about to regain its leadership in quality and productivity that it had lost in the late 1970s, and that efforts were being made to achieve parity. He, too, was right. The U.S. manufacturers did reach parity on quality and productivity, but the U.S. never regained the lead in market share which, in my belief, has been lost for good.

At the end of that conference, four leaders of that marketplace spoke on a panel on semiconductor equipment and materials. Greg Reyes (of Eaton Corporation at that time) forecast that, by 1990, 95% of all production would be under 2 microns. He, too, was right.

Interestingly enough, everyone on that panel agreed that X-ray photolithography would be the technology of choice in 1990. That has not yet come true, but it is interesting to note that later on today we will have a very interesting panel discussion on optical, X ray and e-beam.

One last point to note. On that particular day no one even mentioned the word "Nikon" and the effect that Nikon has had on the photolithography marketplace.

Those are interesting, incredibly accurate views. That brings me back to the point that maybe nothing has really changed. A lot of those things are still very applicable today.

Looking Ahead: Forecast for the 1990s

Now it is time to look ahead and give you my view of the major technology opportunities of the 1990s.

MAJOR TECHNOLOGY OPPORTUNITIES IN THE 1990s

- Widespread use of Smart Cards
- Tremendous advances in medical imaging
- Proliferation of wireless communication
- Integration of office functions
- Major strides toward paperless society
- Breakthroughs in harnessing solar energy
- Expanding use of environmental sensing

I will look at it from two points of view. First, we will look at some industries that are the pull factors of the semiconductor world, those that are going to pull semiconductors and create the demand for the year 2000. Then, I will turn to the semiconductor products and the enabling technologies that are going to be the push factors in that marketplace.

We have a lot of data behind this forecast at Dataquest. If you have any questions about this, I will be here for the next two days and I would be delighted to sit down and talk to you.

Pull Factors

First, wireless communication will soar, to make us all part of the "wireless society."

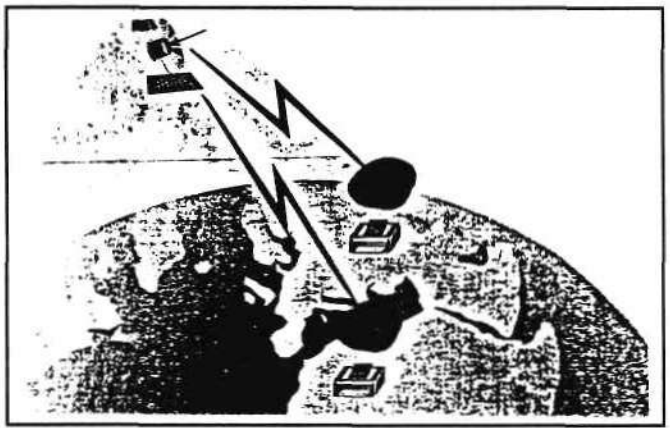


Illustration #1

Communications anywhere in the world will be a reality, whether on cellular fax or by cellular wrist communicators.

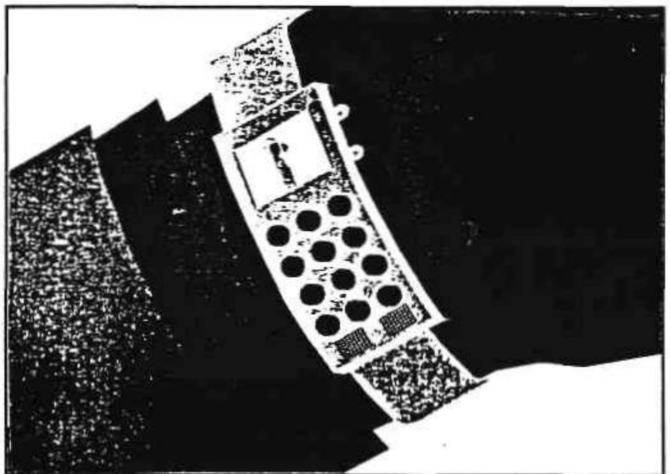


Illustration #2

It is clear that the digital world will be a dominant factor, from sound systems and video, to smart environmental systems and home management.

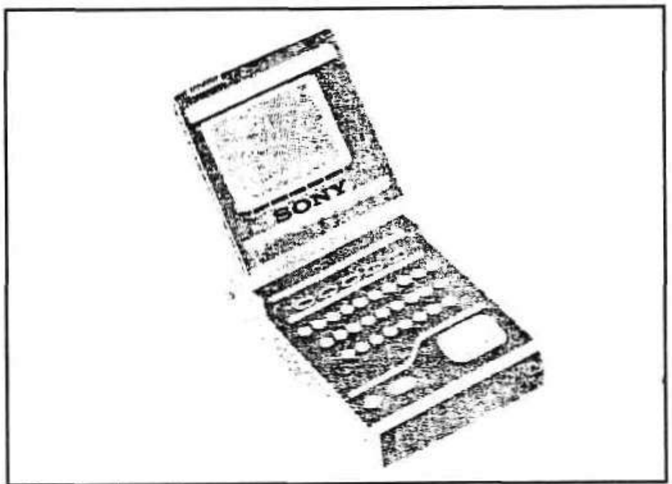


Illustration #3

By the year 2000, we will have the ability to use video communicators, integrating voice, data and images, and we will be doing all of that on a fully remote basis.

Combinational products and the utilization of the many different available wiring systems that exist

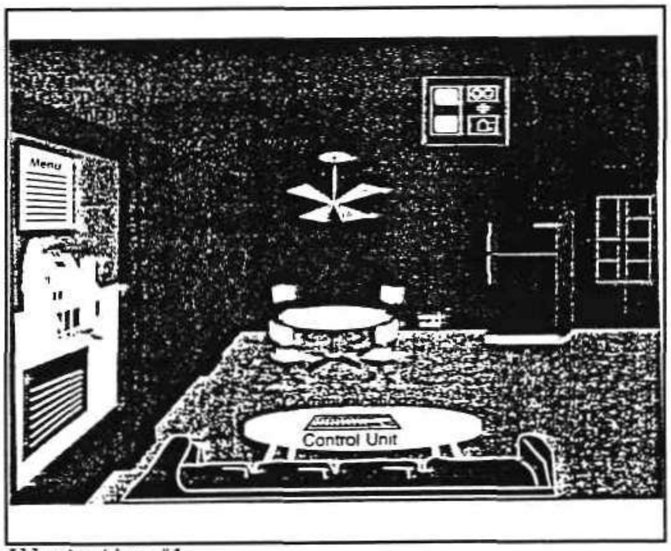


Illustration #4

in homes today will create perhaps one of the most significant opportunities, integration of appliances, computers and entertainment. I believe that the home market is one of the big boons of the next decade.

We in the semiconductor business follow many markets. We have divided the markets into DP, automotive and consumer. I really believe that, as you look ahead to the year 2000, you will be looking at the consumption within the home as one important market that you will follow, to be able to see the particular growth in your business as a pull factor.

Conservation and environmental issues will dominate the 1990s. They will dominate the 1990s because of government influences and the tremendous implications they will have for the economic world. Electronics and semiconductors will play an important role.

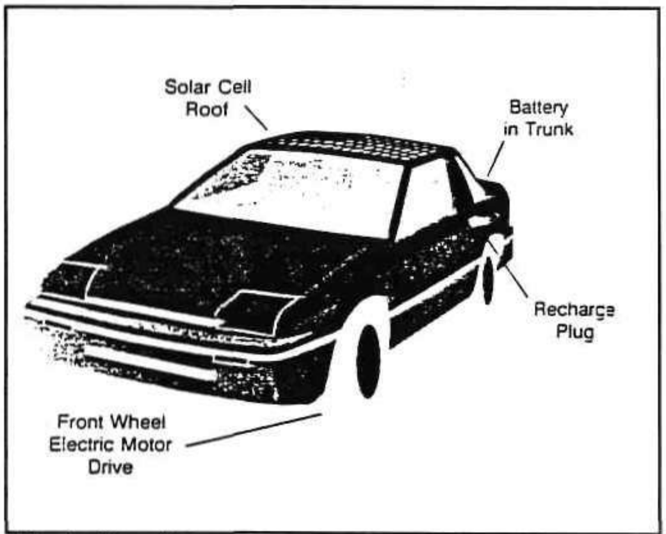


Illustration #5

There will be electric cars and vehicles of all types. Battery technologies will play a key role.

But, at the same time, conservation of paper and waste management will also be significant. Digital storage and the whole storage technology side of the business will play a significant role. Whether we will see this as the Encyclopaedia Britannica on a CD, or a hand-held portable with optical capabilities, or even automobiles with smart global positioning storage capabilities, society will be significantly more mobile. The opportunities for these markets are almost boundless.

It is clear that our work force is going to change and the mobility of that work force is going to create opportunities for all of us to be able to have products at our homes and at remote places of operation. That will have a significant impact as a pull factor for the semiconductor business.

The year 2000 will also see us carrying different kinds of cards than credit cards. There will be a proliferation of the Smart Card that has already begun.

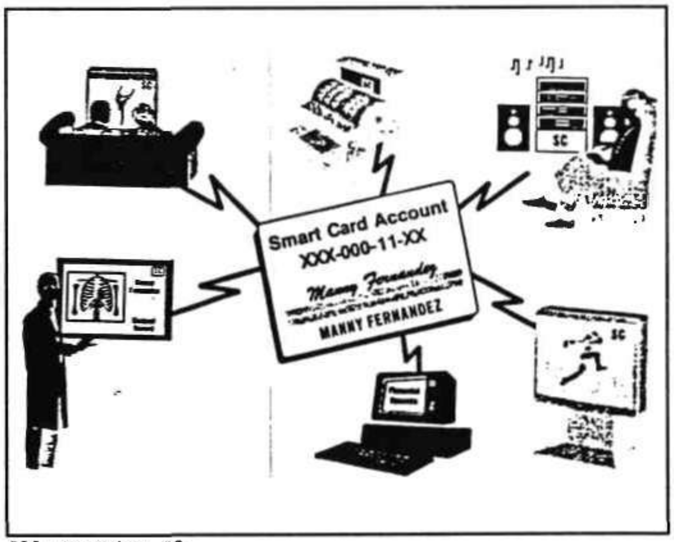


Illustration #6

This will range from picture holders, a place to hold your photographs on individual or personal players, to medical and personal records that will be available to doctors. It will also give us the ability to buy just about anything we want, anywhere in the world, at any time. But probably more important for some of us, it will give us the ability to receive a pay-for-view telecast anywhere in the world. I can just see myself, in the year 2002, picking up my Smart Card, putting it on my personal viewer and dialing up the first game of the World Series when the Oakland A's will be facing the Tokyo Giants in the Dome in Tokyo — and, of course, the A's winning in the ninth inning with their new "Eck" [Dennis Eckersley, Oakland A's pitcher] at that time.

Holography will be employed not only in the entertainment world, when we get to see "Jaws 7" or "Rocky 15" in the year 2004, but will also be used at home, in the office, as well as in medical electronics. Holography will play a very important role.

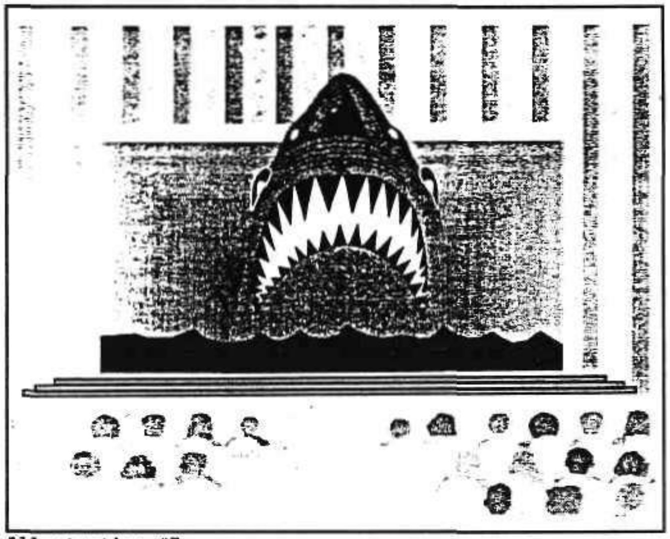


Illustration #7

In the near term, in the office, we will begin to see combinational machines that will have a short-term, as well as a long-term, impact on the demand for semiconductors. We will start seeing the combination of fax, copiers, modems, printers and scanners — all in a single machine. Interestingly enough, Xerox announced such a product last week. I am not talking here of that new Xerox product, but some future products in the near term that will make the combinational machine available to us at the same price paid for any one of those machines by itself in 1989.

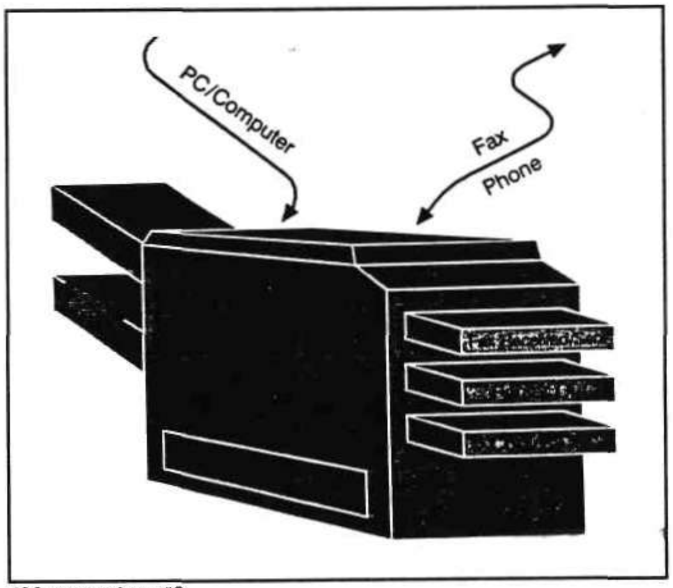


Illustration #8

Again, the impact of the semiconductor world on the decline of the memory prices will enable us to have these new products. Products which it was impossible to even conceive of in the past will be available to all of us and, therefore, fuel the next major growth in the semiconductor business.

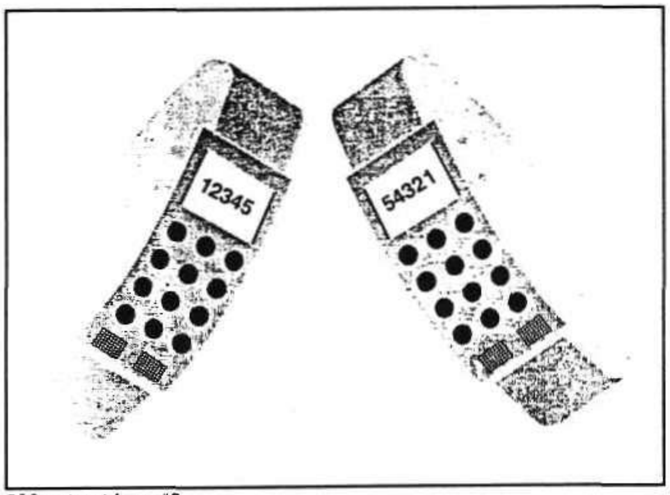


Illustration #9

Voice recognition and audio response will be great markets, where personal communicators will have a field day talking to each other. Can you picture two personal communicators in Hollywood, California trying to figure out when to "do lunch?" I can just see it. But the reality is that we are not that far off, because of voice recognition and the audio response capability.

The electronic revolution will help solve the very serious problem of service and support. Not only will machines call a technician before they break (or even be self-fixing), but will have on-line visual representation of the problem to shorten the mean time-between-failure and time-to-repair.

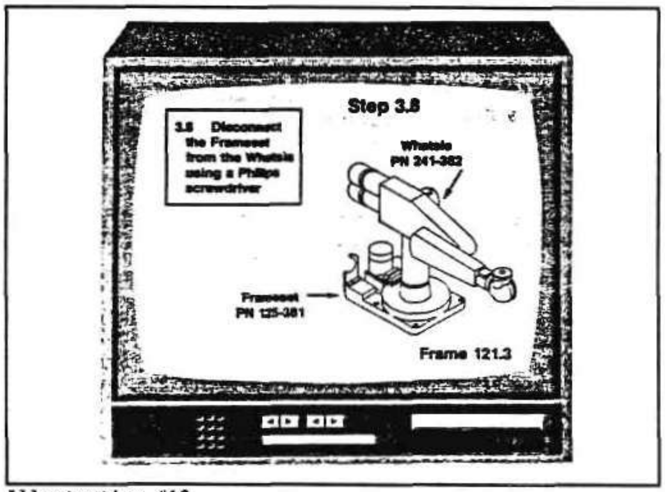


Illustration #10

This is a huge market. I think that the next battleground is going to be service and support. That is the new high ground for many of the end-user markets. I think that semiconductors, again, are going to play a major role here.

That is the pull side as I see it.

The Push Side

Let us look at some of the semiconductor products and the role that they will play in the next millennium.

It is clear that further shrinkage of circuits, with linewidth to 0.15 micron, will take place by the end of the decade. Memory density and shrinkage will continue to be the leading enabler for new markets that we will all participate in. The evolution of shrinkage will also lead us into single-chip systems.

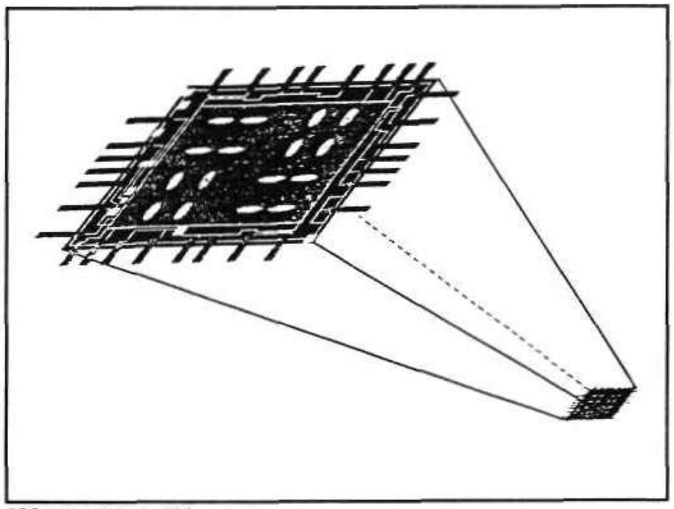


Illustration #11

A good example of this is the Hitachi evolution of the 416. This is a picture of their 64 Mb DRAM. [Slide not available for publication.]

The microprocessor world will not be exempt. It will also see the same level of performance evolution that you see in Illustration #12 for DRAMs.

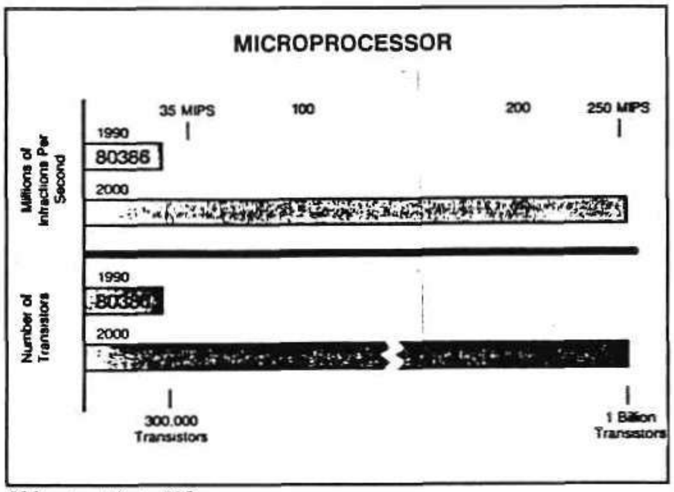


Illustration #12

In the microprocessor world, we believe that by the year 2000, we will reach 250 mips with one billion transistors, making our present state of the art (35 mips with 300,000 transistors) a small fry.

RISC technology will be the dominant architecture during the next decade.

Gordon Moore's comments of 1980 were never more true. We had better solve the software issue if we are to utilize the super-computers, the super-microprocessors. (And, by the way, we will have to come up with some new terminology. "Super-microprocessor" is not good enough. Dataquest has to invent a new word to describe these processors in the year 2000.)

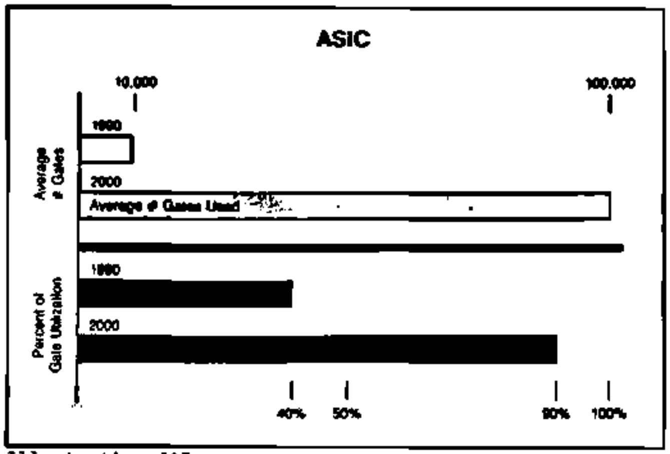


Illustration #13

Not only will we need more innovative architectures to shorten the time to design — as we have seen in companies like Xilinx and others over this past decade — but we will also need to integrate a significant amount of memory within a single chip so as to reach the optimum speed required, and at the same time, allow for utilization of gates within a wafer to go from the existing 40% utilization to the 90% and 95% level by the year 2000.

While we have been spending all of this time talking about digital electronics and digital products, the reality is that analog products will play the pivotal role in sight, sound, motion, light, temperature and pressure.

I thought Illustration #14 was kind of interesting. Can you imagine taking a picture of a bullet coming at you without the new state-of-the-art devices that can capture speed and motion, and do this at gigahertz speed with good resolution instead of the poor resolution we currently have on some of these fast devices?

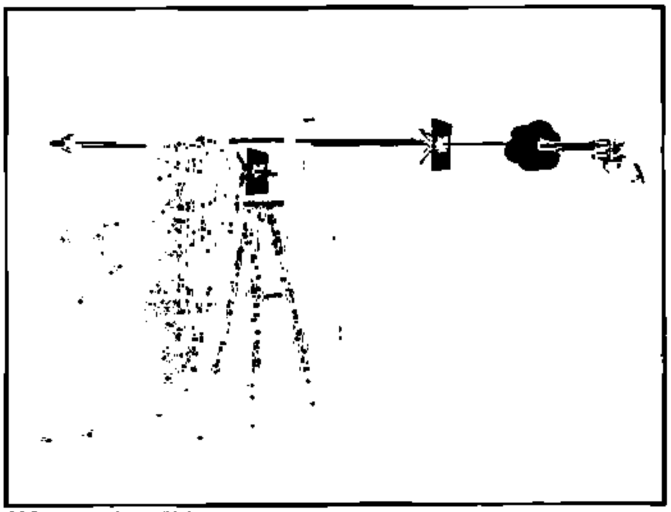


Illustration #14

By the year 2000, even digital satellite broadcasting will continue to use analog devices on the front end to send, receive and clean up data. So, analog will have a significant role throughout this whole period of time. [See Illustration #15.]

Interconnectivity will have to evolve to finally give us full wafer integration, with systems on a wafer or layered circuits, to enable development of the new products and devices and bring them to the end-users. This will necessitate a dramatic change in packaging and board design — and, again, software design to make it happen. [See Illustration #16.]

The last technology is normally viewed as the most mundane: packaging. When I first started

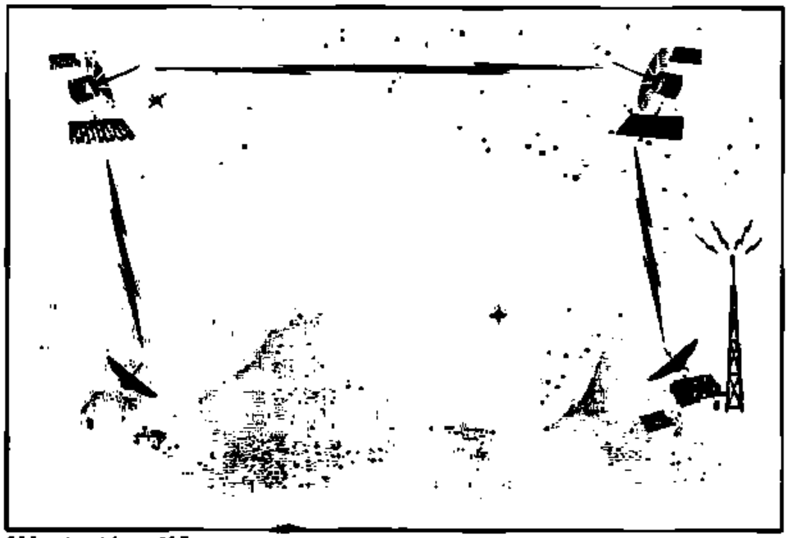


Illustration #15

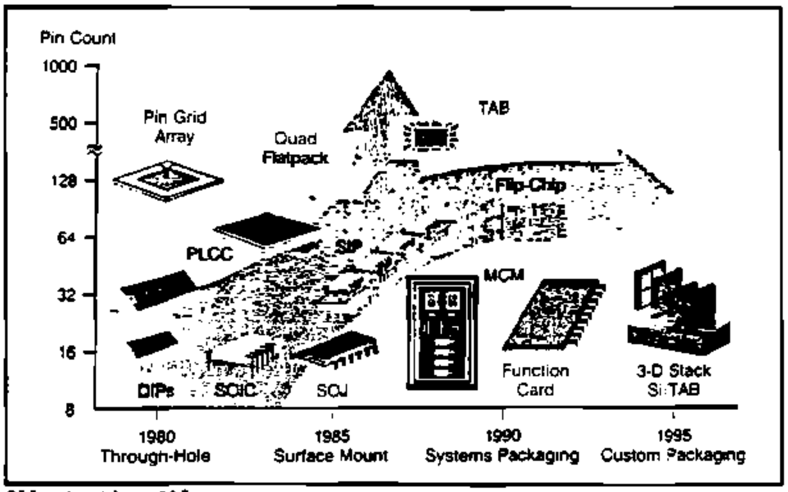


Illustration #16

in this industry, in 1967, the packaging guys were a different breed. They really didn't have to be designers.

I believe that, as we approach the next millennium, packaging could be as important as photolithography was in the 1980s. Without packaging, we are not going to be able to bring it all about. So, I believe that packaging is a critical element in this whole forecast over the next 10 years.

Just as the markets will never reach their potential without semiconductors, the semiconductor world will come to a halt if those of you from the semiconductor equipment and materials side do not keep pace, or if that equipment will not be made available on a broad basis to all participants in the semiconductor business. There is a definite requirement for the semiconductor materials and equipment industry to keep pace at the same — or even faster — rate.

In that panel of 1980, Paul Regan, Jim Morgan and Greg Reyes dealt with one major issue: photolithography. At that time they said X ray would be the winner. Interestingly enough, our panel today will examine three technologies: optical, X ray and e-beam.

Question: Will X ray be the winner, or will the tremendous experience that we have had with e-beam for 15 years be extendable?

I don't know about you, but I will be in the audience listening to that panel, because I think there will be some very interesting insights from the panelists today.

It is clear that the opportunities of the late 1990s will be tremendous. Here I am going to go on the line to tell you that my forecast is that the semiconductor industry will grow at a compound rate of 15.8% over the next 10 years. The reality is that this could very well be a $300 billion market by the year 2000.

I have defined several areas during this presentation that will have explosive growth. I think that concentration on some of these vertical markets

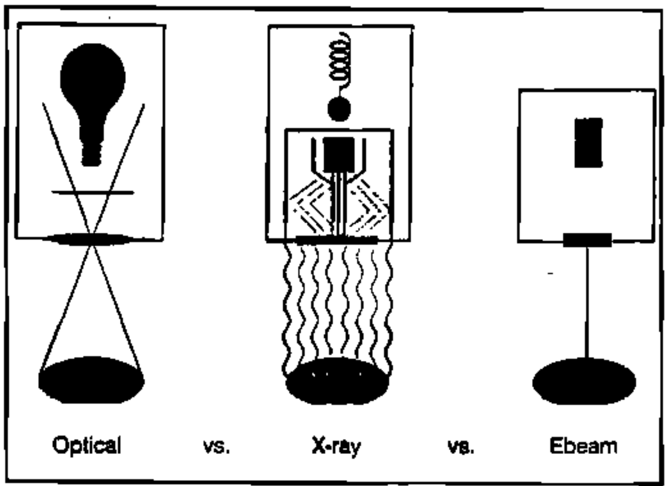


Illustration #17

will be very important. These, among many other opportunities, will really allow us to reach a new level in the next millennium.

Limiting Factors

But before we get there, the industry is going to have to deal with some very important realities. There are many, but I will just talk about three of them.

The People "Infrastructure"

First, people — or, as I call it, the infrastructure of the semiconductor business on a worldwide basis.

Technical education, not only in the United States but around the world, is at a crisis; in the U.S., probably worse than in all other advanced regions. Something must be done. Nowhere in the world are we graduating enough technical talent at the college level — and, probably even worse, the K-12 education in math and science is probably the worst it has ever been.

I believe that, as you look ahead to the year 2000, this will probably be as much of a limiting factor as the other two that I will discuss.

I will leave you with a question, unfortunately not a solution: What are you as an individual and what are you as leaders of an industry doing about this problem?

I believe that government and industry have to come together and begin to attack and solve this problem, or this industry will not be able to grow. This will be the major limiting factor of the year 2000.

Technology Wall

The second reality is what I have described as the "technology wall." As I see it, the second major trap as we move into the next decade will be continuing to push the envelope, by forcing dimensions down to the sub-micron level and getting closer to the silicon level. I do not believe that this technology is extendable forever, any more than germanium was.

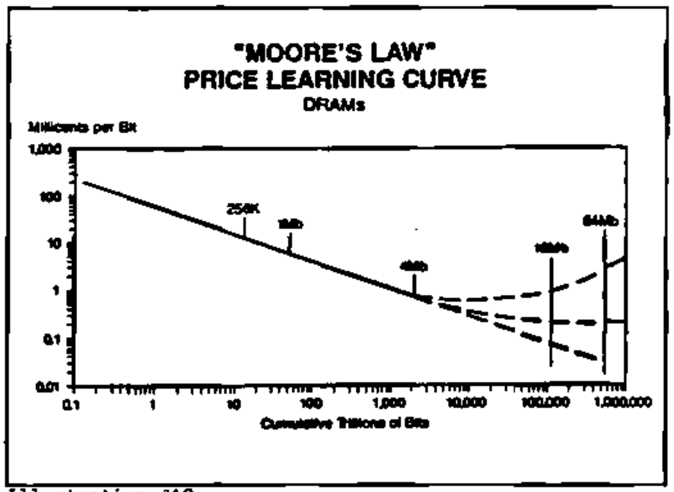


Illustration #18

Manny Fernandez

The reality is that new technologies will come about over the next 10 or 20 years to replace the technology that we love so much — whether this is chemical semiconductors, neuro-optical, or even self-generating transistor cells. I believe that there has to be a change.

Moore's Law is at risk, if nothing else. You cannot continue to push this without understanding that the cost and the time of design will be affected if new technologies do not come about.

Capital Formation

Last, and probably one that is closer to all of our hearts, the problem of capital formation for the semiconductor industry. I believe, for the first time, that this is no longer just a U.S. problem. As we look ahead to the year 2000, this is a region-independent problem.

Forget that in the late 1970s we were building wafer fabs for $2 million or $3 million; that has been overstated. And, also overstated, forget that the new wafer fabs being put into place today to produce 16 Mb DRAMs cost $400 million to $700 million. The reality is, if you extend the present technology and the present methodology ahead into the year 2000, and as we try to put the wafer fabrication into place in the year 2000 to produce the 1 Gb DRAM in the year 2003 or 2004, fabs will cost $2 billion to $2.5 billion. The question is very complex.

• First, not every Tom, Dick and Harry has $2 billion laying around to put in a new fab.

• Second, these investments will have to continue to take place whether it is a good or a bad environment in the financial world. It is going to be very tough in the year 2000 to explain to the financial analysts — whether in the Wall Street, Tokyo or Taiwan markets — that you are making a $2 billion investment in a market that is going to be down 10% for that year. I believe that this change will be necessary and something we are all going to have to come to grips with.

Industry Alliances & Partnerships

Cooperation will be the key factor. I believe, as we look ahead, many new forms of partnerships will have to take place, not only government and industry working together — and again remember, this is not only the U.S., this is everywhere in the world — but also, manufacturers and customers working hand in hand.

I perceive that common R&D will be a fact of life by that time. We will need common factories and significantly more vertical integration for the large companies to survive. The large, multibillion-dollar companies will have to integrate capital-intensive with non-capital-intensive businesses to be able to generate sufficient cash to move on as independent multibillion-dollar corporations. There is no question, I think we have to realize that is a reality of the present.

On the other hand, I am really encouraged that the small companies will continue to find niches to be able to stay away from troubled waters.

Summary

In summary, my prediction is that the pure play of a huge, single semiconductor company — that is, a multibillion-dollar company — looks very doubtful. I think that the squeeze is on the mid-sized, broad supplier, and that those will be extinct kinds of corporations. But, for the small, well-niched companies, I think that there is tremendous potential over the next 10 to 20 years.

In conclusion, the industry structure will change, and will change dramatically.

When we take a look at that satellite photograph in the year 2000, from that vantage point we will again look the same — it will have grown 15.8% per year — but when we come down to earth and look at the action on the ground, we will see that the industry has changed dramatically and it will be a very different industry than we have today, with a tremendous number of successes and many companies doing incredibly well.

Some of those are the companies that David will introduce in the next panel. I think some of those companies have a tremendous future.

With that, thank you very much. Have a great conference. We will see you over the next couple of days.

DIFFERING CORPORATE STRATEGIES: PURE PLAY SEMICONDUCTOR SUPPLIER

T.J. Rodgers

President and Chief Executive Officer
Cypress Semiconductor Corporation

MR. ANGEL: How do you run a company? What are the strategies that will get us through the 1990s? This morning we have a bit of an enigma. We have three individuals from three different companies with three divergent strategies — and the catch is they are all doing well. We are going to hear from each.

After the talks, we will ask the speakers to come back up for a panel and Q&A. If we can get all three of them up here at one time, maybe we can catch them in some controversy.

A long time ago, in a company whose name doesn't even exist anymore, a group of very bright, capable engineers and scientists were perfecting a new idea called VMOS. The technology was perfected, but commercially it was not successful.

I read somewhere that failure is the highway to success, inasmuch as every discovery of what is false leads one to earnestly seek what is truth.

I worked at that company, along with our first speaker, as did some others in this room. Dr. Rodgers left that company, went to a second company for almost five years where he honed his skills in technology and management; and then, in the middle 1980s, founded Cypress Semiconductor Corporation. Growing from $17 million in 1985 to just a million short of $200 million last year, Cypress has been often referred to as one of the examples of what is right about the American semiconductor industry. But they did it the hard way — they did it with great profits. In 1990, a flat year, they continue to do well. Thurman is a timid soul, not one to readily suggest his opinion on the rest of the industry, but we have coaxed him to come down here anyway and give us his views. Should you wish some follow-up, his most recent article in the *Harvard Business Review*, "No Excuses Management" is great reading. T.J., old friend, it's good to see you.

DR. RODGERS: That nameless company is AMI. If you ever wanted a lesson in humility, that was it. I used to drive by the AMI plant every now and then, remember having worked there, having worked hours every bit as hard as the hours I work at Cypress right now. About three years ago I drove by the old homestead — literally, on Homestead Road. I drove by what used to be Fab 3 and Fab 4, and it was ploughed into a field full of grass. In AMI's case it was more economical to go back to fruit orchards in the Silicon Valley than to make semiconductors.

That is a lesson about running scared that I have never forgotten. It is an important lesson that I think our industry has yet to learn.

Is the Sky Falling?

Having heard our obituary from the last speaker, it is difficult to discuss how a pure play semiconductor company can survive. But I guess I'm a throwback, so I'll give it a chance.

I don't like going to Washington to see if my appropriation came through. I don't like complaining about the Japanese as though they were the root cause of problems that I have in my company — and I do have some. I hate subsidies, like SEMATECH. I like fair fights on a level field.

Now, can we survive? After all, the sky is falling. All you have to do is look at the statistics. Take the SIA statistics for 1982 and 1989. In 1982, the American semiconductor industry held 51% of the market, the Japanese 35%. In 1989, the numbers had reversed, 51% for the Japanese, 35% for the Americans — 16 points up in 1982, 16 points down in 1989, 32 points of relative change in only seven years. The sky has fallen.

Sandy Kane, the president of the ill-fated U.S. Memories venture, tells us that it takes $1 billion to build a fab. How are we going to do that? Who will have the money?

Gordon Moore has told us it takes $200-$400 million to get into the microprocessor business. How many companies will be able to roll the dice for a quarter-billion dollars to find out if their architecture makes it in somebody's computer company?

Yesterday's News — The 1980s

Now, the sky *has* fallen a little bit. Let's go back to about 1980 and consider two hypothetical semiconductor companies, both with $200 million in sales, one Japanese and one American. Suppose the Japanese company had a single $100-million fab to support its $200-million business. Suppose further that the fab's yield was 75%, meaning for every wafer coming out of the fab, 75% of the chips on that wafer were good, 25% bad.

In the United States, in 1980, our $100-million wafer fabs had 25% yield — trust me, I was there. Twenty-five percent yield meant that instead of needing one fab to support its business, our hypothetical $200-million American semiconductor company needed three fabs.

Thus, we had two $200-million companies, one needing $100 million, at an interest rate of 3%, to support one fab; the other needing $300 million, at an interest rate of 9%, to support three fabs. The American company, needed three times more money, borrowed at three times the interest rate. The American company suffered nine times higher cost of capital. That recipe for disaster is what happened to the American semiconductor industry in the period of 1975 to 1985. If I could give one example of why we lost semiconductor market share to the Japanese, that would be it.

But you have to remember that the 1980s' story is yesterday's news. The industry is no longer the same, and we can no longer use decade-old models for what we must do to go forward.

A Different Perspective on Statistics

If you take a more careful look, the sky isn't falling nearly as quickly as the subsidy lobbyists would have you believe. (Of course, the faster the sky falls, the harder Congress gets prodded to give out money.)

For example, if you take those same SIA statistics and look at them a different way, you get a totally different picture.

One statistic I omitted is that in our 32-point semiconductor market share loss to the Japanese, the yen/dollar ratio used was 248:1 for 1982 and 139:1 for 1989. In 1982, the Japanese drove up the yen/dollar to 248:1 to make their products artificially cheap to gain market share. In 1989, we drove the yen/dollar down to 139:1 to gain market share. If you remove the currency exchange rate observation from the SIA statistic by using *any* constant yen/dollar exchange rate — for example, the worst case 139:1 figure — you would conclude that 27 of those 32 points of our relative market decline were due to the exchange rate! How do you think the Japanese banks got so big overnight — by boatloads of gold or by inflating currency exchange rates?

Worldwide Competitiveness Quiz

I often give a quiz at talks like this. Some of you have probably heard it before so I won't go through the formality of giving the quiz, but let me give you the contents of a quiz which almost everybody flunks.

First, which foreign country owns the most American assets? The urge is to jump on Japan, owners of the Pebble Beach golf course and the Rockefeller Center. But the fact is the British own twice the American assets as do the Japanese. We always complain about the Japanese taking over this or that property, yet there was not even a whimper when the Mobil Oil signs came down at all the gas stations on the West Coast and the British Petroleum signs went up.

From which country do we import the most? Everybody lunges, "That one has to be the Japanese." But the fact is we import more from the Canadians than we do from the Japanese.

Which country has the largest economy? Half the people get this one wrong. I think it is fairly obvious. The fact is the United States economy is 2.5 times larger than the Japanese economy. If you take the data from the Hoover Institution's Dr. Thomas Moore, you would conclude the Japanese economy will take 189 years to surpass ours — not exactly the kind of number that requires panic action.

Which country has the most engineers? We all know we have more lawyers and doctors and the Japanese have more engineers. Wrong again. The correct answer is the United States. On a per capita basis, we have fewer engineers than the Japanese, but on an absolute basis, we have twice as many engineers. I hope one of the biggest values of the Peace Dividend will be not what we save in the defense budget, but the fact that we liberate some of those very brilliant engineers to start working on commercial and salable products, rather than products we bury in the ground and hope we never have to use.

Which country has the best balance of trade? "That's got to be Japan." Wrong again. Germany, which has an economy like ours, relying on many small companies, not mega-companies and not MITIs, has a better balance of trade than Japan.

Which country is most productive? "Aha! He's finally thrown one down the center slow so I can knock it out of the park." Wrong again. The most productive country in the world is the United States, with estimated productivity 30% higher than that of Japan.

So, as we are listening to "the sky is falling" rhetoric we should remember that we have the best and strongest economy in the world and what we need to do is guide it in the right direction, not panic into stopgap measures.

Sure, we have lost ground in SRAMs. Intel invented the SRAM and now, in effect, it is not part of their own business. National Semiconductor just exited SRAMs, and Advanced Micro Devices has just set a record by leaving the SRAM business for the third time in the last five years.

But those failures don't mean that only the Japanese are left. If you look at last year's statistics, the largest SRAM company in the U.S. was our arch rival, Integrated Device Technology; we were second, both of us with more than $100 million in business; and Micron Technology, closer on our tails than we would like, was third. Three *entrepreneurial companies* holding the fort against the Japanese attack in SRAMs. Where would we be without our entrepreneurial companies?

MITI — The Invincible Force?

We keep hearing about the invincible force, MITI. Ask yourself, "Where was MITI most effective?" DRAMs would be the answer. "What company was the most successful in DRAMs?" Toshiba. "At what density level did Toshiba take over?" The megabit.

You can talk to the program manager who did the megabit program at Toshiba under the aegis of MITI; he is here in the U.S. today. His name is Dr. Yoshio Nishi. He now runs the integrated circuit effort at Hewlett-Packard. Dr. Nishi came to Cypress to replay an IEEE seminar he presented on what MITI meant to his effort at Toshiba — and what it didn't mean. Dr. Nishi says that technical secrets were never exchanged in MITI, that the intense competitors who cohabited at MITI would only deal in the most global generalizations, and that very little co-developed technology propagated to Japanese companies. In fact, all MITI really did to make things better in Japan was to extract a public commitment from all the companies that they would fund their MITI projects regardless of the health of the economy. Thus, MITI, in essence, forced the long-term thinking that we have ascribed to the Japanese forever. Dr. Nishi claims that was MITI's greatest accomplishment in the vaunted Japanese DRAM attack.

By the way, while we are talking about the "unstoppable force" MITI, let's not forget their screw-ups. The DRAM success is now a decade old, and continuing to talk about it is getting old, too. How about TRON? When is the last time you had to worry about TRON?

And how about the fifth generation computer? That was the project that was so scary, because it was going to allow the Japanese to take over the supercomputer industry. It caused us to "have" to form the MCC in order to compete with them on a giant vs. giant basis. The Japanese have even admitted that their fifth generation computer was an ordinary failure, surpassed by commercially available equipment.

The final statement in most of the "whiner" speeches is, "The United States is going to be third. We have MITI in Japan; we have JESSI in Europe; and we've got nothing, so we better get with it." Of course, we can all look at JESSI's strategy for SRAMs with Philips in Europe and see that has also been a great success: Philips recently left the SRAM business.

Let's not just rush headlong into government subsidies and think that will make things better. It will not.

Industry Consolidation Myth

In the recent AMD quarterly report, after excusing poor earnings, Jerry Sanders blamed them on the investments required to become part of the "oligopoly that will emerge in the semiconductor industry in the future" — to become one of the Big Three (if you will) of the semiconductor industry. I think if you asked Ford, General Motors and Chrysler, "Are oligopolies competitive and can they hold the line against foreign competition?", they would (or should) answer, "No."

Prior to this talk, I was in the Dataquest library looking over my notes. I came across a book entitled *The Decade of Semiconductor Start-Ups*. On the bottom it says in big red letters, "Library

Copy. Do not remove!" As someone who never liked rules, I had to bring the book out here to share some data with you. I have to admit it's a pretty good book.

With all this consolidation Jerry Sanders talks about, the facts ought to square with his religion. If we are consolidating toward the "Big Three," then we ought to look at a graph that shows we had 100 semiconductor companies, then 25, then 15, and now 12.

However, if you look on page 3 of the book, you see a graph that shows that 114 semiconductor companies started between 1981 and 1985. During that period, Cypress, IDT, Xylinx, Altera, Performance, Chips and Technologies and LSI Logic were founded. Today, they are all alive, healthy and an important part of our industry. So much for the consolidation pipe dream.

After reviewing the 1981-1985 data, I took a look at the 1960-1980 data for the prior two decades. Guess what? Fewer companies were started in those entire two decades — when Intel, AMD and National were founded — than in the five-year period following.

We are not consolidating. There are more and more semiconductor companies every year — our industry is *diversifying*.

Dataquest laid it out for us on page 11: "The third wave of start-ups share many common characteristics. In general, the more successful companies tend to be as follows:

• Highly focused, flexible, able to move quickly out of stagnant markets into high-growth markets;

• Willing to develop new markets and educate users about their products and design services;

• Positioned at the leading edge because of their advanced process technology and proprietary CAD software;

• Resourceful in attracting venture capital from U.S. and foreign venture capitalists;

• Aggressive in building strategic alliances to develop new applications jointly and secure wafer fab capacity."

They are correct. As a matter of fact, what I just read to you wiped out the middle third of my talk.

Competitive Success

If you take a look at Michael Porter's new book, *The Competitiveness of Nations*, he talks about countries which are successful in given industries, not because of capital, labor resource, cheap coal or oil, but because those countries have many companies competing in a given area. An example of this thesis is Italy, a dominant force in the shoe industry, or Japan in the car industry. The *last* thing we need in this country is an uncompetitive oligopoly in the semiconductor industry.

Tom Peters told us, when he testified against U.S. Memories in Congress, that we shouldn't follow the MITI model, which does not square with reality in Japan, because we will land where the Japanese were, just as they scramble to become more entrepreneurial, knowing that is the way of the future.

George Gilder, in his landmark book, *Microcosm*, which I reviewed in the *Harvard Business Review*, tells us that smaller is better. He says that more powerful computers on the desktop of the future will mean that amazing things will continue to come from small companies housed in garages, as were Hewlett and Packard in the original (literal) garage on Addison Street in Palo Alto in 1939.

Whose Responsibility Is It?

If you look at the 9X statistic I gave you earlier, you will see that it has changed as well. In the early 1980s, the yield used to be 75% in Japan and 25% in America, but now our yields at Cypress are up to 75%. The Japanese are now at 90% or better; they are still ahead of us. But what used to be a 75%-to-25% gap (200%) is now a 90%-to-75% gap (20%), and that is significant progress. And the cost of capital that used to be a 3:1 disadvantage is now closing and is nearly 1:1. Thus, the net 9X capital/productivity disadvantage I discussed earlier is now down to about 2X. The huge Japanese capital formation advantage is collapsing. I believe that after you factor in these elements, and remove the yen/dollar exchange rate from the statistics, the U.S. semiconductor industry has held constant market share from 1985 through 1989.

Another reason I don't like our single-minded focus on relatively unmovable objects like our government and foreign competitors' structural advantage is that it takes away individual responsibility. What really bothers me about our industry right now is that we have become a bunch of whiners. You can work three days a week, lead your company into deep trouble, and declare it's not your fault, it's the Japanese. You can lay off your research and development and cause your average selling price to drop below a dollar, but it's not your fault; it's the fault of your Congressman in Washington who didn't get your subsidy through. You can declare your obsolete computer chip architecture to be as good as your competitors' new RISC architectures because you have to protect your cash cow, and then whine later that you haven't gotten the appropriate protection from the government.

I think, if we need to assign fault for the falling market share of the United States semiconductor industry, we ought to be looking in the mirror, and that includes me.

Welfare doesn't work. In 1964, I heard Lyndon Johnson talk about spending a few hundred million dollars to wipe out hunger in the United States. After two-and-one-half decades of spending billions, there are more hungry people in the United States than there ever were. The government "welfare" program for the U.S. automobile industry — a forced quota on Japanese cars — has made the Japanese stronger and us weaker. Welfare doesn't work.

We are not going to get bailed out by the government. It is a moot point anyway. We won't double on SEMATECH funding because our government can't even afford to keep the Liberty Bell museum open!

I think entrepreneurs continue to represent a major component of American competitiveness. Let me give three examples — each a Cypress subsidiary start-up company.

Cypress Fab 2 — $38 Million Produces $150 Million

First, the billion-dollar fab. Cypress is now, on an annualized rate, about a quarter-billion-dollar company. You may or may not believe it, but the *total investment* in both of our wafer fabs, Fab 1 in San Jose and Fab 2 in Texas, is only $78 million, $35 million in Fab 1 and $38 million in Fab 2. Those fabs do all of our research and development and all of our production. Furthermore, Fab 2 is running at about 50% capacity and is capable of $150 million more in revenue with modest investments. I don't know how the $400-$700 million fab myth came about, but if any of you need to build one I will guarantee to build it for you for $200 million, as long as I can keep half of the difference between your budget and whatever I actually spend on it.

Ross Technology — The David of Microprocessors

Let me tell you about a tiny company called Ross Technology, a Cypress subsidiary. We thought Cypress was *too big* to get into the microprocessor business. We had 1,500 people, at $200 million in sales, and had suffered an alarming outbreak of bureaucracy throughout the company. To solve that problem, we funded Ross Technology's President, Roger Ross, an all-star microprocessor guru who architected Motorola's 88000 RISC chip set.

Ross Technology — for a total investment of $7 million, not the $200-$400 million you hear about elsewhere — brought to market our SPARC chip set which provides the top-of-the-line Sun computer server, and the highest performance computer server available from any workstation company, the Matsushita-Solbourne 5E/908, a 115-Specmark computer. Ross needed only 36 employees to get the product to market.

Intel may claim that it takes buildings full of engineers and $200-$400 million to get into the microprocessor business, but we surely didn't need it, nor could we have afforded it.

Guess what, I'm not even concerned about the Intel 80486. What I'm worried about is that we did our design on old Sun workstations to build chips for the new Sun workstations. We've now got the new Suns as our workstations to build the next generation Suns. Our competitors may start with more powerful computers than we did. We're worried about the start-ups coming up behind us that will provide a chip set for $3.5 million with 15 people. What are we going to do about them, other than run harder?

A final point on Ross Technology. Toshiba decided to make a SPARC laptop machine. They had two choices for vendors, Ross Technology and Fujitsu, both of whom make SPARC chip sets. Which did Toshiba pick to design into their laptop? The answer is, of course, Ross. That is a fact. We won that design.

That win demonstrates two things: (1) that the Japanese are making a serious effort to buy our products, although they are not given a lot of credit for it right now; and (2) that small, agile companies can do things that big companies cannot, and that list includes Japanese, not just American companies.

Aspen Semiconductor — 3 ns RAMs

The final example is another Cypress start-up, Aspen Semiconductor Corporation. They just had a party celebrating their first million-dollar quarter. They are one of only two companies in the world from whom you can buy a 3 ns 4-K SRAM. Aspen has big customers, like Unisys and AT&T, buying those SRAMs. The only company we have to worry about taking that business away from us is Synergy, another company you also have never heard of, another start-up, and the only other company shipping 3 ns SRAMs.

Cooperative Alliances

Cooperation between companies must be in our country's future. Cooperation is inherent in Japan, where they have vertical organizations. The most important aspect of vertical integration isn't the capital formation, but cooperation. Instead of the classic American war between purchasers and vendors, we must learn to cooperate.

I think a good example of cooperation is Sun Microsystems and Cypress. Cypress never could have brought the SPARC RISC microprocessor chip set to the market for $7 million without the cooperation of Sun. That kind of cooperation has big value. America has to find more of it and less of Intel v. AMD or TI v. world lawsuits. Unfortunately, our arch rival, IDT, has found that same cooperation with MIPS; I wish they had not discovered that weapon of cooperation.

Another alliance: Altera and Cypress. Altera, a nominal competitor of ours, was one of those fabless semiconductor companies you will hear Gordy Campbell talk about later. However, Altera has in its products an important technology value-added component. Technology counts for them. Last year, when it was time for Altera to invest in a fab, we teamed up. They bought 9% of our Fab 2 in Round Rock, Texas. Our fab makes them more competitive and, at the same time, they are transferring their technologies into our fab in return for wafers at cost.

Adversarial/Litigious Examples

Here are some examples of adversarial companies that do not cooperate. Let's start with Intel and Advanced Micro Devices. Their soap opera makes for good reading in the *San Jose Mercury News*.

Did you read about the last one? There are two guys both named Webb. A package of documents was sent to AMD's Webb, but Intel's Webb got it. Intel read it and found that AMD was going to use the number "386" for their new clone. Intel sued AMD immediately. Of course, AMD had to counter-sue Intel because, after all, they obviously stole that package containing proprietary information. That is the latest little skirmish in the recent decade of Intel/AMD "cooperation." I'm sure that the Japanese were doing something more productive during that same decade.

Moving past even Intel and AMD, into first place for the useless litigation award is Texas Instruments, which is suing virtually everybody in the semiconductor industry and, for the first time ever, its own customers! TI's lawyers used to talk about making money for TI overall when the operations were losing money. This quarter, if analysts are right, TI will lose money despite its legal "protection" racket.

Can Pure Players Survive?

Can pure play semiconductor companies survive? I don't think that is the real question. I think the question is can the dinosaurs survive? It is getting cold out there. They had better get small, get fast and grow hair real quick if they want to stay around — and a bigger brain wouldn't hurt either. Congress can pass the Ice Age Prevention Act of 1990, but — like SEMATECH — it won't do any good for those unable to compete because they are distracted by so many unproductive activities.

As I look to the future, it is the small companies that will bring to market what we need. The entrepreneurs will bring on the new technologies, the new architectures, the new products. They will do it with their characteristic capital efficiency, which is extremely important in an era of tight capital. As tight capital becomes a global problem, start-ups will be more well positioned than ever to make productive use of scarce capital.

We won't just survive. Small companies and pure play entrepreneurial semiconductor companies are our hope for the future.

DIFFERING CORPORATE STRATEGIES: THE ROLE OF THE BUILDING BLOCK SUPPLIER

Frank C. Gill

Senior Vice President & President, Systems Group
Intel Corporation

MR. ANGEL: What more can be said about Intel? It just keeps rolling on and getting stronger. It is a decidedly different strategy from the first one which we heard this morning.

Frank Gill is Senior Vice President of Intel and President of Intel Systems Group. He joined Intel in 1975 and has successively worked his way up. Prior to that, he held a wide variety of positions at Signetics. We are pleased to have him here today. We look forward to his comments.

MR. GILL: I am pleased to be here to address this group and make a few responses to T.J.'s comments earlier this morning.

The folks at Dataquest initially invited me to address the subject of the vertically integrated semiconductor company. That subject conjured up in my mind the image of a computer company that manufactured their own chips to put into their own proprietary systems and into their own proprietary end product. To me, that is the dinosaur that T.J. was talking about, not the vibrant building block supplier that is intensely competitive, manufacturing the subsystems or modules required to build the new computer industry. I countered and said, "Why don't I come and speak about the role of the building block supplier?" Dataquest graciously accepted. That is what got me here today.

Building Blocks

What do I mean by building blocks? First, let me describe it in the context of Intel's product portfolio, and then in the broader sense.

From the Intel perspective, many of you are well familiar with our product development machine that keeps spitting out ever increasingly complex devices. In doing so, the requirements are to look forward to the total system and integrate more and more of the system on single chips.

"FROM CHIPS TO BOXES"

Controllers

Memory Chips

Microprocessors

Subsystems

PC Platforms

Illustration #1

Microcontrollers is an area where this first occurred, with the CPU unit, program memory, RAM, I/O, all on a single chip — an early building block.

Even memory manufacturers today are building specialty devices other than simply bigger, faster, cheaper blocks of memory. Microprocessors, associated logic, modules, and even subsystems — today, customers are increasingly coming to view these as building blocks.

From the broader context of the industry, I would also argue that things like disk drives, graphic subsystems, advanced ASIC chips and design tools are also building blocks enabling today's standard-based computer industry.

Product Planning

This trend towards building blocks is simply a different way of looking at the product planning problem. Rather than looking at the product planning problem from the perspective of a classic semiconductor company, where one is looking for general-purpose devices (perhaps in the case of memories that paradigm is still true) — or at "How can I develop some standard-purpose device?" — one looks at the end system and takes apart that system to see how that can be broken up into building blocks to which they can add value and then manufacture for the OEM in question.

This trend is being driven by four major forces:

- The underlying technology is driving this trend of building blocks.
- Entrepreneurs and others see market opportunities and rapidly exploit them.
- The move to standards.
- The overall cost of technology development.

Technology Treadmill

Let me talk about the technology treadmill first. This treadmill can most easily be demonstrated by Moore's Law. Since Moore's Law has been talked about a couple of times already today, and certainly it is well known in this industry, I will not belabor the point.

If one looks at where we are today, Intel has introduced a couple of microprocessors that have in excess of a million logic transistors on a single chip. There are no technological barriers. We see no problems that will prohibit this trend from continuing in the future. As we look forward to the end of the decade, we readily see million-transistor logic chips.

These huge transistor budgets (even at a million transistors today) represent a whole new problem for the chip designer — and, I might add, to the marketer. Developing million-transistor chips into markets that represent low volume is an economically inviable situation. Today's chip designers and marketers must be able to address large volume markets into which to sell these chips — therefore, the need for building blocks.

The Incredible Shrinking Machine

The impact of these advanced chips is something I call the incredible shrinking machine. During the mid-1980s, building a reasonably high-performing desktop computer required about 170 logic chips as well as memory. Today, in 1990, people are routinely building even higher performing desktop computers with less than a dozen logic chips and a handful of memory chips. This is only possible by building subsystems into silicon.

I might add, other enabling technologies are seeing and experiencing a similar treadmill. I haven't actually plotted it, but I think if one were to look at hard disk drives, for example, one would see that they are making similar progress in getting faster, cheaper and smaller in this same time period.

I think anybody could easily concur with my argument that, in fact, just the thrusting forward of the packing density advanced chips drives one into the subsystem business, or subsystem on a chip space.

How does one then move forward and say the next logical step is to integrate those silicon chips onto modules, PC boards, or even subsystems or complete systems, for sales to this same customer base?

The answer is really quite simple: By listening to the market. In fact, many entrepreneurs did exactly that and led us to where we are today.

I would like to talk next about some of the entrepreneurs that saw the world changing and did something about it — they approached the world from a building block supplier viewpoint rather than the viewpoint of a classic semiconductor supplier.

Intel's Multibus

First, let me take the example of Intel Corporation. In the mid to late 1970s, we developed, invented and produced a product called Multibus. At that point in time we were probably onto something quite revolutionary, even though I am sure we didn't recognize it at that time.

We did something extraordinary: We created this bus at a great expense and, rather than thinking about it in proprietary terms, we put it in the public domain and went out and encouraged third parties to also build products to this standard. We were on the way toward establishing a more standards-based computer industry.

In preparing for this talk, I looked back at some of the marketing materials of the time and tried to figure out what was in our head and what we were really thinking about. What we were saying then was that we had microprocessor chips, things like the powerful 8080, and we were trying to find a way to speed the flow of that microprocessor technology to our OEM customers. That's what we thought we were doing.

As somebody who was very involved in selling those products at that time in history, that is not what we were doing at all. In fact, we were creating entirely new markets; we were selling into industrial and many other electronic firms that couldn't afford the cost of a hardware engineering infrastructure to go off and develop these type of products. Instead, they had two choices: either they would buy a complete minicomputer; or, simply, the product idea or the project idea they had did not exist or it just simply was not practical to implement.

Multibus Product Line

In essence, we had the genesis of what I would call the semiconductor building block supplier with the Multibus product line.

This business grew and prospered over time, but we didn't quite have it. In fact, we set this business up as the Multibus Business Unit. By charging them to build and facilitate other multibus manufacturers, we still missed the point. What they should have done was listen to the marketplace and build what the market wanted. Certainly, the market wanted lots of multibus products, but it also wanted other things, as we learned.

Western Digital

That would lead me to another early building block entrepreneur, Western Digital. In the early 1980s, Intel developed a very capable floppy disk controller chip. Our main competition was a small company called Western Digital Corporation. Now, take this in the light of Intel having this multibus business. We routinely had a greater than $100 million business selling microprocessors on PC boards, yet we still had the mindset that the rest of Intel was a chip company building standard products.

Standard products typically are general purpose; or, occasionally, one would define an application-specific standard product, like a floppy disk controller, something that is going to be sold into a volume market, and create that chip and sell it. So, we developed this wonderful floppy disk controller chip.

Western Digital, one of our competitors, realized that the customers really had another problem: they were busy trying to build computer systems. They put that chip on a module and sold the customers a disk controller card. Consequently, they got customers to market earlier; they got many design wins; and they took a commanding position in that marketplace. I am sad to report they bloodied our nose quite well in that marketplace.

Chips & Technologies

Another early pioneer was Chips & Technologies. Again, the Intel microprocessor was routinely on the motherboard used by desktop computer manufacturers at that time, as well as many other general-purpose peripheral devices around it. Gordy Campbell is going to speak to you later this morning and he can probably tell you the history of his company better than I.

I think he looked at the problem a little differently. While we were off developing a very high-performance general-purpose graphics coprocessor, Gordy said, "What the market is buying is EGA. Let's integrate that EGA functionality on a single chip." Further, he looked at the rest of the motherboard and said, "I can take several of these Intel plus Motorola plus other people's chips, glom them all together into a single silicon building block and sell them to the customers for greater value" — a semiconductor building block.

He also did something else very clever; he created a whole new way of marketing these products. He took the design expertise or the system expertise from his planning effort and actually designed motherboards. He took those motherboard designs and handed them over to customers — including his chip set, manufacturing film, schematics, and so on and so forth — as a way to enable those customers to go to market. Again, he was very clever in his approach.

This was really some of the early movement toward this building block concept.

Impact of Personal Computers

Certainly, the PC was *the* great event that enabled a lot of this to happen. It was certainly the event that drove the industry toward more of a standard building block approach to things.

If we think back to when the first PC came out — or even, I would argue, many desktop and multiprocessor systems today — you will find that they are built out of largely off-the-shelf standard components.

The significant thing about the PC was that, for the first time, we had an open computer system built out of things that you could buy off the shelf. The consequence for our industry — and certainly for the computer industry — was really quite significant and changed the makeup of this industry forever.

To illustrate the power and impact of this change, I could pick any of the computer companies of the early 1980 vintage and compare them to Compaq. That is the prototype of the new computer age company, which in fact acts much more like a system integrator than an old-time computer company. As a system integrator, I mean they are buying off-the-shelf standard operating systems, standard chips, standard ASIC tools, standard disk drives, even standard keyboards and so forth, and putting these together in a very compelling product line.

Let's just contrast them with Data General. You could pick Data General, Unisys, or even a VAX, or any of the computer companies of that day and age. What were they doing? They were building custom hardware. In fact, I believe, in Data General's case, they were off on a major silicon development to develop custom semiconductor devices to feed that hardware design. In addition, they designed and supported proprietary system software and were bringing all these products to market through a very large direct sales and service organization.

Contrast Compaq and other companies of their generation — Apple, Sun Microsystems, pick the company of your choice. What were they doing? Off-the-shelf components running off-the-shelf operating systems via DOS, Windows, or some flavor of UNIX — industry standard software.

I agree with Manny's comments this morning that software is lagging well behind the hardware development, and that is a key enabling technology we need to spur even greater growth. But the fact is, in this new open environment, we have many more creative, energetic people working on the problem set that will drive this software revolution at a much faster pace than in the old proprietary scenario.

Lastly, they go to market through indirect channels, which is generally more cost-efficient.

Standards-Based Computer Industry

With the advent of what we at Intel call the "new computing industry" — meaning in normal English the standards-based computer industry — the move was on, irreversible. The dynamics and economics were just overwhelming.

The consequences of this change were really quite catastrophic to those that got stuck in the old computing industry paradigm.

I often believe that one of the major advantages that the new computer industry success stories had, like Apple or Compaq, for example, was they had no baggage; they had no huge installed sales and service organization; they had no proprietary installed base to support and worry about.

But the fact is, the economics were so compelling on these new standard-based machines that the end customers were voting with their purchase orders, and they were voting in favor of the new computer industry.

While the market was pulling everybody to these standard-based machines, the cost of technology development was increasing in an exponential fashion.

Technology Cost

Let's look at some cost trends for building a wafer fab. We have heard a few comments this morning about what it really costs to build a wafer fab. Conventional wisdom has it that for a sub-micron 6" facility, capital requirements are greater than half-a-billion dollars — but, after T.J.'s comments this morning, I am going to go out and buy Cypress stock. I am really not concerned that they will ever fail; and, if they ever did get into a business environment that was a little more difficult for them, certainly they could make a bloody fortune consulting to the rest of us on how to build wafer fabs much more inexpensively.

I would also argue that this cost of technology development was not just going on in semiconductor devices. I think the cost of developing many of the underlying technologies was really quite expensive, and it was increasingly difficult to compete if one had to take on the task of developing and supporting a proprietary operating system.

Frank C. Gill

From our experience at Intel, developing something called RMX, which is a very elegant real-time operating system used with our Multibus line, that development effort cost tens of millions of dollars, as well as the supporting of it was a substantial effort. Again, Multibus II, an advanced high-performance bus, was developed at a cost of tens of millions of dollars.

When these are available as industry standards, it certainly leads to a much more cost-efficient end-use product, and certainly these economics are driving the marketplace today.

Intel's Strategy

I opened my comments this morning by stating that it wasn't Intel's intention to turn itself into a vertically integrated semiconductor company or vertically integrated computer company. Instead, sometime during the 1980s — and I don't know exactly when it dawned on us, but sometime during this business period — it occurred to us that we are not really a chip company, we are not really a system company; we are a building block company, and we should listen to our customers and bring our technology to market as rapidly and as quickly as we can and sell it in a format or level of integration that our customers would like to buy — be that at the chip level, the subsystem level, the module level or a complete system.

Essentially, that is Intel's business strategy. I think it makes a lot of sense.

The New Computing Industry

What I would like to do now is transition a little and talk about the computer companies coming at this problem from the other perspective.

