Conference Information

Location

Santa Clara Marriott, 2700 Mission College Blvd., Santa Clara, California 95054
Telephone: (408) 988-1500

Conference Fee—$445

Conference fee includes one copy of all materials presented, lunch, and one seat at the annual SIA forecast dinner to be held the night of the conference.

Registration

- *Reserve your seat today—space is limited.*

Please register by calling the Dataquest Conference Department at **(800) 624-3282**. At the time you make your reservation, please indicate whether or not you will be attending the SIA forecast dinner. If you are planning to attend the SIA forecast dinner *only*, please call the SIA directly at (408) 973-9973.

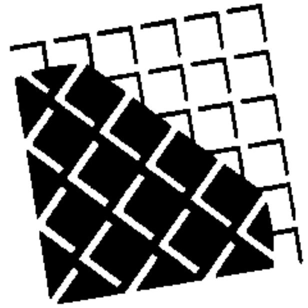
Cancellation Policy

- *Cancellation deadline is Monday, September 26, 1988.*

All cancellations received by Dataquest after September 26, 1988, are subject to a $75 service charge unless the registrant sends a replacement. Registrants who do not cancel and who fail to attend the conference will automatically be assessed a $75 service charge.

1988

Seizing Opportunities of Change: Strategic Electronic Markets for Semiconductors



September 29
Santa Clara Marriott
Santa Clara, California

A Special One-Day Executive Briefing Cosponsored by the Semiconductor Industry Association and Dataquest

SIA Semiconductor Industry Association

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Seizing Opportunities of Change: Strategic Electronic Markets for Semiconductors

A special one-day executive briefing on high-growth, high-visibility, high-technology markets

Receive important information on the health and vitality of key electronics markets in a fact-filled, fast-paced day of authoritative industry briefings and forecasts.

Sponsored by the Semiconductor Industry Association and Dataquest, *Seizing Opportunities of Change* will provide you with insightful information and analysis on the prospects for growth in the following electronics markets:

- Personal computers
- Computer storage
- LANs
- HDTV/video
- On-line transaction processing
- Graphics and imaging
- Voice processing
- Military/aerospace

Conveniently Scheduled

Seizing Opportunities of Change has been scheduled to coincide with the SIA's annual forecast dinner, which will be held the night of the conference. As an added bonus, conference registration entitles each participant to one free seat at the forecast dinner.

Join semiconductor, systems, and peripheral manufacturers and members of the financial community in this midyear update and forecast on the future health and vitality of the electronics industry.

Don't delay—mark your calendars and make your reservations now! Call (800) 624-3282.

Agenda

Seizing Opportunities of Change: Strategic Electronic Markets for Semiconductors

- ***Thursday, September 29***

7:30 a.m. *Registration*

9:00 a.m. *Conference begins*

- ***Welcome and Introduction***

Andrew A. Procassini
President
Semiconductor Industry Association

Manny A. Fernandez
President
Dataquest Incorporated

- ***Dataquest Electronics Outlook***

Anthea C. Stratigos
Director
Semiconductor User and Applications Group
Dataquest Incorporated

- ***Personal Computers***

Allan Alcorn
Apple Fellow
Apple Computer, Inc.

Dennis W. Andrews
Laboratory Director
Entry Systems Division
IBM Corporation

- ***Computer Storage***

George M. Scalise
President and CEO
Maxtor Corporation

- ***Voice Processing***

Robert Cohn
President and CEO
Octel Communications Corporation

- ***On-Line Transaction Processing***

Larry Laurich
Vice President
Transaction Systems Division
Tandem Computers, Inc.

Lunch

- ***HDTV/Video***

Richard Elkus, Jr.
Chairman and CEO
Prometrix

- ***Military***

Gregory L. Sheppard
Senior Industry Analyst
MilAero Technology Service
Dataquest Incorporated

- ***LANs***

J. Daniel Robertson
Vice President Manufacturing
Distributed Systems Division
3COM Corporation

- ***Graphics***

Mike Tyler
Director
Graphics and Imaging Service
Dataquest Incorporated

Conference Adjourns

Cocktails

Annual SIA Forecast Dinner

1987
Semiconductor Industry Conference
Sponsored by
Semiconductor Industry Service and Semiconductor Equipment and Materials Service

October 19–21, 1987
The Pointe at Squaw Peak
Phoenix, Arizona

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1987 SEMICONDUCTOR INDUSTRY CONFERENCE

Semiconductors: Midlife Crisis

October 19–21, 1987
The Pointe at Squaw Peak
Phoenix, Arizona

SUNDAY, October 18

4:00 p.m. to 8:00 p.m.	**Registration**	*Squaw Peak Ballroom Lobby*
7:30 p.m. to 9:30 p.m.	**Cocktails**	*South Garden*

MONDAY, October 19

6:45 a.m.	**Registration Continues**	*Squaw Peak Ballroom Lobby*
	Buffet Breakfast	*Grand Ballroom*
8:00 a.m.	**Welcome and Introduction** Manny A. Fernandez President Dataquest Incorporated	*Squaw Peak Ballroom*
8:15 a.m.	**Semiconductors: Midlife Crisis** Mel Thomsen Director, Semiconductor Industry Service Dataquest Incorporated	*Squaw Peak Ballroom*
8:30 a.m.	**World Economic Outlook** Joseph W. Duncan Corporate Economist and Chief Statistician The Dun & Bradstreet Corporation	*Squaw Peak Ballroom*
9:00 a.m.	**World Chip Industry: Same Game, Different Rules** Gene Norrett Vice President Director, Semiconductor Industry Group Dataquest Incorporated	*Squaw Peak Ballroom*
9:30 a.m.	**The Nature of Capital Spending** Robert McGreary Director, Semiconductor Equipment and Materials Service Dataquest Incorporated	*Squaw Peak Ballroom*
10:00 a.m.	**Coffee Break**	*South Garden*
10:30 a.m.	**VLSI Devices for the Human-Machine Interface** Michael J. Thompson Executive Director, Integrated Circuit Design Division AT&T Bell Laboratories	*Squaw Peak Ballroom*
11:00 a.m.	**Past as Prologue** Jack Kilby Consultant	*Squaw Peak Ballroom*
11:30 a.m.	**Technology after 40** Gordon E. Moore Chairman of the Board Intel Corporation	*Squaw Peak Ballroom*
12:00 Noon	**The Future of Manufacturing Technology** Dr. Hiroe Osafune Chairman of the Board NEC Electronics, Incorporated	*Squaw Peak Ballroom*
12:30 p.m.	**Lunch**	*Grand Ballroom*

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1:30 p.m.	**Panel Session—Surviving in the Land of the Giants** David L. Angel Managing Director DQ Alliances J. Daniel McCranie President and Chief Executive Officer Seeq Technology Michael Burton President and Chief Executive Officer Triad Semiconductors International B.V. James V. Diller President and Chief Executive Officer Sierra Semiconductor Corporation Michael L. Hackworth President and Chief Executive Officer Cirrus Logic, Incorporated	*Squaw Peak Ballroom*
6:00 p.m.	**Buses for Pinnacle Peak** *(Casual Attire)*	*Conference Center*
	Cocktails and Barbeque	*Pinnacle Peak*

TUESDAY, October 20

7:00 a.m.	**Buffet Breakfast**	*Grand Ballroom*
8:15 a.m.	**Introductions**	*Squaw Peak Ballroom*
8:30 a.m.	**Manufacturing Competitiveness** Charles E. Sporck President and Chief Executive Officer National Semiconductor	*Squaw Peak Ballroom*
9:00 a.m.	**Formulas for Success of the U.S. Semiconductor Industries** Sanford L. Kane Vice President, Industry Operations General Technology Division IBM Corporation	*Squaw Peak Ballroom*
9:30 a.m.	**Opportunities for Gigascale Integration** Dr. James D. Meindl Vice President, Academic Affairs and Provost Rensselaer Polytechnic Institute	*Squaw Peak Ballroom*
10:00 a.m.	**Coffee Break**	*South Garden*
10:30 a.m.	**U.S. Competitiveness in the 1990s** William H. Reed Executive Director Semiconductor Equipment and Materials International	*Squaw Peak Ballroom*
11:00 a.m.	**The Technology of Partnering** Irwin Federman Vice Chairman of the Board Advanced Micro Devices, Inc.	*Squaw Peak Ballroom*
11:30 a.m.	**Perspective on Technology Acceleration** Walden C. (Wally) Rhines Vice President Senior Vice President Semiconductor Group Texas Instruments, Incorporated	*Squaw Peak Ballroom*
12:00 Noon	**Lunch**	*Grand Ballroom*
1:30 p.m.	**Mergers, Acquisitions—The Forces that Are Shaping Our Industry** Donald W. Brooks	*Squaw Peak Ballroom*
2:00 p.m.	**Alliances: Requirements for Leadership** Dr. Thomas D. George Senior Vice President and Assistant General Manager Semiconductor Product Sector Motorola Corporation	*Squaw Peak Ballroom*

2:30 p.m.	**Semiconductor Partnerships—Key to Success** Alfred J. Stein Chairman and Chief Executive Officer VLSI Technology	*Squaw Peak Ballroom*
3:00 p.m.	**Coffee Break**	*South Garden*
3:30 p.m.	**Role of Silicon Foundry in the Future Semiconductor Industry** Dr. Morris Chang President Industrial Technology Research Institute (ITRI) Chairman of the Board Taiwan Semiconductor Manufacturing Company	*Squaw Peak Ballroom*
4:00 p.m.	**Status of Semiconductor Technology and ASIC Market in Korea** Dr. P. June Min Senior Managing Director R&D and Business Development Group GoldStar Company, Ltd.	*Squaw Peak Ballroom*
4:30 p.m.	**Globalization: We're Not Too Old to Play** Norman Neumann President and Chief Executive Officer Signetics Corporation	*Squaw Peak Ballroom*
6:30 p.m.	**Cocktails**	*South Garden*
7:30 p.m.	**Dinner**	*Grand Ballroom*
	Dinner Speaker Dr. Sheldon Weinig Chairman and Chief Executive Officer Materials Research Corporation	

WEDNESDAY, October 21

7:00 a.m.	**Buffet Breakfast**	*Grand Ballroom*
8:15 a.m.	**Introductions**	*Squaw Peak Ballroom*
8:30 a.m.	**Capital Formation for U.S. Semiconductor Manufacturing in the 1990s** Dr. Wilmer R. Bottoms Senior Vice President and General Partner Alan Particof Associates, Inc.	*Squaw Peak Ballroom*
9:00 a.m.	**Maskmaking: Life after 5ex** Steven K. Dunbrack Marketing Manager Ultratech Stepper	*Squaw Peak Ballroom*
9:30 a.m.	**Semiconductor Manufacturing Industry—Its Role and Issues in 1990s** Tsuyoshi Kawanishi Senior Vice President and Director of the Board Group Executive, Semiconductor Group Toshiba Corporation	*Squaw Peak Ballroom*
10:00 a.m.	**Coffee Break**	*South Garden*
10:30 a.m.	**A Winning Strategy for U.S. Semiconductors** Dr. Edward E. David, Jr. President EED, Inc.	*Squaw Peak Ballroom*
11:00 a.m.	**Semiconductors Processing Equipment, Competitive Issues, and Sematech—Potential Impact** Larry Hansen Executive Vice President Varian Associates	*Squaw Peak Ballroom*
11:30 a.m.	**International Competitiveness in Advanced Processing** Dr. Peter H. Rose President Semiconductor Equipment Division Eaton Corporation	*Squaw Peak Ballroom*
12:00 Noon	**Lunch**	*Grand Ballroom*

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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. Which of the following best describes your company's primary activities?

☐ Semiconductor manufacturer

Type: ☐ Standard logic ☐ ASIC ☐ DSP
☐ Memory ☐ Microcomponents ☐ Telecommunications
☐ Linear-Analog ☐ Opto-Discrete ☐ All types

☐ Supplier to semiconductor industry

Type: ☐ Test equipment
☐ Design equipment/software
☐ Manufacturing equipment
☐ Materials
☐ Services

☐ User of semiconductor products
☐ Distributor, government agency, consultant, investment advisory
☐ Other ______________________

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

☐ CEO, President, Vice President
☐ Strategic Planning/Business Development
☐ Sales and Marketing Management
☐ Product Management
☐ Product Development/R&D/Engineering Management
☐ Operations Management
☐ Purchasing/Vendor Selection
☐ Other ______________________

3. 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 ______________________
____

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4. Rank the reasons you attend this conference in order of importance (1 being the most important).

	Most				Least
To hear Dataquest's forecasts	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

5. Check each previous year that you personally have attended an October Dataquest Semiconductor Industry Conference.

1986 ____ 1985 ____ 1984 ____ 1983 ____ 1982 ____ 1981 ____

1980 ____ 1979 ____ 1978 ____ 1977 ____ 1976 ____ 1975 ____

6. From which Dataquest services do you personally receive information? Check all that apply.

- ☐ Semiconductor Industry Service
- ☐ Semiconductor Equipment and Materials Service
- ☐ Semiconductor User Information Service
- ☐ European Semiconductor Industry Service
- ☐ Japanese Semiconductor Industry Service
- ☐ Semiconductor Application Markets
- ☐ Telecommunications Industry Service
- ☐ CAD/CAM Industry Service
- ☐ Personal Computer Industry Service
- ☐ Technical Computer Systems Industry Service
- ☐ Financial Services Program
- ☐ Other Dataquest Service ______________________________
- ☐ I'm not sure which Dataquest services my company receives.

7. Should the length of this conference be: ☐ Shorter ☐ Longer ☐ The same

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Semiconductors'
Midlife Crisis

Economic and Industry Outlook

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Semiconductor Industry Conference
October 18 through 21, 1987
Phoenix, Arizona

Final List of Attendees

AMAX Electronics Products, Inc.	Ed Whelan, Senior Staff Metallurigist
AMP Incorporated	Earl R. Kreinberg, Development Engineer David McMullen, Marketing Manager
ANELVA Corporation	Owen Wilkinson, Marketing Applications Engineer
ASM Lithography, Inc.	Gary Emmons, Central Regional Sales Manager Paul Henry, Director, Marketing L. David Sikes, Vice President, Technical Operations Robert Ward, Vice President, Sales & Marketing
AT&T	John L. Bestel, Manager, Market Management Matt C. Bieber, Senior Product Planner Thomas Egan, Department Chief, Strategic Issues Analysis Raymond Reusser, IPLM Manager
AT&T Bell Laboratories	William Evans, Director, Computer Aided Design & Test Laboratory James Goldey, Director, Linear/High Voltage ICs Michael J. Thompson, Executive Director Integrated Circuit Design Division
ATEQ Corporation	Douglas Marsh, Vice President, Sales & Marketing

Actel Corporation	Douglas Rankin, Senior Vice President, Sales & Marketing
Advanced Micro Devices, Inc.	Irvin Federman, Vice Chairman of the Board W. Curtis Francis, Vice President, Strategic Planning
Advantest America Inc.	Frederick Bihler, President
Aerospatiale	Robert Zanotti, Components Engineering Group Manager
Airco Electronic Gases	Jeffrey D. Eagles, Manager, Electronic Business Team
Alan Patricof Associates, Inc.	Wilmer Bottoms, Senior Vice President & General Partner Diane Bottoms
Alcatel	Jez Cunningham, Component Engineering Manager
American Semiconductor Equipment Technologies	Greg Reyes, President
Amsterdam-Rotterdam Bank N.V.	Lawrence Osborne, Vice President Charles G. Riepe, Senior Vice President Suzanne Riepe
Apollo Computer Inc.	Art Krusinski, EDA Market Development Manager
Apple Computer, Inc.	John Jennings, Supply Base Manager Jan Miksad, Supply Base Manager, ASIICS
Applied Materials, Inc.	Dennis Hunter, Director, Corporate Development

Applied Micro Circuits Corporation	Allyn Pon, Product Marketing Manager
Arizona State University	Jim Macek, Deputy Director of CIMSYRC
Arthur Young & Company	Al Crawford, Partner Dan Pereira, Audit Manager
Ashland Chemical Company	Herb Richardson, Operations Manager
Athens, Inc.	Norman Jones, Vice President
Aztek Associates	Gene Miles, Consultant
Bacher GmbH	Willi Bacher, President
Bank of Boston	Jeffrey A. Wellington, Vice President
Branson International Plasma Corporation	Lou Perrone, Vice President, Marketing
CMI	Michael Placko, Director of Decision Support Services Kim Placko
Capital Research Company	Dick Yeung, Vice President
Chesapeake Group	Robert C. Gallagher, General Manager
Chips and Technologies, Inc.	Gordon A. Campbell, President & Chief Executive Officer
Cirrus Logic, Inc.	Michael L. Hackworth, President, Chief Executive Officer
Citicorp (USA), Inc.	Mano Appapillai, Vice President

Cogent Computer Corporation	Ronald Kasper
Columbine Ventures	Mark Kimmel, General Partner
Crosspoint Venture Partners	Bob Hoff, Partner Walter Kortschak, Associate
DQ Alliances	David Angel, Managing Director
Data General Corporation	Majid Ghafghaichi, Director, Semiconductor Operations
Data I/O Corporation	David A. Hannaford, Manager, Corporate Business Development
Dataquest Incorporated	Carol Bender, Conference Assistant Howard Bogert, Vice President, Semiconductor Industry Group Michael Boss, Industry Analyst Gary Bruder, Account Manager George Burns, Industry Analyst Greg Chagaris, Director, Systems Industry Sales Steve Cooper, Industrial Marketing Manager Nicholas J. Corcoleotes, Manager, Industry Marketing Maureen Davies, Conference Assistant Victor De Dios, Senior Industry Analyst Manny Fernandez, President Patricia Galligan, Research Analyst Joseph Grenier, Senior Industry Analyst Barry Haaser, Account Manager John B. Jackson, Vice President, Semiconductor Industry Sales Mimi Johnson, Customer Service Representative Lee-Anne Karcher, Conference Assistant Isadore Katz, Senior Industry Analyst Bart Ladd, Industry Analyst Judith Larsen, Associate, Research Operations C. B. Lee, Industry Analyst Alice Leeper, Industry Analyst Bryan Lewis, Research Analyst

Dataquest Incorporated	Dennis Lyftogt, Manager, Industrial Marketing Bob McGeary, Director, Semiconductor Equipment & Material Service Gene Norrett, Vice President & Director, SIG Mary Olsson, Industry Analyst Janet Oncel, Account Manager Jean Page, Account Manager, SES Carole Phillips, Conference Assistant Andy Prophet, Senior Industry Analyst Robert Ragghanti, Manager, Industrial Marketing Mark Reagan, Research Analyst Jim Riley, Senior Vice President, Corporate Anthea Stratigos, Associate Director, SAM/SUIS Sheridan Tatsuno, Senior Industry Analyst Mel Thomsen, Director, SIS Barbara Van, Industry Analyst Tom Wang, Associate Director, ASETS Peggy Wood, Research Analyst Fred Zieber, Executive Vice President
Delco Electronics Corporation	J. Charles Tracy, Chief Engineer, Integrated Circuits
Dewey, Ballantine, Bushby, Palmer & Wood	Tim Richards, Economist
Digital Equipment Corporation	Vivian Bridgewaters David Richards, Planning Advisor Frank Swiatowiec, Engineer Manager
Dun & Bradstreet Corporation	Joseph W. Duncan, Corporate Economist & Chief Statistician
Dun & Bradstreet Informations Resources	Lee Krueger, Electronic Industries Specialist
EED, Inc.	Edward E. David, Jr., President

Eaton Corporation	Connie J. George, Manager, Strategy Development Peter Rose, President-Semiconductor Equipment Division
Edelson Technology Partners	Anthony Buffa, President & Chief Executive Officer
Electronic Business News	Valerie Rice, Associate Editor
Electronic Engineering Times	Loring Wirbel, Semiconductor Correspondent
Electronic News	Rich Bambrick, Managing Editor
Ericsson Telecom	Ola F. Ekholm, Chief Engineer
FSI International	Charlie A. Peterson, Process Feasibility Manager
Fairchild Semiconductor Corporation	Francine Plaza, Corporate Communications Manager Robert Strain, Director, Technical Coordination
Fidelity Management	Calvin Hori, Analyst
Ford Microelectronics, Inc.	Harry Nystrom, Gallium Arsenide Sales Manager
Fortune Magazine	Gene Bylinsky, Member, Board of Editors
Fujitsu Components of America, Inc.	Jack Foster, Semiconductor Vice President & General Manager Hal Mumma, National Sales Manager, Distribution
Fujitsu Microelectronics, Inc.	Emi Igarashi, Strategic Planning Analyst Gregory Leonard, Manager, Business Development

G2 Incorporated	William O'Meara, President
GCA Corporation	Peter Simone, President & COO
Gemini Technology	Glenn Aumack, Director, Semicon Development & Manufacturing
General Instrument Microelectronics, Inc.	Stephen Maine, Vice President, Business Development Donald Sorchych, President & Chief Executive Officer
Genus, Inc.	William Elder, President Kurt Lightfoot, Vice President, Marketing Paul Reagan, Executive Vice President and COO
GigaBit Logic	James O. Brye, Vice President, Marketing & Sales
GoldStar Company, Ltd.	Dr. P. June Min, Senior Managing Director, R&D & Business Development Group Sue von Min
Goldstar Technologies Inc.	Alan H. Portnoy, Chief Operating Officer
Gould AMI Semiconductors	Joe O'Neill, Vice President, North American Sales
H & Q Technology Partners	Joseph J. Curry, Vice President
Hampshire Instruments	Tom Kulczycki, Director, Sales
Hewlett-Packard Company	Jack Anderson, Group Manufacturing Manager Margie Anderson
Hill & Knowlton Inc.	Bruce LeBoss, Senior Vice President

Hitachi America, Ltd.	Ron Schwarer, Marketing Manager
Hoechst Celanese Corporation	Richard E. Hamilton, Managing Director
Honeywell Bull Italia	Giovanni Pagliosa, Marketing Procurement Manager
Honeywell, Inc.	Eugene R. Hnatek, R & D Engineering Manager
Hughes Aircraft Company	Don Calhoun, Manager, Advanced Technologies Laboratory Paul Hart, Senior Scientist Carroll Perkins, Marketing Manager Carl Salanitro, Manager, Corporate Manager
Hyundai Electronics America	Iksu Kim, Director, Business Development
IBM Corporation	Irv Abzug, GTD Vice President & Director, CCP Harriet Abzug Shakil Ahmed, Director, Product Program Management Ed Boerger, Manager, Competitive Analysis Tim Danko, Program Manager, Market Research Mark Derosiers, Staff Systems Analyst Denis M. Fandel, Senior Business Analyst/Planner Cheryl Fandel Sanford Kane, Vice President, Industry Operations Louise Kane George Ling Frank T. Martin, Program Manager, Industry Operations John Melgalvis, Advisory Engineer Bruce S. Odom, Communications Advisor David Royse, Commercial Analyst
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ICI Array Technology	Bernie Aronson, President
IDS Financial Services	Ray E. Hirsch, Senior Research Analyst
IEEE Spectrum Magazine	Elizabeth Corcoran, Associate Editor
Industrial Technology Research Institute	Dr. Morris Chang, President
Ing. C. Olivetti & C., S.p.A.	Tito Conti, Director, Corporate Quality
Innovus, Inc.	John O'Lear, President
Inova Microelectronics Corporation	Vaemond H. Crane, President & Chief Executive Officer
Instant Circuit Corporation	Bruce Roesher, President
Institute of Defense Analysis	Richard Van Atta, Director, Technology Policy Peggy Van Atta
Insystems, Inc.	Chris Billat, President Susan Billat, Vice President, Technology Development
Integrated Device Technology, Inc.	Larry Jordan, Vice President, Marketing Bill Snow, Strategic Marketing Manager
Intel Corporation	Alan Allan, Marketing Manager Leonard Hills, Manager, Industry Research Don Knowlton, Product Marketing Manager Gordon Moore, Chairman of the Board Mark Norwood, Manager, Corporate Market Research Jane Roorda, Manager, Library & Information Services Steve Sanghi

International CMOS Technology	Drew Allen Osterman, President Doris Osterman
Intersil, Inc.	R. Paul Gupta, President Saroj Gupta
Italtel	Gianalfredo Vecchi, Advanced Purchasing Director
Itausa Export North America	Tin Sek Lau, Vice President
J.P. Morgan Investment	Fred W. Kittler, Vice President
John Hancock Venture Capital Management, Inc.	Laurie Thomsen, Associate
KLA Instruments Corporation	Robert J. Boehlke, Senior Vice President
Keithley Instruments, Inc.	Ed Morgan, Vice President & General Manager B. Karl Price, Special Systems Development Manager
Kemper Financial Services, Inc.	Eric Stromquist, Investment Analyst
Krysalis	Franc DeWeeger, President
L'Air Liquide	Paul V. duSaillant, Manager, Cylinder Sales & Marketing Elec
Lam Research Corporation	Roger D. Emerick, Chief Executive Officer & Chairman of the Board Rebecca Emerick Henk Evenhuis, Vice President, Finance & Administration
Lambda Semiconductors	James Russell, Vice President and General Manager

Lattice Semiconductor Corporation	Jan Johannessen, Vice President, Finance & Administration Paul T. Kollar, Vice President, Sales & Marketing
Lehman Management Company	Lawrence Phillips, First Vice President
Lepton Inc.	Martin P. Lepselter, President Joan Lepselter
Lex Electronics	Milton Grannatt, Vice President, Planning
Limburg Bank	Raymond Bullens, President Catherine Bullens Malcolm McCance, Acquisition Manager Hans Shut, Vice President
Loomis Sayles & Co.	Doug Pratt, Security Analyst
MIP Equity Fund	Hans Severiens, Senior Investment Advisor Barney Ussher, Associate Roel Van der Heide, Project Manager
Mars Electronics	Michael Massari, Senior Buyer Electronics
Materials Research Corporation	Sheldon Weinig, Chairman & Chief Executive Officer
Matrix Integrated Systems, Inc.	Ted Gallagher, President Rick Hazard; Marketing Manager
Meadows Ventures	John Farah, Venture Manager Beth K. Petronis, Venture Manager
Mellon Bank	Sushim Shah, Corporate Banking Officer

Menlo Ventures	Douglas C. Carlisle, General Partner
Micrion Corporation	William McMakin, President
Micro Component Technology	David Barnes, Director, Systems Division
Micro-Rel	James T. Greener, Group Director Marketing
MicroIntelligence, Inc.	Marshall Kidd, Editor and Publisher
Micromanupulator Inc.	John Hancock, President
Micron Technology, Inc.	Gene H. Cloud, Marketing Manager
Mitsubishi International Corp.	Yasukazu Koinuma, President, EED Ray Phillips, Senior Vice President, EED
Monolithic Memories, Inc.	Richard Helfrich
Monsanto Electronic Materials Company	Haskell Vaddle, Vice President, Commercial
Motorola, Inc.	James A. Binneboese, Product Marketing Manager Oliver Edwards, Strategic Marketing Manager Dr. Thomas George, Senior Vice President & Assistant General Manager, Semiconductor Product Sector Bill Huston, Tech Marketing Manager, MCUs Gary Knudson, National Sales Manager Bill Lane, Strategic Planning Manager Don May, Western Regional Manager Scott McKenney, Manager, Analytical Research Wayne R. McLerran, Product Planning & Merchandising Douglas Powell, Vice President & Director Comp Marketing Robert Richardson, President, CTX

Mutual of New York	Tony Blenk
NBK Corporation	Donna Felter, Vice President, Marketing and Sales
NCR Corporation	James Van Tassel, Vice President, Microelectronics Division
NEC Corporation	Hiroe Osafune, Advisor Akiko Osafune
NEC Electronics USA, Inc.	Hideo Nakao, President & Chief Executive Officer Sachiko Nakao
National Semiconductor Corporation	Steve Fields, Director of Strategic Planning Charles Sporck, President & Chief Executive Officer
Netherlands Foreign Investment Agency	Adriaan Roosen, Director, West Coast Operations
Nikon Precision, Inc.	Rick La France, Director, Marketing Takahiro Mogi, Manager, International Market Planning Sid Smith, Branch Manager
Northern Telecom Electronics Inc.	Frank Garbis, Assistant Vice President Mary Garbis Monte Seifers, Director, Semiconductor Group, External Business Operations
OTC America Inc.	M. Ishiguro, Corporate Liaison
Oki Semiconductor	Leonard Distaso, Vice President, Marketing
Olin Hunt Specialty Products, Inc.	Joe Daltner, Director, Marketing

Optical Specialties Inc.	John Dralla, Product Marketing Manager
Orbit Semiconductor, Inc.	Gary Kennedy, President
Osaka Titanium Co., Ltd.	T. Noda, Executive Vice President
PMT Manufacturing Technology	Bob Phillips, President
Peak Systems, Inc.	Robert MacKnight, Vice President Timothy Stultz, President
Perkin-Elmer Corporation	Michael Saba
Philips International B.V.	C. Krijgsman, Senior Managing Director
Phoenix Partners	William Heston, General Partner Kathryn Johnston, Assistant Vice President
Pitney Bowes, Inc.	Michael Y. Swaluk, Director, Advanced Electronic Technology Lynn Swaluk
PlanTek	Larry Campbell, Senior Vice President Dick Sheehy, Vice President
Plessey Semiconductors	Melvyn Larkin, Director of Technology Howard Widdows, Business Planning Manager
Plessey Semiconductors (USA)	Robert Anslow, Vice President & General Manager
Prudential-Bache Securities	Stephen Balog, Systems Vice President, Research Lisa H. Dorsey, Analyst
Qronos Technology, Inc.	Ari Marcus, Marketing Manager Kevin Ostby, Sales Manager

RAMAX Limited	Peter Solomon, Executive Director
Ramtron Corporation	Karl Stjernquist, Vice President
Raychem Corporation	Frederick Hoar, Director, Worldwide Communications
Raytheon Corporation	Marty Geller, Director, Marketing, Semiconductor Division Shirley Geller John Shea, Director, Military Specialist Programs, Semiconductor Division Flor Shea
Regis McKenna, Inc.	Chris Halliwell, Vice President Bob Ingols, Business Unit Manager
Reliance Insurance Co.	Matt Shefler, Investment Analyst
Rensselaer Polytechnic Institute	Dr. James Meindl, Vice President, Academic Affairs & Provost
Republic Investment Company	F. Wayne Mitchell, Vice President
Robert Bosch GmbH	Horst Fischer, Director, Microelectronic Products Division Iris Fischer Gunter E. Matthai, Manager, Technical Planning Paula Matthai
Rockwell International Corporation	Armando Geday, Market Research Analyst/Product Planning Tal Klaus, Application Engineer Gene Stanley, Product Manager
SAMES	Geoffrey Hainebach, Managing Director
SEMELCO	Jean Pierre Melia, Purchasing Manager

SGS Microelettronica SpA	Carl E. Johnson, Director, Product Marketing
Samulon Consulting Group	Henry A. Samulon, President
San Jose Mercury News	Mike Feibus, Business Writer
Seattle Silicon Technology, Inc.	Sam Brown, Executive Vice President
Security Pacific Capital Corporation	James McElvee
Seeq Technology, Inc.	J. Daniel McCranie, President & Chief Executive Officer Mike Villott, Vice President, Marketing
Semiconductor Equipment & Material International	William Reed, Executive Director Steve Ricketts, Senior Data Collection Administrator
Semiconductor Industry Association	Doug Andrey, Manager, Industry Programs
Sharp Electronics Corporation	Vijay Auluck, Product Marketing Manager
Sharp Microelectronics Technology, Inc.	Jon A. Shroyer, President & Chief Executive Officer Barbara Shroyer
Shinko Electric America, Inc.	William Cruickshank, Executive Vice President
Siemens Capital Corporation	Michael A. Hyduk, Director
Siemens Components, Inc.	Ed Caldwell, General Manager/Senior Vice President Michael Stark, Engineering Section Manager Esther Stark

Sierra Semiconductor Corporation	James Diller, President & Chief Executive Officer June Diller Tom Reynolds, Vice President, Sales & Marketing
Signetics Corporation	Norman Neumann, President & Chief Executive Officer Paula Neumann, Susan Scott, Public Relations Manager Maria Tseng, Manager, Corporate Strategic Marketing
Silicon Compilers, Inc.	Peter Rip, Vice President, Business Development
Silicon Valley Group, Inc.	Patrick O'Connor, Senior Vice President, Corporate Development Bonnie O'Connor
Simtek Corporation	Gary Derbenwick, President Richard L. Petritz, Chairman of the Board
Singapore Technology Corporation	Kheng-Nam Lee, Director, Technology Investment M. S. Lim, Deputy Chairman
Softstate Logic	Rahul Sud, President & Chief Executive Officer
Solid State Technology Magazine	Sid Marshall, Editor
Stack GmbH	Bernard Hadley, Managing Director
Standard Microsystems Corporation	John Tweedy, Vice President, New Product Development
State Street Research	Steve Orr

Synergy Semiconductor Corporation	Ralph O. Cognac, Vice President, Sales & Marketing Kenneth G. Wolf, President & Chief Executive Officer
Taiwan Semiconductor Mfg. Co.	Steve L. Pletcher, Vice President, Marketing Gale Pletcher
Tektronix, Inc.	Michael Kondrat, Marketing Manager, STS Division
Telic Alcatel	Joel Delanoue, Purchasing Engineer Jean Lemeunier, Purchasing Engineer
Teradyne, Inc.	Fred Conrad, Purchasing Manager Jane Manchester, Senior Buyer John Ralen, Senior Buyer
Texas Instruments, Inc.	Larry Housey, Marketing Manager Bill Jewell, Market Analyst James Peterman, Vice President, Semiconductor Group Wally Rhines, Vice President, Senior Vice President, Semiconductor Group
The Arizona Republic	Kathie Price, Reporter
The Capital Group	Jim Martin, Senior Vice President Loris K. Martin
Thomson/Mostek	Steve Sparks, Vice President, Strategic Planning
Toshiba America, Inc.	Allan Cox, Director, Semicustom Marketing J. Litus, Jr., Director, Marketing Hidenori Shinoda, Manager, Technology
Toshiba Corporation	Tsuyoshi Kawanishi, Senior VP & Director of the Board Etsuko Kawanishi

Triad Semiconductor, Inc.	Robert E. Welch, Executive Vice President
Triad Semiconductors International BV	Michael Burton, President and Chief Executive Officer Danielle Burton
Ultratech Stepper, Inc.	Ken Agarwal, Segmment Marketing Manager Ray Campbell, Vice President, Finance & Administration Steve Dunbrack, Marketing Manager Debra Dunbrack Daniel Rubin, Product Marketing Manager
Union Carbide Corporation	John Barrere, Process Manager Thomas Nelson, New Application Manager, Electronics Bill Schmeh, Region Sales Manager, Electronic Gases Thomas L. Singman, Marketing Manager, Bulk Electronic Gases
VLSI Standard Inc.	Joe Berger, President
VLSI Technology, Inc.	Peter Bagnall, Vice President, ASIC Marketing Doug Bartek, Vice President, Logic & Government Products Division Doug Fairbairn, Vice President Jim Miller, Vice President, Sales & Marketing Nancy Miller Rex Naden, Director, ASIC Alliances Alfred J. Stein, Chairman & Chief Executive Officer
Varian Associates	Larry Hanson, Vice President
Venture Growth Associates	Jim Berdell, Managing Partner William Welling, Managing Partner
Victorian Investment Corporation	Allan G. Tapley, Managing Director

Wacker Chemitronic GmbH	Max Stallhofer, Manager, Market Analysis
Waferscale Integration, Inc.	Eli Harari, Chairman of the Board
Wall Street Journal	Peter Waldman, Reporter
Western Digital Corporation	Dewey Atchley, Manager, Advanced Technology John Crosby, Vice President, LSI Operations Ken Hallam, Director, Product Planning
Xerox Corporation	Sei Shohara, Manager, Technical Staff James Vesely, Vice President, Microelectronics Center
Xicor, Inc.	Wallace E. Tchon, Vice President, Strategic Planning
Xilinx	James Barnett, Vice President, Administration & Strategic Planning
Xynetics	Gordon C. Westwood, Vice President, Corporate Marketing
Guest Speaker	Donald Brooks, President & Chief Executive Officer
Guest Speaker	Jack Kilby, Consultant
	Jim Downey Kathleen Downey