Let me pick one company that appears to be making a successful transition from the old computing paradigm to the new computing industry. In this case I have picked NCR, obviously because they are a great customer of Intel.

About a week ago, NCR introduced a whole new product line based on the Intel 386 architecture. Essentially, this product line spanned everything from the briefcase to the mainframe. By "briefcase," I mean a portable computer, all the way up to machines that have mainframe-level performance. Here is clearly a company that did in fact have an internal semiconductor development, but could see the power and market pull toward standard-based computers.

On the other hand, what do they do with that semiconductor capability? I haven't spoken to them about this, but I think it is a fairly safe assumption that they are not out developing microprocessors to compete with the Intel 386 family. They are probably not developing DRAMs to compete with Toshiba. They may not even be doing 3 nanosecond SRAMs. Instead, I think they are developing functional building blocks that they both consume internally and sell externally on the merchant market. Their SCSI chip set is an example that comes to mind.

I think this model of being a building block supplier is essentially true both for the semiconductor company that owns its core technology and has some size and for the computer company or systems company that has this capability and some scale and size.

The data seems to support that notion. Illustration #2 shows the top 10 semiconductor companies in 1989.

We see here 10 companies. None of them is a pure play or a start-up. The smallest one is $1.7 billion in sales. All of these generally have different businesses. But what is true, and one of the common things about them, is that their

TOP 10 SEMICONDUCTOR COMPANIES - 1989

1. NEC
2. Toshiba
3. Hitachi
4. Motorola
5. Fujitsu
6. Texas Instruments
7. Mitsubishi
8. Intel
9. Matsushita
10. Philips

Illustration #2

semiconductor divisions have to go out and compete hard in the merchant marketplace and compete in a very intensive and aggressive fashion. In addition, their sister divisions that build computers, or central office switches, or whatever the product may be, also generally buy on the merchant market from people in direct competition with their internal chip division.

External Marketing/Internal Use

Basically, the market forces are at work here. The scale and the economics required to be competitive and fund the development efforts on these key building block technologies are so great, one has to sell these building blocks on the external market as well as use them internally.

If one were looking into the future, I would even argue that is true for semiconductors, disk drives, on and on. I think that will be the trend that we will see in years to come.

NEC

Let's take, for example, the largest of all the semiconductor firms selling in the merchant market, NEC. This I clipped out of a magazine last week. It is an advertisement for one of their latest products. I believe this product comes from NEC Home Electronics, but it is really not important which division it comes from.

The point I am trying to make here is that NEC sells a complete computer system in competition with many of you, and in competition to some extent with Intel. But, if you were to tell the whole story, many of you (and us) view NEC as a valued DRAM supplier, a valued EPROM supplier, and in fact, this same division sells multisynch monitors to many of the top computer companies in the world. Again, the need to have sufficient scale and competition in the very rigorous merchant marketplace leads to this kind of a scenario.

There is one other interesting footnote on NEC. As many of you know, we wasted a lot of energy in a lawsuit over a number of years. During this same period, their chip division and our chip division viewed each other as bitter enemies and we fought with a ferociousness that is only found in the semiconductor industry. Also, NEC's Computer Division in recent years has been one of our top five customers and has recently given us vendor choice awards, even viewing us on parity with local Japanese suppliers, which is quite an accomplishment.

I mentioned Western Digital earlier in the presentation. A similar scenario there. The last time I checked with our people in Folsom who make disk controller chips, they didn't think very much of Western Digital. When I went down to Chandler, Arizona, our people who make microcontrollers there view Western Digital as one of their top customers and work very closely with them. My own Systems Group in Oregon sees Western Digital as a valued vendor. Welcome to the new computer industry. Welcome to the age of building block suppliers.

Conclusions

To summarize, what I have tried to propose this morning is that today's computer industry is based on industry standards, standard building block technologies. The cost of development of these technologies is so great that the suppliers of them, by necessity, must go into the merchant market and compete with those participants who are already there.

The consequence will be some companies that look like vertically integrated companies are competing in these core building blocks in a very intense fashion, although their primary business may be, like NEC, computers and communications. Other firms, like Intel, may be doing likewise, even though our primary thrusts are semiconductor devices and building blocks for OEM manufacturers. The net result will be the same.

DIFFERING CORPORATE STRATEGIES: FABLESS SEMICONDUCTOR SUPPLIER

Gordon Campbell

President and Chief Executive Officer
Chips & Technologies

MR. ANGEL: A moment ago I mentioned how sometimes failure can lead to success in this business. Gordon Campbell's business plan for his new company was not exactly received with overwhelming enthusiasm by our venture capital friends on Sand Hill Road in Menlo Park, and the founders had to go out and secure their financing elsewhere.

But then, something very wonderful, almost in a Ferris Bueller sense, happened: they got what probably all of us secretly desire in our heart — revenge. They have been really successful. From a start in 1985, revenues are now in the $300 million range, and they have started what has become a whole new business in the semiconductor industry.

Gordy, we are pleased to have you here to talk to us today.

MR. CAMPBELL: Good morning. It is always interesting to listen to my esteemed companions on these panels because you come up with different perspectives.

I now know that we have passed the era of chip sets and we are now in building blocks. But, actually, I beg to differ again, in that I think we are in a business of supplying solutions. Ultimately, I think, solutions for customer problems will really be what we will all focus on.

Let's look at some of the things that T.J. mentioned. T.J. and I have had differences in philosophy upon occasion, but I think there are some similarities that I could pick out of his talk this morning.

U.S. Competitive Position

I think one of those similarities is that we really do need a strong U.S. position. I think T.J.'s talk about MITI was very instructive. To a certain degree there is value in having independent, entrepreneurial companies, but there is also value in having a cohesive national policy for a country like the U.S. and for a group of industries and companies like the semiconductor industry.

Today, we are primarily represented by the SIA. I think the SIA has done a good job of representing its membership, but the problem really is that membership. If we look at the last decade, with nearly 200 start-up companies, many of which have been very successful, it would be an interesting exercise to see how few of those 200 are SIA members. I don't think it would be very many. If we look at some of the companies that have been very successful in the last five years — Linear Tech (which I believe was a member briefly), Cypress, IDT, Chips — we represent close to $1 billion of our industry, and yet, we still have no voice in how our policy is shaped in Washington.

I do not think that it is really our role to go to Washington to object to ideas put forth to make us competitive. I think our role is to be constructive, and to try to figure out how we can solve the problem of how we, as a country and an industry, can continue to be competitive.

If we look at that issue, itself, you have to ask yourself: Is SIA representing the spirit of the dinosaurs, or is it representing the spirit of the entrepreneurial effort in the United States?

Chips' Perspective

I would like to make some observations about ways we look at our industry.

Chips took a fresh look at our industry in 1985, predicated on a couple of issues. First, that process technology was more or less at parity throughout the world. That led us to the conclusion that, with some exceptions, there was no real advantage for Chips to bear a huge capital penalty to do its own manufacturing.

To Fab or Not to Fab?

Illustration #1 shows some of the pros and cons typically raised on the issue of whether or not to have a fab.

Fabless Companies

Pros	Cons
Technology Flexibility	Higher Unit Cost
Second Sourcing	Economies of Scale
Reduced Fiscal Risk	"Design House" Mentality
Local Content Sourcing	Leading Edge Technologies
Time to Market	Less Control of Process/Production
R&D Focused on Product Dev.	"No Capacity" in Peak Markets
Faster Ramp Production	

CHIPS · Solutions for a Changing World

Illustration #1

The Pros

On the pro side, I think everybody can easily recognize that:

• You have a lot of technology flexibility. As a start-up company, with a total capitalization of less than $3 million, we were able to bring products to market in bipolar, CMOS and BICMOS technologies. We were able to migrate very quickly from 1.5 micron to 1.25 and 1.0 micron. That basically says that the technologies and lithographies are available for the companies that go out and look for them.

• Second sourcing is also a plus for a fabless corporation. Chips & Technologies uses Toshiba, Fujitsu, Yamaha, Oki, Ricoh and Seiko in Japan; TSMC in Taiwan; we are looking at qualifying some of the Korean manufacturers; in the U.S., we use LSI Logic, National Semiconductor and Texas Instruments; and in the European Community, we will use some of those partners who have fabs there, as well as SGS-Thomson.

• It would be difficult to argue that we could not only have a very effective multiple-sourcing activity, but that we could also source in many different marketplaces.

• We have good time to market. We can use different technologies that you may not be able to afford to support as an individual company. We use a fair amount of gate array technology, a fair amount of standard cell, and we do a lot of full-custom design.

• Interestingly enough, if you look at most companies that have their own fabrication assembly facilities, typically they will put two-thirds of their employees in manufacturing. We were able to structure Chips so that two-thirds of our employees were developing new products. Thus, I think Chips has one of the fastest streams of new product development in our industry.

• Last, but not least, the ability to piggyback our partners' efforts in developing new process technology — at virtually no cost — and our ability to ramp their production was an extreme advantage to Chips & Technologies.

The Cons

On the other side, people have argued:

• It costs you more to buy product and you will never be competitive with people that have fabs. I would like to defer that one until later.

• A "design house" mentality is one of the things that people frequently point out. I would say that is basically a positive. Frank Gill's slide showed the trend in PCs, going from several hundred semiconductor components down to a single chip, with the entire system embodied in one chip, some time in the early to mid 1990s. You need a design house mentality to be effective in that kind of market.

• Leading-edge technology and the availability of that process technology is another issue. Chips has done a very good job maintaining its capability of accessing and utilizing leading-edge technologies.

• One argument against the fabless concept has always been: What will you do in a peak time, when there is no capacity and people can't get enough DRAMs? In the last peak, we grew from $140 million to $217 million.

Profitability

Another argument is fabless companies are more profitable [Illustration #2]. The average profitability for companies with wafer fabs is between 5% and 6%. On the other hand, the companies without fabs have averaged well over 10% — approximately twice the profitability of companies with fabs.

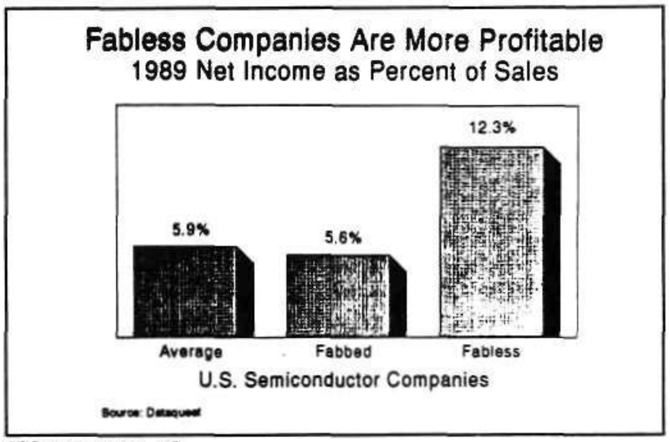


Illustration #2

Productivity

We typically have higher productivity. In terms of sales per employee, the average is $96,000 per employee for a company with a wafer fab. There are many companies with significantly lower averages. Without the efforts of companies like Cypress (with about $200,000 per employee, probably the highest for a company that does its own fabrication), that average would probably be lower.

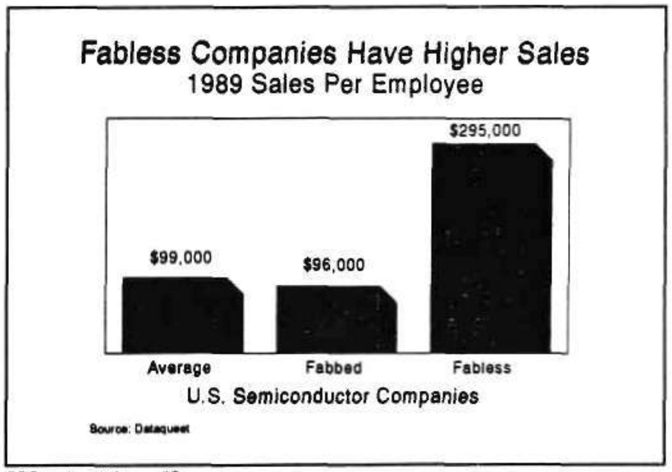


Illustration #3

Chips has been fortunate, in that it has been close to $500,000, so we have been on the high end of the average for the fabless companies.

Risk

Another argument is that there is considerably less risk without a fab. Whether you use the figures that come out of SEMATECH or some of the proposals we have seen of $400-$700 million for a fab, or whether you use T.J.'s numbers — it really doesn't matter — you are talking about a lot of capital intensity to get wafers out the door.

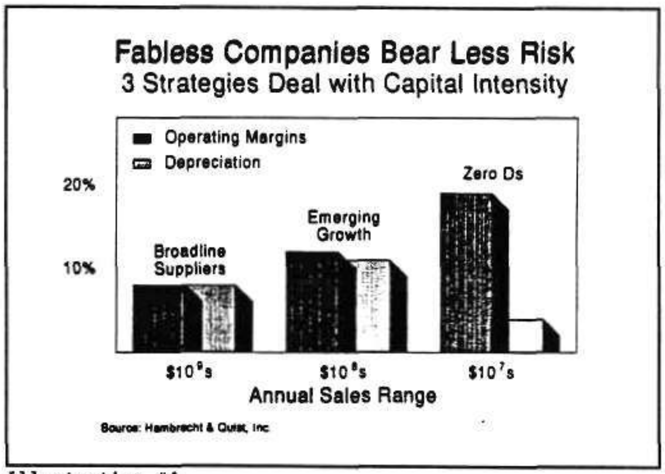


Illustration #4

Interestingly enough, if you look at the impact of depreciation, we are depreciating over a seven-year period something that probably should be depreciated over a much shorter time.

Cost Reduction

Illustration #5 graphically shows one of the ways that we were able to reduce the cost of a product and allow our customers to benefit from that cost reduction.

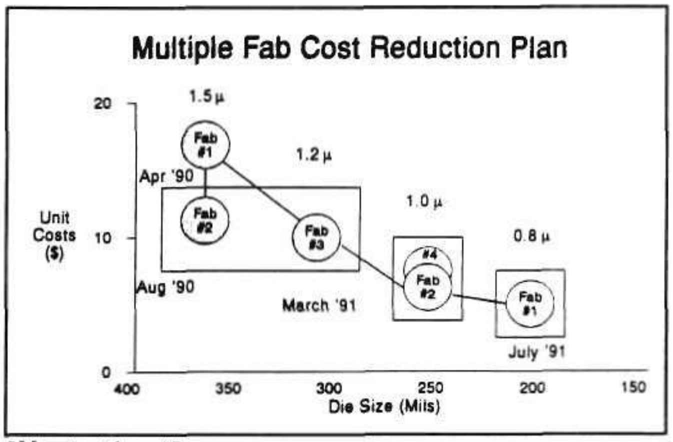


Illustration #5

When we started out with a brand-new product, using 1.5 micron process technology, our cost was close to $20. As we were able to migrate, from gate array, to standard cell, to full-custom, and to smaller lithographies, through the advances in process technology of some of our partners, we were able to ultimately get the cost down to the $5 range. That would be an extremely difficult scenario to manage if you were putting the process technology and equipment together to support a transition from 1.5 micron down to 0.8 micron — and, in the same time frame, you were trying to ramp something from the tens of thousands to the hundreds of thousands per month.

ASP

For fabless companies, the average multiple on the wafer is typically about five times — in other words, it sells for about five times what it costs. That may explain why some of these companies have been very profitable.

Probably more so, it explains why most of those companies focused on value-added areas. They also flew with the times and were very sensitive to changes in their markets. Their operating

The Key to Successful Fabless Operation Is ASP

- Average Multiple on Wafer Costs Is 5x the Wafer Price
- Fabless Margins Average 20% vs 12%

Illustration #6

margins typically were almost twice that of companies with their own manufacturing capabilities.

Value-Added Product

It is necessary for a fabless company to deliver a clearly superior value-added product. I have listed a few examples in Illustration #7.

Fabless Companies Must Deliver a Clearly Value Added Product

Products	Benefit
CHIPSets	Reduce Computer Systems to Chips
Co-Processors	Performance
DSP	Software Content
Field Programmable Logic	Flexibility

Illustration #7

• CHIPSets fit that role — or certainly did several years ago.

• Co-processors today, I think, probably still fit that role.

• DSP is a technology where we are paying more for the software and the algorithms than we are for the actual silicon today.

• Field programmable logic is still waging a war to see which solution will be the most value-added.

The trend in all of these areas is toward more software and more systems content in the silicon. As we make that migration — whether it is chip sets, building blocks, or simply a solution — there will be more intellectual property rights, more software and more value-added.

Manufacturing Flow

Fabless companies can do several things to improve their cost structure. Illustration #8 shows a typical flow, where a company like Chips would either buy finished units from its manufacturing partners, bring them back and ship them to the customers; or, in some cases, it can also improve its manufacturing competitiveness by buying wafers or die and managing its own packaging. That also implies that you have to support a much stronger test program and a number of other things in that area.

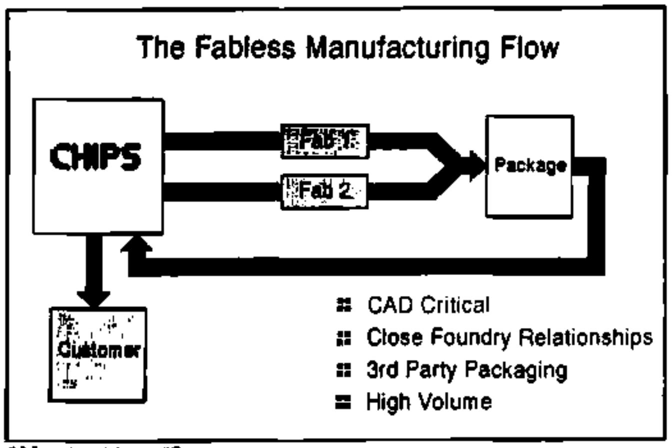


Illustration #8

The CAD or CAE effort is critical to interface with your foundries. You need close foundry relationships that develop and produce trust on both sides. If you want to continue to reduce cost, you need to have third-party packaging. And, I think, as both T.J. and Frank have pointed out, you must have high volumes.

Wafer Cost

If I look at a typical $100 million revenue company — and I won't argue the cost very much — and the fab cost to support that of roughly $82 million and operating cost per year of $37 million, it would lead to some conclusions about wafer cost [Illustration #9].

Typical $100M Revenue Based Company

	Fabless		Fabbed	
■ Capital Costs				
■ Building/Land	0		$28M	
■ Equipment	0	$0	54M	$82M
■ Operating Costs				
■ Material	0		$ 5M	
■ Direct Labor	0		5M	
■ Indirect Labor	0		12M	
■ Indirect Materials	0		1M	
■ Building Depreciation	0		1M	
■ Equipment Depreciation	0	$0	13M	$37M

Illustration #9

One argument is that, for a fabbed company as just described, we would be looking at a cost of about $400-$425 per wafer if that company was at 100% utilization. The fly in the ointment is where, if that wholly-owned and operated fab is not very well utilized, or if we are running a lot of engineering lots, or if we want fast throughput time, that capacity then drops significantly — and, as the capacity utilization drops, our costs go up.

The fabless wafer cost typically is in the $500-$700 range. There is an interesting side to the fabless company: that wafer cost does not change, regardless of how much the fab is utilized.

Capacity Utilization

In Illustration #10 you see a problem the industry has worked with for a long time: the problem of utilization and trying to fill that capacity.

Typical $100M Revenue Based Company
Wafer Costs

	Fabless	Fabbed
■ Capacity Utilization		
■ 100%	$600	$422
■ 75%	$600	$633
■ 50%	$600	$844

Illustration #10

To solve that problem, we have come up with some interesting perspectives on the industry. Certainly, there are a lot of young, entrepreneurial companies trying to take advantage of the fab capacity that is out there. In fact, there is today a large foundry business that has emerged and is alive, healthy and well.

Fabbed Companies Turning Fabless

This fact has not gone unnoticed among the dinosaurs. Today we see many of the dinosaurs actually doing foundry business as well.

Why would they do this? A possible argument is that it is good business, and it allows them some buffer in keeping their own fabs utilized, or in not having enough fab capacity to support 100% of their activity.

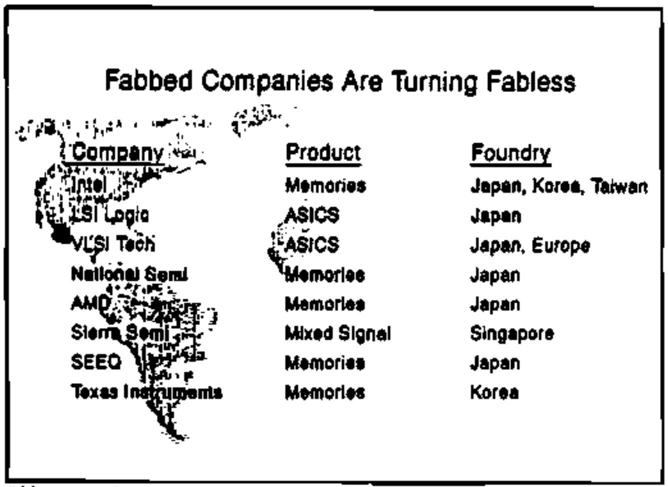


Illustration #11

Summary

On that note, Jerry Sanders has often stated that "real men have fabs" — and in his case, at least currently, no profits. T.J. has advocated the pure play. You might conclude from that that "pure men have fabs" — and, in T.J.'s case profits, but also lawsuits.

Where does that leave Chips & Technologies? That is a good question. I think it leaves us with this statement: "Profitable, real, pure men not only don't have fabs, but they also do not have lawsuits."

DIFFERING CORPORATE STRATEGIES: PANEL DISCUSSION AND OPEN Q&A

Moderator

DAVID ANGEL
Group Vice President and Director of Worldwide Research
Dataquest Incorporated

Panelists

T.J. RODGERS
President and Chief Executive Officer
Cypress Semiconductor

FRANK C. GILL
Group Vice President and President, Systems Group
Intel Corporation

GORDON CAMPBELL
President & Chief Executive Officer
Chips & Technologies

MR. ANGEL: You are correct, Jerry has said that "real men have fabs." And I think John East is the one who is attributed with the quote "real men make profits."

But one concern is the higher cost of capital. A comment from several Japanese companies is that even the Japanese, in the land of interest rates which are perhaps half of those in the United States and Europe, are suddenly seeing that they can no longer continue to invest massive amounts of money in new factories without partners. That is the first time, I think, that we have heard this concept of partnership being used for spreading the capital risk.

Is the situation of the higher cost of capital going to slow down the folks that really are dependent upon fabs?

DR. RODGERS: We are in the fab business, so I will comment. It is a problem, there is no doubt. Cypress has been lucky. We hit the market in 1986, and we went out again in 1987 and brought in $110 million. We still have $100 million in the bank, we are cash flow positive, and we are buying our stock back. So, we cannot actually cry about capital formation.

But one of the problems I have is that I have money and I cannot afford to lose it. I could buy a fab, but then I would have to start depreciating it — seven years for some equipment, five for others — and that creates losses. We cannot tolerate losses, because they crater the stock value which means we cannot raise more money. There is a problem with the cost of capital, but also one with the ability to use it in our short-term mentality environment.

MR. ANGEL: How about the situation for raising money? I think that you commented, at another time when you and I were talking, that it took you six journeys to the market to raise what one

Japanese second-tier company did in one offering.

DR. RODGERS: That is my NMB story. Cypress did four rounds of private placements ($40 million), two public rounds ($110 million), $150 million total. We raised the last money at a valuation of $470 million. NMB came along and, in one offering, raised $470 million!

One of the things I learned at Stanford from Dr. Shockley was his "try simplest case approach." I just took the NMB story to its limit. I said: "What if Cypress and NMB both, at the same time, discovered the 'elixir,' the thing that would make you win, beat everybody in semiconductors at a cost of $475 million?" The comparison between the Japanese and American money markets would be that NMB could raise $475 million in a single IPO and get on with winning, while Cypress would have to sell the entire company for $470 million in order to get the technology to save the company!

MR. ANGEL: Any questions from the audience?

QUESTION [ANDRE LOREK, QUANTUM CORP.]: I have a question for Mr. Campbell. I have heard a very large semiconductor manufacturer discuss the foundry business, describing it to me as being similar to being on a diet of Twinkies — it tastes good, but it is not really nutritional long term. That company was trying to phase out of the foundry business. Do you think that is going to be a problem for companies that are fabless, and how would you address that?

MR. CAMPBELL: I think that it is necessary for both partners in a foundry relationship to be able to make profits. One thing we have tried to do with our partners is work out something that is fair, but still competitive. My sense is that the percentage of the industry being used as foundry capacity is growing, and I think it will continue to grow. At any given time we may have individuals or players that decide they may or may not like it; but, by the same token, I think there are a lot of additional players getting into that.

I do not get the same sense that question would convey. I think most of the partners we work with are committed to a very long-term foundry strategy.

MR. ANGEL: Frank, I have a question here for you — a little incendiary, but a good one: Doesn't the building block strategy create a problem for Intel? How far can you take the strategy without really biting the hand that feeds you — i.e., my interpretation is how far can you go without competing head-on with your customer base?

MR. GILL: I would suggest that our strategy is to deliver solutions — be they chip solutions, modules, board level or subsystem solutions — that our customers are buying. I do not think that will be a particularly troublesome problem, even though it gets a lot of coverage in the press. I think it is symptomatic of a standards-based computer industry, with this many participants all using similar standards, that we have many companies that are customers, vendors, partners and so forth. It is the nature of a standards-based industry versus an industry where everybody is doing their own proprietary thing.

MR. CAMPBELL: Let me add to that. I would probably differ with Frank a little on the building block approach. If we go back into the early 1980s time frame, Intel then had a building block approach. The interrupts, timers, DMAs, processor, real-time clock — these were all the building blocks that IBM chose to build the first PCs.

The reason that the Chips' solution, or the chip set solution, was a significant change in our marketplace is that people wanted something other than a standard building block which was more cost-effective and could offer more features and, in many cases, a unique solution to a problem. I do not think that trend has changed, and I do not hold out a lot of hope for a return to standard building blocks.

I think a strong argument will be that Intel, Chips and other companies will provide solutions to the marketplace. I doubt if we will ever see a return to the standard building blocks that we saw in the early 1980s.

I think the rumored announcement of Intel's Genesis chip is testament to that. That is probably not a standard building block, in the sense that it is more of a solution. And, if it is a standard building block, it would be replaced by Frank's slide, where he shows a single-chip solution only a year-and-a-half or two years later.

MR. GILL: I don't disagree with anything Gordy said. I think we are just putting different handles on the same concept.

MR. ANGEL: Any questions from the audience?

QUESTION [TODD OSETH, RAMTRON CORP.]: We all agree that the costs of fab production are going up. For each of your organizations, what are you doing to help reduce that cost for your long-term business?

DR. RODGERS: In our case the most important thing is cost per square inch, so Fab 1 which is a 5" fab will be converted to 6" and Fab 3 will be 8".

When we buy capital equipment, we also are very sensitive to the cost of that capital. Frankly, we are finding the very large equipment suppliers in many cases offering a $2 million machine and the entrepreneurial equipment suppliers (e.g. Lam and Novellus) supplying equipment that is more cost-efficient for our operation.

QUESTIONER [MR. OSETH]: As a gyration on that, what are you doing to help reduce the cost to those suppliers so that they then, in turn, help you?

DR. RODGERS: That is a good question. Just as badly as the computer industry has always treated us — and I have war stories I can tell you — we also have treated badly the people who supply us equipment. We actually used to sit in my office and say, "Well, we'll lead them along until this point, and then, when they have the capital committed, we will tell them how much we are willing to pay."

We have largely stopped that game playing. We have picked our vendors early. We have told them that we want to work in cooperation with them. We have told them what our cost reduction goals are. We have told them that if they work with us and meet our specs — which might include putting their equipment for the final phases of development at their cost, we will work with them on a long-term basis and they will not have to worry about being undercut on price by some other vendor.

Just as computer companies can work with chip companies to reduce the cost of doing business, we can work with equipment manufacturers. This is an example of a vertical-integration-like structure that does not require vertical integration.

MR. GILL: We have a similar story. First, we are working diligently to get our plant utilization to a very high rate so, as T.J. said, we can get more output out of the existing factories.

In addition, throughout most of the 1980s, we worked very closely with our vendor base to bring up new processes and new technologies. I think Intel pioneered 6" wafers in the production facility. A lot of that learning flowed through to the rest of the industry.

The only difference I would add is that we also try to make profits and generate sufficient cash so that we will be prepared for the next turn of the screw in capital and R&D requirements.

MR. CAMPBELL: About the only thing we can actually contribute to that equation is more business. In that sense, the higher the business volumes, the more efficient the fab utilization of our suppliers. That is really about all we can do.

I have a question along the lines of one of my slides. I would like to ask Mr. Gill why Intel does foundry business.

MR. GILL: Essentially for the same reason that you do. For certain of our businesses it makes good sense to us. We can bring a broader product portfolio to our customer base and utilize our own factories to the maximum. I think your slide was relatively accurate.

MR. CAMPBELL: If that is true, we have an entrepreneurial view here and we have a dinosaur —

MR. GILL: A big dinosaur, I might add.

MR. CAMPBELL: — then I would have to ask T.J., why aren't you doing any foundry business?

DR. RODGERS: In our case I can confess, first of all, I don't have a hang-up on "make your own." I believe Jerry ripped me off. I believe, if you check the record, I was the first guy to say "real men have fabs" in the *San Jose Mercury News*, but he can have it. I am not hung up on that.

My problem with foundries is that we talk about $600 wafers — the prices up there were right — but when Cypress says we make 0.8 micron technology, that is real, honest to God, 0.8 micron technology with electrical dimensions on the order of 0.65 microns. We have looked at a series of foundries, but they cannot make our products.

We are quoting 14-week delivery on RAMs; we cannot make enough. And we are trying to offload some of our 64K and 256K RAMs to start ramping up our megabit SRAM. We can only find two foundries that are even willing to quote us on the technology we want, and they both want $1,100 a wafer. The curve of wafer cost vs. price is very steep.

So, in our case, our business is technology. I can draw the logic diagram for a RAM on the back of a napkin in five minutes. Our business is technology; that is what we do, and there are not a lot of other vendors. And if they have it, they do not want to sell it to you because that technology is their proprietary value-added which they match against yours.

MR. ANGEL: Interesting. Let's move on here a little bit.

QUESTION [JIM CANTORE, OKI SEMICONDUCTOR]: Let's make believe for a second that you have $50 million in your pocket. I would like you each to tell me where you would put this $50 million for the best return on investment. What would be your plan?

MR. ANGEL: Good question. Let's start with you, Gordy. I think he means where in your company would you put that $50 million.

MR. CAMPBELL: If I had $50 million, I would put it into developing a microprocessor to eliminate a current sole-source position in the marketplace.

MR. ANGEL: I think that leads into you, Frank.

MR. GILL: He will need more money. I would add it to the hundreds of millions that we are already spending to keep that microprocessor the highest performing and most popular architecture in the world today and in the future.

MR. CAMPBELL: That is reminiscent of a panel I was once on, where I mentioned to John Sculley that I thought making a clone of the Macintosh chip set would be a real boost for Apple. He responded with a very similar retort.

DR. RODGERS: The first $500,000 I would put into advertising, because it is obvious that many people are not aware that the performance of the 486 — let alone the 386 — is about a factor of three below the SPARC chip set and that it only cost $7 million to get it into production.

I think I would invest the other $49,500,000 the way I have been. When we got big — and, to us, "big" is $200 million — we started investing in start-ups. We have four of them. One brought us the SPARC processor chip set, and another the 3 ns RAMs I talked about. We also have a module company, called Multichip, which makes solutions at higher levels of integration in IC form factors.

I live in Silicon Valley. Entrepreneurs are the way it works. That is the way to make money. I would put the money into hot entrepreneurs who want to come to Cypress.

MR. ANGEL: There have been certain comments alluding to some large animals which roamed the earth some millions of years ago. It would appear that some of the entities in our business are beginning to experience a certain chill in the air. The question is really addressed to all three of you gentlemen: What advice, on an objective basis, would you give the leaders of some of these companies that might be thought of as perhaps underperforming right now, as to how they might extract their companies from the business conditions that they are in?

MR. CAMPBELL: There are a number of issues there. One is that Chips has undergone a restructuring virtually every year since it was formed. We do that because we try to reflect what is happening in the marketplace. You cannot afford to be insensitive to what is happening.

When you look at the one slide I put up there which showed the difference between a lot of the companies that have their own fabrication, the value-added, the profit margins and a number of other things, versus some of the newer companies that do not have fabs, that have a little different perspective, you can interpret that as having a fab or not having a fab, but you could also interpret it as most of those companies comprising the fab category also wind up in the dinosaur category. A lot of them are still making T^2L products. Today there is a declining need for that kind of product.

If you want to keep your company in a reasonable productivity, a reasonable value-added and a reasonable profitability mode, you have to change with the marketplace. I do not believe that a lot of us in the industry have done that to the degree that we should.

A second comment is that you have to understand how the markets are shifting. We are now in a global economy. We now have a semiconductor market in Japan that is about the same size as ours, if not larger. That is a major change for us. If we, as companies, have not already understood that and have started putting all of the resources, facilities and capabilities into position to become global competitors, we are going to lose on a second front.

We have seen our business change dramatically. We do a little over 65% internationally now. I doubt if very many U.S. semiconductor companies do that much as an international segment of their business. I think it is very indicative and very reflective of what we see changing in the marketplace.

I think you have to be very careful about what products you are building and how they fit in your marketplace, and you have to know where those markets are.

MR. GILL: I wouldn't feel particularly comfortable counseling somebody else on how to run their business. I would point to Intel as a 20-year-old company that has been able to go through several transformations — from a DRAM to an EPROM to a logic company -- over this time period, with essentially much of the same management team in place.

I think, as Gordy said, one has to listen to the market, be willing to evolve from business strategies of the past, take chances and be willing to fail.

This morning you heard me joking about Western Digital and Gordy's company taking significant market share from us in some product areas. We often talk and joke internally about the failures we have had, as well as our many successes. This willingness to invest and try new ideas, new products and new concepts has been essential to our long-term growth and current prosperity.

DR. RODGERS: I think Gordy hit on the most important point when he discussed how his company changed every year. We haven't changed quite that often, but I would say every 18 months, Cypress essentially stops running right because we have grown to the Peter Principle limit of our current organizational structure and we have to change. That is one of the reasons we started adding start-ups, as opposed to just trying to grow bigger and emulate other companies. Only Intel has managed to break through the size barrier and still remain successful all along — give credit where credit is due.

You have to be willing to change. I think, to state it negatively, the characteristic of a failing company is a company that has an entrenched management with an entrenched philosophy that is stated like religion. In such companies it is fatal for middle managers to speak against religion — and they either buy the party line or they leave the company. The net result is the company goes in a given direction due to a religion that it cannot change. It heads into oblivion because it cannot adapt.

The market is also changing more rapidly. New generation products are developing more rapidly. We are already talking about ramping down the SPARC processor I told you about earlier. So, change and response to change are the most important things for companies.

MR. ANGEL: One more question from the audience.

QUESTION [RICHARD SULPIZIO, UNISYS]: If we could, let's switch the discussion to government involvement. I think I understand T.J.'s position. Intel, as an active member of SIA, has been very involved in their position. But, Gordy, I haven't really heard your position as far as government involvement in whether or not to bail out the industry.

MR. CAMPBELL: I would comment on that just a bit. I believe we have to have a cohesive policy. I think MITI accomplished a lot in trying to get a slightly different perspective in terms of long-range development. I would agree, I do not see a lot of intense secret-sharing among the Japanese — in fact, I think the rivalries there are, in many cases, more competitive that the rivalries here.

I wasn't a fan of U.S. Memories or really a fan of SEMATECH. But I also could not bring myself to speak out against something when I didn't have a better suggestion. I think it is important for us, as a country, to be cohesive and to come together. We will make some mistakes.

One of the things that I was very vocal about was I thought fair market value was one of the worst things we ever did as an industry. I think some of our larger semiconductor companies wound up skating through a very difficult time under a false umbrella. Most of our systems companies wound up paying an enormous penalty for that for a long period of time. And, I think, we pumped about a billion dollars' worth of margin into the Japanese economy which allowed them to do more development. We cannot afford to blunder like that very often.

We have problems in how we are structured that go way beyond whether we are doing a SEMATECH or a U.S. Memories. In many cases, the representative organizations of our industry do not represent all of what we are. And, if we believe George Gilder's or T.J.'s argument that the entrepreneurial companies are where a lot of the life blood and the spirit is happening in our industry, then we better have them represented somehow, because today they are not. Not all of us are going to troop off to Washington and be quite as vocal as T.J. We have a real problem in not representing a very sizable segment of that industry. If that is the segment of the industry that is going to provide the leverage for competition in the future, we are not using it.

MR. ANGEL: We began by mentioning that you represent three different strategies and they all seem to be working. What is the biggest problem you are going to face in your company in the next five years — expand that if you wish — and what do you think the solution is?

DR. RODGERS: I think the toughest problem that any company faces is to stay on top of it. Running a company is a very difficult job, it is a very demanding job, it is a six-day, 12-15 hour-a-day job. If you are not willing to make that sacrifice, if you get lazy for even 12 months, you are out of it. So, from my own point of view, it is trying to find the energy in myself and my staff and employees to stay with it, because there really is not a substitute for it. Plus, the humility of having been defeated in the past and knowing that it can happen very, very quickly — not reading your own quarterly report, but always being wary that it can happen, and it can happen in an hour.

MR. GILL: I am not sure the loss of technology in the United States would be the single biggest problem, but it is certainly a problem on our mind. We can say all we want about the small entrepreneurial company that implements the SPARC chip or does something very easy and fast, but the real core technology development does in fact cost lots of money, and once that technology is lost, it is very difficult to get it back.

I would suggest, certainly in dynamic memories, that technology is lost. The cost of bringing it back is very great. Future display technology, LCD displays on small form factor computers, is going to be very important. I suggest that technology is lost and there are not companies with the resources to bring it back. I think this loss of major core technologies to foreign competitors bodes very poorly for our country's future.

MR. CAMPBELL: I would agree with both comments. My difficulty, looking into the future, is that we have enormous technical challenges in our industry. We will see much more software and intellectual property content embodied in some of the things that will appear in the future.

What does that mean? It means that we are going to see some changes again, as we have seen over the past five years or the past decade or the past 40 years. Those changes are going to spell trouble for some of us and they are going to spell opportunity for some of us. The real issue is whether we have the right concept of that change and we can formulate the right team and the right plan of action.

Some of us have been successful because, at least occasionally, we have been right in being able to put that combination together. But it is a constant struggle, as T.J. mentioned, and it is a struggle that we are going to be facing even more in the future.

Probably the best way we could describe it is we are in a soft market right now. What does that mean? It means that we should be looking for those new opportunities, we should be looking for the new markets that will be emerging, and we should be looking for the new margin opportunities. They are there. The only difficulty is finding them and executing on them.

MR. ANGEL: Gentlemen, I thank you. We are unfortunately out of time.

UPDATE FROM WASHINGTON: BUDGET AND MIDEAST CRISES

Tom Campbell

Congressman, 12th District of California
U.S. House of Representatives

Thank you very much. I deeply regret not being there for two reasons: one that I am not with you, and the other is that I am stuck here.

I think some reflections and comments on the present budget deficit situation would be of most interest to everybody, so that is where I will focus my remarks.

Let me begin, if I may, with comments on where we are on the budget. I will speak a little bit about the Middle East as well, because, in an interesting way, the two are related.

The opening comment I would like to make is one of thanks to Dataquest for inviting me, and all of you for allowing me to appear in this manner instead of being there in person. I left the Congress at 4:00 o'clock this morning, where we worked practically all night, and we reconvene at 8:00 o'clock tonight, the intervening time necessitated while the Senate analyzes the most recent compromise.

Stock Market Response

For a conference like Dataquest's, I thought it would be helpful to observe how the markets have responded to the budget proposal.

First of all, on the news that we had a budget agreement which the President announced with the leadership of both the Democratic and Republican parties, the market initially, upon opening, fell. Later in the day on Monday it rose. That is to say, it was the good news from the President's speech at the United Nations and the prospect for a lower price in the petroleum market that brought the market up. The actual reaction to the budget agreement was negative.

A second observation, which is a little unusual, is that after the House of Representatives on Thursday defeated the compromise proposal that the President, the Speaker and the leaders of both parties had approved, on Friday the market went up, and there was no other news to cause that.

The inference I draw as a matter of market prediction is that the market has essentially given up on the ability of the United States government to work out a serious budget deal — or, another way of putting it, the markets have discounted any further disappointment from a failure to reach a budget deal. That is a sad comment, but not really a surprising one to anybody who has followed this process over the years. We have never achieved a substantial budget deficit reduction, and the market appears to understand that.

That bears upon where I think the markets will go tomorrow and the next day if the catastrophe, as predicted, occurs and we have a sequester. I may be very, very wrong in this prediction, of course, but, not having any money to invest, I can make predictions like this. That is, I predict we will probably not see a serious negative bounce in the market if things go from bad to worse. That is based on a quick overview of how the market has responded so far.

Congressman Tom Campbell

Original Budget Proposal

Let me now speak to what happened with the budget deal that was worked out by the President, the Speaker of the House, the Majority Leader of the Senate, the Majority Leader of the House, the Minority Leader of the Senate and the Minority Leader of the House.

This was for the $500 billion deficit reduction over five years. It fell apart, in large part, for four different reasons: Medicare, taxes, growth incentives, and economic assumptions.

Compromise Budget Proposal

Having fallen apart on those four areas, the Democratic leadership has attempted, in the last 24 hours, to piece together another budget compromise that would address the bases for the first one having failed. Let me outline the flaws in the original one and how they have been improved in the most recent offer. I emphasize, however, that the most recent offer has the support of the Democratic leadership and not of the Republican leadership.

Medicare

First of all, Medicare. Over the last eight years, domestic discretionary spending did undergo some limitation in growth, but there was no limitation in growth on the so-called entitlements.

What is the difference between the two? Entitlements are programs in law which continue to grow if nothing else happens (e.g., Social Security, agricultural crop price support systems, Medicare, civil service retirement). Domestic discretionary programs, by contrast, need to be reauthorized every year (such things as unemployment insurance assistance, the women-infant-and-children assistance program, federal aid to education, NASA, space exploration, ét cetera).

In that the last eight years have seen some curbing effect on domestic discretionary, but none on entitlements, the leaders of the Senate and the House and the President decided that it was in the entitlement area that most of the cuts would come, along with defense. In the entitlement area, therefore, they came up with $60 billion to be taken out of Medicare.

Let me just put to you how very difficult that conclusion is in the political world. You may recall that last year the provision for catastrophic health care insurance for senior citizens was repealed in the Congress because the senior citizens who received more benefits did not think the increased premiums were worth paying for those benefits. By contrast, here we would have an increase in the premium (the so-called Part B), an increase in the amount of income susceptible to the Medicare tax, and a $30 billion reduction in the compensation going to Medicare providers, or an increase in tax and a drop in benefits.

It was doomed from the start. The political history written so recently, as of a year ago, predicted that the senior community could not accept, and would put pressure upon the Congress to reject, so steep a cut in Medicare.

In the defense area, there was ready agreement, by contrast, after a little original posturing of both sides. What is unique about the entire budget today is that Democrats and Republicans, Senators, Congressmen, Congresswomen and the President have all agreed, more or less, on the appropriate cuts in defense. Those will total roughly $180 billion over the next five years.

However, the $120 billion from entitlement cuts ($60 billion to come from Medicare, and the remaining $60 billion to come from civil service and agricultural price support payments) became the sticking point.

On the first topic, here is what the new proposal does to cure it. It announces that there will be between $10 billion and $20 billion less cuts in entitlements. It does not say which entitlements. It does not say that this necessarily is to be restored to Medicare. But it allows those who were concerned about the cuts for senior citizens to say, "Well, it won't be $60 billion, it will be $40 billion." And for those who said, "It is good that we finally have some cuts in Medicare, that is very hard to get and that is a plus in this program," can now say, "Well, maybe we will still get the $60 billion cut; the lowered amount could mean restored cuts in agriculture and civil service."

In other words, the proposed cure is merely an ambiguity. The total number of savings remains the same, but we have departed from predicting that it would be out of Medicare.

Taxes

The budget agreement reached over last weekend reduced the deficit by increasing taxes in the amount of $134 billion. This ran into severe trouble on the conservative side of the spectrum. Indeed, all of you who have been following *The Wall Street Journal* have seen the list of Members of Congress who signed a "no new tax" pledge. *The Wall Street Journal* has delighted in reprinting that list, reminding Members of Congress what they promised and their obligations under that pledge. So, from the start, there was trouble on the conservative side for those who had taken the pledge of no new taxes.

Any way you look at that budget agreement, there were new taxes — gasoline, alcohol, a cap on deductions — and the supposed growth incentives really did not offset that in any way sufficient to claim that one was not voting for increased taxes.

Here I want to observe a very interesting point of departure between the President and the Republican party in the House and in the Senate. The President and the Senate are, by and large, not running for reelection in 30 days. I and all of my other colleagues in the House are. You now have the fundamental distinction between our perceptions of this problem.

I was fortunate in that I did not take the "no new tax" pledge. I believed from the start that the budget deficit was so serious, we would eventually have to address it with taxes as well as budget cuts. But the majority of my Republican colleagues said something like the following when they were campaigning last November: "Read my lips, too. President Bush said 'no new taxes.' I say no new taxes." And, whereas President Bush has two more years, and possibly several more policy successes between now and when he stands for reelection, we do not.

To conclude on the second topic, the taxes issue was extremely difficult for the conservatives. The proposed Democratic fix is quite similar to the fix proposed in Medicare. It announced that, instead of $134 billion in taxes, we will only have $124 billion in taxes, or a $10 billion diminution in the amount of budget deficit reduction from new taxes.

How do we make up this $10 billion shortfall in taxes plus the $10 billion shortfall in Medicare cuts, the so-called "$20 billion gap?" I am not kidding you, it is somewhat tragic to report, but the answer, reading from the report that was voted on last night, is: "$20 billion more in unspecified reconciled deficit reductions." That is to say, we know what we don't like; we have no idea what we like. We know what cannot sell; we have reached no consensus on what we can accept. And so, we will take $10 billion less in Medicare cuts, $10 billion less in tax increases, and simply fudge $20 billion "unspecified deficit reductions."

Ways and Means Committee

The phrase "unspecified reconciled deficit reductions" means that we will give the matter to the Ways and Means Committee to decide. This is the lead into my next topic, the third of the four topics, of what went wrong with the budget agreement, and that is the degree to which we trust the Ways and Means Committee.

The Ways and Means Committee has 36 members (23 Democrat, 13 Republican). Most House Committees are allocated according to the percentage of Democrats and Republicans in the House at large. The Ways and Means Committee, however, is skewed in favor of Democratic representation. It has a disproportionately high percentage of Democrats, and intentionally so. Every other Committee generally reflects Democrats and Republicans. Indeed, it is said — and I have not checked if this is fair or not, but it is so wonderful I will simply repeat it to you — that in return for having underrepresented Republicans on the Ways and Means Committee, the Congress has allowed Republicans to be overrepresented on the District of Columbia Committee.

Growth Incentives

Moving to the third topic, growth incentives, in this proposal we are taking the suggestions for the small business incentives which were in the original proposal and now say "Maybe." You all, no doubt, saw the details of the proposed Initiatives for Growth in the original budget deal: Enterprise Zone, research and development tax credit for one year, a special 25% credit for investment in a small company to be recaptured on selling your stock in it, indexing of that stock after expensing of tangibles, et cetera. Those were, by and large, dropped from heaven in the last hours of the budget negotiations.

What do I mean by "dropped from heaven?" I mean that no human had discussed them, only people at the summit. As a result, when they were brought forward, there was no basis in economics for predicting what effect they would have. Various economists went in exactly opposite directions. *The Wall Street Journal*, for example, predicted that this would be "tax haven heaven" for lawyers, that companies which were capitalized at more than $50 million would suddenly spin themselves out into smaller, $50 million corporations, et cetera.

The adjective I am going to use to describe what happened to these growth incentives is one that has actually been applied to Medicare and to the tax proposal. They have all been "Rostefied." To Rostefy something is to give it to Rostenskowski. We now have the Chairman of the Ways and Means Committee deciding what growth incentives we will have, what tax increases we will have, and what entitlement cuts we will accept.

This degree of uncertainty has allowed the Democratic side to join in and find a majority in favor. On the Republican side, it has simply added to the consternation and lack of confidence in the budget agreement, so that whereas 40% of the Republicans voted for the agreement that the President had sponsored, less than 10% of the Republicans voted for the agreement that the Democratic side brought forward last night.

There is one ray of hope in that: there is now increasing discussion within the Republican side that we held out too long for the maximum rate of 28%, and that had we been willing to trade a higher national rate on personal income tax at, let us say, 32%, we might have been able to receive a capital gains tax reduction down to 20%.

What surprised me was that at the Republican Conference yesterday, a rough show of hands indicated an overwhelming majority of Republican members would have accepted that deal, being able to explain, even among those who signed the tax pledge, that getting a lower capital gains tax across the board was a tremendous growth incentive.

My prediction is that when this goes to the Ways and Means Committee, you may very well see exactly that trade-off, 20% capital gains for something like a 32% or 33% maximum bracket.

Economic Assumptions

I said there were four topics that led this agreement to go awry. I would like to turn now to the fourth, the economic assumptions. The underlying bases for the numbers that I have given you, in terms of savings, are premised upon the fact that the amount of interest paid by the federal government for debt service will decline by $70 billion over the next five years.

They are premised also on the assumption that domestic discretionary spending and foreign aid, and all entitlements (e.g. Medicare, agriculture, civil service retirement, social security) will all grow modestly because the inflation rate will not be great.

Both of those assumptions are seriously wrong, in my view. That is to say, the assumption that the amount of debt service paid by the federal government will drop because interest rates will drop is, to my way of thinking, extremely dangerous. And to provide no cap at all on domestic discretionary spending or foreign aid or entitlements other than Medicare is extremely dangerous. "No cap at all" is not quite right. There is the cap of inflation; whatever the inflation rate, it is allowed to grow in those categories equal to the inflation rate.

I would now like to read to all of you the assumptions put out by the leadership of both parties, the White House and OMB that underlay the original budget agreement. I am going to read straight from that, and I trust, by the end of it, you will share with me the conclusion that these assumptions are not only erroneous, they are unprofessional.

• Inflation is assumed for 1990 to be 5.2%, the next year 4.6%, drops to 3.4% in 1992, drops to 3.2% in 1993, 3% inflation in 1994, 2.8% inflation in 1995.

• Interest rates: 7.7% on 90-day Treasury bills today, 7.2% in 1991, 5.7% in 1992, 4.9% in 1993, 4.4% in 1994, 4.2% in 1995.

• The price of petroleum is assumed to be $21 a barrel today. Next year it will rise to $24 a barrel — but don't worry, it drops back to $21 by 1992.

• Finally, the percentage of real growth. It is understood that this year's real growth will be under 1%; but it will double next year and triple in 1992.

Those assumptions are printed. The entire budget agreement is premised on these assumptions. If they do not pan out, the possibility exists that the growth in domestic discretionary and foreign aid and entitlements that are permitted to grow with inflation will actually swamp the savings in defense, entitlements and the increased revenue from taxes.

I did my own calculation and came up with the conclusion that, if interest rates remain where they are, an inflation rate of 6% will cause this budget agreement to be a deficit-increasing, not deficit-reducing, agreement. The missing element, in other words, is a cap other than the inflation rate on all categories of government.

Congressman Tom Campbell

To conclude with my analysis of the budget agreement on the economics, the assumptions underlying the model are wrong and continue to be wrong. From my own perspective, now speaking just for one Member of Congress, I cannot sign a budget agreement unless I believe it will lead to a lower deficit. This agreement which has been signed will likely lead to an increased deficit. All it takes is an inflation rate of 6% — and, if interest rates rise instead of staying steady, an inflation rate of less than that.

Growth incentives, taxes and entitlement cuts have all been sent to the Ways and Means Committee from which they will emerge in two weeks and we shall have another crisis as to whether they are acceptable or not.

Political Factors

Finally, I wanted to give you a word on politics, how this is played out.

There is no doubt that the President has suffered a severe blow to his prestige. So also has the Democratic leadership. President Bush, Speaker Foley, Senate Majority Leader Mitchell, House Majority Leader Gephardt, House Minority Leader Michel, Senate Minority Leader Dole, all agreed and signed on to this — and 60% of both the Democratic party and the Republican party rejected it. It led to a battle for leadership, and that battle is right now being waged.

There is within the Republican Conference a clear schism. Efforts to patch it up are, at least as of this moment, not yet successful. The schism is over whether we believe a budget agreement can be reached without tax increases and whether we are willing to accept a budget agreement with these economic assumptions in it.

One side of the argument is: "It's the best game in town. It may not be perfect. It was good enough for the President and Dick Darman, for God's sake, it should be good enough for you." The other camp says, "I don't much care what you tell me it is, I know better, and I will vote according to my principles. This is how I was elected and I must face the people who elected me in 30 days."

Middle East

In this context introduce now the Middle East. A couple of points I have mentioned already touch on the Middle East — for instance, that the assumptions of the model are conditioned upon such things as $21 per barrel of oil.

But the Middle East figures in a different way as well. I would pray for peace and hope we have peace, but I offer you a very pessimistic view. I don't think we will have peace in the Middle East. I believe that, within the near future — and that may be as soon as a month — there will be a shooting war. I wish that were not so, but I have tried to parse out the alternatives and they all involve a major change of attitude on our side or on the side of Saddam Hussein.

If I am right, and I pray I am wrong, what you will see within the not-too-distant future is a foreign policy challenge, with the United States needing to marshall all of its forces in support of a quick victory in the Middle East, and then, a longer term effort to establish peace, a new government in Iraq, restoration of some government in Kuwait.

It has been said that when you have domestic crises you should make foreign war. I don't suggest for the slightest moment that is intentionally being done by any of our leaders. But I do put to you the chilling phenomena that we have two crises coming to a head at the same time. We continue to go from day to day with a weakened President who has been rejected on this major issue by a majority of his own party, and a weakened Democratic leadership similarly rebuffed. But all that could change in the context of a foreign threat. If, therefore, events independently — not by design — lead to a war in the Middle East, I think you will see a resurgence of presidential authority, a resurgence of bipartisanship, and, with it, the happy fallout of a budget agreement. In that context, both sides coming together for the good of the nation, putting aside the differences such as I have outlined, and agreeing to something in the nature of deficit reduction that would be applauded by all sides as necessary in the present crisis.

Whether that happens before or after the election is quite open. My sense is that the timing is largely dictated by Saddam Hussein and whether he takes any provocative action between now and then. But I repeat my prediction, that in the near future there will be some provocation, some event, that will cause the Middle East to go from a stalemate to war. With that, we might have, oddly enough, and not by anybody's plan, a resolution of the budget agreement and the crisis that has led to it.

Conclusion

That is my report from Washington. I repeat, I would so much rather be with you. Instead, I will go to Congress in four hours and stay up all night as we try to agree to another one-week extension before closing down the government.

I will conclude before I take your questions with just one last observation. One of the great mistakes in the closing down of the government is that we thereby close down the Smithsonian and the National Zoo. As a result, tourists in Washington have no place to go except the House of Representatives. The argument was raised that we were doing our very best to provide as much amusement as watching the orangutans at the National Zoo would have provided.

I'd be delighted to take any questions.

Questions & Answers

MR. FERNANDEZ: Thank you for being with us.

MR. CAMPBELL: My pleasure, Manny. Thanks for letting me be here by long distance.

MR. FERNANDEZ: It seems to me that probably there is no need for a zoo in Washington with what is going on. OMB and the rest of the forecasters are doing a good job of being a zoo attraction.

Tom, one quick question to begin with. At this time what is your short-term forecast on the extension, and how long do you think it will be before we end up with a budget — 30 days, 45 days, or longer?

MR. CAMPBELL: I will take a little bit longer answering your question, Manny, if I may, because it brings up a very interesting topic about a lame duck session of Congress. The Democratic proposal extends the present budget until October 20th. This passed the House at 4:00 in the morning. It is now being debated in the Senate. It will, no doubt, be approved in the Senate. The question is whether the President signs it or not. If he signs it, then we are all right until October 20th. Furthermore, I would then predict that we will be okay in the near term, as we will extend it from week to week, and probably eventually reach some budget agreement shortly after the election.

If the President vetoes this, however, we will then have a vote to override the veto. If we sustain the President's veto, we will go into an actual hard sequester, and that will hit as of tomorrow morning. My prediction is that if we have that hard sequester, the President will nevertheless take steps to soften some of its more difficult edges (such as air traffic controllers, meat inspectors, vaccinations for children), under the authority that was argued first by President Carter to take care under emergency circumstances.

Now, you are asking for a prediction as to what the President will do and whether we will override the President. Here is my prediction, and it is not very valuable at all, I'm afraid. I am guessing. My guess is that it will pass the House and Senate and the President will sign it. He will lose a little bit of face because he said that he was not going to sign a continuing resolution until there had been a budget resolution that was satisfactory to him. But he may be able to say, just as the Democratic leadership has, that the new agreement is sufficiently close to the original one, with just a little bit of flexibility, that it is premature for him to veto it. After all, we don't know what the Ways and Means Committee will do.

If I am right about that, then we will go until October 20th. I think what we will then see, with the election only two weeks away, is a continuing resolution for three weeks, extending it past the election, and we will then have a lame duck session. If, however, the President wants to be extremely tough, to perhaps reassert his leadership in this area, and perhaps also reestablish his credentials with the conservative side, he would veto this resolution and allow the government to begin to suffer a hard sequester with the modifications I described.

One last point, I believe there will be a lame duck session of Congress anyway for a very specific reason: The House of Representatives increased its salaries for the next Congress; the Senate has not. It is inconceivable to me that Senators would permit themselves to be paid less than Representatives in Congress. The optimum time for the Senate to increase their own salaries is in a lame duck session. It is the maximum distance until the next election, and you have a number of defeated, holdover, or retiring Senators who can vote yes.

MR. FERNANDEZ: Thanks, Tom. We are now going to open the floor for questions.

QUESTION: Tom, I was curious as far as the Federal Reserve's response to this same budget accord. Alan Greenspan has said that interest rates are going to be tied to some sort of a solution to the budget crisis. Is this new package you are talking about going to help out?

MR. CAMPBELL: That is a very good question. Yes, I think it will. If this agreement is accepted and the President signs it, Alan Greenspan has every bit as much of a basis to lower interest rates as he did last week when he announced that he would do so. The basis for his lowering interest rates was that we had a one-year $40 billion in deficit reduction, and that is what we will have. The new agreement has $40 billion; it simply doesn't tell you where it is coming from. But the $40 billion number is the same.

Let me use your question, if I may, to address a fear. I think most investors and most people who follow the market would like to see the Federal Reserve Board be generous on money supply. But let me express a fear about that. If Alan Greenspan increases the money supply significantly and real growth does not bounce back as quickly as these assumptions — namely, doubling next year and then tripling in 1992 — we will have inflation. We cannot repeal the law that if the money supply grows faster than real output, and velocity remains the same, the price levels will rise.

QUESTION: There were frequent references to the elections and the President and the Senate not being up for reelection. At what point does doing the right thing become the important issue in Washington?

MR. CAMPBELL: In my own heart, I reached that point last week when I voted no on the budget agreement. I think every other Member of Congress is coming close to that very point. The initial reaction is to go with your party, go with your leadership, go with your President, paper it over. Doing the right thing is what caused us, in my judgment, to defeat the budget agreement. I could easily have looked the other way and said, "Well, it's the best we are going to get." People of good will said that, and I don't fault them a bit. But I dug into it, looked at these economic assumptions, and said, "I am not going down that path again."

You remember David Stockman's book, where he jokingly spoke of a rosy scenario, where he was able to make numbers do what he wanted, predicting a rosy scenario? This is a rosy scenario.

In my own mind, the point of doing the right thing was reached when I cast that vote.

My comment about the Senators and the President being far away from reelection was not so much that they might, therefore, be more inclined to do the right thing and I and my House colleagues more inclined to do the political thing. It was, rather, that the President could look to the intervening two years for public relations victories that would allow the voters to forget his reneging on a promise about no new taxes.

I think he did the right thing to renege on that promise. I also think, with all loyalty and respect to him, that he gave it away too soon in the negotiating. He should not have given it up until he had capital gains.

But my point was really not that one side was doing the right thing and the other the political. It was simply that, driven by an election, the most recent event prior to this election will be the budget crisis. Members of the House will do the right thing with that in mind. Members of the Senate and the President can hope for two years of other events.

QUESTION: I appreciate your inside view of the budget crisis, but I thought we were going to hear about the Bush Administration's position on high technology. Would you care to comment on that?

MR. CAMPBELL: I am very pleased to. I apologize for changing the topic, but I made the guess that this would be of more immediate interest. I will be happy to speak to that. Of course, I do not have the authority to speak for the Bush Administration. I do, however, know a fair amount about their policy.

The debate right now is whether we are to have incentives directed to high technology or whether the macroeconomic work of lowering interest rates, lowering the budget deficit, attempting to restore an R&D tax credit and obtaining an intellectual property element in the GATT Uruguay Round accord, will not be sufficient.

On the trade side, the Democratic leadership is increasingly pushing for more; namely, that we need to beef up "super 301," and that we even need to review Exon-Florio. Exon-Florio presently allows the federal government to bar the acquisition of an American company by a foreign company where there is risk to national security. The discussion now centers on changing that so that an acquisition of an American company by a foreign company can be barred when there is risk to American economic or commercial interests, not simply national security. I predict that you will see that bill introduced by Mr. Gephardt, who is the Majority Leader, at the very start of the next session of Congress.

Congressman Tom Campbell

The firing of Craig Fields, at DARPA, set a very bad example and left a very bad taste in the mouths of people who observe the Administration. The notion that there would not be industrial policy in this Administration was one with which I had become familiar. But I thought that where you had federal research dollars, such as in DARPA, being directed to commercial use as well, we were all the winners. In the firing of Craig Fields, I took that as a clear signal that we would not be directing funds in that manner within DARPA or using defense money itself in that manner.

We are left, therefore, with the following element in the Administration's attitude toward high technology: Lower the interest rate, restore the R&D tax credit, make a lower capital gains tax permanent, get a better international regime on intellectual property, and we will assume the market will take care of the rest.

The Democratic leadership is saying that all of that might be good, but, in addition, we should have a law that allows us to bar acquisitions in the manner I have described, and an improved "super 301" process whereby we can punish Japan, for example, for not allowing us access to their chips. Between those two I think there is a ground for compromise.

Let me put forward two proposals and then, if there are any additional points you would like to have discussed, please raise them. The two compromises are:

• First, create a tax incentive for targeted growth. That is to say, not simply a research and development tax credit available to all for incremental R&D, but a start-up R&D tax credit for companies that must invest a lot in R&D for, let's say, the first five years. This is not addressed in the present tax structure because the R&D tax credit is available only for incremental, not for aggregate, expenditure in R&D. So, if you go from 50 to 51 to 52, you only get credit for one and two, in effect, in the second and third year.

I have been pushing for this change. I have received a very warm welcome at the Commerce Department with that idea. I have also received a warm welcome in Roger Porter's office in the White House.

• The second middle ground is to allocate money directly by the federal government with a civilian DARPA, admitted to be such. Rather than run money through the Defense Department and get it into commercial enterprise, grant the money through the Commerce Department or through some oversight by government and industry to allocate federal tax dollars.

I believe the White House will resist that almost to the last breath. The White House believes that is industrial policy, "picking winners," and we have never done it well and are likely to fall victim to the political process in doing it.

MR. ANGEL: Tom, on behalf of Dataquest and all of the folks here, we thank you for taking the time to be with us today in what is going to be a hectic, long period for you. We are indebted to you. Best of wishes, my friend.

MR. CAMPBELL: My deep thanks to all of you. Dave and Manny, thank you, and all who have kindly given me your attention. I can only say I can do better in person and I can do better with more than four hours of sleep, but I gave you the best I have.

MR. ANGEL: Outstanding. We thank you.

WAKE-UP CALL FOR THE U.S. SEMICONDUCTOR INDUSTRY

Carver A. Mead

Gordon and Betty Moore Professor of Computer Science
California Institute of Technology

MR. ANGEL: Jerry Banks, who manages our ASICs business, is going to get us started this afternoon.

MR. BANKS: Good afternoon, ladies and gentlemen. Some of you may recall, in April 1988, our next speaker was featured on the cover of *Forbes* magazine. The cover story was written by none other than George Gilder, who has been mentioned a few times today. Mr. Gilder began his article as follows: "No single individual has exerted a more profound influence on modern human productivity than the visionary physicist pictured on our cover." That visionary physicist is our next speaker, Dr. Carver A. Mead.

During his illustrious career, Carver Mead has excelled in, and provided major contributions to, three challenging disciplines: device physics, computer science and neural networks. As a result of his extensive work on device scaling, he recognized that integrated circuits could be built which would contain millions of transistors. He also realized that without structured design techniques and sophisticated design tools, designing and debugging such complex chips would be nearly impossible and take a long time to do.

In keeping with his reputation as an innovative solver of complex problems, Dr. Mead joined with Lynn Conway to write the book *Introduction to VLSI Systems*. Virtually all of today's VLSI integrated circuits are designed using the principles set forth in this textbook.

Dr. Mead is currently focusing on modeling neuronal structures, such as the retina and the cochlea using analog — yes, I said analog — VLSI systems. His latest book, *Analog VLSI and Neural Systems*, has recently been published by Addison-Wesley.

Dr. Mead holds the title of Gordon and Betty Moore Professor of Computer Science at the California Institute of Technology, where he has taught for over 30 years. He is a member of the National Academy of Sciences, the National Academy of Engineering, a foreign member of the Royal Swedish Academy of Engineering Sciences, a Fellow of the American Physical Society, and a Life Fellow of the Franklin Institute. He is also a recipient of a number of awards, including the centennial medal of the IEEE.

And, in the words of a fellow entrepreneur, John East, President and CEO of Actel: "Carver Mead is a scholar, an inventor, an educator, and an entrepreneur. More importantly, he is a good, decent human being."

Ladies and gentlemen, please join me in welcoming Dr. Carver Mead.

DR. MEAD: Thanks, Jerry. You are hearing from all the leaders of our great industry at this conference, and the last thing in the world you need is to have an academic stand up here and tell you how the industry works. But what I might be able to do is stand back a little bit and, in the context of the theme of this conference, "Looking Into the Next Decade," look back a decade or two and see where we have come from, and think forward into the future a little to what might be coming up on a longer time scale than battling it out over the next generation of microprocessors.

Technology Transition

I will go back a fair ways here, all the way back to when there were vacuum tubes. The term "dinosaur" was used today. It is funny hearing that term used with respect to semiconductor companies. I always think of it with regard to the kind of technology which was commonplace when I started designing electronics.

We have come a long way, down through vacuum tubes, smaller vacuum tubes, printed circuit boards, discrete transistors, and then the big transition, in 1959, between the discrete transistor and the integrated circuit.

I am indebted to Gordon Moore, after whom I am named, for some of these slides.

ICs: The "Missing Link"

The early integrated circuits are the "missing links" in the evolutionary chain. When they dig everything up a million years from now, they won't find any of these. They will find the big microprocessors that are in these hulks of PCs that are buried under the layers and layers of civilization, but they won't find the individual gates and flip-flops, because they were the early ones, the "missing links."

As technology evolved, we developed semiconductor memory to replace magnetic cores, and, in 1971, Federico Faggin created the first microprocessor, the 4004.

Evolution of Moore's Law

We heard about Moore's Law earlier today. Illustration #1 is the very first Gordon Moore plot of Moore's Law. When he gave me this slide in

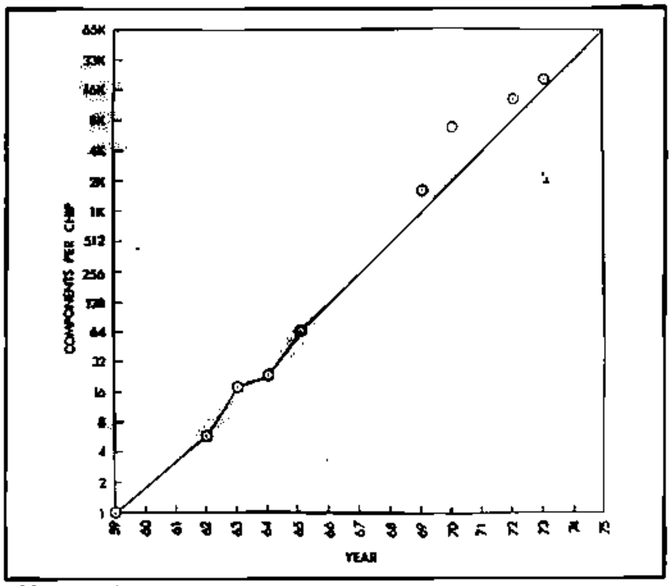


Illustration #1

1970, he apologized, saying, "Intel is a small company and we can't afford fancy graphics."

Then, as time went on, Moore's Law developed further. Illustration #2 is the 1979 version, shown at a talk on the Cal Tech campus. There was a little hesitance there at the end, but that's okay.

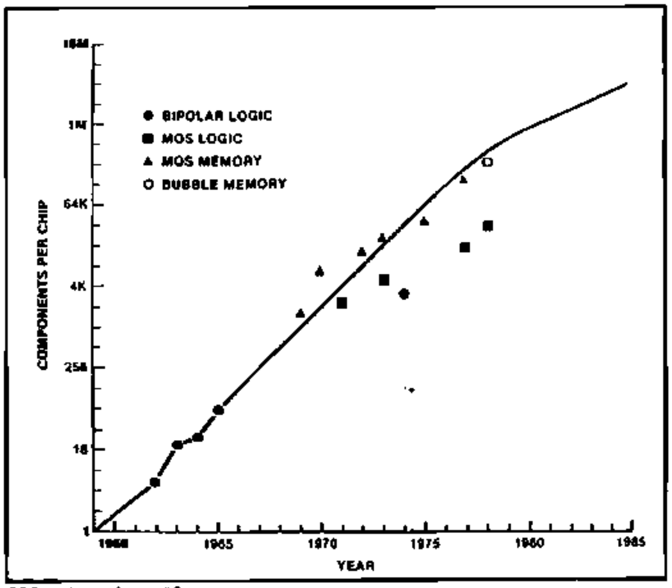


Illustration #2

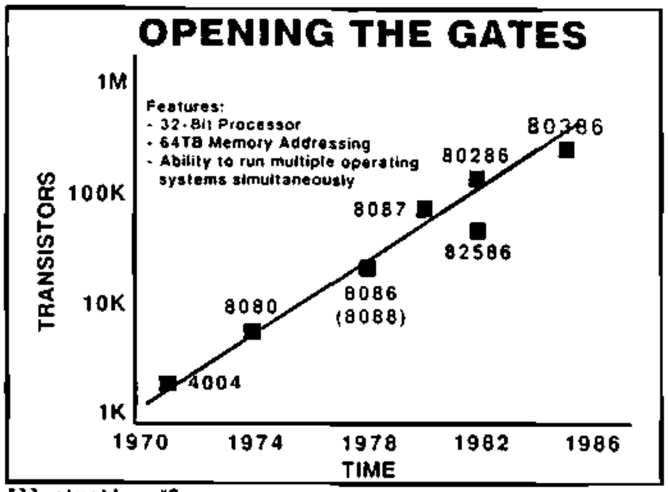


Illustration #3

Illustration #3 shows Moore's Law from last year. You can see, as Intel has grown and prospered, the quality of the graphics has come to match.

Henderson Learning Curve

When I first learned about Moore's Law, I was very excited about it. I was talking to a friend of mine, Tom Perkins, from the Kleiner, Perkins venture capital firm, about this great exponential explosion in our microelectronics capability over time. He said, "Aw, Carver, it's just a learning curve. Bruce Henderson, at the Boston Consulting Group, has studied learning curves a lot. All you have to do is to plot the log of the cost as a function of the log of the cumulative volume of any product or service, and you get one of these straight lines on this kind of a plot. That's really all that's going on there."

Learning curves, like Illustration #4, were actually discovered during World War II. If you make this kind of plot for many different products and services, you get a fractional power law over a very large range of cumulative volume.

It is a really interesting phenomenon, that as we produce more things, we learn how to do it better. A lot of learning goes into one of these learning curves. The semiconductor industry has

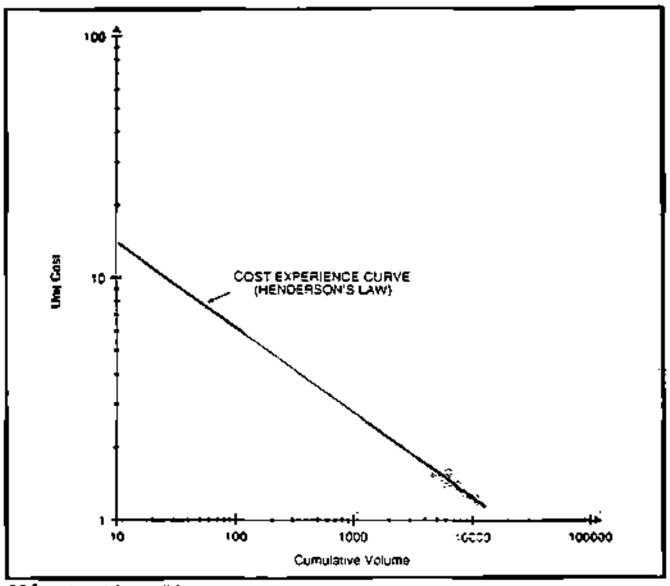


Illustration #4

made an institution out of this principle, and often prices things according to where the learning curve is going, instead of where it has been.

A Featureless Landscape

It seems to me there is something missing in a strict learning-curve view of our industry. I think of one of these curves as a featureless landscape, where there is no signpost that really tells you with any exactness where you are. I know many of you feel this way sometimes.

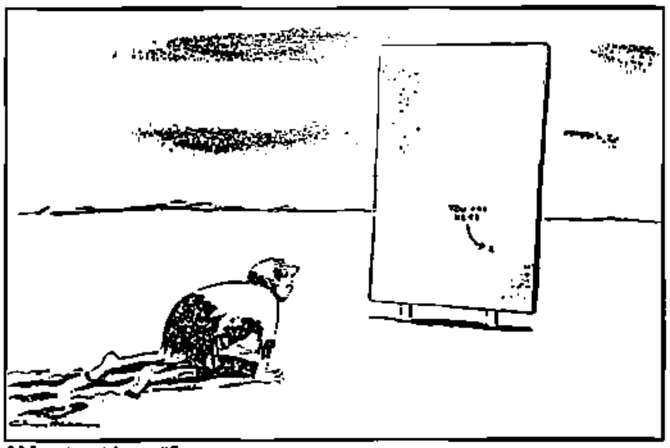


Illustration #5

Carver A. Mead

The 12-Year Cycle

It seems to me that view doesn't exactly capture the roller coaster we have been on in our industry. Here we are in an industry where the transistor was invented in 1947, the integrated circuit in 1959, the microprocessor in 1971, and so forth. These major inventions have punctuated our industry at rather regular intervals. I call it the 12-year cycle.

Mead's Law of Innovation Economics

I spent a lot of time thinking about how we might conceptualize what really goes on in response to one of these major inventions. I want to share with you a set of thoughts that I have put together and modestly called Mead's Laws of the Economics of Innovation.

There is a problem with economics that is summarized in a story about Professor Jones, a professor of economics, giving a talk at a professional society meeting. Professor Jones drones on for about an hour. At the end of his discussion of his new theory of economics, someone in the back of the room raises their hand and says, "Professor Jones, how does your theory apply to the crisis in Silicon Valley?" Jones scratched his head a little bit and said, "Well, my theory applies more in general than in any specific case." That's a problem with economic theories.

There is a great deal of innovation in the semiconductor industry, in particular in electronics, and the information industry in general. I think there are some things we can say about it that are quite different from traditional economic theory. I would like to share those things with you today.

If we think about skating down a Henderson learning curve, like Illustration #4, it had to start

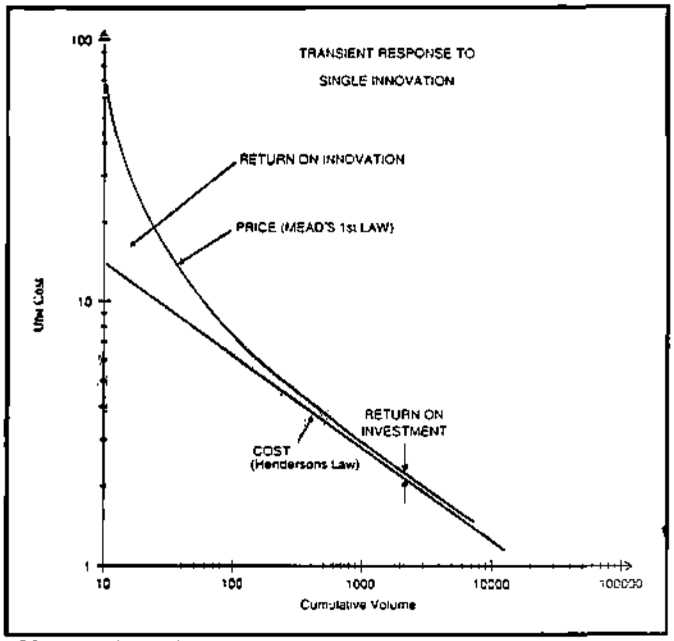


Illustration #6

somewhere. Essentially, all of you are with companies that were started in the last 20 years. That is where most of the action is in the information industry today. Things got started with some kind of innovation.

What happens when there is this step function of innovation, when there is a new thing discovered — a transistor or an integrated circuit — is shown in Illustration #6.

Price Premium Over Cost

Usually, the thing you can do with a new technology has value. If it doesn't, it will not last long, so those aren't the ones we will talk about. That value allows you to charge a price in excess of your cost. And for something that is really new, that you and only you can do, and which creates a lot of value for other people, the premium of price over cost can be substantial.

With time, other people will learn how to do the new thing, too. They will learn how to make the integrated circuits or they will learn how to copy your latest microprocessor — "second source" I guess is the proper term — and so the price will no longer be something that you have free rein to set however you like, and it will come down under competitive pressure.

Eventually, in steady state, the price will be set by manufacturing cost. You get to charge a little premium, which in traditional economics we have always called the "return on investment." In general, economics, as a field and as a theory, addresses the tail end of the curve where steady-state conditions apply, and we are not near any break point in the invention sense, and we are able to charge a premium over our cost of production. That gives us a return on investment.

Return on Innovation

I don't have to tell you that production economics is a game that can be played worldwide, and there are countries like Japan that play it much better than we do. But the other thing that we must realize is that the information technology is not, by and large, dominated by the steady-state learning curve and steady-state return on investment. In the presence of these step functions due to major innovations, there is a premium of price over cost that is considerably larger than that dictated by the return on investment alone. I have termed the shaded area between the two curves in Illustration #6 the "return on innovation." That is the return on venture capital, that is what makes start-up firms with new ideas do very well, and that is what is really fueling the information economy in which we live today.

So, we are really not living down on the steady-state part of the curve except in old, sort of buggy whip style products, like the TTL which Gordy Campbell mentioned earlier today, products that are very well evolved. The newer products are well up on this curve and there is a lot of value to be added, both for the customer and for the supplier, early on in the evolution of a new innovation.

A succinct summary of the first principle: The price comes down to the cost level only asymptotically, and, in the meantime, there is the notion of return on innovation that is separate from the age-old concept of return on investment.

Headroom Principle

A second idea that I would like to share with you is called the Headroom Principle, shown in Illustration #7.

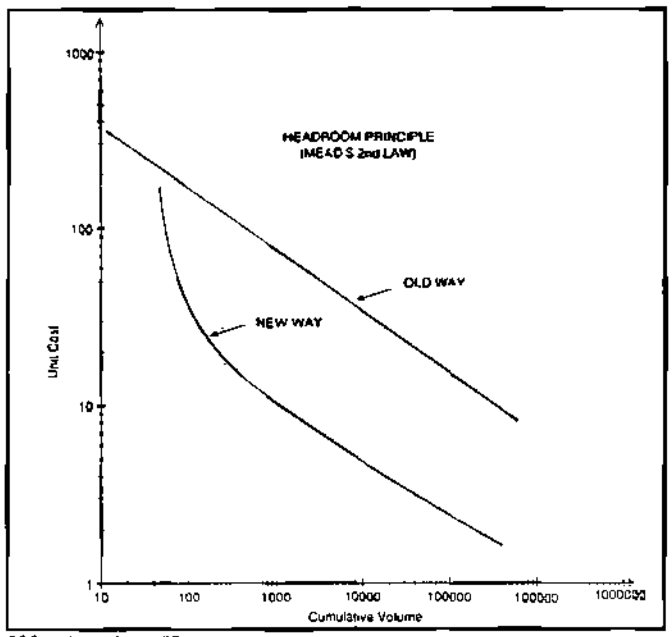


Illustration #7

Usually, the new idea, the new technology, is replacing some existing technology. For example, the transistor replaced the vacuum tube, the integrated circuit replaced circuit boards with discrete transistors on them, and so forth. So, there is usually an old way of doing things, and the old way is skating down its own learning curve. Then we introduce a new technology, and if we are careful (and lucky), the new method will have some headroom.

If the learning curve, once we get to steady state for the new way, isn't well below the learning curve for the old way, we really don't have any headroom here: There is no place to get a return on innovation, and it is very, very hard to get a new technology started that way. That is what happened to bubble memories, for example; there just wasn't any headroom.

There was narrowly enough headroom for semiconductor memories. We take them for granted today, but as those of us who lived through that transition know, the core memory people put up a significant fight because they were on their own learning curve. In fact, there was a period where there was a serious question in the marketplace as to which technology would survive.

In summary, the Headroom Principle is that the price you can charge for a new way must be below the cost of doing it the old way.

My own personal rule of thumb is you should have a factor of 10; if you don't, the old way is going to dominate. And, even if the new way is "better," it won't survive if you only have a factor of two, because your competition is skating down the Henderson curve for the old technology faster than you can ever catch up and you are behind the power curve.

Repeated Major Innovations

The most important thing I have to say to you is my third observation: We live in an industry where there are repeated major innovations. We went from tubes, to transistors, to integrated circuits, to microprocessors, and we are now in an era where computer-aided design of solutions, as Gordy Campbell calls them, is a major part of what is happening in the marketplace. Each of these innovations has made a big difference in the cost of arriving at a solution in a new way.

For that reason, the marketplace never gets into a steady-state learning curve. Each of these, like the discrete transistors, evolves according to its own learning curve. But, before the transition curve ever got to steady state, we had an integrated circuit. And SSI was skating down its learning curve, and then the microprocessor came along, and so forth. So, in an industry punctuated by these major, major innovations we never get to where the raw return on investment is really the dominant factor in the economics. We are always dominated by the next major innovation that is coming along.

As a country, the United States has thrived in this turmoil. It is the kind of environment that creates a lot of opportunity for entrepreneurs, it is certainly the kind of thing we are still doing very well, and it is certainly the kind of thing the next decade is all about. Information technology, above any technology we have ever seen, is driven by this repeated punctuation with major innovation.

Composite Learning Curve

The effect of repeated major innovation is shown in the composite learning curve of Illustration #8.

If we stand back and defocus this curve a little bit and put a box around it, we notice that it looks like a learning curve, but it is much steeper than any of the manufacturing learning curves. That additional slope is because of major innovations. We have an industry which is growing exponentially faster — in terms of the capability that is delivering to the marketplace — than any individual manufacturing learning curve.

That is my third observation: Given these major innovations, the composite learning curve is ex-

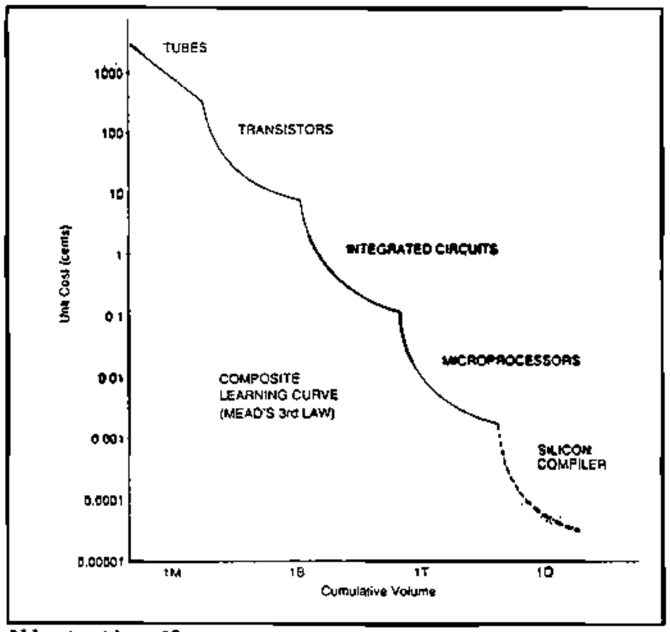


Illustration #8

ponentially steeper than any individual Henderson curve.

Right-Angle Turns in Innovative Technology

I have a fourth observation: What makes an innovation a "major" innovation, a breakthrough technology if you like? We can always argue about the fringes, but my definition of a breakthrough is we weren't looking for it there. For most of the innovations mentioned earlier, I was standing right there looking, but I was looking the wrong way.

When we were all trying to make better, higher-performance discrete transistors, Bob Noyes came along and said, "Why don't you just use the aluminum that is there already to hook up the transistors that are there already and then you don't have to cut them all apart and put them on circuit boards to do that?" So, it was an innovation in the interconnect technology, not an innovation in the transistor itself.

And so it has gone. We were all making standard products, and then the microprocessor made a product that we could configure to a particular use. Then, just about the time everyone was looking at how to make more programmable devices, the design technology came along that allowed us to make better dedicated solutions to large system problems.

The major innovations are always the ones that strike out in a different direction than everybody is going. For that reason they are not things we can plan, and they are often contrary to the corporate cultures that have been so effective in producing a stream of products of the last generation. Few companies have been able to transition from one generation to the next. It is very hard to do, given that the technology takes these right-angle turns, but it is the strength of our industry.

Design Cost

One example of this phenomenon of looking in a different direction I can show you in particular. In 1979, Gordon Moore gave a talk at Cal Tech where he showed Illustration #2, the middle of the three Moore's Law slides. He also showed Illustration #9, a slide of the human cost of designing a VLSI chip as a function of the year.

You can see the data points and you can see Gordon Moore's extrapolation as to where design costs were going. This was, of course, predicated upon doing design the way it had always been done.

Ten years later, Gordon came back and gave another talk at Cal Tech, and he showed Illustration #10 — again, the design time as a function of the year.

You notice it carries quite a different story. That story had to do with the development of com-

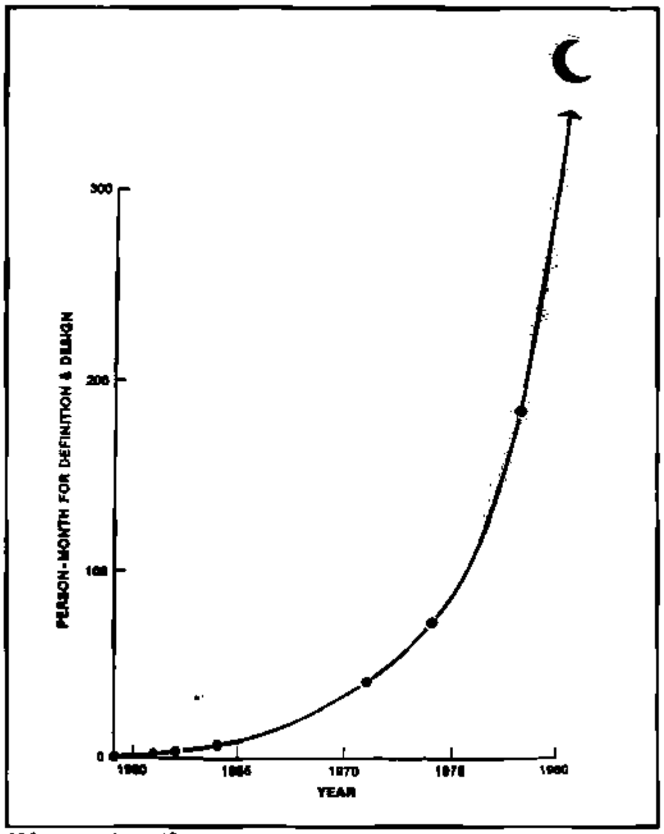


Illustration #9

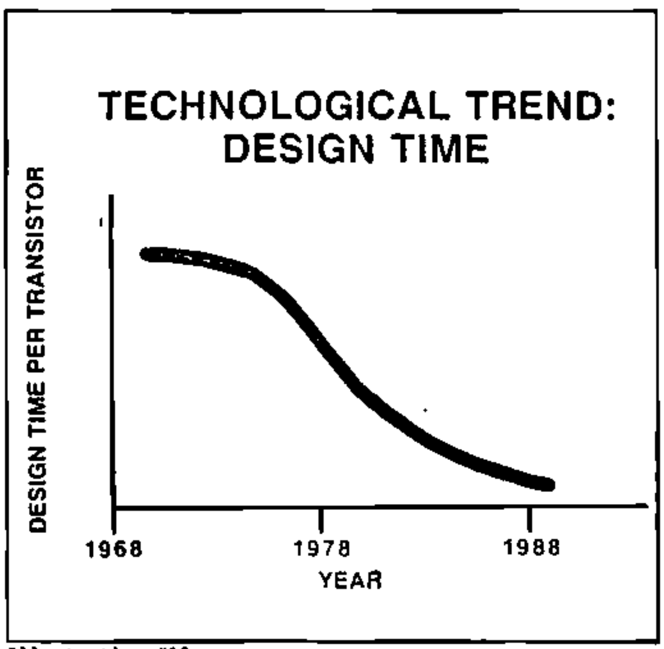


Illustration #10

puter-aided techniques for designing complex chips that had happened during the 1980s. It has made a big difference to our industry, that we can design very complex chips with far less human effort than was required to design, for example, the first microprocessor.

That example of innovation wasn't about semiconductor processing, it wasn't about device physics, it wasn't about interconnect; it was about human effort in the design process.

Complex Systems Design

The semiconductor industry today is really about providing a base technology for the information age. Silicon is the medium for realizing information technology. A silicon wafer is like an unpainted canvas to an artist. It is an undedicated medium in which we can realize systems of any kind. The process for realizing those systems is not dependent upon the particular design. Semiconductor technology shares with printing and film processing the property that the particular image determines the functionality, not the process by which realization of that silicon image is accomplished.

That notion, that silicon processing is by and large pattern independent, and that the design process really is quite different from the fabrication process, leads us to an interesting line of thought, which has been mentioned in this morning's session and I just want to say a few words about it this afternoon.

As the chips have become more and more complex, and the design techniques and design tools have become more and more sophisticated, more and more of the effort in a complex chip design goes into managing the complexity itself, and a smaller and smaller fraction of the effort is silicon specific. Thus, much of the expertise required to design a modern system on silicon is involved with the system level trade-offs and the system-level design, and less and less of it is specific to the individual transistors and techniques down on the silicon itself. For that reason silicon design has become more and more like software and less and less like, for example, laying out highways, designing a bridge, or something which is specific to the particular medium.

Personal Computers

There is an interesting parallel with the personal computer business which I would like to point out. It used to be that the computer companies not only built the big tin boxes with all the heat generating electronics inside, but also made the operating systems, and often, the application programs as well. During that era there wasn't much software, and what software there was wasn't very good.

The personal computer has given us a common medium into which software applications can be plugged (or mapped, if you like). We have an enormous wave of innovation in software development, although it is still difficult for that software to keep up with the hardware development. There is a reason for that difficulty: Most of the complexity in modern systems has been relegated to the software side of things.

How is it that we get any of it done at all if that's where all the complexity is, and we can go out and buy all of that complexity for a few hundred bucks? The reason is that there is a whole industry out there providing software, and that software gives us the application specificity to what is otherwise a pretty prosaic product, the personal computer. So, there is a whole new industry, a whole new way of doing business, and a whole new wave of innovation that has come about because of the personal computer.

Value-Added Design

We are just now seeing, in companies like Gordy Campbell's [Chips & Technologies], Weitek, Brooktree, Actel and many others, companies that have chosen to make their contribution by concentrating on the design process, putting the expertise into the design and leaving the manufacturing process to those who are good at silicon manufacturing. We heard a debate about that this morning which I won't go into. Gordy defends that turf much better than I.

We are noticing that there is a lot of value-added in the design process. And there are companies — a whole industry — now taking advantage of the fact that people are expert at manufacturing silicon. One can work with them and deal with them on the silicon manufacturing and put one's energy into the design process, where there is a lot of value to be added. From the corporate perspective, that means there is money to be made there.

None of that economics is shown in the previous figures, which are specific to the transistor-based hardware side of the business. But, if we made such a plot for software, the personal computer would be one of the innovations from a direction wholly unexpected by the then-existing industry.

The Industry Today

The industry that we are looking at today has quite a different structure than it did 20 years ago [Illustration #11].

Twenty years ago, semiconductors really meant standard products, nobody did silicon foundry, and there wasn't really a design tools industry as such. Since then, we have seen the semiconductor foundry service come on as a full-fledged partner in this business, and we have seen a

Carver A. Mead

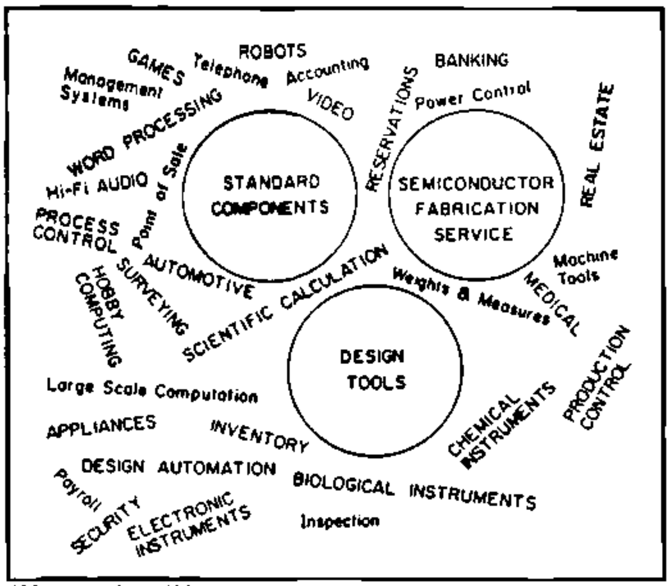


Illustration #11

blossoming of the design tools business. The rate at which design tools are evolving has not slowed down; we are seeing innovation on that front all the time.

It is an exciting world we are living in today: The result of this structure is just now really being felt — the fact that there are advanced computer-aided design techniques, there are people who spend their energy doing specific applications without having to provide all of the manufacturing elements, and we have the infrastructure in the form of the silicon foundries and the design tool suppliers.

The fact that Gordy's company has been such a resounding success has helped a lot, and there are a lot more behind him providing solutions for various problems — opportunities — in our information age.

The 1990s

We hear about the woes of the software industry and the fact that everybody can copy software. We are beginning to see a lot of information technology delivered on silicon instead of on floppy disk. I predict that there will be a lot more of that in the future. Because silicon ends up being the substrate for the information in any case, it is sort of silly to have it on a floppy disk. Putting it on a chip that will also execute the intellectual property that is there, not just provide it for execution by a general-purpose computer, is often a more rewarding way to go.

More and more people are figuring that out. There are more and more chips being supplied that are full solutions to certain applications. I predict that we are going to see much more of that in the 1990s.

Future Major Innovations

How about beyond the 1990s? Are there going to be more major innovations?

I don't see any slackening in the pace of innovation, major or minor, in Silicon Valley. I find a very healthy atmosphere. I see a lot of innovation, a lot of entrepreneurship, and a lot of health in the information industry. I am absolutely sure that in the next decade we will see major innovations happening.

I am working on a technology that I believe will be one such major innovation: using silicon to build systems that mimic the operation of the brains of animals. The brains of animals are about a billion times more effective at processing information than are our most advanced computers.

We can learn a lot of lessons from studying biology about how information is processed in those brains. Most of the lessons we learn teach us that the principles used in the brains of animals can also be implemented in our silicon medium. That's the good news.

The bad news is a lot of processing that goes on in the brain is analog. So, just now that the universities have stopped teaching analog courses and none of the books have any analog circuits in them anymore, we are going to have to go back and learn all that stuff again. Like I say, the breakthrough technologies always come in the direction you're not expecting. This one is no exception.

PACKAGING FOR HIGH-PERFORMANCE SYSTEMS: MOVING TOWARD 2000

Mary Olsson

Industry Analyst, Semiconductor Industry Service
Dataquest Incorporated

MR. BANKS: Our next speaker is on a return engagement. Mary Olsson is an industry analyst for Dataquest Semiconductor Industry Service. She has been with Dataquest for eight years, and has worked in technology assessment, market research and consulting for a total of 10 years.

Ms. Olsson has specialized in two critical areas for Dataquest: nonvolatile memories and worldwide packaging. She has recently completed a comprehensive packaging study which formed the basis of a very successful Dataquest product entitled "VLSI Packaging Study."

MS. OLSSON: Good afternoon. I would like to thank David for extending the invitation to speak before such an esteemed group of people on the subject of Dataquest's view of high-performance system packaging and what directions interconnect technology could take during the next decade.

Before moving on into the world of the unknown, I will be reviewing what we have seen take place in the worldwide market in 1990, and then, what we expect to see develop by the year 2000. This review covers emerging technologies and the infrastructure that we believe is needed to support a fully integrated interconnect technology solution for cost-driven high-performance system applications. I will also be discussing changes going on in existing and emerging technologies that will support these technologies' requirements in systems applications. And finally, what business opportunities are available and what multidisciplinary strategies are necessary for successful development of a high-performance systems packaging solution.

1990 Worldwide IC Package Market

Illustration #1 reviews the package directions for semiconductor ICs through 1990. Indications are that through-hole technology, specifically the dual inline package (DIP), while still the leader, continues to decline in share, from 79% of packaged ICs in 1989 to 68%. More important, however, was the continued shift that we have seen over the past few years to surface-mount technology (SMT). Surface-mount devices captured 32% share of total ICs in 1990, up from 21% the previous year. Most of the usage continues to be concentrated in the area of small outline packages driven by the MOS memory device families. This was followed by quad flat packs, often referred to as "the DIP package of the future," for the high-density pin count devices.

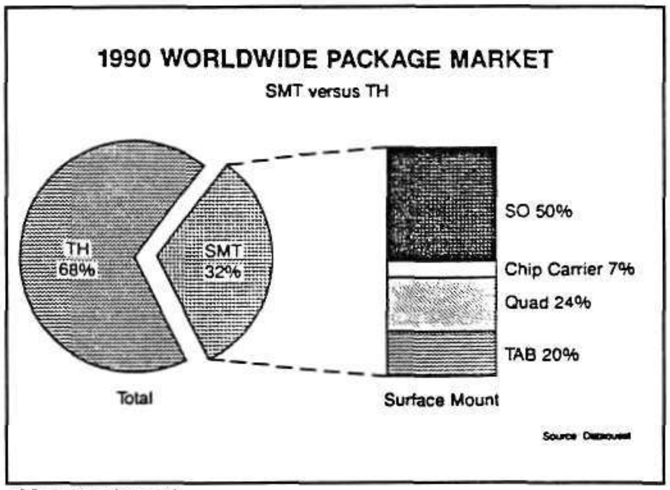


Illustration #1

Mary Olsson

Package Technology Trends

Illustration #2 is Dataquest's short-term and long-term view of packaging changes and development that could affect your long-range business plans over the next decade.

PACKAGE TECHNOLOGY TRENDS

	Current	Near Term 1993-1995	Long Term 1997-2000
DIP	Declining	Declining	End of life
SMT	Evolving	Lead space/cost	Dominance
Quad	ASIC	10,000-20,000 gates	190-600 leads
TAB	Emerging	> 200 leads/QFP	Performance 80-600 leads
Flip Chip	Emerging	Density driven	Interconnect
Multichip	Emerging	High-end driven	1,000 mips

Illustration #2

The DIP package, developed in 1963, has long served as the standard package for the majority of semiconductor devices. DIP consumption began to decline in the product areas that we cover during the 1987 time frame. It is expected to continue a normal life cycle decline through the next decade. Overall, surface-mount technology, as we see it, is still evolving.

New packages continue to be developed and new standards continue to be proposed, especially in the memory area — and challenged — all adding to package manufacturers' and board contractors' nightmares.

- Of all the surface-mount packages introduced, the quad flat pack will have the strongest growth and be the biggest star of all the surface-mount packages through the next decade. Its growth is being fueled basically by ASIC devices, with volume production currently averaging 100 leads, moving out to volume production of 600-lead devices expected by the end of this decade.

- High lead count TAB is just now emerging, driven by performance, not cost, and will be used where wire bond is no longer feasible.

- The flip-chip area, long controlled and dominated and used extensively by IBM, ultimately offers the best density of any interconnect scheme that we have seen developed up to this point.

- Finally, the multichip module [MCM], which is a collection of multiple die on a thin-film multilayer interconnect scheme, uses substrates which are either silicon, alumina, silicon carbide or aluminum nitride. We believe that this technology will offer not only system level cost savings, but also increased system performance.

We continue to believe that multichip module technology is the breakthrough of packaging interconnect that will address key limitations of advanced computation rates and chip interconnect to keep pace with the advanced semiconductor technology that is currently being developed. With this in mind, we believe that the potential demand for die into multichip modules at the end of the decade could be tremendous.

System Packaging - 2000

Surface-mount packages, as we know them today, aside from the chip onboard, TAB and flip-chip devices, will be the dominant single-chip package solution for semiconductors. Ultimately, the convergence of die into some form of MCM substrate could be rapid, and could approach 31% of total semiconductor die produced in the year 2000. [Illustration #3]

HDI Market Development

The potential demand for a high-density interconnect in a multichip module structure will only be

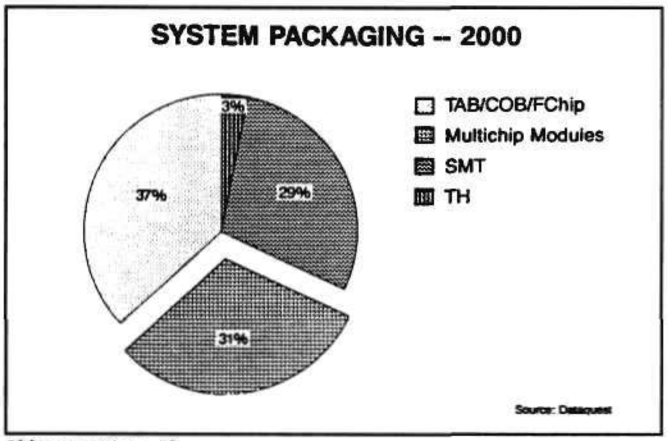


Illustration #3

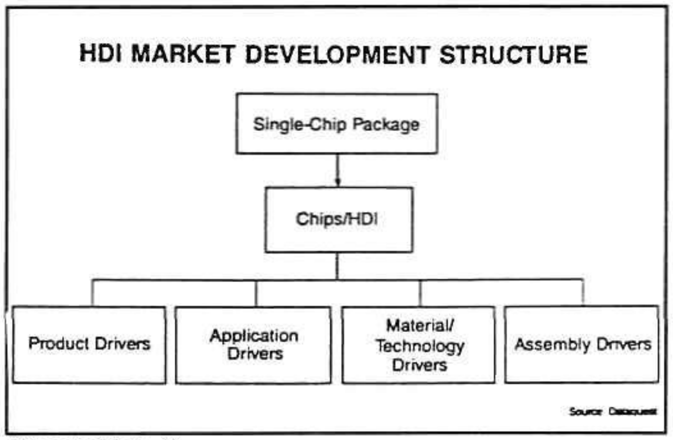


Illustration #4

possible if the infrastructure that we believe is needed is in place. [Illustration #4]

Its growth is dependent on device technology driven by the needs of end-market applications for density, speed and performance, and supported by the experience in materials technology, and ultimately, the artistic capability and design expertise from the assembly side.

MCM Drivers

If we look at the multichip module drivers from the product side [Illustration #5], today's system designer relies almost exclusively on IC technology to meet the goals of improved performance in speed, smaller size and lower power consumption, so increased system performance goes hand in hand with the development of advanced ICs.

System clock frequencies are currently averaging 20-30 MHz and are expected to reach 100 MHz by 1994. There is little question at this time about 300 MHz capability by the end of the decade.

MCM DRIVERS

	Products		
	Current	Near Term 1993-1995	Long Term 1997-2000
MPU Speed	20 MHz	100 MHz	300 MHz
ECL Logic/ASIC	150-400ps	50-150ps	Photonic logic 1.5-2.0ps
Memory	CMOS	BiCMOS	BiCMOS/FERRAM
PC	1MB	16MB	128MB
Workstation	8MB	128MB	512MB
Speed	20-80ns	9-60ns	< 25ns
GaAs Logic/ASIC	50-80ps	20-60ps	< 5-10ps?
Memory	16K/3ns	> 60K/3ns	> 100K/3ns

Source: Dataquest

Illustration #5

ASIC technologies, both CMOS and bipolar, have coped with increased system performance needs through higher gate densities and faster gate speeds. While CMOS technology performance has reduced rate delays into the 500 picosecond range and bipolar gate delays have declined to 100 picoseconds, BICMOS technology is now positioned between CMOS and ECL as it provides a solution to the fundamental limitations for both bipolar and CMOS. While there is discussion about the greater speed benefits of photonic logic devices on the horizon, BICMOS and gallium arsenide are the emerging technologies for the next decade.

The high-speed PC and workstation areas are pushing for faster memory. And, since most DRAMs could not keep up with the access times required by the next generation of microprocessors, alternate solutions have surfaced. Cache SRAMs and new cached DRAMs, with access speeds down to 12 nanoseconds, are paving the way for BICMOS megabit memories in the 1995 time frame. These will include non-multiplexed DRAMs at 35 nanoseconds and multiplexed DRAMs with sub-40 nanosecond access times.

We continue to believe that ferroelectric memory should be monitored, since successful development of this technology could have a major impact on several memory areas, including DRAM, nonvolatile and solid-state mass storage devices.

ASIC Lead Count Trends

ASIC devices, specifically gate arrays, continue to be the product area contributing to both package proliferation and development through the next decade.

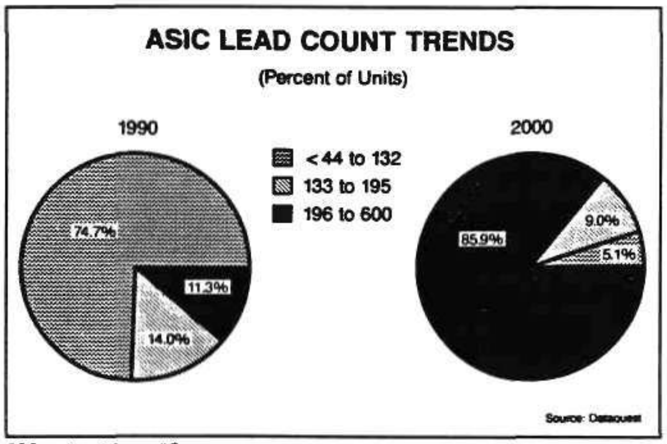


Illustration #6

The data compiled in Illustration #6 is the result of a survey of ASIC suppliers and their estimates of lead count as a percent of units over time. While the <44-pin through 132-pin consumed the largest share of gate arrays in 1990, a shift to the >200 pin count package is expected by the year 2000.

MOS DRAM Package Production

For DRAM in general, the trend continues toward the SOJ and the TSOP packages. This is expected to demonstrate the greatest area of growth for memory devices into some form of SIP/SIMM module [Illustration #7].

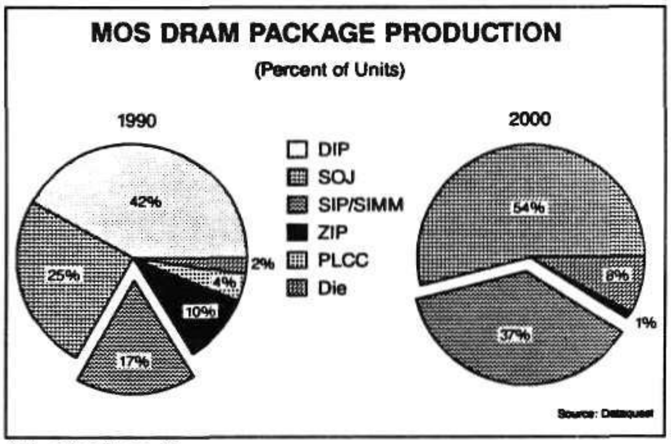


Illustration #7

While most of the development effort with TSOP packages is coming from Japan, the North American market continues to be the largest producer and consumer of the DRAM modules.

MPU Speed

While PC equipment and workstation markets still remain the highest single volume potential user of the 4 Mb DRAM device, we are recently seeing that volume purchases of 4 Mb DRAMs into modules, especially as SIMM modules, have been an easy conversion to the next density of devices.

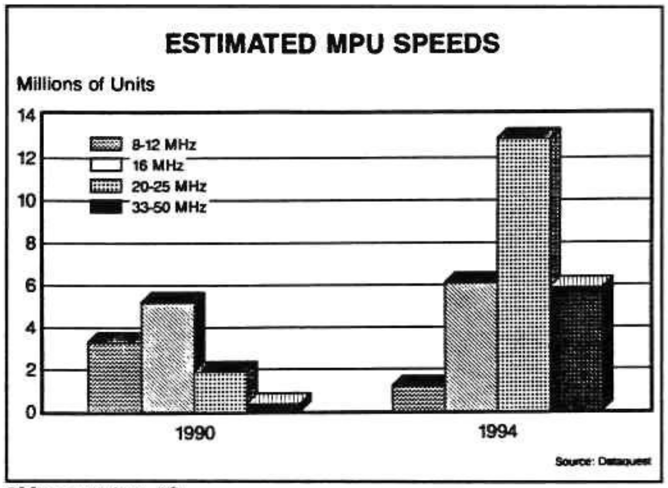


Illustration #8

Although the majority of microprocessor units shipped averaged 16 MHz and above, system clock frequencies are expected to reach 50 MHz during the next year and 100 MHz by the 1994, leaving only 20 nanosecond and 10 nanosecond clock periods for calculation cycles. There are multichip module technologies currently available that offer up to 50% performance gains at 75 MHz.

MCM Drivers

We have seen recently that for every emerging technology being developed there needs to be a driving application. The multichip module drivers from the application segments will be high-performance systems, such as those listed in Illustration #9.

All of this could represent over $100 billion in electronic revenue during the next decade. Technical workstations have been pinpointed as the equipment area offering the most potential for growth in process and multichip module technologies.

MCM DRIVERS

Applications

• Workstations	• Satellite communications
• Supercomputers	• Portable telecoms
• Portable/desktop PCs	• Optical telecoms
• LAN servers	• Energy management systems
• Laser printers	• Flight systems

Illustration #9

Computation Rate Trends

In terms of computation rates from the computer segment, workstations will challenge the limits of today's technologies, requiring leading edge speeds.

TRENDS IN COMPUTATION RATE

	Current	Near Term 1993-1995	Long Term 1997-2000
PCs	10 MHz	50 MHz	120 MHz
Workstations	10 mips	70 mips	1,000 mips
	1.5 mflops	15 mflops	200 mflops
Computer Servers	30 mips	250 mips	4,000 mips
	9 mflops	100 mflops	800 mflops
Mainframes	110 mips	400 mips	1,000 + mips
	CISC	CISC	CISC
Supercomputers	1 gflops	15 gflops	200 gflops
Parallel Computers	4 gflops	100 gflops	1 tflops

Source: Dataquest

Illustration #10

In terms of architectural design, while CISC-based workstations were the primary drivers of revenue growth in technical workstations, the RISC-based workstations are expected to claim over 60% of revenue by the middle of this decade.

Mary Olsson

Industry Trends

In the future, new applications are expected to be run on workstations and PCs that were previously run on higher order computers, thus expanding workstations and PC technologies to all types of interactive computing environments.

INDUSTRY TRENDS

Current	Near Term 1993-1995	Long Term 1997-2000
PCs Workstations	Merge to personal station	Individual systems and overall network become blurred
Computer Servers Mainframes	Merge to general server systems: compute, file, network	
Supercomputers Parallel Computers	Merge to simulation modeling server	

Illustration #11

Ultimately, we believe that the high-end and low-end systems will continue merging into each other's area, resulting in a very gray area of technical characteristic differentiation.

>50-MHz MCM Market

Of the total technical workstations produced in 1994 that are 50 MHz and above, 33% have been targeted as potential users of some form of multichip module structure, with an expected share of 44% by the year 2000 [Illustration #12].

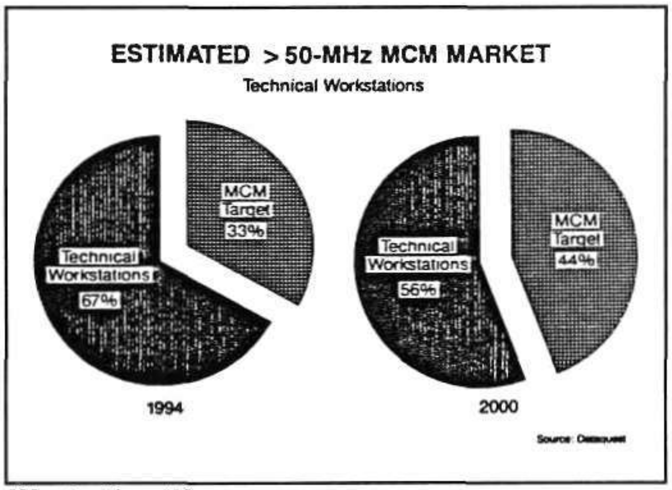


Illustration #12

Materials/Technology

We have selected a list of multichip module participants and the base substrates that they currently use for multichip modules [Illustration #13]. These can include either one or all of the above — silicon, alumina, silicon carbide and aluminum nitride.

MCM DRIVERS

Materials/Technology

Company	Substrate
Advanced Packaging Systems	Silicon/ceramic
AT&T	Silicon
Boeing	Silicon
CNET	Silicon
DEC	Copper
Dow Chemical	Silicon
Fujitsu	Glass-ceramic
General Electric	Alumina
Hewlett-Packard	Alumina
Hitachi	SiC/alumina
Holz Industries	Silicon/alumina

Illustration #13

Suppliers

Illustration #14 is a partial list of companies currently involved in some form of multichip module technology. There are currently over 47 companies that have entered the multichip module market, with services that vary from materials expertise through full-service design and development. Of these 47 companies, 34 are North American companies.

One very exciting example of this technology is the recent announcement by nChip, a start-up

MCM SUPPLIERS

Alcoa	MCNC	Polylithics
HDI Integration	Midway	Rockwell
Honeywell	Mitsubishi	Rogers
Hughes	Mosaic Systems	Siemens
Ibiden	nChip	Sumitomo
IBM	NEC	Texas Instruments
Irvine Sensors	NTK	Thorn-EMI
Kawasaki Steel	NTT	Toshiba
Kyocera	Oki	Unistructure
MCC	Polycon	Unisys

Illustration #14

that was formed and founded in 1989. This is their application-specific integrated module. Their actual module size is 1½ x 1½. It is a five-chip module that includes a licensed SPARC chip, ASICs and two cache SRAM devices.

MCM Opportunities

Ultimately what could multichip module technology mean in terms of strategic opportunities for your company or a variety of companies and their investments?

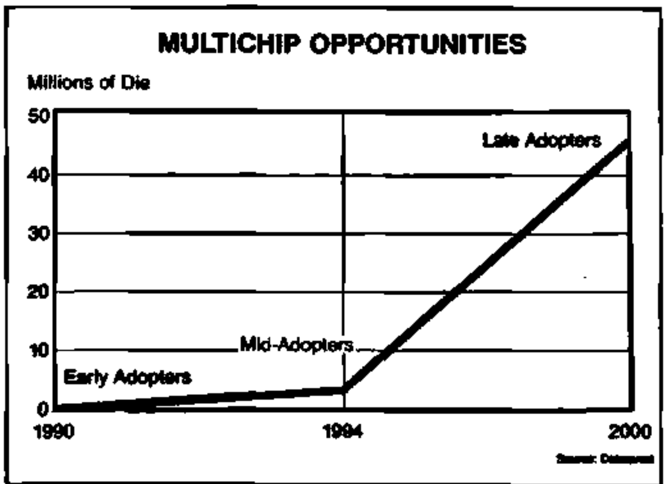


Illustration #15

The early adopters of this technology ranged from captive system houses to small groups of engineers who were taking their mainframe and custom military expertise into the technical workstation market. They will drive the initial market growth through 1995.

Since the assembly of bare chips into modules is extremely complex, most of those early adopters that survive will become specialized module manufacturers that are not necessarily semiconductor manufacturers. The mid-adopters will continue to come from the non-semiconductor manufacturing side. At this point we expect that only one-third of the module manufacturing that takes place will come from semiconductor manufacturers.

By 2000, we can assume that while semiconductor manufacturer presence will have increased, 70% of the expected merchant modules will be built by module manufacturers that are non-semiconductor.

IC Packaging - 2000

What could this possibly do to the industry?

The semiconductor manufacturers, as we know of them today, will ship standard multichip modules, as well as license and sell their technology. The other participants will concentrate on very custom multichip module specifications. The substrate vendors, of which there are many, will have to understand how to test and assemble the module.

Essentially what has been discussed, researched and designed in North American university, government and captive labs up to this point as the most cost-effective high-density interconnect [HDI] technology for high-performance systems in 2000 is now just coming out of the lab and is ready for commercial applications.

Mary Olsson

The success of the 47 participants currently involved in this market will be based on their ability to understand and incorporate all the multidisciplinary issues listed below and then be able to make the multichip module work.

- Semiconductor and PCB assembly — combine efforts.

- Semiconductor manufacturers — sell technology and modules.

- Systems houses — license technology.

Market Trends

While we believe that multichip module technology and other advanced forms that we see being developed at this point in time are the breakthroughs that will address key limitations for the advanced computers and chip interconnect, it could take five to six years before momentum actually builds.

Small entrants in this market have to deal with the start-up investment mentality, which is typically a short-term affair, with expected two-to-five year turnaround time for return on investment.

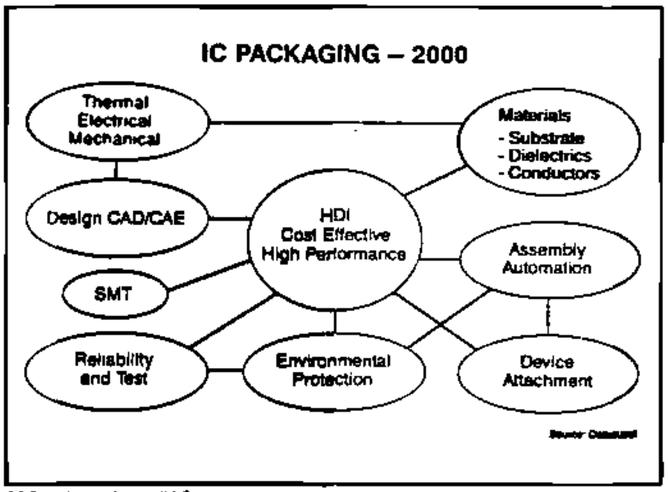


Illustration #16

Although burn-in and test are currently available and the problems in this area are being addressed, the industry does lack the CAD tools necessary for volume production.

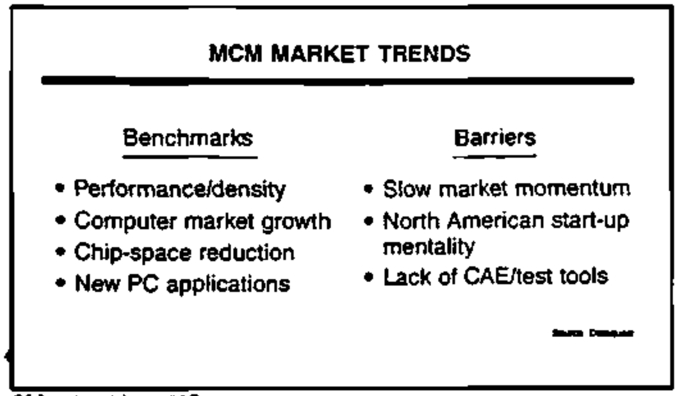


Illustration #17

Summary & Conclusions

In summary, although this new multilayer thin-film technology is just an emerging technology, it has significant potential in the world of the >50 MHz machines for tomorrow.

We believe that, although a square inch of multichip module real estate will be more expensive than a square inch of printed circuit board, the cost savings will be realized to support such a technology.

The increased value realized through surface-mount technology has paved the way for emerging interconnect technologies being developed today. Thus, we definitely believe that some form of high-density interconnect technology will change the semiconductor and printed circuit board industry as it is currently structured.

Questions & Answers

MR. ANGEL: Thank you, Mary. We have time for one or two questions. I had one handed to me on the way down. How do you think multichip modules will impact offshore assembly of integrated circuits?

MS. OLSSON: I guess the best way to answer that is to deal with the way the question was presented to the offshore assembly manufacturers. For instance, in talking to a corporation such as Anam Amkor, they had made such a tremendous investment in the surface-mount technology 10 years ago, that they feel it is necessary to continue in the same vein for the multichip module technology. They are currently dealing with it in terms of memory modules, and they feel it will be a natural transition on into the multichip module technology. Whether the capital investment will be made solely on the part of their own corporation, was in doubt.

We believe that most of the companies will make some form of cooperative effort, very similar to an nChip, where they will share the experience, the benefits and the capital investment needed to put a technology such as this into place.

MR. ANGEL: Any other questions?

QUESTION: Do you have any cost projections for the unit real estate of multichip modules, including the substrate itself, and compared to the unit density of interconnect?

MS. OLSSON: That is an area that we covered extensively in the packaging study. I would be glad to discuss it you outside and show you the study. You are welcome to look at the charts in the study where we have broken out the cost and the value of the substrate in comparison to the semiconductor content that would be placed on a module.

MR. ANGEL: I don't want this to sound like a commercial, that's not why we are here today, but Dataquest does have a special study on packaging.

LITHOGRAPHY STRATEGIES: PUSHING THE LIMITS

Peggy Marie Wood

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

I would like to welcome you to the final session of our proceedings this afternoon. I am an analyst with Dataquest's Semiconductor Equipment, Manufacturing and Materials Service. Those of you that were lying awake last night listening to the sea lions and pondering the significance of the extra "M" in the acronym SEMMS now know the answer: "M" stands for manufacturing, a new emphasis of research in our group at Dataquest.

This afternoon I am pleased to be the moderator for our panel "Lithography Strategies in the 1990s: Pushing the Limits."

Lithography equipment constitutes the largest segment within the worldwide wafer fab equipment market, essentially 25 cents of every dollar spent on front-end equipment. Currently a $1.5 billion market, we expect lithography to top $2.5 billion by 1994.

From a technology perspective, lithography equipment represents the engine driving wafer fabrication in the sub-micron regime. Lithographic processing, however, is much more than just a stepper; it is a synergistic relationship between equipment, exposure source, lens optics, resist and the mask.

With the high cost in both time and money to develop and characterize a new lithography tool and process, semiconductor manufacturers must carefully evaluate their future lithographic strategies.

There are a number of options currently under consideration, including high numerical aperture G-line, I-line (with and without phase shift masks), excimer/deep UV, direct write e-beam, point source and synchrotron X-ray lithography, in addition to a variety of mix-and-match strategies.

Today we are pleased to have four speakers discuss lithography strategies in the 1990s. We feel fortunate to have the perspective from both the supplier and the user sides of the business. Our speakers will address the current and future requirements and limitations, and, hopefully, respond to some of the controversies surrounding the use of optical, X-ray and e-beam lithography.

Often in this industry we tend to focus just on the equipment. Today, however, we have asked our fourth speaker to provide the perspective from the maskmaking side of the business, in particular, what requirements will be required from maskmaking to meet these advanced lithography strategies.

Our format this afternoon is each of our speakers will come to the podium and present their talk. At the conclusion of the fourth presentation, all of the speakers will be available to respond to questions from the audience.

We chose a panel format specifically for this topic because we want to encourage interaction and discussion, not only among our speakers, but also with the audience. So I ask you to pull out your pencils, rip a spare piece of paper out of your binder and jot down your notes, thoughts and comments regarding lithography strategies in the 1990s.

Our first speaker this afternoon is Gene Fuller, Manager of Stepper Programs at SEMATECH. We have set Gene a fairly difficult task today: Summarize in 15-20 minutes everything we need to consider in optical lithography strategies for the future. While this may seem a bit daunting, Gene is particularly well suited to the task. As a TI assignee to SEMATECH and as a manager of advanced lithography for TI's Semiconductor Process and Design Center in Dallas, Gene has been guiding, managing and evaluating development programs in optical, as well as X-ray and e-beam lithography. We look forward to his comments and perspective.

We are pleased to have Bob Hill speak on the topic of X-ray lithography, as his company, IBM, represents the major effort in this area within the United States. Bob's position at IBM is Manager for Advanced Lithography Systems Development at IBM's Advanced Technology Center in East Fishkill. His responsibilities include metrology, optical lithography (including IBM's step-and-scan program), resist development, in addition to IBM's X-ray lithography program and facility. With such a broad scope of responsibilities across the spectrum of lithographic processing, we believe Bob is uniquely qualified to present a status report on X-ray lithography, share his insights on its future, and perhaps, even let us in on the secret of when that future will be.

Neil Berglund will discuss the outlook for e-beam lithography. We are pleased to have Neil participate on our panel, as he brings experience and perspective from both the semiconductor and equipment side of the business. As many of you know, Neil has well-defined views of the role that e-beam technology will play in advanced lithography strategies for both maskmaking and direct write applications.

In addition to managing his own consulting business, Neil is Special Assistant to the President and Executive Director of Marketing for Etec Systems. For anyone who has been residing in a cave this last year, Etec is the industry alliance that was formed to acquire the Perkin-Elmer e-beam operations earlier this year.

Several months back, when we were designing the makeup of our lithography panel for today, we felt it was essential to include a member from the maskmaking community. As you will hear from our first three speakers, maskmaking is a key and vital component of any advanced lithography strategy.

Maskmakers face their own sets of challenges. They need to produce defect-free masks with smaller patterns, tighter specifications, in a timely fashion and, of course, at a cost acceptable to both the semiconductor manufacturer and the maskmaker.

We are pleased to have as our fourth and final speaker this afternoon John Skinner, from Dupont Photomask, one of the major suppliers of photomask to the semiconductor industry today. John joined Dupont earlier this year to head its Advanced Technology Group. Prior to joining Dupont, John was with Bell Labs in a variety of positions, including responsibility for the operations of its mask shop. We look forward to his insight and perspective on maskmaking issues in the 1990s.

LITHOGRAPHY STRATEGIES: PUSHING THE LIMITS OPTICAL LITHOGRAPHY

Gene Fuller

Manager, Stepper Programs
SEMATECH/Texas Instruments

I want to cover four areas here: a broad overview of some issues in lithography and comparison technologies, as well as where I see the directions in optical lithography and my guesstimate on an outlook.

Key Lithography Issues

KEY LITHOGRAPHY ISSUES

○ TECHNICAL PERFORMANCE
- RESOLUTION
- FIELD SIZE
- ALIGNMENT/REGISTRATION
- OVERLAY
- DEPTH OF FOCUS

This is all very old news. The point of showing the lithography issues in this way is that technical performance issues have been discussed since the beginning, and people have liked to focus in on resolution, field size, overlay and all those sorts of things.

Manufacturing Performance

In the last few years, we have started to put a lot more emphasis on (and, of course, at SEMATECH there is a key emphasis on) manufacturing performance — reliability, mean time to failure, mean time to repair, utilization, availability and so on — which all drive down to the bottom line: the cost of ownership.

MANUFACTURING PERFORMANCE

- RELIABILITY
- AVAILABILITY/UTILIZATION
- CAPITAL COST
- OUTPUT/YIELD/REWORK
- SEND AHEADS/TEST WAFERS/ SETUP
- COST OF OWNERSHIP

Send aheads, test wafers and setup time have become very important issues. If you are not doing something productive, you are really wasting money, so I think this is a key element in any lithography strategy.

Issues for the 1990s

These are what I would call the issues for the 1990s. Some may take strong exception to some of these requirements, but I see a lot of involvement in:

• CIM architectures of the future.

• Automated factories — I'm not talking about lights-out factories, but certainly a lot more automation.

• Clustering of tools, where you cluster coaters and developers in with the steppers, and perhaps, some other metrology tools as well.

• In optical lithography, a problem is certainly going to be managing topography. Depth of focus is ever decreasing in the stepper capability.

• Something new, what I call "wavefront engineering" — I don't know if anyone else calls it that, but I do — phase shift masks and dynamic focusing. I will mention a little more about phase shift masks later, and I think John Skinner will have more to say about that.

• Real-time process control. We have gone through the total quality scenario in most companies and are really starting to make that work. That includes statistical process control and all the data collection that goes with that. What we are looking at here are machines that take care of themselves — real time.

• And a big issue, of course, for optical, as well as some of the other technologies, is the very large field size or the large chip size that we expect.

Principal Lithography Technologies

Illustration #1 is a summary. This is a very complex field. There are two basic types of lithography technologies: the pattern replicators are those systems that use a mask; the pattern generators are those systems that get their information directly off a computer tape and do not need a mask.

I am going to focus on the optical area. Again, we have reduction type systems (5:1, 4:1, 10:1, et cetera) and 1:1 systems in a variety of flavors.

You will hear later from Bob Hill about X-ray systems, I think primarily in the synchrotron area. And there are new, exciting areas in reduction X ray, but I think that is pretty far off.

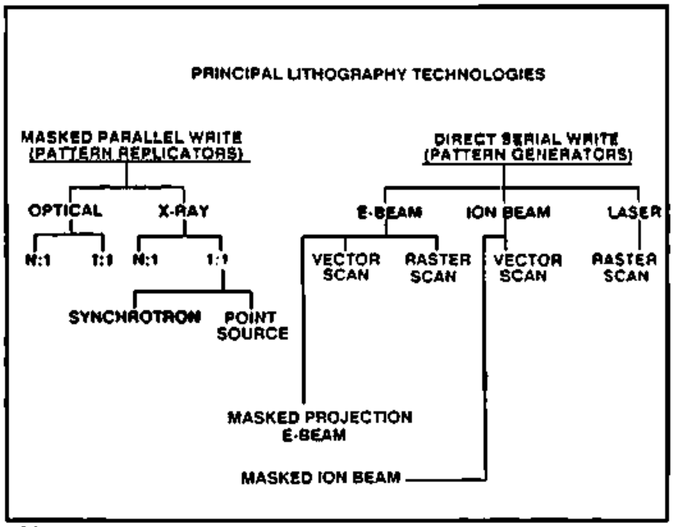


Illustration #1

We will let Neil Berglund talk about e-beam. There are currently two categories of systems. I don't think anyone takes ion beam seriously for direct semiconductor patterning on large scale, but, nonetheless, it is there.

Finally, laser lithography. One might claim that it is an optical technology — and it is in the broadest sense — but it really fits in more neatly with the e-beam and ion beam because it is a pattern generator type of technique.

Down at the bottom I have thrown in a couple of hybrids that really are not going to make a major impact in the 1990s.

Masked v. Direct Write

The big difference that we are looking at here is masked versus direct write. Again, I am not saying anything terribly new here [Illustration #2].

The masked has a parallel writing mode; therefore it automatically gives you higher throughput. And it is a high-volume technique. Of course, the disadvantage is the cost of the mask and the

MASKED VS. DIRECT WRITE

	ADVANTAGES	DISADVANTAGES
MASKED PARALLEL WRITE	HIGH THROUGHPUT MACHINE STABILITY "LOW" COST BEST FOR HIGH VOLUME	COST OF MASK MASK ERRORS/DEFECTS OVERLAY PRECISION
DIRECT SERIAL WRITE	RAPID DESIGN TURNAROUND ACCURATE ALIGNMENT FLEXIBILITY NO MASK COST BEST FOR LOW VOLUME	LOW THROUGHPUT HIGH MACHINE COST

Illustration #2

difficulty in making the mask, and it adds more complications to overlaying one level to another.