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Semiconductor Industry Conference
October 18 through 21, 1987
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Final List of Attendees

Harriet Abzug	IBM Corporation
Irv Abzug	IBM Corporation
Ken Agarwal	Ultratech Stepper, Inc.
Shakil Ahmed	IBM Corporation
Alan Allan	Intel Corporation
Jack Anderson	Hewlett-Packard Company
Margie Anderson	Hewlett-Packard Company
Doug Andrey	Semiconductor Industry Association
David Angel	DQ Alliances
Robert Anslow	Plessey Semiconductors (USA)
Mano Appapillai	Citicorp (USA), Inc.
Bernie Aronson	ICI Array Technology
Dewey Atchley	Western Digital Corporation
Vijay Auluck	Sharp Electronics Corporation
Glenn Aumack	Gemini Technology
Willi Bacher	Bacher GmbH
Peter Bagnall	VLSI Technology, Inc.
Stephen Balog	Prudential-Bache Securities
Rich Bambrick	Electronic News
David Barnes	Micro Component Technology
James Barnett	Xilinx

John Barrere	Union Carbide Corporation
Doug Bartek	VLSI Technology, Inc.
Carol Bender	Dataquest Incorporated
Jim Berdell	Venture Growth Associates
Joe Berger	VLSI Standard Inc.
John L. Bestel	AT&T
Matt C. Bieber	AT&T
Frederick Bihler	Advantest America Inc.
Chris Billat	Insystems, Inc.
Susan Billat	Insystems, Inc.
James A. Binneboese	Motorola, Inc.
Tony Blenk	Mutual of New York
Robert J. Boehlke	KLA Instruments Corporation
Ed Boerger	IBM Corporation
Howard Bogert	Dataquest Incorporated
Michael Boss	Dataquest Incorporated
Diane Bottoms	Alan Patricof Associates, Inc.
Wilmer Bottoms	Alan Patricof Associates, Inc.
Vivian Bridgewaters	Digital Equipment Corporation
Donald Brooks	
Sam Brown	Seattle Silicon Technology, Inc.
Gary Bruder	Dataquest Incorporated
James O. Brye	GigaBit Logic
Anthony Buffa	Edelson Technology Partners
Catherine Bullens	Limburg Bank
Raymond Bullens	Limburg Bank

George Burns	Dataquest Incorporated
Danielle Burton	Triad Semiconductors International BV
Michael Burton	Triad Semiconductors International BV
Gene Bylinsky	Fortune Magazine
Ed Caldwell	Siemens Components, Inc.
Don Calhoun	Hughes Aircraft Company
Gordon A. Campbell	Chips and Technologies, Inc.
Larry Campbell	PlanTek
Ray Campbell	Ultratech Stepper, Inc.
Douglas C. Carlisle	Menlo Ventures
Greg Chagaris	Dataquest Incorporated
Dr. Morris Chang	Industrial Technology Research Institute
Gene H. Cloud	Micron Technology, Inc.
Ralph O. Cognac	Synergy Semiconductor Corporation
Fred Conrad	Teradyne, Inc.
Tito Conti	Ing. C. Olivetti & C., S.p.A.
Steve Cooper	Dataquest Incorporated
Nicholas J. Corcoleotes	Dataquest Incorporated
Elizabeth Corcoran	IEEE Spectrum Magazine
Allan Cox	Toshiba America, Inc.
Vaemond H. Crane	Inova Microelectronics Corporation
Al Crawford	Arthur Young & Company
John Crosby	Western Digital Corporation
William Cruickshank	Shinko Electric America, Inc.
Jez Cunningham	Alcatel
Joseph J. Curry	H & Q Technology Partners

Joe Daltner	Olin Hunt Specialty Products, Inc.
Tim Danko	IBM Corporation
Edward E. David, Jr.	EED, Inc.
Maureen Davies	Dataquest Incorporated
Victor De Dios	Dataquest Incorporated
Franc DeWeeger	Krysalis
Joel Delanoue	Telic Alcatel
Gary Derbenwick	Simtek Corporation
Mark Derosiers	IBM Corporation
James Diller	Sierra Semiconductor Corporation
June Diller	Sierra Semiconductor Corporation
Leonard Distaso	Oki Semiconductor
Lisa H. Dorsey	Prudential-Bache Securities
Jim Downey	
Kathleen Downey	
John Dralla	Optical Specialties Inc.
Debra Dunbrack	Ultratech Stepper, Inc.
Steve Dunbrack	Ultratech Stepper, Inc.
Joseph W. Duncan	Dun & Bradstreet Corporation
Jeffrey D. Eagles	Airco Electronic Gases
Oliver Edwards	Motorola, Inc.
Thomas Egan	AT&T
Ola F. Ekholm	Ericsson Telecom
William Elder	Genus, Inc.
Rebecca Emerick	Lam Research Corporation

Roger D. Emerick	Lam Research Corporation
Gary Emmons	ASM Lithography, Inc.
William Evans	AT&T Bell Laboratories
Henk Evenhuis	Lam Research Corporation
Doug Fairbairn	VLSI Technology, Inc.
Cheryl Fandel	IBM Corporation
Denis M. Fandel	IBM Corporation
John Farah	Meadows Ventures
Irwin Federman	Advanced Micro Devices, Inc.
Mike Feibus	San Jose Mercury News
Donna Felter	NBK Corporation
Manny Fernandez	Dataquest Incorporated
Steve Fields	National Semiconductor Corporation
Horst Fischer	Robert Bosch GmbH
Iris Fischer	Robert Bosch GmbH
Jack Foster	Fujitsu Components of America, Inc.
W. Curtis Francis	Advanced Micro Devices, Inc.
Robert C. Gallagher	Chesapeake Group
Ted Gallagher	Matrix Integrated Systems, Inc.
Patricia Galligan	Dataquest Incorporated
Frank Garbis	Northern Telecom Electronics Inc.
Mary Garbis	Northern Telecom Electronics Inc.
Armando Geday	Rockwell International Corporation
Marty Geller	Raytheon Corporation
Shirley Geller	Raytheon Corporation

Connie J. George	Eaton Corporation
Dr. Thomas George	Motorola, Inc.
Majid Ghafghaichi	Data General Corporation
James Goldey	AT&T Bell Laboratories
Milton Grannatt	Lex Electronics
James T. Greener	Micro-Rel
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Saroj Gupta	Intersil, Inc.
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Bernard Hadley	Stack GmbH
Geoffrey Hainebach	SAMES
Ken Hallam	Western Digital Corporation
Chris Halliwell	Regis McKenna, Inc.
Richard E. Hamilton	Hoechst Celanese Corporation
John Hancock	Micromanupulator Inc.
David A. Hannaford	Data I/O Corporation
Larry Hanson	Varian Associates
Eli Harari	Waferscale Integration, Inc.
Paul Hart	Hughes Aircraft Company
Rick Hazard	Matrix Integrated Systems, Inc.
Richard Helfrich	Monolithic Memories, Inc.
Paul Henry	ASM Lithography, Inc.
William Heston	Phoenix Partners

Leonard Hills	Intel Corporation
Ray E. Hirsch	IDS Financial Services
Eugene R. Hnatek	Honeywell, Inc.
Frederick Hoar	Raychem Corporation
Bob Hoff	Crosspoint Venture Partners
Calvin Hori	Fidelity Management
Larry Housey	Texas Instruments, Inc.
Dennis Hunter	Applied Materials, Inc.
Bill Huston	Motorola, Inc.
Michael A. Hyduk	Siemens Capital Corporation
Emi Igarashi	Fujitsu Microelectronics, Inc.
Bob Ingols	Regis McKenna, Inc.
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John Jennings	Apple Computer, Inc.
Bill Jewell	Texas Instruments, Inc.
Jan Johannessen	Lattice Semiconductor Corporation
Carl E. Johnson	SGS Microelettronica SpA
Mimi Johnson	Dataquest Incorporated
Kathryn Johnston	Phoenix Partners
Norman Jones	Athens, Inc.
Larry Jordan	Integrated Device Technology, Inc.
Louise Kane	IBM Corporation
Sanford Kane	IBM Corporation
Lee-Anne Karcher	Dataquest Incorporated

Ronald Kasper	Cogent Computer Corporation
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Tsuyoshi Kawanishi	Toshiba Corporation
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Marshall Kidd	MicroIntelligence, Inc.
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Iksu Kim	Hyundai Electronics America
Mark Kimmel	Columbine Ventures
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Tal Klaus	Rockwell International Corporation
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Gary Knudson	Motorola, Inc.
Yasukazu Koinuma	Mitsubishi International Corp.
Paul T. Kollar	Lattice Semiconductor Corporation
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Jean Lemeunier	Telic Alcatel
Gregory Leonard	Fujitsu Microelectronics, Inc.
Joan Lepselter	Lepton Inc.
Martin P. Lepselter	Lepton Inc.
Bryan Lewis	Dataquest Incorporated
Kurt Lightfoot	Genus, Inc.
M. S. Lim	Singapore Technology Corporation
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Dennis Lyftogt	Dataquest Incorporated
Robert MacKnight	Peak Systems, Inc.
Jim Macek	Arizona State University
Stephen Maine	General Instrument Microelectronics, Inc
Jane Manchester	Teradyne, Inc.
Ari Marcus	Qronos Technology, Inc.
Douglas Marsh	ATEQ Corporation
Sid Marshall	Solid State Technology Magazine
Frank T. Martin	IBM Corporation

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Loris K. Martin	The Capital Group
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Paula Matthai	Robert Bosch GmbH
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David McMullen	AMP Incorporated
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John Melgalvis	IBM Corporation
Jean Pierre Melia	SEMELCO
Jan Miksad	Apple Computer, Inc.
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Jim Miller	VLSI Technology, Inc.
Nancy Miller	VLSI Technology, Inc.
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Sue von Min	GoldStar Company, Ltd.
F. Wayne Mitchell	Republic Investment Company
Takahiro Mogi	Nikon Precision, Inc.

Gordon Moore	Intel Corporation
Ed Morgan	Keithley Instruments, Inc.
Hal Mumma	Fujitsu Components of America, Inc.
Rex Naden	VLSI Technology, Inc.
Hideo Nakao	NEC Electronics USA, Inc.
Sachiko Nakao	NEC Electronics USA, Inc.
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Norman Neumann	Signetics Corporation
Paula Neumann	Signetics Corporation
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Patrick O'Connor	Silicon Valley Group, Inc.
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Hiroe Osafune	NEC Corporation
Lawrence Osborne	Amsterdam-Rotterdam Bank N.V.

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Doris Osterman	International CMOS Technology
Drew Allen Osterman	International CMOS Technology
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Dan Pereira	Arthur Young & Company
Carroll Perkins	Hughes Aircraft Company
Lou Perrone	Branson International Plasma Corporation
James Peterman	Texas Instruments, Inc.
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Ray Phillips	Mitsubishi International Corp.
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Michael Placko	CMI
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Gale Pletcher	Taiwan Semiconductor Mfg. Co.
Steve L. Pletcher	Taiwan Semiconductor Mfg. Co.
Allyn Pon	Applied Micro Circuits Corporation
Alan H. Portnoy	Goldstar Technologies Inc.
Douglas Powell	Motorola, Inc.
Doug Pratt	Loomis Sayles & Co.

B. Karl Price	Keithley Instruments, Inc.
Kathie Price	The Arizona Republic
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Robert Ragghanti	Dataquest Incorporated
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Raymond Reusser	AT&T
Greg Reyes	American Semiconductor Equipment Tech.
Tom Reynolds	Sierra Semiconductor Corporation
Wally Rhines	Texas Instruments, Inc.
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David Richards	Digital Equipment Corporation
Tim Richards	Dewey, Ballantine, Bushby, Palmer & Wood
Herb Richardson	Ashland Chemical Company
Robert Richardson	Motorola, Inc.
Steve Ricketts	Semiconductor Equipment & Mat'l Int'l
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Suzanne Riepe	Amsterdam-Rotterdam Bank N.V.
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Bill Robson	ICI Americas, Inc.
Bruce Roesher	Instant Circuit Corporation

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Adriaan Roosen	Netherlands Foreign Investment Agency
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Daniel Rubin	Ultratech Stepper, Inc.
James Russell	Lambda Semiconductors
Michael Saba	Perkin-Elmer Corporation
Barbara Salanitro	Hughes Aircraft Company
Carl Salanitro	Hughes Aircraft Company
Henry A. Samulon	Samulon Consulting Group
Steve Sanghi	Intel Corporation
Bill Schmeh	Union Carbide Corporation
Ron Schwarer	Hitachi America, Ltd.
Susan Scott	Signetics Corporation
Monte Seifers	Northern Telecom Electronics Inc.
Hans Severiens	MIP Equity Fund
Sushim Shah	Mellon Bank
Flor Shea	Raytheon Corporation
John Shea	Raytheon Corporation
Dick Sheehy	PlanTek
Matt Shefler	Reliance Insurance Co.
Hidenori Shinoda	Toshiba America, Inc.
Sei Shohara	Xerox Corporation
Barbara Shroyer	Sharp Microelectronics Technology, Inc.
Jon A. Shroyer	Sharp Microelectronics Technology, Inc.

Hans Shut	Limburg Bank
L. David Sikes	ASM Lithography, Inc.
Peter Simone	GCA Corporation
Thomas L. Singman	Union Carbide Corporation
Sid Smith	Nikon Precision, Inc.
Bill Snow	Integrated Device Technology, Inc.
Peter Solomon	RAMAX Limited
Donald Sorchych	General Instrument Microelectronics, Inc
Steve Sparks	Thomson/Mostek
Charles Sporck	National Semiconductor Corporation
Max Stallhofer	Wacker Chemitronic GmbH
Gene Stanley	Rockwell International Corporation
Esther Stark	Siemens Components, Inc.
Michael Stark	Siemens Components, Inc.
Alfred J. Stein	VLSI Technology, Inc.
Karl Stjernquist	Ramtron Corporation
Robert Strain	Fairchild Semiconductor Corporation
Anthea Stratigos	Dataquest Incorporated
Eric Stromquist	Kemper Financial Services, Inc.
Timothy Stultz	Peak Systems, Inc.
Rahul Sud	Softstate Logic
Lynn Swaluk	Pitney Bowes, Inc.
Michael Y. Swaluk	Pitney Bowes, Inc.
Frank Swiatowiec	Digital Equipment Corporation
Allan G. Tapley	Victorian Investment Corporation

Sheridan Tatsuno	Dataquest Incorporated
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Maria Tseng	Signetics Corporation
John Tweedy	Standard Microsystems Corporation
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Barbara Van	Dataquest Incorporated
Peggy Van Atta	Institute of Defense Analysis
Richard Van Atta	Institute of Defense Analysis
James Van Tassel	NCR Corporation
Roel Van der Heide	MIP Equity Fund
Gianalfredo Vecchi	Italtel
James Vesely	Xerox Corporation
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Sheldon Weinig	Materials Research Corporation
Robert E. Welch	Triad Semiconductor, Inc.
William Welling	Venture Growth Associates
Jeffrey A. Wellington	Bank of Boston

Gordon C. Westwood	Xynetics
Ed Whelan	AMAX Electronics Products, Inc.
Howard Widdows	Plessey Semiconductors
Owen Wilkinson	ANELVA Corporation
Loring Wirbel	Electronic Engineering Times
Kenneth G. Wolf	Synergy Semiconductor Corporation
Peggy Wood	Dataquest Incorporated
Dick Yeung	Capital Research Company
Robert Zanotti	Aerospatiale
Fred Zieber	Dataquest Incorporated
Paul V. duSaillant	L'Air Liquide

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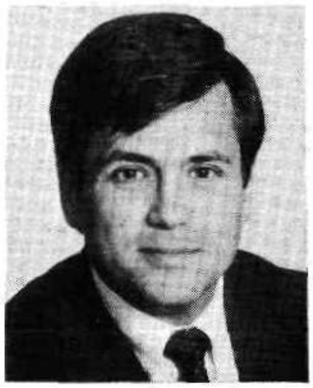
WELCOME AND INTRODUCTION



Manny A. Fernandez
President and Chief Executive Officer
Dataquest Incorporated

Mr. Fernandez is the President and CEO of Dataquest. He has been involved in high-technology industries for the past 16 years. Prior to joining Dataquest, Mr. Fernandez was President and CEO of Gavilan Computer Corporation, where he directed that company's efforts in the portable computer marketplace. Before founding Gavilan, he was President and CEO of Zilog, Inc. Zilog grew by more than 500 percent during Mr. Fernandez's tenure, and expanded its facilities to 11 countries. Prior to joining Zilog, Mr. Fernandez was Group Vice President for Fairchild Camera & Instrument Corporation, where he was responsible for three divisions with a combined revenue responsibility of more than $120 million. He began his career as a design engineer, and held several engineering management positions at ITT Semiconductor and Harris Intertype before going to Fairchild. Mr. Fernandez received B.S. and M.S. degrees in Electrical Engineering from the University of Florida.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

Economic and Industry Outlook

MANNY A. FERNANDEZ

President
Dataquest Incorporated

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SEMICONDUCTORS: MIDLIFE CRISIS

Mel Thomsen
Director
Semiconductor Industry Service
Dataquest Incorporated

Mr. Thomsen is the Director of Dataquest's Semiconductor Industry Service. He has been with Dataquest since 1983 and has held positions as Senior Industry Analyst for microcomponents research and later as Associate Director of the Semiconductor Industry Service. He has more than 20 years of industry experience in design engineering, project management, application engineering, and marketing. Prior to joining Dataquest, he was a Field Applications Engineer and later, Product Marketing Manager, for Zilog, Inc. During that time he had marketing responsibility for microcomputer boards, memory components, and microperipheral components. Mr. Thomsen was also a Product Manager for Aehr Test Systems, where he was responsible for marketing the dynamic burn-in systems used for semiconductor reliability testing. He has also held positions as a Senior Design Engineer at Heathkit and as a Design Engineer at Magnavox, Inc., and Sylvania Systems Division. Mr. Thomsen received a B.S.E.E. degree from the University of Michigan and an M.S.E.E. degree from Purdue University.

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MEL THOMSEN

Director, Semiconductor Industry Service
Dataquest Incorporated

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WORLDWIDE ECONOMIC OUTLOOK

Joseph W. Duncan
Corporate Economist and Chief Statistician
The Dun & Bradstreet Corporation

Dr. Duncan is Corporate Economist and Chief Statistician for The Dun & Bradstreet Corporation. He works with D&B's information resources to develop new economics-related products and services to analyze economic trends and evaluate the economic impact of government policies and business practices as head of the corporate Economic Analysis Department. Dr. Duncan also writes columns in three major Dun & Bradstreet publications. He was previously statistician for the Office of Information and Regulatory Affairs in the Office of Management and Budget where he was responsible for national statistical policy. He also serves as the U.S. representative to the United Nations Statistical Commission, of which he was chairman in 1981. Dr. Duncan received a B.S.M.E. degree from Case Institute of Technology, an M.B.A. degree from Harvard Graduate School of Business Administration, and a Ph.D. in Economics from Ohio State University. He also attended the London School of Economics.

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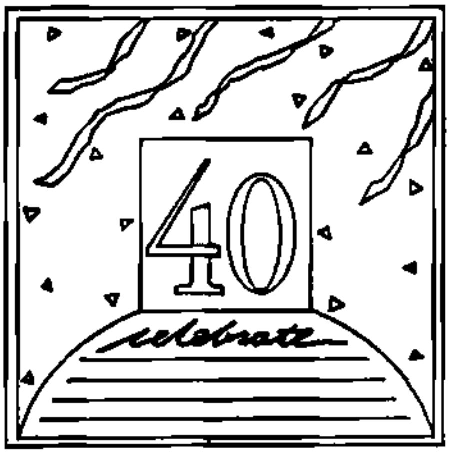

Semiconductors' Midlife Crisis

Economic and Industry Outlook

JOSEPH W. DUNCAN

Corporate Economist and Chief Statistician
The Dun & Bradstreet Corporation

WORLDWIDE ECONOMIC OUTLOOK

You know that fundamentally, growth in the last couple of years has been rather soft - under 2-1/2%. Most economists feel that 3% is the normal growth rate that would lead to balanced, sustained growth. 2-1/2% is typically labeled a soft economy. We have spurts, as you can see during this period that goes back to 1984, where the overall economy grew nearly 6%, as we came out of the recession. Fundamentally, the current statistics suggest a fairly soft economy when looked at from the point of view of GNP. But I'd like to use a different figure to indicate what's happening, at least in the U.S., and that's a statistic that you don't see published but is calculated in final sales to domestic purchasers. Basically what that statistic recognizes is—that exports we sell go to another market place.

Exports to not represent what's happening in our market place; they do represent demand for our manufacturers, but they don't represent demand inside our borders. Imports which are consumed here do satisfy local demands. Inventory change is basically a mistake somebody made when they got too much inventory on the shelf. When they build inventories it is because they didn't engage consumer demand. And when their inventory is sharply dropped, they didn't have exactly what the consumer wanted, so they're running out of stock. If you subtract inventory change because it's not final demand, subtract exports because they are not consumed within these borders, add back into GNP imports, you get a different picture, which is final sales to domestic purchasers.

The negative in the first quarter is a statistical aberration caused by the fact that farm sales from inventories held by the government were weaker than they should have been, so it took away from final demand. But, basically when you compare final demand with gross national product, our economy has been much stronger than GNP tells us. And the reason for that of course, is the trade deficit.

The trade deficit subtracts from our gross national product when it's increasing as it has been doing. This is a picture of net exports which is the balance between imports and exports, and you'll notice that for the last several quarters it really was increasing very sharply. The deficit was getting bigger and bigger. I still hold the view that it probably peaked in the third quarter of 1986, but I must confess that some of the preliminary numbers that we have seen for the third quarter of this year indicate that the third quarter may be almost as much as the fourth quarter of last year. It probably won't exceed the third quarter of 1986. But fundamentally we are in an improving trade situation and that's particularly true if you look at the volume of imports, not the dollar value. The volume of imports has been declining. The price is higher because of the weaker dollar and therefore the nominal numbers have been quite weak. Exports have been picking up, both in dollars and in value. My view is that we have turned the corner, but nevertheless, net exports have been a serious drag on our total economy.

Some other features of the recent economic period, of course, are personal incomes. Personal incomes grew very dramatically as we pulled out of the recession and there has been a lot of job growth. But if you notice the last three or four quarters, basically personal income has not been growing very rapidly and that's partly because 15% of personal income is interest income. And as you know interest rates have been declining; that's means the people that had CDs, even those that got double digit interest about three years ago, are getting single digit interest income currently, and consequently interest income has declined for several quarters pulling down total personal income.

The housing industry as you know has been sluggish. Housing starts have been dropping for four out of the last five quarters and with the uptake in interest rates that has occurred most recently, there is a lot of concern in the housing industry about how healthy that industry will be in future quarters. Interest rates have even peaked more than this chart indicates, clearly they have been on an upward swing now for several months. So there are signs of stress in our economic system while in imports and exports, the net exports are improving a little bit, but there is weakness in many other sectors of our economy. So the question really is, "What's the outlook for the next eighteen months to two years?"

Before I get into the outlook specifically, I'd like to give you some of the information we have at Dun & Bradstreet. My forecast is slightly different from other people's because I have a lot of data that we collect through our various divisions. I'd would like to introduce you to a little of it very very quickly. One of the things we look at very carefully, and certainly is of great interest to your industry is new business start-ups. We track data from the fifty states in terms of new incorporation activities, and for much of this business cycle new incorporations have been increasing, period by period. This is monthly data going back to the beginning of last year and you'll notice that starting about mid-year, new business incorporations, with the exception of a big spurt in December, were declining on a year-to-year basis, fundamentally.

People were getting concerned about where future opportunities were, but the most important thing is, as you recall in 1986 as we moved from February, everybody thought no tax reform like that would occur because the congress was split. By mid-year there was talk that a tax reform was going to happen. It introduced however, a lot of uncertainty. Business people did not know where the final bill was going to come out and so that slowed down new incorporating activity.

We also look at business starts. These are people now that do not just incorporate legally, but actually get into business and are in trade transactions that are noted in Dun & Bradstreets business files. That too began to decline and in fact has continued to decline into this year. There is less entreprenuerial activity in our economy today than there was a year ago. I would point out, however, that the absolute level of both new incorporations and start-ups remains very high. There are number of people forming new businesses, but that spirit of expansion and growth has certainly weakened as a result of economic uncertainty and still remains uncertain of the tax code.

On the other side of the coin are business start-ups and business failures, and the first point I would like to make to you is with the great spurt in entrepreneural activity it's rather amazing that business failures haven't increased more than they have, because inevitably a few companies will fail out of every one hundred that are started up, and that lifts the failure rate. There are a couple of other factors that keep failure rates high these days: one is that while interest rates have declined generally over the last several years, they remain very high to the small business person. Small businesses borrow at three and four percentage points above prime rate. So there, you have very severe financial stress on their balance sheets when things slow down or their plans don't fully occur. It is interesting that in the third quarter, for the first time now in over two years, there has been an actual decline in the level of failures over a each previous quarter's level. I think it's too early to get a trend out of that, but clearly the level of failures has slowed down recently as a by-product of the slow down in entrepreneural activity.

The other thing that we do at Dun & Bradstreet is talk to business people every quarter. We ask them, "How are you doing?", "What's the outlook for the coming period in your business?" We focus primarily on manufacturing firms and wholesale and retail trade, we have some interviews with the service sector, but that's not as volatile, as you know, as the manufacturing sector. What we do is ask them a very simple question, "For your company, do you expect sales next quarter to be higher or lower than they were for the same quarter one year ago?" Then I calculate an index which I call the "optimism index". It's the percentage of people that I expected to increase, minus the percentage of people that expect a decrease. The result is an index which you can see here over a longer time period, because I want to show you that during the recession periods in 1980, 1981, and 1982, businesses were not seeing improved order books, they were seeing weaker order books. So the optimism index was very very low, and as we emerged from the recession optimism got very high.

In 1984 almost everybody was seeing improved orders over what they had during the recession. What's impressive right at the moment is that despite the softness I talked about just a few minutes ago, business people feel increasing levels of optimism. Our outlook for the fourth quarter is the highest it has been since the end of 1984. That, to me, is a very positive sign which is basically based on another survey we did that asked them how their exports were doing based on improved export orders. So the trade situation is beginning to particularly effect our manufacturing sector.

The bottom line, of course, for businesses' profits is their outlook for profits and for those of you who are worried about the stock market, don't forget that ultimately profits and how companies perform will have an influence on stock prices.

The profit outlook also retains a relatively high level of optimism given the competitive stress that you're going to hear a lot about during this session. Finally, I do a survey of five thousand companies were I get detailed point type information. I get the full income statement and their balance sheet and I ask them questions about how their business is doing. This is basically a panel that's representative of all U.S. enterprises.

One of the things I do every January is ask them about their employment outlook. Because it is representative of the entire economy I can estimate, for example, total employment gains as reported to me by businesses at the beginning of the year and you'll notice the track record is pretty good. The red line is the forecast that I made in January, the blue line is the actual result that the Bureau of Labor Statistics reported at the the end of that year. I don't have the results for this year yet, but we are tracking very close to my forecast of about 2.6 million new jobs this year. Now that means that during this current period of business expansion, the U.S. economy will have created 14 million new jobs since the recession in 1982. That is a dramatic and impressive record and it's that job growth that is creating the incomes that are the source of our domestic demand. So one of the key questions for next year will be, "How strong will job growth be?", "Will we continue to add incomes and will people continue to spend those incomes?".

Before I go to the forecast, I want to make one other point from the employment survey. What a lot of people don't recognize is that big business is not the source of employment gains. As a matter of fact, if you look at businesses that have a total employment of over 25,000 workers, there will be an absolute decline in the total employment of all those companies. One estimate I saw not too long ago said that during the last seven years those businesses have lost nearly two million jobs in aggregate. An enormous reduction has been occurring among big businesses as they cut their overheads. They in effect have been outsourcing their labor force. Part-time employment is the second fastest growing industry today. Many people are working in small companies that are providing services to large companies, and that leads to this chart. 50% percent of the jobs that are going to be created in 1987 are going to be jobs in businesses who have a total employment of fewer than 15% employees. The entrepreneurial spirit I talked about before therefore is very crucial to our broad economic outlook. Therefore, the economic conditions and incentives are important to our economic outlook.

Let me talk about the forecast briefly, and then tell some of the issues behind it. I'm going to go through some of the same elements that I did in terms of the recent history. Let's talk about net exports: this my forecast for net exports and I do show them improving. My numbers are probably going to be wrong for the third quarter. That will be reported on a preliminary basis on Thursday of this week and we may see a deterioration in the trade account as far as gross national product is concerned. It's very hard to tell from the monthly numbers exactly what's going on because they get adjusted before they're incorporated into the national income accounts that lead to the gross national product. But fundamentally, given our surveys of exports orders and our evidence on what's happening with imports, clearly the trade deficit is going to be reduced. That will be a plus for gross national product measurement. But I would point out that just as my earlier statistics on final sales suggested, net exports include the balance of exports and imports and exports are that are consumed outside of our boundaries.

Let's talk about gross national product. I'm expecting a fairly weak number for the third quarter as we make adjustments. If you look at the production side, the auto industries cut back production the third quarter and there is some inventory adjustment going on, so it's very hard to predict exactly how it's going to come out. We may have over 1% growth representative for the third quarter. But in reality the economy is in very good balance and I am looking for strong economic growth for the next several quarters. For the people who are running for election next year, they are going to have a good economic record. GNP is probably going to exceed 3% at least the first three quarters of next year, which is of course what will be the data reflected by election time. The fourth quarter numbers will be out after the new president is sworn in. The economy however will be slowing by the end of 1988, and if you look at the result of this in point estimate terms, we're talking about an economic growth that's between 3.4% and 3.6%. That compares with 2.5% for this year; GNP is going to be better.

Let's go back to my final sales domestic purchasers. As I said, a large part of that stimulus for our growth in 1988 is going to be trade driven and it's going to be on the export side. Manufacturing is going to be the hot sector of U.S. economy in 1988, but a lot of that production is going to go overseas. The result is that final sales to domestic purchasers is going to remain fairly sluggish. Unlike the previous period, for the next few quarters, we are going to see gross national product reflecting stronger what is occurring inside our domestic boundaries. Now the good news form that is that most people don't calculate my final sales numbers. People are not going to evaluate the economy on final sales; they're going to be looking at GNP. So we are going to feel good about the economy in 1988.

Now let me talk about some of the issues behind that forecast because that's really what's crucial to the total economic outlook. The big happening last year was tax reform, which is so dramatic in terms of its impact on behavior that if any economist says they know the impact, just turn away and talk to somebody else because literately no one is able to predict all of the decisions that are going to flow out of tax reform. Let me illustrate that with one area. When tax reform was passed the headlines said that because accelerated appreciation was being wiped out and the investment tax credit was being wiped out that capital investment would plummet.

You probably remember these headlines. We did a survey in November of last year right after the bill was signed into law. We asked business people what impact it would have on their capital expenditures for 1987. Nearly 70% said no impact. Now think about that for a minute in terms of your own business. How many investments do you make because there is a loop hole in the tax code, compared with how many you make because you want to increase your plan efficiency, you want to introduce a new product, or you want to remain competitive?

My point is that tax reform was grossly overrated in behavioral terms about its impact on business decision and when you asked the business people, they told you that. But when you asked the economist and the tax analyst, they told you the opposite. Now it makes a big difference in your economic outlook forecast whether you think that the tax reform is going to be plus or minus for capital investment because it's an important part of economic expansion. In fact, for 1988 I'm expecting to see a continued pick-up in capital spending.

The reason it has been somewhat sluggish this year is not because there has not been a lot more investment, but because of the lack of investment in the oil sector. One sector alone has killed our capital spending program in the country for this year. It is growing but not as much as it should in normal times. I don't have to talk to you about the importance of the value of the dollar and the trade balance because you're all involved in heavily competitive world level interest where trade is crucial. But there are a couple of things we could say about it.

The key to our long term export picture is world economic growth. Even if we are competitive because the dollar is low, if nobody else is growing and demanding product, we're not going to have stong export markets. And you see that the oil shocks that have occurred have had a major impact on world economic growth patterns. This year world growth is going to be a little less than it was during the period 1983 to 1986. The sad part about 1987 world growth is that as the year has progressed, all of the individual countries have been scaling back their economic forecasts, and the international organizations like the World Bank scale back, so that this year has actually already proven to be a disappointing year.

Now I am a little bit more optimistic for the next few years because I think the seeds are there for a slight pick-up in world growth. But it's not going to be what we had in the late 1970s. So the world economic picture is a key factor in our economic outlook. It would greatly behoove the policy makers of our domestic interest to do anything that can be done to stimulate world trade. The arguments that are going on right now with Japan and Germany from Secretary Treasurer Baker really aren't helping the situation much. We haven't really been able to get the coordinated economic policy and investment at the world level that's needed. The less developed countries are suffering from severe capital constraints. One third of our trade deficit is currently because of reduced exports to South and Central America, for example, and they are not going to buy things until they find economic resources, mainly loans and international funding to expand their trade. So the world growth dimensions are a very important thing to keep dry on.

I mentioned oil and its impact on world growth, and oil is obviously a very important part of our economic assumption. One of Dun & Bradstreet's companies is Petroleum Information. We worry about the oil industry on a regular basis because it's an important part of the U.S. economy as well as the world economy. It's very difficult to predict the price of oil. For those of you who follow that spot market, you know it has been moving around a lot and every week there is another report about what OPEC is doing or thinking. The Iran/Iraq war and the problems in the Gulf create vast uncertainty. But to make a forecast I have to make some assumptions. My assumptions about the price of oil fundamentally are that it's not going to sharply go up and it's not going to sharply go down. It's going to drift around the $18/barrel contract price that's officially from OPEC, and the real transaction price is going to go up very gradually over the next couple of years. Now that forecast is fairly critical because it feeds into the inflation forecast and it feeds into world economic growth.

Another major oil shock, meaning a big cutoff of the supply from the Gulf, could destroy several big economies like Japan and Germany. I don't look for that to happen, but you have to watch that set of developments as a key part of the economic outlook because oil clearly has vast implications on world economic growth and individual national behavior. I talk about inflation which is affected by oil prices, last year inflation dropped dramatically partly because the decline in oil prices reflected on the gasoline pump and home heating oil, and for industrial uses, had a reducing effect offsetting other price increases. So we had an abnormally low inflation rate last year. If at the end of last year you looked at our inflation rate and took out the impact of oil, we were at about 4% inflation as opposed to 1.2% as officially reported for the year.

My forecast is that inflationary pressures do exist, but they are very modest. Commodity prices, while they have fundamentally recovered a little bit, are not a source of sharp price increases for manufacturing input. Wage settlements are at a 17-year low in terms of the union settlements and the use of contract labor, part-time employment, and other overhead reducing activities which are keeping total wage cost very very moderate. The things that are going to keep the inflation rate growing over the next couple of years are primarily increased inflation service - things like education, medical care, and some government-type programs that have inflationary biases in them right at the moment. But, we are not looking for sharp acceleration or a return to the double-digit inflation we had in the 1980's.

Now, I know interest rates are telling a different story and people are worried about the sources of inflation, but in reality there is no economic indicators presently that we are going to have a return of inflation. That's something you need to track because if you see inflationary pressures building, that's going to weaken the economic outlook. And, it's really increased inflation more than any other single factor that would drive us into a recessional period.