Direct serial write (e-beam, for example) is an excellent way to get rapid design turnaround. You can sit at a keyboard and come out with a circuit on the wafer in minutes. It typically has very good alignment, it is flexible and so forth; but, unfortunately, the throughput is low and the machine cost tends to be very high.

Masked Optical Lithography

I will now focus on the advantages and disadvantages of optical.

MASKED OPTICAL LITHOGRAPHY

ADVANTAGES	DISADVANTAGES
VERY MATURE "LOW" COST HIGH THROUGHPUT ROBUST MASKS MANY SUITABLE RESISTS NO VACUUM, NO HIGH VOLTAGE	LIMITED DEPTH OF FOCUS DIFFRACTION LIMITED RESOLUTION LIMITED FIELD SIZE OVERLAY PRECISION LINEWIDTH CONTROL -REFLECTION FROM SUBSTRATE -STANDING WAVES -LIMITED RESIST ASPECT RATIO

STATUS:

- ALMOST ALL LITHOGRAPHY TODAY IS OPTICAL.
- WIDE VARIETY OF EQUIPMENT AVAILABLE.
- STRONG SUPPORTING RESIST TECHNOLOGY.
- LIKELY TO REMAIN AS MOST USED LITHOGRAPHY SYSTEM THROUGHOUT THE 90'S.

Illustration #3

As opposed to X ray, for example, the advantages are:

• It is a very mature technology which has been with us from the beginning of the semiconductor industry. I will talk more about the maturity issue later.

• Relatively speaking, it is a low-cost solution, although I must make the point that we are looking at tools that individually are going to be costing more than $2 million.

• Relatively high throughput.

• The masks are robust. They are relatively stable pieces of quartz. They are not easily breakable, like X-ray masks, for example.

• Lots and lots of suitable resists. That is really not a major issue.

• From a technology standpoint, it doesn't involve high vacuum, high voltage and so on.

It has all the disadvantages that people have attributed to it:

• Limited depth of focus.

• Diffraction limited resolution. A very interesting thing that we do not always talk about is that optical lithography, in the traditional sense, is the only lithography technology that is at its physical limit at all times. In other words, we are using the diffraction limit, the optical/physical limit, for our production use. If you go to X ray or e-beam, the theoretical limits of resolution are way beyond what we are actually trying to use.

• Field size is a problem.

• Overlay precision.

• Linewidth control may be the biggest problem, however, because of reflectivity from the substrate; problems actually patterning deep resist; and so on.

Nonetheless, lithography is almost all optical today, and I think it will remain that way.

Why New Technologies Didn't Take Over

If you look at the past 15 or 20 years, every few years somebody would say, "Okay, optical is dead, e-beam is going to take over, X ray is going to take over, focused ion beams are going to take over," or whatever it is. So, the question comes up: What happened? Why didn't this occur?

I think this is an important lesson for the future. It didn't happen really for three reasons:

• Optical lithography was not really at its limit; it was only at the limit of what we were willing to pay for and what we knew how to do at that time.

• Typically, the new technologies — whether e-beam, X ray, or even new optical technologies — had projections that were more optimistic than reality, and there were various delays, technical difficulties and so on.

• The technical and manufacturing environment has continued to change in the following ways:

- New technology capabilities — this is the sort of bootstrapping that we are all familiar with in many areas, but it also applies to the optical lithography tools.

- Revised cost requirements. Looking back 10 years, an optical stepper which was just coming out cost on the order of $500,000. For the 1991-type of steppers, what has been published, we are looking at more like $2 million — more capability and so on; but, nonetheless, the price has gone up a lot.

However, if you look at what has happened to all of the other areas in the fab — whether it's RIE etching, or diffusion, or cleaning or whatever else — those elements have gone up at least as fast, and maybe even at a faster rate. Peggy just said that lithography is 25% of the cost of the equipment in a wafer fab. That has basically been true for about the last 20 years. So, there are some changes in the cost picture that allow us to continue to advance the technology.

Stepper Projection Optics

I will not spend much time on Illustration #4. I just want to point out several things for those who are uninitiated in lithography.

STEPPER PROJECTION OPTICS

- DEFINITIONS
  - -- NUMERICAL APERTURE (NA) = SIN θ
  - -- λ (G-LINE) = 436 nm
  - -- λ (I-LINE) = 365 nm
  - -- λ (DUV) = 250 nm
- RESOLUTION $R = K\frac{\lambda}{NA}$
  - -- PRODUCTION K=0.8→0.7
  - -- LAB K=0.5
- DEPTH OF FOCUS
  - -- THEORETICAL $DOF = \frac{\lambda}{NA^2}$
  - -- ALTERNATE EXPRESSION $DOF = \frac{R^2}{K^2\lambda}$
- STEPPER COMPARISON (CALCULATED, K = 0.8)

	NA	R (µm)	DOF (µm)
G-LINE	.28	1.25	5.6
G-LINE	.54	0.65	1.5
I-LINE	.45	0.65	1.8
I-LINE	.73	0.40	0.7
DUV	.50	0.40	1.0

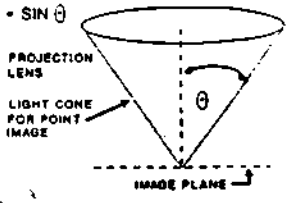


Illustration #4

G-line and I-line refer to blue and UV wavelengths; in DUV, we are typically talking about 250 nanometers or so.

You will hear numerical aperture talked about many times. It is a simple concept. If there are any opticians or optical engineers in the audience, I apologize. This is too crude, but it is very simply related to the angle of the cone of light that comes out of the lens.

Another thing you will hear talked about is the K-factor. Again, this is a number that is just thrown in as part of the equation for calculating resolution from the wavelength and numerical aperture.

There are a couple of different ways of expressing depth of focus. The original popular G-line stepper 10 years ago had a resolution of 1.25 microns and a depth of focus that really wasn't a problem. A current version G-line has about double the resolution performance, or half the feature size, but you will notice that the depth of focus has gone down a lot.

Finally, I will point out one of the reasons for using deep UV. If you wanted to get down, say, to 0.4 micron, the sub-0.5 micron regime, you are really pushing the I-line pretty hard, and the deep UV provides you an easier lens to build as well as more depth of focus.

The G-Line/I-Line/DUV Debate

You hear a lot today about G-line, I-line, and to some extent deep UV. I believe the G-line/I-line debate, if it is a debate, is way overblown. In fact, what you really need are good quality lenses of either variety. It is true that the world is moving toward I-line, but that is not what I would put in the category of a "breakthrough."

I think it is well understood by everyone that I-line will rapidly displace G-line for new sales. People are not going to rip out their G-line steppers and throw them away just so they can have I-line; but for new sales I think that I-line is going to rapidly displace G-line.

DUV still has some problems in the source, especially if it is a laser system: The resists are

G/I VS. DUV

- o DUE TO IMPROVED GLASS TECHNOLOGY I-LINE LENSES CAN BE MADE AT SAME QUALITY LEVEL AS G-LINE.

  I-LINE WILL RAPIDLY DISPLACE G-LINE FOR NEW SALES.

- o DUV (250 nm) STILL IMMATURE IN:
  - SOURCE, ESPECIALLY LASER
  - RESIST, ESPECIALLY HIGH SENSITIVITY
  - MASK/PELLICLE
- o DUV LENS DESIGN/MANUFACTURING COMPARABLE COMPLEXITY TO G/I.
- o EXCIMER LASERS MAKING STRONG PROGRESS
  - REMAINING CHALLENGES IN OVERALL LITHOGRAPHY INTEGRATION.
  - NARROW BANDWIDTH EXACERBATES REFLECTIVITY AND STANDING WAVE PROBLEMS.

Illustration #5

not exactly mature. There are still some issues about the mask and the protection on the mask, the pellicles. John may address some of those.

However, the lens design/manufacturing for the rest of the system is really no more complex than for the G-line or the I-line. The lasers are making some progress, but they are still at an immature state at this point.

New Optical Manufacturing Technologies

I mentioned before that I thought there were some new technology capabilities and I referred to the issue of bootstrapping.

In optical manufacturing, there has been a breakthrough of a sort, in that it is now possible to use a lot more computing resources to design new lenses. Designs that were not possible even five years ago are quite easily done with the kinds of workstations available today. The number of optical rays you trace through, the number of surfaces and so on, that combination has gone up by orders of magnitude.

Better quality glasses are available today. This is part of the infrastructure and technology that has helped us.

Developments in control systems on the steppers also helped push the industry along. You can now buy a workstation that you use as a controller on an optical stepper. I guess you could use it on X ray or e-beam as well.

Digital processing of the alignment signals and so on.

And, one new idea that is impacting the entire equipment industry is going to more modern software structures. The equipment industry has been a little behind with respect to some of the other technologies. There are still a lot of machine code and hard-coded kinds of things; but, with UNIX-based modular C-type languages and so on, there is a lot of progress being made.

In the area of metrology, the building of the lenses, there are much better interferometers for large area lenses. There has been a lot of progress in laser interferometers on stages, as well as overlay and optical metrology built right into the steppers themselves, so they tend to be more self-correcting.

Key Enablers

There are a couple of key enablers. I won't say much more about these [Illustration #6].

• Phase shift mask is one area that I think John is going to talk about. It is not easy to do. It has been a known technology for a long time. If you can in fact build the masks, it gives what I call virtually "free" resolution to the fab engineer. The user of these masks ought to be able to take advantage of them without worrying about exactly how they were made.

• Another area that I think is going to become a key enabler in optical lithography is surface imaging resists. This can include some semi-exotic sorts of things — for example, the so-called Desire process that came out of UCB in Belgium — or it could include such things as multilayer, trilayer, bilayer, whatever kinds of resists people have talked about for many years.

KEY ENABLERS

- o PHASE SHIFT MASKS
  - DEMONSTRATED APPROXIMATELY 10 YEARS AGO
  - TREMENDOUS INTEREST/ACTIVITY TODAY
  - MOST OF THE COMPLEXITY IN MASK PROCESS
  - VIRTUALLY "FREE" RESOLUTION TO FAB ENGINEER
- o SURFACE IMAGING RESISTS
  - SEPARATION OF RESIST FUNCTIONS
  - DECOUPLING OF SUBSTRATE ISSUES
  - WELL SUITED TO DRY PROCESSING
  - PROVEN, BUT COMMERCIALLY IMMATURE
  - COST NO LONGER A MAJOR DIFFERENTIATOR

Illustration #6

In any case, it will be necessary to separate the use of the resist as something to block an etch or an implant from the imaging function. Some things that fall out of this:

• The surface imaging resist is well suited to dry processing. There is a major problem that certainly people here are aware of, but it is true in Texas as well, disposing of used chemicals. Resist developer is a chemical that is a problem if used in high volume. So, there is a lot of interest in going to dry processing of the resist development.

• These things are proven technologically, but they are commercially immature at this point.

• I say cost is no longer a major differentiator here, but I don't want people to think that I am absolutely free with dollars. Again coming back to the idea that the equipment costs have gone up so much, if we look at the cost of a dry etcher to do this kind of processing now compared to the state-of-the-art resist developer spinner, (which temperature and humidity control, end-point detection and so on) the cost is no longer the factor of 10 that it was some years ago. There is still a larger cost for the dry processing than for wet processing when you look at the capital equipment, but it has really narrowed.

Potential Pitfalls

It is not all good. There could be some problems.

POTENTIAL PITFALLS

- o FIELD SIZE
  - HOW BIG CAN/WILL CHIPS GROW?
  - MAY NEED DYNAMIC EXPOSURE TECHNIQUES
    - "STEP-AND-SCAN"
    - SUB-FIELD STITCHING
- o DEPTH OF FOCUS LIMITATIONS
  - REQUIRES CIRCUIT TOPOGRAPHY CONTROL
  - STRONGLY FAVORS SURFACE IMAGING RESIST
  - DRIVES WAFER FLATNESS TO SUB-0.25 UM
- o RETICLE ISSUES
  - PHASE SHIFT MASK COMPLEXITY/COST
  - LARGE FIELD SIZE, 5X VS. 1X
- o PROTOTYPING/ASICs
  - LOW VOLUME REMAINS COSTLY DUE TO MASKS
  - MUST ELIMINATE SET-UPS AND SEND AHEADS
  - FAB AUTOMATION/RETICLE MANAGEMENT VITAL

Illustration #7

• Field size is certainly an issue with optical lithography. We already have a step-and-scan technique from SVG Lithography (formerly Perkin-Elmer). People have talked about, and even experimented with, sub-field stitching of various sorts. But this could be a problem.

• Depth of focus is definitely going to be a problem. It requires us to control the circuit topography. We definitely would favor surface imaging resist. And, it drives the wafer flatness requirements to the order of 0.25 micron over the imaging field which, as we know, we want to get larger.

• Another area is the phase shift mask — what field size do you go to and so on.

• Again, you end up with a problem that e-beam, ion beam, direct write laser and so on have been around to solve for a long time: It is difficult to do low-volume prototyping with optical lithography (or, presumably, any other masked lithography). In order to make this at all feasible, we have to eliminate delays and changeover times, and we will probably need to have more fab automation and reticle management.

Future Stars

I won't really say anything more about holography and laser direct write. I think these are two areas that could develop, although holography is certainly quite a ways off yet.

POSSIBLE FUTURE STARS

- o HOLOGRAPHY
  - -MANY POTENTIAL ADVANTAGES
    - -FIELD SIZE
    - -DEFECT IMMUNITY
    - -SIMPLE OPTICS
  - -SEVERAL RESEARCH DEMONSTRATIONS, STILL SOME YEARS AWAY FROM COMMERCIALIZATION.
- o LASER DIRECT WRITE
  - -ADVANTAGES OF E-BEAM, WITH LOWER SYSTEM COMPLEXITY.
  - -PROBABLY BEST USED FOR LOW VOLUME APPLICATIONS.

Illustration #8

Gene Fuller

Challenges in the 1990s

I want to close with a sort of "good news/bad news" scenario. I think a similar chart was shown at this Dataquest conference last year by Graydon Larrabee of Texas Instruments.

MICROELECTRONIC MANUFACTURING
CHALLENGES IN THE 90'S

HISTORY OF DISCONTINUITIES

TOOL OR TECHNOLOGY	YEAR DEVELOPED	YEAR IMPLEMENTED IN PRODUCTION	DELTA (YEARS)
SILICON EPITAXY	1960-61	1964	4
SILICON NITRIDE (ATMOS)	1965	1967-68	2
ION IMPLANT	1969	1973	4
TiW METALLIZATION	1969-70	1975-77	6
SCHOTTKY TTL	1970	1974-75	6
CCD'S	1970	1981	11
RIE	1975-76	1980	5
ADVANCED SCHOTTKY (ALS)	1976	1980	4
POLY EMITTER	1976	1984-85	8
REFRACTORY GATE	1976	1983	7
SOI-ION IMPLANT	1978	1989	11
TRENCH	1979	1987	8
SILICIDE	1978	1985	7
LIGHTLY DOPED DRAIN	1980	1986	6
TiN LI	1986	1988	2

MEDIAN TIME FROM DEVELOPMENT TO IMPLEMENTATION -----> 6-7 YEARS

SOURCE: GRAYDON LARRABEE, TEXAS INSTRUMENTS

Illustration #9

In order to introduce some new technology — most of these are new materials or, in a few cases, new product types — the average time from when you have developed it until when it goes on to a product in some reasonable volume is six to seven years.

Another way to look at that is shown in Illustration #10, also from Graydon Larrabee: What is a road map for developing a 1-gigabit memory, let's say, that comes out in 1999 or 2000?

The new technologies — whether it is optical lithography versus X ray or whatever — have to come in about 10 years earlier than that. You do not really start product development for some time, but you must have the technology development behind that.

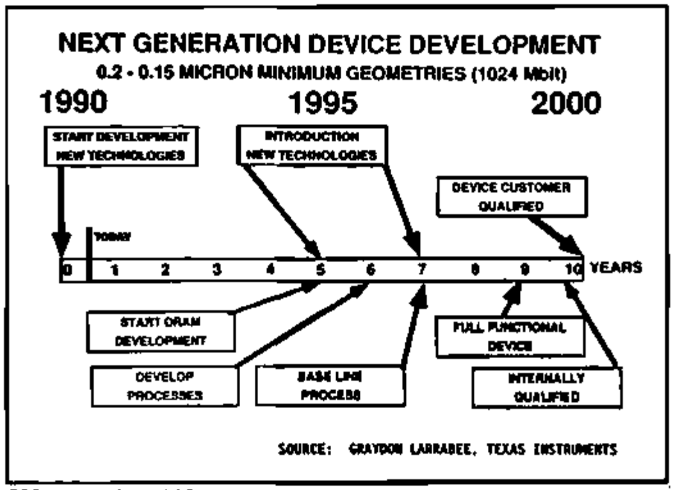


Illustration #10

This drives two things:

• First, optical lithography is here and must be the tool of choice for some time to come.

• Second, if X ray, e-beam, ion beam, or whatever, is going to take over ultimately, whether that is five years or 10 years down the road, we need to have major activities ongoing right now or we will be too late when we need it.

Requirements for Sub-0.5 Micron Optical Lithography

Illustration #11 is somewhat of a recap. We need:

• "Perfect" imaging systems, which means flat imaging, no field curvature — absolutely perfect, no astigmatism and all the other problems that come with it.

• Planarized wafers — topography must be less than depth of focus.

• Surface imaging resists — minimized depth of focus requirement and reflectivity control.

REQUIREMENTS FOR SUB 0.5 MICRON
OPTICAL LITHOGRAPHY

- "PERFECT" IMAGING SYSTEMS
  - DIFFRACTION LIMITED OPTICS
  - FLAT IMAGE SURFACE
- PLANARIZED WAFERS
  - TOPOGRAPHY MUST BE LESS THAN D.O.F.
- SURFACE IMAGING RESISTS
  - MINIMIZED D.O.F. REQUIREMENT
  - REFLECTIVITY CONTROL
- WAVEFRONT TUNING IN THE FAB
  - PHASE SHIFT MASKS
  - ADJUSTABLE FOCUS DURING EXPOSURE

Illustration #11

• Wavefront engineering (or wavefront tuning) in the fab — phase shift masks; adjustable focus during exposure.

Outlook for Optical Lithography

What do I think is possible?

• Optical will go down to 0.25 micron.

• Depth of focus is a problem.

• CD control is always difficult, but it will happen.

• Down in the 250 nanometer range is certain for exposure wavelength, possibly below that.

• Overlay probably isn't a whole lot different for optical than a lot of the other technologies, but that will get there as well.

• Field size greater than 20 mm x 20 mm.

• Resist is not a problem.

• I think 1X masks are going to be difficult, but we will let John Skinner tell us about that.

One Conceivable Scenario

Illustration #12 is one conceivable scenario for the mid to late 1990s. This is my own hallucination. I don't want anybody to interpret this as a SEMATECH view or a TI view.

HOW FAR CAN OPTICAL LITHOGRAPHY TAKE US?

ONE CONCEIVABLE SCENARIO FOR THE MID TO LATE '90'S

WAVELENGTH:	250 NM
NA:	0.65
FIELD SIZE:	30 MM x 30 MM
SUPPORT TECHNOLOGIES:	PHASE SHIFT MASKS SURFACE IMAGING RESIST DYNAMIC FOCUSING PLANAR TOPOGRAPHY
K-FACTOR:	0.5
RESOLUTION:	0.20 MICRON
DEPTH OF FOCUS:	0.5 MICRON

Illustration #12

What we might accomplish here:

• DUV.

• A fairly high numerical aperture, but quite doable.

• Field size of 30 mm x 30 mm, or some variation on that.

• In order to make that happen, I think we need these four support technologies — or at least the phase shift masks, surface imaging resist and planar topography. Dynamic focusing, where you actually vary the focus during exposure, is still up in the air.

Gene Fuller

- I think we are going to drive our process so that the K-factor can approach 0.5.
- That gives us a resolution below 0.25 micron.
- And, very minimal depth of focus (0.5 micron).

Summary

In summary, optical lithography still lives — and I think it will continue to live for a long time.

There is a lot of R&D going on. Due to the changing technical infrastructure, optical lithography looks strong and will continue to develop.

I am not going to be an optical bigot and say that is the only way to go, but it certainly will be the dominant approach in the next decade for high-volume semiconductor production.

Thank you.

LITHOGRAPHY STRATEGIES: PUSHING THE LIMITS
X-RAY LITHOGRAPHY

Robert W. Hill

Manager, Advanced Lithography Systems Development
IBM Corporation

I will speak about X-ray lithography technology. First, I will go into "why X ray?"; second, the X-ray system itself and its various key elements; third, programs in other places in the world; fourth, XRL extendability; and then I will summarize.

Why X Ray?

First of all, I agree with Gene that optics will go down in resolution to the 0.20-0.25 micron region. In fact, I believe that ultimately optical resolution will get down into the 0.10 micron region.

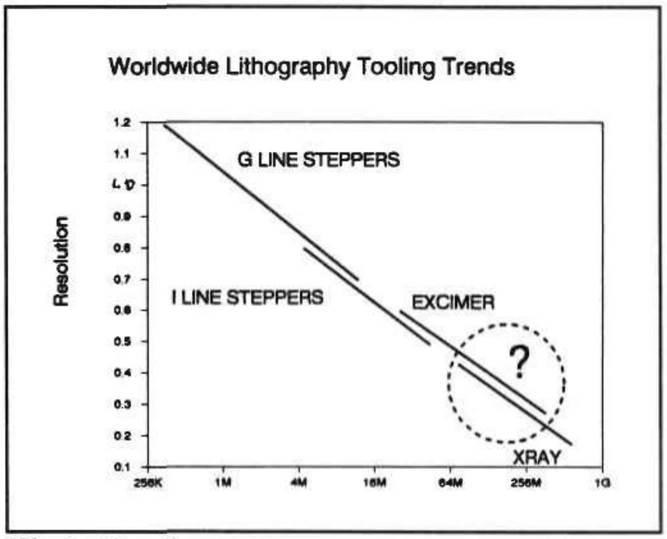


Illustration #1

I do not think resolution is going to be the limiting factor. The problem is the decreasing depth of focus which, in turn, causes us to use "tricks" in the optical arena which involve additional processing and additional defect susceptibility.

X ray offers us much greater depth of focus and the resolution capabilities that we need. And, by the way, it will be driven by DRAM-type applications.

What Is X Ray?

What is X ray? I have a foil here of X-ray proximity printing [Illustration #2]. There are really two types: the point source and the synchrotron type of printing. The point source is used in this illustration.

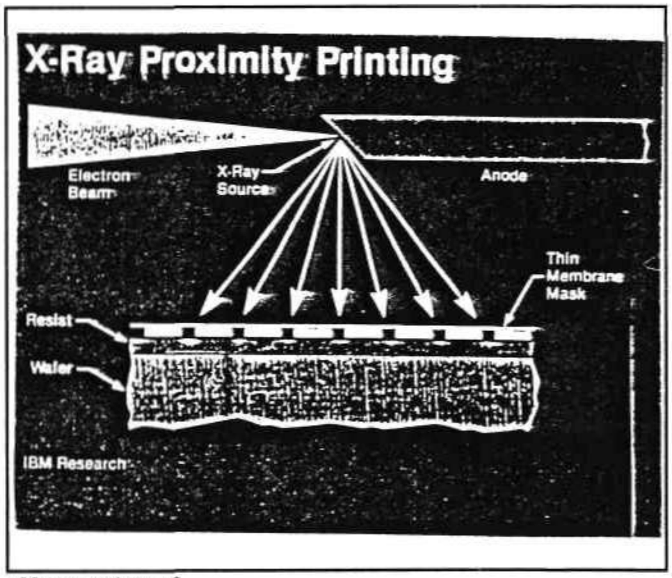


Illustration #2

The X rays diverge from the point source, pass through a silicon mask and the pattern on the absorber (we use gold); thus, the image is transferred through the mask into the resist where it is developed and transferred to the wafer.

Robert W. Hill

Advantages

The advantages of X ray are:

- High resolution.

- Increased depth of focus.

- We believe and we have demonstrated — IBM Research has processed 10 levels of CMOS devices — that X ray has simpler and more robust photo process steps. We have been able to do 0.5 micron CMOS devices with all single-level resist processes, and there is no reason why X ray cannot go down to the 0.25 micron region.

- We also believe X ray has a greater defect insensitivity. For the wavelength that we have selected (10 Angstroms), X ray can write through particles up to roughly 4 microns in size with an atomic number similar to carbon.

- We believe that the simpler process steps, the greater defect insensitivity and the necessity of not having to use multilevel resist systems for X ray, will give us lower processing costs.

Disadvantages

However, there is no free lunch counter in the lithography business. As most of you know, there are some disadvantages:

- For synchrotron X ray, there is high initial cost of the synchrotron X-ray facility and it must be made three to four years in advance of when you will use it.

- There is also a general reluctance to make a major lithography technology change. I believe that you will have to show substantial improvements in cost over optical methods in order to make it happen. As we heard earlier in Dr. Mead's second principle, you need "headroom."

- It has a much more complex 1X mask technology than what we are presently using with optical reduction.

Key Elements

X ray is a rather complex system.

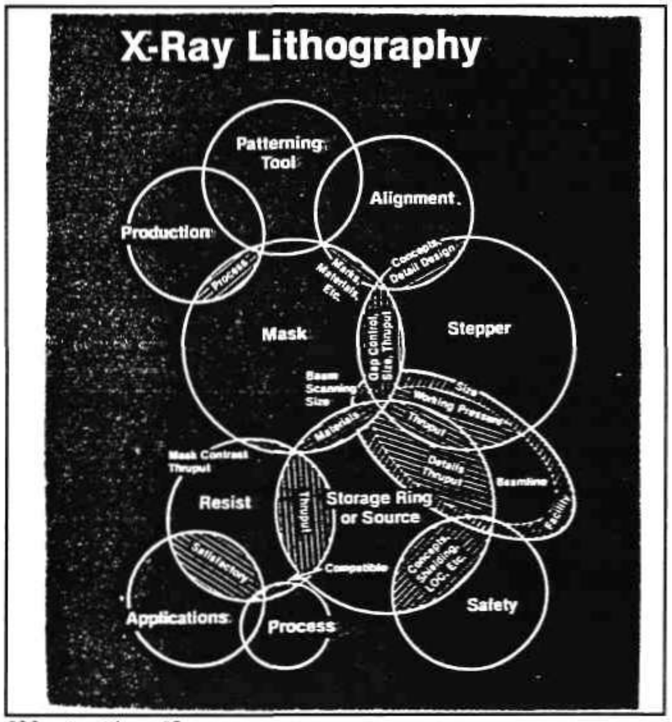


Illustration #3

I will just touch on the key elements:

- Mask.

- Stepper.

- In the case of synchrotron, there is another element between the stepper and the "light bulb" (or storage ring), and that is the beam line.

• In addition, you have resist.

• We have found, by installing one of the first industrial synchrotrons in the world, that there was a lot that had to be done in the industrial safety area. We are still writing the standards and specifications at the present time.

• The facility that is required to house the ring and the steppers is very complex and helps to tie all of the key elements together. It is not shown on this slide.

X-Ray Mask Status

The mask is one of the most difficult items for X-ray technology.

X-RAY SYSTEM COMPONENTS

X-RAY MASK STATUS

- Structure
  - Substrate: B-doped Si, Si Nitride, Some SiC and Diamond Work.
  - Absorber: Au, W, Ta and Combinations
  - Frame: Considered for Standardization (NIST)
- Patterning: E-Beam
- Inspection and Repair: Tools Under Development (Micrion and KLA)

Illustration #4

The substrate that is presently being used in most facilities is boron-doped silicon (B-doped Si). Some of the Japanese companies are using silicon nitride. In Europe there has been some silicon carbide work, as well as there is some diamond work being done which has been sponsored by DARPA.

In the absorber area, a number of absorbers have been used. Gold is the favorite one at the moment, but there is also tungsten, tantalum and combinations of the two.

For the mask frame we are presently trying to come up with a standard so that stepper manufacturers and mask manufacturers can use a common mask format. NIST has a committee presently working on that, again under DARPA auspices.

For patterning there is the e-beam. Neil Berglund is going to talk a little bit more about that.

For mask inspection and repair, there are tools under development for inspecting and repairing 1X mask by KLA (inspection) and Micrion (repair). These are DARPA programs.

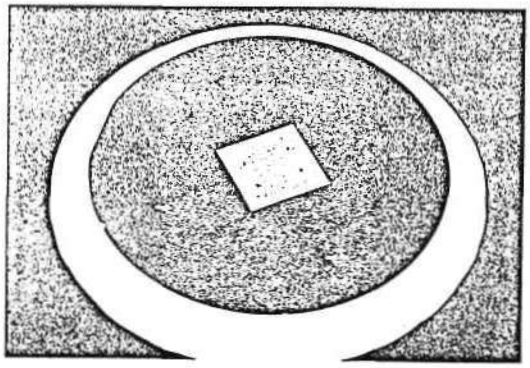
Illustration #5 is a picture of an X-ray mask. This was manufactured at IBM Research in Yorktown. They are pioneers in the field. You see a roughly 1" x 1" patterned gold absorber. On it you can see the device pattern. The little black spots on the outside are alignment windows. The silicon membrane is roughly 2 microns thick. The overall size is about 10 centimeters (4").

Source

The source is the device in X-ray technology that tends to draw attention as it is the first use of synchrotron for industrial purposes. There are a number of other potential sources for X-ray radiation [Illustration #6]. They are:

• Nikon and Perkin-Elmer have produced tools with point sources.

• The synchrotron storage ring, which is at present the most popular source, and probably most of the X-ray exposures around the world have been exposed by synchrotrons installed at na-



X-RAY MASK WITH:

2.4 x 2.4 cm B-Si MEMBRANE 2 μm THICK.

0.5 μm GOLD ABSORBER WITH A DEVICE PATTERN

FREE-STANDING ALIGNMENT MARKS IN WINDOWS

OVERALL MASK SIZE: 10.0 cm.

MOUNTED ON PYREX RING.

Illustration #5

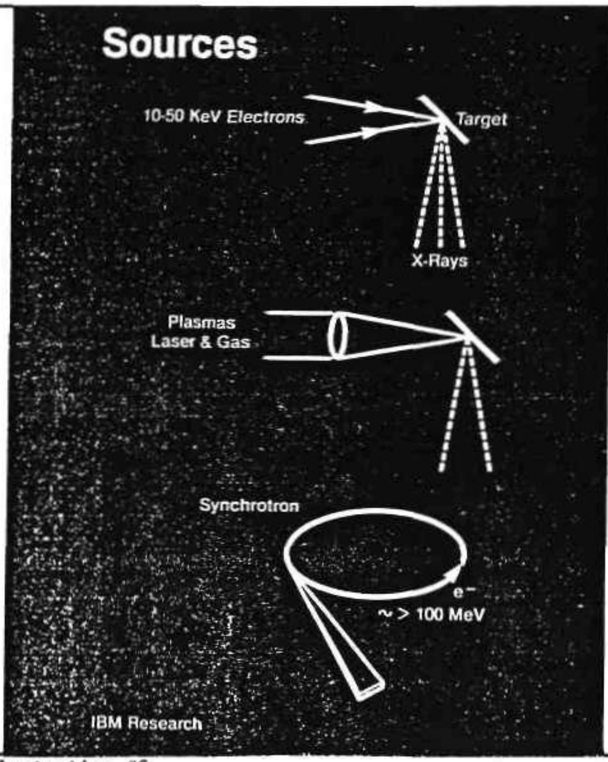


Illustration #6

tional labs and various other government facilities.

- Pulsed plasma.

  - Laser-heated plasma (Hampshire tool).

  - Pinched gas plasma (the Suss tool, in Germany).

  - There has been some activity lately in exploding wire.

There hasn't been too much done with the last two:

- Transition radiation, which is bombarding a foil with electrons which produces X rays on the opposite side.

- X-ray laser.

Illustration #6, the most popular sources, shows the point source, the laser plasma source and the synchrotron.

Because of the long length of the beam line, the x-ray radiation at the wafer appears to be collimated; the point source, the laser plasma and gas plasma sources all require additional collimation.

X-Ray Source Contenders

The main X-ray source contenders today are:

- The IBM/Oxford storage ring.

- There are also Japanese storage rings of the CSOR [Compact Storage Ring] type. One of them is the Aurora ring being manufactured by Sumitomo Heavy Industries.

• There are also numerous "warm" rings. One of these, and probably the best one for lithography applications in this country, is the ring being manufactured by Maxwell Brobeck Co. for Louisiana State University.

• In the laser plasma region is the Hampshire Instrument Company's exposure tool.

• Gas plasma is used by the Suss Gmbh tool.

Illustration #7 is a photograph of the IBM/Oxford ring. This is now in the commissioning process and is operating at about 50% of its final energy at present. The commissioning has been going very well and we are looking forward to receiving it for the IBM Advanced Technology Center in East Fishkill, New York.

The high technical risk area for this type of ring is the helium cooled dipole magnets which have a 4.5 Tesla field (45 kilogauss) and are extremely strong bending magnets.

Exposure Tools

Illustration #8 is a picture of the Hampshire Series 5000 X-ray stepper system. These are now starting into production and will be delivered to American companies in the near future.

Series 5000 X-Ray Stepper System

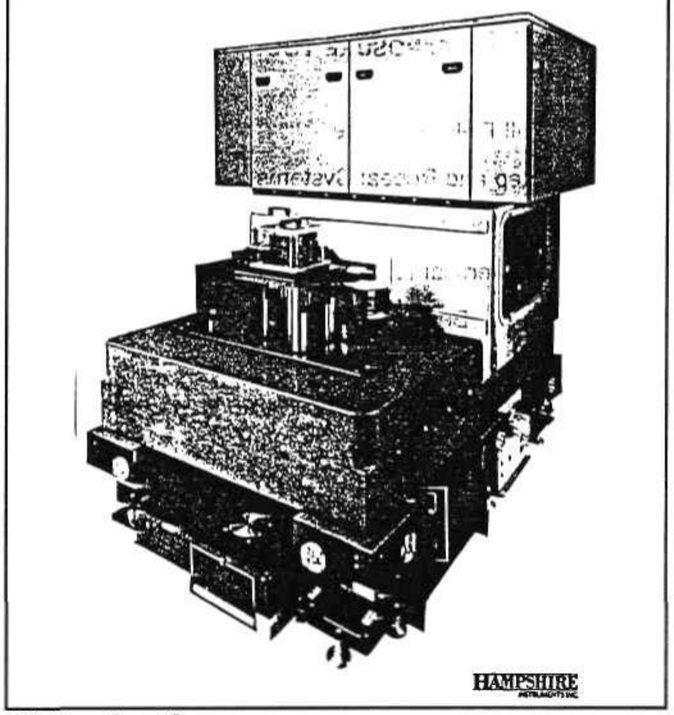


Illustration #8

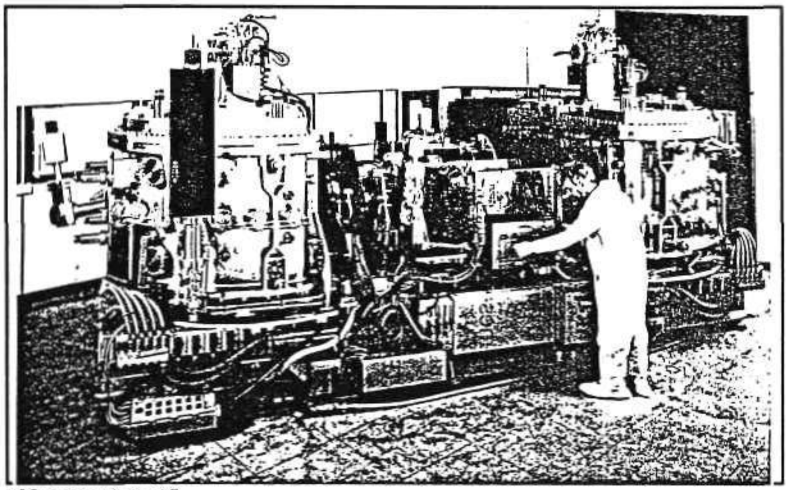


Illustration #7

Let's talk a little bit about the stepper which goes on the end of the beam line. It is a full field exposure step and repeat system. The field can run anywhere from 25mm x 25mm out to 20mm x 50mm.

Point sources use horizontal tables. The vertical tables are used on the synchrotron type of applications. They are connected to a beam line which connects them to a synchrotron, and installed in the beam line there are beam scanning optics which scan the field on the exposure tool. The stepper then moves the wafer field by field.

On the end of the beam line, to preserve the vacuum and also act as a filter, is a beryllium window.

Robert W. Hill

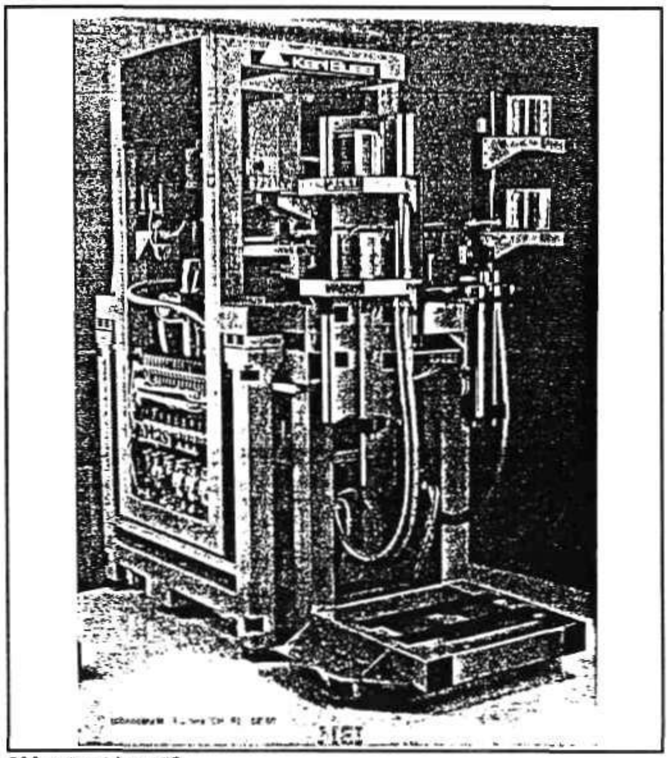


Illustration #9

Illustration #9 is a picture of one of those tools. There are two companies producing synchrotron exposure tools in the Western world. One is the Suss tool, which is being used at Brookhaven on the IBM beam line, and in addition will be used in the Alf facility as we bring it up. It is also being used at Fraunhofer Institut in Berlin. There is also a DARPA project with SVGL which will produce a stepper that will be used initially at the University of Wisconsin facility.

Resist Requirements

I'm not going to say too much about resist. It has essentially the same needs as optical resist. We have done a lot of X-ray patterning in optical resist. I will show you some photographs that were done in a Novolac type photoresist that we have used for the last 10 years. I believe there will be — and there are available now — some pretty good resists in the X-ray regime.

These are some pictures of processed device structures that were taken by the IBM Research Division. They are 0.5 micron contacts. Notice the very sharp edges that you get with X ray and with lines going over other lines. This is characteristic. It is hard to get bad pictures with X-ray exposures.

Worldwide Programs

There are a number of X-ray lithography programs around the world right now:

• The main one in the United States is IBM. It was started in its Research Division in 1980. We presently are bringing up a full facility in the Advanced Technology Center utilizing it. DARPA is funding a number of support programs as well as source programs, such as at Hampshire Instruments.

• In Japan, there are a number of TRON programs. NTT is one of the major ones. There is the SORTEC group which presently has a warm ring operation, and they are starting to do lithography experiments.

• In Europe, the Europeans initially were the farthest ahead. The Fraunhofer Institute in Berlin has two rings that they have used: the BESSY ring, which is the conventional ring; and a compact synchrotron called COZY. They are used by a consortium of German-based companies exploring X-ray lithography.

Unresolved Issues

There are issues in X ray, most of which I assume will be discussed by the panel. Some of these are:

• When do we expect X ray to come in? We expect to be ready late in the 64 megabit time frame.

• X ray suffers from high initial instrument cost, particularly the synchrotron form of X ray.

• The 1X mask technology is probably the major technical exposure today.

• Extendability is an issue, not because of the diffraction limits, but as you approach the diffraction limits, the gap between wafer and mask shrinks and becomes very small.

Where we end up will depend on how close to the wafer we can "fly" the mask. It is probably somewhere in the 6-10 micron region. It is believed the lower resolution limit will be around 0.15 for very complex patterns.

In the area of ultimate resolution capability, Dr. "Hank" Smith, of MIT, has demonstrated 400 Angstrom isolated lines using X ray. More experiments are needed to better define the limit, and they are now in the process of being designed.

From the standpoint of the future, AT&T has recently demonstrated future potential for projection X-ray lithography using the ring and an undulator on their beam line at Brookhaven National Laboratory.

Summary

To summarize:

• X-ray technology is here.

• We believe that shorter wavelengths offer us substantially better depth of focus and resolution.

• We believe that the depth of focus will ultimately be diffraction limited by the gap between the mask and wafer.

• The 1X mask technology is the main risk. John Skinner will talk about that a little bit more.

• We believe very strongly that it will result in simpler, more defect-free processing and cheaper processing costs.

LITHOGRAPHY STRATEGIES: PUSHING THE LIMITS
E-BEAM LITHOGRAPHY

C. Neil Berglund

Special Assistant to the President and
Executive Director of Marketing
Etec Systems, Inc.

For many years I have been firmly convinced that optical systems are going to meet the needs of the industry throughout the rest of this century. I first came to this conclusion when I unsuccessfully tried to build an electron beam system in the early 1970s, and I haven't changed my mind since.

But the issue of the lithography direction is much more complex than which one is going to "win." They are all going to win to one degree or another, and they are all going to have their applications. I would like to address some of those for you.

E-Beam Lithography Status

The first point I would like to make is that the lithography process is only part of an overall system problem of going from a design tape to a finished wafer. I am going to talk a little bit about that because it is impossible to try to compare direct write e-beam to some of the other systems that need masks without taking that perspective; otherwise, you get into an apples-to-oranges comparison. I am then going to address two major applications of electron beam lithography systems: one in maskmaking and one in direct write. Finally, I will summarize some of the general conclusions that I, at least, have come to.

Device Patterning Flow

The lithographic process, to me, starts at the design data interface and extends all the way through to the finished wafers. I have to take that perspective in order to compare them, as I have said before.

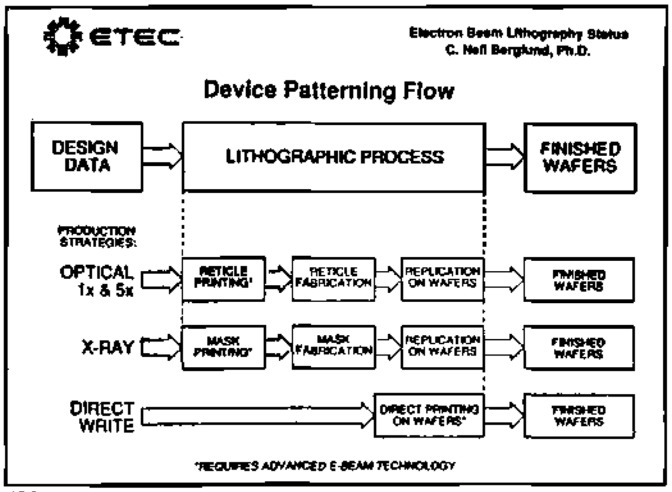


Illustration #1

If you start with that kind of a general system view, you recognize the first thing you do when you make a partitioning of that sort, where you architect the problem in that way, is to clearly define some boundaries in such a way that maybe you can deal with one side of the boundary independent of the other side. That is generally true. For example, on the design data, you handle that particular interface with design rules.

Within the general lithographic process, in the case of masked processes you can divide it up into three steps:

• The printing of the reticle pattern; that is, taking the design data and printing it.

• The fabrication of the reticle, which includes not only the processing itself, but issues such as inspection and repair and the pelliclization of the finished device.

• You then have to replicate that on the wafer. In the optical case that involves a stepper, but, as you can see, it is only one of three parts of the lithographic process.

You can make a similar argument for X ray. In direct write, you eliminate the mask and you are directly printing onto the wafers.

I have asterisked various points to show you that, regardless of which one wins, electron beam technology is fundamental. It is going to be important, regardless of which way you go. It is important for (a) the maskmaking and (b) for the direct writing. So, the issue of which technology is going to be dominant is really not of great importance to Etec, and it is certainly the reason why I am intensely interested in electron beam technology, and in doing what I can to make it available on a timely basis for the industry.

I will now come back to the boundaries between these various parts of the problem. We have always fundamentally tried to draw these lines so we can ignore what happens on one side if you are on the other side of the boundary.

In the case of maskmaking, people have established a set of specifications for masks which, to my knowledge, have really not been verified as reflecting what the silicon needs in detail. I can say categorically that it does not measure all of the characteristics that are of importance.

As a result, the simple way to handle mask specifications — and John Skinner might refer to this a little later — is you try to make the mask have specifications which make its errors negligible on the wafer. That is one way of transferring the problem from one guy to the next.

Phase Shift Mask

Phase shift mask is another way of doing it. If you look at what happens with phase shift masks, what you are asking for is multiple layers on the mask, and possibly much higher resolution on the mask, in order to get higher resolution on the wafer. Those kinds of tradeoffs go on all the time.

The technical breakthroughs that will occur primarily result from changes in those boundary conditions or changes in the fundamental architecture of the system. So, if you try to compare, for example, optical to X ray, you are ignoring the differences in the mask fabrication portion of it. And if you try to compare direct writing to any of these others, you are again in an apples-to-oranges type comparison unless you look at this overall problem and its various implications.

Maskmaking

Let me turn now to the mask requirements. You will hear some more about mask requirements from John Skinner a little later. He may even make some more demanding requirements. I want to make a few points with Illustration #2.

As you can see, the pattern address grid that is used to make up the 5X reticle does not necessarily reflect the design grid that is used by the

5X Reticle Specifications
1987 - 1996

Year	1987	1990	1993	1996
DRAM Generation	4 Mb	16 Mb	64 Mb	256 Mb
Minimum Feature Size (wafer)	0.8 μm	0.5 μm	0.35 μm	0.25 μm
Pattern Address Grid (5X reticle)	0.25 μm	0.10 μm	0.05 μm	0.025 μm
Layer Data Size	30 MB	120 MB	200 MB*	300 MB*
Registration (two-point align)	0.20 μm	0.12 μm	0.08 μm	0.05 μm
Throughput	<1 hr	<1 hr	<1 hr	<1 hr
Maximum Corner Radius	0.25 μm	0.15 μm	0.10 μm	0.05 μm

* Assumes data compaction

Illustration #2

designer. In fact, the primary reason for the finer address grid is driven by increments in critical dimension control, not from the design grid itself. You can see that they go down more or less by a factor of two every generation of DRAM, which corresponds to the increase in the density. The data size similarly goes up.

At some point, you run into a data handling problem which gets totally out of hand. You have to put in some form of data compacting, or data hierarchy, in order to be able to handle the designs.

The registration gets progressively smaller, but the throughput demanded stays the same. This means that maskmaking equipment is on the same treadmill as steppers or some of the other key fab equipment; that is, for every generation of DRAM, you need a major improvement in its performance on a three-year cycle. With a piece of equipment as complex as an electron beam system, this is extremely difficult to do. The amount of research that has been going on worldwide in this area is insufficient to be able to do this over the long term. Etec is very fortunate to have access to the IBM technology to allow them to at least try to address this problem at this point in time, but that is not a long-term solution.

I will not talk about corner radius too much, except to say that as you get into these very fine features, the corners become a more important part of the device, and they are going to become increasingly important because if the corners are too round you have trouble even inspecting for defects.

Integration of Wafer Fab & Maskmaking

Another point I wanted to make is that, as part of the partitioning and architectural issue I talked about earlier, I believe that the silicon manufacturing people have to view maskmaking as an integral part of their process. There are too many subtle tradeoffs that are going on now, and they are going to become even more important in the future.

A few are shown in Illustration #3. There may be others that I haven't mentioned here.

Integration of Maskmaking Technology with Wafer Fab Process

Year	1987	1990	1993	1996
DRAM Generation	4 Mb	16 Mb	64 Mb	256 Mb
Compensate Stepper Distortion	No	Maybe	Yes	Yes
Localized Sizing	No	Maybe	Yes	Yes
Phase Shift Masks	No	Maybe	Yes	Yes
Proximity Effect Correction	No	No	Maybe	Yes

Illustration #3

• One issue of extreme importance to the fab is to try to do multiple layers, or do different layers on different stepper tools, in production. But there is an extremely difficult problem of matching one stepper to the other in terms of overlay.

One possible solution to this that is being examined by a number of companies is to distort the reticle to compensate for the distortion in each lens. That is what I mean by stepper distortion compensation.

• Another thing that is happening, even today, certainly in the R&D labs, and will become commonplace in future technologies, is the issue of localized sizing. What I mean by that is that critical dimensions on the masks have to be varied within a design rather than globally across a design. It turns out there are issues like resist thinning which lead to different CDs [critical dimensions] across the finished device, and you have to compensate for those locally.

• Phase shift masks you have heard about, and you will probably hear more.

• Proximity effect correction is unique, at least as a term, to electron beam systems, and that will have to be included in the future, certainly by the time the 64 Mb is done — and maybe sooner — depending on the resolution requirements demanded by phase shift masks.

I am not going to spend any more time on the maskmaking, but the point I wanted to make is that electron beam technology is going to be fundamental to the maskmaking portion of this technology in the future, and it is basically running against the limits right now for 5X reticles, which is what I have been talking about. If you think of what is going to happen for the 1X systems, like 1X optical or 1X X ray, you can start to see that the problems in getting quality masks are going to get extremely difficult in the future.

Vector Scan vs. Raster Scan

When we come to e-beam lithography systems, there are basically two approaches that are common: a vector scan system and the raster scan system. The raster scan systems that I am referring to here are primarily shaped beam raster scan systems. Illustration #4 is my projection of what is going to happen to the relative percentage of the market for these machines over time.

Raster scan systems have a lot of advantages. They are going to be with us for as long as I can see. While this is a small percent of the market, you will find that, since the market increases with time, the raster scan total market is quite respectable right out through the rest of this century.

In the vector scan area, I see the market increasing with time. There are a number of reasons why that is going to happen.

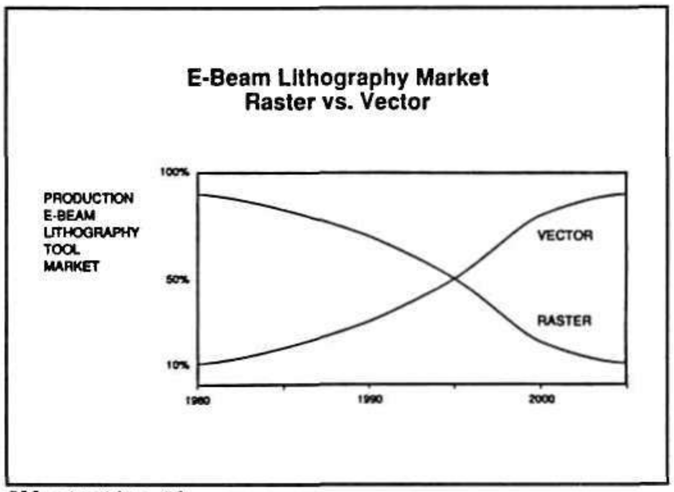


Illustration #4

Before I get into that, let me explain why this happened. Back in the 1970s, Bell Laboratories developed a raster scan system called EBES, which was then commercialized by Perkin Elmer (or by Etec) and by Varian, and became the standard for making masks in the world. That is the primary reason why it has captured such a large share of the market early.

System Architecture: Raster vs. Vector

However, some of the trends that I talked about are driving us farther and farther toward the vector scan system.

• The maskmaking tools will tend towards a vector scan architecture because of economics. In a raster scan system, you are printing every pixel whether there is an exposure there or not; whereas, in a vector scan system, you only expose those areas that need to be exposed.

• The data file size is one of the biggest reasons why you are going to go to a vector scan machine. A shaped beam vector scan machine inherently has hierarchy in it, and allows you to greatly simplify the data files for any given design. I will come back to that a little bit when I talk about direct write.

• Another reason is that you can separate edge placement precision from the address grid itself. In raster scan systems, the edge placement precision determines the address grid you must use. That gets so small that the time it takes to run a machine starts to increase unacceptably.

• Elimination is too strong a term, but you can greatly reduce corner rounding because you have independent control of it.

• In the maskmaking area, the dominant machine is a raster scan machine. Raster scan machines have never been a major factor for direct write. They have always been vector scan machines in one way or another.

Direct Write

Let me now turn to the direct write issues. I am going to take a marketing viewpoint rather than a technology viewpoint. Illustration #5 is my own way of separating it. I will explain why in a moment.

I see three applications of electron beam direct write:

Direct Write

Market Segments:

- **Research & development requirement**
  - **Advanced prototyping**
  - **Very high resolution, very low volume**
- **Low volume production**
  - **ASIC, Gate Array, GaAs**
  - **Medium to high resolution**
- **High volume production**
  - **DRAM production**
  - **High resolution Mix & Match**

Illustration #5

• The research and development area. I define that as being the area where you want to use the direct writer to enhance your R&D so that your analysis of return on investment, cost of ownership and so on, is more strategic than fundamental from a manufacturing point of view.

There are two areas within this research and development segment that are of interest:

- Very high resolution/very low volume has been the traditional area of direct writers for many years.

- Advanced prototyping is a relatively new application for these machines. You heard earlier, particularly in Gene Fuller's talk, why this is important. This is being done primarily in Asia, not so much in the United States.

The application is this: In order to develop the new RAM technologies, you need to be able to not only do the lithography, but you have to have something to allow you to develop the devices, do the device characterization, develop the etching processes, the deposition processes, and you need those well in advance of when you are going to go into production. The earlier you can get them, the better off you are.

The optical systems are getting later and later in being available for such uses, so an increasing number of people are buying direct write e-beam machines strictly to prototype advanced DRAMs so that they can get started at an early stage on the development of the other related aspects of the processing.

At this point in time this is probably the most solid application of direct write that exists.

There are two production-type applications. One is the ASICs (low-volume) production, which is medium to high resolution. I am going to talk about that for a moment and come back to this foil later on for the high-volume.

The application of direct write for ASICs is really restricted on the low-volume end by doing it, for example, using programmable logic devices and the like. On the high-volume end, it is limited becase it is more cost-effective to use an optical mask for replication.

Direct Write vs. Optical Costs

Illustration #6 shows the lithography cost per wafer level — just the cost of processing the lithography per wafer level — versus the number of wafers that are run.

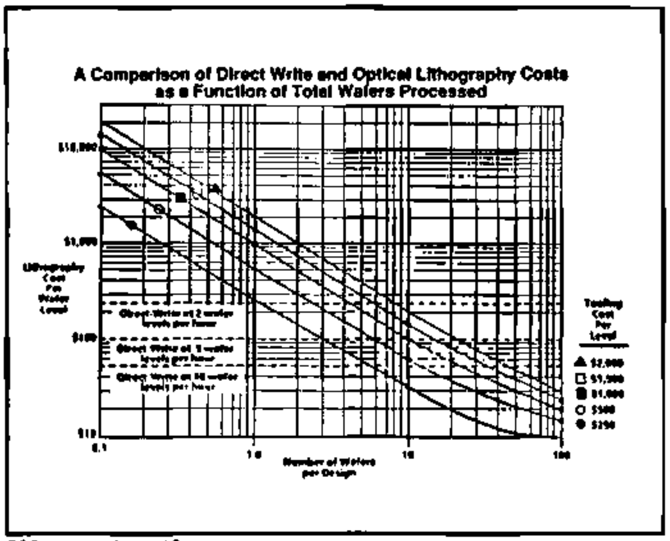


Illustration #6

If you have to spend a lot of money on a set of masks or a set of reticles, then you have to amortize that total cost over the number of wafers. In direct write you don't have that cost.

This provides you with a comparison depending on the reticle cost. In view of some of the comments here, I might have stopped too soon at $2,000. I suspect some of these phase shift masks are going to be extremely expensive. On the low-volume side, PLDs and similar kinds of devices are much more cost-effective than anything you might do with direct write. Above 100 wafers or so, optical processing is the most cost-effective way to manufacture.

Direct Write Applications

But there is this range in between, which generally covers a number of wafers that is roughly equivalent to the average number of ASIC devices that are bought today by a typical customer. So, you have this area which is very, very promising for manufacture. That is one of the application areas which, at this time, only one commercial house and a number of systems houses, in particular one very large U.S. company, do in manufacture for gate arrays.

I see the low-volume ASIC production and application as the major place where you are going to use direct write in the future.

Another area which nobody is doing right now, but which Hitachi is just starting to address and we are starting to address also, is the high-volume production for DRAMs. There is no doubt in my mind that it will be many years before a direct writer will produce wafers or process wafers cheaper than an optical system.

However, a vector scan system has the advantage — or disadvantage, if you want — of having a throughput which is highly dependent on the percentage coverage of each layer. One of the applications that you can think of for direct write is to actually focus a direct writer to apply to specific layers only, in a mix-and-match mode.

Let me give you an example. Suppose you went after only the contact layer with the direct write e-beam. You would strip that machine down so that's the only thing it did. It would not be a general-purpose direct writer. It could do that maybe with difficulty, but the focus would be strictly on that low coverage contact layer. If, for example, you made contacts half the size that you can do *optically* at any given generation, I submit that, even with today's machines, you can make a very strong argument that the return on investment of a machine such as that is extremely positive.

Hitachi has taken the view that they are going to go a step further and use custom apertures, where you have particular shapes — dog bones, squares, rectangles, whatever you want — and if you work that back to the designer and say to the designer, "use only these shapes," then you can get up to, say, 20 wafers an hour out of an electron beam machine because you don't have to spend time shaping the beam, and it becomes much more effective to use.

This comes back to the point I made earlier. If we start looking at this as a system problem and work back from what we want on the wafer back to the designer through the lithography tool, you can come to some interesting conclusions, particularly if you open up yourself to the thought that you can mix and match on a layer by layer basis.

Lithography Cost Trends

Illustration #7 is my projection of lithography costs. You can argue with the absolute numbers. For example, lithography cost per wafer level is direct cost. I have left out all the extra costs associated with getting the high-precision flatness, planarization and all the other stuff that goes with these complex optical processes.

The lithography cost per layer for optical looks something like this:

• With 1X aligners, it was down in the $1.00 range.

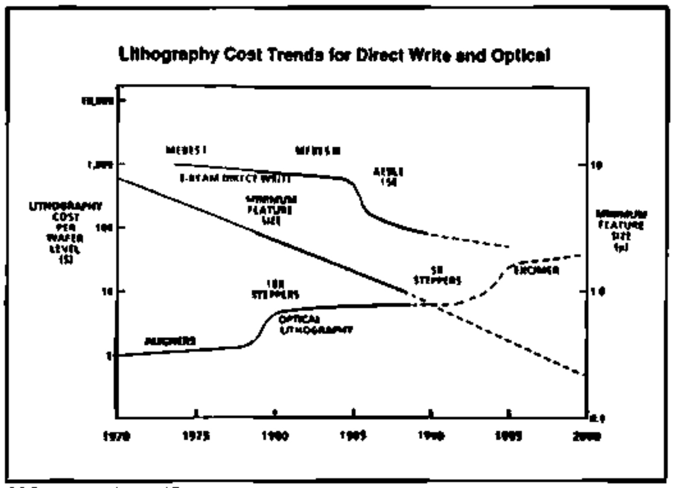


Illustration #7

• When you went to steppers, either 10X or 5X, which occurred in the 1980 time frame, there was an initial jump in the cost, to the $5-$10 range per layer, which then stayed relatively constant. It stayed constant despite the resolution getting tighter and tighter. That was primarily a learning curve effect. In other words, you had competition going on between the cost of the machine to get tighter and tighter resolution, and the learning curve which was getting the throughput up and the up-time such that and the net cost was roughly the same.

What is going to happen when we get into excimer steppers or some of the other novel stepper techniques, is that you are going to have another jump in cost. You can argue about this, but you will probably get up somewhere in the $20-$30 range. At that point the whole economics of manufacture — particularly, if you are up around 30 layers, you are talking about $600 a wafer just in the lithography cost alone — is going to make people sit back and start to look at alternatives.

During this same time frame — not because the machine didn't get more expensive, but because the throughput went up — direct write systems have been on this kind of a curve.

Prior to 1986, the reference is to a raster scan system. After 1960, I refer to the Aeble 150, a vector scan system. If you project the costs of direct write e-beam, you are down into comparable numbers around the end of the century.

Before that happens, as I mentioned, specific layers done by direct write e-beam are going to be quite cost-effective if they are low percentage coverage.

So, I see a very bright future for direct write e-beam if one opens up the spectrum to look at mix and match and to change the way in which you set the design rules and the way in which you integrate direct write into your processes.

Conclusions

In summary, I believe:

- E-beam is a key technology for maskmaking — and, in fact, is a key technology for anything we are going to be doing.

- Vector scan is going to dominate long term.

- Direct write is economical for low-volume production today, particularly for ASICs, and I believe it will be cost-competitive against any of the other techniques for selected production layers by the mid-1990s.

LITHOGRAPHY STRATEGIES: PUSHING THE LIMITS MASKMAKING

John G. Skinner, Ph.D.

Director of Advanced Photomask Technology
Dupont Photomasks, Inc.

The previous talks described three competing lithographic techniques: optical lithography, X ray and direct write. Optical lithography is the predominant technology for today's IC designs, X-ray lithography is waiting in the background for optics to run out of steam, and e-beam direct write is nibbling at both technologies trying to take the low volume codes, or maybe fill in for high resolution where it may be needed on short notice.

Fortunately for the maskmaker, masks can be used with all three technologies.

Questions for Maskmakers

There are two questions facing the maskmaker today:

1. When must we replace our present equipment and processes to meet future optical needs?

2. When must we get ready for X-ray masks?

Since the advent of a commercial e-beam system, MEBES (which, as Neil mentioned was the outcome of an AT&T development called EBES), which became available in the early 1970s, maskmaking has too often been taken for granted. The e-beam system allowed masks to be made relatively easily and with higher precision.

This being taken for granted is coming to an end. Fortunately for the maskmakers, SEMATECH, through Dick Clover of Intel, included maskmaking as part of their study and recognized that photomask must be considered whenever you consider the IC manufacture.

In addition to the maskmakers, the tool makers are also there. Between the maskmakers, the tool makers and SEMATECH, we were able to predict some of the specifications required for a year or so from now.

However, even with that kind of a working arrangement, it is very difficult to predict five years ahead. For that reason, the maskmaker must use his own initiative to determine his future.

Procedure

The procedure I have used is to:

• Summarize the probable limit and the time schedule for available optical technologies.

• Estimate the optical mask specifications as a function of time.

• Use the industry's recommendation as to when X ray will become a major lithography tool.

Lithography Time Schedule

If you look to the predominant steps that are going to take place in lithography, the 0.5 micron lithography is coming in about now [Table 1]. The time schedule that I have given for 1991 is the time period when we are getting toward the end of the R&D and the beginning of qualification of production. The R&D period is about 3% of the mass required and the qualified produc-

LITHOGRAPHY TIME SCHEDULE

MIN. WAFER FEATURE	TIME SCHEDULE	LITHO TECHNOLOGY	DEVICE [DRAM]
0.50 um	1990/1	I-LINE CM*	16 M
0.35 um	1992/3	I-LINE PSM** Kr-F	64 M
0.25 um	1994/5	Kr-F PSM** X-RAY	
0.20 um	1996/7	Kr-F PSM** X-RAY	256 M

*CM CONVENTIONAL MASK
**PSM PHASE SHIFT MASK

TABLE 1

tion is about 10%-14%. It looks as though that can be done with I-line using conventional masks.

If we look at 0.35 lithography, that will begin to come in for qualification production in 1992-93 using I-line with phase shift masks, and maybe deep UV.

I had thought that maybe one of the previous speakers would describe phase shift masks. I do not have a sketch of it, but during the discussion period I will gladly use the viewgraph machine to show you what it is.

It is generally believed that X ray will come in at somewhere around 0.25 micron (in the 1984-95 region), and it may also be the deep UV using phase shift masks.

Optical lithography is projected to go down to 0.20 um or less resolution. That will be coming in 1996-97. Again, it will be with deep UV with phase shift masks or with X-ray lithography.

5X Reticle Specifications

Table 2 may look a little complicated. I have put certain mask parameters down the left column.

5X RETICLE SPECIFICATIONS

[CONVENTIONAL MASKS]

MASK PARAMETER	YEAR	90/91	92/93	94/95	96/97
	MIN. FEATURE / TOLERANCE	0.50	0.35	0.25	0.20
REGISTRATION	X 20 %	0.10	0.07	0.05	0.04
CD-TO TARGET	X 10 %	0.05	0.035	0.025	0.02
CD-RANGE [3 sigma]	X 8 %	0.04	0.028	0.02	0.016
DEFECT SIZE	X 50 %	0.25	0.18	0.13	0.10
EDGE ROUGHNESS	TO BE SPECIFIED	?	?	?	?
SUBSTRATE	QUARTZ	90 mils	250 mils	250 mils	250 mils
MIN. MASK FEATURE	X 4	2.0	1.4	1.0	0.8

ALL DIMENSIONS IN MICROMETERS, EXCEPT WHERE SPECIFIED.

TABLE 2

Across the top is the year when qualification production starts. There is the minimum feature on the wafer. The next column is the tolerance of a 5X reticule based on a certain percentage of the minimum feature of the wafer.

For example, for 0.5 micron lithography, the registration would be 20% of that, which is 0.1. If you look out to the 1996-97 range, it becomes about 40 nanometers.

The CD-to-target is approximately 10% of the wafer feature. This means that if you measure many features on the mask, the average of those features to the specified value has to be within that value. That is going from 50 nanometers down to approximately 20 nanometers.

The total variation across a 5X reticule can be only 40 nanometers for the mask required in a year or two. That has to drop down to about 16 nanometers in five years.

There is some disagreement as to what defect size will be required, but it is something of the order of 50% of the minimum feature size on a 5X reticle. That requires detection of all defects of 0.25 micron or larger in the next year or two, dropping down to detection of 0.10 micron five years from now.