Let's talk about consumer confidence. The consumer is two-thirds of our economic system in the U.S. and therefore how the consumer goes is really very critical to how the economy goes. Now you have read a lot of stories about the deaf burden of the consumer, Al Malbray's book talks a lot about that, but the reality is that the consumer right now feels very good. The University of Michigan does a survey of consumer sentiment much like I do a survey of business sentiment. While there has been some easing of the optimism of the consumer, their intentions to buy autos, houses, and major appliances remain relatively high. And if you ask them what they think of government economic policy, they say it's terrible. They are worried about the national economy. You ask them what they think about their family finances and you personal economy for next year and the next five years and they tell you it is the highest level it's ever been. The consumer feels very good because of the increase in jobs and the increased income in total terms that they are bringing into the household. A break in consumer confidence would obviously have a serious negative impact on economic outlook.

Let me mention two other kinds of background cloud items that you need to keep your eyes on: one is the banking system. I've already talked about the problems of less developed country debt, but let's talk about the portfolio of loans held by the banks in terms of corporate issues. Another Dun & Bradstreet company is Moody's which rates individual bonds of major listed companies. During the recession there was a flurry of downgrading of bonds because of economic stress. But look what happened last year in 1986: a record level of downgradings because of leveraged buyouts, because of equity buybacks, and the debt equity ratio is reaching an all time high.

In the current period, with interest rates at the present levels, that's not a serious issue but if we were to get a spike in interest rate because of inflation, we could drive many companies to the wall in terms of servicing their debt. That would stress the portfolios of our banking system. When you add to the corporate portfolio the weak portfolio in agriculture, the particularly weak portfolio around the energy sector, and the LDC debt, you can see their banking system is in a very precarious position. If you want to know why the prime rate has been going up, it's because they're trying to build their asset base to build greater reserves to deal with this. But this latest round of prime rate increase may not stick, because people are worried about other stresses in our economic system and they may not be able to get that increased income into the banking system.

Keep your eye on the banks; I personally do not believe there will be major banking failure and collapse. I think the regulatory agencies will adjust and adapt to overcome those problems, but let me just suggest to you that the weak spot in our current economic is the banking system. We need to watch that very carefully as a harbinger a future economic activity.

Finally, the Achilles heel of our economy is and has been for the last several years, the federal deficit. We are going to have an enormous improvement in the deficit this year. As a matter of a fact the deficit for fiscal 1987 will be somewhere around $65 to $70 billion less than it was in fiscal 1986. But until congress acts on fiscal 1988 we have growing deficits facing us. My forecast is for modest improvement in the level of the deficit. But it is going to take hard work to get there. If we don't move that deficit down even more than I show here, we are going to be adding to national debt and the problems I spoke of in our banking system are going to be reflected at our national economy. We are at very great risk if we don't solve that problem. Unfortunately it looks like it's going to take the 1988 presidential election to get into a change of direction, regardless of party, the redirect will change after that election. Hopefully the action will change as well.

Well, that's the Dun & Bradstreet economic outlook. I hope it's not overwhelmingly pessimistic with all these problems. Just remember my fundamental forecast is for sustained economic growth through 1988. It's hard to predict 1989 until I know what the results of the election are, but there is no reason why we cannot get through the balance of this decade with no recession if appropriate economic policy measures are followed in Washington and around the world.

ECONOMIC OUTLOOK
1987 - 1988

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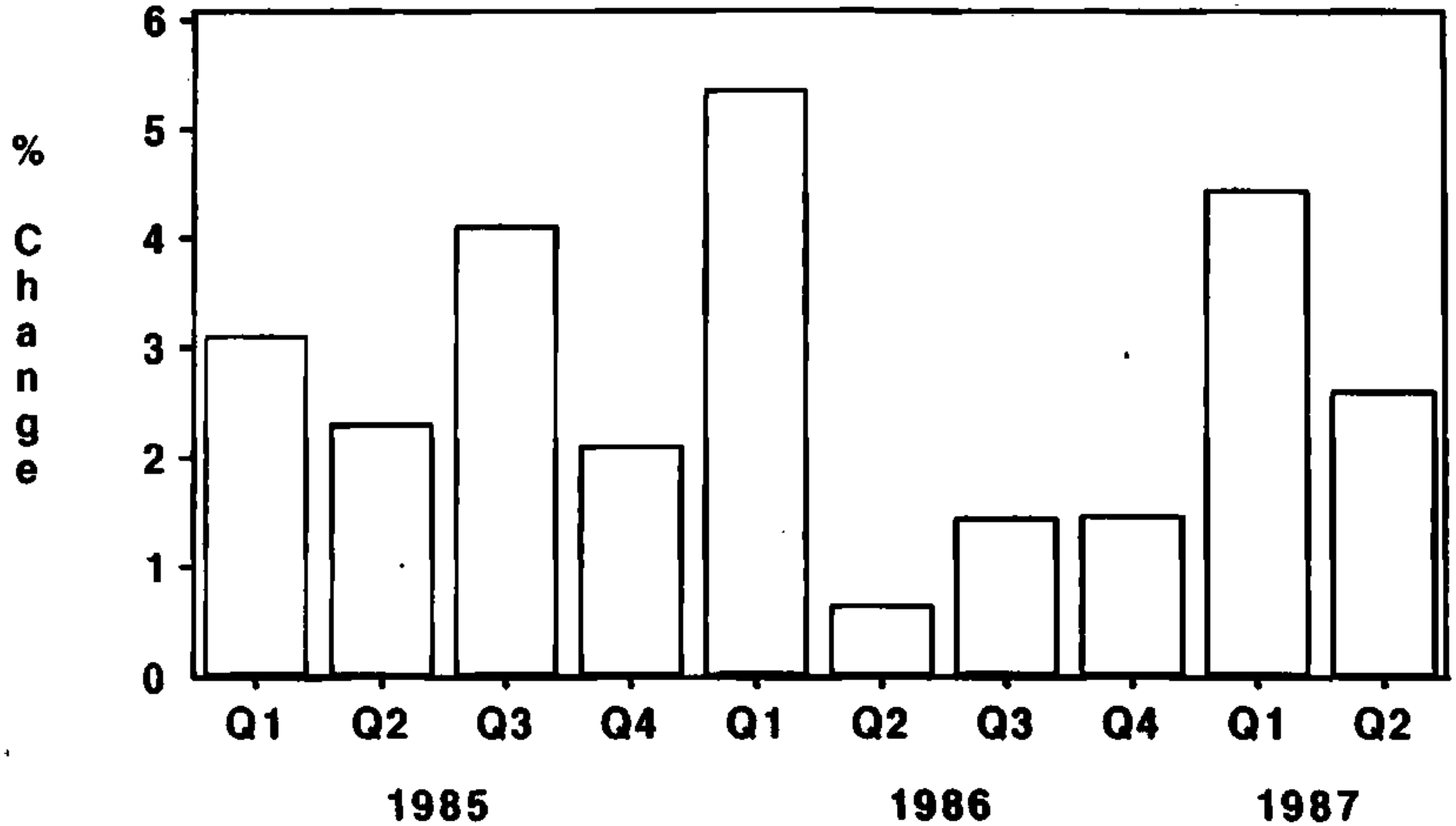
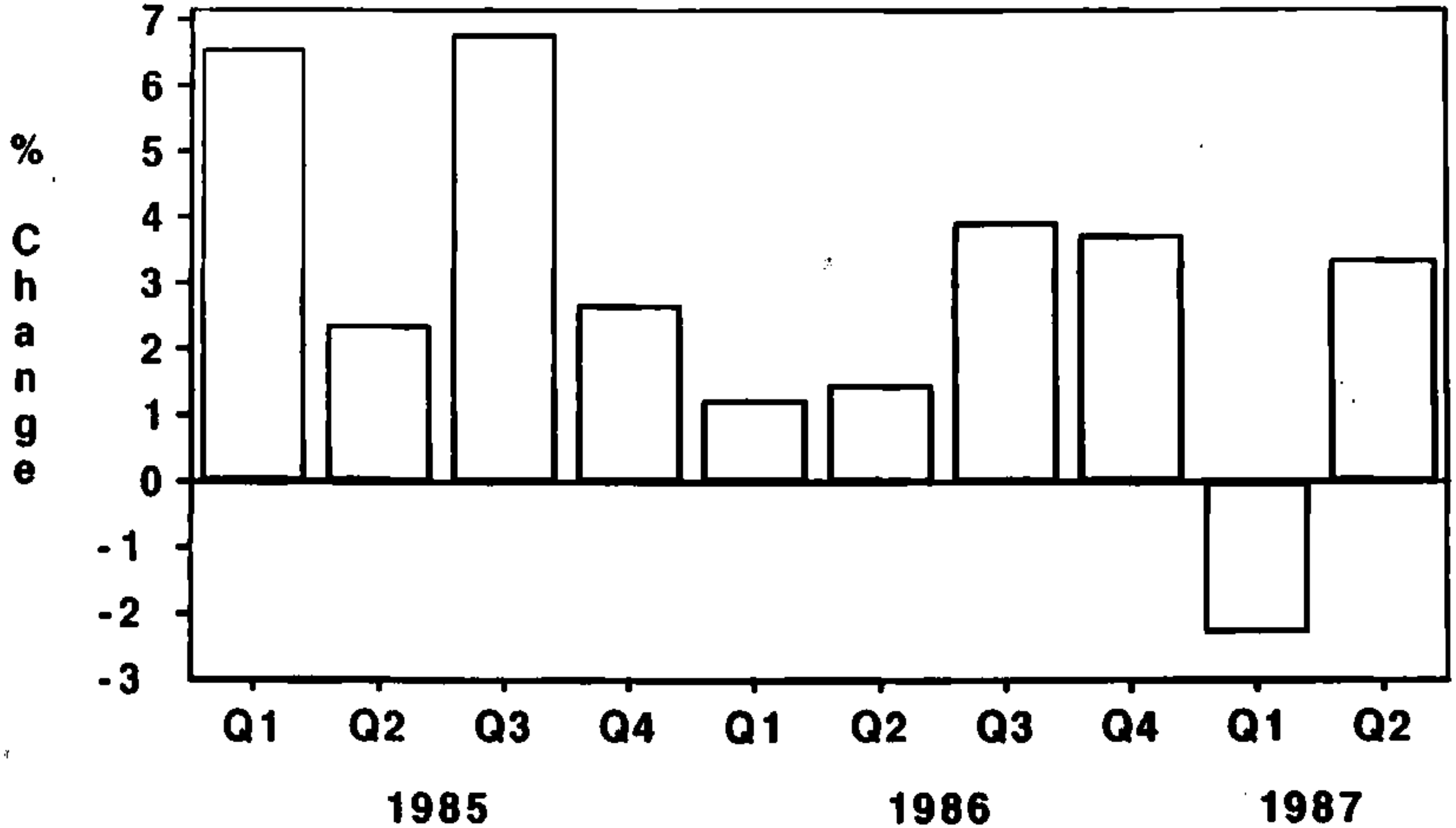
Recent Economic Indicators

- Gross National Product
- Final Sales to Domestic Purchasers
- Quarterly Trade Balance
- Consumer Income
- Housing Starts
- Interest Rates

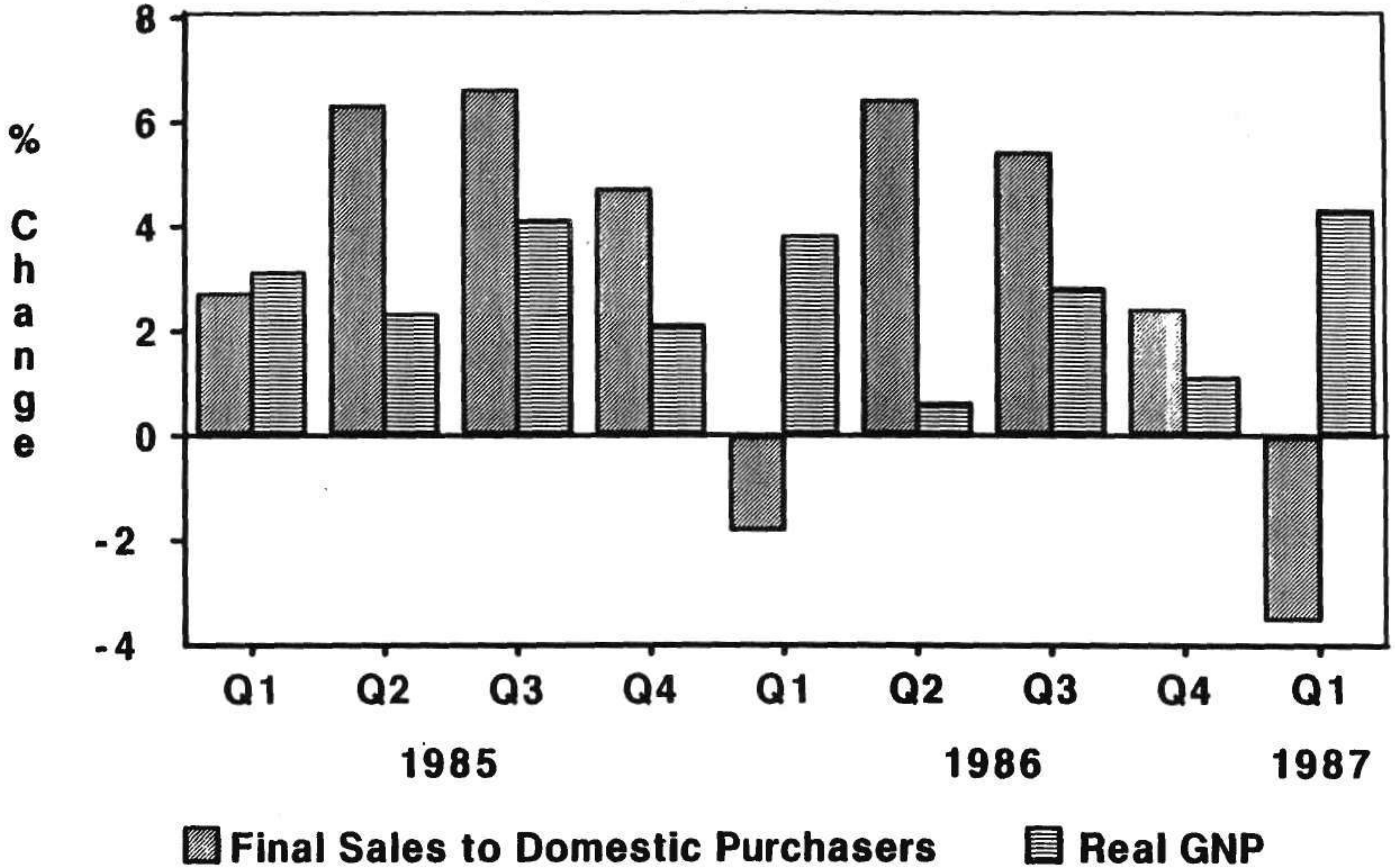
REAL GNP
Annual Percent Change



Final Sales to Domestic Purchasers
Annual Percent Change



Final Sales to Domestic Purchasers vs. Real GNP



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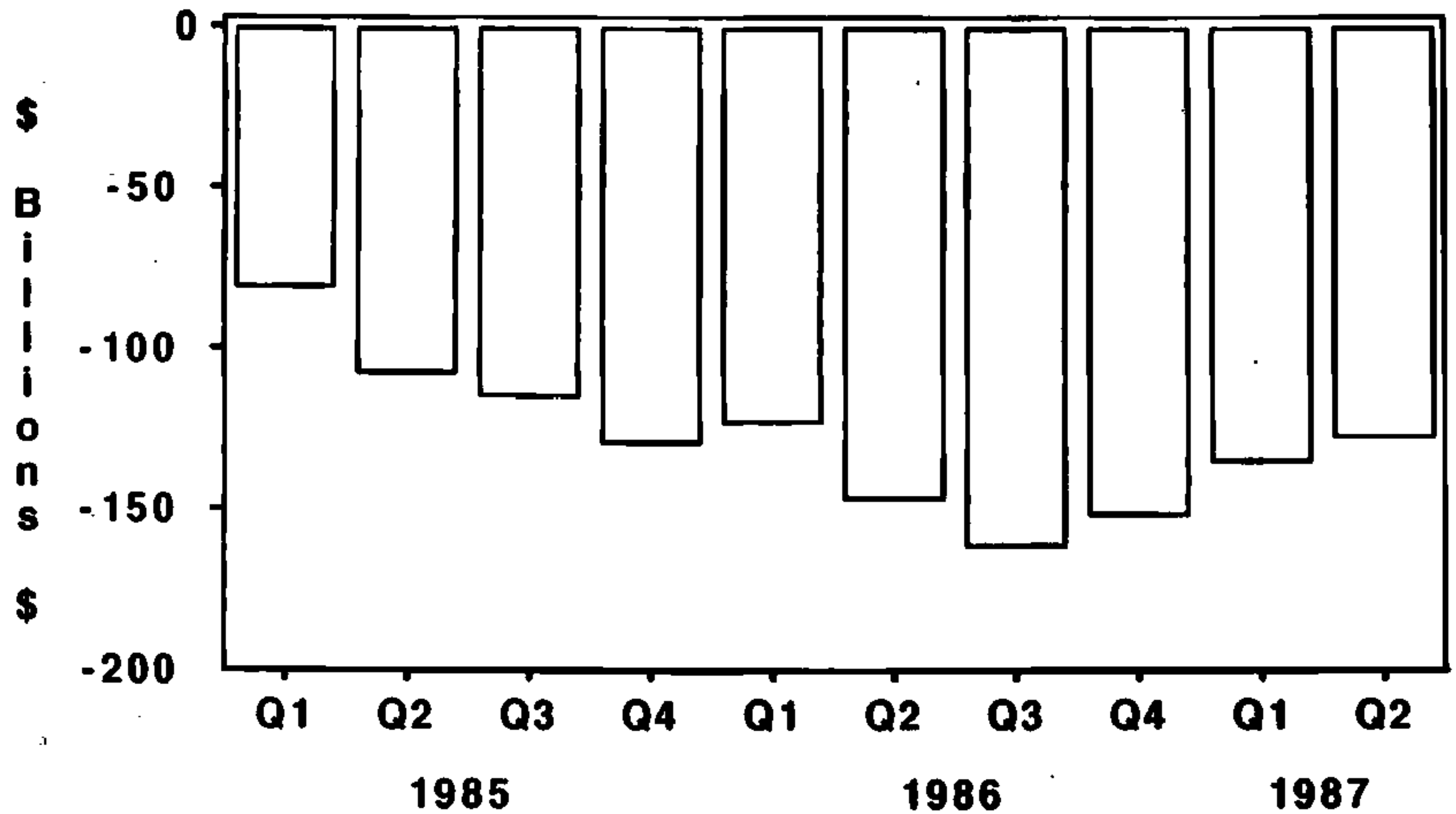
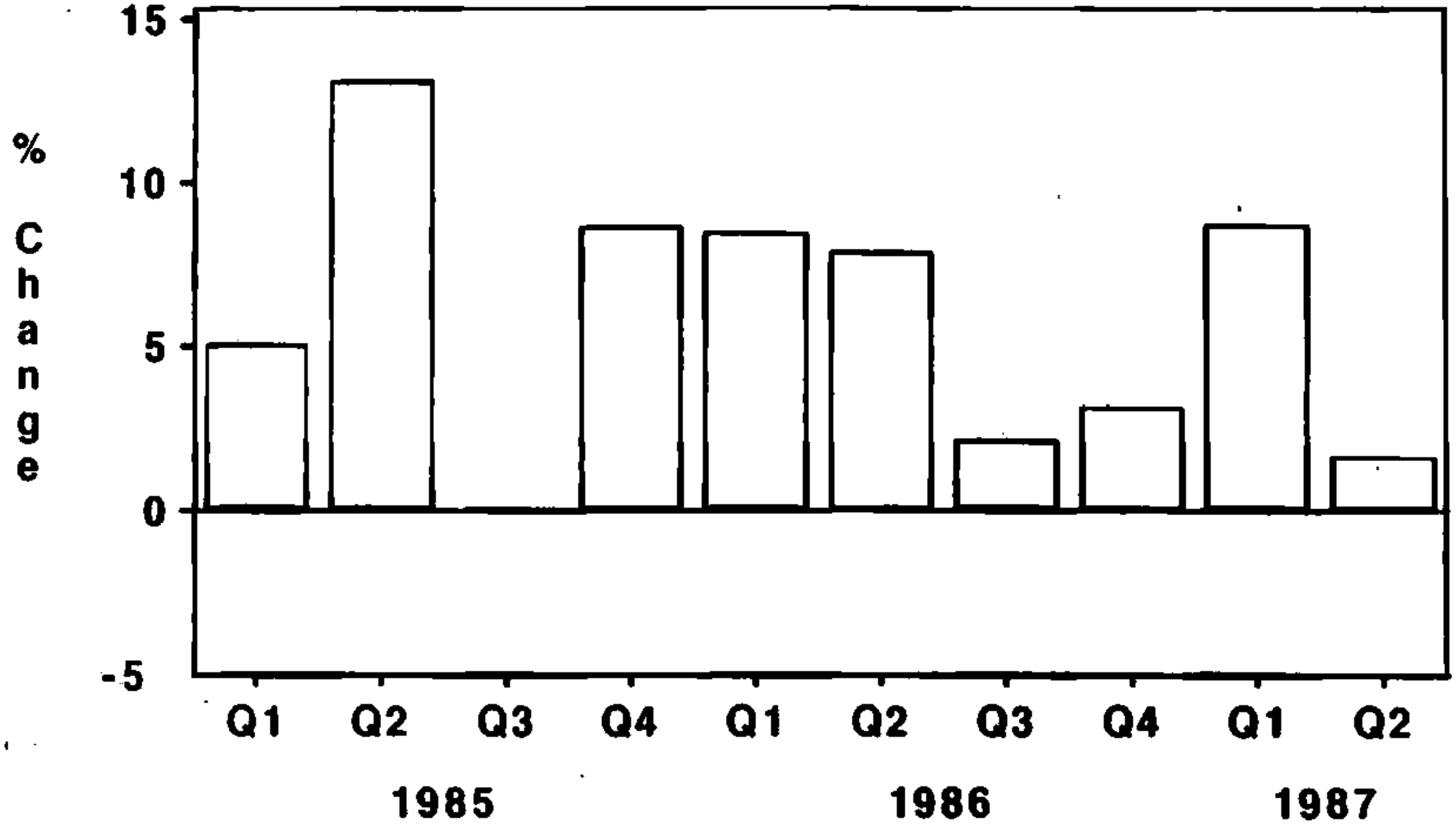
NET EXPORTS
Annual Level

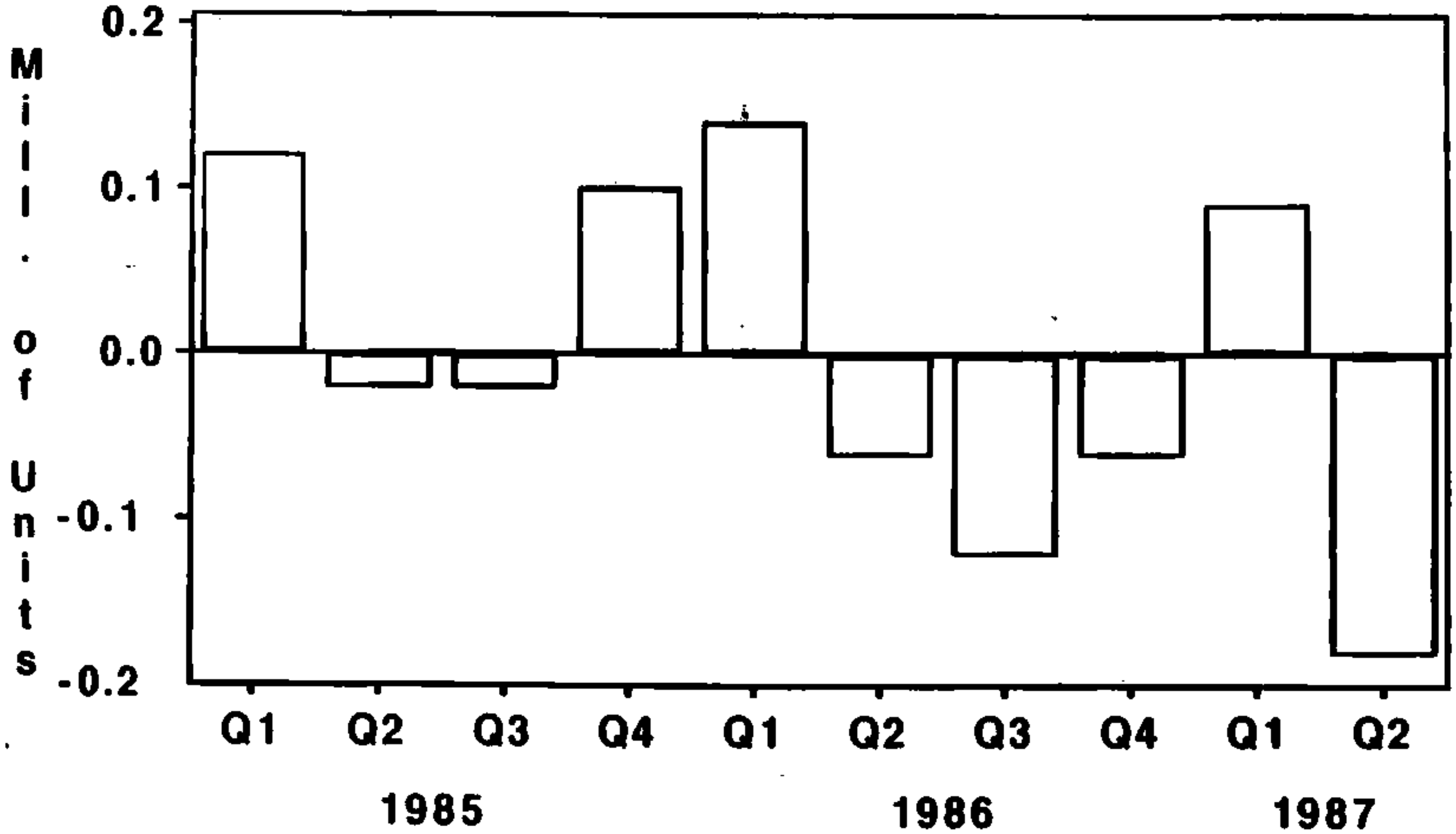


TOTAL PERSONAL INCOME
Annual Percent Change

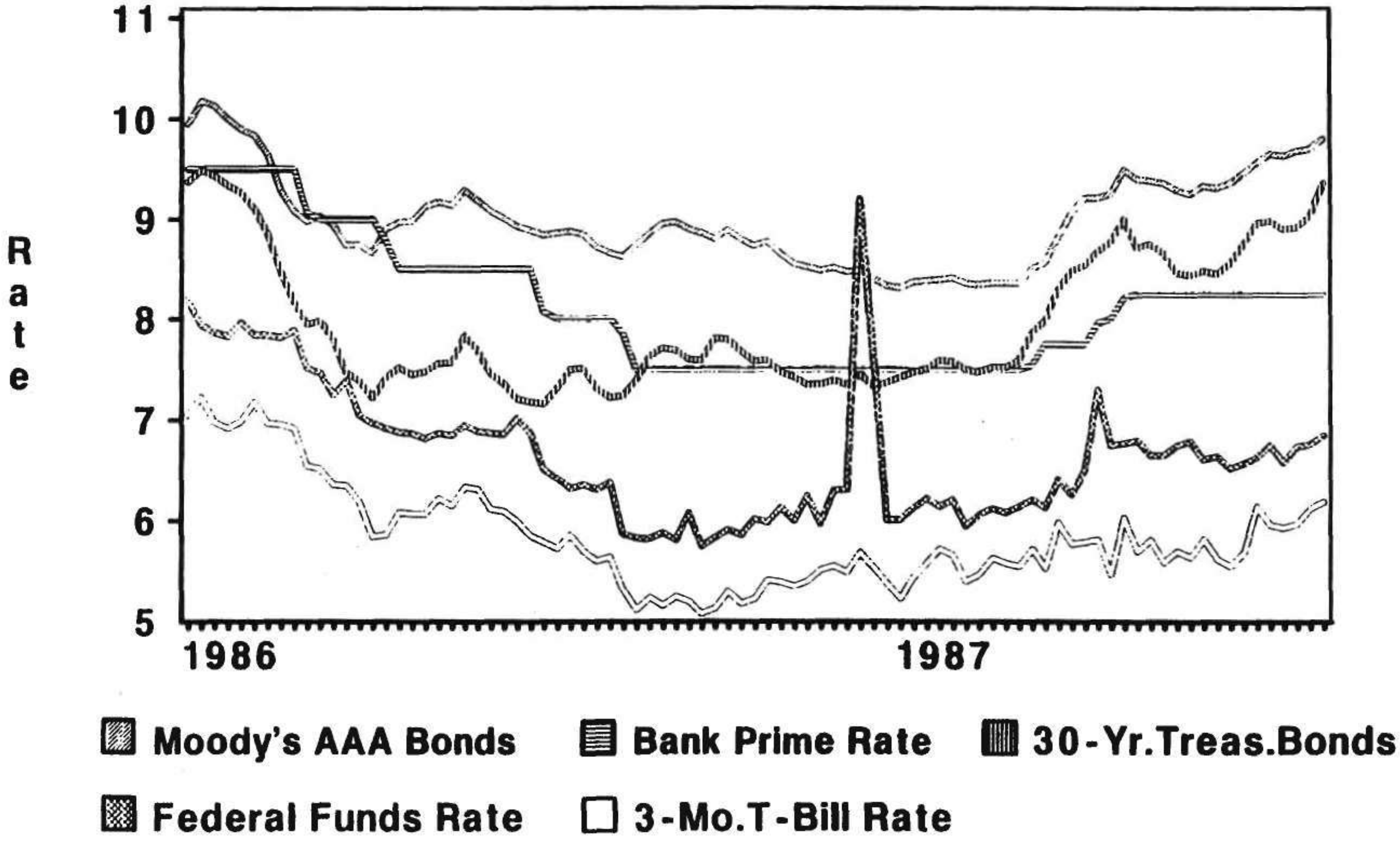


Current Dollars

HOUSING STARTS
Change in Level



WEEKLY INTEREST RATES
1986 to Present



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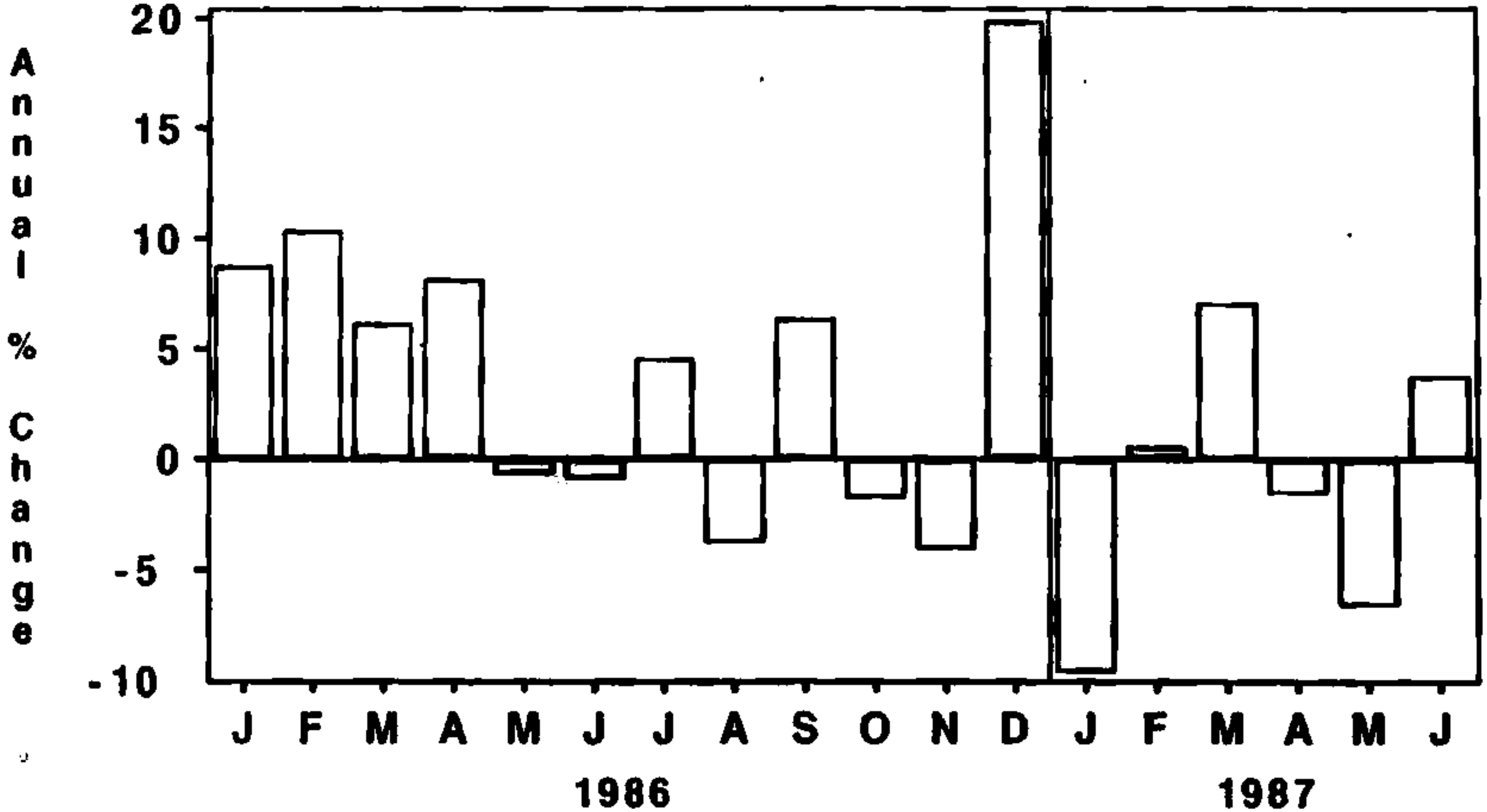
D&B Indicators

- New Incorporations

New Business Incorporations



Source: Dun & Bradstreet

D&B Indicators

- New Incorporations
- New Business Starts

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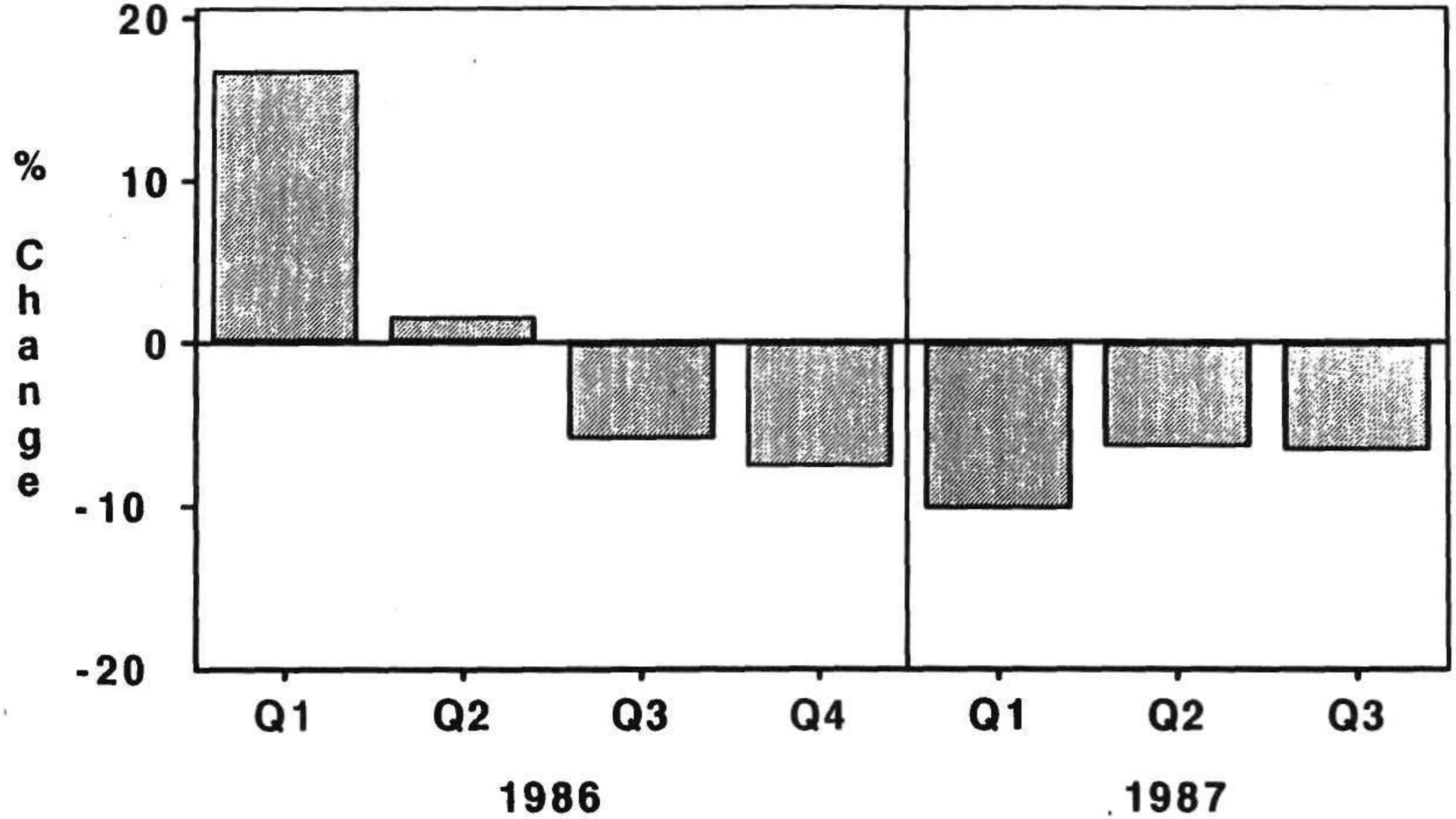
BUSINESS STARTS
Change Over Year Ago