The edge roughness is beginning to play an important role in the quality of a mask. For example, with the typical process techniques that are used today, the uncertainty in the width of a feature line due to the shape of the edge can be greater than the total CD-range which is allowed (40 nanometers).

The substrate is almost certain to be 90 mils for the next year or two, mainly because of availability. But, as we look ahead, the error in length due to the gravitational sag in the 90 mil 5" substrate is approximately 20% of the total error that you are allowed in precisely placing the pattern. That is very important.

The minimum mask feature is given down below. The minimum feature on the wafer is always a little bit less than 5X. It is going to be roughly 2 microns on the 5X reticule for the next year or two, dropping down to about 0.8 microns five years from now.

Some liberty is taken with these specifications. The actual values that are being asked for by the mask users are about one-third less than these. I believe there will be a balance between what is being asked and what will be available. Therefore, these numbers are slightly larger than the values being asked for today.

If we look at 1X reticules, the specifications are going to be approximately one-third those values. The registration will have to be over an area that is 1/25 compared to that same pattern on a 5X reticule. So, the registration may be possible, but the CD-to-target to get one-third of the CD variation across a 1X mask is going to be very difficult, be it in optical lithography or X-ray lithography.

Improvements Needed 1991-1996

Having said what we need, what do we have available?

IMPROVEMENTS NEEDED TO MEET

1991 TO 1996 PHOTOMASK NEEDS

YEAR	1990/1	1992/3	1994/5	1996/7
REGISTRATION [PATTERN GEN]	UPGRADE OR NEW	NEW [FASTER]	NEW + MULTIPLE WRITE.	
CD CONTROL	IMPROVED PROCESS	NEW MATERIAL & PROCESSING. MORE AUTOMATION. CONCERN WITH EDGE PROFILE		
	IMPROVED CD STANDARDS NEEDED.			
EDGE ROUGHNESS	ACCEPTABLE	IMPROVE. MEASURE EVERY MASK.		
DEFECT DETECTION	AVAILABLE	SIGNIFICANT DEVELOPMENT NEEDED.		
SUBSTRATE	QUARTZ - NO DOMESTIC SOURCE.			
METROLOGY	AVAILABLE	WILL NEED IMPROVED CD & LENGTH MEASURING TOOLS.		
PHASE SHIFT MASKS	DEVELOP TECHNOLOGY	ROUTINE USE		
X-RAY MASKS		PREPARE		

TABLE 3

In Table 3, I have summarized the status of maskmaking today compared to what is needed in the years ahead.

Registration

Registration is the ability to overlay one level with another — or, preferably, the ability to overlay to a standard grid. In order to achieve the specification that is needed (approximately 0.1 micron), we either have to upgrade our existing MEBES machines, or pattern generators, or we have to purchase new ones. There was nothing purchased in the 1980s that meets any of the specifications that we need for the 1990s.

When we are talking about pattern positioning accuracies of the order of tens of nanometers, it is almost impossible to build an electro-optical mechanical tool with that accuracy, and so there will be an increased use of multiple writes, multiple exposures, in order to improve the accuracy. That is going to require multiple write and longer times as we go toward the 1995 period.

CD Control and Measurement

We can no doubt achieve what is needed in CD control by improving our present process, but as we look ahead to 1992 and beyond, we are going to need new materials and new processing techniques.

There has to be more automation. Much of the process at the present time in maskmaking is done manually.

There have to be more smart systems which have feedback to control the operations, similar to the one described by AT&T last year, and that has been running in AT&T's shop for about four years now.

We have no real CD standards. The present quality is ±50 nanometers, and we are looking to specifications on the production mask of ±40, going down to ±20.

The edge roughness that is available today is acceptable, but as we look ahead, the uncertainty in the width due to edge roughness is greater than can be allowed. We will be setting up a technique to measure the edge roughness on every mask that is delivered.

Defects

Defect detection is available now. There are defect inspection tools that in the die-to-die mode will go down to 0.25 micron, to 95%-99% probability, but that is still not 100%. When we go to a single die and we have to go die-to-data, that will take more complexity.

There is going to be significant development needed at significant cost to go down to 99% probability for 0.10 micron.

Substrates

In substrates, we have a problem inasmuch as there is no domestic source. There is the ability to both deposit the chrome films on top of quartz substrate and also to polish them, but we have no manufactured source of quartz in this country.

Metrology is available for today, but we need improved length measuring and linewidth measuring tools for 1992 and beyond.

Phase Shift Masks

This year the technology is being developed in phase shift masks. Phase shift masks have the ability of extending the life of millions of dollars of existing wafer exposure tools, but they do not come without a price. That price is you have to be using your wafer exposure tools at their limit in order to take advantage of phase shift masks.

In X-ray masks, we obviously have to be prepared for that.

Summary

In conclusion, the IC industry, including maskmaking, is very capital intensive. The difference between wafer and mask fabrication is that wafer people talk about throughput on a given machine in wafers per hour. The maskmaker has to talk about hours per mask.

As we approach the mid-1990s, the cost of the mask has to go up to reflect not only longer writing time due to multiple writes and larger pattern densities, but also for the higher precision needed on the mask.

The industry has to recognize that as the design rules go down and mask specifications get tighter, the cost of photomask has to increase. But one thing it does give you is a continuation of an established process that is, I am sure, going to continue for a long time.

As I said earlier, photomask will never die, it won't even fade away.

LITHOGRAPHY STRATEGIES: PUSHING THE LIMITS
PANEL DISCUSSION AND OPEN Q&A

Moderator

PEGGY MARIE WOOD
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Panelists

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Special Assistant to the President and
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GENE FULLER
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SEMATECH

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Manager, Advanced Lithography Systems Development
IBM Corporation

JOHN G. SKINNER
Director of Advanced Photomask Technology
Dupont Photomasks, Inc.

DR. WOOD: I would like to ask our four speakers to return to the stage and join us for the question session. As I mentioned, we encourage questions from the audience. In the meantime, I have a few questions of my own.

One of the factors that Gene alluded to in his talk was the development cycle for wafer fabrication equipment and the requirement to be actively developing tools far in advance of when they will actually be used in a production environment. The question I would like to address to the panel at large is: How do you think that the development cycle will change in the future? Do you expect it to get substantially longer in the future for advanced lithography tools, and how do you expect incremental development costs to be affected by this?

DR. FULLER: I hope it doesn't get any longer than the 10 years or so I alluded to. Now, of course, that was development from the basic technology all the way to shipping volume semiconductor product to more and more customers.

The cost of everything seems to be going up. I think that has been an issue of many conferences and discussions. I don't see anything that I am aware of in optical lithography, for example, that is going to drive that cost back down.

DR. BERGLUND: One of the comments I would like to make on that is that in recent years we have become increasingly limited in the development time cycle by the availability of equipment. In particular, Gene alluded to roughly a 10-year cycle on a new technology. To develop a new electron beam machine, for example, takes on the order of eight years when you take a similar perspective. Furthermore, somewhere well back in that 10-year cycle you have to have the masks for the technology, so we are talking a much longer cycle for the total technology development than the 10 years Gene is talking about. I can see that this problem is going to get worse in the future than it has been in the past.

MR. HILL: I have looked at that a little bit. I find if you look at the X-ray technology, IBM started its X-ray program in 1978. It is 1990 now. And were we to proceed with it for production and order a second ring today, it would require a minimum of three years. A lot of these advanced technologies today take 12 to 16 years from start of research to production. Major technology advancements can take greater than 10 years in my opinion, far greater.

I would also point out that the ion beam writing machine being developed in Vienna has been under development in various places and companies for 10 to 12 years, and it probably has another three to four years before it is ready for production.

DR. FULLER: Let me add one comment. I think one of the problems — or perhaps one solution — is if we could figure out how to do certain things in parallel, we could telescope the time. But, as I indicated, a lot of this stuff is bootstrapping of sorts. It takes developments in the semiconductor industry to further develop the equipment and so on. That is a challenge for us all.

DR. SKINNER: Can I just add a comment on maskmaking?

DR. WOOD: Sure.

DR. SKINNER: One of the problems with maskmaking is that it is a fairly small field. Talking from experience, the maskmakers tried for many years to get improved equipment. The problem is nobody else wants it. The market is so small that equipment manufacturers are very reluctant to put the effort into such a small field, even if it is needed, and so that effort has to come from the IC industry and not just from maskmakers.

The other problem is a lot of equipment has been developed for wafers and then tried to be adapted for masks. A good example is linewidth equipment. In most cases a mask is used in transmission. Most of the wafer metrology tools are built for reflective systems. There is a difference in the width of a feature depending whether you measure it in reflection or transmission. That is the sort of problem that faces the maskmaker.

DR. WOOD: I would ask John Skinner to respond to this question as well as any of the other panel members who would like to share their opinion. In the past, semiconductor manufacturers themselves largely produced their own masks, but there seems to be a trend toward the merchant maskmaking business. Please comment on the reasons for this and what we can expect to see in the future.

DR. SKINNER: One of the primary reasons is that we are getting into a period again where there is very little that exists that can be used for the 1990 photomasks. Almost everything has to be developed and has to be purchased new.

The statistics that I was given by Dataquest say that leading edge is only 3% of business. It is very difficult for a captive house to justify completely new equipment for that 3% that is going to be a leading edge. Whereas, a larger facility, such as Dupont, Dainippon or Toppan in Japan, can afford to invest in the equipment, assuming the market is there, and then share that cost over many users. So, I think that is a trend.

DR. FULLER: I think one of the important things that came out this morning is the concept of building blocks, partnering between supplier and customer, the old theme of vertical integration being the only way to keep control of all your processing, and so on, is really not the modern thinking.

Coming from an operation that had a captive mask house and has sold it, but maintains a strong partnering relationship, and also working at SEMATECH where partnering is a way of life, I think we are going to see more and more of this throughout the industry, that you don't have to do everything yourself, but you do have to make strong strategic alliances with a few key suppliers.

DR. WOOD: We have heard quite a bit of discussion from all four speakers today regarding phase shift masks. They appear to be the hottest topic in lithography today. I would address this again to all members of the panel: Who do you expect will bear the burden of the development cost for phase shift mask technology — the maskmakers, the semiconductor manufacturers, or the lithography companies?

DR. SKINNER: At the present time I think it is going to be a combination between maskmakers and users. That kind of activity is going on at the present time. But I would emphasize that the phase shift mask is not the answer to all the mask user's problems. The lithography tool has to be used at its limit now in order for the phase shift mask to show some advantage.

DR. BERGLUND: I tend to disagree just a little bit with John. There probably is going to be a need to have tighter specifications on the maskmaking equipment and on the inspection equipment that is needed to check the masks. I believe the equipment makers are going to have to play a big role in making the best possible phase shift masks for the industry. So, I think it is a three-party partnership that has to exist.

DR. WOOD: Did you have some comments, Bob?

MR. HILL: I only have one comment on that. I believe that the "dinosaurs" serve a very useful role in some of these things. If you look at the work that has been done in phase shift masks today, it has been primarily by the "dinosaurs" — Toshiba, Hitachi, IBM. I believe that a lot of the technology for that type of thing will have to come from this group of folks.

DR. WOOD: Let's hear it for the dinosaurs!

This is a question for Bob Hill. IBM is recognized as being the largest captive producer of photoresist in the world. What is the strategic importance of this program and how does it impact IBM's dealings with the merchant vendors? As a follow-on, can you discuss the arrangement between IBM and Silicon Valley Group Lithography regarding the IBM photoresist for the Micrascan?

MR. HILL: Let's take that in sections.

DR. WOOD: The first question is that IBM is recognized as being the largest captive producer of resist. What is the strategic importance of this program and how does it impact your dealings with the merchant photoresist community?

MR. HILL: First of all, we make primarily most all of our own resists; that gives us lithographic or cost leverage. Our manufacturing facility is in East Fishkill, N.Y., and is in my area of responsibility.

It is a very important area to us because, coupled with the tools that we have purchased, it has enabled us to optimize our lithographic systems, and will continue to do so.

It has not impacted our dealings with the merchant resist industry, as we buy some of the components from them and subcontract some resist manufacture to them. We are making some of our DUV resist available to our SVGL partner, who will resell it to SEMATECH and SEMATECH members.

DR. WOOD: A general question to our panel: What level of automation will be necessary for the lithography tools of the 1990s to meet the stringent mean-time-between-failure and mean-time-to-repair levels demanded by the lithography users? Will the tools incorporate onboard adaptive process control, or will a host computer or cell controller be used to monitor process parameters and make real-time adjustments?

MR. HILL: I think all of what you asked will be used. If you look at the steppers, there are steppers today that are getting over 500 hours of MTF and 1000 hours is in the near future. I think that you will see future stepper generations coming with far more onboard diagnostics. They will have the capability to dial back to the stepper company for troubleshooting. Manny Fernandez showed diagrams this morning of a similar thing. I am not sure it will go that far for a while, but I see a lot more interactive work coming up between the equipment manufacturers and the customers to enhance equipment performance in the environments mentioned.

Gene, you have massive programs in that area.

DR. FULLER: I want to really emphasize more the routine processing. Certainly, failures and predicting failures and so on is a very important idea, but I think, kind of like the F-16 which I am told will not fly without its computers because no human can control it, we are going to see that kind of equipment coming out in the future too. In order to get these 10 nanometer kinds of numbers we are talking about in overlay, or CD control, or whatever it is, there will have to be real-time monitoring and real-time control and feedback of many of the subsystems in a future generation stepper. That ties in with the overall factory automation perhaps; but, just as a stand-alone, the process control has to be automated.

DR. BERGLUND: I would like to make a comment about electron beam systems. E-beam systems are inherently compatible with automation. In fact, the worldwide experience with electron beam systems in terms of up-time has been phenomenal, well over 90%.

The interesting point about direct write that I didn't mention earlier is that when you eliminate the masks, you make it far easier to automate your whole lithography process. In fact, if you are in the ASIC business, there are so many masks that you have to take care of that, just the business of dealing with all the necessary reticles becomes a major limiter in how you run a fab. One of the potential advantages of direct write, which is very difficult to quantify, is eliminating that and making it much more compatible to automation.

DR. SKINNER: In mask processing, automation will be coming. More commercial equipment is being made available to talk to a host computer, and the technology does exist to be able to completely automate the maskmaking process.

DR. WOOD: What is the effect of 4X reticles, such as those for the Micrascan, instead of 5X, on maskmaking and wafer lithography?

DR. SKINNER: If the 6 x 9 substrate is required, which I believe in the long term will be, then the fact that it is a noncircular or nonsquare substrate does lead to a nonuniform disk. That is one of the problems.

But in terms of the specifications, it will be approximately the same as the 5X. It is a broadband illumination system which should relax the mask specifications slightly if the mask users would relax a little. It should be compatible to a 5X reticle.

MR. HILL: Having helped set the architecture of a couple of the tools, the reason for the 4X mask was that the 5" glass could not take advantage of the full field size. Consequently, we had to reduce the magnification ratio since the large glass plates were not available at the time that tools were being designed.

DR. WOOD: This is a question to Bob Hill: If an optical lithography system costs about $125-$150 million, say 25% of a $500-$600 million fab, how much does an X-ray system cost?

MR. HILL: Again, an X-ray system is primarily geared to the DRAM type of market. You really have to be running 400 or greater, 200 millimeter levels. It is equivalent to optical investment cost at that point and becomes cheaper as you add more wafer starts.

You have to make the X-ray investment and X-ray decision further in advance than you would have to make the optical decision. A synchrotron today is roughly three years lead time. You have to bring it up with steppers, beam lines and qualify it after you install it; so it will be initially around a four-year lead time.

Optical steppers today have a distinct advantage there. You can order an optical stepper and be using it in essentially two years.

DR. WOOD: Neil, this is a question for you in the e-beam area: Many people believe that direct write e-beam will be a viable mix-and-match strategy with mask-based optical lithography. At the same time, throughput is perceived to be the major limiting factor. What technological advances do you expect will allow e-beam technology to break through the throughput barrier?

DR. BERGLUND: The statement that the throughput is the big limiter is exactly right. It becomes an economic issue when you think of it not in terms of throughput, but in terms of dollars per layer, compared to other approaches.

The advantage of a vector scan, particularly a shaped beam vector scan system, is that you have a significant number of degrees of freedom to improve the throughput, but they all involve tradeoffs between the processing on the one hand and the design methodology on the other.

A vector scan tool has extremely high throughput if the pattern complexity (coverage) is low. The throughput gets progressively worse as the coverage gets progressively larger. So, if you use it only for low coverage patterns, or if you use it with patterns that are repetitions of only a few different shapes, which you can then replicate all over the plate or the wafer, you can vastly improve the throughput. Numbers on the order of 10 wafers are almost routine today for the very low coverage layers; that is, if you think of it as being limited strictly by alignment and stage motion and the like, rather than exposure. And 20 wafers per hour is not a number that is going to be too difficult to meet in a few years.

I see this as primarily an electronic and software speed-up within the machine, as well as some methodology approach. I think that is the way it has to go. You can expect to see those rough kind of numbers over the next five years or so.

DR. WOOD: This is for Gene Fuller and/or John Skinner: Does the technique of phase shift masks require, or benefit more, from negative tone or positive tone resist systems with respect to resolution, depth of focus and CD control?

DR. FULLER: I don't think I can directly answer that question. As you may or may not know, there are at least seven or eight different phase shift schemes that are out in the world.

DR. WOOD: I know of seven.

DR. FULLER: Obviously, today, positive resist is certainly the dominant resist in the I-line and G-line world; although it is actually the opposite in the deep UV world, the negative is dominant, what little of it there is.

I think, again, you are getting into an integrated picture here, that the availability of the resist and the phase shift mask, the preferred technique for manufacturability, will all be tied together.

DR. SKINNER: From the maskmaker's point of view, the simplest — if there is such a thing as simple — mask to make is the one developed by Mark Levenson, of IBM, which is the alternating phase shift and lines; and to use that you have to use a negative resist. The extension of that, which led to the Toshiba method, can use the positive; and, of course, the Toshiba self-aligning technique can also be used with positive resist.

The maximum benefit can be obtained from IBM's; the next one is possibly Hitachi's; and one that is fairly easy to make, the self-aligning Toshiba, has less advantage than the other two. Then; there is a whole host of other types of phase shift along the way.

DR. WOOD: Nobody mentioned site-by-site alignment. At what design rule do the panel members think that site-by-site will be necessary, and how will we cope with the reduced throughput?

DR. FULLER: Certainly the experience over the past few years is that full site-by-site alignment is not at all necessary — or even desirable — on systems that have good mapping characteristics. Some people call it "extended global;" some call it "mapping." If you characterize the wafer, it turns out that the systems to date have a better ability to place an overlaying pattern where they want it than to measure it and do a site-by-site alignment and then place the pattern there.

I think site-by-site got a lot of emphasis when people were talking about continental drift on wafers and so forth. I rarely hear that kind of discussion any more. I think most people agree that any scaling of the wafers is more or less well-behaved, and you do not have different die going in different directions on the same wafer.

MR. HILL: I believe it also came about at a time when we were having a lot of trouble with global alignment systems; where those systems gave us a very rough alignment accuracy, so site-by-site was put on the tools to compensate for that. Since then, there has been substantial progress in global alignment to the point where site-by-site is actually in some cases less accurate than using a global type of system.

DR. SKINNER: If you try to overlay two patterns, the best accuracy can be achieved if you use many points to align them. When a reticle is used in a stepper, the reticle is aligned by two points. It would be beneficial to both the maskmaker and the user to be able to offset those alignment points, be they two or three, to optimize the alignment of the primary pattern with some standard grid.

An offset arrangement was allowed in a previous stepper, namely the Ultratech. The present steppers do not allow that.

A plea I would make to stepper manufacturers is allow the maskmaker to be able to specify an offset required in the machine in order to get the best alignment between one reticle and another.

DR. WOOD: John, this is another question directed at the maskmaking side: What is the level of capital investment that will be required by the maskmaking companies to do sub-0.5 micron masks?

DR. SKINNER: Everything that we need, from the pattern generator down to the inspection tools, has to be purchased as new equipment. There is essentially nothing that was available for purchase in the 1980s that can be used to make the mask for 1992.

DR. WOOD: So the answer is "a lot."

DR. SKINNER: Yes.

DR. WOOD: At this point in time, if there are no more questions from the audience, I would like to ask our panel members if they could each take a couple of minutes to summarize the two or three points that they would like our audience to walk away with today in terms of an understanding of advanced lithography strategies.

DR. FULLER: I think I will repeat the same points that I made in wrapping up my talk.

• First of all, optical lithography is clearly the dominant technology today. Because of the time lags involved and so on, it will continue to be the dominant technology for a number of years.

• Another point, kind of the corollary to that, is that if we are going to replace optical with direct write e-beam, X ray or whatever, it is not too early to put full effort on those kind of programs. The industry has had difficulty understanding how long it takes to develop new technologies from the point of a lab demonstration, writing some papers and presenting them at the SPIE conference and so forth, how long it takes from that point to actually shipping high volume of product. That is the message that I would leave.

MR. HILL: The message I would like to relay is that the technologies are all needed. There is a real tendency in the semiconductor world to try to play one technology off against another. No one technology will solve all problems and they all have advantages in certain applications.

X ray will someday have a strong advantage in DRAMs and high volume logic part numbers. Because of the mask cost, it may not be quite as economical for low volume logic. So, you need an optical solution to parallel the X-ray solution.

Electron beam has a real role to play in early development cycles and in maskmaking.

For that reason, I believe that all of the lithography technologies we have today are going to be around long after I am out of the lithography business and in the beach business and we need to look at ways to enhance them all. I think this is very important, particularly if we are going to overtake and lead the world in lithography. We have to be good at all of them and use each in its best application.

DR. BERGLUND: My key message has to do with mix-and-match. I believe that, as time goes on, we are going to not only find that different layers have different needs in terms of maskmaking or lithography generally, but that you are going to need different characteristics depending on where you are in the design cycle — the early prototyping phase or the volume production phase.

We have to take a look at this from a system approach and start making different trade-offs than we have made in the past. I believe we have the basic technology that is going to allow us to meet the needs, certainly through the rest of this century, and keep on Gordon Moore's curve.

DR. SKINNER: I am confident that optical lithography will play a role in the leading edge technology through the next decade. There are several things required to help that:

• First, I urge SEMATECH to continue the arrangement of trying to organize users and manufacturers so we can develop a common set of specifications and argue out our respective problems.

• There also have to be partnerships. The high cost of capital that is going to be required for the leading edge technology will require partnerships between the maskmakers and mask users.

• I would put in a plea for the wavelength of whatever is used in the optical lithography to stay above 190 or 200 nanometers. The thought of changing from a quartz substrate to any of the calcium fluorides or anything else would be frightening. I hope that we stay there.

• Mask users, please recognize that the capital cost is getting very high and mask prices have to go up accordingly.

DR. WOOD: On that note I would like to thank all of our panel members for participating today. It has been a pleasure working with you gentlemen.

SEMICONDUCTOR MEMORIES
IN THE COMING DECADE

Tsugio Makimoto

Director and General Manager,
Semiconductor Design & Development Center
Hitachi Limited

MR. GRENIER: Today is "DRAM Day." I think you will know everything you want to know about DRAMs — and more — by the time we are done with today's session.

We will discuss DRAM pricing, DRAM manufacturing and capacity, characteristics of semiconductor memories in the next 10 years, DRAM life cycles and DRAM market volatility. Whether you are a semiconductor manufacturer, an equipment and materials supplier, or an investor in the industry, I think you will find today's discussions all very relevant to your business.

This afternoon, we will take a peek into the future — growth in personal computers, growth in personal electronics, the rising cost of doing business and some user/supplier business strategies — at DRAM applications and general business issues.

Our first speaker this morning is Dr. Tsugio Makimoto, Director and General Manager of the Semiconductor Design & Development Center of Hitachi Limited. His current responsibilities include all MOS and bipolar device development operations, including microprocessors, memories, ASICs, linear, digital, LSI, et cetera. He has been with Hitachi since 1959. Dr. Makimoto received a B.S. degree in Applied Physics from the University of Tokyo, an M.S. degree in Electrical Engineering from Stanford, and a Ph.D. from the University of Tokyo.

Dr. Makimoto will discuss some characteristics of semiconductor memories in the ensuing decade.

DR. MAKIMOTO: Thank you, Joe. Good morning, ladies and gentlemen. It is my great pleasure to talk on the subject of semiconductor memories in the coming decade. I intend to cover some important technical and marketing issues which I expect to arise in the 1990s. At the end of my talk, I will summarize and propose guidelines for the direction of technology development in terms of figure of merit.

Market Trends

Illustration #1 shows the trends in the total semiconductor and MOS memory market.

In 1990, the MOS memory market is about $14 billion, about 25% of the total market. In the year 2000, the MOS memory market is estimted to

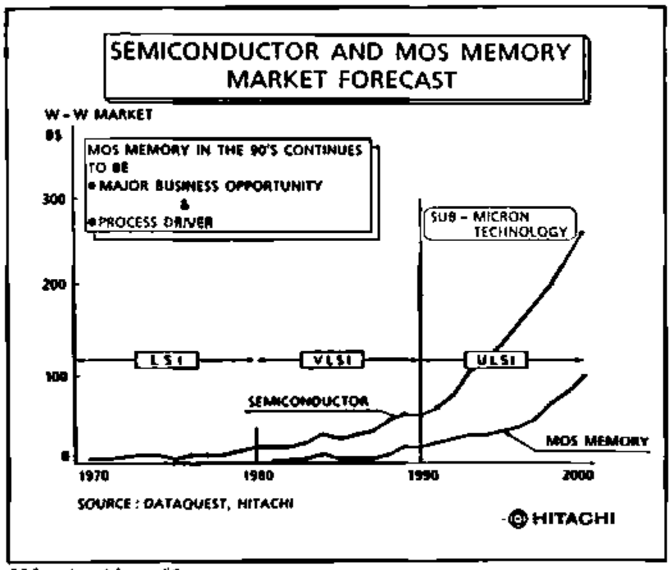

Illustration #1

reach approximately $100 billion, about seven times today's size. So, MOS memory continues to provide the major business opportunity and remains the process technology driver.

The decade of the 1990s will be characterized by sub-micron technology.

DRAM Trend

Illustration #2 shows the generation changes in memory products, which I expect to follow the past historical trend of the whole.

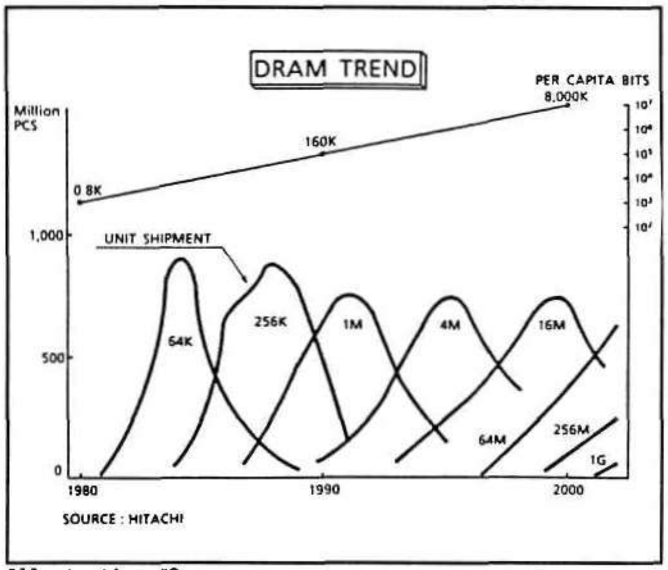

Illustration #2

The top line shows memory bit consumption per capita. Today, the world population is about five billion, and each person consumes about 160 Kb of memory. By 2000, it is estimated that the world population may increase to about six billion and memory consumption per capita will reach a surprising 8 Mb, about 50 times the level of today.

You have to be fully prepared to utilize this large number of memory bits in the coming decade. The 1990s will be an exciting decade for both semiconductor manufacturers and for semiconductor users.

From "Mega" to "Giga"

Let us discuss how the memory density increases four times each generation. Illustration #3 shows the factoring of density increase, starting with the 256K DRAM. The contribution is due partly to finer geometry and partly to larger chip area. Roughly speaking, finer geometry contributes two-thirds, and the larger chip area contributes about one-third.

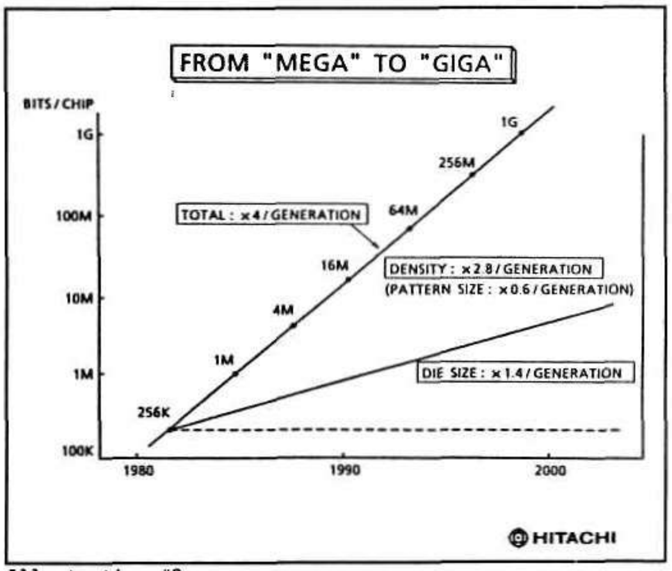

Illustration #3

This corresponds to the trend of the pattern size decreases by a factor of about 60%, yielding a density increase of 2.8 times each generation. Chip area increases 1.4 times per generation.

This year is the beginning of the sub-micron technology, with mass production of 4 MB DRAMs, based on the 0.8 micron process. By 2000, 1 Gb DRAM is expected to appear, based on 0.1 micron technology. Therefore, the decade of the 1990s could be described as the transition from megabit to gigabit.

System Requirements

From the systems viewpoint, I think three factors are the most important: space, intelligence and cost. I will discuss some details of each factor.

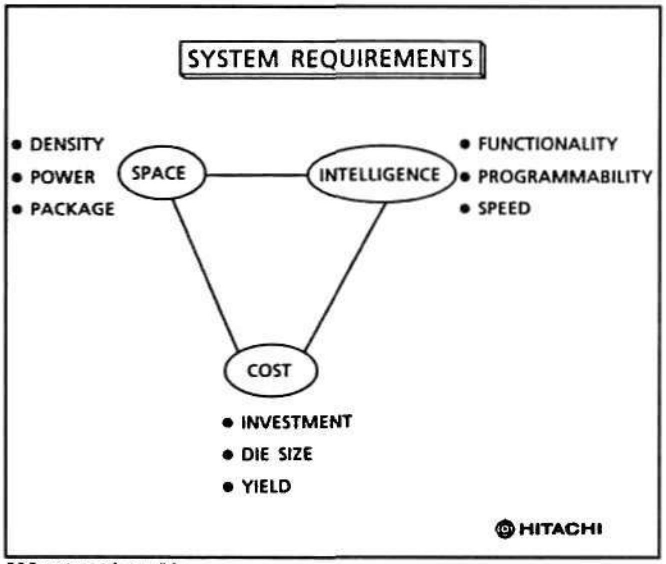

Illustration #4

Space

First, space. The issues are how to make systems smaller and lighter. Influencing factors include memory density, power consumption and packaging technology.

We expect to see gigantic 1 Gb memory chips by the end of the decade. Pattern size will be around 0.1 micron. Chip size will be around 20 mm^2. It is difficult to imagine how fine the linewidth is in the real world, so let me use an analogy: If the chip size is expanded to the size of a football stadium, the 0.1 micron line would be expanded to a 0.5 millimeter line in the football stadium [Illustration #5].

In order to have good yield, you have to eliminate all particles and dust of linewidth size. That corresponds to the football stadium without a

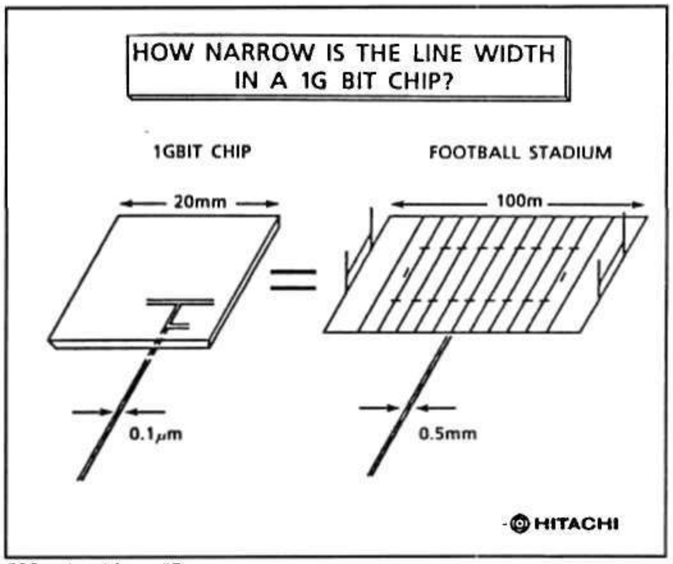

Illustration #5

single particle larger than 0.5 millimeter. This gives you an idea of the super-clean technology required by the year 2000.

Lithography Technology

Lithography technology will be critical for realizing the finer geometry devices. This was the main topic of yesterday afternoon's panel. Currently, either g-line or i-line steppers are most common. The phase shift mask technology looks quite promising for enhancing stepper capability [Illustration #6].

For 64 Mb or 256 Mb DRAM, the excimer stepper is a strong, promising candidate. Beyond 1 Gb DRAM, we have good candidates, such as e-beam or X ray; however, it is too early to predict the winner today.

Illustration #7 demonstrates the principle of phase shift mask lithography. I will not get into the details here, but I will note that this technology would expand the life span of the optical method.

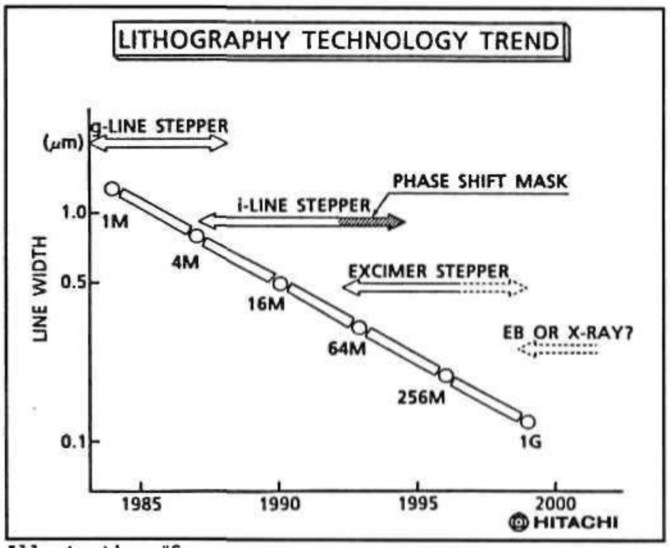

Illustration #6

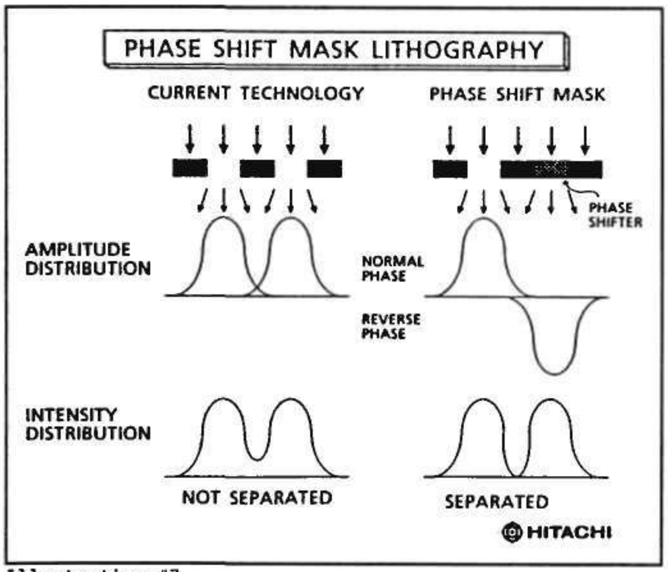

Illustration #7

The 4 Mb DRAM (5.9 x 15.2 mm^2) is currently in production; the 16 Mb DRAM (8.2 x 15.6 mm^2) is in the prototype stage; the 64 Mb DRAM (9.7 x 20.3 mm^2) is also a prototype.

Illustration #8 is a cross-section of a 64 Mb DRAM memory cell. I will not discuss the details here, but you may be impressed by this very complicated and strange structure. Since the

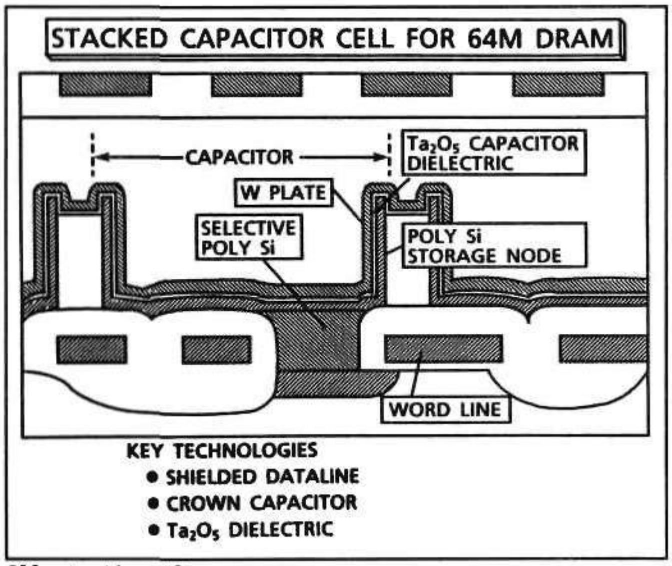

Illustration #8

shape looks like the crown of a king, this particular cell is called a "crown cell." It is unfortunate, however, that the 64 Mb DRAM cannot sell at the price of a crown, even though there are 64 million crowns on the chip.

Memory Packaging Technology

Packaging technology is becoming very important for realizing smaller systems. Illustration #9 shows the trend of unit volume per bit of each package type by DRAM generation.

DIL was the most common for 64K. SOJ dominated the 1 Mb generation. TSOP is becoming popular for the 4 Mb DRAM. It is important to note that you can advance one or two generations in density by using the smaller packaging structure.

Personal Computers

The PC is a typical example of electronic apparatus in which the space factor is of prime importance. Illustration #10 shows PC volume trend.

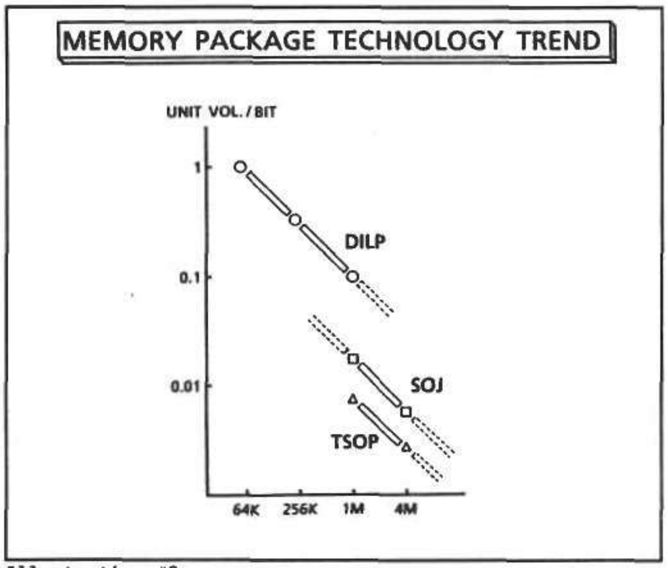

Illustration #9

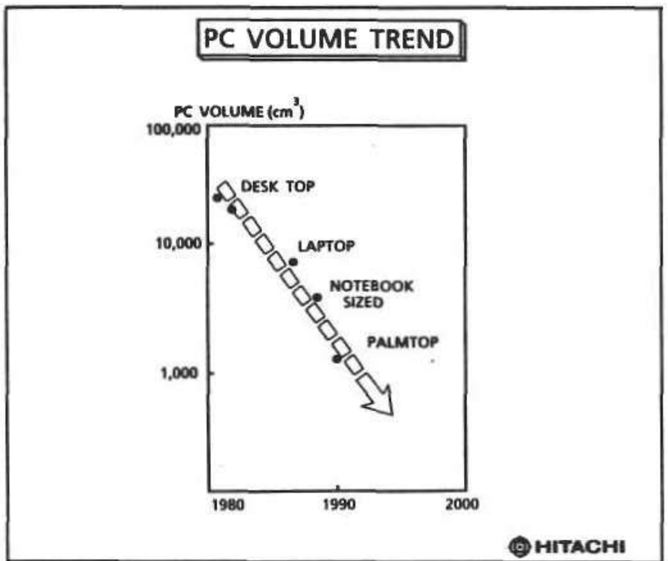

Illustration #10

There have been generation changes, starting from desktop, to laptop, and today's best-selling model, book-sized PCs. If you extrapolate this trend to the year 2000, the PCs would be the size of a passport that you can carry in your pocket.

Memory Density Limitations

Let's see if there are any fundamental limits for memory density. There have been many arguments from various viewpoints about the fundamental limits, summarized in Illustration #11.

WHERE ARE FUNDAMENTAL LIMITS?

VIEW POINT		LIMIT	LIMITING FACTOR	REFERENCE
(1) COST		0.3~0.2μm	BIT COST SATURATION	T. HAGIWARA (89/8 NIKKEI MICRODEVICE)
(2) DEVICE PERFORMANCE		0.2μm	ACCESS TIME SATURATION	M. TAGUCHI (89/8 NIKKEI MICRODEVICE)
(3) RELIABILITY		0.10μm	BREAK DOWN BY TUNNELING EFFECT	B. HOENEISEN & C. A. MEAD (SOLID STATE ELECTRON 15,819 (1972))
(4) MANU-FACTURING	YIELD	0.10μm	YIELD LIMIT BY FLUCTUATIONS	K. NATORI (89/8 NIKKEI MICRODEVICE)
	LITHO-GRAPHY	0.10μm	OPTICAL LITHOGRAPHY LIMIT	A. ANZAI (89/8 NIKKEI MICRODEVICE)
		<0.10μm	EB OR X-RAY?	

HITACHI

Illustration #11

The forecast for the limit ranges widely, from very conservative to reasonably aggressive. The most conservative argument comes from the saturation of the bit cost. On the other hand, from the manufacturing viewpoint, the limit can be extended below 0.1 micron by making use of new technology, such as X ray or electron beam.

This table, however, doesn't tell you the real fundamental limit. Let me talk a little about the real fundamental limit.

"Real Fundamental Limit"

One day I discussed this subject with a very smart person. He said, "I know the real fundamental limit. The real fundamental limit will come when the device dimension reaches the diameter of an electron." I asked, "What is the diameter of an electron?" He said, "Nobody has measured it." So, don't worry about the fundamental limit today.

The second important factor is intelligence, by which I mean more functionality, more programmability and higher operating speed.

Diversification

We will see a lot of diversification of memory applications in the 1990s.

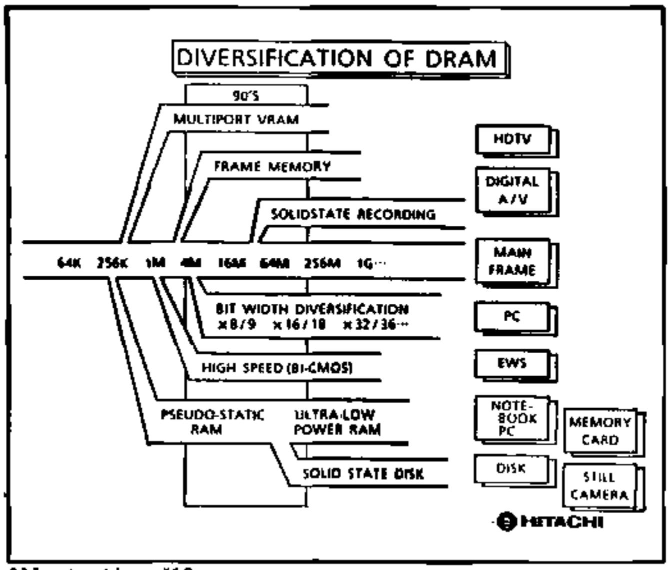

Illustration #12

Office automation systems and consumer electronics (e.g. digital audio or digital video systems) will lead the diversification. HDTV will create a large market for memories and other semiconductor products.

Corresponding to the diversification of applications, memory products will also be diversified. Standard DRAMs will be followed by multiport VRAMs and pseudo-SRAMs. In the late 1990s, it is expected that the low-power/low-cost DRAM will create a huge solid-state disk market.

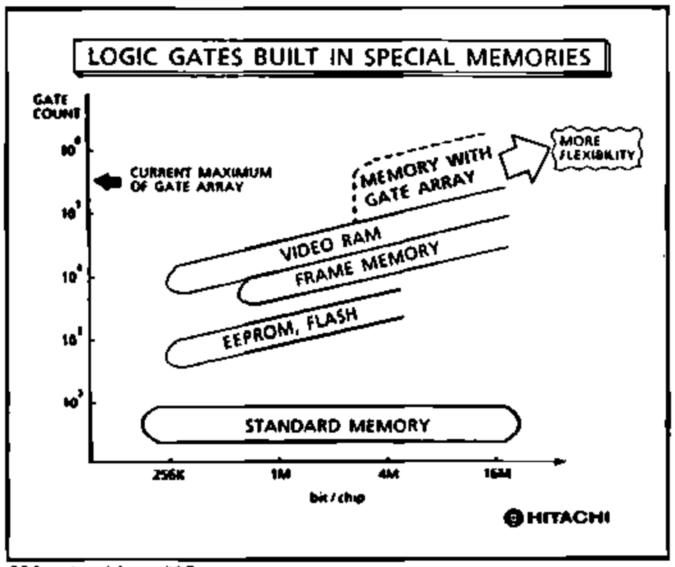

Illustration #13

Illustration #13 shows the trend of increasing complexity in application of specific memories. Gate count is increasing steadily. In the future, memory and logic will be combined in a single chip as a custom-oriented product. This will offer greater flexibility to users.

The problem, at this point, is how to classify the combined chip. Is it a memory chip or is it a logic chip? Someone, possibly Dataquest, will invent a proper word for this. Since memory and logic are combined on the chip, it could be called a "mogic" chip. This "mogic" chip will give users greater flexibility.

Nonvolatile Memories

Nonvolatile memories are also a key factor in flexibility. Illustration #14 shows the positioning of various technologies as they relate to cost and flexibility.

At the extreme right is NVRAM [nonvolatile RAM]. There have been various approaches for NVRAM, and much work is still on the way. The NVRAM is the ideal form of memory, since it has the

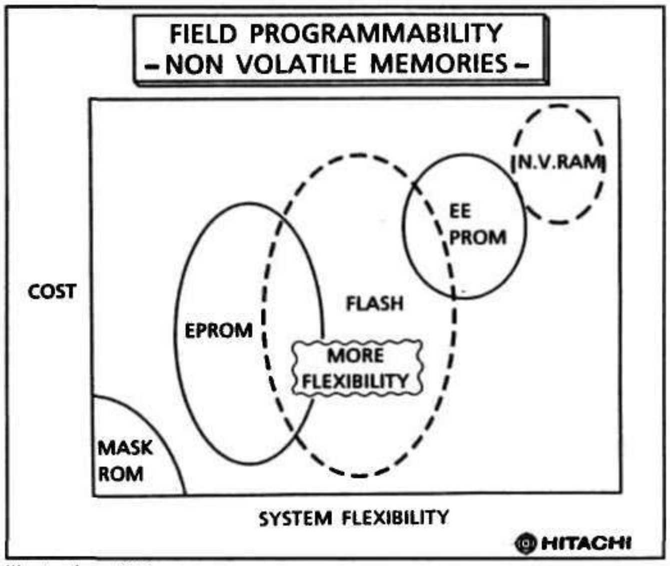

Illustration #14

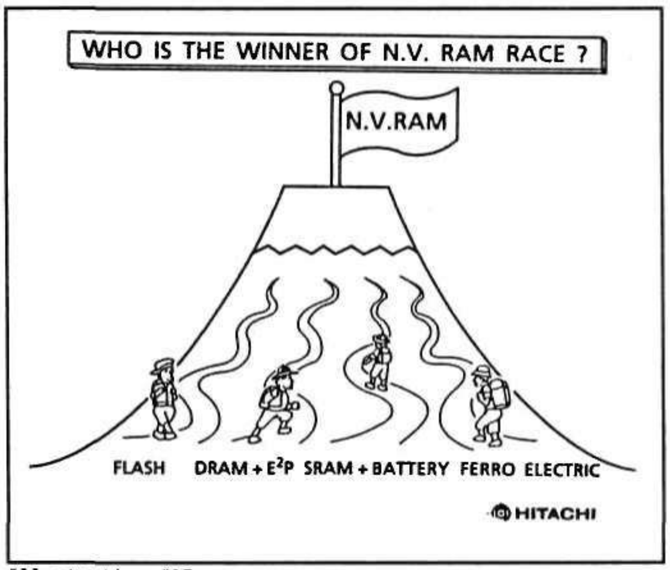

Illustration #15

capability of data retention even while the power is down. This field is wide open for accepting the challenge.

Illustration #15 shows various approaches for the ideal NVRAM. If anyone achieves high-density, cost-effective and reliable NVRAM, he should be a candidate for the Nobel Prize — if not the Nobel Prize, certainly the Makimoto Prize will be assured.

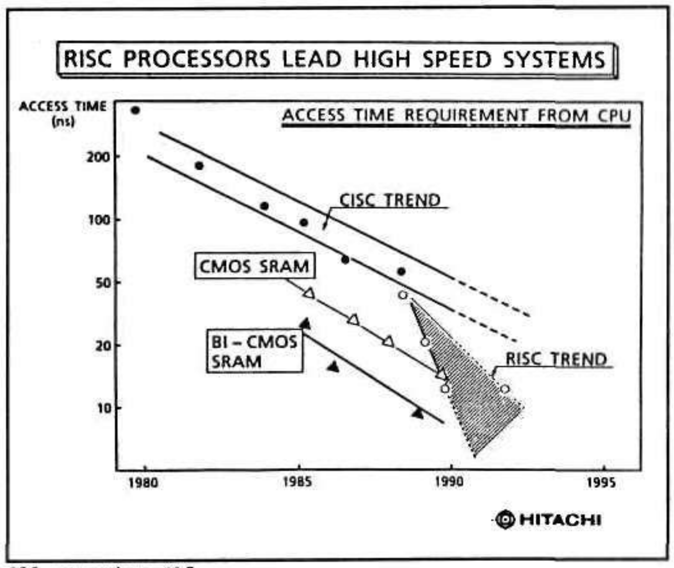

Illustration #16

CISC and RISC Trends

Two trends in speed requirements are shown in Illustration #16, CISC and RISC. A RISC processor is very speed hungry. In order to make the best use of the RISC concept, high-speed memory is needed. From the technology viewpoint, BICMOS will provide the most appropriate way to meet the requirements of a RISC processor.

Cost

The third and most important factor is cost. This is affected by the amount of investment, die size and yield.

Illustration #17 shows the investment trend. The amount of investment needed for producing one million pieces per month is shown: 256K DRAM, $35 million; 1 Mb, $70 million; 4 Mb, $120 million; and, for 16 Mb, it is expected to cost $210 million.

Yield

Yield is also a very important factor in cost. Yield is expressed by the fairly simple expression

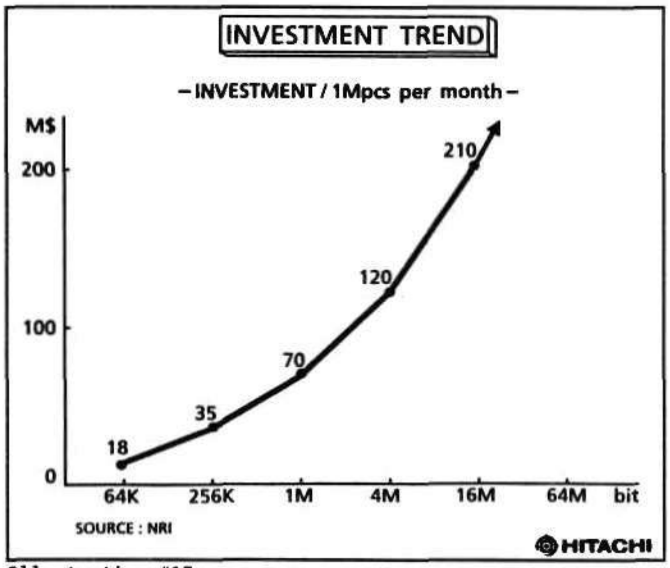

Illustration #17

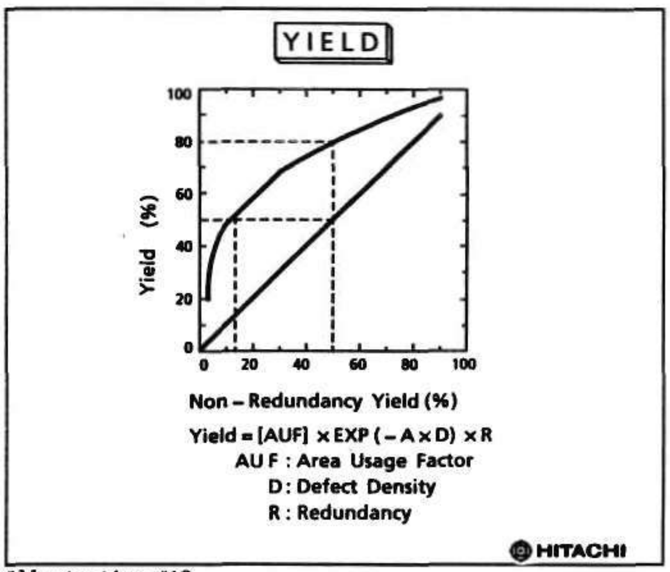

Illustration #18

shown in Illustration #18. This simple equation, however, does not necessarily mean that yield enhancement is simple.

The redundancy factor is becoming very important and very effective. If you have 15% yield without redundancy, it could be improved to 50% with redundancy. So, this is a very powerful means for the yield improvement.

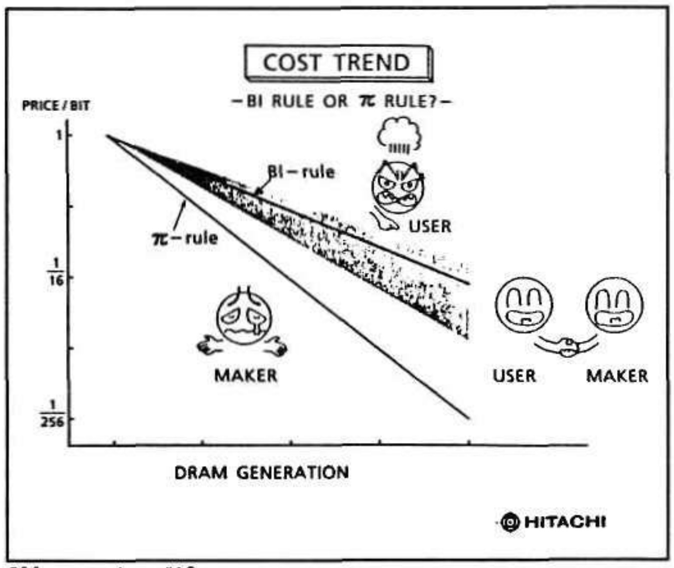

Illustration #19

Cost/Price Issue

Let's discuss the cost and price issue. Pricing is a very delicate and sensitive subject. Suppliers tend to say price is too low. On the other hand, users always say price is too high.

There have been two theories in the past for predicting the pricing trends of memories [Illustration #19]: One is the Pi Rule (bottom line) which predicts the bit price decline by a factor of a quarter per generation. The other is the Bi Rule (upper line), which predicts the bit price decline by a factor of 50% per generation.

The Pi Rule is a very sad rule for the maker, so you see him crying under the bottom line. But the Bi Rule makes users unhappy, so you see him looking very angry above the Bi Rule line.

I expect there is some reasonable and amicable zone for makers and users between the Pi Rule and the Bi Rule — a pricing zone where the maker and the user can shake hands.

New Applications

One critical issue in the coming decade is how the technology will be utilized. You are expected to use your imagination for developing new applications.

As I discussed earlier, the coming decade is a transition period from mega to giga. By the end of the century, gigabit memories and GIPS processors will be emerging. A GIPS processor will be capable of performing one giga instruction per second (1000 MIPS). So, tiny translation systems will become a reality using the GIPS processor and gigabit memories.

Portable Translators

In Illustration #20, an American boy is trying to communicate with a Chinese girl using a portable translation system. Since the subject is a very serious one, it is important that the tiny machine does not make any mistakes.

The translation machine could make a great contribution toward removing the language barriers which exist between different nations today. I believe that semiconductor technology will be able to contribute to peace in the world through the language translation system.

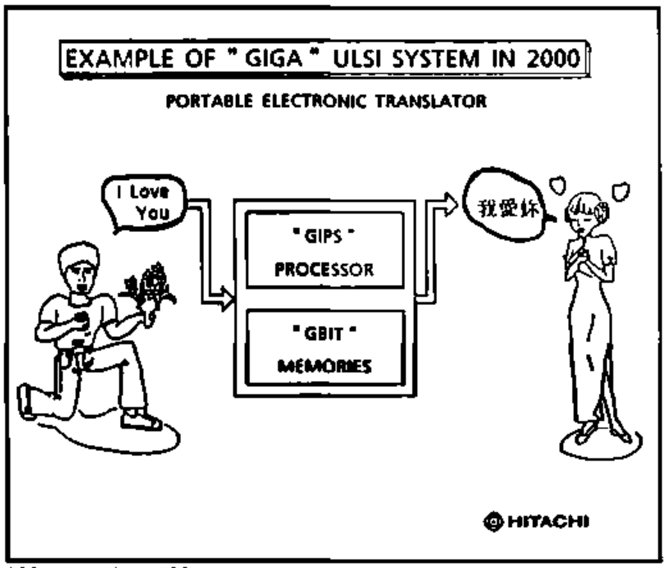

Illustration #20

Conclusions

A guideline for the direction of semiconductor technology is shown in Illustration #21.

CONCLUSION

- ***FIGURE OF MERIT OF SEMICONDUCTOR TECHNOLOGY***
  $$\frac{\textbf{MORE INTELLIGENCE}}{\textbf{SPACE x COST}}$$
- ***HEAVY INVESTMENT FOR R&D AND MANUFACTURING***
  COOPERATION THROUGH PARTNERSHIP
- ***IS THERE PROFITABILITY ?***
  RIGHT MIXING OF π-RULE & BI-RULE IS THE KEY

Illustration #21

The formula for figure of merit is more intelligence per space per cost. Intelligence factors include flexibility, operating speed and field programmability. Space factors include chip density, packaging and power consumption. Cost factors include investment, die size and yield.

• Heavy investment is needed for research and development and for manufacturing. Therefore, cooperation through partnership is required.

• The last and most important issue is whether there is profitability. The right mixture of the Pi Rule and the Bi Rule will be the key for the profitability.

As I mentioned earlier, in the coming 10 years we will see a transition from mega to giga, and the 1990s will be an exciting decade, providing great opportunities for all semiconductor manufacturers and users.

Tsugio Makimoto

Questions & Answers

MR. GRENIER: We have time for some questions.

QUESTION: Carver Mead mentioned that most technology breakthroughs come from areas that have not been looked at. Will the semiconductor memory market be surprised within the next 10 years?

DR. MAKIMOTO: I think this is a very good question. Most of my talk has been on predictions and progress which are coming in 10 years — that is, a straight line each time memory bit density increases four times every three years. I think that, certainly, memory is going to evolve in this way.

But, I think, another dimension will certainly come to reality. One possibility will be the nonvolatile memory area. There is a wide-open area for getting into the challenge of the nonvolatile memory area. That is one very promising area.

QUESTION: What role will ferroelectric memories play in the market over the next 10 years?

DR. MAKIMOTO: This is again related to my first comment. Ferroelectric memory is now being developed as one very strong candidate for nonvolatile memory — if it can be achieved with very high density, if it is cost-effective and if it can be made reliable.

QUESTION: Strategic alliances have become commonplace between DRAM giants — Motorola/Toshiba, IBM/Siemens, Hitachi/TI. How has Hitachi benefitted from its alliance with TI? Why didn't Hitachi go it alone without a partner?

DR. MAKIMOTO: This question is related to the fact that the developing new generation memories require a huge amount of resources — not only money, but a large number of people. So, we can get a lot of benefit from sharing the engineering resources through a partnership. Otherwise, it would be very difficult for a single company to develop a completely new generation memory product. I mentioned in my last slide that partnerships will become very important in the coming decade.

MR. GRENIER: Dr. Makimoto, thank you very much.

EUROPE: REDRAWING THE SEMICONDUCTOR BORDERS

Jonathan P.V. Drazin

Senior Industry Analyst,
European Components Group
Dataquest Europe Ltd.

MR. GRENIER: Our next speaker is Jonathan Drazin, from the Dataquest office in Denham, England, just outside of London, near Heathrow.

Dr. Drazin's academic career includes a Ph.D. in Amorphous Silicon Materials from Imperial College, London, and an M.B.A. Degree from London City Business School. Before joining Dataquest, Dr. Drazin worked on the development of a BICMOS process for the joint venture between STC and LSI Logic.

At Dataquest's London Office, Jonathan manages the European Semiconductor Application Service which analyzes how semiconductors are used in various products in Europe. Jonathan's talk will focus on what is happening in the European semiconductor market, and comments on Eastern Europe as well.

DR. DRAZIN: Joe, thank you very much for that introduction. Ladies and gentlemen, good morning.

The word "border" conjures up many meanings for every industrial sector in Europe, not just for semiconductors. A couple of years ago, when we talked about borders in Europe, we would have meant only those scheduled to disappear within the European Community by the end of 1992.

How things have changed since then! As recently as a year ago, few of us would have predicted that the Berlin Wall would fall this century. And, as it fell, the consensus in Europe shifted to the view that full unification of East and West Germany would take years to achieve. However, by July, economic and monetary union had already occurred; and, as we all know, last week there was full political union.

I suspect that, today, few of us really believe that we will see the newly democratized countries (like Hungary, Poland and Czechoslovakia) unifying with the European Community before the end of this century. But again, I think we have to be prepared for another surprise.

For Europe, the 1990s is going to be a period of massive restructuring and enormous geopolitical confusion. It is with this rather extraordinary environment in mind that I am going to talk about the boundaries that the semiconductor industry faces this decade.

Given the time available, I have chosen five crucial factors that will shape semiconductor business conditions in Europe over the next few years.

I will begin by putting Europe into perspective in the global scene, and then look at a few of the strands of 1992 that touch on European electronics. This will lead us to areas related to 1992 — namely, trade measures, such as floor pricing, and the EC Origin Rule. I will then look at how Europe is beginning to guide its electronics industries, through focus on research, standards and applications. Finally, I will touch on Eastern Europe and review some of the fundamental implications this area will have on the semiconductor markets.

Jonathan Drazin

Europe's Semiconductor Market

First, let us put the European semiconductor market in a worldwide perspective.

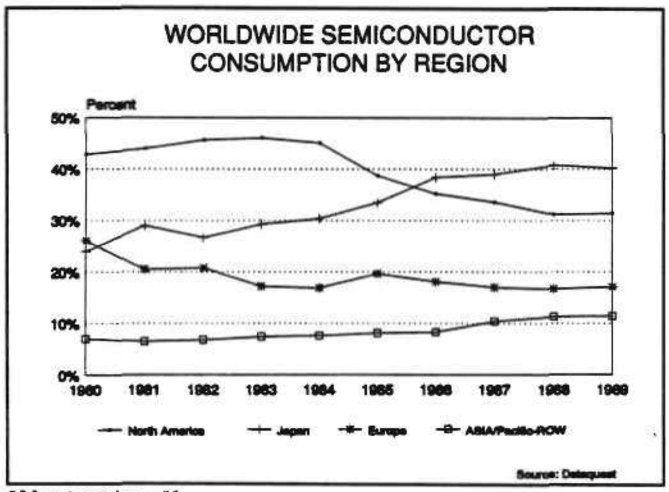

Illustration #1

For Europe, the last decade was a rather painful one. In 1980, our market was second in size only to North America, accounting for more than one-quarter of world consumption — although, I am afraid to say, Europe has been in free fall practically ever since.

By the end of the 1980s, the scene had changed beyond recognition. Unlike North America, we have long since been overtaken by semiconductor consumption in Japan. Last year, our market accounted for less than one-fifth of the total world market.

However, when you look at the past couple of years, things don't look quite so bad.

European semiconductor consumption grew faster last year than any other world region. The estimate for this year indicates a continuing comparatively high growth, although I should point out that we have revised our estimate very slightly, down by two points.

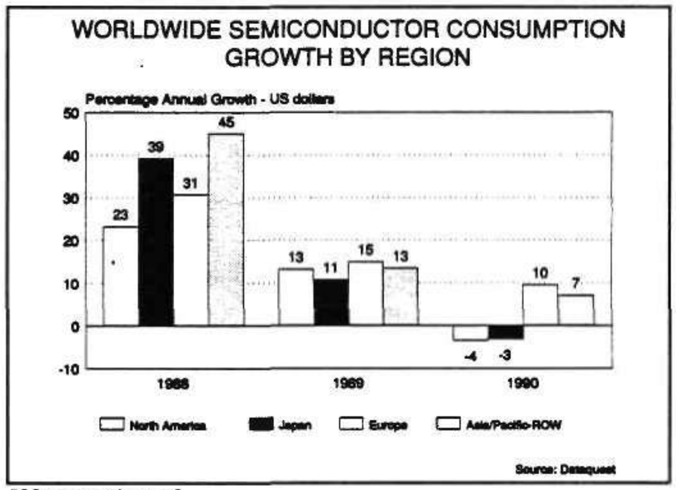

Illustration #2

Origin of Growth

What is its origin? From the perspective of Europe's indigenous firms, this recent growth may be a false dawn.