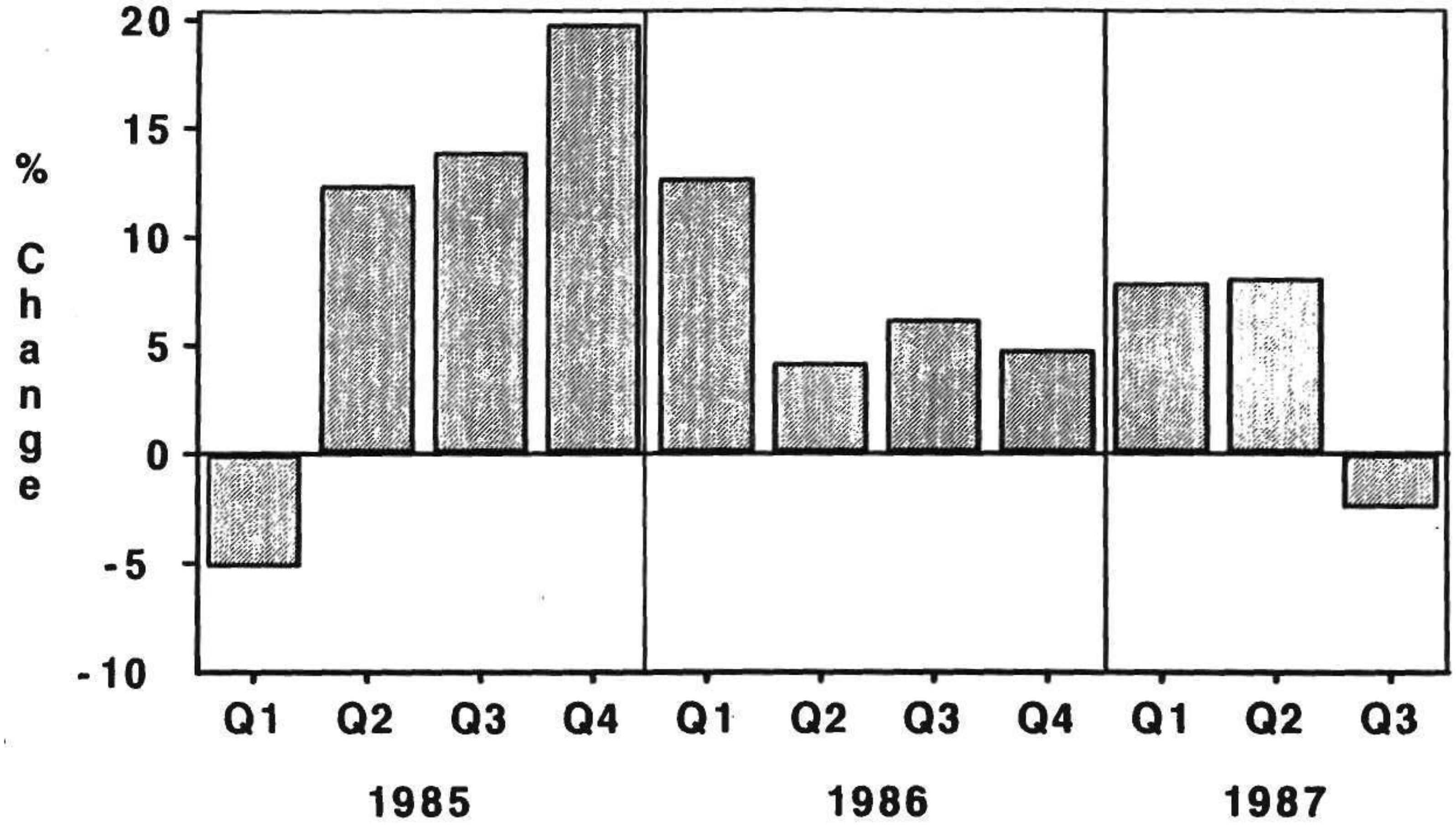


Source: Dun & Bradstreet

D&B Indicators

- New Incorporations
- New Business Starts
- Business Failures

BUSINESS FAILURES
Change Over Year Ago



Source: Dun & Bradstreet

D&B Indicators

- New Incorporations
- New Business Starts
- Business Failures
- Business Expectations

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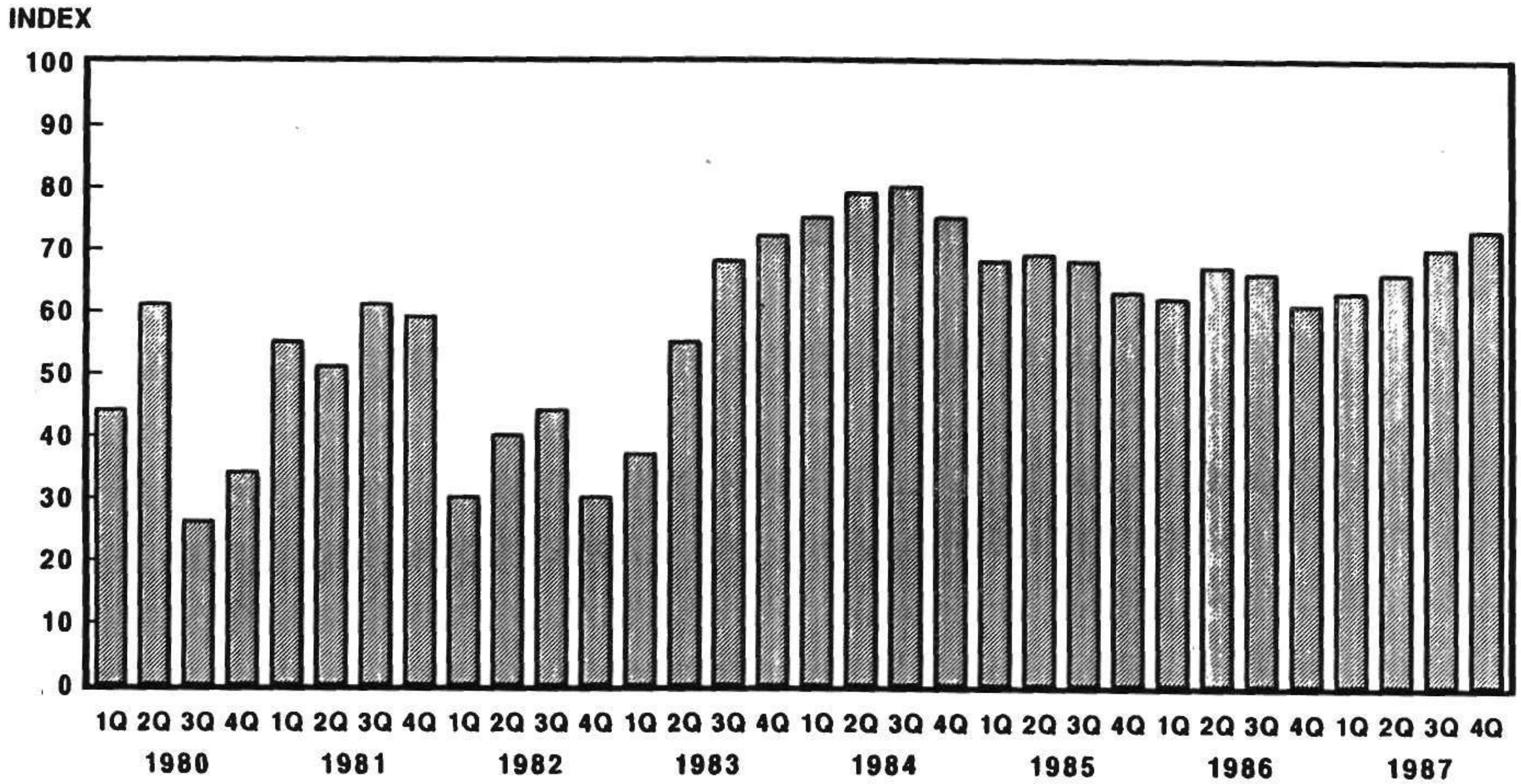
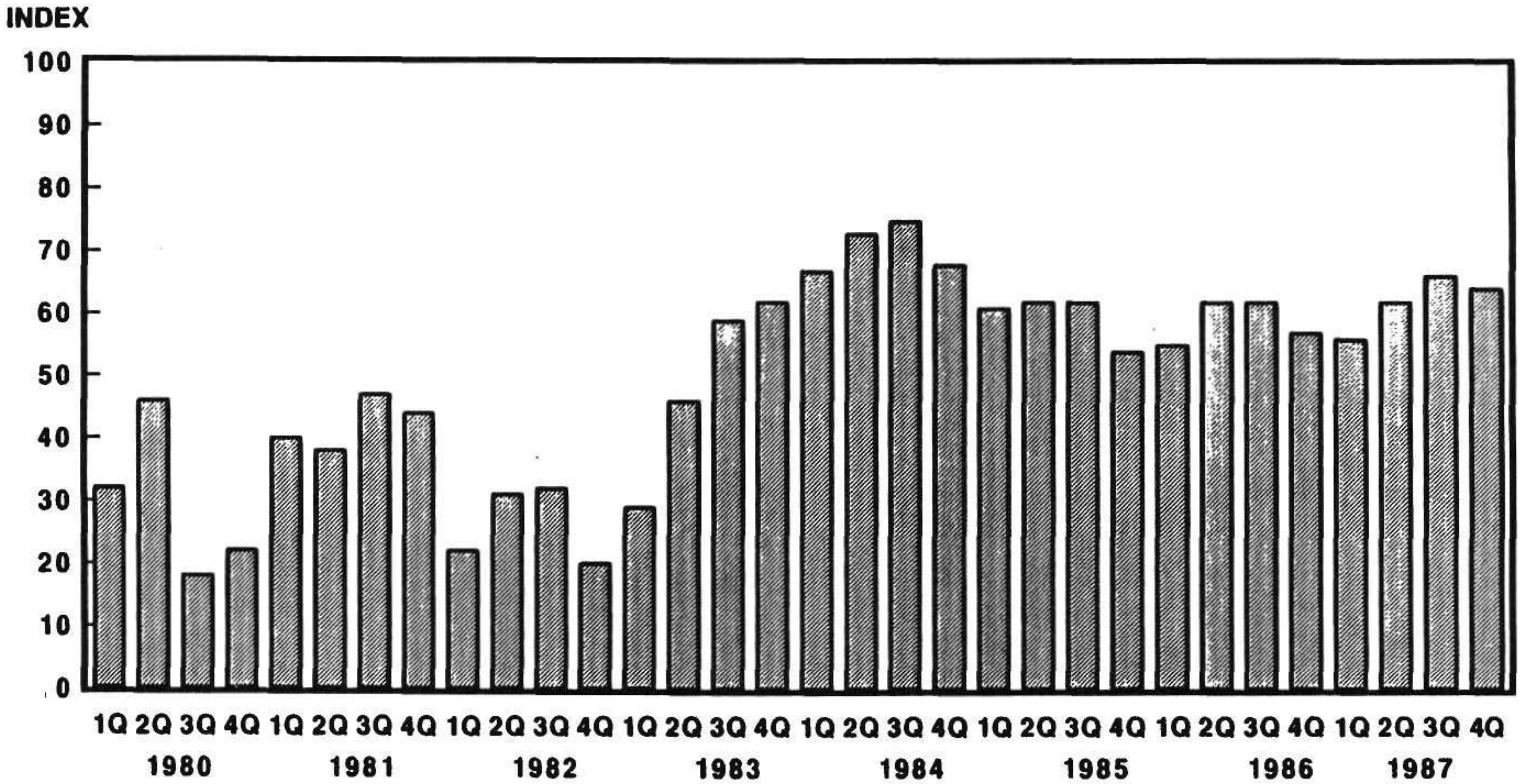
D&B EXPECTATIONS SURVEY

OPTIMISM INDEX - NET SALES



D&B EXPECTATIONS SURVEY

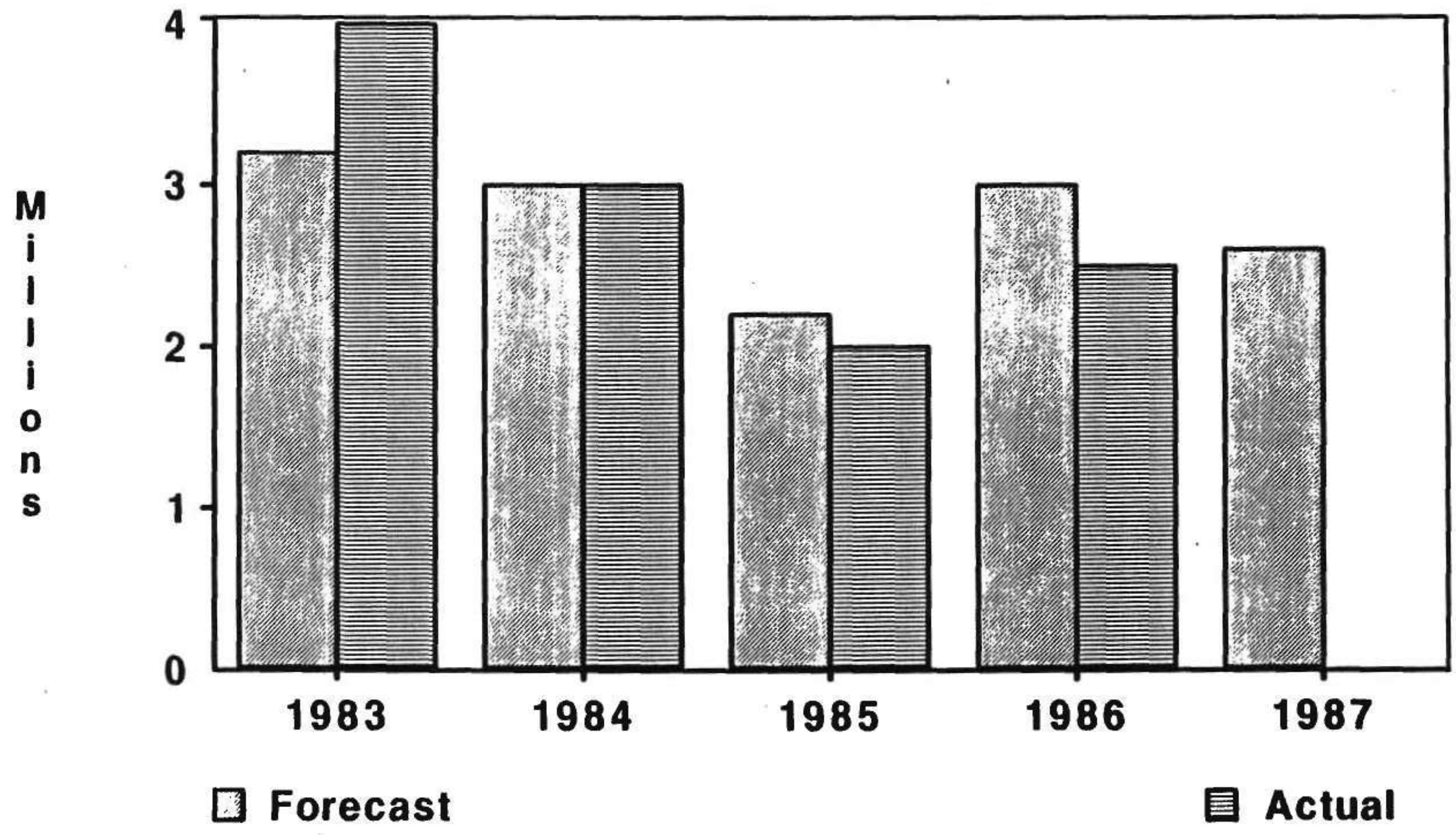
OPTIMISM INDEX - NET PROFITS



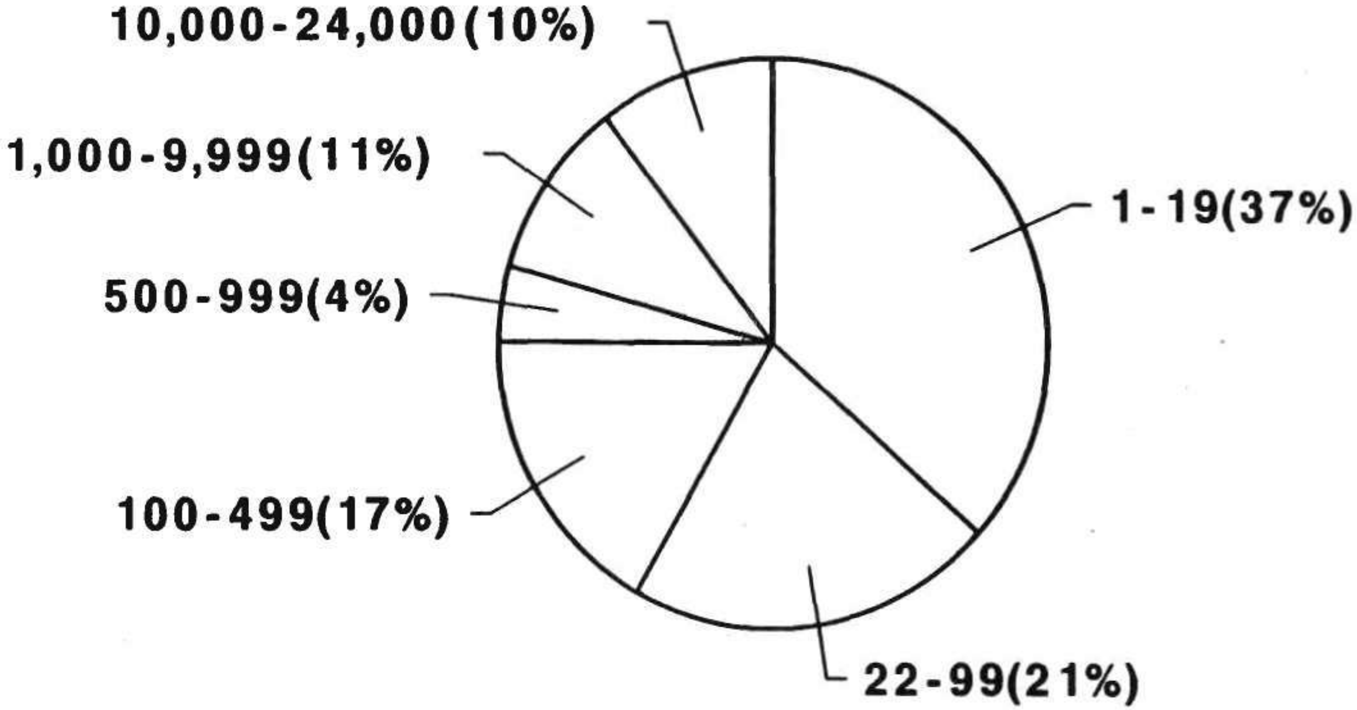
D&B Indicators

- New Incorporations
- New Business Starts
- Business Failures
- Business Expectations
- Dun's 5,000 Survey

Duns5000 Employment Forecast of New Jobs



Duns5000
Employment Outlook Survey, 1987



Firms with over 25,000 employment will actually decline by 0.4 percent

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Outline

- Recent Economic Indicators
- Basic Factors in the Outlook

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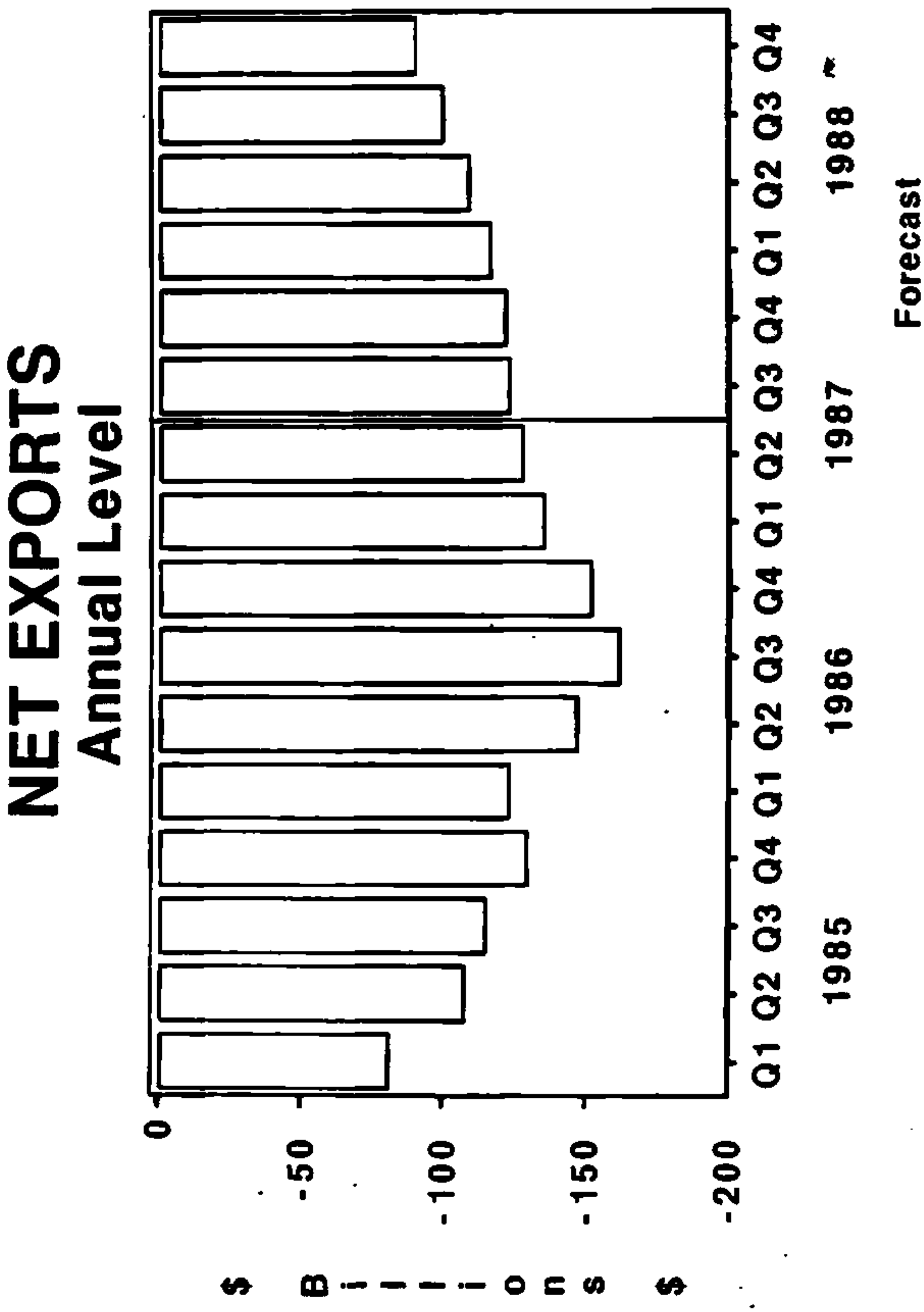
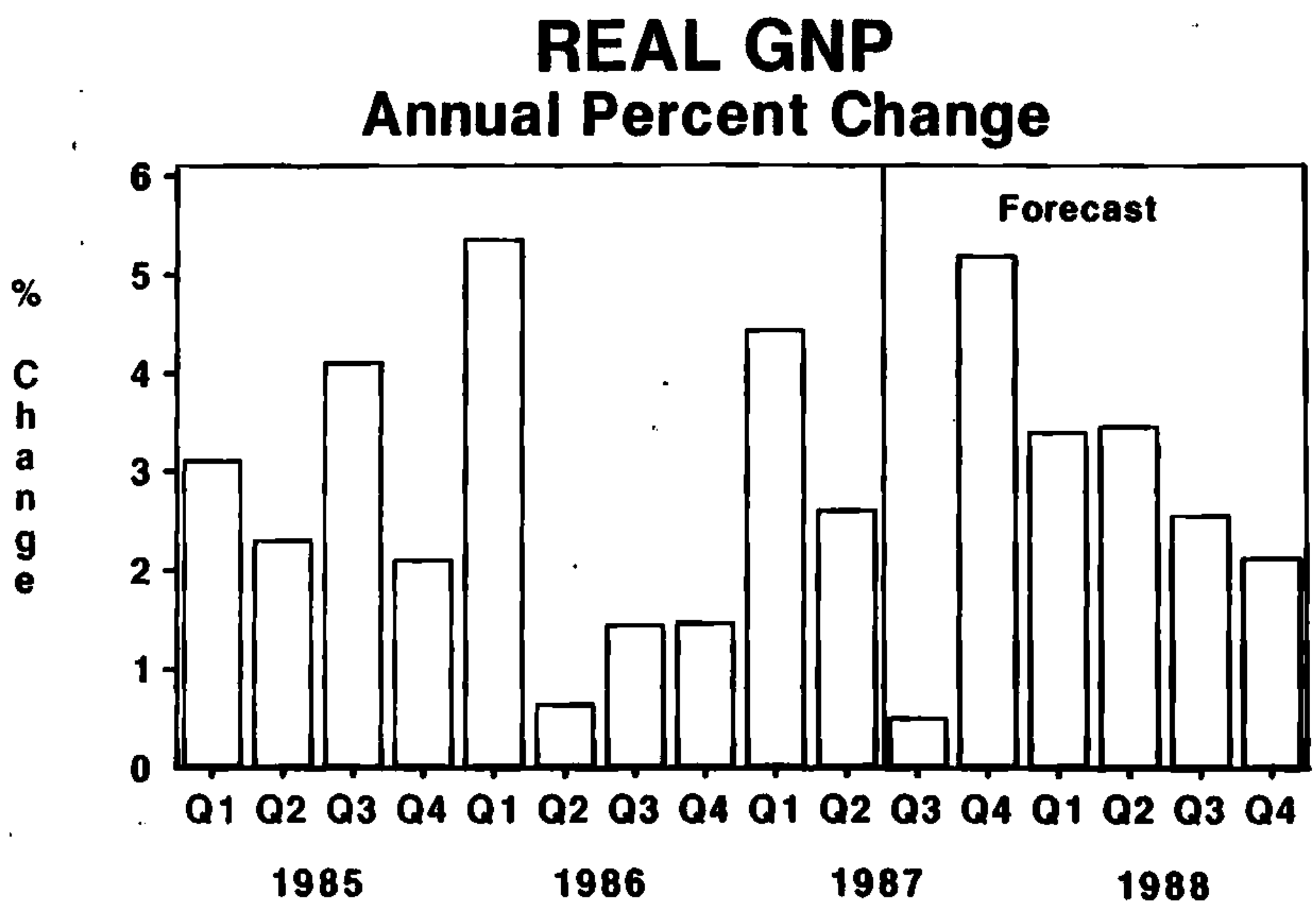
The Short-Term Outlook

- Trade Balance
- Value of the Dollar
- Interest Rates
- Gross National Product Components
- Gross National Product
- Final Sales to Domestic Purchasers


NET EXPORTS
Annual Level
$ Billions $
0
-50
-100
-150
-200
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
1985
1986
1987
1988
Forecast



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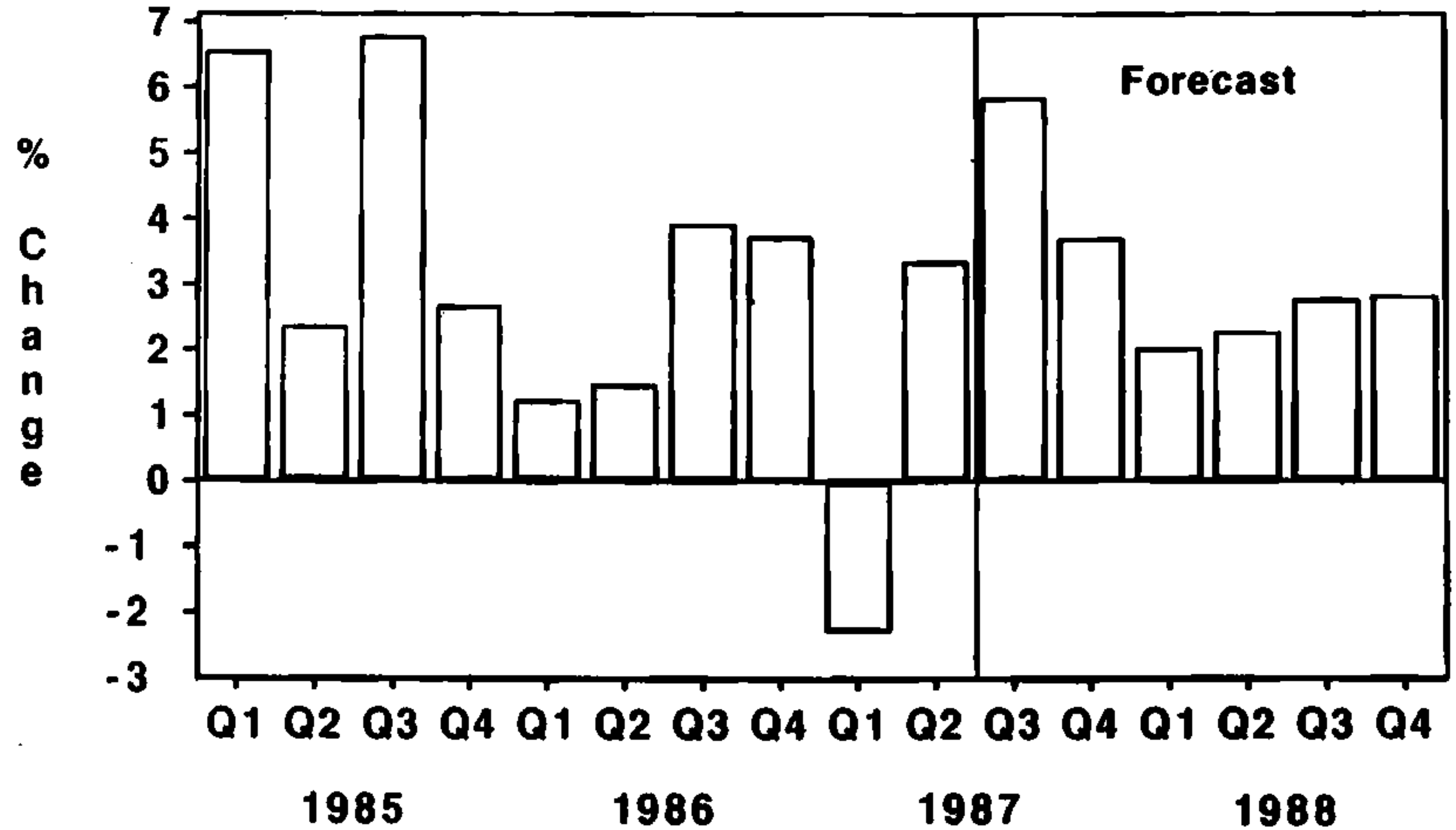
Final Sales to Domestic Purchasers
Annual Percent Change