RECENT GROWTH - KEY FACTORS

- Foreign investment in production:
  - Just-in time
  - Yen appreciation
  - EC local content
- Strong US operations in computers:
  - IBM (UK, F, I)
  - Compaq (UK)
  - Hewlett-Packard (UK, WG)
  - NCR (WG)
  - Sun (UK)
  - Tandon (Aus)

Illustration #3

The lion's share of this growth in the European market is coming from Far Eastern and North American firms who, for logistic, macroeconomic and other trade reasons, have moved their production into Europe.

Nearly all the North American computer firms are now manufacturing in Europe. Our recent research indicates that 60% of all PC production and more than 90% of workstation production in Europe comes from American-owned companies.

Until recently, Japanese activities in data processing have been confined mainly to printer manufacture. Growth in the printer segment has been truly astronomic. Back in 1987, there was only one Japanese printer manufacturer in Europe (Epson, near Paris). A year later, the number of Japanese printer manufacturers had risen to 14.

We are now seeing a similar trend in computers.

JAPANESE PRODUCTION - COMPUTERS

RECENT DEVELOPMENTS

Manufacturer	Product (Location)	Commenced
Toshiba	PCs (WG)	April '90
Mitsubishi (Apricot)	PCs (UK)	March '90
Fujitsu (ICL)	Mainframes (UK)	July '90
NEC	PCs (?)	tba

Illustration #4

Mitsubishi and Fujitsu have, very significantly, been through acquisitions of European companies, Apricot and ICL.

A key difference between Far Eastern and North American companies is that the Far Eastern ones have not confined themselves to computers and data processing peripherals. For example, in the consumer segment, some 65 Japanese-owned factories have been established in Western Europe, most of them less than four years old.

JAPANESE PRODUCTION (continued)

- Activities not confined to computers alone
- Strong presence in printers, cellular, consumer and facsimile
- Consumer (prod. lines)
  - TV (22)
  - VCR (32)
  - CD (13)
  - microwaves ovens (8)

Illustration #5

The point I want to make is that the recent growth in European consumption is due more to the efforts of foreign-owned companies beginning to purchase locally than to Europe's indigenous players.

The picture is worse when you compare Europe's semiconductor vendors with the rest of the world.

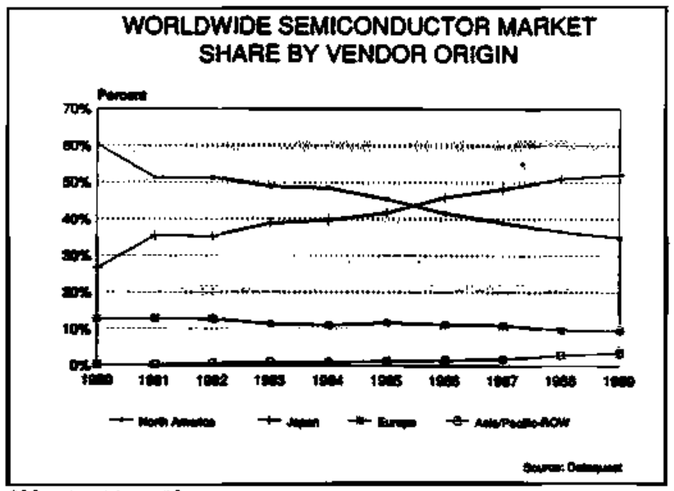

Illustration #6

As shown in Illustration #6, the European firms steadily lost ground during the 1980s. There is little from recent history to suggest that their fortunes are changing. Today, only one company, Philips, figures in the worldwide top 10 ranking, in tenth place.

Europe In the 1990s

This is the situation today. I now need to convince you that this recent performance does not form a reliable basis for predicting where Europe will be in the 1990s.

Jonathan Drazin

Put simply, Europe is rearranging its borders on every front, and the borders to trade within Europe are being dismantled and replaced by measures that will confer on its industries opportunities that they have never enjoyed before.

I need to dismiss straight away the worth of making militaristic analogies between the pentagon you see in Illustration #7 and the one in Washington, D.C.

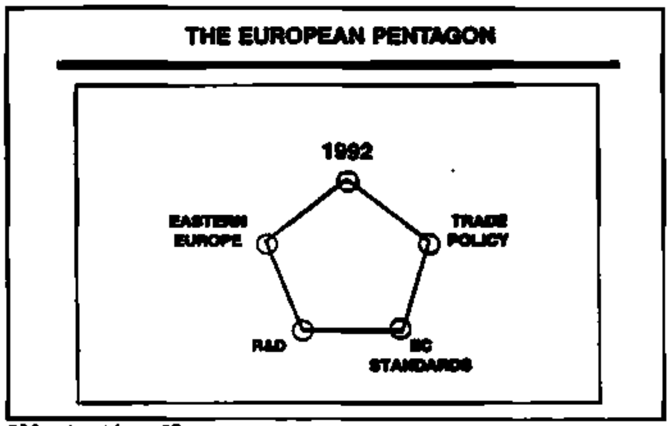

Illustration #7

Suggestions that Europe is becoming a "fortress" are certainly true, in the sense that industrial and foreign trade policies are increasingly being conducted in a coherent way from one center in Brussels. But, in other respects, these five pillars represent to non-European companies more opportunities than threats. I hope to demonstrate this to you.

1992

Let's start with 1992, the top and central pillar. The single market in Europe has theoretically been in place for more than 30 years now, dating back to the Treaty of Rome in 1957. That was fine in theory, but in practice nobody paid very much attention to it. So, 1992 must be regarded as a renewed quest toward achieving a single market in Europe.

PRE-1992 PREDICAMENTS

- National protectionism
- Players confined to small markets
- Single Market - 279 measures
- Semiconductors affected by many factors

Illustration #8

Historically, out of a myopic sense of national duty, European governments have discriminated in favor of their own national suppliers where they perceived industries of long-term value. Nurturing national players has meant excluding foreign rivals. Thus, until recently, Siemens would have sold switches only into the West German market, Olivetti would have sold computers only into Italy, or why Matra Communication would have sold telephones only to France.

1992 is about breaking the many invisible borders between European states that permit this to continue. These borders vary from industry to industry, which is why the Single European Act is not one directive, but 279, each targeted to a specific industry or to a specific aspect, such as technical standards, monetary union or competition policy.

Assessing the impact of 1992 on the semiconductor industry in Europe is about as imponderable as assessing the effect, say, the Gulf Crisis is having on DRAM prices. That may have woken a few of you up, but I am not going to talk about the Gulf Crisis. What I am going to do, instead, is explore 1992 in more detail.

Telecoms Policy

Telecoms is one such area. Europe's PTTs are prime examples of how industrial nationalism has gone rife in Europe. In addition to charging what they like, each PTT buys telecom hardware from preferred national suppliers and prohibits its customers — ordinary people like you and me — from buying telephones from anybody except themselves. So far, the United Kingdom is the only major case where a PTT has been privatized and has competition, but even here the competition is weak and the government still has control.

1992 - TELECOMS POLICY

- Telecoms run by monopolistic PTTs
- 1992 will weaken their hold
- Liberalization of equipment suppliers
- Global companies growing from national ones

Illustration #9

This scene is rapidly changing. Since July 1990, liberalization of hardware supply has been in force in Germany.

Beginning in 1992, telecom equipment will be included in the European Commission's new procurement rules, so that when, for example, Milan's town council wants to install a new telephone system, its business will not automatically go to Stets or Italtel. As a result, pan-European hardware telecom markets are now forming from fragmented ones.

Hardware suppliers — your customers — are undergoing the same process. Europe is now breeding the equivalent of IBM in the computer world. Today we believe it is ALCATEL, not AT&T, that ranks as the world's largest telecom supplier. ALCATEL is followed very closely by Erickson and Siemens, two other very aspirant European companies.

Electronics Restructuring

One key measure of 1992 success is how quickly European industry will adapt to this new competitive deregulated climate. With more than two years to go before the end-of-1992 deadline, we can already cite major cases where restructuring is already occurring.

1992 - EUROPE RESTRUCTURING

Siemens/GEC	Plessey
Siemens	Nixdorf
Siemens	Bendix
Bull	Zenith Data
Thomson-CSF	Philips Defense
Aerospatiale/Thomson-CSF	Sextant Avionics
GEC	Ferranti Defense
Philips	Bang & Olufsen

Illustration #10

One example is the GEC (of the U.K.) and Siemens (of West Germany) acquisition earlier this year of the British telecom and defense company, Plessey. A few years ago, such an acquisition would have been unthinkable anywhere in Europe. Indeed, only four years ago, GEC had attempted to buy Plessey, but was blocked by the British government on the grounds that it reduced competition at a national level.

Nixdorf's merger, again earlier this year, is another case of how critical mass is being achieved from within Europe. Their combined operations now rank them firmly as global players in the top 10 computer companies worldwide, alongside other Europeans, such as Bull and Olivetti.

Semiconductor Restructuring

What about semiconductors? Some restructuring has already occurred.

Jonathan Drazin

SEMICONDUCTORS - RESTRUCTURING

Waiting for a Bang?

- SGS-Thomson acquires Inmos
- Low activity in MOS memory
- High investment compared to revenues
- Collaboration in production inevitable

Illustration #11

Witness SGS-Thomson's acquisition last year of Inmos. Inmos, as acquisitions go, is rather small; and, thus far, we have not seen anything like the shakeup needed to transform the European players into the global force needed for their survival into the 1990s.

Each of the major firms — Philips, Siemens and SGS-Thomson — openly recognizes the importance of being at the leading edge of semiconductor technology. Only one, Siemens, is in the DRAM business today, although SGS-Thomson has openly stated its intention to be in DRAMs as soon as possible.

The investment needed to start DRAM production has never been higher, with estimates on the order of $1 billion required to build a new generation 16 Mb plant. From the European perspective, this is nearly twice the total revenue of all MOS memory sales — not just DRAM, but SRAM and other nonvolatile forms — twice all worldwide MOS memory sales of all European firms last year.

Given that DRAM capability is essential to stay in the game, these companies now recognize that they must merge or collaborate at the production level. This is a very major step beyond the technology collaborations that they have entered into so far.

With a two-year gap between breaking ground for a fab and commencing production, and with 16 Mb parts likely to appear from Japanese players by 1992, these decisions from the Europeans cannot be far away.

Trade Policy

I would now like to turn to trade policy and convey to you, not just the details, but some of the spirit in which it is conducted in Europe. Probably the best way to illustrate this is with a metaphor.

In Illustration #12, the plankton represent the equipment and material suppliers to the semiconductor vendors. The little fish are the semiconductor vendors themselves. The big fish are their customers, the systems companies.

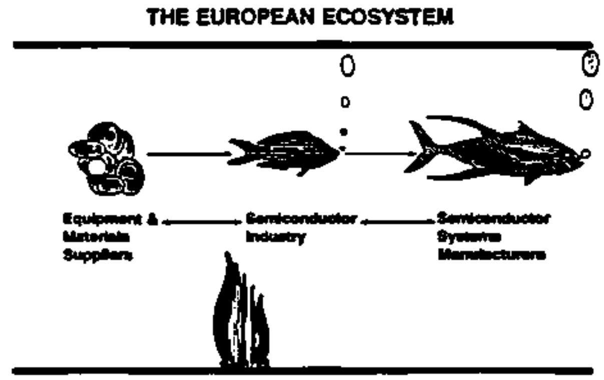

Illustration #12

Today, the integration of systems with silicon is recognized everywhere as a crucial success factor, particularly if you are in the highly competitive computer or consumer segments. If you allow the plankton and the small fish to die, the big fish starve and die also.

However, this interdependence of semiconductors and systems is much more two-way than this food chain analogy here suggests. If the systems industry turns sick, local semiconductor vendors become starved of their customers and die also.

In Europe, semiconductors and systems have come to be regarded by the European Commission as one ecosystem, with mutually consistent policies developed for each. This is not surprising, because some of the Commission's keenest lobbyists are powerful, vertically integrated companies —like Philips, Siemens and Thomson — whose feet stand firmly in both camps.

Illustration #13 shows some of the steps being taken to preserve this ecosystem in Europe and the impact of each along the chain. I will look at only the more prominent ones.

THE EUROPEAN ECOSYSTEM

MEASURE	Semiconductor Equip./Materials	Semiconductor Manufacturers	Electronic Equip Manufacturers
TRADE			
Diffusion Rule	○	○	●
Import Duty	●	●	●
Reference Price		●	○
Local Content		○	●
Anti-dumping		○	●
R&D			
JESSI	●	●	○
Eureka		○	●
Esprit	○	●	●
STANDARDS			
ETSI		○	●
CEN		○	●
CENELEC			●

● mainly affected ○ partially affected

Source: Dataquest

Illustration #13

Reference Price

Earlier this year, after two years of investigation by the European Commission, it chose reference price as the way to stop dumping on the European semiconductor markets [Illustration #14].

Last January, it struck price agreements with Japanese-based DRAM manufacturers. Prior to each quarter, minimum prices are set for each

REFERENCE PRICE

- Voluntary DRAM price agreements
- Commenced April 1990
- Preventive measures - preferable to antidumping duties
- Few criticisms (but price fluctuation is a problem)
- EPROM prices to follow

Illustration #14

type of DRAM based upon cost data supplied by the manufacturers. Normally, these prices are somewhere below market prices so that market forces are not affected.

Reference pricing is claimed to act as a safety net, with European vendors benefitting from the mechanism only for as long as they need it, and no longer. It is also an assurance to new entrants into the market, like SGS-Thomson. So far, it appears to be working well, with EPROM equivalents of DRAM pricing expected to appear from the European Commission in October 1990.

No intervention is popular with buyers. But, thus far, the only major criticism is the volatile way in which these prices have fluctuated over the past couple of quarters.

EC Diffusion Rule

Of the other trade measures, possibly the most widely misunderstood is the Commission's reinterpretation last year of what qualifies an integrated circuit as "made in Europe." The ruling now is that an IC qualifies if the diffusion stages occur in Europe.

There was widespread anxiety when the ruling came out that it represented the first break in the new trade fortress. With North American and

EC DIFFUSION RULE

- Widely misunderstood
- "Made in Europe" if diffusion occurs in EC
- Does not change duties paid
- Targeted at equipment manufacturers faced with local content requirements

Illustration #15

Japanese vendors alike, the thought process ran something to the effect that if they didn't diffuse in Europe, they would be stung by a 14% duty on what they sold there. In fact, this rule is a lot more diffuse than that. It doesn't change the duties paid on ICs sold into Europe by a single cent, no matter what manufacturing stages occur or do not occur there.

Although the rule refers to the semiconductor industry, its real targets are those firms hit by anti-dumping actions which have or plan to set up screwdriver operations in Europe. Today, these firms are Japanese manufacturers of printers, typewriters and photocopiers. The rule's objective is to encourage these companies to procure locally made parts. If these companies are your major customers, then, yes, from the point of view of the Diffusion Rule, you do need to consider diffusing in Europe.

Research & Development

Pan-European research projects that span many countries and many companies are another critical factor in preserving the semiconductor ecosystem in Europe.

One example is the seven-year, $4 billion JESSI initiative to allow European industry to catch up in semiconductor technology. JESSI reflects a recognition that leading edge capabilities in semiconductor development depend on mastery of all the links in the semiconductor chain, from semiconductor equipment and materials through to end applications. JESSI's silicon developments will be linked to other research programs in Europe, including those of ESPRIT, BRITE, RACE and Eureka.

EUROPEAN R&D

- Shift from national to European R&D
- Coordinated across EC and EFTA
- JESSI ($4bn) directed to semiconductors
- JESSI ties into other programs:
  - Eureka
  - Esprit
  - RACE
  - BRITE

Illustration #16

One example of many Eureka applications is a prototype high-definition television. The Commission is funding a "massive," $200,000, 30-company program to develop a single HDTV standard in Europe. This is chicken feed compared to the $3.5 billion that Philips and Thomson plan to jointly commit to research and development on this one application over the next few years. Without the Commission's initiative and guidance, it is very questionable whether either company would have the confidence to commit so much of its own resources to such a rewarding, but highly speculative, area.

Standards

The development of pan-European standards is another example of how European countries are coordinating their activities as a single market.

ETSI [European Telecommunication Standards Institute], based in France, is a new center for all of future European telecom standards, including those for HDTV.

EUROPEAN STANDARDS
• ETSI to develop pan-European standards • Will lead to major semiconductor markets in: - digital cellular (GSM) - cordless telephony (DECT) - personal communications (PCN) - high-definition TV (HD-MAC) • Large single market - good for everyone

Illustration #17

Another major ETSI standard being set is GSM [Group Special Mobile], a standard for the new digital cellular networks expected to commence in the middle of next year throughout the whole of Western Europe.

Parallel advances are being made in cordless telephony, where ETSI is working on DECT [Digital European Cordless Telephone].

To better its achievements in cellular and cordless telephony, ETSI has now commenced work on standards for personal communications networks [PCNs], making it probable that Western Europe will be the first world region to enter the PCN era.

PCNs are derivatives of today's cellular networks, but likely to open up radio telephony to truly mass markets in a way that cellular never will. Research indicates that if there is any application that will make the same splash in the semiconductor markets of the 1990s as did the personal computer during the 1980s, we believe that will be PCNs.

Highly advanced systems (e.g. GSM, HDTV, or PCN for that matter) are also extremely costly to develop. Consequently, we see this coordinated approach to standards as essential for the growing fixed costs to be spread across the greatest potential market. We believe that benefits will accrue for both European and non-European firms alike, because single standards and approval procedures make everybody's job easier, wherever and whoever you happen to be.

This is evidenced in the GSN case by the fact that, quite undoubtedly, one of the main market leaders in this area is expected to be an American firm, Motorola.

Eastern Europe

Finally, I have reached the last, and least predictable, pillar to impact semiconductors in Europe during the 1990s: Eastern Europe.

EASTERN EUROPE
• Pillar of least certainty • Sharply diminished output hampers ability to purchase • Highest priority: technologies that enable industrial efficiency • Telecommunications: next after food?

Illustration #18

Scarcely a day passes without an announcement of some form of contract or venture with the West. But the dire economic conditions in Eastern Europe and Russia will dictate and limit their trading and venture options for many years.

In some of these countries, Poland and Russia particularly, the transition away from a command economy is causing sharply diminished economic output, causing even worse shortages and making new investment much harder to make. For these countries, we see a growing hierarchy of basic technology needs that will dominate all areas, including semiconductors.

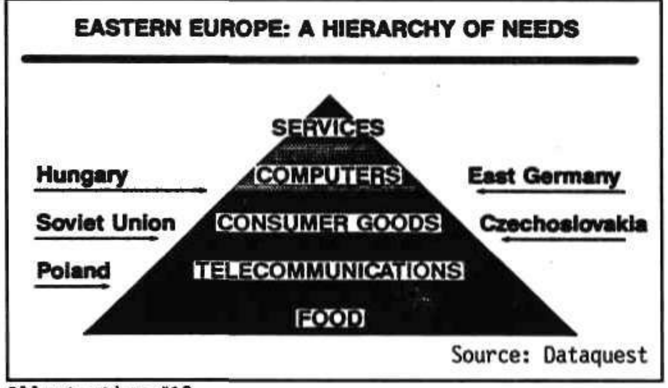

Illustration #19

In this hierarchy, telecom has become the most basic requirement, after food. For instance, in some parts of Russia, their lines actually predate the Bolshevik Revolution. Installed by Erickson in 1907, they are still working. The real problem is not their age, but their absence. In the Soviet Union, only one in eight homes currently has a telephone. Each level here depends on the level beneath it. Without a telecom infrastructure that works, no industry in Eastern Europe can compete effectively. Without an industry, there will be no private income for individuals to sustain the consumer electronics market.

EAST EUROPEAN JOINT VENTURES AND TRADE AGREEMENTS
(announcements June - August '90)

	Hungary	Poland	Czech.	Sov. Un.	E. Germ.	Other	TOTAL
Consumer	2			1	4	2	9
Computer				1	3		4
Telecoms	6	3	3	4	4	1	21
Other electronic	1	1		1	1		4
Semiconductor	2			1			3
TOTAL	11	4	3	8	12	3	41

Source: Dataquest

Illustration #20

EASTERN EUROPE (continued)

TELESTROIKA

- Very low on infrastructure
- Cannot wait to build own industry - must import
- Contracts going predominantly to Western European firms
- Already driving Western (not Eastern) European semiconductor markets

Illustration #21

East/West Ventures & Trade Agreements

One interesting exercise is to count the announcements of ventures and trade agreements between East and West. There have been many hundreds in total. To keep things simple, I have recorded in Illustration #20 only those that have occurred over a recent three-month period.

Eastern Europe cannot afford to wait to build its own telecom infrastructure from the inside, which means that it must import these systems from the West. [See Illustration #21.]

The massive scale of opportunities in telecom is as clearly evident here as the apparent dearth of opportunities in semiconductors. But appearances can be rather deceiving — deceiving because, today, big opportunities exist to sell components to West European telecom firms exporting to the East. The main applications affected include switches, transmission systems, line cards and telephones.

ALCATEL, for example, recently won a single contract to install a quarter-of-a-million lines in the Soviet Union, valued at about $1 billion. But that is nothing compared to Siemens, who won another contract to supply one million lines in Poland. And, of course, we can cite many other cases.

Following German unification, growth in telecom semiconductor demand has already begun, with German book-to-bill figures for telecom IC supplies reported to be in the 1.3% to 2% range this quarter.

Summary

To conclude, I did not boast today about shattering new developments from Europe, the 64-bit RISC chips or 64 Mb DRAMs, because leading-edge products, until now, have not been their major strength. But I do hope that I have demonstrated that these five pillars will comfortably drive rejuvenation in the European semiconductor market which will bear little resemblance to the history of the 1980s.

Whether the European semiconductor industry will enjoy the same fortune as we predict for the market is less clear, but the outlook is good for two reasons:

- First, the top players are integrated into much larger systems companies that now recognize the importance of silicon to the whole European econosystem.

- Second, collaboration between these and other European players is growing at a very rapid pace, partly due to the growing participation in Community projects, like JESSI and ESPRIT, and partly due to the fact that, with the imminence of 1992, they now face the same market.

For those contemplating business in Eastern Europe, I suggest that you consider Western Europe as your springboard. Many of the opportunities to sell in the East are going to come through this back door, particularly in the first few years.

I make no apologies for giving telecom as much coverage as I have. Whether due to Western Europe's new liberalized climate and proactive approach on standards, or whether due to Eastern Europe's urgent needs, this is clearly Europe's most dynamic segment. If the sheer economic size of Europe were all that counted, the semiconductor market of a united Europe would surpass those of Japan and the United States. But it isn't, and our progress will be much less dramatic than that.

Decades after the single market is accomplished, we will still live with the limitations of some 20 different languages, many conflicting cultures and six-week holidays per year.

Questions & Answers

MR. GRENIER: We have time for a couple of questions before the break.

QUESTION: Do you see Eastern European countries becoming part of the EC, and if so, when?

MR. DRAZIN: I don't know the answer any more than I knew the answer on the fall of the Berlin Wall and what followed. But I think it will be sooner rather than later, because if you go back two years and you look at what the West European statesmen stated that the main condition for Eastern countries being included in the Community was that they have democracy. At that time, they didn't believe that would happen. Now it has happened.

There are other hurdles to come, but they are smaller. So, I think the answer — and I will now stick my neck out — is yes, I would foresee some of those countries being included — possibly Hungary, obviously East Germany. That is taken for granted now. But there are other countries trying to get into the EC which are far more Western than these Eastern European countries. I'm thinking of countries like, for example, Turkey.

So, there is a series of priorities, and those Eastern European countries will be somewhere low down as a priority.

QUESTION: Philips has gotten out of the JESSI program and SRAM. How much will that hurt JESSI and the R&D program?

MR. DRAZIN: I think the first point is that Philips has only pulled out of SRAM. Philips has gone to a great deal of effort to emphasize that its main core interests — consumer, and particularly HDTV — carry on unabated and uninterrupted. Philips has gone through a fair amount of trouble over the last year, so consolidating to its core activity is, I guess, a wise business decision.

From the point of view of JESSI, yes, I think that this is a blow. JESSI was intended to be the focus for European collaboration on all forms of memory, both SRAM and DRAM. The loss of SRAM clearly indicates that some of those West European companies will look outside Europe for collaboration if they cannot find it within JESSI.

QUESTION: Can you comment on how IPR rights will be determined and shared in European-wide R&D projects?

MR. DRAZIN: I understand that, for many of these Eureka projects, IPR still belongs to the individual participants. For example, Siemens recently bought IPR patents from Motorola.

PRICES, PROFITS, PROJECTIONS: IS THIS MARKET TOO DRAM VOLATILE?

Panel Moderator

David Angel

Group Vice President and
Director of Worldwide Research
Dataquest Incorporated

Good morning. I want to reminisce for a moment before we get into our DRAM panel. I would like to go back just a little bit. Some of the folks in the room will remember this.

1972 Perspective

The year was 1972. Richard Nixon was in the White House, China had just opened up to the Western world, the Supreme Court ruled that the death penalty was unconstitutional, the Miami Dolphins were the first professional football team to go unbeaten in a single season, and the memory market was flat.

I was working for a company that was producing semiconductor memories, and, while many systems companies were still using magnetic core for storage, we knew that it was going to be just a matter of time before semiconductor memories would rule the world.

Our yields were good, we thought. I should explain, for the youngsters in the crowd, when I said in 1972 that our yields were "good," I meant that we produced some wafers that actually had good working die on them, as opposed to the 90% yield that we all get today.

The problem was that the parts were not selling very well. We had some of the very best technical and marketing minds in the business. In a moment of desperation, we assembled all these great minds to see if a solution to this problem could be found. At the end of the day, the remedy that came down the mountain from this assembled enclave was so simple and so straightforward that it would set the pattern for the industry for many years to come. The message was contained in three simple one-syllable words: "Cut the price."

So, we elected to sell a 1024 bit DRAM — no "K" or "M" in there — for a penny a bit, $10.24. And boy, did we take heat for cutting prices! Quite simply, my friends, the DRAM world would never be the same.

Future of the Semiconductor Memory Market

I think, however, the future of the semiconductor memory market, as we have talked about and as Makimoto-san has shown us, is, indeed, good.

Most of us have read about the forecast increased use of memories and personal communication devices in nonrotating storage and in many other applications. We are starting to see a proliferation of memories in automobiles. As Makimoto-san indicated earlier, there is the belief that a whole new era exists in hand-held custom computers for specific applications which will be memory-intensive.

Growth in Memory Demand

A key force that will drive the substantial increase in memory consumption this decade is that knowledge is doubling about every four years. All of this information needs to be accessed, manipulated and stored. This will create an immense need for memory.

One deep thinker at Dataquest believes that we are not going to see any real saturation in the demand for memory until systems possess the same level of memory as the human brain. I am probably down a few bits, but, for reference, he believes that the memory capacity of the human brain is about $1x10^{15}$ bits. If my math is correct, that is equivalent to about 1 billion 64 Mb chips. So, we have a ways to go.

There is the argument that the interconnect scheme isn't as good and that access time is going to be an issue, but I think you get the point — that is, we think memory demand is going to be strong for quite a long time.

Near-Term Memory Market Forecast

I want to take a look at how strong we think the memory market is going to be over the next few years. Illustration #1 is a rather traditional Dataquest graphic showing actual DRAM unit shipments in 1986, 1987, 1988 and 1989; and then, we have put in our forecast for 1990-94.

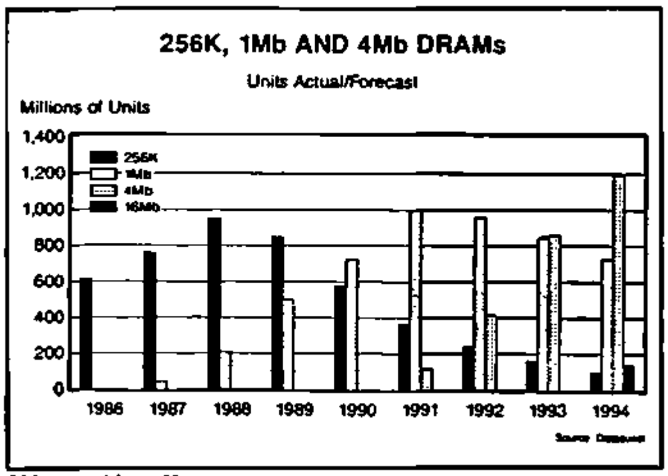

Illustration #1

The 256K DRAMs peaked in 1988. The 1 Mb device is forecast to peak next year. The 4 Mb device, we believe, will crest in the 1994-95 time period.

The 4 Mb device shows its first serious production in the 1992 time frame, then climbs to about 1.2 billion units by 1994. We also begin to see the first significant production of 16 Mb DRAMs in the 1994 time frame.

On the basis of what we have talked about so far, I think we can see why this business is so attractive. We begin to get an appreciation for why the Japanese have invested so much money in this business, why the Korean companies are moving very aggressively at this point, why various Taiwan chip producers are now entering this market, and why certain Asian chemical and steel companies, particularly in Japan, have announced that they are entering the DRAM market.

The Future of DRAM Manufacture

It was not until I began to dig deeper into this situation, trying to understand what was behind this forecast, that I developed a serious apprehension about the future of the DRAM manufacturers.

One of the joys of being associated with Dataquest is that there is an almost unlimited amount of information on the semiconductor industry available to anybody with an inquiring mind. If you couple that with a cadre of highly intelligent and informed people who are always willing to sit down and discuss an issue, you can come up with some very unusual insights as to what the future might hold.

I set out to try to understand what the numbers meant. Now, a word of caution. The Chinese have a saying that when the numbers are tortured, they will tell you anything. I have given you one confession already. I am going to give you a second one. I will admit to torturing some of these numbers almost to the point of being inhuman. I will confess that I did not take the decimal point out to the fifth place for unparalleled accuracy. I tried to gain an understanding of the trends and the events that would give us some specific insight as to what the future may hold for this growing group, or nucleus, of DRAM manufacturers.

I am going to skip over Illustration #2. Makimoto-san gave us a good idea, and I would like to give our panel a little more time.

	Revenue	Multiple
64K DRAM	$ 1.6B	-
256K DRAM	$ 9.9B	6.2
1Mb DRAM	$24.9B	2.5
4Mb DRAM	$41.8B	1.7
16Mb DRAM		

Illustration #2

DRAM Price Trends

One of the first observations is that the selling price of DRAMs has traditionally declined down a fairly sharp price curve. Illustration #3 indicates the price decline curve for both the 1 Mb and the 4 Mb DRAMs. If we torture the numbers a little, we can gain more insight. In the five-year period from 1987-91, the average selling price of the 1 Mb DRAM declined 68%.

Let me go at that another way. The price that we forecast for the end of 1991 will only be 38% of the price as it entered this box in the 1987 time frame.

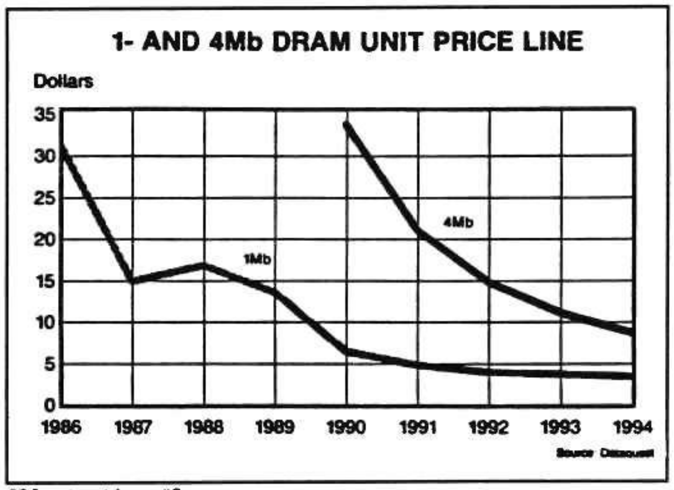

Illustration #3

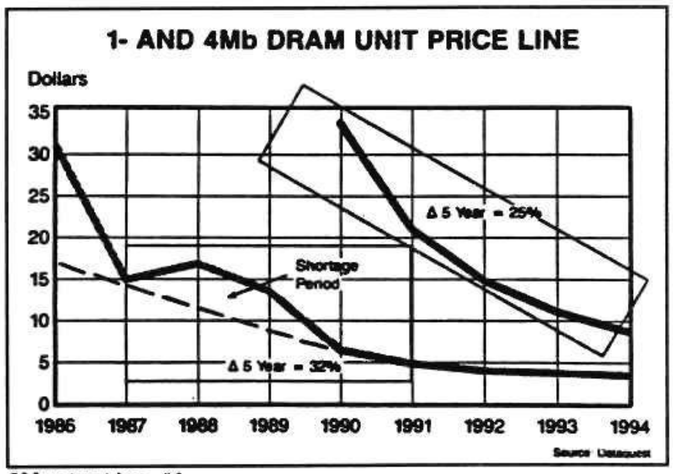

Illustration #4

This took a certain amount of doing. If we integrate the area under the curve, this goes up in 1987, where the 1 Mb chip reversed the price trend. It actually increased in price for about two years. The 1 Mb DRAM suppliers enjoyed about a $2.6 billion increase in revenues over what they would have realized if the 1 Mb device had stayed on its traditional curve. This, of course, as all the users know, was the famous DRAM shortage of 1988.

David Angel

Let's change our view for a moment to the 4 Mb DRAM. By 1994, the average selling price is forecast to be $8.72, only 25% of what the price was five years earlier.

Profitability

I would like to direct some questions to our panel. Is this a developing trend? Will each successive DRAM generation come down the price curve at a steeper decline than the previous generation?

There are those who argue that, even at the lower ESP [estimated selling price], the DRAM producers should, nevertheless, be making acceptable profit margins, the rationale being that the industry has almost 20 years of manufacturing experience.

Manufacturing Cost Estimates

Illustration #5 is Dataquest's view of DRAM manufacturing cost per bit over time.

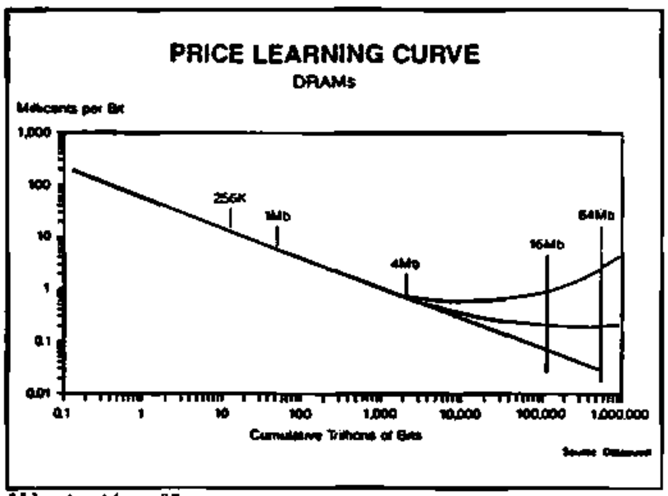

Illustration #5

The curve is fairly consistent until just beyond the 4 Mb generation where we branch out into what appears to be a family of curves. These are not our curves; basically, they are based on the opinions of several producers and users we have interviewed over time. The Japanese producers represent the most upward curve on this slide. In general, the Japanese producers hold that the immense capital investment must have a greater cost impact than in the prior generations. They state that the cost of manufacturing is going to go up and, consequently, the price per bit to the user — possibly for the 16 Mb DRAM, but certainly for the 64 Mb DRAM — will be higher than for the 4 Mb part.

The advocates of the curve in the center hold that, as we approach 0.25 micron geometries, up to 25 or 30 masking levels, and perhaps three to four dielectric layers, we are no longer going to be able to realize continued increases in yield.

One individual proposed this model: The number of good bits that we are going to get off a wafer of 64 Mb DRAMs will be less than the number of good bits off an equivalent size wafer of 1 Mb DRAMs.

The proponents of the bottom curve, showing the continued downward trend in bit cost, claim that the other two camps are alarmists, that the industry has always overcome technical challenges, and the ever-increasing volume of each generation over the prior density will more than allow for the increased capital investments.

So, to the panel: Who is right? Who is wrong? What is the answer?

Worldwide DRAM Production Capacity

Another function Dataquest serves is one of being an industry integrator. Over the past year or so, we have been listening to industry analysts talk about all the capacity that they are installing for DRAMs so as to be positioned when the good times return. I have heard this in Japan, in North America, in Korea, in the Republic of China, in Singapore and, as Jonathan just told us, in Europe.

What concerned us was whether the world's DRAM users could consume all of the DRAMs that could potentially — and "potentially" is a key word here — come to market in the 1990s. We have what we think is the world's only comprehensive data base of all the wafer fabrication facilities in the world, including the capacity that is planned to be added in 1991, 1992, 1993, 1994 and so forth.

Using a sophisticated model we have developed, we converted all the existing capacity specifically stated to be for 1 Mb or 4 Mb DRAMs into units that could be shipped if the facilities were operated at capacity as stated by the owners.

We have a good understanding of yields, efficiencies, defect densities and other parameters. We can vary the parameters in our model by geographic region, by a certain manufacturer's position on the bit learning curve — that is, has the facility produced 100 million parts, or is it just coming on line and so forth — so it is a fairly sophisticated model.

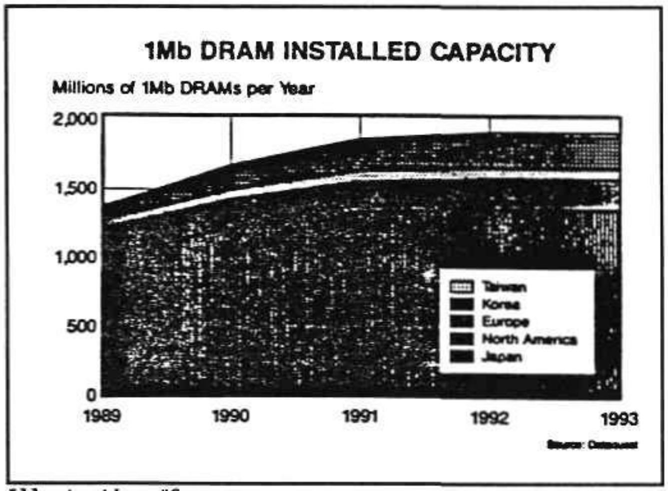

Illustration #6

What we see in Illustration #6 is that, based on this rather conservative model, there is enough capacity in place in 1990, at least intrinsically, to produce over 1.5 billion 1 Mb DRAMs. The capacity is sorted by geographic region. We focused upon wafer fabrication capability within a specific geographic region, regardless of country of ownership. For example, a Japanese factory in California is treated as North American capacity. A Korean factory in the United Kingdom is considered European capacity. A U.S. wafer fab in the Republic of China is considered Taiwan capacity. I will accept your arguments that is not necessarily the best approach; however, it keeps the model simple, which was our goal.

Potential Future Capacity

The significance of the information can be seen in Illustration #7, which depicts Dataquest's estimate of 1 Mb DRAM through 1993, under what we believe to be the potential worldwide capacity.

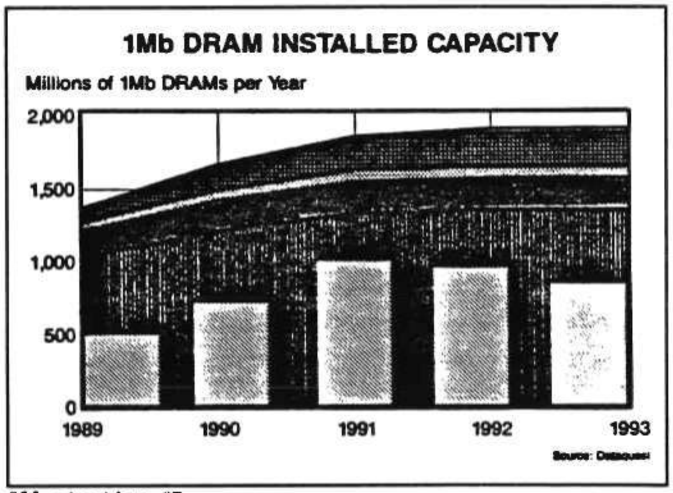

Illustration #7

When I started my analysis, one question was to resolve whether or not there is concern for another DRAM shortage based upon demand exceeding planned capacity. This does not appear to be the situation.

Illustration #8 indicates the potential 4 Mb DRAM installed capacity. The same rules apply as for the 1 Mb chip.

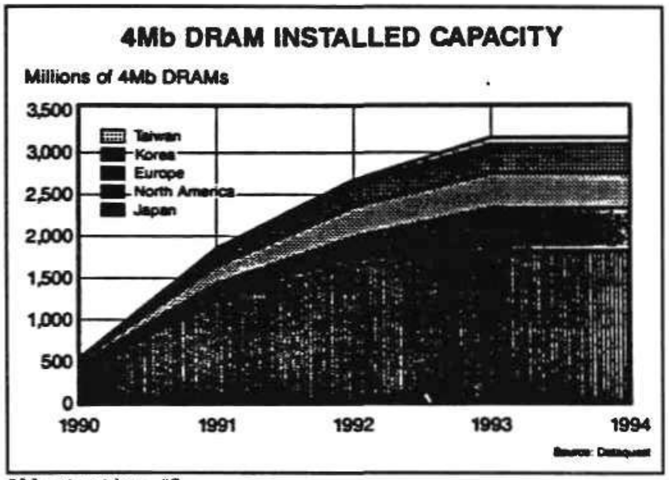

Illustration #8

I want to make it clear that we only included capacity that was specifically stated to be for the manufacture of 4 Mb DRAMs. If an entity indicated that they were going to install 0.8 micron wafer fabrication which they might use for microprocessors or gate arrays, or maybe DRAMs, we did not use this capacity in our model.

Growth in Demand

Illustration #9 is the "holy Toledo!" slide. This slide is an overlay of the 4 Mb DRAM demand onto what we believe to be the intrinsic installed 4 Mb capacity.

I think it speaks for itself. It is obvious that the amount of 4 Mb DRAM capacity that the worldwide producers claim they are going to install appears to be substantially out of line with what we believe to be the demand.

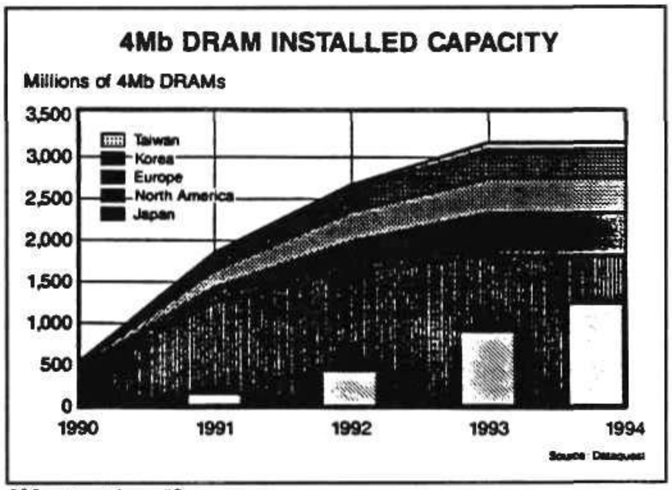

Illustration #9

Another word of caution, particularly as it applies to the 4 Mb device: Planned capacity is just that; it does not guarantee that any bricks and mortar will be put into place. If the building is actually put in place, it doesn't mean that the clean rooms will be completed; if the clean rooms are completed, it doesn't necessarily mean that the steppers will be put into place; if the steppers are in place, it doesn't really mean that they will be run at full capacity.

4 Mb DRAM Shortage

However, let's go back to the other side of this equation for one moment. Our data base confirms that the capacity that was forecast for the 1 Mb chip largely came into being. It is possible there could be an error in our model, and you should know that for your own planning. However, if there is an error by as much as a factor of two, it still appears that there is minimal potential for a 4 Mb DRAM shortage based upon capacity.

Questions for the Panel

I have purposefully been controversial. I wanted to stir things up a little bit. Let's get on with our panel. The purpose of the panel is to address these and other issues. Let's ask some questions.

• There are so many entrants to the DRAM market, is it a buyer's market, or is that just wishful thinking on the part of the user community? Is anybody going to be able to make any money? We are not necessarily in this business for the fun of it, and if we can't make any money, what is the answer?

• We have heard that the low 1 Mb prices may extend the lifetime of that chip and the accelerated 16 Mb activity may produce parts sooner than anticipated. Will this compress the 4 Mb generation? Will the manufacturers of the 4 Mb chip be able to get any return on the massive investment which has already been made in the 4 Mb device?

• Finally, who is right and who is wrong on the manufacturing bit cost curve?

Panel Introductions

Today we have some people who ought to understand this business: David Sear, Vice President of Fujitsu America; Bob Brown, Vice President and Group Executive of Toshiba America Electronic Components; Bill Gsand, Vice President and General Manager of Hitachi America, Ltd.; Joseph Parkinson, Chairman and Chief Executive Officer of Micron; and Frank Jelenko, Vice President of NEC Corporation.

We will give each panelists time to make some opening remarks about their position, and then we will bring everybody up to begin the panel discussion and answer questions.

PRICES, PROFITS, PROJECTIONS:
IS THIS MARKET TOO DRAM VOLATILE?

David Sear

Vice President
Fujitsu America

Thank you, David. I think you have posed some very tough questions which I hope my presentation will answer.

Long-Term Market Demand

The long-term market demand for DRAMs appears to be excellent. On a per bit basis, memory demand has maintained a quarterly compound growth rate of 20% for the past few years. This is expected to continue at a somewhat slower rate for the next five to 10 years.

This insatiable demand for memory is driven by the fact that, on a price per bit basis, the cost of memory has historically fallen dramatically since the introduction of the 1K DRAM.

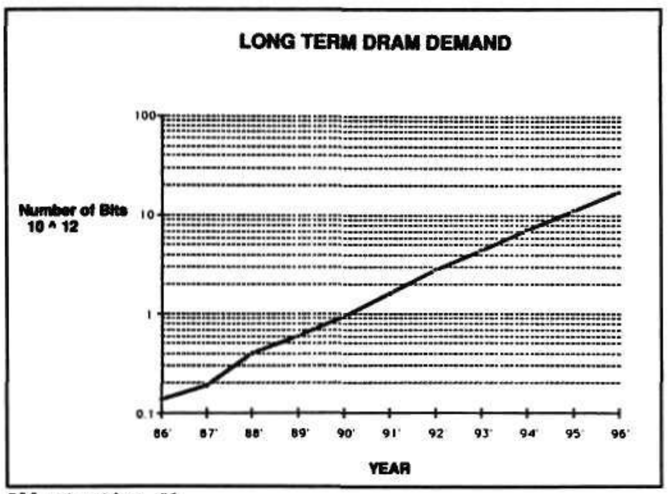

Illustration #1

In my opinion, this cost reduction will continue, but at a somewhat slower pace, as we enter the megabit generation of products, as opposed to the kilobit generation that we are now exiting.

Driving Factors for Memory Usage

The spectacular success of the personal computer business has driven the demand for memory in a manner that is unprecedented in the semiconductor industry.

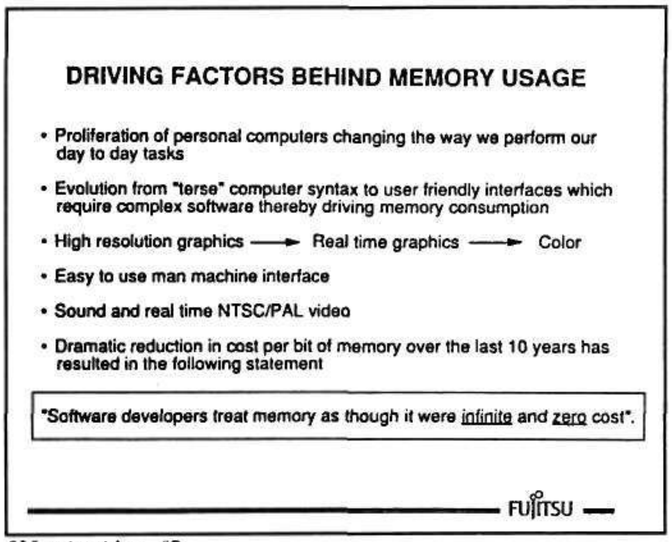

Illustration #2

The proliferation of the PC is changing the way we perform our day-to-day tasks. This increased dependence on computers has forced developers to evolve from terse computer syntax to user-friendly interfaces utilizing very complex software.

Complex software consumes enormous amounts of memory. Other devices, such as high-resolution graphics, real-time graphics and color, all become part of a general sophisticated man/machine interface — which, again, consumes large amounts of memory.

David Sear

Futuristic applications, such as real-time NTSC/PAL video and CD quality audio, will continue to drive DRAM demand. All of this is possible because the cost of memory, on per bit basis, has been dramatically reduced. I believe that when software was being developed over the last five (possibly eight) years, the software designers never thought about the amount of memory that software was going to use; in fact, I believe that they treated memory as though it were infinite in size and zero in cost. It was not a consideration.

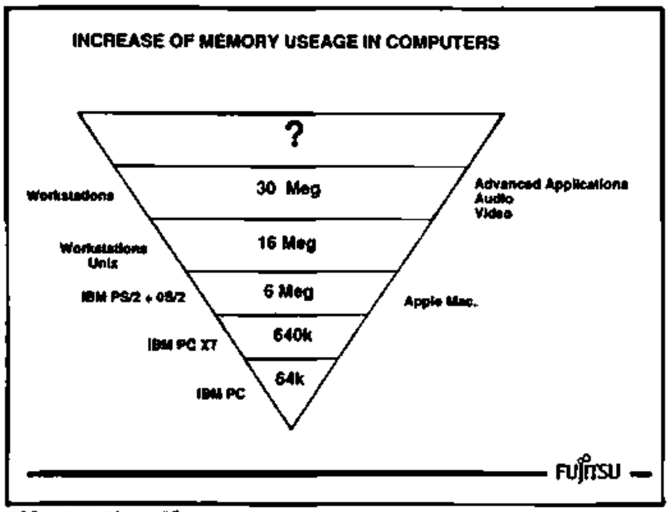

Illustration #3

The first PCs, such as IBM's, utilized an operating system which was developed from the early micro development systems. Its total memory capacity was 64 KB, which was considered enough then. This rapidly changed, with the introduction of the PC/XT, which uses 640 KB; and the PS/2, running OS/2, which requires 6 MB. The Apple Macintosh family requires between 5 MB and 8 MB. Both systems run sophisticated multi-user operating systems with Windows as the man/machine interface.

The latest trend is the migration to workstations based on UNIX, sophisticated graphics and man/machine interface. These machines could easily use 16 MB — and, in fact, if we include other applications, it is not out of the question that they could be up to 30+ MB.

Is there an end to this growth in memory demand? Based on history, it seems unlikely.

Price Learning Curve

Historically, price reduction in memory has followed something like a 60% or 70% learning curve. That means price is reduced by 30% for every doubling of volume on a per bit basis. As shown in Illustration #4, this traditional straight-line learning curve is an approximation to the actual observed pricing. Over the long term, it appears to have been reasonably accurate.

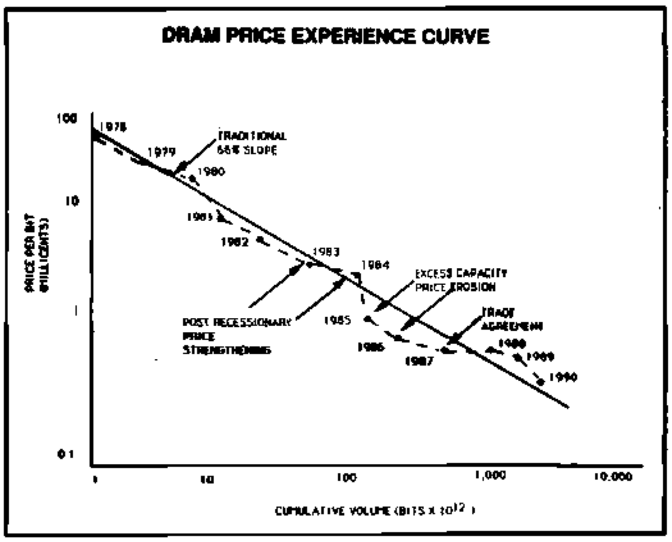

Illustration #4

Significant departures from this line occurred in 1980-82, when prices fell more rapidly due to extreme competitive pressure. This period was followed by a strengthening, in 1983 and 1984, due to demand exceeding supply, before demand fell way below supply in the crash of 1985.

Since 1987, the actual pricing trend has stabilized and has not shown the wild vagaries of the past. The primary reason for this stabilization was U.S. government intervention, in the form of the Trade Agreement with Japan. This put into effect the FMV [fair market value] system of pricing, which set a minimum selling price for DRAMs imported from Japan. At this time, the highest percentage of DRAM production was in Japan. Consequently, the introduction of FMVs helped stabilize prices.

Another factor that caused prices to rise instead of fall during the 1988 period was that demand exceeded supply. After the crash of 1985, most of the semiconductor industry, and especially the Japanese, decreased capital spending, resulting in insufficient capacity in place when demand started to rise.

Massive expansions ensued, but were late in bringing new capacity on line for the 1 Mb, thereby causing a shortage and higher prices. In fact, according to David, we may have been in an oversupply situation for some time.

Today, supply definitely exceeds demand. It is generally felt that prices will once again fall in line with the traditional learning curve.

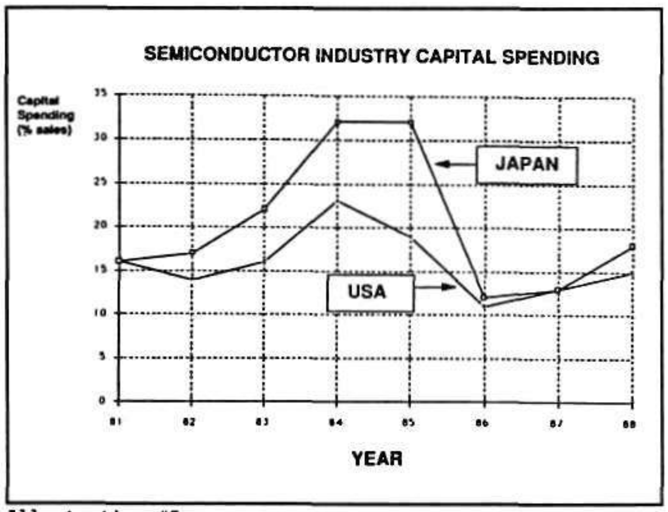

Illustration #5

However, I feel that, with the introduction of the 1 Mb DRAM, which is the megabit generation of products, the fundamental economics of silicon-based memories changed. In my opinion, the megabit generation will not follow the same aggressive erosion that we have become used to. A price reduction learning curve of possibly 80% or 85% might be more applicable than the 70% curve that we have been used to in the past. What are the reasons for this?

Die Size

Let's look at die size. When the actual die size plus some projected die sizes of memories are extrapolated, from 1K to the 1 Gb, there are some interesting trends [Illustration #6].

The 1K was introduced in 1979. By 1974, when it had reached its peak, it had die size of approximately 20,000 square mils and sold for $10.24. By the time the 4K had reached its maturity, its die size was only 25,000 square mils — a small increase in die size for a quadrupling of the number of bits.

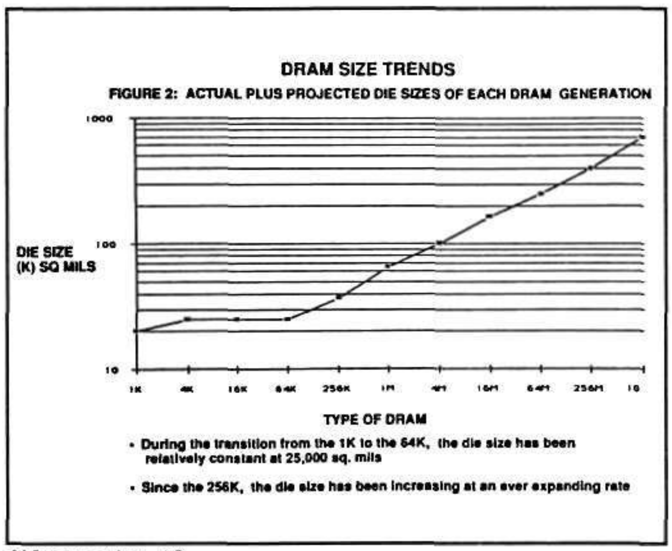

Illustration #6

David Sear

The containment of die size was achieved by improving processing resolution from 10 microns down to eight, and then to five. The cell size was sufficiently reduced, enabling four times the number of bits to be packed into virtually the same size of die as the 1K. This die size containment, in fact, did continue to the 16K and 64K by further improvements in process resolution, as well as by reducing the number of transistors per cell from three to one.

Storage Capacity

In addition, the cell area was continuously reduced and some clever schemes were developed to increase the cell storage or capacity size. Amazingly, while the density increased 64 times (1K to 64K), the die size stayed virtually constant. This trend caused many people in the industry to expect that DRAM prices would always fall to some historical low. In fact, many a purchaser has been heard to say, "DRAM prices always eventually fall to $2.00 per chip," regardless of what generation it is.

As seen in illustration #7, successive generations of DRAMs have required further reduction in process line resolution. Today, 4 Mb requires 0.8 micron technology and 16 Mb will require 0.5 or below. The megabit generation is forcing us to develop creative ways to increase capacity size while reducing area, such as a vertical capacitor.

In order to reach the gigabit generation, other improvements will be essential. It seems clear that, even when we allow for this incredible scaling improvement, we still cannot keep the die size of progressive generations from increasing. The straight line (rising from 256K up to 1 Gb) on a logarithmic scale, such as shown here, is an exponential increase.

I would point out that, even though the die size can no longer be contained, as these projections

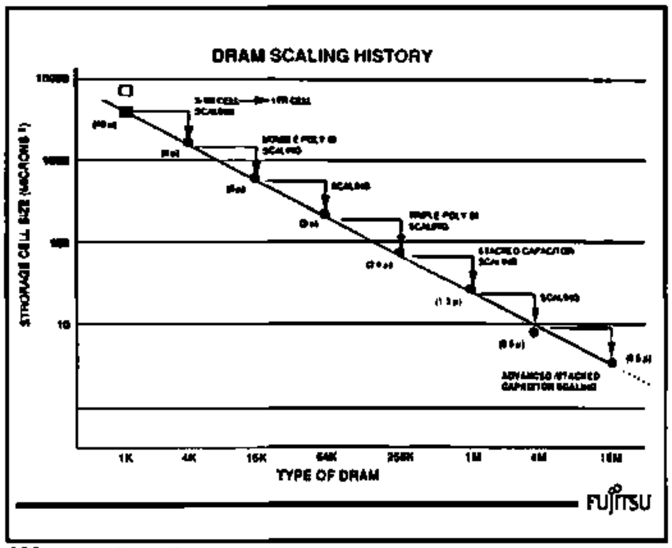

Illustration #7

show, it still provides an incredible demonstration of the ability of semiconductor technology to provide ever-improving cost/performance. While the bit density is increasing 4000 times (256K to 1 Gb), the die area will only increase 20 times, based on some of the extrapolations that I have just talked about.

What is so important about die size? Die size determines how many you get per wafer. Increases in the die size I have indicated will result in far fewer being available on a wafer of fixed size.

Wafer Size

In parallel to the improvements in process technology and cell design, the wafer size being used for production has been increasing. This increase helps offset the potential cost increases due to the die size increases by providing more available die.

For example, the 5" wafer, a 40,000 square mil die, which costs $300, will generate approximately 300 units; whereas, a 6" wafer, which only costs $400, will generate approximately 450 units. Therefore, the potential cost of a 40,000 square mil die on a 5" wafer will be about $1.00, and on a 6" wafer it would be $0.89. So, you can get cost reductions by simply increasing the wafer size. However, this kind of improvement is only achieved with the sizable capital investment needed to upgrade 5" to 6" and onwards.

Defect Reduction

Further improvements in cost can be achieved by increasing the production yield through reducing the number of defects present in the process. Regardless of all these improvements being made, concurrently, as quickly as possible, the die size is still increasing, thereby changing the basic economics of memory production.

Let me take a moment to explain Illustration #8. The downward slide in the number of available die, from 64K down to 64 Mb, assumes that the 1 Mb would be on 6" wafers throughout. I believe we have to go to 8" when we get to 16 Mb. If we do, that lifts the curve slightly in terms of available die; but it is certinly not back to the levels experienced in the old days when we got many hundreds per wafer.

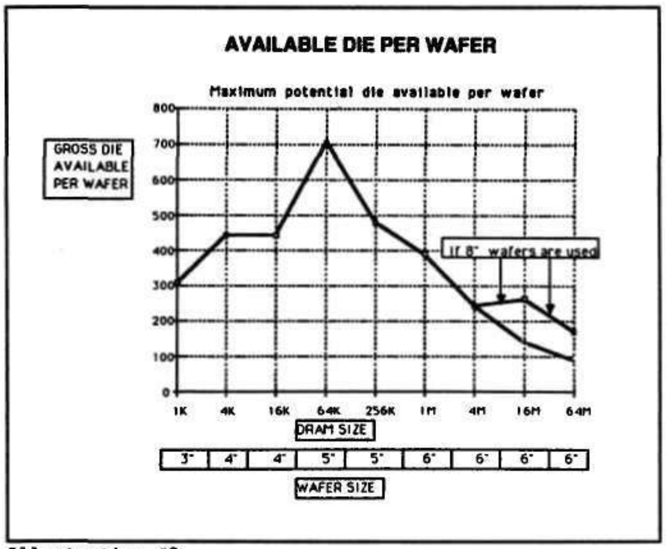

Illustration #8

Die Cost

When the cost is normalized to the 1K level, it becomes clear that, for many years, we have enjoyed ever decreasing costs for successive generations of DRAMs.

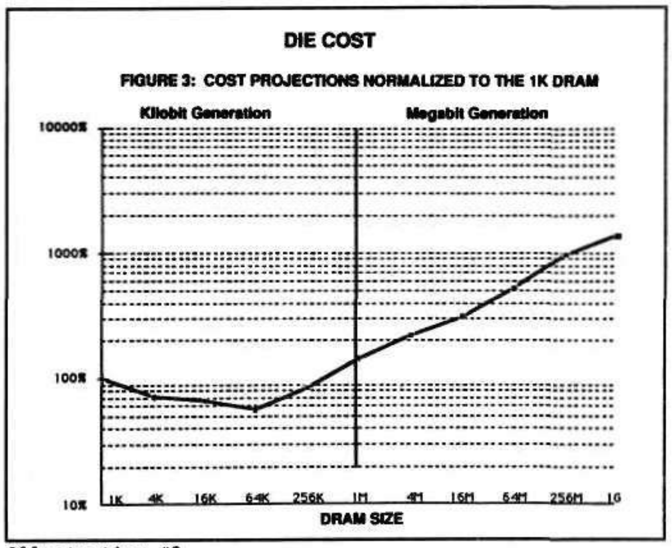

Illustration #9

This curve is normalized to 100%, which is the 1K. Let's compare how everything changed since the introduction of the 1K. The lowest-cost product relative to the 1K was the 64K, which was a good deal. In terms of cost, it was 70% of the cost of a 1K, even though it was 64 times the number of bits. By the time the 256K arrived, it was not quite as good, at 83%. So, it started to climb.

The break in this economic curve occurs at the 1 Mb level. It has now gone above 1K. It is actually 140% of the 1K because the die size is growing faster than we can contain using all the techniques I mentioned.

From the 1 Mb point on — the "megabit generation" — the economics are clearly on a different curve than we have traditionally been used to.

David Sear

This trend will continue to the 4 Mb, 16 Mb and all of the megabit generation of products, thereby causing, I believe, a slowdown in the rate at which the price per bit will erode.

The "Ultimate Manufacturing Challenge"

For semiconductor companies, the DRAM has long been the ultimate manufacturing challenge. The incessant development necessary to remain in the DRAM market has enabled DRAM technology to be the process driver for other product families. Now that the DRAM battleground has shifted from the 64K and the 256K to the megabit generation, the rules of the game have changed dramatically. The DRAM business is now not only brutally competitive, but has also become much more expensive to participate in.

DRAM Life Cycles

In an attempt to quantify the size of the capital investment needed to take our industry into the 16 Mb and the 64 Mb DRAM, I have made some projections on future DRAM life cycles.

The task of estimating DRAM life cycles is quite complex, because the rise time, fall time and peak amplitude for each generation are dependent upon the previous generations plus the future generation; they are interdependent. However, using Dataquest estimates, we can see the distribution for each family in Illustration #10.

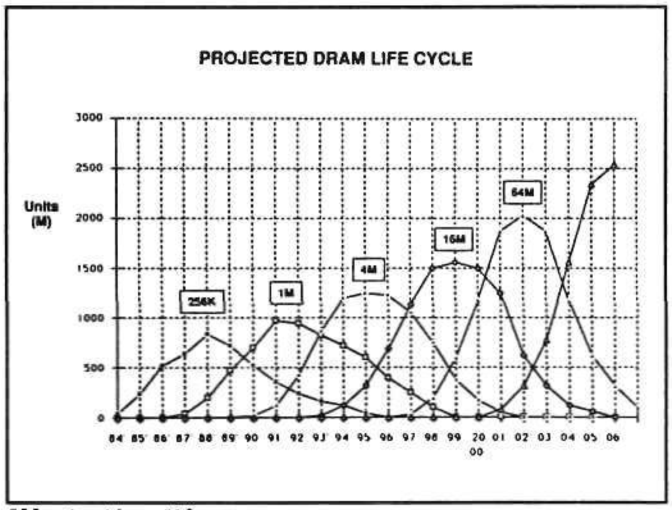

Illustration #10

The 256K peaked at about 800 million units worldwide in 1988. The 1 Mb is projected to peak at about 1 billion units in 1991. The rate at which these decline is a function of how fast the next generation comes on and the speed at which applications can be converted to take advantage of high-density product.

Another overriding factor appears to be that when we sum all of the bits consumed each year by all these generations, they would probably follow that first slide I showed you, which is a log demand curve. So, that is another overriding factor, the total number of bits in the marketplace.

Taking all of these factors into account, as well as Dataquest's earlier estimate up through 1994, I extrapolated a little bit. I didn't torture the numbers, but rather; I was nice and kind to them. I may be somewhat off. It is possible that the 4 Mb will peak at about 1.2 billion units in 1995; the 16 Mb could peak at 1.5 billion units in 1999; the 64 Mb could peak at something like 2 billion units in the year 2003.

Wafer Fab Capital Cost

What is the result of all that? In Illustration #11, the left-hand figure shows an estimate of the ever increasing capital cost to build the fabs necessary to run process technology down to 0.3 microns on 8" wafers with defect densities below 0.1.