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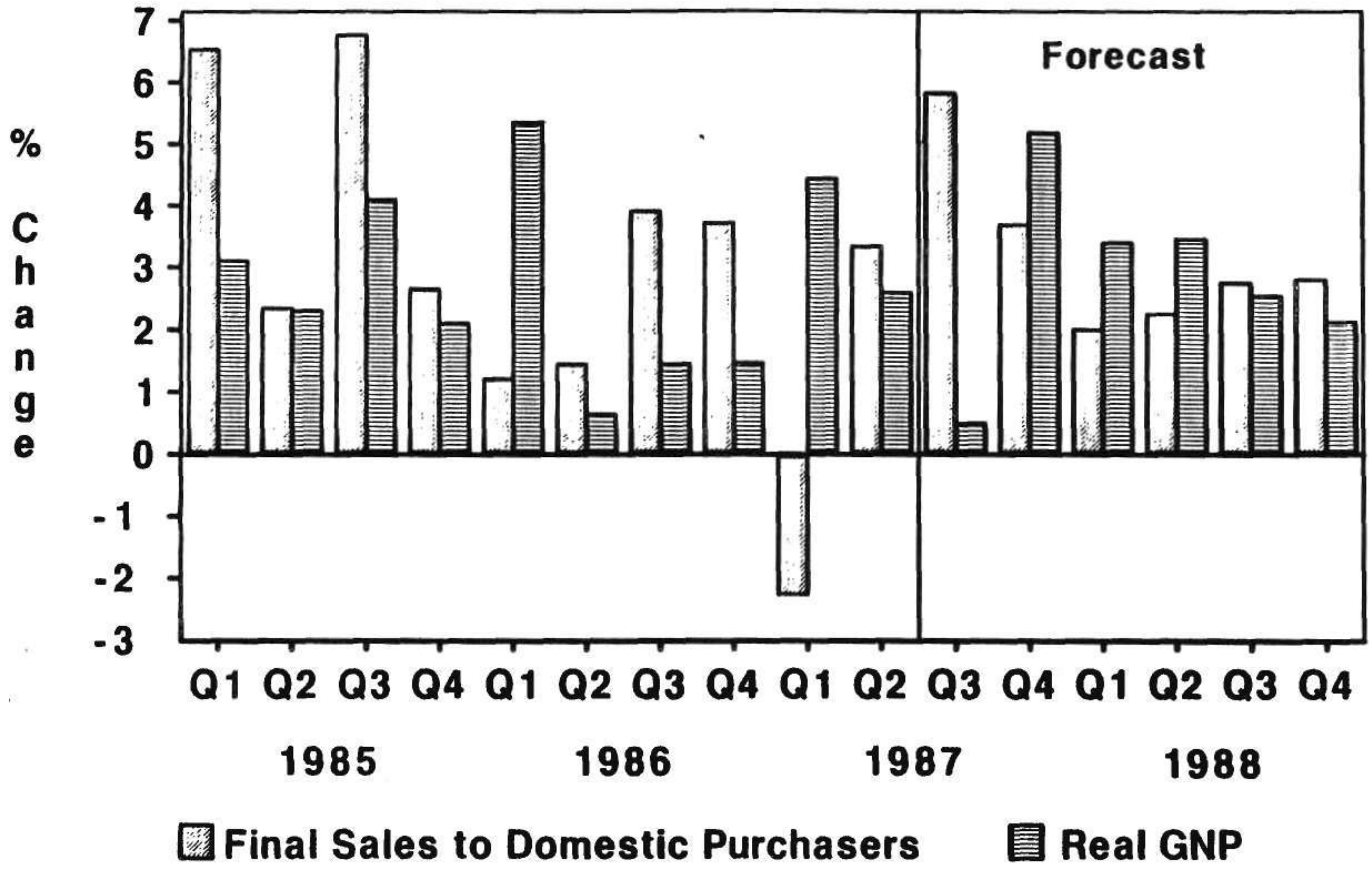
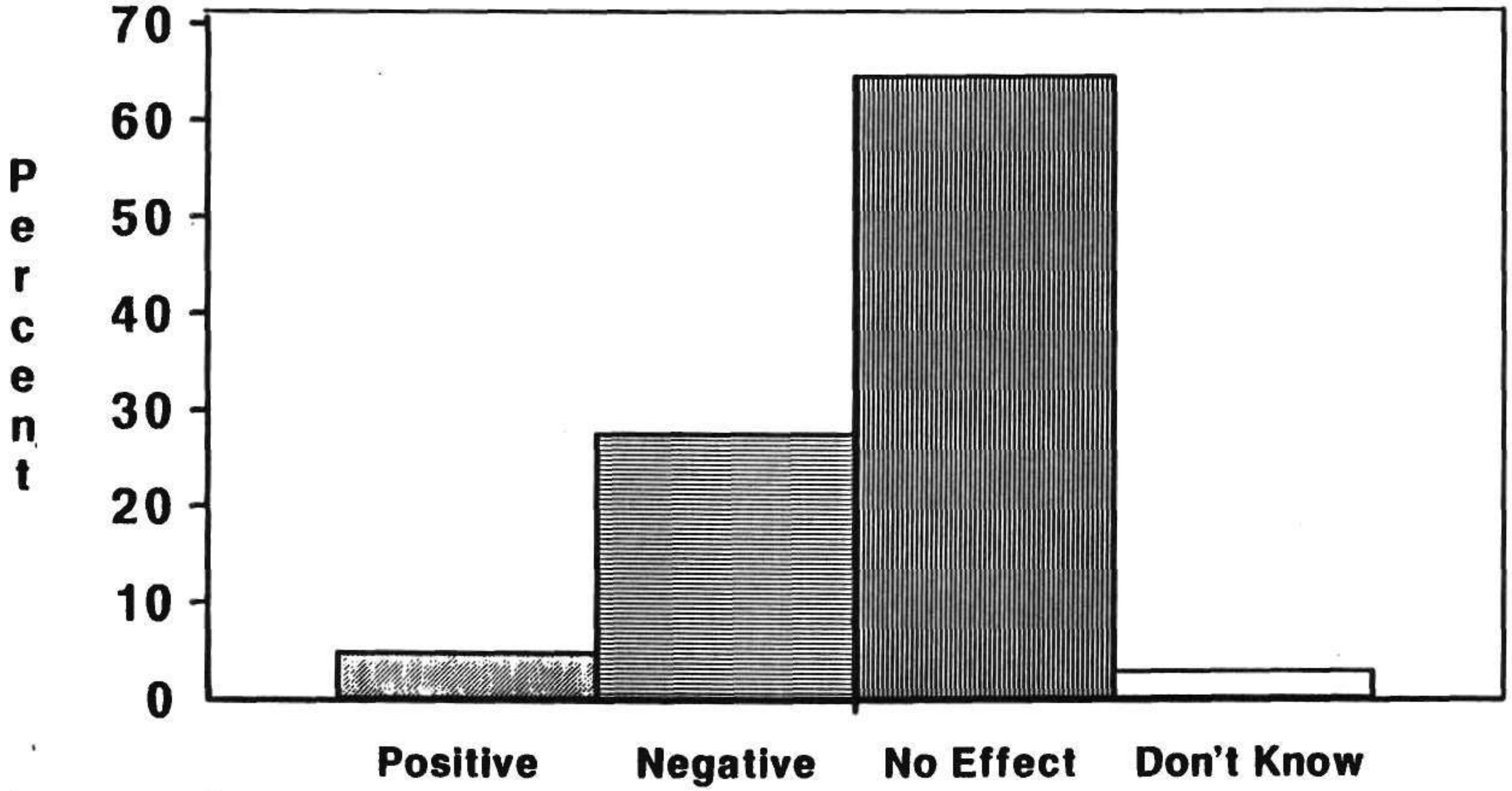
Final Sales to Domestic Purchasers vs. Real GNP



Issues

- Impact of tax reform

Effects of Tax Reform on Capital Expenditure

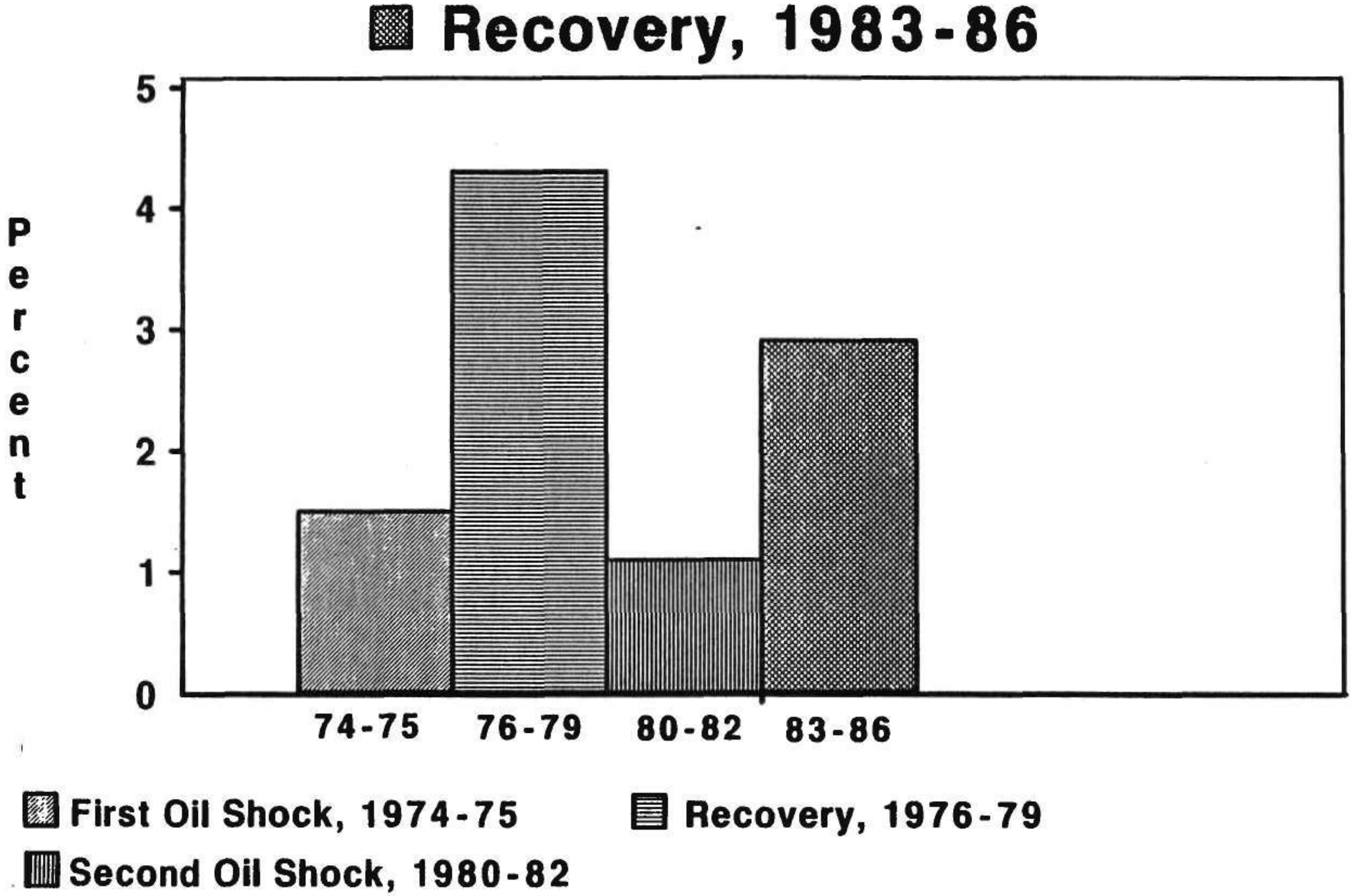


Source: Dun's 5,000 Survey, Nov. 1986

Issues

- Impact of tax reform
- Value of the dollar and trade

World Economic Growth Rates



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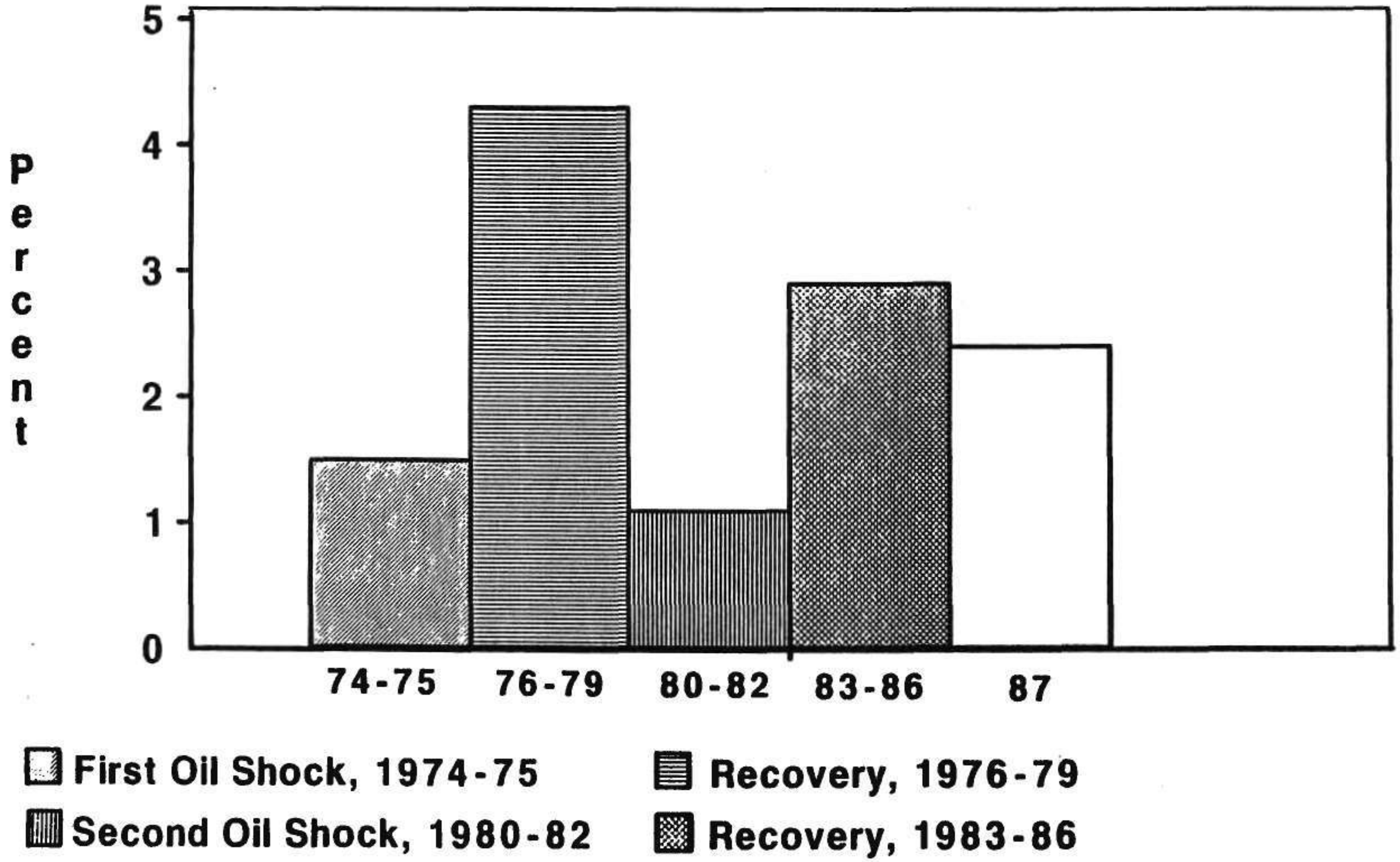
World Economic Growth Rates

☐ This Year, 1987



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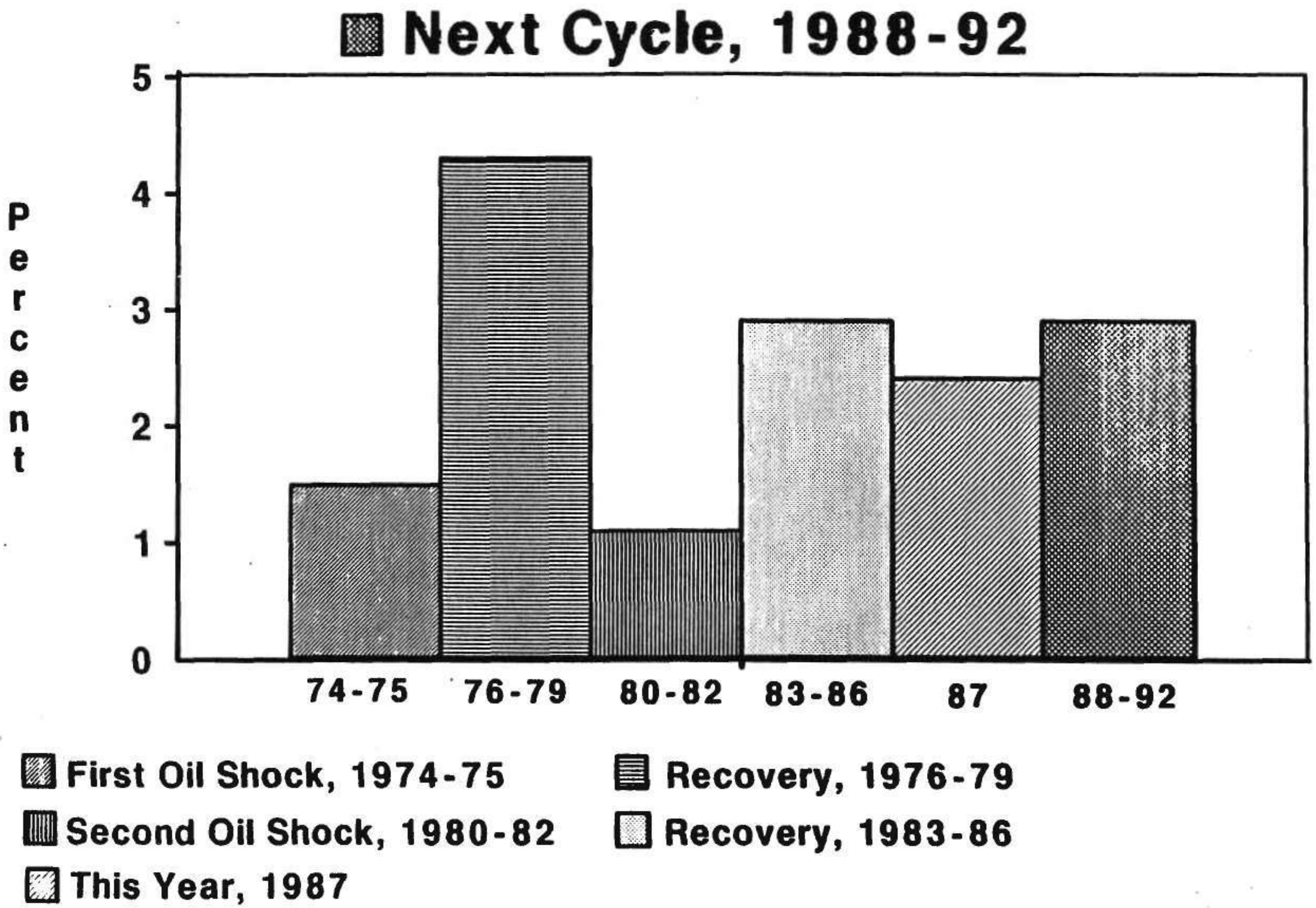
World Economic Growth Rates



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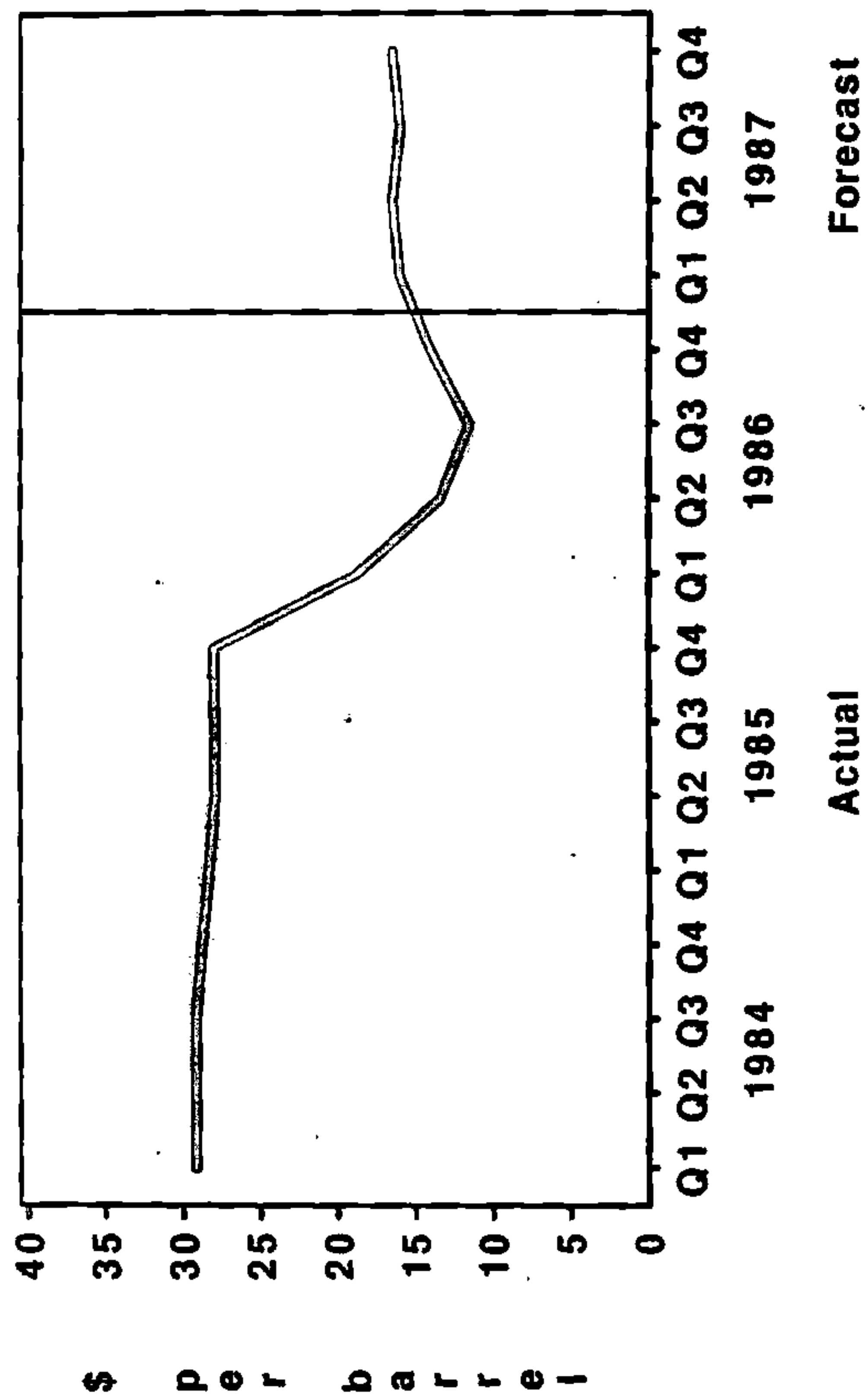
Issues

- Impact of tax reform
- Value of the dollar and trade
- Price of oil

QUARTERLY OIL PRICE AVERAGE



Issues

- Impact of tax reform
- Value of the dollar and trade
- Price of oil
- Inflation outlook

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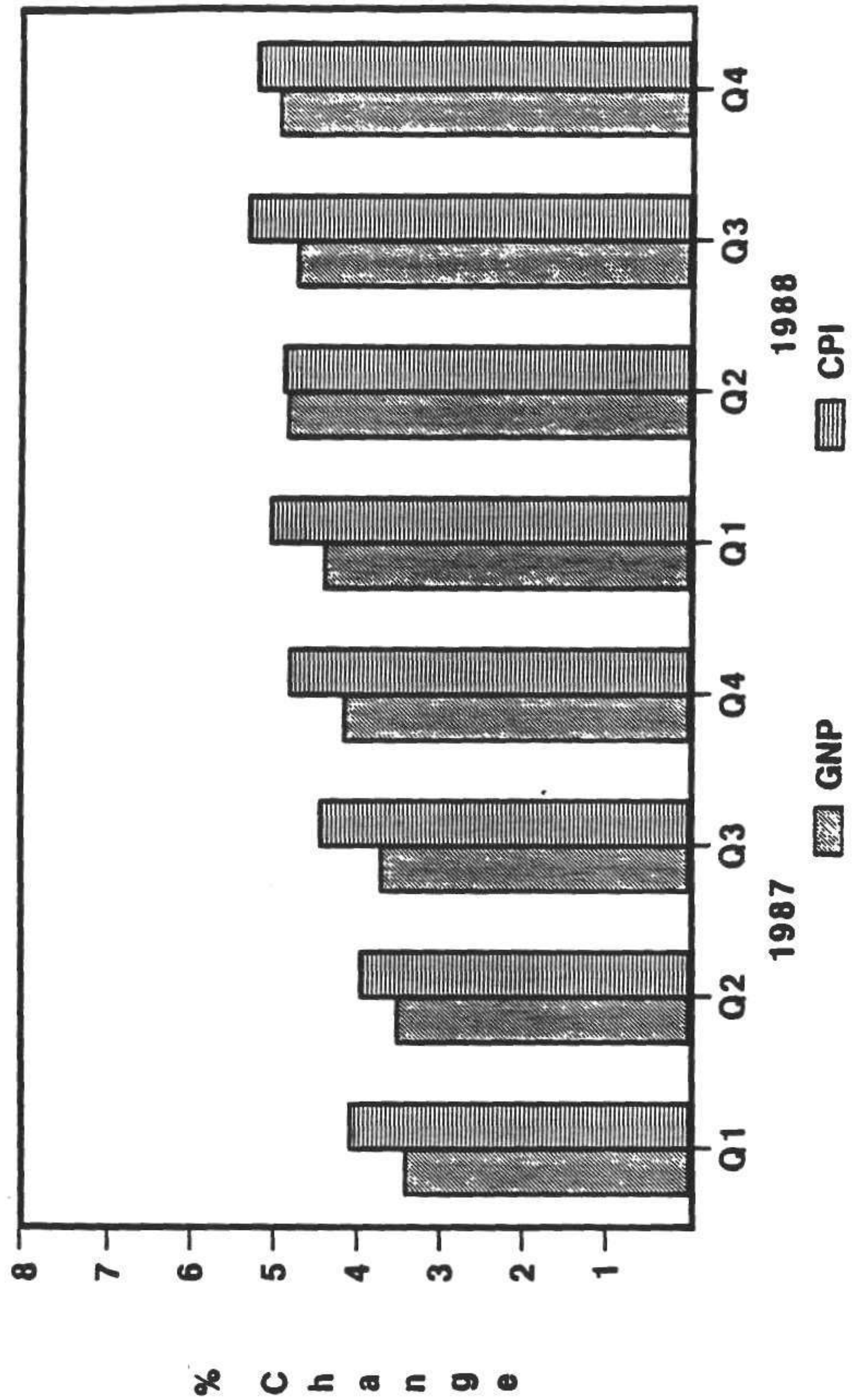
INFLATION



Issues

- Impact of tax reform
- Value of the dollar and trade
- Price of oil
- Inflation outlook
- Consumer confidence

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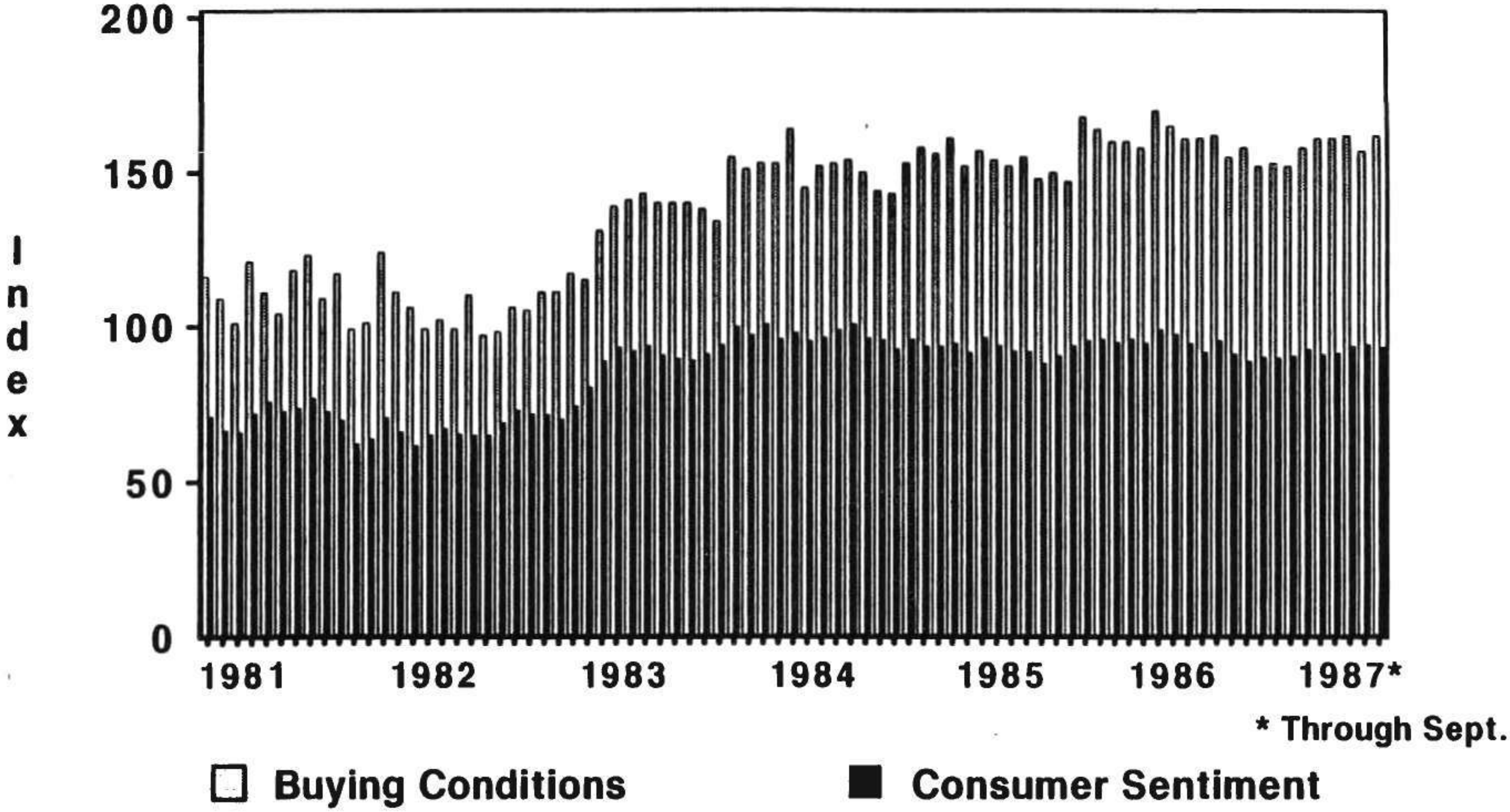
Index of Consumer Sentiment and Buying Conditions



Source: Univ. of Michigan

Issues

- Impact of tax reform
- Value of the dollar and trade
- Price of oil
- Inflation outlook
- Consumer confidence
- The banking system

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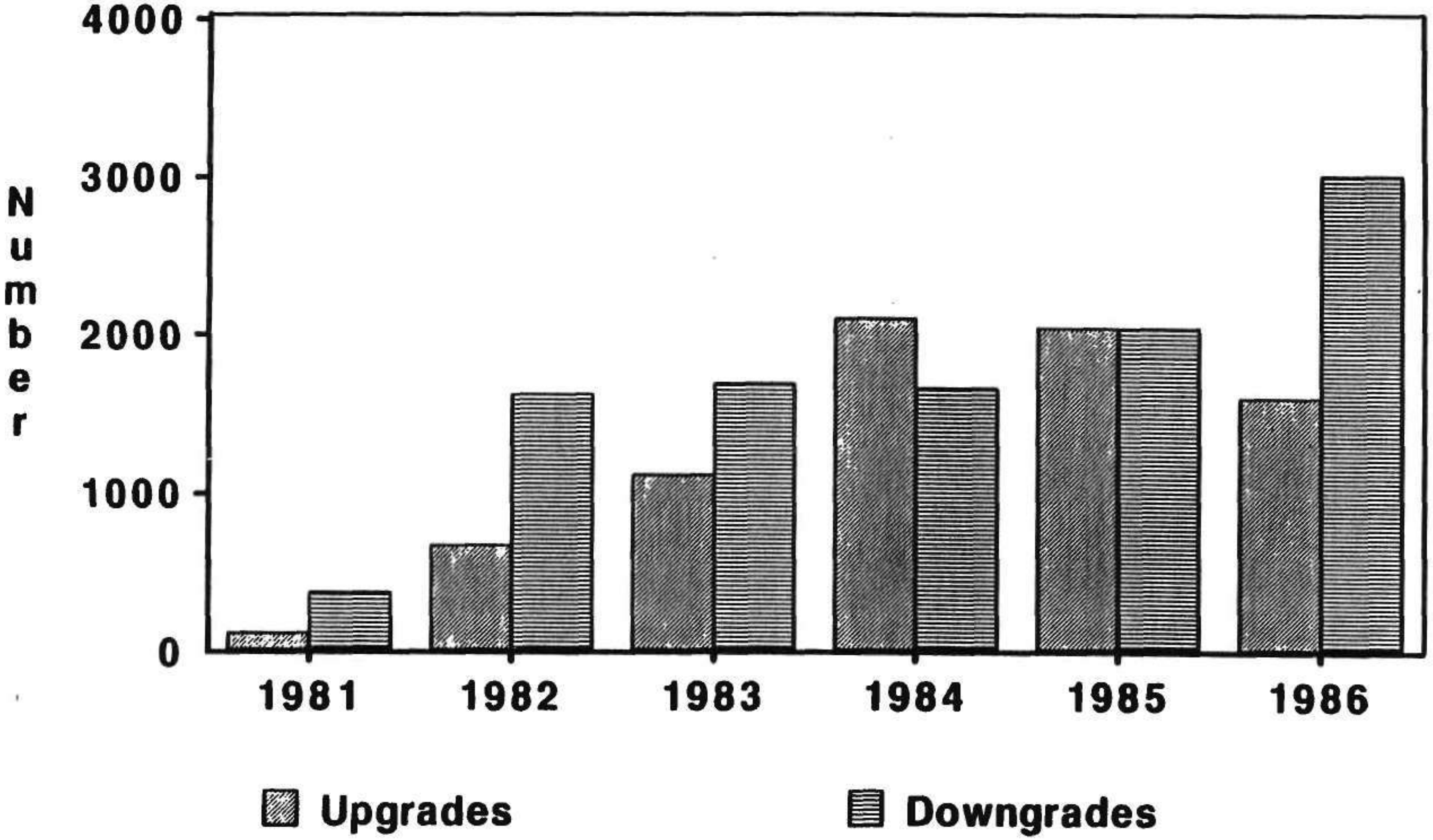
MOODY'S RATINGS
Changes in Corporate Issues



Issues

- Impact of tax reform
- Value of the dollar and trade
- Price of oil
- Inflation outlook
- Consumer confidence
- The banking system
- Fiscal policy - the deficit

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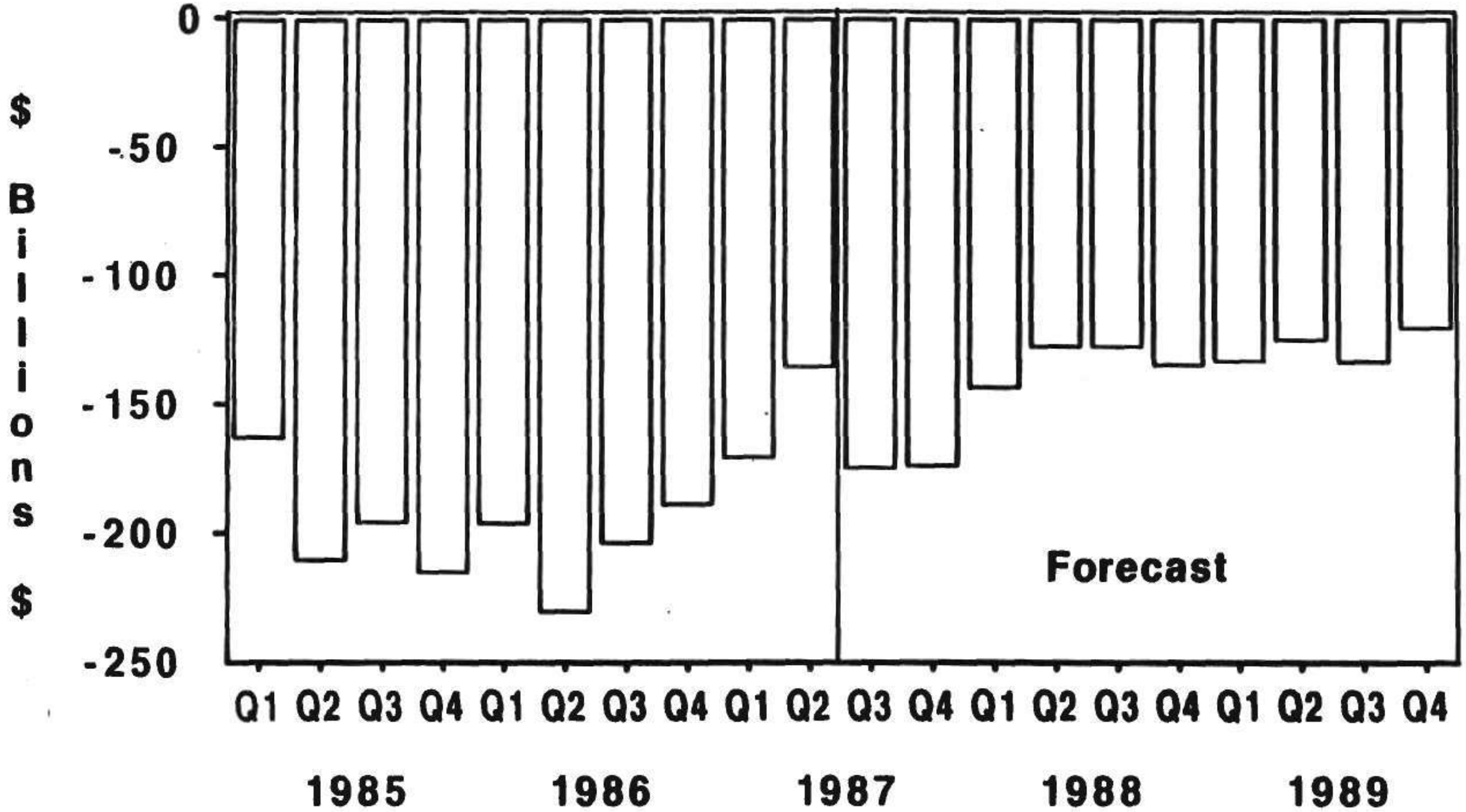
Federal Government Deficit
(NIA Basis)



Current Dollars

Dataquest

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The Dun & Bradstreet Corporation

Dataquest

a company of
The Dun & Bradstreet Corporation

WORLD CHIP INDUSTRY SAME GAME: DIFFERENT RULES

Gene Norrett
Vice President
Director, Semiconductor
Industry Group (SIG)
Dataquest Incorporated

Mr. Norrett is a Vice President of Dataquest and Director of its Semiconductor Industry Group (SIG). In this capacity, he has direct responsibility for all U.S. research and coordinates European and Japan-based research. Prior to becoming SIG director, he founded Dataquest's Japanese Semiconductor Industry Service and was Acting Managing Director of Dataquest Japan K.K. Before joining Dataquest, Mr. Norrett spent 14 years with the Motorola Semiconductor Product Sector, serving in various marketing and management positions. He has traveled extensively in Japan, Hong Kong, Taiwan, Korea, China, and Europe. Mr. Norrett's educational background includes a B.A. degree in Mathematics from Temple University and an M.S. degree in Applied Statistics from Villanova University. He has also taken graduate courses in Marketing from Arizona State University.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

Economic and Industry Outlook

GENE NORRETT

Vice President
Director, Semiconductor Industry Group
Dataquest Incorporated

Semiconductors' Midlife Crisis

WORLD CHIP INDUSTRY: SAME GAME, DIFFERENT RULES

GENE NORRETT

Vice President
Director, Components Group
Dataquest Incorporated

CHIP INDUSTRY

- Same game
  - An overview of the current economic situation
- Different rules
  - An assessment of the changes that are affecting your business
- Looking ahead

SAME GAME - ECONOMICS

Estimated Revenue, Billions of Dollars

	1987	1990
World Manufacturing	$2,600.0	$2,800.0
World Electronic Equipment	$ 470.0	$ 600.0
World Semiconductor (incl. IBM, AT&T)	$ 42.5	$ 60.0
World Semiconductor Manufacturing Equipment	$ 5.8	$ 9.5

Source: Dataquest

SAME GAME - COMPETITION

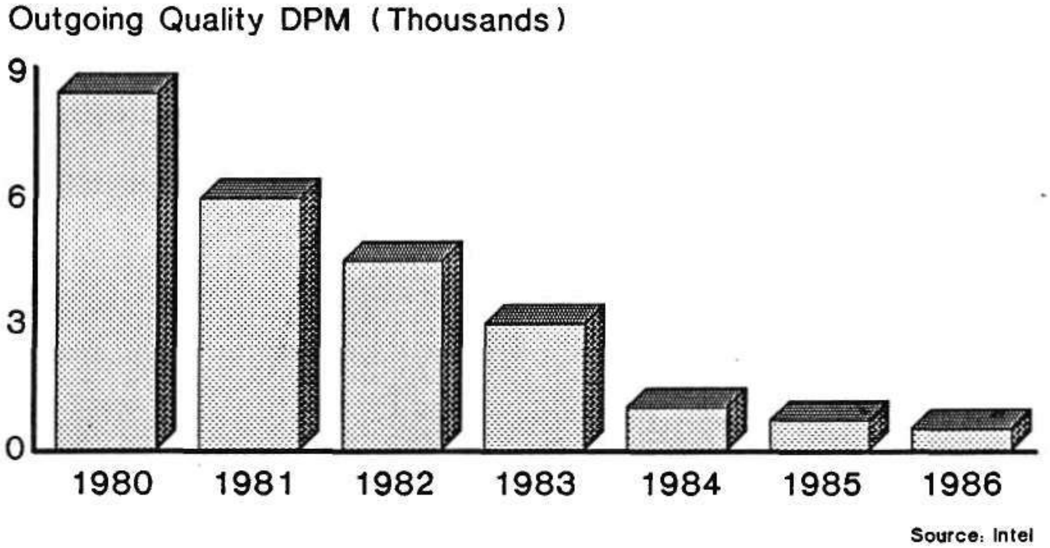
Worldwide Semiconductor Market Shares
(Millions of Dollars)

1986 Rank	1985 Rank		1985	1986	Percent Change
1	1	NEC	1,984	2,638	33.0%
2	4	Hitachi	1,671	2,305	37.9%
3	5	Toshiba	1,468	2,276	55.0%
4	2	Motorola	1,830	2,025	10.7%
5	3	Texas Instruments	1,742	1,781	2.2%
6	6	National/Fairchild	1,417	1,485	4.8%
7	7	Philips-Signetics	1,065	1,361	27.8%
8	9	Fujitsu	1,019	1,309	28.5%
9	10	Matsushita	906	1,204	32.9%
10	12	Mitsubishi	662	1,140	72.2%
11	8	Intel	1,020	991	(2.8%)
12	11	AMD/MMI	787	838	6.5%

Source: Dataquest

SAME GAME - QUALITY

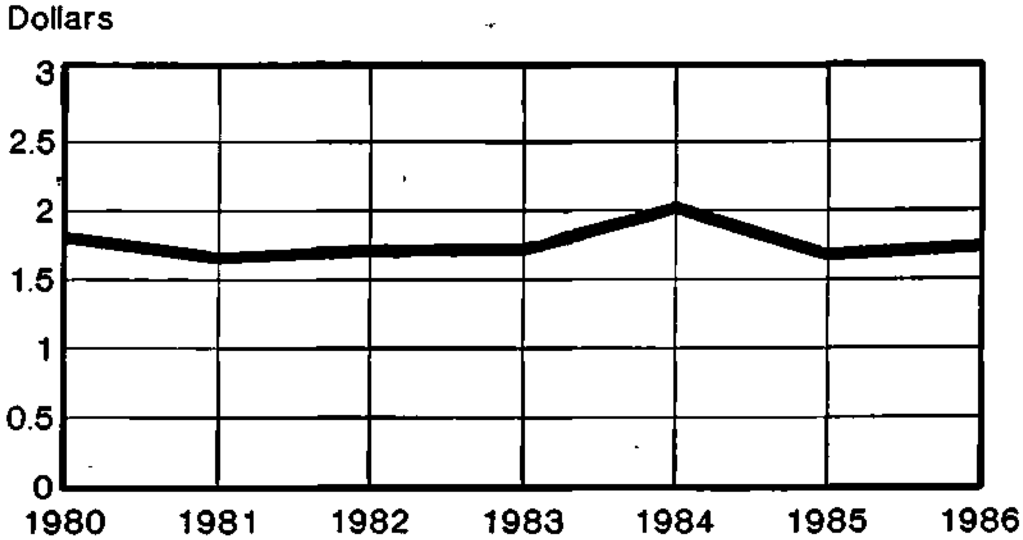
Component DPM Levels
(Customer Perceptions)



Source: Intel

SAME GAME - PRICES

Total MOS ASPs



Source: Dataquest

SAME GAME - APPLICATIONS

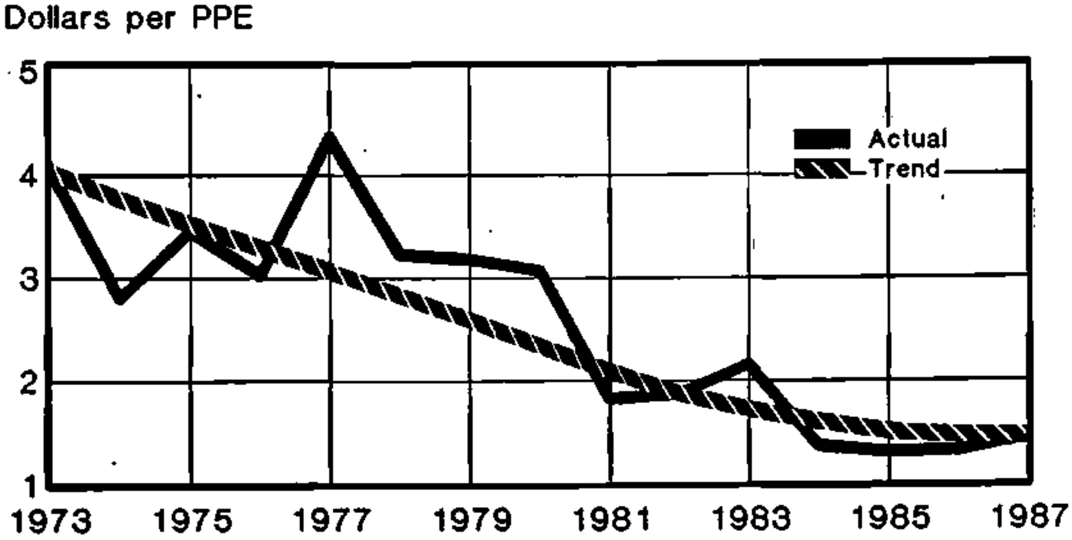
Percent of Region
1986

	Japan	U.S.	Europe	ROW
Data Processing	33.2	37.4	22.7	41.0
Communications	13.6	13.7	26.5	9.0
Industrial	11.2	20.9	16.8	2.0
Consumer	40.3	13.7	8.2	46.0
Military	0	8.3	16.3	0
Transportation	1.7	6.0	9.5	2.0
Total	100.0	100.0	100.0	100.0

Source: Dataquest

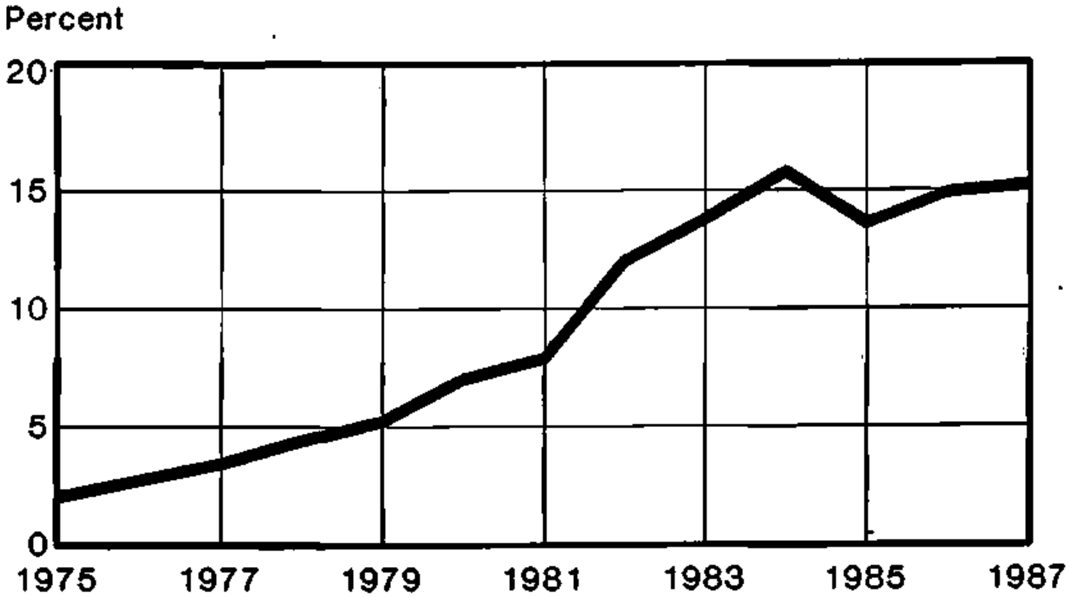
SAME GAME - RETURN OF CAPITAL

Revenue (T+1)/PPE



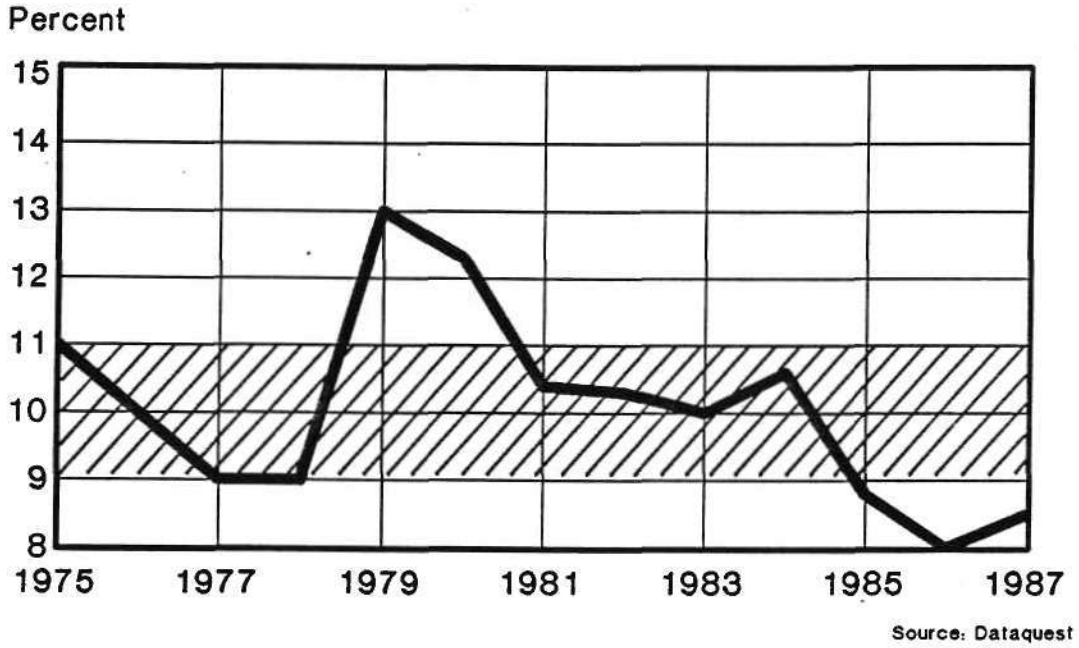
Source: Dataquest

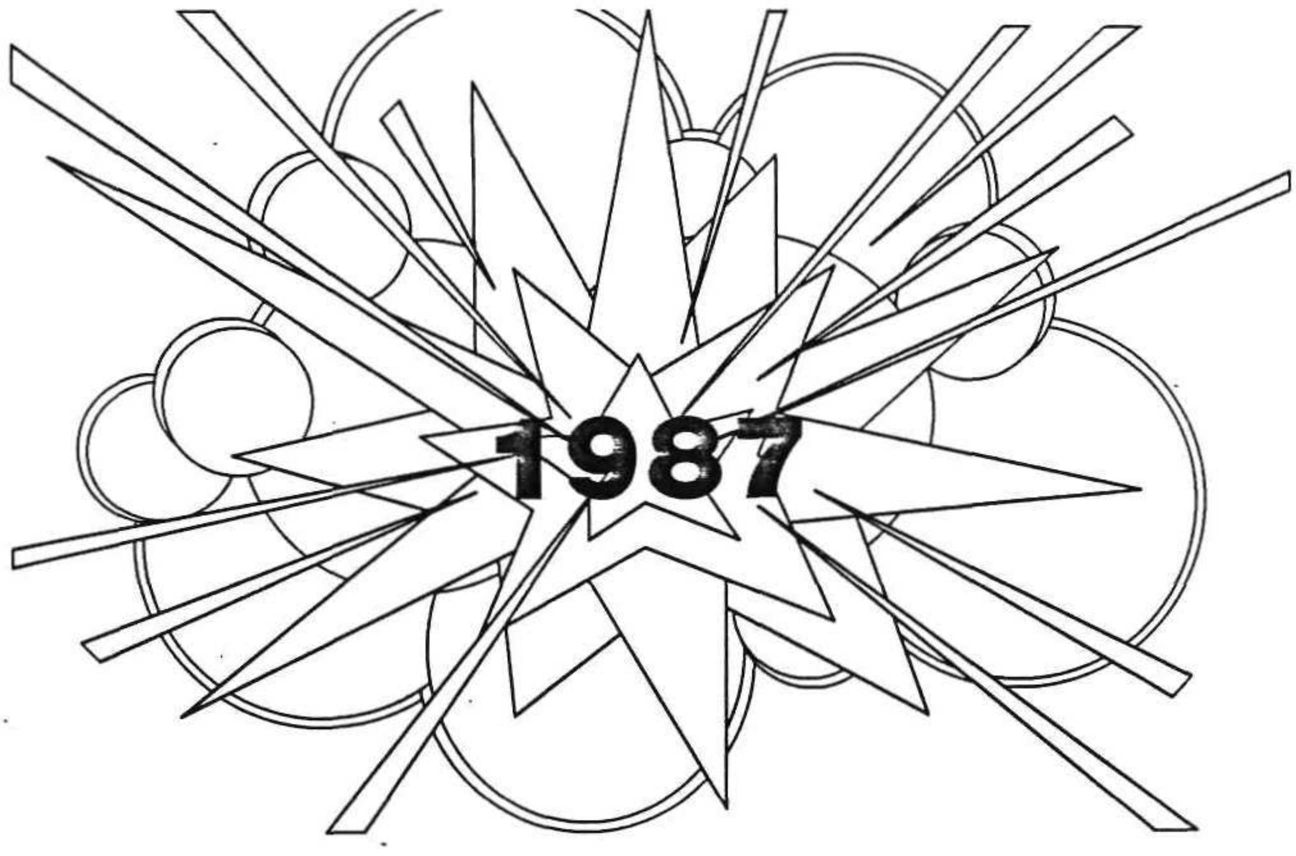
JAPANESE SHARE OF U.S. MARKET



Source: Dataquest

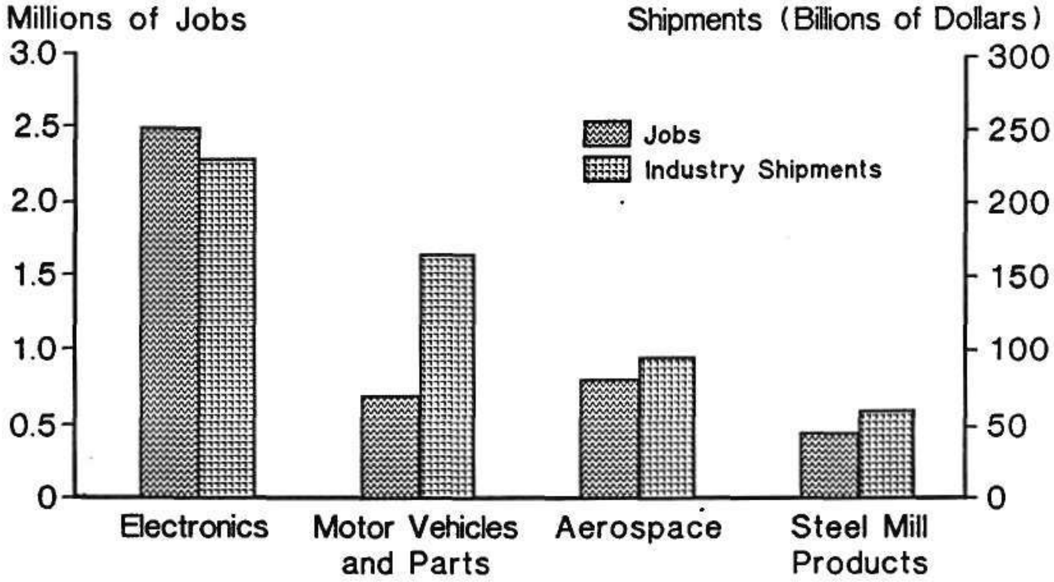
U.S. SHARE OF JAPANESE MARKET





DIFFERENT RULES - ELECTRONICS

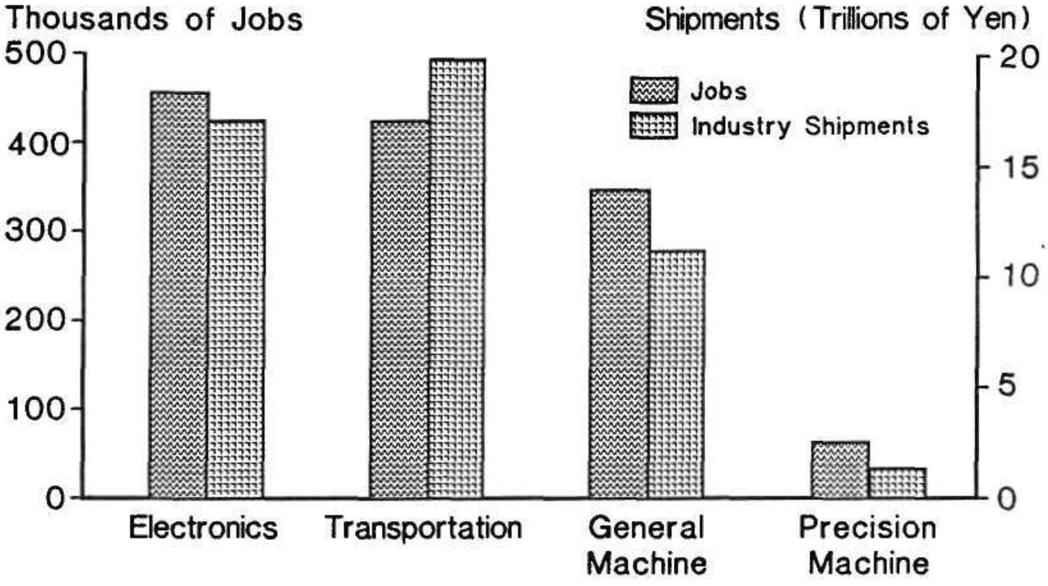
Electronics is America's Largest Industry



Source: National Semiconductor

DIFFERENT RULES - ELECTRONICS

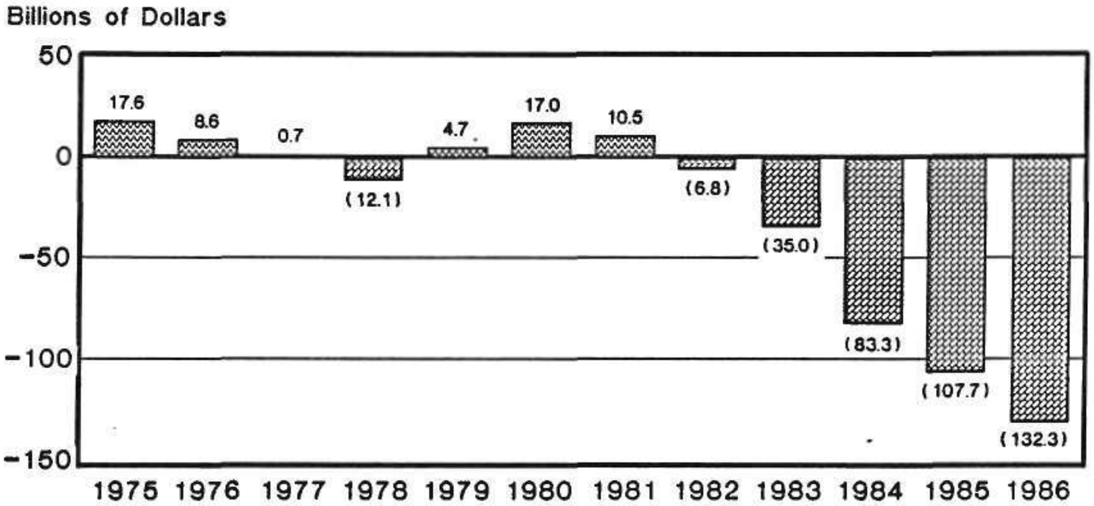
Electronics is Japan's Largest Industry



Source: MITI

DIFFERENT RULES - TRADE IMBALANCE

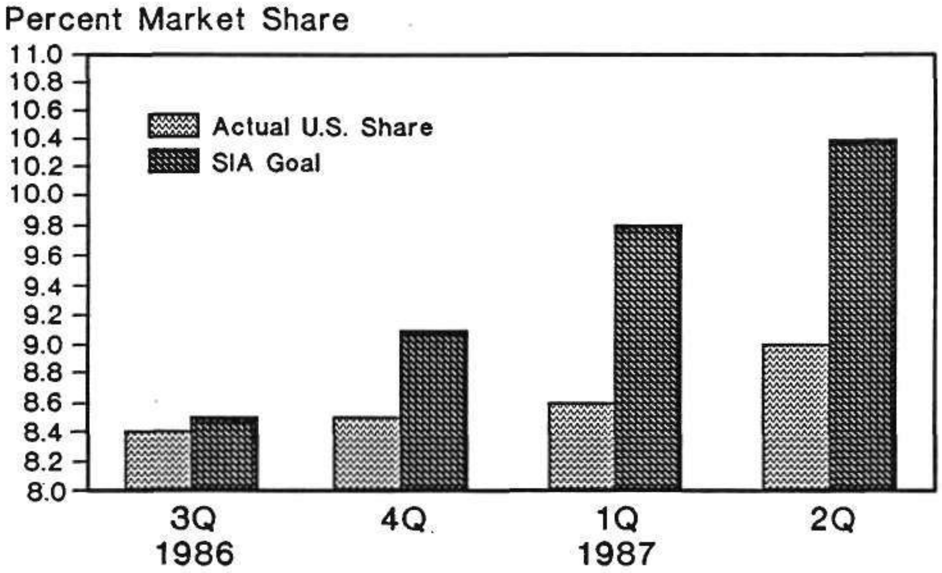
U.S. Manufacturing Trade Balance
1975 through 1986 (Est.)



Source: National Semiconductor

DIFFERENT RULES - TRADE AGREEMENT

Estimated Japanese Semiconductor Market Share



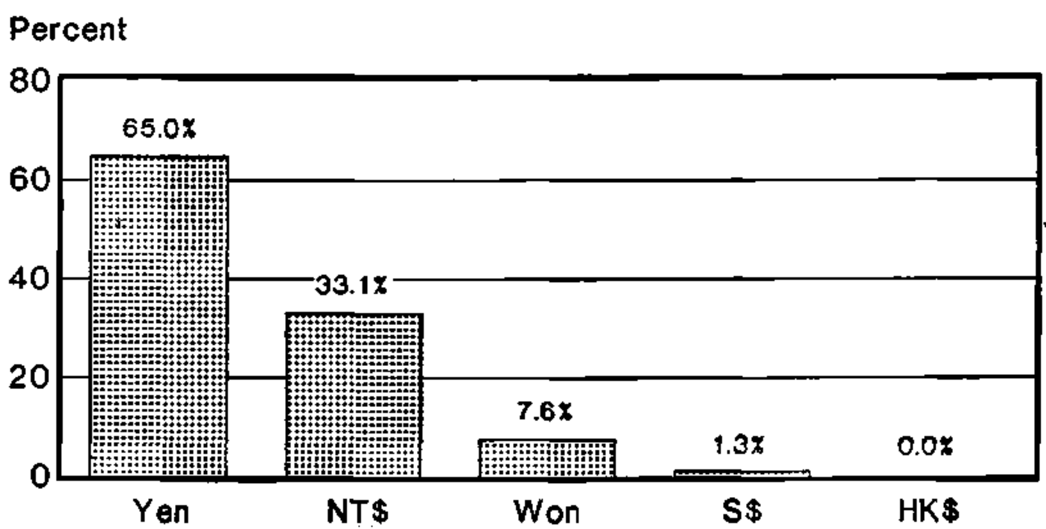
Source: Semiconductor Industry Association

DIFFERENT RULES - TARGETING SEMICONDUCTORS

- United States
  - Sematech
- Japan
  - VLSI projects
- Korea
  - VLSI projects
- Europe
  - Mega project
- Taiwan
  - ERSO

DIFFERENT RULES - CURRENCY

Appreciation against U.S. Dollar – 1985 to Present



Source: Dataquest

DIFFERENT RULES - IMPORTANCE OF ASIA

Estimated Semiconductor Market Growth
(Percent)

	1986	1987	1988
Korea	56	60	50
Taiwan	40	60	35
Hong Kong	43	65	40
Singapore	45	65	40
United States	6	20	23
Europe	17	17	19
Japan	44	14	21

Source: Dataquest

DIFFERENT RULES - MILESTONE LAWSUITS

Apple vs. Franklin	ROM software
Whelan vs. Jaslow	Structural similarities in software
Lotus vs. Paperback Software	"Look and feel"
MMI vs. Lattice/Altera	Patent infringement
NEC vs. Intel	Microcode copyright
TI vs. Japanese chip makers	DRAM patents
Intel vs. AMD	286/386 MPU

DIFFERENT RULES - PRODUCT SHIFT (ASICs)

Estimated Share of Total IC

	1986	1987	1990
Standard ICs	79%	78%	74%
ASICs	21	22	26
Total ICs	100%	100%	100%
Total (Billions of Dollars)	$23.6	$29.0	$41.0

Source: Dataquest

DIFFERENT RULES - NEW APPLICATIONS

- Minisuper PCs with voice recognition and 3D graphics
- Personal, satellite, and mobile communications
- Home control and entertainment system
- Biometric security systems
- 16-bit MPUs for engine management
- Integrated printers, facsimile, copier, data processing, and modems

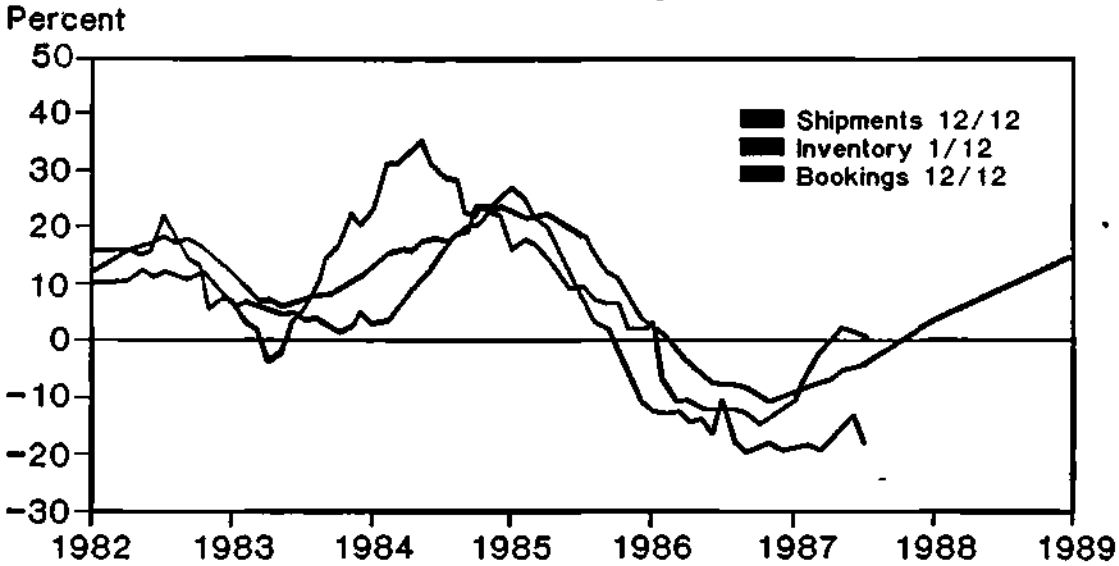
LOOKING AHEAD - ECONOMICS

	1987	1988
United States		
Real GDP	2.7%	3.6%
Industrial Production	3.1%	3.6%
Japan		
Real GDP	2.5%	3.4%
Industrial Production	2.5%	3.2%
Europe		
Real GDP	2.2%	2.2%
Industrial Production	2.8%	2.1%

Source: Dataquest Estimates

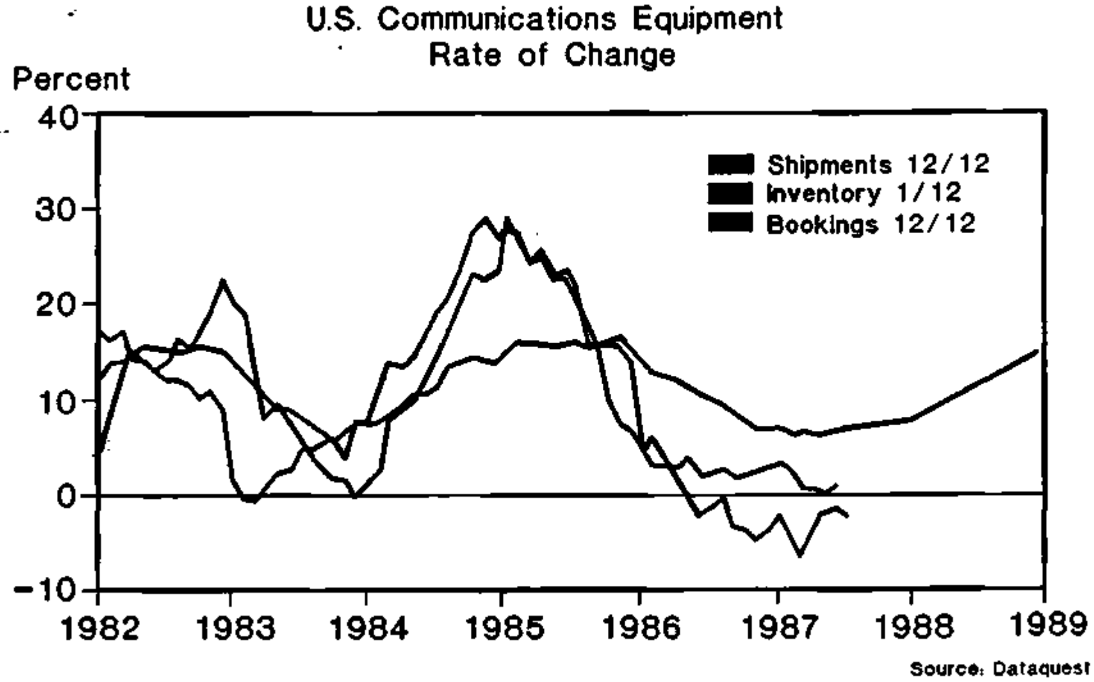
LOOKING AHEAD - ELECTRONICS

U.S. Computers and Office Equipment
Rate of Change

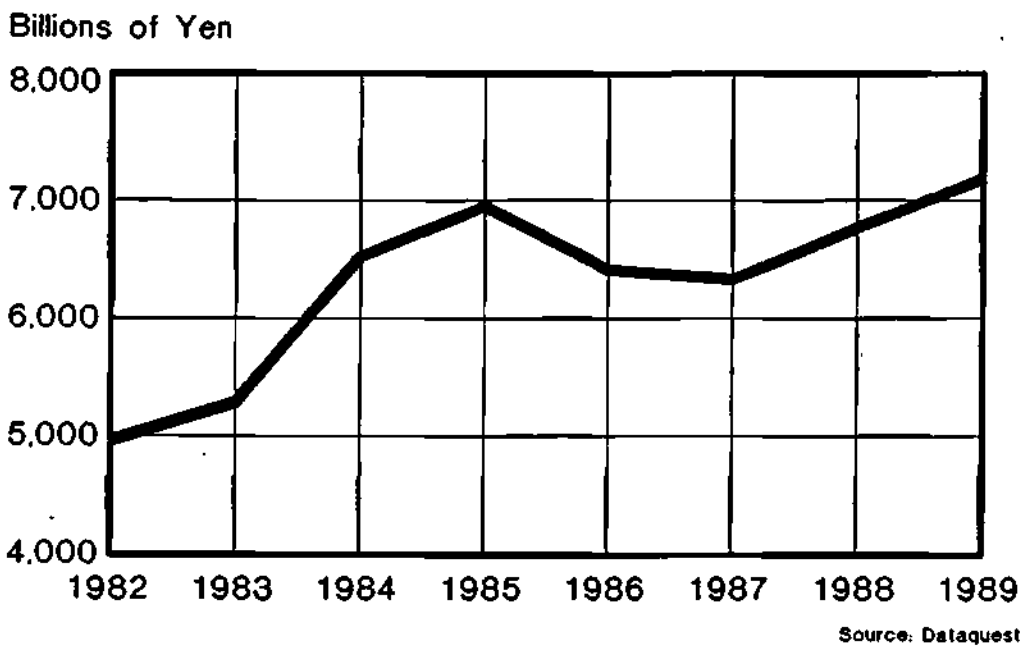


Source: Dataquest

LOOKING AHEAD - ELECTRONICS

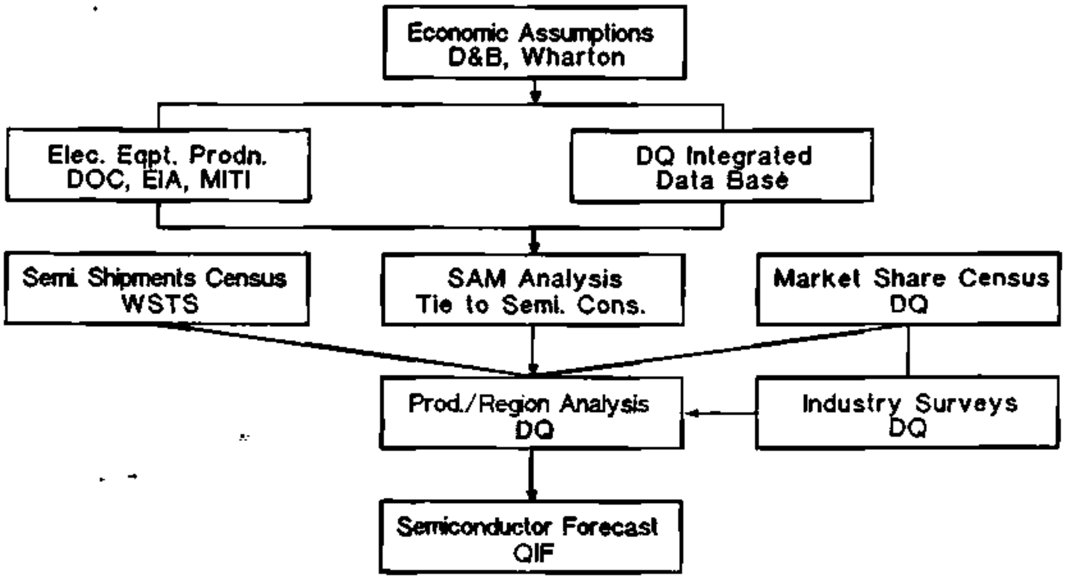


LOOKING AHEAD - ELECTRONICS



LOOKING AHEAD - SEMICONDUCTORS

Semiconductor Forecasting
QIF System



LOOKING AHEAD - SEMICONDUCTORS

Percent Change, U.S. Dollars

1987 (Preliminary)

	Q1	Q2	Q3	Q4	Year
North America	4.3%	11.7%	4.7%	5.0%	21.0%
Japan	(2.8%)	14.1%	5.4%	2.9%	16.5%
Europe	11.9%	9.9%	(1.8%)	5.3%	22.6%
ROW	16.0%	25.9%	10.7%	4.3%	68.2%
Total	4.0%	13.9%	4.5%	4.2%	23.9%

Source: Dataquest

LOOKING AHEAD - SEMICONDUCTORS

Percent Change, U.S. Dollars

	1988 (Preliminary)				
	Q1	Q2	Q3	Q4	Year
North America	5.0%	7.1%	3.1%	2.5%	23.0%
Japan	2.5%	5.8%	6.4%	3.9%	20.5%
Europe	5.1%	5.9%	3.1%	5.1%	19.0%
ROW	8.7%	11.1%	8.1%	4.7%	41.4%
Total	4.6%	7.0%	5.0%	3.8%	23.7%

Source: Dataquest

LOOKING AHEAD - SEMICONDUCTORS

High-Growth Semiconductor Products

Product	Estimated CAGR 1986-1991
Cell-Based ICs	38.6%
Specialty Memories	38.2%
DSP Chips	27.9%
Graphics Chips	42.0%
32-Bit MPUs	46.3%
8-Bit MCUs (Smart Cards)	50.0%
1Mb DRAMs	57.0%

Source: Dataquest

SUMMARY

- Same game
- Different rules
- Looking ahead

Dataquest

a company of
The Dun & Bradstreet Corporation

THE NATURE OF CAPITAL SPENDING

Robert E. McGeary
Director
Semiconductor Equipment and
Materials Service
Dataquest Incorporated

Mr. McGeary is Director of Dataquest's Semiconductor Equipment and Materials Service. He was previously a Senior Industry Analyst for Dataquest's Semiconductor Industry Service and was responsible for the Industry and Technology portion of the service. Before joining Dataquest, he was Product Marketing Manager at Applied Materials, Inc., where he managed the worldwide product marketing activities for the Dry Etch Division and managed product support for the European dry etch business. Before that, he worked as Product Marketing Manager at GCA Corporation/IC Systems Group, as Accelerator Physicist at Lawrence Berkeley Laboratories, as a nuclear engineer at Mare Island Naval Shipyard, and as a reactor operator at the University of Washington. He received B.S. degrees in Physics and Mathematics from the University of Washington and an M.B.A. degree from St. Mary's College.