It is interesting to note that beyond the 4 Mb we need to go to 8" wafers. Beyond 64 Mb, we are probably required to go to 10" wafers. Currently,

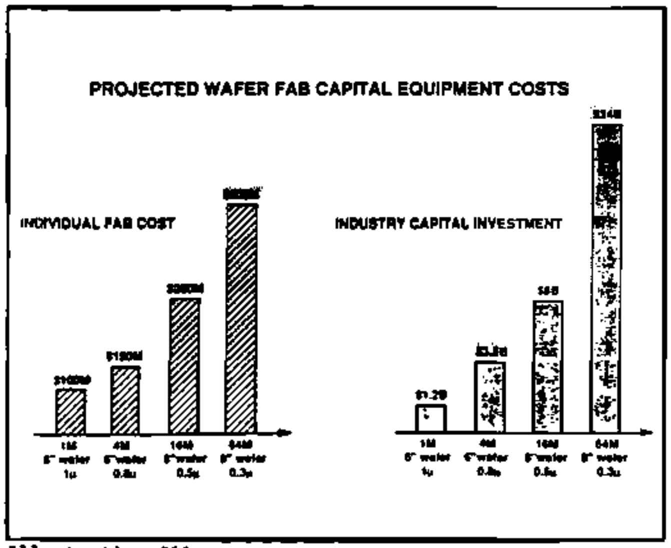

Illustration #11

there is virtually no 8" capacity in the world — there is some, but not a lot — and there is definitely no 10" capacity in the world.

Assuming that each successive generation of DRAM will reach the peak volumes I have indicated, which certainly seems to be the trend so far, and one fab is capable of processing 20,000-25,000 wafers a month, the capital investment needed to supply the market demand for 16 Mb and beyond can be predicted.

As seen on the right-hand side, with all the 4 Mb capacity that David talked about as being in place to date, our industry has probably spent something like $1.2 billion on the 1 Mb and $3 or $4 billion on the 4 Mb. The interesting point is, though, if we go to the 16 Mb and there is no 8" capacity, it has to be put in place. So, the industry is going to have to invest something on the order of $8 billion to meet that demand. If you go up to 64 Mb, it is a staggering $24 billion. That is food for thought. Today, DRAMs have become an ultra-large-scale proposition.

Future Outlook

In conclusion, long-term demand for memory appears to be insatiable. The economics of the megabit generation, I believe, have changed from the kilobit generation. The price per bit will continue to fall. It is not that they are getting more expensive and prices will rise — I am not in that camp — but I believe the rate at which price reduction will occur is going to be slower.

I project wafer fab costs to increase, causing the DRAM business to be extremely capital-intensive. The ante has been raised.

I believe DRAMs are still an excellent business to be in. In fact, DRAMs have become of such national importance, and it is such a large marketplace, that they have now become almost as important to the world economy as a barrel of oil.

Those are my thoughts. I will pass to the next speaker. Thank you very much.

PRICES, PROFITS, PROJECTIONS: IS THIS MARKET TOO DRAM VOLATILE?

Robert Brown

Vice President and Group Executive
Toshiba America Electronic Components

Good morning. I would like to thank Dave Angel for including me in this fantastic set-up.

After enjoying yesterday morning's panel, I did a self-assessment based on T.J.'s comments on dinosaurs. I believe his comments were, "Get small, get fast and grow hair." For those of you who have known me a while, I am not getting any smaller, and neither is Toshiba. Along those lines, I am not getting any faster — Toshiba is getting a little bit faster. But, in terms of growing hair, I must say that, after the last seven and a half years with Toshiba I now have twice as many hairs on my chest as I used to have. So, I do not *think* I am a dinosaur.

I reflected on other comments that T.J. made. I appreciated his objectiveness about Japan. I also appreciated having Toshiba included in his quiz. Boy, I am sure glad that Toshiba chose his SPARC chip set, because I wouldn't want to have him talking against us.

I also appreciated Gordy Campbell's comments on the fact that Japanese companies are not all alike. I agree that we compete very fiercely. I find it amazing that the four people representing the Japanese companies at this forum today are Americans. I doubt that Dataquest would have forecast that 10 years ago.

I will keep my comments about Frank Gill very brief because Frank is an esteemed customer — and so is Gordy, so I won't comment on his comments.

I would like to keep my remarks this morning rather noncontroversial and general because I know that our customers in the audience are looking forward to the questions and answers. Also, a lot of the points that I had planned to make were made eloquently this morning by Dr. Makimoto. I can't top them, and his English is probably better than mine.

Toshiba's Forecast

I will begin with Toshiba's forecast, as shown in Illustration #1.

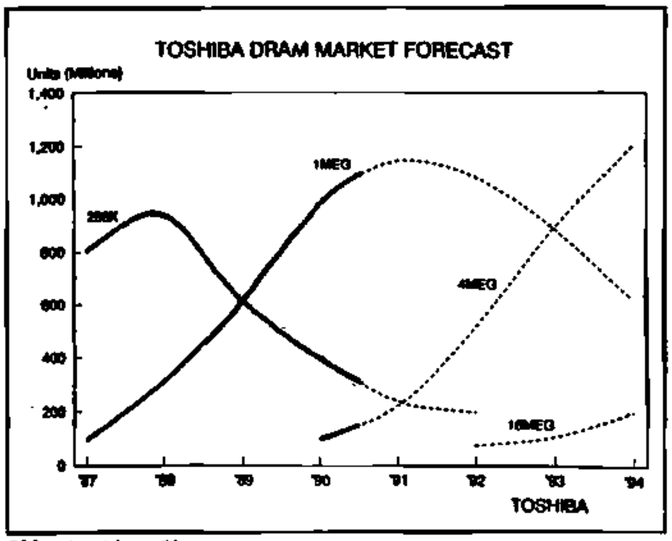

Illustration #1

Basically, I have no problem with the forecast data in terms of units that have been talked about so far. We could quibble about whether or not it is plus or minus 10%. I won't spend a lot of time on this, but please understand that I am the same guy who said a year ago that the 1 Mb DRAM price would not fall below $10 in 1989. Boy, did I blow that!

DRAM Trends

Let's talk about DRAM trends. I would like to dispel the myth that many people believe, that the DRAM business is a simple business — you make one part and you sell it for one price. Unfortunately, the business is often reported that way. Illustration #2 shows some of the reasons why that is not the case.

DRAM TRENDS

- **PACKAGING**
- **DEVICE ORGANIZATION**
- **MODULE ORGANIZATION**
- **APPLICATION SPECIFIC MEMORY**
- **POWER SUPPLY VOLTAGE**
- **PROCESS**
- **SPEED**

Illustration #2

Packaging

First of all, in the area of packaging, what I have shown here are four generations of DRAMs, from 256K up to 16 Mb. You can see in Illustration #3 the various packaging technologies — going from DIP, PLCC, SOJ, ZIP, TSOP, modules, and most recently, memory cards.

The difference between "X"s and "0"s is that the "0"s are products currently in Toshiba's portfolio, and the "X"s are those that are nonexistent or we don't plan to produce. This is not a "one part/ one package" business.

PACKAGING TRENDS

	DIP	PLCC	SOJ	ZIP	TSOP	MODULES	CARDS
256K	0	0	X	0	X	0	X
1MEG	0	X	0	0	0	0	0
4MEG	0	X	0	0	0	0	0
16MEG	X	X	0	0	0	0	0

Illustration #3

DEVICE ORGANIZATION

	X1	X4	X8	X9	X16	X18
256K	0	0				
1MEG	0	0			0	
4MEG	0	0	0	0	0	0
16MEG	0	0	0	0	0	0

Illustration #4

Device Organization

Next, is device organization — again, four generations of DRAMs. As you can see in Illustration #4, we went from two organizations at 256K, to three at the 1 Mb level and six at the 4 and 16 Mb levels.

Module Organization

Illustration #5 is an interesting one called module organization. Once again, the 256K level has only two organizations; the 1 Mb has six organizations; the 4 Mb has seven; and the 16 Mb has up to eight — and that is probably a minimum at this point in time.

I would like to comment on DRAM modules and the chart on DRAM modules that Mary Olsson showed us yesterday. Mary's chart showed that

MODULE ORGANIZATION TREND

	X8	X9	X18	X32	X33	X36	X40	X72
256K	0	0						
1MEG	0	0		0	(0)	0	0	
4MEG	0	0	0	0	(0)	0	0	
16MEG	(0)	(0)	(0)	0	(0)	0	0	(0)

Illustration #5

37% of the DRAM business would be in multi-chip modules in the year 2000. Our position has been that, at least at the 4 Mb level, we will see in excess of 50% of the 4 Mb DRAMs being sold in module form during the 4 Mb generation. In our discussion at the break, Mary agreed that the 37% number is probably a little understated. I have actually gone on the record as saying that at 4 Mb it could go as high as 60% to 65%.

ASIC Memory

Another area is application specific memory. Makimoto-san had a nicer slide than mine on application specific memory this morning.

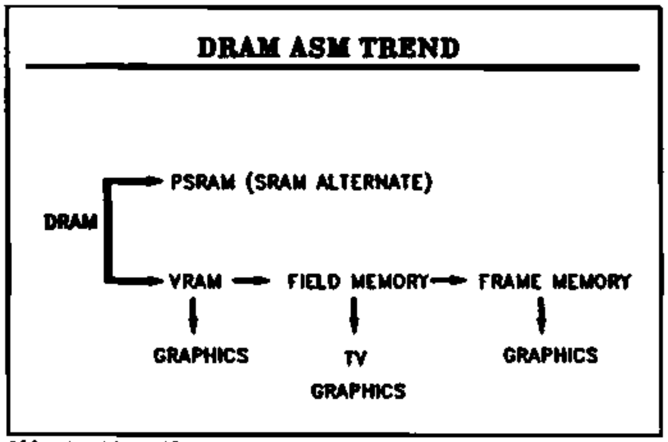

Illustration #6

Clearly, this is an area that allows for growth in the consumption of DRAMs, as well as the ability for DRAM manufacturers to get a better return on investment. We depicted that the DRAM business will branch out into areas of pseudo-SRAMs, VRAMs for graphics applications, field memory that will be used in consumer TV, and again, frame memory for higher resolution graphics. In our opinion, all of these will contribute to lengthening the life cycle of each generation of DRAMs.

Power Supply

Another issue that we have to contend with as suppliers and customers is the power supply trend.

DRAM POWER SUPPLY TREND

	5.5V EXT 5.5V INTERNAL	5.5V EXT 3.3V INTERNAL	3.3V EXT 3.3V INTERNAL
256K	0		
1MEG	0		
4MEG	0		
16MEG		0	(0)
64MEG			0

Illustration #7

We are very quickly going to see an evolution from a 5.5 volt to a 3.3 volt DRAM. This will have considerable impact on the technology utilized by the manufacturers; and also, it will impact the start-up of new generation DRAMs as our customers need to implement these into their systems.

Process

The next area is process. I am by no means a process expert — in fact, far from it. I think Makimoto-san did an excellent job this morning on this. Illustration #8 shows graphically what we think is happening in terms of design rules, chip size and process steps.

That chart shows two times the number of process steps at the 16 Mb level than at the 256K level — getting more complex, die sizes growing bigger, and I believe that the cost of producing these DRAMs will go up.

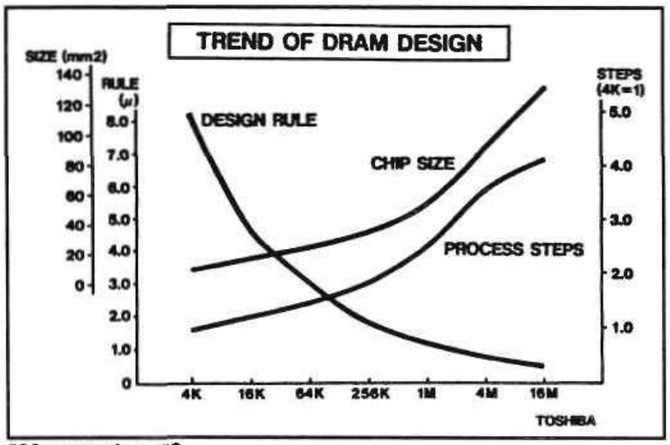

Illustration #8

Application Speed

Another area impacting DRAMs is the application speed in our customer systems. Illustration #9 shows the speed source of various DRAMs from the 256K level to the 16 Mb level. A 150 ns or 120 ns device will no longer exist at the 16 Mb level. In fact, we may see speed sorts even faster than 60 at that level.

Applications

We have seen that introducing DRAMs to the marketplace is very dependent upon the applications that can use DRAMs. Simply, each generation is somewhat different in what particular application will start to use that part early on.

On the right-hand side of Illustration #10, HDTV and audio are in parentheses because we wanted to highlight that at this time we are not sure

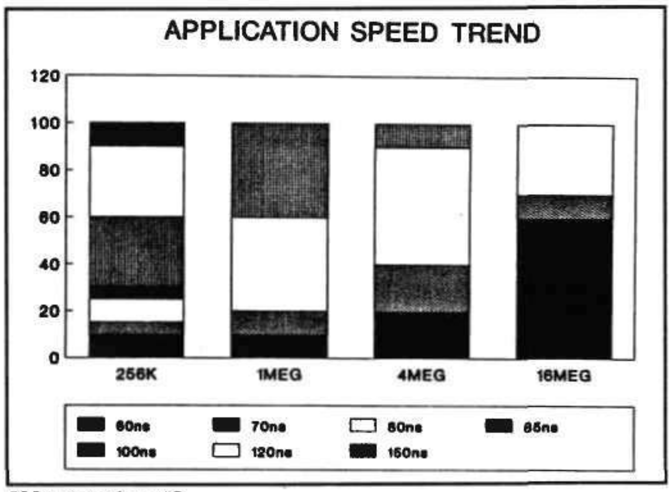

Illustration #9

DRAM APPLICATIONS

256K	1MEG	4MEG	16MEG
MAINFRAME	PC	FILESERVER	FILE SERVER
TELECOM	EWS	LAPTOP	LAPTOP
IND CNTRLS	MNFRM	EWS	(HDTV)
PRINTERS	TELECOM	MNFRM	(AUDIO)
PC	PRINTERS	IND CNTRL	SSD
EWS	IND CNTRL	SSD	EWS
	SSD	PC	MNFRM
	PRINTERS	TELECOM	IND CNTRLS
	LAPTOP	PRINTERS	PC
	HAND HELD	INSTRUMENTS	TELECOM
			PRINTERS
TOSHIBA AMERICA			INSTRUMENTS

Illustration #10

exactly what applications those are in. However, we do feel very strongly that the utilization of speech in the area of PCs will have a significant impact on the application of DRAMs.

Summary

In summary, I would like to say that DRAMs are not a simple business. Those who succeed have a tremendous challenge to manage a considerable mix of products. Those who stay in this business will continue to make money, continue to expand their products, and have a good business.

PRICES, PROFITS, PROJECTIONS: IS THIS MARKET TOO DRAM VOLATILE?

William Gsand

Vice President and General Manager
Hitachi America, Ltd.

Thank you, David. We are getting to the point in the program where there isn't a lot more to say about DRAMs. My direction is going to be a little different. I am going to philosophize more and use fewer charts. I would like to touch on some different points than the other speakers.

Prices

Let me be prophetic. Prices will certainly go down. How fast they go down — in what time frame and at what level — is dependent on a lot of factors which I will cover.

Profitability

The profits are going to go up. The companies that do things right will be in a position to make money in this business. Certainly, there is no disagreement that there will be growth and there will be diversification, although it is somewhat out of focus.

What the prices, the profits and the projections will do are very heavily dependent on three factors:

- Technology
- Competition
- Customer needs

All of these have a relationship to the prices, profits and projections we are talking about.

Getting in Early

Traditional wisdom says that you must have gotten into this business early. The guy on the left looks like he probably did it right; the guy on the right possibly didn't fare so well. The sign says: "Past performances are really no indication of future results."

There was an attitude that getting into the business early, making a large investment in R&D, jumping on the merry-go-round and grabbing the gold ring, and then getting off the merry-go-round and into the next generation quickly, was the way to go. You leave the mature technology to the leaders in trailing edge technology who will stay and support the customer base after the third, fourth or fifth years of a generation.

That may be changing. As we move forward, we have to look at different ways of staying in the business longer and ways of making money rather than being there for six months, charging very high prices up front and then backing out once the volume has passed beyond the median range and there are seven or eight competitors in the market.

Price Stability

Longer periods of price stability is one major issue. That is driven primarily by supply and demand. While there are variations and gyrations in the DRAM market, it is certainly much more stable and predictable than it has been in the past, with forecasting systems, EDP systems and the maturity of the business.

Fab v. Fabless

I wasn't here for Gordy Campbell's presentation yesterday, but I know his position. Most people look at the fabless environment as a situation where you are designing and using the value of that design to justify paying a price to a foundry that is slightly higher than it would cost you to do it yourself. It may be lower, depending upon how much boundary you can put in or how much capacity you can afford to put in.

On the other end of the spectrum is staying in the business longer by phasing down and not having your own fab in the latter part of a generation phase. That is a way to continue to make a profit and take advantage of transferring that technology to someone else. In that way you can continue to have the profitability advantage on a longer term basis without limiting moving forward into the next generation.

The big companies in DRAM are multidivisional, and in most cases multinational. They have the capability — and probably the necessity — of building in-house semiconductor equipment. That can definitely give you a leadership position, and will drive your business in-house more strongly. You are less dependent on a marketplace where each of your competitors is able to get the equipment at the same price as you can.

Intellectual Property & Patents

The last point is tied to royalties, alliances, and to some extent, intellectual property, where the return on a technology extends well beyond the first six to 12 months of being in a market.

If you look at the patents issued in 1989, according to Department of Congress numbers, five of the top 10 are in the DRAM business. That includes Siemens and IBM. We don't like IBM being in the DRAM business because we would like to sell them many more, but they claim they want to be there and they are in a very strong technology position.

Nonetheless, there is a tie between the patents and the high technology companies with the money to make investments in R&D and stay 10 to 15 years ahead on the patent technology.

Market Differentiation

Let's look at the second piece of competition. There are probably more than a dozen companies out there at this point looking for ways to provide a differential advantage to their customer base in order to succeed in this very competitive marketplace.

Unfortunately, the market — our customers — does not allow us to be loners anymore. Customers want multiple sourcing. They want standards. They don't want somebody who is out there well ahead of the pack because it puts them in a much higher risk situation.

I think the solution to this sole-source environment is that you need to fit into a classification if you are going to succeed.

• Category 1: Mainstream Suppliers — the ones who are speaking today, plus several others — are integrated suppliers. They also are involved in the second and third categories.

• Category 2: Alliances.

• Category 3: Benevolence. This includes ties to university technology, U.S. government-backed technology and some situations where major companies who have semiconductor technology (e.g. AT&T, IBM, Bell Labs) will share that with the industry. Those interactions are going to be necessary in order to profitably stay in this business.

Unless you are involved in at least two of these categories, you are going to have a major problem competing in this industry.

Market Responsiveness

The customer is what we are all about. We really cannot substantiate the prices or the profitability in our projections with any reasonable validity unless we are responsive to the market. Packaging complexity, modules, integration, the "mogic chip" combining memory and logic on a single chip, which Dr. Makimoto alluded to, are all going to be key issues in servicing customers and in providing a way to be in the DRAM business.

The process investment, the knowledge of the process and the massive size of the DRAM business allow us to be cost competitive, not only on the memory side, but on the logic side as well.

Product Complexity

Let's now discuss complexity of the product. Hitachi will build over 500 configurations or variations of the 4 Mb DRAM. Again, it is not a simple business.

• We will get to the point where only the companies who have access to major resources — people and money — and have the staying power and commitment to be in the DRAM side of the business are going to survive.

• It will require a 10% (or greater) share to be able to make money in this business. It is a big market, but five or six people are going to end up with a greater than 10% share in the future. The profits are going to be there.

• Prices are going to be volatile, but they are going to be workable. They will be dependent on the supply and demand in the industry.

• Regardless of what available capacity could be, it will be geared toward market demand.

Conclusions

The DRAM business is not going to be easy. It probably will not be dominated by any one or two people, although the leadership generation to generation tends to bounce back and forth. There will be several major companies involved.

• It will probably be more predictable than it has been in the past, but certainly not as predictable as some of the more stable industries such as Hitachi's — power plants that take 10 years, railroad cars and those kinds of businesses. We have to stay flexible to continue to compete in this market.

• It will be profitable. All the numbers show that it is going to be very big. There is no question that it is going to be exciting.

Hitachi is committed to being a factor. We are moving forward. Hopefully, with our talent and resources, we can crusade around the world to grow our business on a worldwide basis, as unification happens in Europe and localization occurs in the United States. We are looking forward to a very strong future in DRAM.

PRICES, PROFITS, PROJECTIONS: IS THIS MARKET TOO DRAM VOLATILE?

Joseph Parkinson

Chairman and Chief Executive Officer
Micron Technology

I think there is plenty more that could be said about DRAMs, but if we were to touch on the really sensitive issues I am afraid we would touch off the earthquake, as Dataquest did last year. So far, everyone has very studiously avoided FMVs, patent lawsuits and other realities of the industry, and I probably should also.

I want to thank Manny Fernandez and Dave Angel for inviting Micron to participate. Whether Hitachi believes we deserve a place here or not, we are pleased to be here today.

I do agree, Hitachi probably will take a 10% market share; but I am not sure I agree with Hitachi's implication that Micron is not going to be a part of this business in years to come. We are certainly here to compete, and I think we have a shot at doing that.

Worldwide DRAM Market

First of all, I want to echo what has been said before about the strength of the DRAM business. While I respect Dave's charts and the theoretical excess capacity, I am not sure all that capacity is going to be around.

I recall the last downturn. What started out with a boom was shortly followed with a severe bust. In my experience, cycles are not over until people exit the business. I believe that will happen again in this next downturn, and it will not be over until we have a narrowing of the crowd. In any event, the long-term demand is going to be phenomenal.

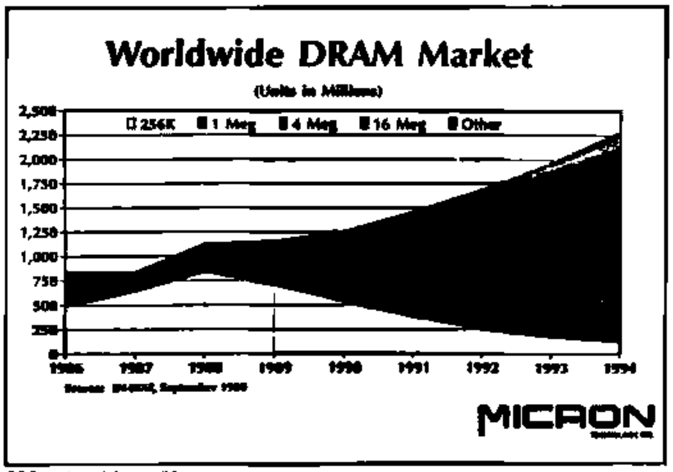

Illustration #1

Related SRAM & VRAM Markets

I want to touch on some related markets to also show the importance of being in the DRAM business. In my estimation, you cannot compete in the second and third largest markets — which, I want to emphasize, are the SRAM and VRAM markets — without a foundation in DRAM. I believe that they are all closely related, that the same process advantages you have in DRAMs will carry over to SRAMs and to VRAMs. Accordingly, I would anticipate that the same basic players will dominate all three. If you are not in all three markets, you will have difficulty competing on a long-term basis. [See Illustrations #2 & #3.]

Micron has used their expertise in DRAMs to expand very effectively into the SRAM and VRAM markets. [See Illustration #4.]

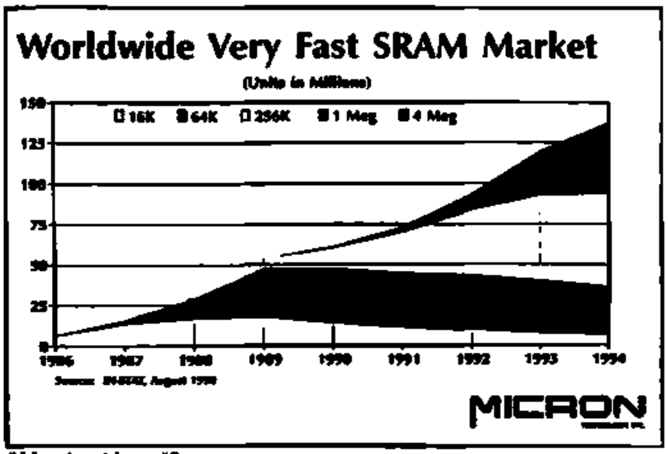

Illustration #2

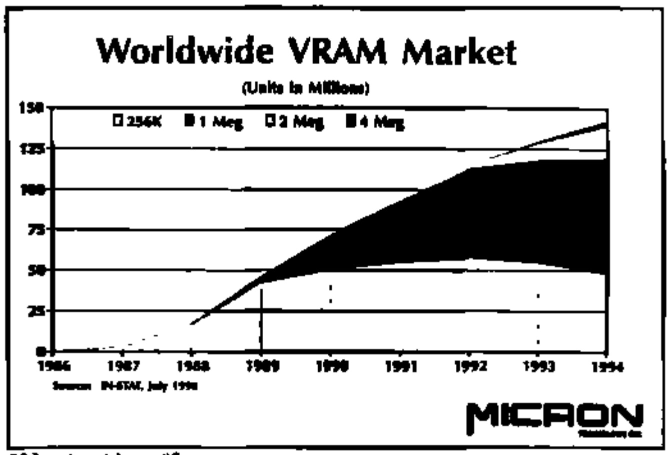

Illustration #3

Micron Has Used DRAM Technology and Production Expertise

To expand into

SRAMs
VRAMs

To address emerging markets with derivative products

Triple Port DRAM
64K x 16 DRAM
QUAD CAS DRAM
Cache Data SRAMs

Illustration #4

Other Emerging Markets

We are also targeting other emerging markets that we see as very promising, based, I emphasize, on our DRAM technology.

Die Size

The other fallacious point, in my mind, of the earlier charts is the notion that everything is fairly predictable. Do you remember the chart that showed that the 1K through 64K were fairly stable in die size, and the chart showed a 25,000 square mil die size? That was at a time that Micron was producing a 64K at a 14,000 square mil die size, which was half the size of the next smallest producer. Motorola was in there at about 50,000 square mils.

So, die sizes are not the same for all producers. Those with the smallest die sizes and fewest mask layers tend to dominate this business long term.

Technological Breakthroughs

There are technological breakthroughs that explain why some players are in this market today and why others exited.

One of the breakthroughs that Micron has — which explains why we will be a survivor — is the triple port DRAM that we have developed. It was recently featured on the cover of one of our technical magazines. We have been getting a lot of press.

I believe that our small die sizes and adding logic to the DRAM will give us a very strong position long term, as well as in other markets (e.g. 64Kx16 and Quad CAS DRAMs) which are important in the modules and were alluded to as eventually growing to over half the market, as well as the cache data SRAMs.

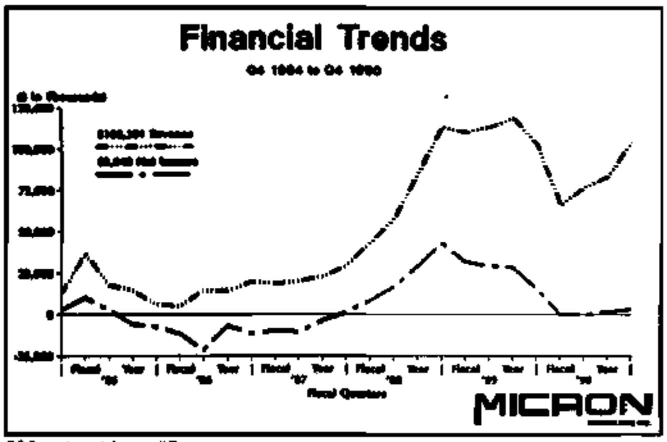

Illustration #5

Micron's Financial Trends

Our financial trends mirror the industry generally. In Illustration #5, you can see periods of incredible revenue growth and periods of losses, particularly in the 1985-86 time period. But, in the current time period, where we are again facing a severe price pressure, we have, at least so far, managed to keep out of the loss column. I would attribute that to a couple of things.

• A much narrower supply base, at least in the United States production.

• We have a broader product line, with the SRAMs and VRAMs, and a much broader customer lineup going into this downturn than we had in earlier downturns.

U.S. DRAM Production

That is important for maintaining DRAM production here in the United States. I would quibble with the Hitachi assertion that IBM should not be in the DRAM business. I think it would be a tragedy if the United States lost yet another producer.

The infrastructure is so important, and much of that infrastructure is built around DRAM production. So, I guess I would take the opposite viewpoint and say that I hope IBM not only stays in the DRAM production business, but also continues to help others in the business in the United States, including Micron.

Net Worth vs. Debt

As shown in illustration #6, our net worth has improved dramatically. We have been able to hold our debt down, which gives us a financial strength going into this downturn — a strength which we certainly have not had in the past.

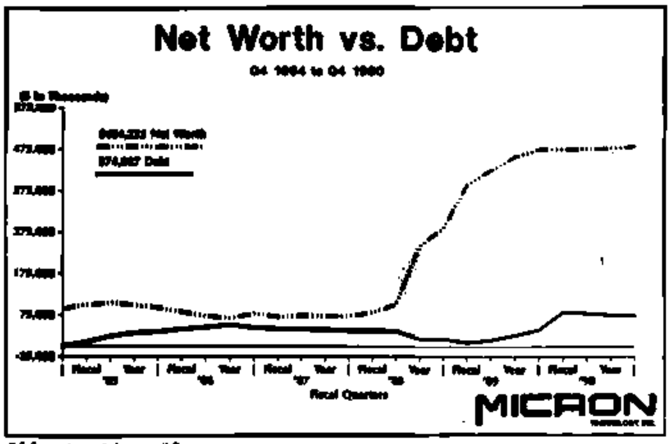

Illustration #6

Endurance Factors

The biggest factors, I would say, for Micron's long-term endurance — and, for that matter, anyone's endurance — are not the factors that Hitachi alluded to. I don't believe that you have to be a multinational giant with integrated power plants and such. I would say that the key ingredient to success in any business is going to be focus [Illustration #7].

• Our focus has resulted in consistently smaller die sizes in virtually every generation of DRAMs, SRAMs and VRAMs that we have been in.

Factors for Endurance in Semiconductor Manufacturing

- Smaller die sizes
- Reduced mask layers
- Equipment selection and automation
- Fab configurations and wafer sizes
- Continued improvements in product speed
- Continually lower manufacturing costs
- Excellent quality
- Proven reliability
- Intelligent burn-in (AMBYX)

Illustration #7

• Another factor alluded to by one of the speakers was the multiplication of mask steps, as if this were an inevitable phenomenon, in that you have to have more mask steps as you get to greater density. Again, I think Micron belies that notion by virtue of our having, in some cases, half the mask steps of our competitors.

• Concerning equipment selection and automation, I would severely question Hitachi's belief that you have to make your own equipment in order to be in this business. The big thing is that the equipment be available on the open market. For that reason, I see IBM as a very important long-term player, with its support to Etec, the photolithography spin-off from Perkin Elmer.

We need to maintain this equipment base in the United States to be able to compete with Japan long term. This is one reason that the majority of the money issued by SEMATECH today is going to the American base of equipment suppliers. We, at Micron, see that as vital.

• Fab configurations and wafer sizes also figure greatly in the cost of production. When I look at these multinationals and the time that their executives must spend flying continent to continent, looking at their facilities, flying their parts from continent to continent depending on where they are performing a certain step or production, whether it is wafer, assembly or test, it looks like a headache to me. You must suffer severe jet lag and increase your cost of production.

Micron will eventually have to face that situation someday if we are going to achieve that 10% market share that seems so important in Hitachi's opinion. We have now concentrated all of our production in Boise, Idaho, and we somehow manage to survive against these giants from the Far East.

• Product speed, I agree, is important, but not at the expense of mask layers and cost. If it requires double-metal processes, BICMOS on SRAMS to get the high speed, it will not be competitive long term, unless you can get those exotic processes in the same number of mask layers that your competitors have.

• Finally, quality and reliability. When you are going against Japan, with its perceived quality advantage, whether in automobiles, consumer products or DRAMs, you cannot be equally good; you have to be better in order to neutralize that perceived advantage.

Quality Advantage

I believe that one of the reasons Micron has survived is by virtue of NCR going public and announcing an unprecedented Quality Award to Micron. That award and others, from Northern Telecom for instance, reflect the fact that Micron has a unique quality advantage over the Japanese.

Ours is not just built-in quality through process control, but such unique systems as our intelligent burn-in (AMBYX), whereby we not only burn in all of our product, but we monitor what is happening during that burn-in so that we get real-time data. This increases the types of tests that we can do, and, most importantly, accelerates the feedback to our production line so that we can make improvements that widen our margin and give us that long-term higher quality.

These are the advantages that Micron has over these foreign giants, without regard to their size or current market share.

Summary

In conclusion, I want to just briefly touch on issues that I think have been studiously avoided in earlier speeches.

- One would be the prospects for the current Trade Agreement. As you know, the American industry has finally come together, not only the user community in the form of CSPP, but also the supplier community, in the form of the Semiconductor Industry Association. We have announced a joint effort to try to resolve the very serious trade issues that we are facing.

You will remember the two-part Trade Agreement that involved a commitment by Japan not to dump any longer. This was after eight American producers had gone out of business. You saw the cartoon: The guy sitting on the street with his hand out was an American. That represents the 55,000 jobs that were lost in the DRAM business when all of these companies were going out of production in the face of illegal Japanese dumping.

- The other was a commitment on the part of Japan to open up its markets and to achieve a 20% foreign market share by next year. Neither of these objectives were honored by the Japanese. It is very clear — and everyone acknowledges it — that 20% market share will not be achieved next year.

I have to give credit to the SIA and the user community for coming together and trying to avoid a conflict this time around in order to reach some resolution with the Japanese government that will somehow extend the agreement, allowing a little more time to work with these people to resolve these issues in a friendly fashion, without an earthquake.

Based on that, I want to thank you all for the opportunity to present here today. Micron will be here, with or without a 10% market share.

PRICES, PROFITS, PROJECTIONS:
IS THIS MARKET TOO DRAM VOLATILE?

Frank Jelenko

Vice President
NEC Corporation

I have an interesting position to play in the roles of the speakers. As you will see, my presentation is a little more focused on what customers and suppliers can do to help stabilize the DRAM industry. I do promise that I will try to be reasonably brief.

Before I start off on this path, I feel some responsibility to make a comment to my esteemed colleague regarding the previous presentation. I have been around for a few years and I have a different view in terms of how the dumping was started in the 1983-84 time frame.

NEC's DRAM Industry Perspective

I would like to give you our view of the DRAM industry. We see DRAMs as being similar to many attractive things in life: It is very hard to live without them, but they always seem to be giving you some type of headache.

Clearly, DRAMs have become worldwide strategic commodities, certainly to electronic equipment manufacturers and to semiconductor manufacturers. As mentioned before, they are often considered in national and international policy by nations throughout the world. So, we can't live without them, but they still keep giving us a headache.

Like many commodities, there is a lot of competition. Due to the strategic nature of DRAMs, there has been — and probably will continue to be — a continual stream of new competitors. This severely competitive environment, along with other factors, is causing a highly volatile marketplace.

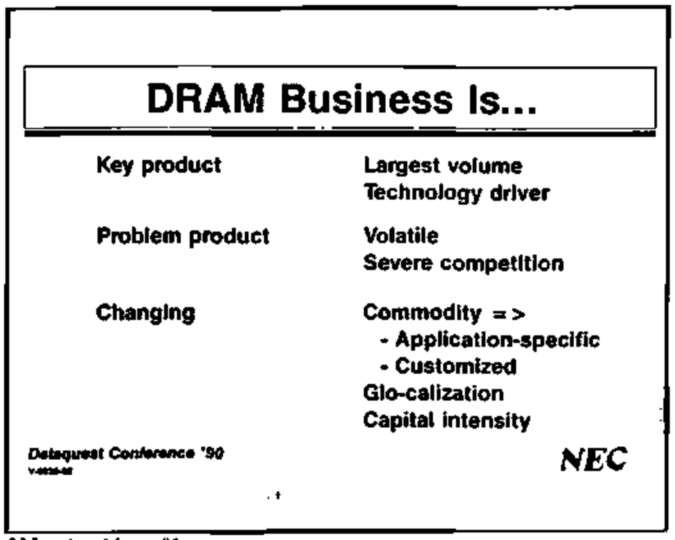

Illustration #1

Entering a Period of Change

While our industry, as many people have shown, has been constantly changing, we are now entering a period of change as great — and perhaps greater — than ever before.

DRAM volume was previously limited mainly to a few standard part types. In the future we will see an increasing number of variations in the memory organizations and package styles.

We will see the popularization of so-called application specific memory [ASM]. These ASMs, as has been mentioned, will be configured by the users, the customers, in terms of memory array organization, itself, and with some dedicated logic.

Also, we are entering a period, or era, of glocalization. That is, suppliers will have worldwide reach, but will provide products and services tailored to the local customer.

Finally, as we are all very aware, the capital requirements for DRAMs are increasing at what is virtually a geometric rate. This causes DRAM manufacturers, quite frankly, to carefully consider the timing for each new fab, and to find ways to extend the productive and useful life of these fabs.

Volatility

What is actually the volatility in all this?

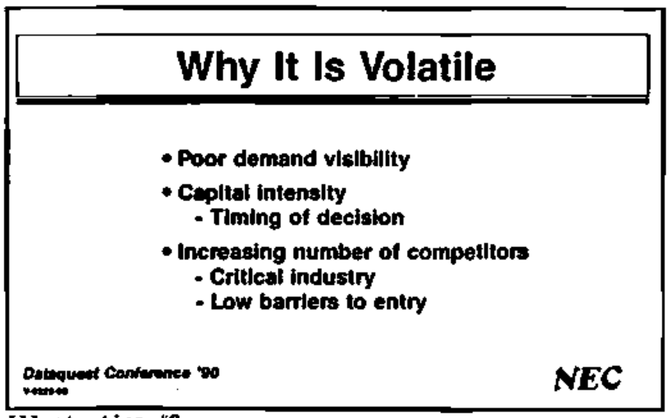

Illustration #2

From the semiconductor manufacturer's standpoint, if we just had a clear picture of future demand, we would easily prepare the necessary production capacity. However, accurate forecasts are rather like hen's teeth. They are not so easy to find. So, we don't always have the right production capacity when our customers need it.

Another factor, as I mentioned, is the increasing amount of cash required for each new fab. You can't put up just any old fab. To keep the end-customer demand growing, we must all provide constantly improving cost/performance. This, combined with the various business cycles so clearly shown by other people, means that sometimes the cash required is actually not available.

And, of course, we have a whole bunch of new guys trying to get into DRAMs. While competition is basically good for any industry, dedicated newcomers have a habit of making waves. So far, the DRAM industry has been relatively volatile.

Reducing the Volatility — Suppliers

As responsible members of this community, we should have some ideas on how to reduce the volatility.

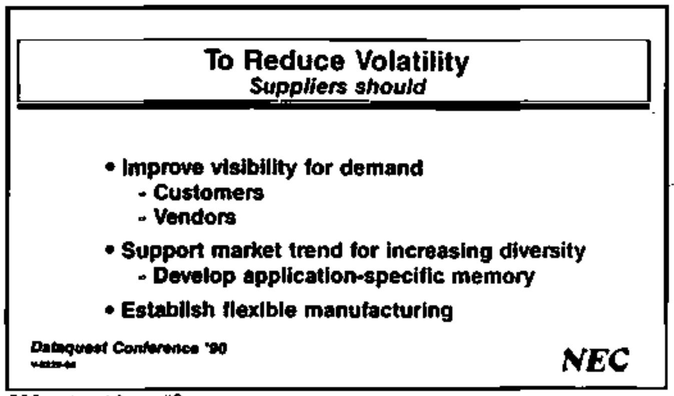

Illustration #3

From the suppliers' side, we need to:

• Continue to improve our visibility for future demand. We should continue to develop our own forecast capabilities, and work closer with the customers to understand the final demand. Also, we need to improve our forecast to the semiconductor equipment and material manufacturers so that they can also be better prepared.

• We all need to support the trend toward market diversity. We need to be prepared with the internal design capability to support the increasing number of memory organizations and package styles as well as provide the CAD support necessary for these application specific memories.

• Finally, we must prepare our DRAM manufacturing facilities to handle the number of small lots inherent in this trend toward diversity. We have to do this in a cost-effective manner so that we can all continue to deliver products that the end customer will buy.

Reducing the Volatility — Users

Certainly, DRAM suppliers, as you would expect, have a role in reducing volatility. How about the users? You bet they do.

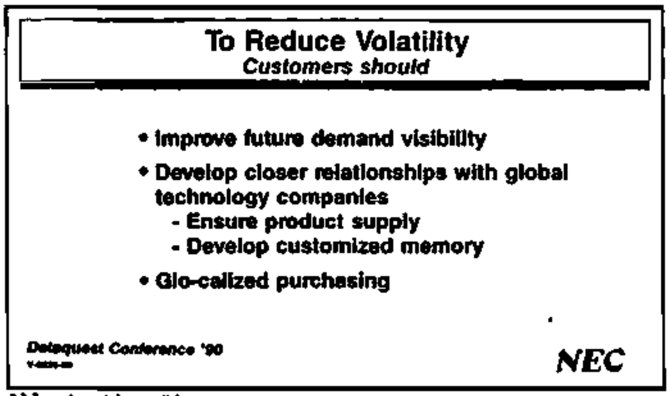

Illustration #4

• As I mentioned before, our biggest fundamental problem is visibility for future demand. Of course, no one knows exactly what the future will hold, but the users should increase their own efforts to improve their understanding of the future demand and to communicate this to the suppliers.

• Users should work closer with global technology companies to establish assured supply and to develop the various customized and ASM products.

"Glo-calization"

NEC's wafer fab and assembly facility in Roseville is an example of so-called glo-calized support. This aerial photo shows our Phase 1 (the darker buildings) which is currently manufacturing DRAMs, SRAMs and micros. These are mainly delivered to customers in the United States, although we are exporting some to Japan, Hong Kong and Europe. It also shows Phase 2, which is still under construction.

Through facilities such as these, global technology companies can design and manufacture the right products for local customers, improve visibility for supply and demand, provide ensured supply of products and provide quick response on delivery and technical issues.

• Further, we would recommend that customers should take a more glo-calized approach to DRAM procurement. That is, they should negotiate based upon their total worldwide requirements, but actually purchase as best fits the need.

For example, they could place a purchase order centrally or locally. The products could be shipped either from a local production facility, such as the ones in Roseville, Ireland or Southeast Asia, drop shipped from overseas, or transshipped, as many companies like, through an international purchasing office.

The Future

Now, I would like to show you our view of the future for DRAMs [Illustration #5]. Basically, we are bullish on DRAMs.

• We see strong growth in the demand for total megabytes of memory. Again, I think that this is very clear. There is no question about strong demand.

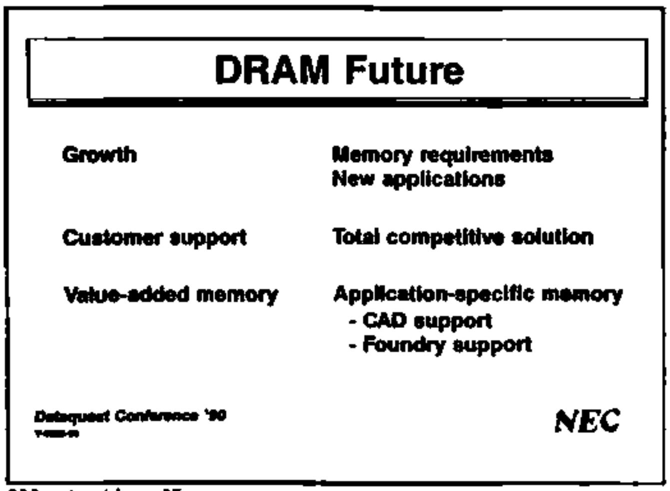

Illustration #5

We see the drive to improve user friendliness requiring continual increases in existing applications, such as PCs, network file servers, page printers and so on. Also, there is no question that future growth will be driven by new applications, such as notebook PCs, voice I/O and instantaneous language translation. And, for the United States, we should not rule out HDTV; that is going to happen.

• We see the meaning and execution of customer service or support greatly improving. Basically, DRAM suppliers need to see themselves more from the customer's view. With this view, they will improve the basic business infrastructure that is required to make doing business easier for all of us.

• Finally, we see the application specific memories playing a more predominant role, driven mainly by the increasing segmentation in the end markets.

Summary

In summary, DRAMs have become strategic components, not only for users and suppliers, but they have also assumed international importance. In the past we have had to live with volatility in these markets due to insufficient visibility of future demand, the capital intensity inherent in the industry, and more recently, an increasing number of new competitors.

There are things that we can do. The initial steps are being taken, such as establishing local production facilities throughout the world, developing closer communication between customers and suppliers, and finally, improving the basic infrastructure necessary. While I won't predict that we are going to eliminate volatility, I think we will make a big dent in it.

Thank you very much.

PRICES, PROFITS, PROJECTIONS: IS THIS MARKET TOO DRAM VOLATILE? PANEL DISCUSSION AND OPEN Q&A

Moderator

DAVID ANGEL
Group Vice President and Director of Worldwide Research
Dataquest Incorporated

Panelists

ROBERT BROWN
Vice President and Group Executive
Toshiba America Electronic Components

WILLIAM GSAND
Vice President and General Manager
Hitachi America, Ltd.

FRANK JELENKO
Vice President
NEC Corporation

JOSEPH PARKINSON
Chairman and Chief Executive Officer
Micron Technology

DAVID SEAR
Vice President
Fujitsu America

MR. ANGEL: Thank you. Now, if I could get the other four to come up, we will go to our panel. We already have a lot of questions, so I assume that there is a lot of interest. There is a lot of kindness up there. I haven't seen this much kindness since the Mother Theresa convention. Let's get to some issues while waiting for the questions to come up.

As Joe has indicated, SIA and the computer organizations have said, "We don't need fair market prices anymore. That is no longer necessary." What is your view on that? Is that real? Can the industry operate with FMVs [fair market values], or are we through that period, and can life go forward now?

MR. JELENKO: Let me confirm the question. The question is are we through the period for FMVs, and can we live without them?

MR. ANGEL: Pretty much so. I believe the recommendation was made that we do not need to renew FMV prices.

MR. PARKINSON: I think we need to be clear, though, that the FMV measure by the Commerce Department under this two-part proposal would be deleted as a formal mechanism monitored by Commerce, but it would continue to be monitored by MITI, so that the data is available for a quick action by the Commerce Department based on that MITI data in the event that there was alleged dumping.

MR. ANGEL: Joe, I have a question directed to you. Micron is perceived — and I will inject that perception is not fact — to be somewhat more at risk because of the enormous amounts of capital that this business requires. Generally speaking, you have to go to the equity markets to raise capital. We heard T.J. say yesterday that it took him six rounds to accomplish what one company accomplished in one round in Japan. How are you going to get around that problem, compared to the other four gentlemen up here who would like us to believe that their resources are deeper?

MR. PARKINSON: I would say that capital is the least of the problems. I don't think we have ever encountered difficulty getting the facilities up. We happen to have four fabs, counting a research and development fab we have recently put up. We have converted the earlier fab to 6", so we are probably the only producer who will be exclusively on 6" by the end of the year. I would say we have no excuse, from that standpoint.

I think all of the panelists would agree that the real challenge is a technological one, in terms of design for die size and process for reduced mask layers and in keeping up with the proliferation of package types. So, I would say our objectives and obsessions would move more to the R&D side of the equation and the enormous costs involved there, which I think are potentially even greater, in terms of getting the manpower, the team arranged and the right tools in their hands. That is an even bigger challenge than raising capital.

MR. ANGEL: We are swamped with questions. You gentlemen certainly provoked some interest.

A question for Toshiba. Bob, when is the DRAM power supply crossover going to occur?

MR. BROWN: The answer to that is, I really don't know, but I would suggest that it is probably going to happen around 1994-95.

MR. ANGEL: Question for NEC. In the slide entitled, "Why is the DRAM Industry Volatile?", you said that the reason that there are many players is that there is a low entry barrier. This seems to contradict your earlier statement that this is a very capital-intensive business. Would you clarify that, please?

MR. JELENKO: I would be happy to. Our view is that, while the capital requirements to enter the DRAM business are not low, they are among the lowest, considering the other opportunities within the semiconductor industry, such as microprocessors and ASICs. In microprocessors and ASICs, the research and development effort is much greater, and particularly in the microprocessor area, the merchandising or the selling of the architecture is an enormous task. So, simply, given the technological barriers, it is one of the lower barriers of the three.

MR. ANGEL: David, let's route this one your way. When, if ever, DRAMs go to EPI wafers, what is the incorporation of epitaxial growth into the process? Basically what we are saying here is that the reference is that a 6" non-EPI wafer sells for about $35; if you have to go to EPI, it is about $85. The implication is, is the industry going to have to go to an EPI based wafer? If so, when? And what is going to be the impact of that?

MR. SEAR: That is a good question. What I tried to show in my charts was the fact that we currently are on 6" wafers. I believe in order to go to the 16 meg we have to be on 8" wafers. I tried to keep away from absolute costs. I showed some numbers at one time that showed $100 to $200 a wafer.

Yes, we have to do something to get the wafer cost down. I think that is inevitable. I think it will probably occur between 16 and 64 meg.

MR. ANGEL: Bill, you have indicated that in-house development of equipment has been a strong asset to your company. Would you comment about in-house development of materials? The allusion here is to photoresist technology. Does Hitachi have something unique going on here? Is this also an added strength? Is this going to be one of the tools that is going to be necessary to carry forward into this decade?

MR. GSAND: I think they are all pieces. The big issue is that you have a little piece of everything in order to drive the DRAM business. It does drive the processing; it does drive the semiconductor industry. In order to be on the leading edge, you have to have either outside suppliers or inside suppliers who can move in volumes with the demand of a major market. You cannot support a major market without those things.

As a large semiconductor company, the niche business is not really a viable solution. You are at the leading edge of almost every piece of the technology when you are driving this business three to five years ahead.

So, yes, I think you need both.

MR. ANGEL: How does the panel view the effects of multichip modules on the next generation of semiconductor memories?

MR. BROWN: I'll assume you are referring to Mary Olsson's presentation yesterday.

MR. ANGEL: Yes, please do.

MR. BROWN: I would expect that the comments that Mary made are relatively accurate. It is probably going to require companies like ours to take a different view toward the die business.

I think I can speak for my counterparts here, that it has not been desirable to sell die. But I think we may have to reassess that. Multichip modules will be a significant market.

MR. SEAR: I would like to make a comment. One of the speakers did talk about the fact that we were going to go by 1, by 4, by 8, by 16, by 18 — many, many different configurations. When that happens the number of I/O pins goes up.

In reality, when you look at what we do with memory, it is a packaging problem. Traditionally, we have small packages. They are growing larger and larger as time goes on. When you need high performance, it is inevitable that we are going to need some kind of module approach which can give high-density packaging. I agree with Bob, it needs to be looked at carefully.

MR. ANGEL: Any other comments?

MR. PARKINSON: I would add that the die size, where we spend a lot of time in evaluation, is growing, as demonstrated on those charts. In part, that is due to the bonding pads taking up a bigger and bigger percentage of the die area. It is inevitable that we are going to have to make some kind of fundamental break from the past and move to some substitute, either in the form of these cards or some other breakthrough, that would eliminate this problem of the bonding pads.

MR. JELENKO: The multichip module business is clearly an emerging trend. I think that it is important from our side to watch carefully what applications actually develop.

As an example, I would separate it into two kinds of things. One is memory modules. The other might be some type of functional module, like a CPU module.

So, whether we strongly support some kind of die business depends upon how this works out in terms of being evaluated for our own company, versus competing with ourselves in the market.

MR. ANGEL: For Mr. Parkinson: Should the United States government's intervention be included in Micron's list of strengths? Didn't the Trade Agreement allow Micron to not only survive, but to prosper?

MR. PARKINSON: I am glad to have that question asked. I feel very strongly that the timely action by President Reagan, Malcolm Baldridge, Clayton Yeutter — the people who were certainly in the forefront at that time — and their intervention and moving forward with our 64K DRAM dumping case, the first dumping case filed, put the world on notice that these people were in fact dumping.

We had at that time a die size much smaller than our competitors'. When they started selling below our cost we proved that every one of these Japanese suppliers was dumping and selling below cost at that time. That then caused a self-initiated case for the 256K.

The comment was made earlier that, as a result of FMVs, pricing stabilized and moved up. I hated to let that comment slip by. Since you have given me another excuse now, I would have to say that an equally valid point is that 10 of the American producers were driven out of the business. Those included MOSTEK, the leading producer of the prior decade; Intel, the inventor of the DRAM, and some other major players. You eliminate the supply, and that is also a factor in the pricing equation.

The government is slow to move, but when it did, it certainly had an effect. Micron gives a lot of credit to them. We certainly do.

MR. ANGEL: I have another one which came down sort of burnt around the edges. I am going to summarize the question. The question basically begs the question as to where the price competition really is right now? In talking with most of the Japanese-based suppliers, it is clear that the Japanese companies would prefer to have higher prices for 1 megs and 4 megs. Empirical information seems to prove that the price leaders are coming now from sources other than the Japanese.

Are any of you brave enough to tackle that one?

MR. GSAND: Sure, I'll give it a try. Somebody has to start, right?

With DRAMs, I think the pricing and the leadership on the pricing side has not come from the Japanese in the last several years.

Part of it has been because of government intervention. I think Joe is right. I think it did a lot of good things for stabilizing this business. The two pieces of the suspension agreement are the market access and the FMVs. As long as the FMVs are there, and as long as the Japanese dominate the market share, the prices from Japan will probably be higher. The flexibility is not there to go in and get market share and to reallocate cost to support a marketing strategy. So, there are limitations.

It appears that, in the long run, the cost will come down in Japan; the market share will be maintained in Japan, at least at this point; and the pricing will stay competitive. If you want to consider the Japanese were dumping, you could apply the same rules to anyone else. There were exchange rates. There were a lot of things that changed that. Dumping tends to be an international issue, but it may be a national issue as well.

There are limitations on the amount of competition and the amount of price aggressiveness the Japanese companies can have because of the FMV, and because of the dumping rules and laws. I don't think there is anybody up here representing the Japanese companies who would say that anybody has even come close to violating these laws since they have been in effect.

Whether that has been a good deal or a bad deal for the users in the United States, or whether that will be good or bad in the future is a tough question. We have to stay competitive at the system level. Our customers have to stay competitive. From that perspective, I think the government would do well to focus on market access and let the U.S. buy in a free market on FMVs.

MR. ANGEL: Another comment?

MR. BROWN: I'll get brave. I don't have any conflict with Bill's comments, but today's price competition is clearly coming from U.S. suppliers, European suppliers, Asian suppliers, and probably, the lesser level Japanese suppliers.

MR. SEAR: This is the third comment from a Japanese supplier, and it is very similar. Definitely, the price competition is coming from U.S. suppliers and others outside of Japan.

We, as a company, have not been the most aggressive in pricing, but we try to be as competitive as we can and stay with the major Japanese. I have heard comments from users that they would like to get their product as low cost as possible.

Earlier, the gentleman showed an interesting curve. It showed a smiling face and a tearful face, depending on where the pricing was. Users want to get their memory at as low a price as they can. I have seen prices from other suppliers. They are quite low. I am getting very close to FMVs for our company. I can't do much about that.

We just talked about Intel, one of the companies forced out of the business. They are one of the most aggressive companies today in the DRAM business — albeit it is not their own product — but they are still in the market.

MR. JELENKO: From our side, we recognize that there are complex issues involved in terms of both national and international balance of trade. Mainly, we would say that we are happy to see that there is apparently some consensus between the SIA and the user community, so that whatever constructs we go forward with will be something that we can all live with more easily. Hopefully, it will allow the kind of stability we have seen in the past.

Our focus is mainly that we are able to support our users and customers here, in the United States, without having to revert to some kind of artificial construct.

MR. ANGEL: One final question. I sketched some companies that just came to mind that were supplying DRAMs. Just quickly, I came up with 19. If all have a 10% market share — carry the three, divide by two, integrate this — I can't do the math, but I think I have a problem.

I know all five of you clearly believe that if we hold a conference in 1995 and we talk about leaders in DRAMs, all five of you are going to be up there. But let's face some realities. This is not a Dataquest endorsement, but I think probably a 10% market share or something in that range is going to be necessary due to the dynamics of the capital investment.

Are any of you able to say where the fallout might occur?

MR. GSAND: I think you are going to see more alliances. That's not a cop out. I believe you are going to see some more joint ventures, and you are going to see some more sharing of the technology that is coming from overseas in the United States, and vice versa.

The world is going to get smaller, and people are going to start dealing with each other because of necessity. You won't have 19 guys who look like 19 guys in the marketplace. I think that is what is going to happen.

MR. ANGEL: Anyone else?

MR. SEAR: Absolutely, I think there will be many more alliances. But one of the other things is that the capital cost is very high. That would perhaps indicate a shakeout. And actually, I agree with Joe on this one.

Getting the most use out of the fab capital that you spend is important. DRAMs are the first process driver, or the first product, but then you have SRAMs and ASICs and other products behind that. So, the trick is to get the best use out of your fab possible and average those costs, so you don't necessarily have to depreciate everything over the first product. If you do, you would be out of business. So, there are other products. If you are a diverse, broad range supplier, I think that is going to help. That will force some alliances.

MR. ANGEL: Joe?

MR. PARKINSON: Let me say that I am not positive that even Micron will be one of the survivors for sure. It is a tough row to hoe. But I would say it is not going to be based on how much money you have in your pocket, which is the simple way people would like to look at things. They like to assume that the guy with the deep pocket or the big structure is going to be the one that survives.

I am absolutely convinced that it is a technology challenge. I will repeat what was on the slides. I believe that a guy could predict the fallout in 1984-85 by sitting down and looking at the die sizes and the mask layers. The ones with the big die sizes and lots of mask layers are not with us today. And you could do the same thing today and arrive at the conclusion of who will not be with us two or three years from now.

You can also throw the performance into that equation, the 60 nanosecond units that we talked about earlier. That is what will decide the outcome of this battle more than anything else.

MR. ANGEL: I want to thank the audience. We could not get to all of the questions. Gentlemen, I thank you. Our audience thanks you.

THE PRICE OF THE FUTURE

Fred Zieber

Senior Vice President
Dataquest Incorporated

Doing business in the semiconductor industry is expensive, and becoming more so every day. Whether we are companies, industries, part of the infrastructure, or — like Silicon Valley — a geography closely aligned with semiconductors, the cost of healthy survival is rapidly escalating. I would like to explore some aspects of this cost with an eye to shaping our thinking and our actions for the future — in order to ensure the future: the price we must pay.

Historical Perspective

To look at the future, please excuse me if I refer to history. But historical developments that have been changing costs in the industry are, with some exceptions, also a reasonable guide to the future. While costs have been rising for a long time, it is the magnitude of current and future costs that make a critical difference. They are to the point where the structure and nature of the industry will change.

I go back a long way, so history comes easy to me. I joined the semiconductor industry in 1961 as a technician — I was working my way through Stanford — and soon found myself enmeshed in device processing and design. I was paid $2.00 an hour; some things change. But I didn't know anything then; some things never change. For the current discussion, however, I will stay within modern history, the last 20 years, and the foreseeable future, the next five years.

Industry Accomplishments

Since, as an industry, we like to pat ourselves on the back, we often hear many impressive numbers regarding the accomplishments of the industry: how density has increased; how tolerances have shrunk; how cost per transistor or gate or bit has plummeted. And we hear how those meritorious figures will improve in the future. Rightly so, the industry should be proud. But those astonishing improvements have not, and will not, come free. Let's look at design costs, marketing costs, and wafer fab and processing costs.

Design Cost

Chip density has increased 2000-fold in the last 20 years. Design cost, per bit, transistor, or gate is now about 1/40th the cost of the early 1970s. Truly immense progress. But that means that the design cost per device has gone up, way up. Obviously, there is a lot of variation depending on what figures are used, but that should not detract from the fact that this is a major trend. A good rule of thumb is that design and/or development costs go up with the square root of density. While CAD is tremendously beneficial, it only partially offsets the tremendous increase in complexity of today's devices, and that trend will continue.

According to Intel, development cost for the 486 microprocessor is $250 million (a quarter of a billion dollars!) versus $100 million for the 386 microprocessor and $25 million for the 8086 microprocessor more than 10 years ago. Big bucks! Of course, other designs (especially design only) are less, a lot less, but for apple-to-apple/orange-to-orange comparisons, the range of change is similar: by my estimate, an increase of 45 times over the last two decades.

(On a personal note, I did 19 designs. The first 18 worked the first time through fab, and the last convinced me that market research was a better idea. Total development cost, including special processing for several designs, averaged about $25,000 each.)

Marketing Costs

Marketing costs have similarly skyrocketed, but for different reasons. In the old days marketing barely existed. More recently, costs have increased because of the increase in market size and the movement to worldwide markets. The former accounts for about an eight times increase and the latter about a three times increase, or about 25 times altogether. Currently, attention and competition at the applications level is rapidly pushing these costs up.

Wafer Fab Costs

But the sweepstakes winners in costs are wafer fabrication facilities. What price dimension reduction? In the past — my past — the cost of a wafer fabrication facility was in the six figures, i.e., hundreds of thousands of dollars, not hundreds of millions. If anything, the increasing costs of fabs has accelerated recently. What's going on?

Dimension reduction is getting tougher and the advantages of scaling less and less because the physical limits of devices are being approached; that is, the minimum possible size for transistors, resistors and interconnects. This does not stop progress. But unfortunately, the "cleverness" to continue to increase density is exacting a toll on design, processing and equipment. Over the next two generations of DRAMs the number of mask levels will reach (in some cases) 27, an increase on the average of about 70%. This is necessary in order to provide more interconnect levels, wells, BICMOS, et cetera. The number of process steps will double. Routinely, equipment costs for a single station are exceeding $1 million and increasing rapidly.

The demands for control and dimensional tolerance are intense. It is instructive to look at a microcosm of this world — an individual part — to see at that level the efforts being made to meet the demands of the industry, the quality demands up and down the vertical infrastructure, and the cooperation required both horizontally and vertically in the infrastructure. Five years ago the part cost $50, today it costs $200, and five years from now its costs may exceed $1,000. (In certain instances that is the case today in Japan.)

The bad news is clear. More steps; more costs per step; and the more steps the more need for tolerance control in the processing. All of this multiplies cost.

To a certain extent, this is a new phenomenon. While facility costs have been going up steadily for a long time, the costs were offset in the 1970s by increased throughput and holding the number of mask steps down. More recently, 24-hour operation and higher yields (a basic tripling) have kept cost per good die reasonable. No longer. In the past two decades fab costs have increased 100-fold. They will continue to increase more than 60% for each new product generation. Projections are that five years from now state-of-the-art wafer fabs will cost $500 million to $1 billion. This is not penny ante. The stakes required to compete are very high.

Wafer processing costs tend to track capital costs. Future wafers will be hit both with high capital cost and high processing cost, and in some cases major design and development cost.

Quality of Life

Let me switch, for a moment, from manufacturing to Silicon Valley. Many of you represent non-manufacturing segments — companies or divisions where the output relies on the creativity or intellectual effort of people. Now, for the record, in the last 20 years the GNP deflator has risen 2.5 times and engineering salaries have risen five times. Engineers are paid significantly better now than in the past. But the price of housing in the Valley is up 15 times; highways are clogged; education is deteriorating; open space is disappearing; and the environment is not getting better. Quality of life is an issue. These problems and these imbalances must be redressed for Silicon Valley to remain a viable location that attracts talent. The piper must be paid; costs will skyrocket.

Annual Growth Rates

To summarize these costs, let me put them in the perspective of annual growth rates as best as I can calculate, and please take all of the caveats of imprecision into account:

Marketing	14% per annum
Design & development	17%
Wafer fab facility	22%
Processing	20%
Professional salaries	9%

Not a pretty picture.

Given these facts I'd like to draw some conclusions:

• For a large part of the mainstream of semiconductor products the minimum ante to compete is, or will be, very high, and it is growing faster than the semiconductor market itself. At the SIA Dinner, Andy Grove said that scale is important. He is right. The entry fee (or continuation fee) is high enough to endanger a significant segment of the U.S. semiconductor industry — and, for that matter, industry worldwide. A corollary: there will be significant attrition.

• In some product areas success will have as much to do with finance as with technology (assuming technology crosses borders). There appear to be lots of folks willing to pay the bill.

• The cost, and the complexity, of building a state-of-the-art fab is moving management of fab construction from the company to outside professionals. The fabs are contracted. To a certain extent, aided by suppliers, this has a leveling effect on technology and technological advantage. (The lead times that some companies enjoyed in the past no longer exist.) Both fab financing and fab productivity become critically important. A slow ramp in production will be disastrous both in terms of carrying cost and market prices. If this was true in the past, it will be more true in the future.

• Because the number of chips per wafer is expected to decline, and wafer capital and processing costs increase, it is clear that chip costs will rise substantially. I believe that a consequence of these costs will be a marked slowdown in the rate of price/performance improvement, i.e. prices will not fall as fast as in the past, technology change will be slower, the market (in bits or gates, not dollars) will grow slower, and products and fabs will have a longer lifetime. They are all interconnected. The analysis is complex, and murky, but I repeat: price/performance improvements will slow. Heresy? Yes! For 20 years I have been a proponent of the industry's experience curve. No longer. That slope is breaking; it will be plainly evident in two to three years.

Fred Zieber

• There will be more pressure on mid-sized semiconductor companies, undersized in the big markets and oversized for a protected niche. In major product areas there will be fewer boutiques, if any. A corollary: there will exist a large quantum step for small players to become major players.

• To some extent, companies will choose between competing with dollars or with creativity. Furthermore, but not the same thing, companies will choose to forego fabs (as some have done already), or marketing, or design. (Personally, I see a plethora of fabs under construction or in planning. Without a killer application to drive the market, supply is not likely to be endangered for the fabless. Economic generated growth can be supplied adequately.)