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Semiconductors' Midlife Crisis

Economic and Industry Outlook

ROBERT McGEARY

Director, Semiconductor Equipment and Materials Service
Dataquest Incorporated

Semiconductors' Midlife Crisis

THE NATURE OF CAPITAL SPENDING

ROBERT E. McGEARY

Director

Semiconductor Equipment and Materials Service

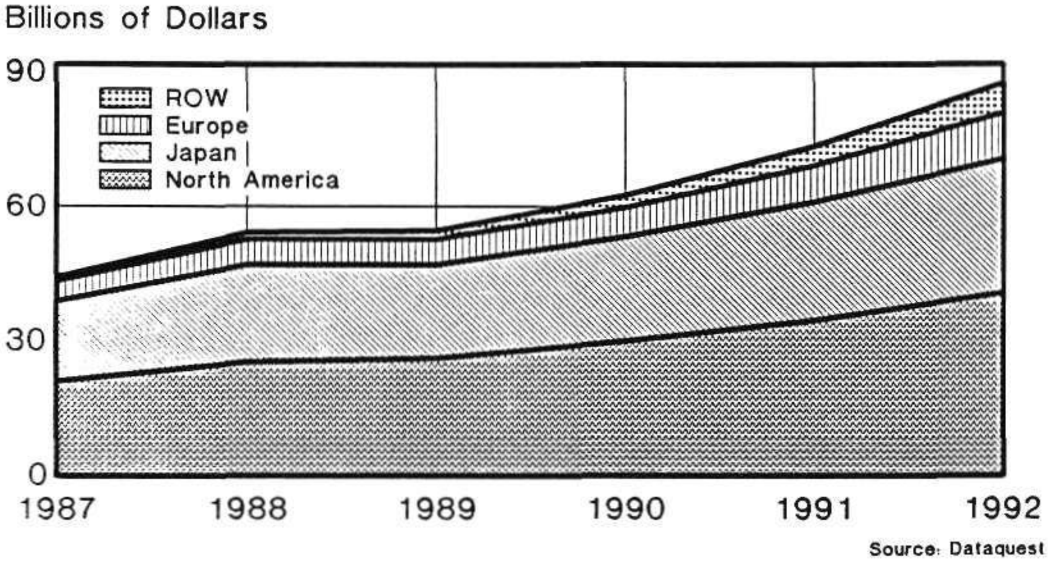
Dataquest Incorporated

AGENDA

- Capital spending and capacity
- The nature of capacity
- Technology-driven upturn
- Factory evolution
- Summary

WORLDWIDE SEMICONDUCTOR FABRICATION

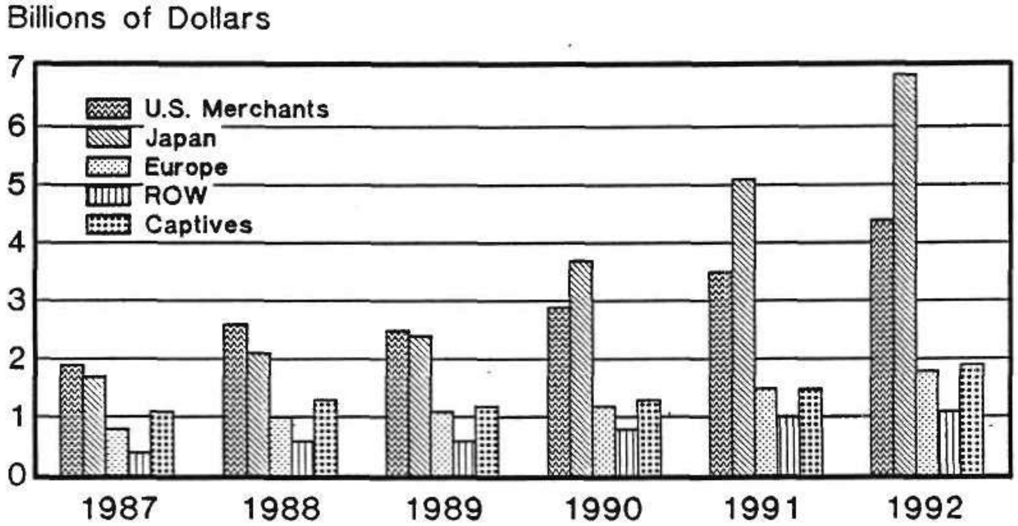
Annual Forecast Growth



Source: Dataquest

WORLDWIDE CAPITAL SPENDING

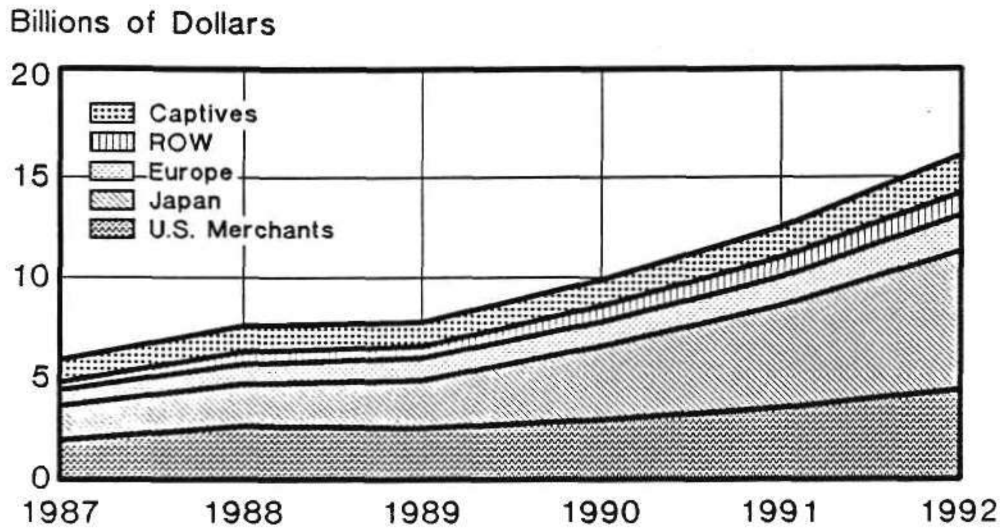
Annual Dollar Forecast



Source: Dataquest

WORLDWIDE CAPITAL SPENDING

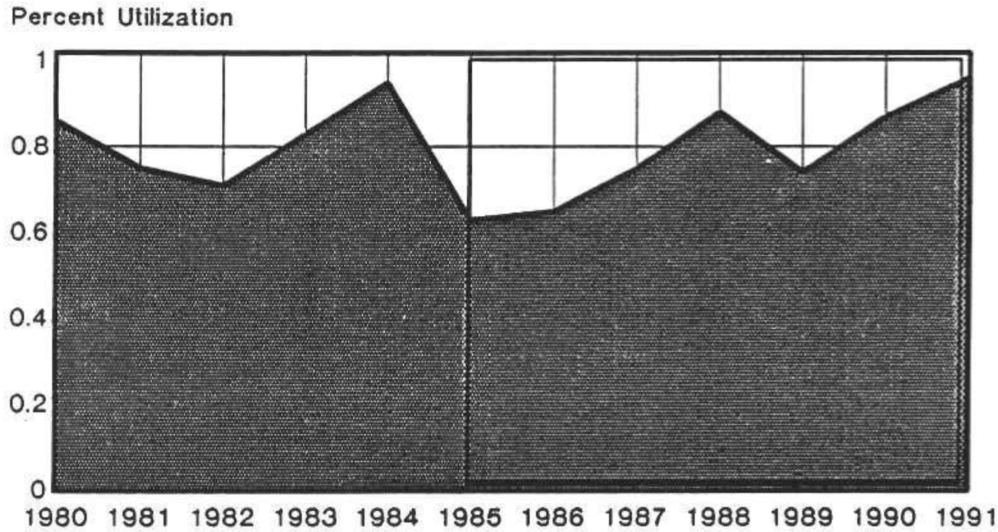
Annual Dollar Forecast



Source: Dataquest

WORLDWIDE CAPACITY UTILIZATION

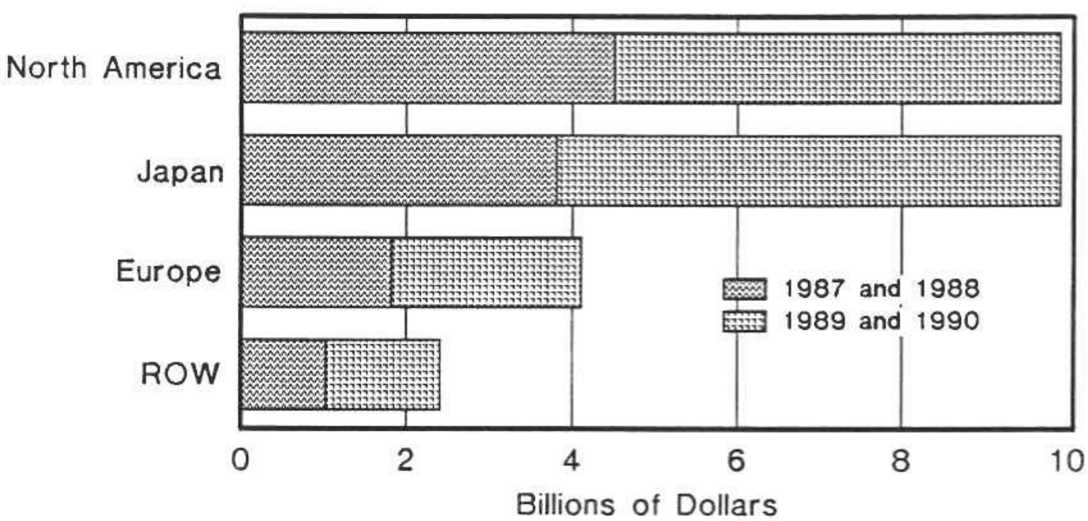
Climbing Out of the Hole



Source: Dataquest

WORLDWIDE MERCHANT CAPITAL SPENDING

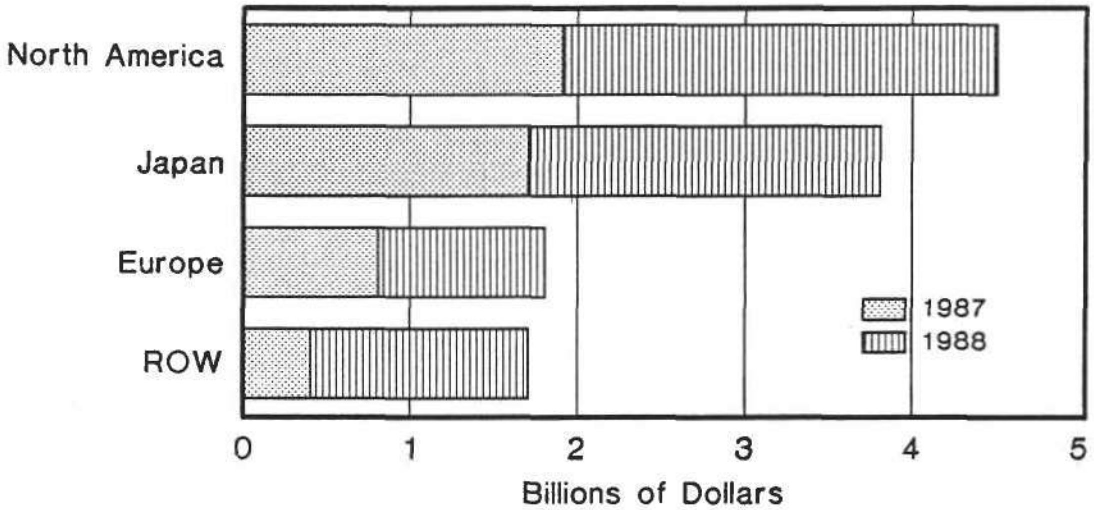
1987 through 1990



Source: Dataquest

ESTIMATED MERCHANT REGIONAL CAPITAL SPENDING

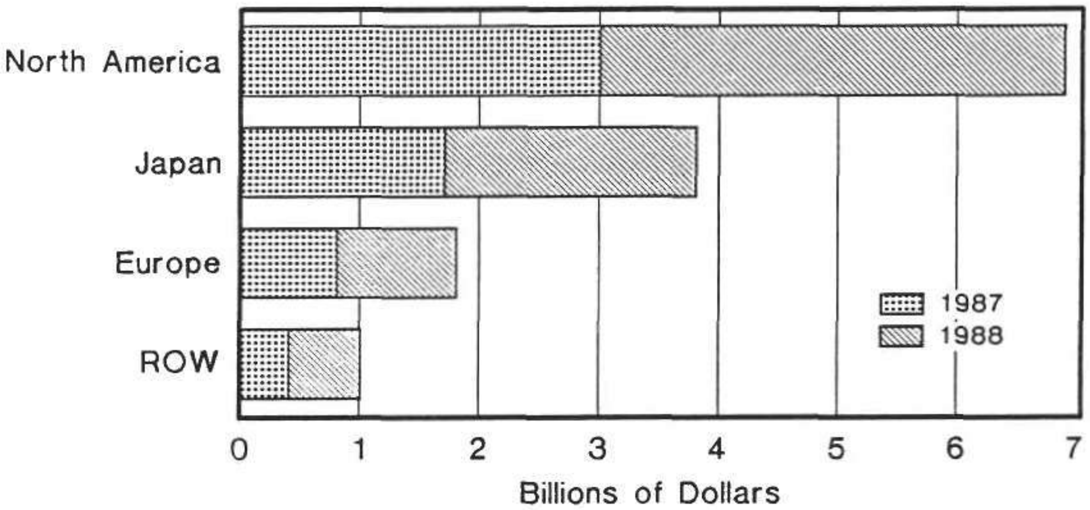
1987 and 1988



Source: Dataquest

ESTIMATED TOTAL REGIONAL CAPITAL SPENDING

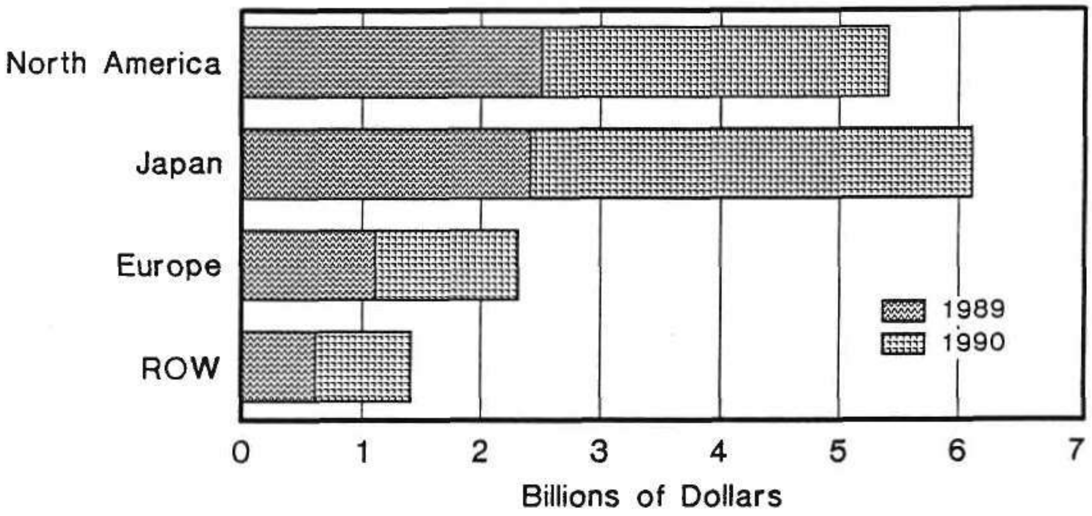
1987 and 1988



Source: Dataquest

ESTIMATED MERCHANT REGIONAL CAPITAL SPENDING

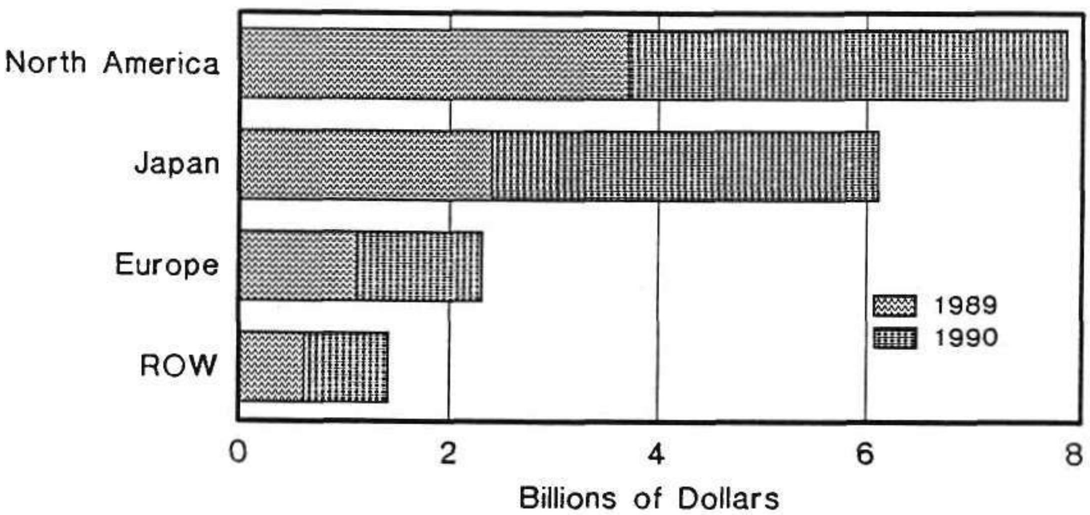
1989 and 1990



Source: Dataquest

ESTIMATED TOTAL REGIONAL CAPITAL SPENDING

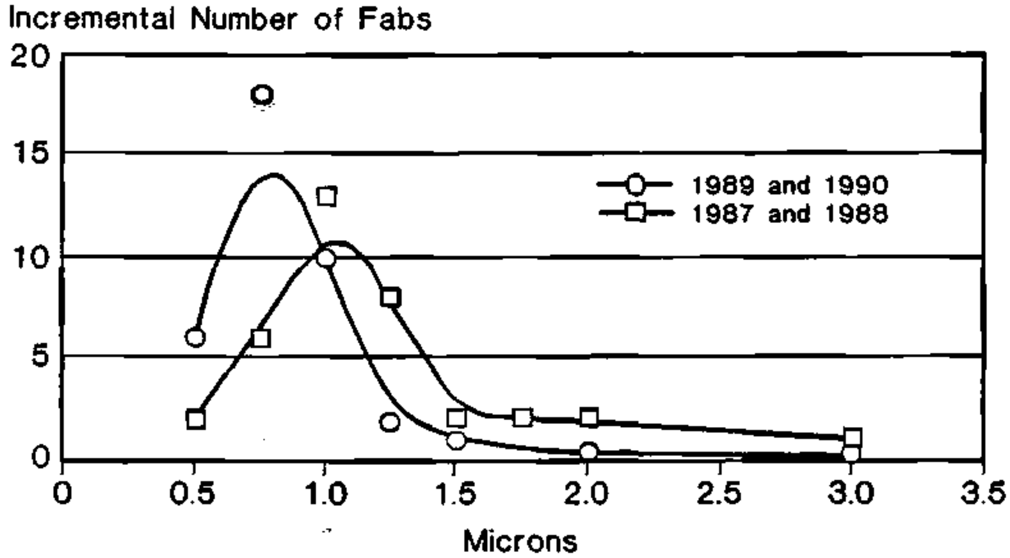
1989 and 1990



Source: Dataquest

PRODUCTION GROWTH

Ranked by Line Geometry



Source: Dataquest

REQUIRED FABRICATION PROCESSES

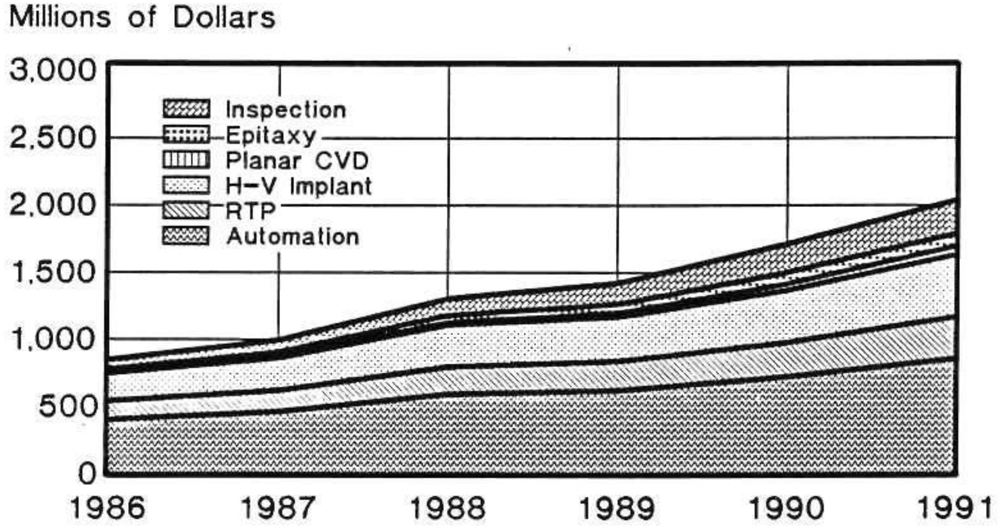
Below 1 Micron

- Planar CVD
- Rapid thermal processing
- High-voltage implantation
- MOS on epitaxial layers
- In-line inspection
- Wafer cleaning

  and
- Optical steppers

NEW PROCESS EQUIPMENT

Forecast Dollar Sales



Source: Dataquest

REQUIRED FABRICATION PROCESSES

Below 1 Micron

- **Planar CVD**
- Rapid thermal processing
- High-voltage implantation
- MOS on epitaxial layers
- In-line inspection
- Wafer cleaning

  and
- Optical steppers

CVD NEEDS

4Mb Requirements

- Eliminate hillock formation
- Improve film uniformity
- Improve cleanliness
- Improve film planarity

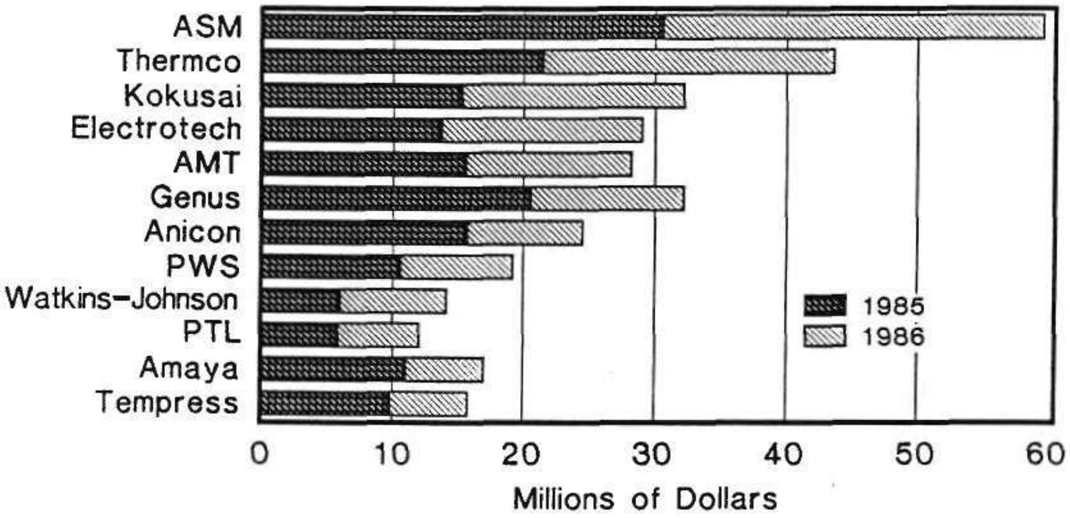
PLANAR CVD STRATEGIES

Dielectrics vs. Refractories

- Dielectrics
  - Applied Materials
  - Novellus
  - Focus
  - Electrotech
  - Machine Technology
  - Sumitomo
- Refractories
  - Varian
  - Ulvac
  - Genus
  - Spectrum CVD

CVD SHARES

Worldwide Dollar Sales



Source: Dataquest

REQUIRED FABRICATION PROCESSES

Below 1 Micron

- Planar CVD
- **Rapid thermal processing**
- High-voltage implantation
- MOS on epitaxial layers
- In-line inspection
- Wafer cleaning

  and
- Optical steppers

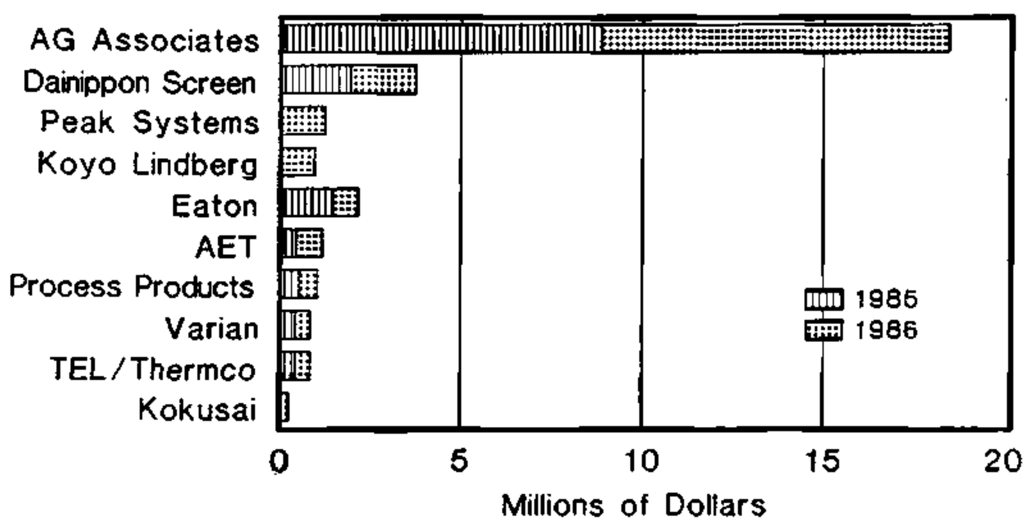
RTP DRIVING FORCES

Lower Thermal Budget

- Better junction definition
- Rapid anneal after implant
- Improved well profiles

RTP SHARES

Worldwide Dollar Sales



Source: Dataquest

REQUIRED FABRICATION PROCESSES

Below 1 Micron

- Planar CVD
- Rapid thermal processing
- **High-voltage implantation**
- MOS on epitaxial layers
- In-line inspection
- Wafer cleaning

  and
- Optical steppers

EPI/HV IMPLANT TRADE-OFFS

Finding the Window

Attribute	Epitaxy	HV Implant
Device Performance	Good	Adequate
Latch Immunity	Good	Good
Equipment Cost	› $1M	› $2M
Availability	Now	Development

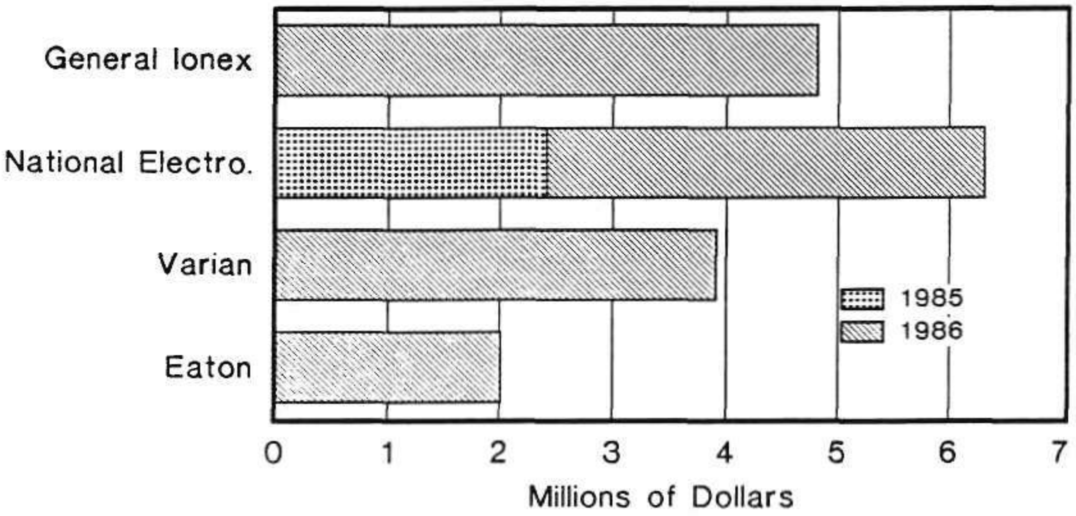
HV IMPLANT APPLICATIONS

Performance Benefits

Applications	Benefit
Field Isolation	Increased Density
Retrograde Wells	Latch-up Immunity
Buried Grid	Soft Error Immunity
Buried Layer	Latch-up Immunity
ROM Programming	Yields, Turnaround

H-V IMPLANTER SHARES

Worldwide Dollar Sales



Source: Dataquest

REQUIRED FABRICATION PROCESSES

Below 1 Micron

- Planar CVD
- Rapid thermal processing
- High-voltage implantation
- **MOS on epitaxial layers**
- In-line inspection
- Wafer cleaning
  and
- Optical steppers

MOS ON EPITAXY

The Die Is Cast

- Process benefits
  - Latch-up immunity
  - Device performance
- Cost and quality are issues
- New products
  - Applied Materials 7010
  - Gemini Tetron I
  - Epsilon/ASM - October introduction

REQUIRED FABRICATION PROCESSES

Below 1 Micron

- Planar CVD
- Rapid thermal processing
- High-voltage implantation
- MOS on epitaxial layers
- **In-line inspection**
- Wafer cleaning
  and
- Optical steppers

IN-LINE WAFER INSPECTION

Keeping an Eye on the Process

Company	CD	Defects
Cambridge Inst.	Polycheck	
Heidelberg Inst.	LPM	
IVS, Inc.	AccuVision	
Nanometrics	Model 400	
OSI*	MV-360CD	MPC System
KLA*		2028/2030
Insystems*		Model 8600
Nikon	LAMPAS-HD	
Wild-Leitz	MVP-CD2	WIS
SiSCAN	SiSCAN-IIA	
Waterloo	WSI-1000CD	
Vickers	Quaestor	
Estek/Aeronca		AE 1000
Hitachi	LAMU-600	

*Fully automated inspection

REQUIRED FABRICATION PROCESSES

Below 1 Micron

- Planar CVD
- Rapid thermal processing
- High-voltage implantation
- MOS on epitaxial layers
- In-line inspection
- **Wafer cleaning**

  and
- Optical steppers

WAFER CLEANING

The 10 Percent Solution

- Deposition/implant processes
  - Pre-furnace
  - Pre-epi
  - Pre-CVD
- Megasonic cleaning
  - Verteq (600 systems)
  - FSI (120 systems)
  - Estek/Kodak (20 systems)
- Oxidation etch
  - HF dip
  - FSI/Excaliber

REQUIRED FABRICATION PROCESSES

Below 1 Micron

- Planar CVD
- Rapid thermal processing
- High-voltage implantation
- MOS on epitaxial layers
- In-line inspection
- Wafer cleaning

 and

- **Optical steppers**

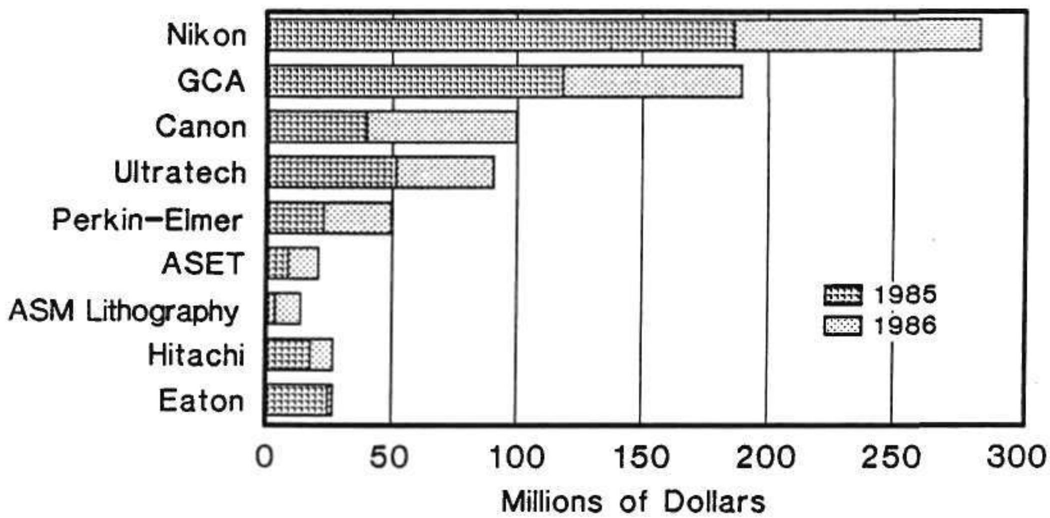
DEVICE GEOMETRIES

The Leading-Edge Technology

Decade/Technology	Beginning	End
1970s - Optical Proj.	1K-4µM	16K-2.5µM
1980s - Optical Step.	64K-2µM	1M-1.2µM
1990s - Optical Step.	4M-0.8µM	64M-0.4µM
2000s - X-ray?	256M-0.3µM	4B-0.15µM