• Lastly, companies must look to new alternatives for reducing costs. These lie outside their corporate walls, but encompass cooperation with suppliers, customers and other industry participants: shared resources; joint alliances to provide scale; and division of capabilities among companies according to what they do best. The full-service company will disappear.

Survival & Prosperity

So, what does this mean in terms of the individual manager? Two things.

First, I believe that a large majority of semiconductor (and related) companies will either not survive or not prosper through the next five years. Those that do, either large or small, will have pursued a role that makes long-term strategic sense. The time has come to think deeply about that role and act upon it.

Second, it is clear that no company is an island. The costs of our technologies and their complexity make that a reality. Survival and prosperity need the help of the federal, state and local governments, industry consortia or cooperation, alliance, joint efforts, et cetera. There is a long list of items that can, should, and must be done to affect the level of the competitive playing field or to help reduce costs. I do not mean subsidies or monopolistic conspiracies, but the healthy ground in between. This includes industry consensus and government action on trade, finance, R&D, intellectual property, shared research in industry, and so forth. This is a fundamental, major long-term change in industrial organization and operation. It will affect not only the semiconductor industry and other electronics, but eventually all industry.

The point is, there is a need for external action and cooperation that is multiplying tremendously, on the political front, with industry, with other groups with aligned interests, and with suppliers and vendors. The SIA and SEMI have accomplished tremendous things, but those accomplishments are a small drop in the bucket compared to what is needed. And, of course, a consensus on that is a place to start. U.S. industry and government need to get their act together. Corporations need to adapt to the future, changing how they operate. The stakes are huge.

The costs of fabs, et cetera, can be enumerated. But what *must* be done to ensure healthy companies and *industry requires a quantum increase* in the efforts outside the walls of our respective corporations. You, me, all of us. That is the real price of the future.

THE EVOLVING PERSONALCOMPUTER

Roger Johnson

Chairman, President and Chief Executive Officer
Western Digital Corporation

MR. ANGEL: After a couple of hours, we should have a better understanding of what this decade holds for us in the area of personal computers, personal electronics and user-supplier relationships.

As I mentioned yesterday, a few months back I was privileged to spend some time with Western Digital in one of their strategy meetings. At the end of that meeting, I felt that this company had a unique view of the future. We would like to see if we could get them to share that with us today.

I met Roger Johnson at another meeting and asked if he would spend some time with us. He graciously consented. Mr. Johnson is President, Chief Executive Officer and Chairman of the Board of Western Digital. He joined the company in 1982. I think those of you who follow the financial performance of the company know that there has been a marked improvement. Prior to that, he was President of the Office Systems Group of Burroughs Corporation. He has had numerous other executive positions.

Roger, we are delighted that you could take some time to be with us today.

MR. JOHNSON: Thank you. I am always intrigued by how people introduce you. I guess Dr. Mizuno, Irv and I are senior people. At least for me, that must mean that I am old. I know I'm old because yesterday my wife read me something in the paper, and she said, "Look at this. It says that old people should not eat health food anymore because we need all the preservatives we can get."

Someone was asking me how business was. I had just gotten off a plane and saw a mug that depicts how I sometimes feel these days. The mug said: "Since I've run out of sick days, I'm going to call in dead."

I do not know enough to talk for 45 minutes. In fact, I am not going to talk. You have had a long two days of conference where you have heard from wonderful people. You know more about what I am going to talk about than I do. So, I am just going to make some observations; then, perhaps, we will have some time for discussion.

PC Driving Force

The evolution of the personal computer is something that we all feel is very real in our everyday lives. The practice of putting more and more into less and less stopped being any type of revolution long ago; it is merely how things are. It is the consistent migration that is driving the semiconductor industry.

The evolution toward smaller — which means less weight, more function, less power, lower cost — is the driving force in the future for those of us who build semiconductors, not only because of the personal computer, but because of the pervasiveness of computing, which also has, at its core, smaller, more function, less weight and lower cost.

Without acting either like an historian or someone with a crystal glass, I would like to talk about some of the technologies behind that, or at least our view of that. I will then discuss market opportunities. I will conclude with some comments — perhaps controversial — about the atmosphere in which we have to live and grow our businesses. This is an atmosphere which I think may be more threatening to us than any of the things we normally talk about.

It is hard to believe that the personal computer is less than 10 years old. It is hard for me to believe that, because I came into this industry in the early 1960s with a company called Friden, that built rotating calculators, with a specialized sales force that sold on applications. So, I can see, even in my short career, quite a parallel. We are seeing a similar story between the evolution of the calculator from the 1960s and 1970s and what we now call the personal computer.

As products change over time, so must the approach to product development. Desktop computers have a predetermined set of parameters for size and functionality. They have become quite standard over time. The evolution of the personal computer (which is really a synonym for small things that compute) is and will be, to a greater degree, driven much more by people's needs. This means you need to have a more flexible view when you are planning a product.

People's needs change. We don't like to be standard. The only people who like standards are manufacturers. If people liked standards, we would all be driving black, square cars.

I think those of us involved in helping to define what the products are and how we contribute to them really have to understand that people want things that do different things that they need, not what we want to produce in some standard way.

New Product Evolution

More importantly, the computer that is evolving will be a companion to the way people think. It is going to go with its user everywhere, every day.

Being carryable, as opposed to portable, I think is an important distinction. For the most part, today's laptops, and even notebooks, are portable; they are not really carryable. They are comparable to a bowling ball. You can get it around, but you don't want to take it to lunch.

By following this path that we are on, this industry — which we, the people who make things smaller, tend to drive — will offer personal computers in the next three to five years that provide today's desktop performance and functionality that can be held in your hand. They are commonly called "palmtop." I think the palmtop of the next two to three years will have that level of power, full function, weigh less than four pounds, with all internal circuitry (maybe 10 chips or less), in about a 3x4 motherboard.

This type of very small computer will replace pad and paper in some instances. It will, for the first time, bring it into the hands of truly noncomputer users. In the 1960s and 1970s, we took the calculator out of the specialists' hands in accounting and moved it out to people who didn't really understand anything about its insides.

Enabling Technologies

Many technologies enabled that degree of evolution. Some basic technologies that enabled the migration from desktops to laptops are the same; others are new. Among the major driving technical forces are mass storage, computer display, input, connectivity, communications, digital signal processing and power management. All of these rely heavily on what we in the semiconductor business do.

As designers and manufacturers, we need to find ways of driving higher and higher levels of integration. That, of course, is what drives the size situation.

Mass Storage

It will be necessary for us to understand more about battery technologies, as well as some other technologies that are akin to what we do. Mass storage is crucial to the future development of small computers, because storage requirements for small computers will vary more than they have in the past. The days of standard capacities, standard interfaces and form factors are for the most part gone.

In fact, many portable applications cannot take anything mechanical because their size, power and performance will be destroyed as they go into environments that are not very friendly. Therefore, an alternative to rotating storage is absolutely necessary.

I have worked in the rotating storage and semiconductor businesses long enough to see every chart predicting that every technology will be wiped out by every other technology. It never happens. And I am not predicting that here. However, there is a need for solid-state storage, which will probably come in the form of a flash EPROM. We and several others are working on that.

Proprietary Flash Product

We are developing a proprietary flash product that can be managed like magnetic media. This is a little different approach. It can interface to a system, just like a disk drive. The catch here is that nothing rotates. This is achieved by utilizing existing storage technologies, such as data compression, defect management buffering and error correction, with nonvolatile high density memory. The result will be a solution that meets stringent requirements for small computers. It is light, fast, rugged and consumes very little power when compared even to a 2½" Winchester drive. Solid-state storage can be up to 100 times faster and deliver performance using up to 300 times less energy. It is currently too costly. However, those problems, as we all know, are something our industry addresses quite nicely.

Perhaps the most unique feature of this technology is that it is not limited to a specific form factor. It can be configured to look like a very small drive or a memory card. It can be imbedded on a motherboard or it can be designed into almost any form factor needed. So, it inherently possesses the versatility and flexibility required by emerging small computers.

Flash goes where Winchester technology can't go, and therefore, we feel it will be a major enabling technology for small computers.

Eliminating the Keyboard

In parallel, the natural evolution of the computer will also lead to functional systems that could be operated without a keyboard. We have seen a lot of those things coming along with limited function, stylist-based machines. They are now a reality.

As we move toward the in-your-hand computer, another once-distant technology may come to fruition. Advanced features, such as touch screens, write-on screens, and the application of more sophisticated pointing devices will become commonplace. All of these can benefit from the advancement of data signal processing that basically embeds the code information within the sound, pictures or written material the user has at his control.

Digital signal processing in small systems was not feasible a couple of years ago. Today, there are strides being made and we are working in some of these areas. With regard to handwriting, voice recognition, the ability to store condensed written and spoken information efficiently, it is really not that far away. A system could be developed that can recognize and translate information using advanced forms of digital signal processing.

Communications

The evolution toward smaller machines will also dictate that we find new ways to communicate and use the information. It does little good to have this hand-held computer if, to access and get at your work, you have to rent a pack horse to bring along your personal printer and fax. Dedicated fax and modem capabilities, realized through a single chip or a mini insertable card, will be one of the ways that tomorrow's small computers can attain true usability. Some of this functionality is already available or in development.

Connectivity

Along with the ability to quickly communicate, connectivity is going to be central to the usefulness of this little computer. The next generation of small computers will need to be dockable. It means that same physical computer will be used at home, on the road or at the office. Through advanced functionality integrated into the silicon, a hand-held computer could be utilized in this environment and still function quite effectively.

The hardware in these very small computers will need to be totally configurable. For example, when using the computer on the road, the system interfaces with specific video and storage functions and a limited set of peripherals. However, when that same computer is brought and applied to the office environment, those interfaces will change. There will be different keyboards, a larger monitor and higher resolution video. The system may be retrieving data from a tape and interfacing with a laser printer or the fax machine over LAN.

Integration

Again, many technologies and innovations that make this continued evolution toward small computers possible depend on the engineering ingenuity that we all are familiar with and our ability to translate that into silicon.

The geometries are, of course, one of the barriers. To get the levels of integration that we need to drive this functionality, we have to keep making things very much smaller.

Today, many of these disparate functions are working well and are being successfully integrated in themselves. Several of us are beginning to merge those functions and physically integrate across functions. More and more of that will be necessary in the future.

One of the successful techniques that must be employed by our industry is that those of us who grew up on the semiconductor side of things and those who grew up on the systems side will have to put those together. It is going to be very difficult for us to succeed unless we have people in our organizations who are systems knowledgeable and who understand how these generic functions really work in computing.

We need people who can talk with their OEM customers at a system design level and understand what the customer is telling us he needs, and then be able to interpret that to our logic designers. I think the day of the technical process driving the products needs in the semiconductor business is pretty well finished, unless you are really moving into the commodity high-volume RAM business.

A lot of these approaches are with us today. There will be a whole variety of new systems introduced at COMDEX. I think, if you look inside some of those, you will find some hints of what may come in the future.

Market Impediments

I would like to switch for a second to a discussion of markets, and to a little bit of what might be considered to be impediments to this.

One of the things that can limit us is the lack of market. Right now, we are all going through some difficult times. Yet, if we step back from that and look at market opportunities, we see a variety of things happening.

The small computer will drive extraordinary market expansion — maybe not this quarter or next quarter, but it certainly will. As we bring this power to people not technically inclined — as with the calculator, the automobile and a variety of other examples — we will observe that they will find miraculous additional things to do with it. So, within our existing free world markets, we have a huge growth opportunity ahead of us.

Emerging New International Markets

There is a lot of talk about the great emerging markets of Soviet Russia, East Germany and Eastern Europe and a lot of debate on how long it will take. But, for those of you who deal there, the small computer is a national objective. They need to manufacture their own computing; they are going to do that, one way or another. That is a huge market. I had some studies done for my company that say the Eastern market, alone, over the next 10 years, represents a doubling of today's free world markets for the things we do. You can argue about when that will evolve.

If you believe that the People's Republic of China will someday go, and if the surrounding infrastructure which speaks the language and knows the culture moves in rapidly, that will be a third growth market.

So, you could say that in 10 years the opportunity exists to grow two times what we know today. To do that will take many things: Mostly, it will take a long-term view; it will take patience; it will take money; it will take a lot of perseverance. We are, of course, not alone in looking at those markets, speaking now as an American executive looking to the future of our industry. Everyone is looking at that.

Capital Cost

Set that aside for a second. We have heard a lot of discussion on the cost of what we do — huge numbers, half-a-billion dollars, a billion dollars — and some prediction that there will be a lot of dropout. I agree with that. But I don't think that it has to be necessarily so.

The capital structures of our country have real fundamental flaws in them. I asked about the Tokyo Stock Exchange before I left this morning. After yesterday's close, it had a price/earnings ratio of about 40:1 after collapsing. My competitors and myself, whom I watch very carefully, are somewhere in the area of 6:1 to 8:1. That means that we have to earn, depending on the multiple you want to use, five to seven times the earnings to raise one dollar of equity.

Why is that? Is that because we are inherently shortsighted? With all due respect to my Japanese friends and associates, is that because of the wine they drink or their cultural heritage? No, it's arithmetic.

Roger Johnson

Capital Gains Tax

Let's look at one simple thing. The long-term capital gains tax and the incentive to save, not only in Japan, but in Taiwan and some other countries, is very large. Essentially, there are no long-term capital gains. And there is a very high tax on current earnings.

Our country, however, from a capital structure at this point, encourages consuming. From our viewpoint, it not only encourages consuming, but it encourages eating past investments. That is what LBOs are all about. You make more money eating the seed corn than waiting for it to grow. So, we do not invest in the future, but we eat what somebody did yesterday. That's why we are all sitting and being driven by the equity markets for short-term results.

I was in Washington last week, which is one of the more depressing trips you can make. I talked with some people there, and suggested they raise the capital gains tax. I am a Republican from Orange County. They almost didn't allow me back in. While in Washington, I did get Bob Dole's attention, along with the attention of a couple of other people. They asked me how I could suggest that.

I said, "What is a capital gain? How long do you hold it? What is it, nine months?" There's an interesting definition of investment. So, I said, "What I think we want to do is raise any taxes on capital gains within one year to 50%, take two years to 35%, leave three years where it is, make four years 20% and five years zero."

All the hubbub is because we are trying to protect the gains of the traders, the people who are churning paper and don't build anything.

What we need is a structure that allows people to come back and invest in us, the people who, when we do earn a dollar, will say, "Fine, I'll give you 30," not "What are you going to do next week?"

Solutions

We talked a little bit earlier about what to do about that. I really think that there are a couple of things we can do.

Cooperative Alliances

First of all, in a very practical sense, the notion of working together is something that needs to be taken out of theoretical discussion and brought into practicalities.

Our company has a very good relationship with AT&T. We worked out an arrangement three years ago that was quite unique. We had to build a wafer fab, we had no choice; we were looking at a huge bill which we were ready to pay. At that point the AT&T people came to us. They had a lot of capacity. We didn't want to work out a foundry relationship, however, because we can get foundry all over the place. We said, "Let's try to work out an arrangement where your fab looks like ours and we both make out."

Without getting into the details, we came within a few dollars of what we thought the cost was. Then we said, "Fine. If we are going to build a fab, we are going to incur certain costs. If you build for us, we will avoid those costs. We are willing to pay you the costs we avoid. If that's enough cost for you to load your fab, we're both okay." We did, and we were, and we have lasted for three years doing that.

In addition, the yield data coming off the Orlando fab and the yield data coming out of Madrid now comes in real time to my engineers. We now get the probe data right there. It looks like our factory. We don't give them purchase orders, we give them forecasts, and we mess them up just like we do our own people.

The point here, I think, is not to go through something we have done, but we do need to look across our industry and deal at much more strategic levels. I grew up in the General Electric Company, where I learned that if I didn't sell or buy from my competitors I wouldn't sell or buy from anybody, because we built everything but automobiles.

This industry is mature enough now to start looking at some of those things amongst ourselves. It is not unmacho to share some things and figure out joint developments of products and improve the cost effectiveness of very expensive resources.

Although our current situation is a little like the coffee cup, I think our long-term situation looks pretty good. We have some very creative people in this industry. I look forward to being with you and being in this business for a long time.

Questions & Answers

MR. ANGEL: Thank you, Roger. Questions and comments?

QUESTION: How much data compression are you achieving on your solid-state disk?

MR. JOHNSON: I think Kathy told me we are now pushing 2:1 in certain applications.

QUESTION: What will the right selling price be for the personal computer? When will the market take off?

MR. JOHNSON: I think we are selling 20 million of them a year. So, it's not too bad right now.

Where did the calculator take off? At under $100. I would guess that, under $500, the full-function personal computer will be as pervasive, selling hundreds of millions of units around the world, maybe five years from now. That is my personal guess.

THE NEW FACE OF PERSONAL ELECTRONICS

Hiroyuki Mizuno

Executive Vice President and
Member of the Board
Matsushita Electric Industrial Co. Inc.

MR. ANGEL: We are most pleased to have Dr. Mizuno, Executive Vice President and Member of the Board of Directors of Matsushita Electric Industrial Company, Ltd., here today. He is in charge of all engineering and research and development activities for the company, where he has been employed since 1952.

Of particular note, Mizuno-san served as Chairman of the Foreign Semiconductor Users' Committee of the Electronics Industry Association of Japan, the committee studying ways to increase the penetration of U.S. chip makers' products of the Japanese semiconductor market.

By way of background, he holds both a B.S. and a Ph.D. in Physics from Kyoto University. He also attended the University of Illinois.

DR. MIZUNO: Thank you. Good afternoon, ladies and gentlemen. I am honored to have been asked once again to participate in Dataquest's Annual Semiconductor Industry Conference and to be here today with you.

As you are well aware, enormous changes have occurred in our world during the 12 short months since we last came together here in Monterey. The course of East-West political and economic relations has been fundamentally altered, and a new and major threat to world peace suddenly arose in the Persian Gulf. Also, while less noticeable, this past year has brought great technological changes as well.

Future years are bound to be just as full of change and uncertainty. Today, in an effort to make the future slightly more predictable, I would like to provide my assessment of the changes which we can expect to see in the area of consumer electronics during the next decade.

I would like to begin with an overview of the current state of home electronics. Second, I will discuss the technologies which have supported the home electronics revolution. I shall then give my thoughts on the incipient transformation from home to personal electronics. After that, I will attempt to forecast how changes in electronic technologies and markets will impact upon our lifestyles in the future. I shall conclude with a few comments regarding my recent tenure as Chairman of the EIAJ's Foreign Semiconductor Users' Committee and the future of U.S.-Japan relations.

Home Electronics Overview

I thought it might be useful to begin my overview of the current state of home electronics with a quick look at my own company, Matsushita Electric, since I believe we are fairly typical of the major multinational electronics manufacturers in terms of our sales and product breakdowns.

Illustration #1 shows Matsushita's sales and product breakdowns for each of the past three years. During this period, the category of information/communication equipment (which includes such items as facsimile machines, telephone equipment and PCs) has been rapidly and steadily gaining ground against our traditional home electronic products areas, such as video equipment (namely TVs and VCRs), audio equipment (including radios and stereo systems) and home

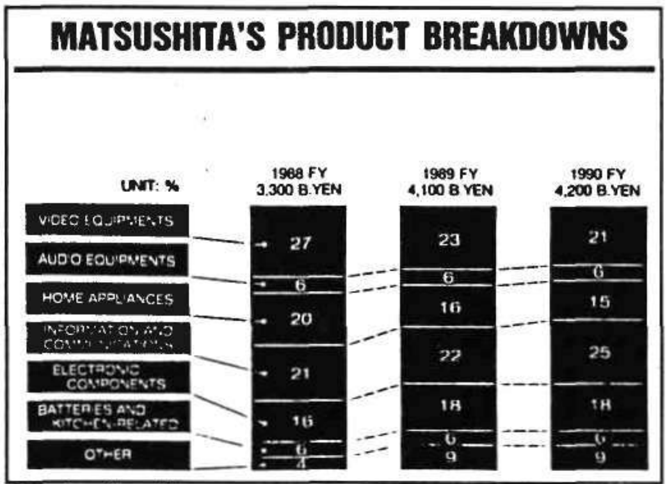

Illustration #1

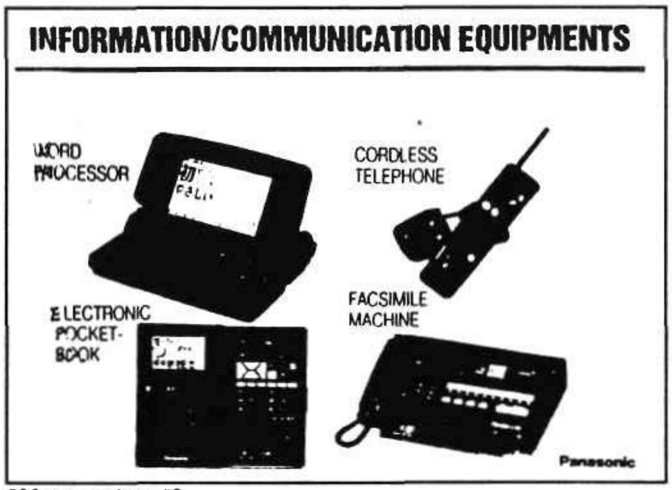

Illustration #2

appliances (such as refrigerators and washing machines).

Information/Communication Products

Of course, a major reason for this is that advancements in semiconductor technology have allowed us to reduce the size and cost of these information/communication products, such as the products shown in Illustration #2, to the point where they have become available and suitable for home use. As a result, Japan's factory output of facsimile machines, for example, rose during 1989 to the level of $4 billion.

This transformation in the use of information/communication products should not have come as a complete surprise, because the traditional pattern in the electronics field has been one of new innovations being developed first for use in the scientific, military and other special markets, and then being transferred through industrial applications to the home market.

What has been surprising, however, is the extent to which the former boundary between industrial electronics and consumer electronics has begun to fade away during the past few years.

Home Electronic Products

Illustration #3 shows a few familiar home electronic products. They are categorized as audio, audiovisual or appliance products. Their operating cores actually consist of a number of information processing technologies.

For instance, remote control for TV sets and the digital recording/playback for CD players are clearly based upon such technologies. Also, state-of-the-art video cameras contain 11 microcomputers, and new washing machines utilize fuzzy logic to automatically regulate detergent

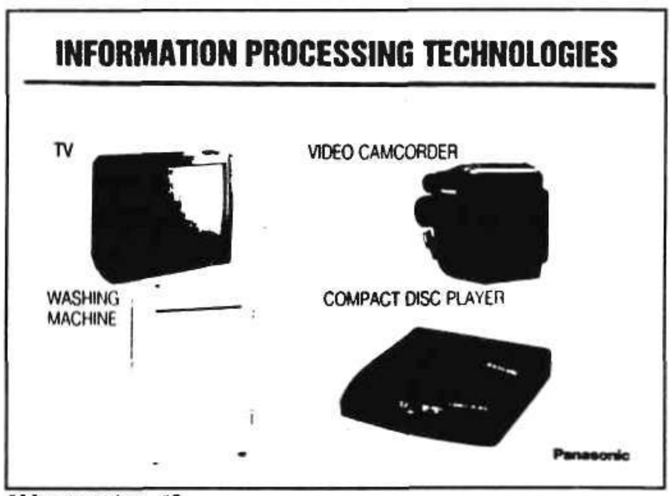

Illustration #3

use and wash time based upon the amount of dirt in each load of clothing.

Home Bus

Given the broad use of information processing technologies in our current crop of electronic products, it was inevitable that someone would come up with the idea of linking all such household products, appliances and equipment, onto a single home bus. Illustration #4 gives you a feel for the probable scope of such a home bus system in the future.

Via a home bus, we will be able to both receive and send information. This will allow us to remotely monitor and regulate in-home lighting, audiovisual equipment, heat and air-conditioning, security systems, et cetera.

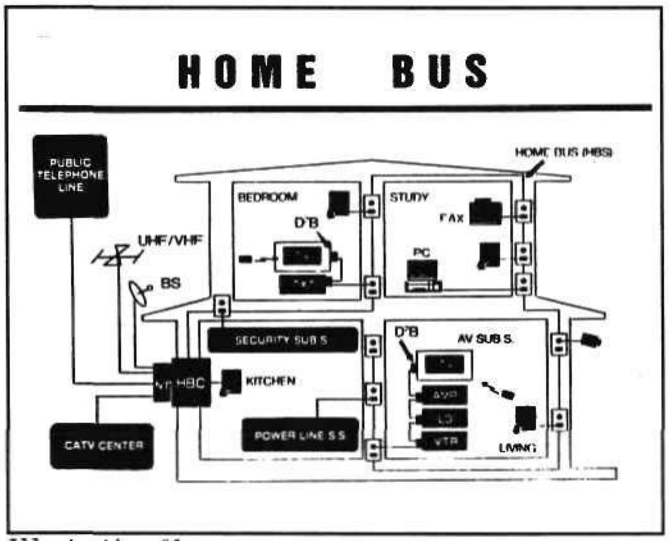

Illustration #4

As you can see, a number of microcomputers are used on the bus lines in connection with various pieces of equipment and at each connection node in the bus. Thus, future home electronics will integrate more computer and communications technologies than ever before.

Our cutting-edge Hi-Vision (or high definition) TV is, once again, a type of information processing equipment in that it is comprised of a series of computers and memory devices. One advantage of HDTV is that its resolution is some five times that of conventional NTSC sets. In addition, this technology can be utilized to transmit movies, publishing materials and medical information.

CD-I will become another key electronic application during the coming 10 years. As you know, the CD player is a piece of audio equipment; however, CD-I products will be multimedia products which will include text and video that can be utilized interactively.

As Illustration #5 reveals, CD-I equipment contains almost the same structure as a computer. It has a central system processor which controls its overall functions via a system bus. Information is sent from the disc on the left and, after being recorded and synthesized, emerges on the right in the form of sound and image.

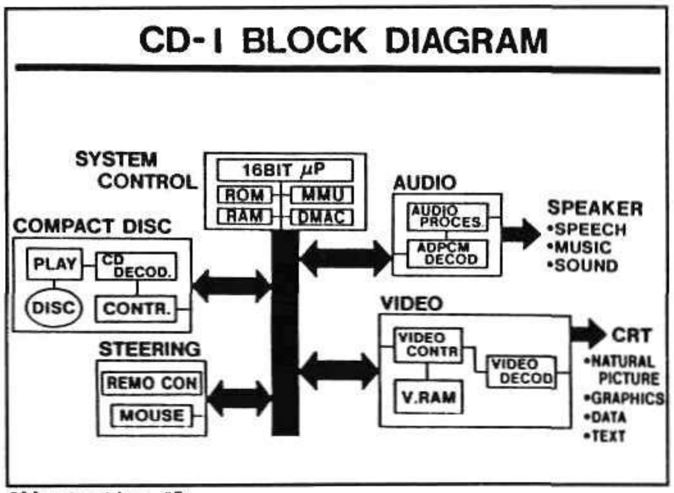

Illustration #5

"Human Electronics"

Matsushita has developed the concept of "Human Electronics" which dictates that products be designed and manufactured from the viewpoint of the consumer. In other words, we are committed to the development of innovative and highly user-friendly products. Illustration #6 lists a few examples of such products and technologies.

HUMAN ELECTRONICS

COMFORT and USER FRIENDLY

- **1/f FLUCTUATION PHENOMENA**
  electric fans, air conditioners, lighting products
- **FUZZY LOGIC**
  washing machines, vacuum cleaners, video camcorders
- **NEUROCOMPUTER**
  air conditioners

Illustration #6

To begin with, we will see the emergence of a new group of products based upon the 1/f fluctuation phenomenon, which was first observed in the field of physical phenomena, such as electrical noise, and which has recently been found to exist in the fields of biology, sociology and even economics.

An electric fan employing 1/f technology is capable of sending both a strong and faint breeze at irregular intervals. This mixed current of air creates a more refreshing and comfortable atmosphere than a conventional fan. And this principle applies to lighting and air-conditioning systems as well.

Fuzzy Logic

Secondly, as touched upon earlier, we will see a heightened use of fuzzy logic. In the past, home appliances, such as washing machines and vacuum cleaners, could not respond in any precise way to the input of ambiguous information (such as "hot" or "cold," or "clean" or "dirty") since they were designed merely to respond to digitized values. But now fuzzy logic will now render them capable of responding to such input with great precision.

Neurocomputers

Finally, we will witness the introduction of neurocomputers in everyday life. For example, neurocomputerized air-conditioning systems will be able to provide customized comfort by regulating temperature and humidity in accordance with the number of persons in the room, outside temperature and so forth.

In summary, we can see that future home electronic products will increasingly make use of the kind of advanced technologies which, until recently, were limited to scientists and very advanced applications.

Fundamental Technologies

I would now like to discuss the technologies which have supported the home electronics boom of the past two decades and which will continue to be the driving force behind the consumer electronic trends during the 1990s.

As you are well aware, the fundamental technologies that drove the advancement of electronics in our era have been semiconductor technology and computers (or digital) technology.

Semiconductor Technology

Needless to say, there could not have been an electronics revolution without the incredible progress made in the area of semiconductor technology. During the past five decades, the size and price of semiconductors have been reduced 1/100,000,000 and 1/10,000,000, respectively. And, in terms of performance, today's tiny micro-

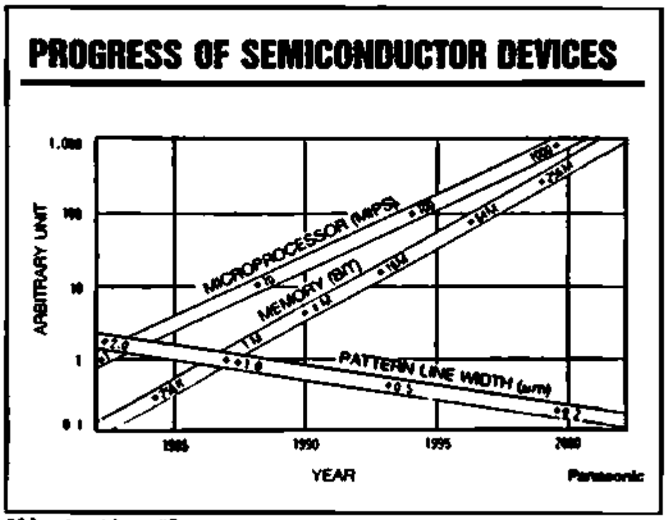

Illustration #7

ADVANCE IN DIGITAL TECHNOLOGIES

- EVERYTHING (DATA, TEXT, OPERATION) IS REDUCED TO ARRAYS OF BITS (0, 1), AND ARITHMETICALLY MANIPULATED
- TIME IS ALSO DISCRETE. REGARDLESS OF TIME SEQUENCE, ARRAYS OF BITS ARE REARRANGED, PROCESSED, AND RESTORED
- AUDIO AND VIDEO SIGNALS ARE ALSO ABLE TO BE REDUCED TO ARRAYS OF BITS, AND PROCESSED AS WELL

Illustration #8

processor, weighing only 10 grams and priced in the range of several hundred dollars, is far more powerful than the IBM 370 mainframes of about 20 years ago.

As for the future, Illustration #7 provides a forecast for semiconductor performance 10 years hence.

We predict that memory capacity will be increased from 4 Mb to 256 Mb, which is roughly equal to the volume of information contained in an entire encyclopedia. Also, microprocessor performance will increase from 10 mips to 1000 mips, which is comparable to that of present-day supercomputers. Above all, in 10 years, we will be able to purchase such devices, encapsulated in tiny packages, at very low cost. It is mind boggling to contemplate the impact which such semiconductor devices will have upon home and personal electronics.

Digital (Information Processing) Technology

During the past few decades, the conversion of analog signals into digital signals has become common in the electronics industry [Illustration #8].

Data, text, graphics, and even operations, have been reduced in the world of computers to arrays of numbers (0's and 1's) which can be arithmetically manipulated to express human thought and ideas. Likewise, recent technological advances have made it possible to process audio and video signals on a computer. This will add a whole new dimension in home and personal electronics.

Expanding From Home to Personal Use

Radio and TV sets were originally home electronic products in that they were used by family members as a group. Gradually, though, with size and price reductions, they have come to be owned and used by a single member of the family.

During the past year or two, we have begun to see an acceleration in the shift from home to personal use. In my view, there are at least three reasons for this:

• First, economic development has allowed vast numbers of people to shift their goals from merely satisfying basic living requirements to the search for heightened comfort and convenience.

We have now reached a point where people are seeking comfort, convenience and creativity through the personalization of their consumer products.

• Second, Japanese, American and European societies have come to demand, or expect, people to act more individually. Manufacturers have responded to this by attempting to differentiate their mass-produced goods..

• Finally, various technological advances of the past several years have both enabled and spurred this personalization trend. For example, new technologies have given us compactness, portability, lower prices and greater ease of use.

Personal Electronics

In my view, there are already three distinct categories of personal electronics:

• The first category includes small and inexpensive items which can be owned and used by a single individual as opposed to an entire household. In terms of audiovisual equipment, this category would include: pocket radios, headphone stereos, liquid crystal TVs and, as they become palm-sized and less expensive, video camcorders.

This category also includes "information" products, such as calculators, word processors, personal computers and workstations, which are becoming personalized in the form of desktop, laptop, notebook and card models.

Lastly, this first category includes communications equipment, such as portable facsimile machines and cellular mobile telephones.

• The second category of personal electronics consists of educational, business and entertainment products which are still operated by a single individual, but which are interactive in nature. Video games are a typical example of such products, but this category also includes CD-ROM, CD-I and DVI.

• The third category consists of products designed to assist small children, handicapped persons and the elderly. For example, until now, the programmed recording and editing functions on most VCRs have been far too complicated for even the general consumer to use. In the near future, electronics firms will need to provide much more user-friendly and useful products for these groups based on neurocomputers, artificial intelligence and cognitive science.

At Matsushita, we have developed speech therapy systems containing visual aids which compare the user's speech against a normal speech pattern, to help the orally handicapped with pronunciation and word ordering. Not only are such efforts important for the handicapped segment of the society, but they have also taught us a great deal about machine/human interface in general.

Changing Lifestyles

How will this trend toward personal electronics affect our lifestyles during the coming decade?

• To begin with, this trend will, for better or worse, enhance the drive toward greater individuality and creativity. Lifestyles will become more personalized.

• Second, this trend will lead us to rely more on interactive multimedia technologies for our entertainment and education.

Multimedia — Information

For example, this depicts a multimedia movie tour of India. A participant in this tour who might become curious about India's history could stop the tour to receive historical information on any given topic or place of interest. And, if the viewer suddenly decided that he wanted to visit India, he could use his multimedia computer to check airline fares, travel schedules and to make his reservations and purchase his tickets.

Multimedia — Education

Similarly, the study of mathematics and physics could be made more interesting and enjoyable through multimedia systems providing immediate feedback and assistance. This will lead to yet another lifestyle trend: the fusing of study and hobby.

Multimedia — Business

In addition, this trend will encourage working at home. Given the right communication tools, it would appear possible to do both our individual and collaborative office work out of our homes, thus freeing us from an unproductive and time-consuming commute.

An employee working at home could utilize a communication system to discuss a work topic with several colleagues at the same time. Thus, the distinction between home and office will also begin to fade away within the coming decade.
Personal electronics will also enable us to perform complex scientific and research chores on our own. For instance, with new advances in computer graphics, a lone researcher will be able to perform new and better simulations. This will allow him to acquire research results much faster than before and to provide a more visual presentation of those results.

Computer Animation

Likewise, the next 10 years will usher in great advances in the area of animation. Illustration #9 depicts a computer animation of seaweed and

COMPUTER ANIMATION

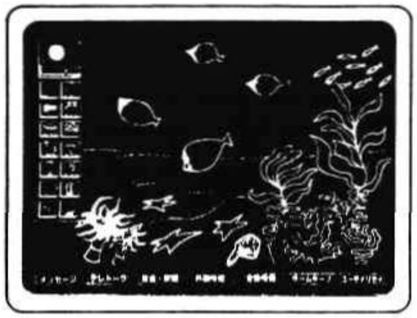

Illustration #9

fish movement in the sea. Using such animation, a single researcher would be able to explore fish and undersea flora behavior which could only have been understood by a team of researchers in the past.

Advanced Simulation & Computer Graphics

By the way, I should mention that since the U.S. remains about five to 10 years ahead of Japan in the area of advanced simulation and computer graphics, I believe that the emergence of personal electronics presents U.S. firms with a golden commercial opportunity.

The Japan-U.S. Relationship

During the past year, I had a rare opportunity to witness first hand the process of dealing with a major trade dispute between our two nations. I want you to know that I did my best to help advance the 20% market share goal for American chip sales in Japan.

For example, upon becoming Chairman of the Users' Committee, I asked the major Japanese electronics firms to establish company goals and procurement arms dedicated to buying foreign chips. I also asked these firms to participate in market access exhibitions and seminars and to send procurement teams to the U.S. to discuss automotive, consumer electronics and HDTV design-ins.

As a result of this and other efforts, foreign market share in Japan has improved considerably, but we have a ways to go. However, I am more optimistic than before that we will in fact reach our mutual goal in the near future.

I learned a great deal from this experience, and I came to several conclusions about U.S.-Japan relations in general:

CONCLUSION

LESSONS LEARNED FROM MY TENURE AS CHAIRMAN OF THE EIAJ'S FOREIGN SEMICONDUCTOR USER'S COMMITTEE:

- **WE'VE MORE IN COMMON THAN WE HAVE DIFFERENCES.**
- **STICKS AND STONES ... WORDS CAN INDEED HURT US.**
- **DON'T UNDERESTIMATE THE POWER OF AMERICAN INNOVATION.**

Illustration #10

• To begin with, despite all the talk about how unique Japanese society is, I have come to believe that, in the present era, Japanese and American citizens have far more in common than we have differences. We share the same basic values and are increasingly interested in each other's history, language and popular culture. In short, we are not the strangers we once were.

• Second, I have come to the conclusion that American and Japanese officials, journalists, commentators and other opinion makers need to use more discretion in their use of language when discussing our bilateral relationship. Terms such as "war" (as in "trade war") and "threat" (as in "the Japanese threat to the U.S."), and all of their Japanese counterparts, greatly overstate the areas of disagreement and friction in our bilateral marriage. If nothing else, this year's Persian Gulf Crisis should have served as a reminder that we need to apply such terms sparingly and only in situations where they are truly warranted.

• Finally, I have come to the conclusion that, to borrow a phrase from Mark Twain, the rumors of America's economic demise have been greatly exaggerated. My contact with numerous American high tech companies during the past year has confirmed my belief that America remains the most innovative nation on earth. And, as discussed in this conference, now that you are re-emphasizing your industrial and manufacturing roots, I suspect that you will give Japanese firms like Matsushita a great deal to think and worry about. But we welcome that competition and we wish you well.

Thank you very much.

Questions & Answers

MR. ANGEL: That was wonderful. Are there any questions?

QUESTION: What are the key technologies needed to bring multimedia capabilities to the mainstream PC user?

MR. MIZUNO: That is a very difficult question. I don't believe that the computer is going in the way we are imagining. I don't know what it will be. But at least I can say that the future is in mass production computers. When the computer is made in mass production styles, the same as TVs, the computer should be equipped with a lot of the video and audio features. At the present time the computer is not so people friendly.

So, in order to develop very friendly computers, we have to include a lot of capabilities in the audiovideo performance. The technology for that, I believe, is software for graphics. And second, to realize semiconductor technologies might go to sub-microns, because in order to realize the graphics we will need very fast microprocessors, faster than the present ones. And we need larger memories to store the image. So, we need very much, indeed, the sub-micron VLSI technology.

HOW USER/SUPPLIER RELATIONS WILL CHANGE

Irv Abzug

GTD Vice President and
Director of Corporate Component Procurement
IBM Corporation

MR. ANGEL: We are privileged that Irv Abzug has joined us today to provide, I think, a special perspective. As I mentioned yesterday, we think that IBM is the largest consumer of semiconductor devices in the world. This is the gentleman who oversees the acquisition of those electronic components.

Irv is Vice President of the General Technology Division and Director of Corporate Component Procurement for IBM Corporation. He joined IBM in 1947, and has been associated with a series of highly successful programs. As you can see in his biography, these are immediately recognizable major achievements of the corporation.

Irv, we are most pleased to have you here today, and I look forward to your comments.

MR. ABZUG: Good afternoon. There is something enviable about being the last speaker on the agenda here.

David, I want to thank you for inviting me to join this Dataquest Conference. It has been a real pleasure for me, a visitor from the East, to come to California and to mingle with "dinosaurs" and "fabless bigots" — I guess that's the word.

Today I would like to discuss the evolution of the relationship between IBM and the electronic component industry. I will briefly review the history and the changes in this relationship, and then talk to the challenges of the 1990s.

But first, for those of you who are not familiar with IBM's Corporate Component Procurement [CCP] Organization, I would like to describe our mission and our structure.

CCP's Mission & Structure

You might say that CCP is the bridge between the world of IBM and the world of the electronic component industry. Our mission is to support IBM's development and manufacturing product divisions with technologies that we procure from qualified suppliers.

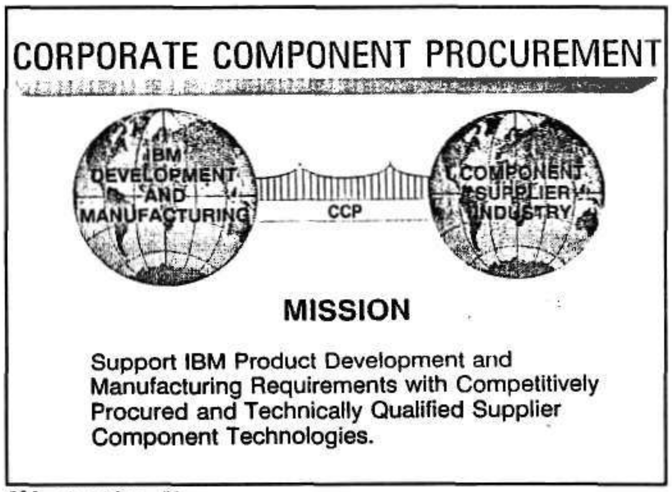

Illustration #1

We are a self-contained organization. Our structure includes:

• Our Product Support group interfaces directly with our internal IBM customers, to assist them in defining their technology requirements.

• Our Engineering arm works closely with suppliers' engineers to specify the application and reliability requirements.

• Materials Management consolidates production demands from IBM plants around the world. They place the necessary purchase orders and manage the flow of incoming parts from our suppliers to IBM's assembly plants.

• Quality Assurance verifies the ongoing quality of our purchased components.

• And finally, Finance manages our financial plans and activities.

I should also add that we serve as a strong advocate of industry technology within IBM.

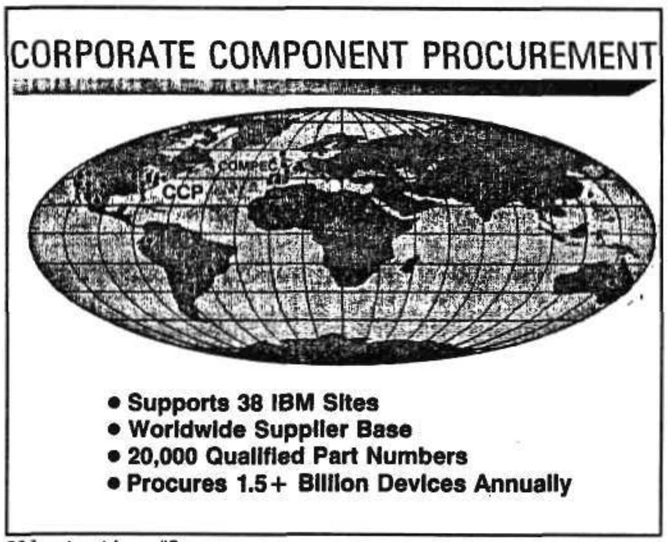

Illustration #2

CCP provides purchased components to 54 development and manufacturing organizations at 38 IBM sites located around the world. As you can see on Illustration #2, we have identified COMPEC [Component Procurement European Center], our sister organization, which is located in Bordeaux, France. Its primary responsibility is to provide purchased component technology to IBM's manufacturing facilities in Europe.

Our supplier base is worldwide, with the majority of our purchases coming from fewer than 100 suppliers. We have a product menu of about 20,000 part numbers, and we procure more than 1.5 billion devices per year.

Component Purchase Strategy

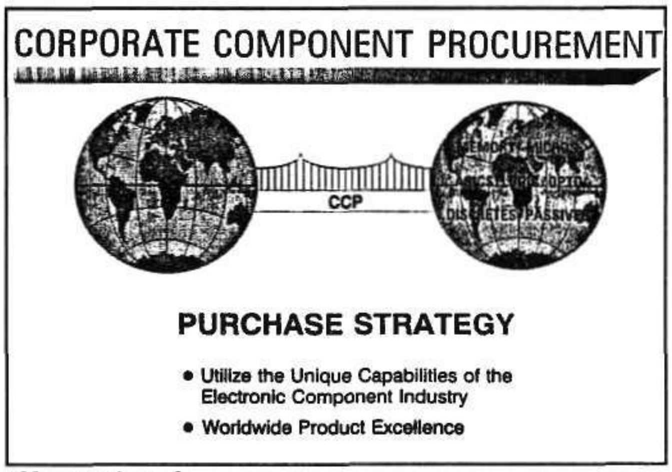

Illustration #3

Our purchase strategy is rather straightforward. It is to employ those special and unique capabilities of the semiconductor industry which complement IBM's internal development and manufacturing strategies.

Those industry capabilities, which are of prime importance to IBM, include: memory and logic commodity products; application-specific devices; microprocessors and controllers; optics, including LED and lasers; and discrete passive components. Our procurement strategy is predicated on worldwide supplier excellence in products and services.

History of Supplier Relationships

Now that you have a general idea of our mission, structure and strategy, I would like to briefly review the history of our supplier relationships. This should help you to understand the evolving changes. And, most importantly, it will help you to identify how we are positioned today to meet the challenges of the 1990s.

1970s: "Arm's Length" Relationships

Then, as now, CCP was the bridge between the IBM world, with its distinctive culture and purchase practices, and the supplier world, with its own ways of doing business. As Illustration #4 shows, it was a *very long* bridge.

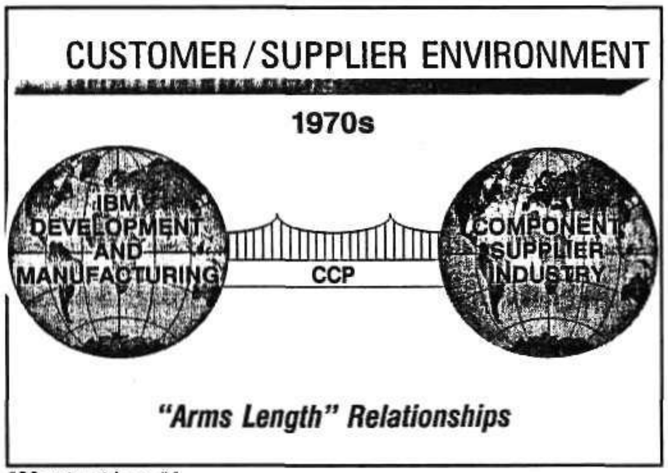

Illustration #4

Many of you experienced working with IBM during the 1970s, in what I refer to as an "arm's length relationship" — one that limited our suppliers to just enough information to permit them to make parts which met our specifications. That relationship allowed for very little in the way of communication about IBM's product plans, long-range strategies, or supplier opportunities.

In those days, IBM's component requirements were almost exclusively mainframe driven, with design cycles generally lasting several years. In addition, IBM's specifications for function and reliability were often tighter and more demanding than the standard offerings of the component industry.

CUSTOMER / SUPPLIER ENVIRONMENT

1970s

IBM	SUPPLIER
• REQUIREMENTS MAINFRAME DRIVEN	• SUPPLIER BASE U.S. DOMINATED
• LONG DESIGN CYCLES	• INCONSISTENT DELIVERY AND QUALITY PERFORMANCE
• UNIQUE IBM SPECS	• PREMIUM PRICING FOR COMPUTER GRADE TECHNOLOGY
• HIGH RELIABILITY	

Illustration #5

In the 1970s, American companies dominated the electronic component industry. Most of you will recall that during that decade, a quality level (or QL) of 1% was considered acceptable. Obviously, we could not tolerate that kind of quality today. Nor would we tolerate the delivery performance we considered acceptable in the 1970s. Back then, it was not uncommon for IBM to be obliged to pay premiums for nonstandard specifications for computer-grade technologies.

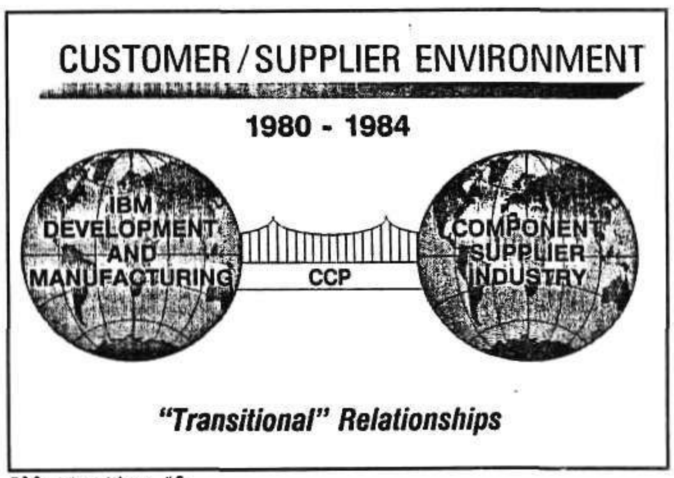

Illustration #6

1980-1984: "Transitional" Relationships

As we entered the 1980s, not much had changed. Mainframes were still driving our component purchases.

Then came August 12, 1981, the day that IBM announced its first personal computer — ushering in a decade of dramatic transition in the relationship between IBM and its suppliers. It was a relationship characterized by rapid changes in technology and unprecedented demands on the supplier industry.

CUSTOMER / SUPPLIER ENVIRONMENT

1980 - 1984

IBM	SUPPLIER
• PC MAJOR NEW DRIVER - Short Development Cycles - Reduced Qualification Time - High-Volume Demand	• UNPRECEDENTED DEMAND • CAPACITY CONSTRAINTS • DELIVERY AND QUALITY PERFORMANCE INCONSISTENT
• INDUSTRY STANDARD PARTS	• GLOBAL SUPPLIER BASE

Illustration #7

Unlike our long-existing mainframe business, IBM's success in the new PC business depended on our need to adjust to changes in product development cycles, reduced qualification times and short lead-time/high-volume demands. It also depended on a much greater use of industry standard or catalog components in IBM products.

On the industry side, component demand was unprecedented. From 1980 to 1984, spurred in large part by the PC phenomenon, worldwide semiconductor sales doubled from $14 billion to nearly $29 billion. The book-to-bill ratio reached a mind-boggling 1.66 at the end of 1983. Capacities became very constrained. We were faced with shortages and allocations. Delivery and quality continued to be inconsistent, and we found it necessary to expand our supplier base beyond the United States to meet our requirements.

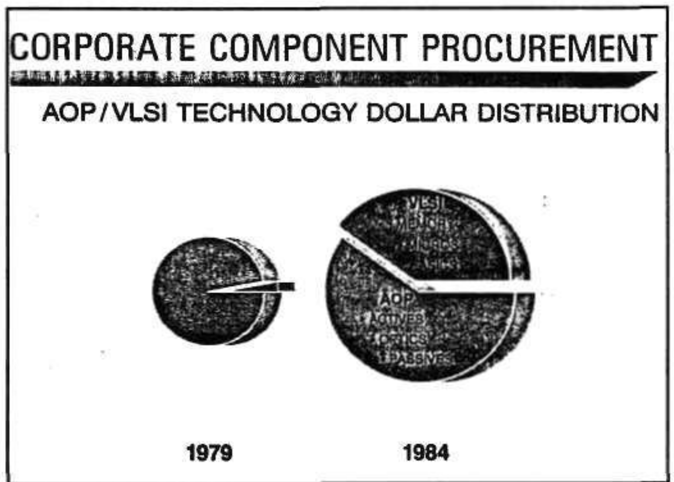

Illustration #8

The pie chart in Illustration #8 gives you an idea of the huge growth and the dramatic change we experienced in IBM.

By the mid-1980s, we had doubled our purchases of mature technologies. In addition, we had added a whole new VLSI business. It was larger than our entire procurement expenditure for 1979.

By the beginning of 1984, CCP and its suppliers were under considerable stress. Working at arm's length had become as obsolete as the vacuum tube. CCP and its suppliers simply had to move closer together.

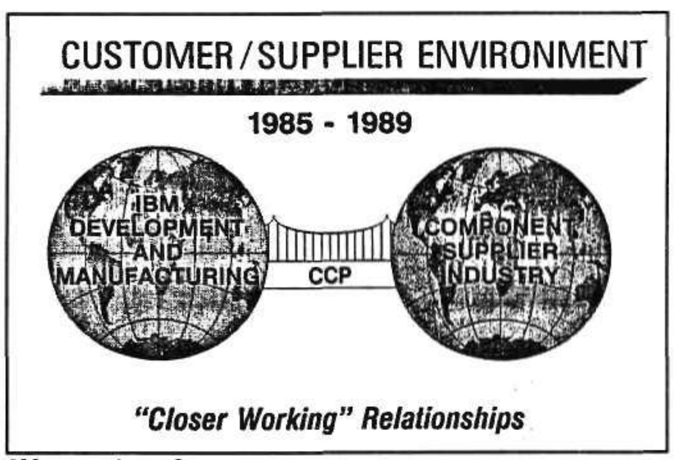

Illustration #9

1985-1989

1985 marked the beginning of closer relationships with our suppliers. These relationships were driven by the demands of CCP's internal customers for improved responsiveness, quality and reliability. We saw a real need to change our business processes.

Pencil and paper were still used to prepare requisitions and purchase orders in the early 1980s. But, as we looked into the future, with its dynamic growth and demand, we saw the need to develop a system which could place purchase orders automatically. It became apparent to us that EDI [Electronic Data Interchange] between CCP and its suppliers was the way to go, not only for business placement, but also for the timely and accurate transmission of engineering and quality data.

CUSTOMER / SUPPLIER ENVIRONMENT

1985 - 1989

IBM — SUPPLIER

- INCREASING CUSTOMER DEMANDS
  - Responsiveness
  - Quality / Reliability
- CHANGING CCP PROCESSES
  - Automated Business Placement
  - Electronic Data Interchange
  - Source Acceptance
  - Joint Qualifications

Illustration #10

We made other departures from the way we used to operate. For example, we established a source acceptance program with our better suppliers. As a result, we began to drop ship much of what we ordered directly to IBM manufacturing sites.

These closer working relationships produced other substantial benefits.

Qualification testing of components used to be done sequentially, first by suppliers, and then by CCP. It was a cumbersome process. Slowly, it gave way to joint qualifications. This change in the way we conducted business was very significant in savings of time and resources.

Even more dramatic was the fact that our relationship had advanced to the point where we had confidence in, and were willing to accept, critical engineering testing by our suppliers.

With the benefit of hindsight, it is obvious that this was a major milestone. It was when we began to establish the trust, confidence and close relationships we believe are essential to meeting the challenges of the 1990s.

CUSTOMER / SUPPLIER ENVIRONMENT

1985 - 1989

IBM	SUPPLIER
• INCREASING CUSTOMER DEMANDS	• IMPROVING PERFORMANCE
- Responsiveness	- Delivery
- Quality / Reliability	- Quality
• CHANGING CCP PROCESSES	- Reliability
- Automated Business Placement	- Lead Times
- Electronic Data Interchange	- Customer Oriented
- Source Acceptance	
- Joint Qualifications	• NEW WORLDWIDE SUPPLIERS

Illustration #11

We were changing, and so were our suppliers. The semiconductor industry was advancing on all fronts. Deliveries, quality levels, component reliability and manufacturing lead times were all showing real improvement. The supplier base began to take on new shapes, with the entry of dozens of start-up companies in the U.S., Korea and Taiwan, and the new Japanese mega-corporations were also joining the ranks of this rapidly growing industry.

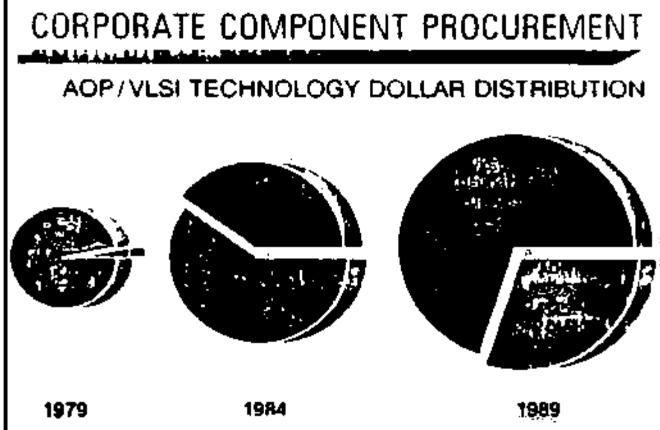

Illustration #12

Let's take a moment and review some of the changes we experienced in the 1980s.

IBM's component dollar purchases had grown by almost six times in just 10 years. VLSI had now become the dominant technology, and it accounted for two-thirds of our purchases. These statistics pretty much sum up the progress we made with the considerable help of our suppliers.

DECADE OF CHANGE — 1980s

AVERAGE CYCLE TIME REDUCTION	63%
AUTOMATED BUSINESS PLACEMENT	85%
DROP SHIP (VOLUME)	89%
INVENTORY DOLLAR REDUCTION	60%
INCOMING QUALITY IMPROVEMENT	150X

Illustration #13

We are especially proud of the 150-fold improvement in incoming quality levels that we were achieving through joint quality programs with our key suppliers. We have come a long way. And I say thanks for a job well done — and, I hasten to add, it is just the beginning.

Challenges of the 1990s

Now, let's move on to the challenges of the 1990s. The IBM watchers would tell you that during most of the 1980s IBM sold and delivered products. Today, delivering products is just not good enough. The expectations of IBM's customers have increased, and their message to us is quite simple: "We need solutions; solutions that satisfy our business needs and allow us to operate our enterprises more efficiently and more reliably."

For IBM and its industry, and for other industries as well, the decade of the 1990s is shaping up as a market-driven decade. Clearly, we are entering a period when companies will either satisfy their customers or simply pass into history.

We in IBM, from the Chairman of the Board through every level of management and every employee, are giving market-driven quality our very highest priority. Our objective is no less than *total* customer satisfaction. That means we are going to deliver products and services on time and at the highest quality and reliability levels. And we are going to deliver them at the lowest total cost, not just the lowest price.

Though the rate of improvements of the 1980s was certainly impressive, it was not nearly sufficient to achieve the market-driven quality objectives of the 1990s.

Let me give you some perspective on some of the challenges we face.

• Conventional wisdom would say that 99.9% defect-free product is pretty good. Recall that earlier in my presentation, I stated that IBM procures in excess of 1.5 billion devices a year from the component industry. At 99.9%, the industry will ship 1.5 million defective components to IBM's manufacturing facilities. This is totally un-acceptable in a market that is demanding defect-free products and services.

• Considering what I have just said, it should not surprise you to learn that we in IBM have a new and a greater urgency to quicken the pace of change, and to accelerate improvements in quality, in reliability and in technology. It is clear to us that to become world class in the information systems industry, we must have suppliers who are also world class in their industry.

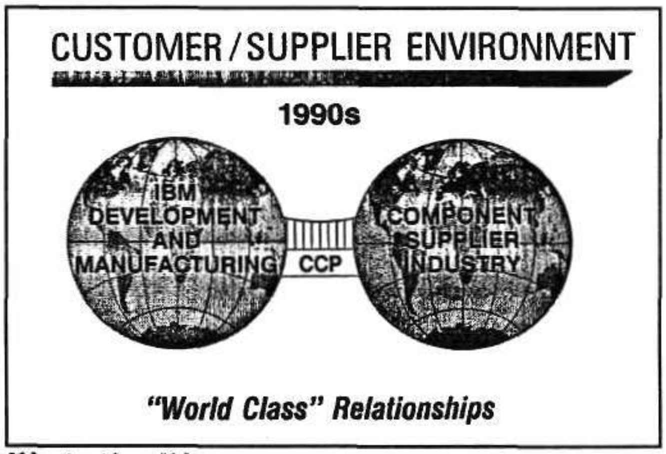

Illustration #14

• We need — and we will form — special alliances with our very best suppliers. These partnerships for the future will be very close. They will be founded on a high level of mutual trust and considerable confidence in the skills of each other.

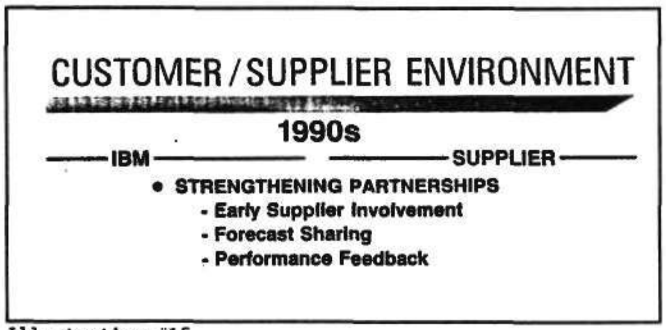

Illustration #15

• For our part, we in IBM need to involve suppliers in our product cycles earlier than ever before. We need to share more detail on our volume and technology forecasts with our key suppliers. And together, we need to develop a measurement and performance feedback system that is directed at achieving world class-status.

World-Class Supplier

Illustration #16 defines our view of a world-class supplier. It is one who achieves excellence and is a leader in technology, in product and in services. A supplier who measures success in terms of market driven principles and total customer satisfaction.

Illustration #16

Frankly, I am very excited about the idea of world-class partnerships for the future. I am excited about working with suppliers who are willing to commit to the same principles of success in their industry as we have in ours. I know that both of us, the supplier and IBM, can — and will — pull this off. And when we do, we will not simply satisfy customers, we will delight them. Delighted customers have a habit of coming back.

CCP Goals

Let me switch gears and tell you about a set of goals that we in CCP developed two years ago. They were an early effort aimed at making CCP more market-driven in serving the needs of our internal customers. Those of you who have visited our buildings have seen these goals posted in nearly every one of our offices.

CORPORATE COMPONENT PROCUREMENT

GOALS

- **To Grow Consistent with IBM's Demand for Supplier Component Technology.**
- **To Provide Component Leadership in the Application of Supplier Technologies in IBM Products.**
- **To be the Most Competitive Provider of Supplier Components in Terms of Quality, Cost, Technical Support, and Cycle Time.**
- **To Enhance Customer and Supplier Relationships.**
- **To Create an Environment for Creativity, Excellence and Individual Fulfillment.**

Illustration #17

• Our first goal is to grow, consistent with IBM's demand for supplier component technology. During the next decade, IBM's annual procurement of electronic components will continue to grow to very sizeable dollar values. IBM and suppliers alike must be prepared to meet all the challenges that growth will entail, and to meet them with improved levels of performance.

• Our second goal is to provide leadership in the application of supplier technologies. As we have in the past, CCP will continue to serve the IBM Corporation as a center of competence in the application of supplier technologies. And, as never before, we will need the help and the involvement of our world-class suppliers earlier in our development cycles.

• The third goal is to be the most competitive provider of supplier components. Our objective is to assure that our internal customers receive defect-free products from the component industry when they need them and at their best value.

• Goal number four captures the essence of market-driven quality and customer satisfaction. We are going to continue to improve customer and supplier relationships whenever and wherever we can. I would like to never have to say "no" to an IBM customer again. I am beginning to think that this goal may be achievable with the right kind of supplier relationships.

• Finally, we are creating an environment for creativity, excellence and individual fulfillment. We know that, despite all of the automation and all the sophisticated hardware and software, it is our people who make it happen.

We ask a lot from our employees. We believe that it is part of our responsibility to assure that they find their work challenging and that they have the opportunity to be creative in their jobs. So we empower them with considerable responsibility to get the job done. Empowering our employees nurtures a sense of individual fulfillment; and, in general, results in greater productivity and efficiency.

When we began to formulate an IBM supplier strategy for the 1990s, we considered developing a set of goals to help our suppliers understand our focus and our direction. We soon recognized that we couldn't do much better than the goals we had already set for ourselves. We also realized that shared common goals can have the effect of fostering an even closer working relationship and improving teamwork with our suppliers.

Summary

In closing, I would like to say "thanks" for the exciting times of the 1970s and the 1980s. We have come a long way from that old "arm's length" relationship.

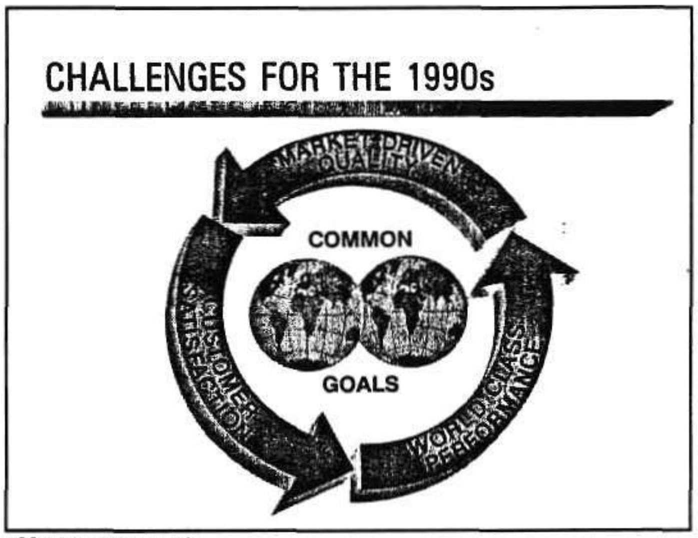

Illustration #18

As for the 1990s, we in IBM are making market-driven quality and customer satisfaction an obsession. We are looking forward to growth in our industry and sharing this growth with our suppliers, particularly with those suppliers who dedicate themselves to excellence in products and services.

In the demanding market of the 1990s, we simply cannot afford anything less than world-class performance — world-class performance achieved with world-class partners.

MR. ANGEL: We are at the end of the conference. Thank you so much for supporting it. Again, thank you for your business.

We will see you next year. While we do not know exactly where it will be, if I were a betting man, I would say we will be right back here.

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