STEPPER SHARES

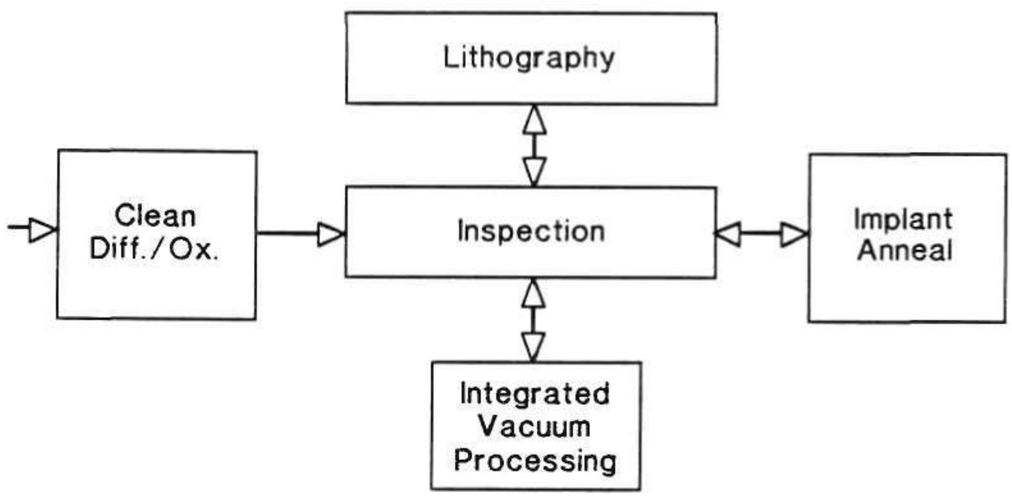
Worldwide Dollar Sales



Source: Dataquest

FABRICATION EVOLUTION

Islands of Automation



INTEGRATED VACUUM PROCESSING

Multichamber Capability

Company	Capability
Applied Materials	CVD, Etch
Varian	CVD, Etch, PVD, RTP
Anelva	Etch, PVD
Ulvac	CVD, Etch, PVD
General Signal	CVD, Etch, PVD
Electrotech	CVD, Etch
LAM/Sumitomo	CVD, Etch
Spectrum CVD/Tegal	CVD, Etch
MRC/NTT	CVD, PVD, Etch

SUMMARY

This Is What I Said

- The incipient upturn
  - Now through 18 months – capacity
  - After 18 months – technology
- Production
  - Balancing the Occident and the Orient
  - Vertical integration is important
- One billion transistors on a chip
  - In a mere 20 years
  - The possibilities are ***LIMITLESS***

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Semiconductors'
Midlife Crisis

Technology over the Next 40 Years

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VLSI DEVICES FOR THE HUMAN-MACHINE INTERFACE

Michael J. Thompson
Executive Director
Integrated Circuit Design Division
AT&T Bell Laboratories

Mr. Thompson is Executive Director of the Integrated Circuit Design Division of AT&T Bell Laboratories. This division designs a broad range of VLSI telecommunications devices and application-specific integrated circuits for AT&T, featuring leading-edge linear and digital CMOS technologies and advanced CAD methods. Earlier at AT&T Bell Labs, Mr. Thompson worked on radar systems for ballistic missile defense and led the development of digital coding and transmission equipment for video-telephone applications. He has served as director of development organizations responsible for digital transmission terminals for No. 4 ESS and other applications, for DIMENSION PBXs, and for local central office switching. Mr. Thompson holds bachelor's degrees in Liberal Arts and Electrical Engineering from the University of Notre Dame and an M.S. degree in Electrical Engineering from New York University.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

Technology over the Next 40 Years

MICHAEL J. THOMPSON

Executive Director
Integrated Circuit Design Division
AT&T Bell Laboratories

VLSI EVOLUTION

	MEMORY	LOGIC
STAGE 1 Replacement	Alternative to Ferrite Cores	Gate Consolidation
STAGE 2 New Methods	Transistor — Capacitor Cell	Dynamic Logic
STAGE 3 New Horizons	Merged Storage and Logic	VLSI Architecture

VLSI CUSTOM DESIGN CAPABILITY

How the challenge has evolved

			# of Transistors
1977	**—**	**Prove a custom chip can be defined, designed, debugged, and manufactured**	**3×10^3**
1982	**—**	**Establish a dependable, error-free design system with productivity growth matching chip complexity growth**	**3×10^4**
1987	**—**	**Create new applications made feasible by VLSI**	**3×10^5**

CUSTOM VLSI ⟷ HUMAN-MACHINE INTERFACE

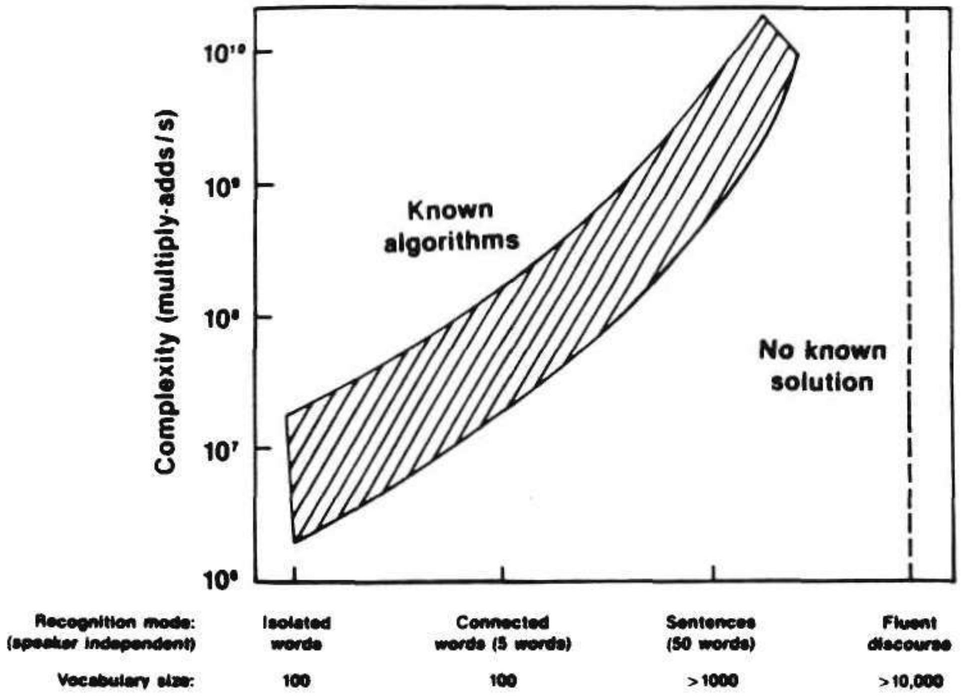
- **Complex algorithms become feasible**
- **Dedicated design accelerates performance to real-time level**
- **Two-dimensional sensing requires high resolution arrays**

SOME APPLICATIONS

Speech	**Text-to-speech synthesis**
	Connected word recognition
Vision	**Graphics display processing**
	Robotic vision
AI Systems	**Massively parallel computers**
	Neural networks

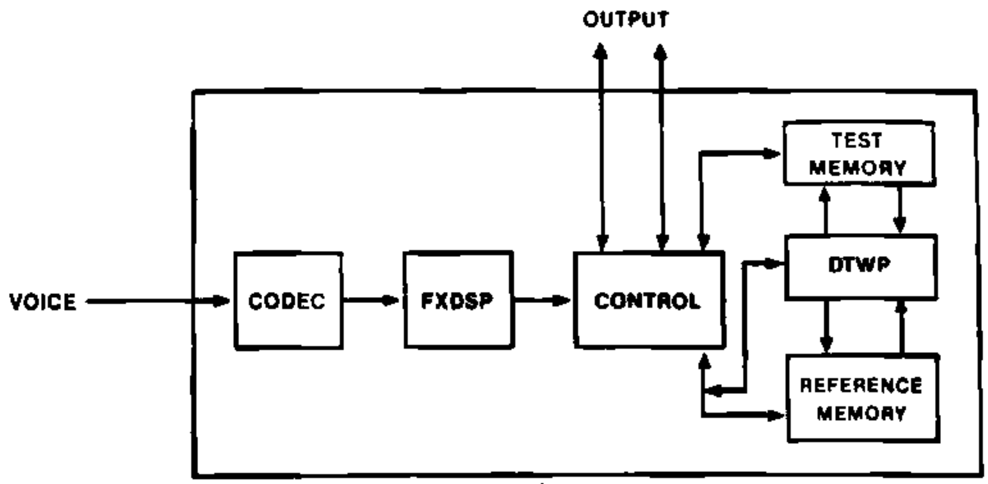
VLSI ⟷ *SPEECH*

Synthesis	—	**Stored patterns** **Text-to-speech**
Recognition	—	**Isolated word** **Connected speech**
Coding/Compression	—	**Waveform processing** **Feature extraction**
VLSI Devices	—	**Dynamic time warp processor** **Digital signal processor** **Graph search machine**



Complexity (multiply-adds/s)
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
Known algorithms
No known solution
Recognition mode: (speaker independent)
Isolated words
Connected words (5 words)
Sentences (50 words)
Fluent discourse
Vocabulary size:
100
100
>1000
>10,000

ISOLATED WORD RECOGNITION



DIGITAL SIGNAL PROCESSORS

- **Basic building block for speech processing**
- **Performs feature extraction for word recognition**
- **1.0μ CMOS DSP**

  140,000 transistors

  16-bit multiplication
  36-bit addition

  60 nsec cycle time

  2048 16-bit program memory
  512 16-bit data memory

GRAPH SEARCH ALGORITHMS

- **Applicable to a broad set of recognition and processing functions**
- **Utilize different math operations**

  DSP: Multiply-accumulate

  GSM: Minimum-accumulate
- **Can be realized as VLSI device**

  1.5μ CMOS

  35,000 transistors

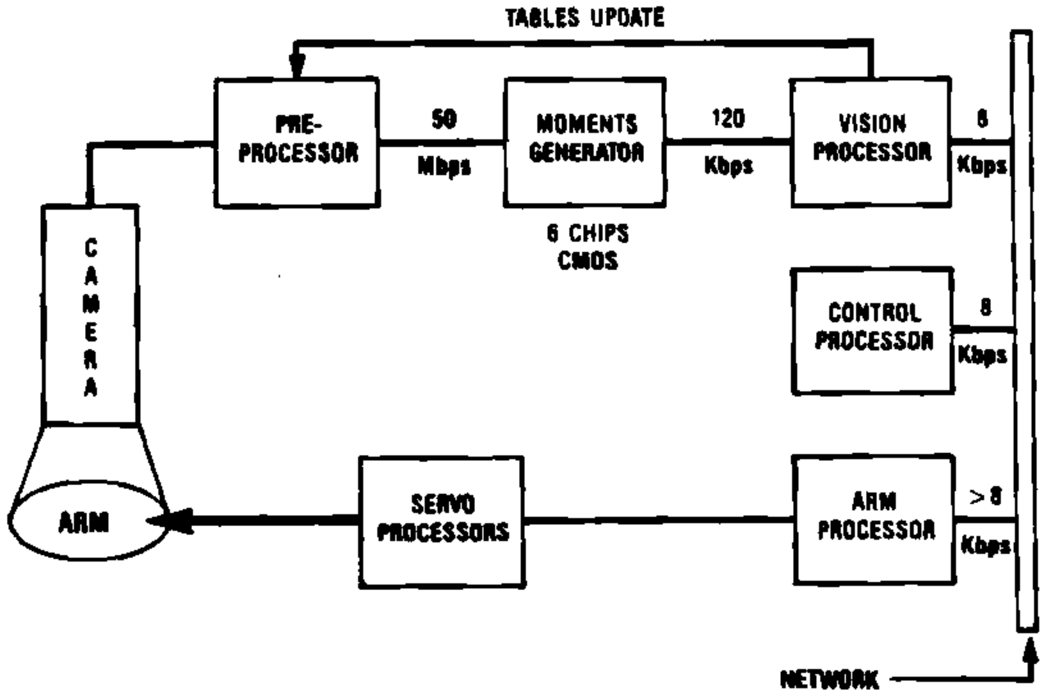
  40 MIPS

  Searches 500 patterns in real time

VLSI ⟷ *VISION*

Scanning	**— Conventional video raster the dominant approach**
	— Innate parallelism not used, creating high apparent data rates
Processing	**— Data compression Feature extraction**
VLSI Devices	**— 1.4 × 10^6 pixel CCD imagers 45 Mb/s DPCM video CODECs Moment generators for robotic vision Wafer scale graphics processors**

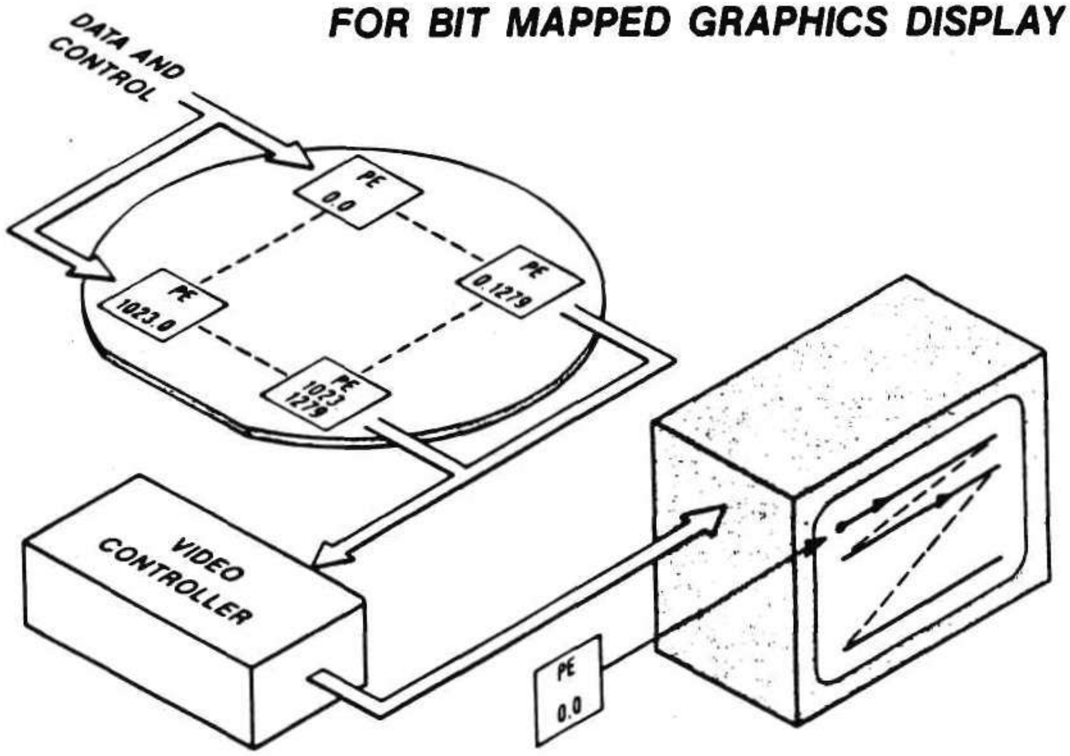
REAL-TIME ROBOT VISION SYSTEM



HUMAN / MACHINE ISSUES FOR BIT-MAPPED GRAPHICS DISPLAY

- **Resolution: 1280 pixels × 1024 lines typical**
- **Image realism: 24 bits/pixel**
- **Display update interval: 10^5 tiles/sec**
- **Applications software**
  - **Human/machine interaction**
  - **Performs useful tasks**

WAFER SCALE PROCESSING FOR BIT MAPPED GRAPHICS DISPLAY



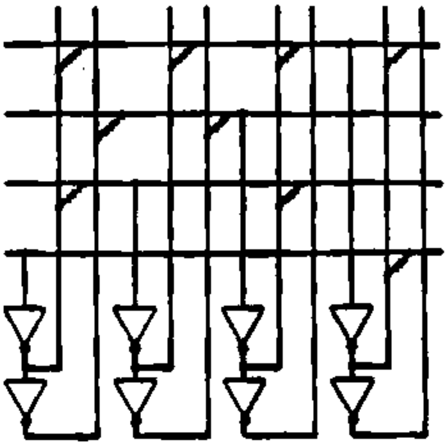
VLSI ⟷ AI SYSTEMS

- **Aside from sensing, little application of specialized hardware**
- **Highly parallel computer architectures a major focus**
- **Neural networks a promising approach**

VLSI Devices — High connectivity processing elements
Associative (neural) memories

ASSOCIATIVE MEMORY CIRCUIT

MATRIX OF RESISTIVE INTERCONNECTIONS



ARRAY OF AMPLIFIER UNITS

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PAST AS PROLOGUE

Jack S. Kilby
Independent Consultant

Mr. Kilby is an independent consultant. Previously, he worked with Texas Instruments, where he was responsible for the invention and development of the monolithic integrated circuit. He has been awarded more than 50 patents for his work in the integrated circuit field, including the first patent for a hand-held calculator and the first patent on a semiconductor thermal printer. Mr. Kilby also worked at the Centralab division of Globe-Union, Inc., where he was responsible for the design and development of thick-film hybrid circuits and compatible transistors. He received a B.S.E.E. degree from the University of Illinois and an M.S.E.E. degree from the University of Wisconsin. Mr. Kilby's accomplishments have been recognized by the Institute of Electrical and Electronic Engineers and other technical groups, and he has received the National Medal of Science and has been inducted into the National Inventors Hall of Fame.

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Semiconductors' Midlife Crisis

Technology over the Next 40 Years

JACK S. KILBY

Consultant

PAST AS PROLOGUE

You've all heard of the value of redundancy in electronics and this morning you may get more than you would like, since I should've coordinated my talk with Gordon [Moore], and did not. Some of these things will seem a little repititious, but I agree completely with his opening statement that the inverse of Murphy's Law is very much at work, that the industry has really been based on this rather peculiar circumstance: that as geometry shrinks, everything gets better. Certainly the costs decrease, the performance goes up and it's been an unmixed blessing. And because that's so, it's all been rather easy to plot our progress because much of it stems back to a single factor and that is geometries, line widths (call it what you will). What I have done this morning is take a set of four of those parameters, for which there is very good historical data, and extrapolated them for the next forty years, which is very easy to do because they are all straight-lined. In every case I think I showed the source of the data which I used for the extrapolation and I would like to make it very clear at this point that those people are innocent participants in this. They did not contribute to the extrapolation, they are not aware of it, and in no way can they be held responsible for the thing.

As they say, the size dependence is a very critical thing, and we do have a great deal of history on this; we also have some fairly recent projections into the next ten or fifteen years. In this case, what it shows is that today's line widths are typically one micron. They might be something like .15 microns by the year 2000 and go to around 500 angstroms by 2027. 500 angstroms, of course, is getting very small. The other thing that has gone along with this sort of projection is chip size projections and particularly for memories. For quite a long time we were able to make each successful increase by a factor of 4 in the memory capacity without much change in chip size. More recently, each time the memory increases by 4, the size is roughly doubled. So that this projection carries us again to the year 2000, starting with a chip roughly 1/4" on a side in 1985. By the year 2000 the chip would be 2" on a side and by the year 2027, they would be 12" on a side. A square foot of silicon!

I'm sorry Gordon has left, but this is the famous "Moore curve" which has been slightly modified by Intel to separate out memory and logic. What this shows is that the megabit chip was first introduced in 1985. We should hit a gigabit by the year 2000 and I don't know the term for it, but we'd have 10^{13} bits on this square foot chip in the year 2027. Logic, as you will notice, falls considerably behind this. The 386 has about 300,000 transistors, and could be considered a 1985 unit. These projections would suggest that you might have about 15 million transistors by the year 200, and 10^{11} by 2027.

And finally, memory cost per bit, which has been a very dramatic one, around 10^{-3} cents per bit in 1985, 10^{-5} cents in the year 2000, and 10^{-11} cents per bit in the year 2027. Interestingly enough, this one-square foot package with 10^{11} bits in it is going to cost about $3 a package and that's a little surprising but our Dallas newspaper the other day carried the story of an analyst on the West coast who noticed that memory packages always cost a couple dollars a bit. He had read that IBM was working on 16- and 64-megabit chips and his conclusion was that this was a time to sell your stock in the disk drive manufacturers. So as extreme as these things are, they have had some significance: they are used by planning and for projections over the next few years by almost every company in the business. Admittedly, nobody carries them for forty years but they have provided a road map and guidance. So I think it's worthwhile to go back through these, and let's talk about them a little bit and perhaps we can see where each of them might begin to shift a little bit because I think it's pretty obvious that regardless of your faith in integrated circuits and humanity, that we ain't gonna sell one square foot chunks of silicon in a plastic package for $2 in the year 2027.

The memory linewidth actually includes a number of factors. Lithography, of course, is extremely important, but it also requires the development of a full set of related processors to go along with it. Line width is of particular importance in the future and today substantially all of our integrated circuit designs are dominated by their interconnections. The active device areas, and things of that sort, are not too important. Some of this pressure has been relieved by the development of double level and triple level metal, perhaps if Gordon is right and we have 40 levels by the year 2000, 2/3 of those will be interconnect. But the other parameter which doesn't show in here is device performance and that does begin to level off as the geometries approach 1/4 micron and drop below it.

In the case of chip size, Gordon mentioned the reduction in defects. This has been extremely important, the progress of this curve just simply wouldn't have happened without those changes. Today the best fabs in the world, those producing large memory chips, are running well below one defect per square centimeter and these benefits that Gordon talked about are very real. On the other hand, it does mean that we are not going to double yields again. They are already above 50% in many of these cases. To achieve this requires a dedicated front end for the purpose. And today memory fabs are built to produce basically only memory chips. So that some of this improvement in defect density has come at the expense of flexibility.

Another trend which is apparent in here is that increasing portions of the process cost are becoming area dependent. A wafer stepper, for example, takes a given time to cover a 4" wafer and a longer time to cover a 6" and a still longer one to cover an 8". The ion implant processes are the same, so that to the extent that these area dependent processes come into play from a cost standpoint it makes less and less sense to make the chips bigger and bigger. There may still be performance reasons for wanting to do that, but the economics do not show the same kinds of gains that we've seen in the past.

This is particularly important in the case of memory, where a megabit memory doesn't provide any function that four 256K chips will provide. People want to buy megabit chips and will buy them when they are convinced that they will cost less than the 256K chips over the life cycle of the equipment that they are producing. It's true that there are some minor performance advantages that go with that, but these could probably be realized by shrinking the geometries on the 256K. So, particularly in the case of memory, chip size is a purely economic decision and I think that maintaining progress on these costs will be extremely difficult to do.

In complexity, again, it's essential to separate the memory and logic. Memory is a very easy case in that the next generation of products is very readily definable. A very long time ago it was determined that memory should increase in factors of 4 and we've been doing that so that people can tell you that we're going to do 1 megabit, 4 megabits, 16 megabits, 64 megabits, and keep talking until they are tired. Memory is also simpler in that it has very regular interconnections and so it's very understandable that the memory complexities are appreciably higher than logic.

I think that if we were to look today, we would find that this gap which you see between memory and logic has already begun to widen considerably more than this shows. One reason for that is that the logic designs are expensive and becoming more so. We designed the Series 51, which was a family of 6 not-very-good integrated circuits in 1960 at a total cost of something less than $50,000. Today a new microprocessor design has been quoted at $50 million. There has been a tremendous amount of progress in computer-aided design and reduction of design costs, but what that's done so far is make an intolerable cost just painful. There is a great deal more to be done in that area and unless it is done, the size of the logic chips will be limited.

It's also possible, I think, that we will begin to see for the first time, a split in integrated circuit applications because of the smaller is better thing. The smaller parts always became over time the lowest cost parts. This may not always be true: it may be possible and desirable, as the cost of these smaller geometries increase, that designs will deliberately use looser design rules, wider spacing, simply to achieve lower costs and this would be a significant difference.

Finally, in the memory cost per bit, this is a very difficult area. In the past, memory cost projections have been important guideposts for the industry. Today, I think we have somewhat lost that. One of the reasons is that memory has become particularly capital-intensive. The time cost of these changes may be as much as five years when the memory producers build new plants for a new generation because they are so capital-intensive by semiconductor standards. As such, the most economical course is to operate these at the maximum rate and to take what you can get for the product. We do know that if you look at the profits of the semiconductor makers who made most of the memory chips last year, that they may have lost as much as $2 billion on perhaps $6 billion worth of memory billings. It's not fair to say that all of those losses were ascribed to memory, but I would think that they probably didn't lose very much on chips for VCRs or TV sets. So that there is some uncertainty in that portion of it.

Finally, at the moment, the price for memory chips is being set by bureaucrats in Tokyo and Washington who are armed with charts like this one and so that I think in terms of memory cost per bit, we really don't know where we are on this curve anymore. I feel sure that the 1 megabit, 4 megabit chips will arrive, but they may not arrive quite on schedule and that if this is progressing more rapidly than the cost structure will support, the optimum strategy is probably to delay the introduction or to announce its limited availability for fairly long periods. And I think it's very questionable whether you should assume that each new generation of memory products is going to appear on the same time schedule it has in the past.

So I think for many reasons that these curves that you've seen will probably begin to show inflection points within the next five years. I think it inevitable. I don't think that this is necessarily bad for the industry, in part because the ever increasing capital expense required to pursue this may not make it very profitable course, anyway.

It's also, of course, stupid to expect to extrapolate anything for 40 years. As Mike [Thompson] has told you, DeForest would not have projected the transistor when he did the first triode. It would not have been reasonable to expect even Shockley to project our 1985 or 1986 results. What we can be sure of is that some things will happen to change these.

We can speculate a little on what it would take to change these things. I think we know that the substitution of a new device for the existing silicon transistor will not have very much impact. I'm sorry if that offends the gallium arsenide people, but I think we've learned that on these highly complex circuits, the performance is so completely dominated by the interconnect that it makes very little difference whether you're talking about silicon transistors, gallium arsenide transistors, or Josefson Junctions. The performance and the complexity is much the same for all of those and since silicon has such a tremendous head start, as well as the benefit of the large planning, as Gordon told you, it's very difficult to see how that would produce an inflection point.

I do think that there are some other things that are apparent: particularly for logic circuits. These increased design costs have to be recovered in some way and one of the difficulties of projecting a 100 million bit logic circuit is finding an application that can pay for the design. In many cases, if you were able to recover a normal profit on the engineering costs involved in designing it (the normal NRE expense), you could afford to give away the production units and this is a change that I think the industry has been slow to make. It's true that in gate arrays, some of the standard cells, that people have begun to pay these NRE costs. In very few cases, though, I think, are they expected to pay the full cost. The company tends to assume that there will be some production following, and basically underbids in recovering their engineering expense. This, I think, will have to change and probably do so rather quickly.

I think another trend worth noting is that these designs that we're talking about will be better protected than they have been. For the first 30 years of this semiconductor activity that we're talking about, patents were basically of little value in this country. The corporate objective was to swap them with other people so that they didn't have to pay any royalties and didn't have to be bothered with it. Within the last few years, the value of intellectual property has gone up probably more rapidly than Moore's curve. And it does mean that people who do original designs and original processes will try very hard to protect them. I think this will make it more difficult for some of the smaller ventures, particularly those that are parasites (to use Gordon's phrase), to actually get off the ground.

As I said, I don't think there's a lot of progress to be made in devices. I think that architectures are extremely promising, because these have the possibility of reducing the interconnection difficulties. I was interested in your garden slug analogy, Mike, because that has relatively few interconnections for the area, at least as I've read the thing and there are undoubtedly clues in that.

So I think we'll progress and I think that we may progress at the same rate that we have in the past, but I don't think we'll do so on the basis of these every decreasing line widths and ever decreasing cost per function.

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TECHNOLOGY BEGINS AT 40

Gordon E. Moore
Chairman of the Board
Intel Corporation

Dr. Moore is Chairman of the Board and a cofounder of Intel Corporation. He served initially as Executive Vice President of Intel, then became President before being elected Chairman and Chief Executive Officer. Before founding Intel, Dr. Moore was Director of Research and Development for the Fairchild Semiconductor Division of Fairchild Camera and Instrument Corporation, which he cofounded in 1957. He is a member of the National Academy of Engineering, a Fellow of the IEEE, and a Trustee of the California Institute of Technology. Dr. Moore earned a B.S. degree in Chemistry from the University of California at Berkeley and a Ph.D. in Chemistry and Physics from the California Institute of Technology.

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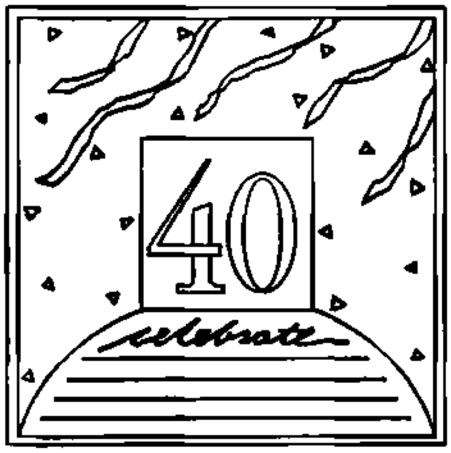

Semiconductors' Midlife Crisis

Technology over the Next 40 Years

GORDON E. MOORE

Chairman of the Board
Intel Corporation

TECHNOLOGY AFTER 40

Now we know the logic power it takes to make a garden slug; I wonder what it takes to make someone that can defeat a garden slug (Ed. note: reference to speech by Mike Thompson, AT&T).

I was asked to map the course of technology for the next forty years in twenty minutes; that's about two years a minute so you'll have to pay careful attention here. The technology certainly has evolved rapidly throughout the thirty plus years I've been associated with it. I am continually amazed at what we're able to accomplish frankly. Two things have been key in driving this technology. One is what I call a violation of Murphy's Law. We have a peculiar situation here where making things smaller seems to improve them in all dimensions simultaneously with essentially no trade off. They go faster, they use less power, and very importantly they become less expensive because we pack more function in the same amount of area and therefore, lower the production costs. This alone wouldn't drive the development of the technology because as the prices of the devices went down the industry would spiral into some kind of a death throe except for one thing: the market has proved phenomenonally elastic. We double the amount of electronics in the world every year as we move on to higher functionality and smaller dimensions. So these are the two things that have driven the technology in the past.

Now, extrapolations of the past are generally a valid way to look at least a short distance into the future, and we'll go through a few of these. Nothing is more important than what's happening to our minimum dimension, giving the importance of moving down to smaller sizes to continue to exploit this violation of Murphy's Law. I have been amazed that progress to smaller dimensions has proceeded on a straight line on semi-log paper from the introduction of the first planar transistor in 1959, which was kind of the beginning of the technology we have been pursuing. It doesn't show any sign of rounding off as we approach a limit I think we generally agree is something around a tenth of a micron where the physics of the material start getting fouled up. You know we've passed several of the single cell creatures there and are now working in the realm of viruses insofar as dimensions are concerned. Clearly though, this is going to have to do something well before the forty years is up. Either we're going to slow our rate of progress, my limit is going to prove wrong or something. But we see that sometime in the next twenty years, we're going to come very strongly against some fundemental limitations.

Now, another part of the technology that has been extremely important of course, is that relating to our ability to design products of this phenomenal complexity. When we made the first microprocessor some 17 years ago, designing a product of that complexity was really at the limit of what was possible. Now we make things orders of magnitude more complex and are really disappointed if they don't work the first time. The reason is: we've made extensive use of the computer for a design technology and these together, the improving process technology and the improving design technology are clearly going to continue to be important. But it's not really the directions I want to address today.

Before I go on to some things I do consider important, I do want to address one particular question and it's the one that was asked to Mike [Thompson, AT&T], and that is: "Is silicon going to continue to be the important material or is there going to be some major change there?" Well, I think this is an area where we carefully made very important choices when we began. A group of us sat down with a table of the relative abundance of the chemical elements in the earth's crust. We started down through here since we realized this was going to be a big industry, we wanted to be sure we chose materials that would be readily available. So we started with oxygen. Well, oxygen is a gas and you can't use that very well for solid state electronics, so we had to move on to the second one there. Lo and behold, silicon. Silicon is a nice semiconductor and readily available so we had our choice there. And then seeing that we could combine the silicon with the oxygen in almost the porportion that exists in the earth's crust, we could get an excellent insulator in silicon dioxide. The third thing you need besides the semiconductor and the insulator is obviously a conductor, and look what comes next. How could anything replace this choice of materials for such a basic industry? By the way, I've gone on to include 99 percent of the earth's crust and I don't see gallium or arsenic or a variety of other things showing up there.

While the technologies I mentioned earlier are clearly still key, I'd like to focus on three trends that relate to the course of technology over the next several years which I don't think have been adequately appreciated. First one, no more defects. I don't mean zero defects in the sense of the military . . . that is that the user won't see any. What I mean is a real change in the direction in a lot of the technology development. We've spent the last 25 years tracking down yield-limiting defects. We find our cause and then go back in and reduce their incidence. Just about the time the yield starts getting in control, the next technology generation comes along, redefines what a defect is because a smaller dimension is important as you shrink the geometry and everything else, and we had to start all over again. So we have been continually going around this circle of fighting defects.
We're finally making progress in eliminating defects more rapidly than new generations of technology are turning over. This has very important implications on what we consider doing. Here I've plotted a simple yield model, that is a model of random defects which fits pretty well at least now, and shows the kind of yield you could expect at various die sizes depending on the average defect density on the wafer. And you see that if your defect density exceeds something like one per square centimeter, as you get up to the devices the size of 256K memories, or 1 megabit memories, your yields start getting very, very low. The right hand axis here of one square centimeter corresponds almost exactly to the area of an 80386. Clearly we couldn't have made one with the kind of defect

densities that were around not very long ago. On the other hand, as you creep up toward a tenth of a defect per square centimeter or even zero, you approach the one hundred percent yield. This has a dramatic impact. We've spent a very good portion of our time trying to reduce the area of products because the cost essentially improved exponentially as we decreased the area, because not only did the number of possible die on a wafer increase but the percentage yield went up dramatically, in fact along an exponential curve here. And clearly improving the yield was the strongest thing to do on reducing cost.

This is the reason there was a push toward simple processes. The original justification for MOS over bipolar was that it was a 4 mass process instead of the 6 mask process you needed for bipolar circuitry. And the more steps you had, the more defects you introduced since these are not fundamental but are introduced during the processing of the silicon. With zero defects the constraints are lifted. The cost of the die becomes linear in area rather than exponential. And process complexity also contributes linearly rather than much more strongly to the cost of the product. I see this leading to huge dice. A huge die is still 1/2 inch on a side as far as I'm concerned. But the idea of waferscale products becomes much more realistic because of this trend toward zero defects in the processing.

Process complexity can climb. It has already climbed quite a ways from the old 4-mask MOS. We are not overly concerned with the 15- or even a 20-mask process today. I see that continuing to climb maybe at five additional mask layers per decade so that we could look at a forty mask process at the end of this time. It seems less unlikely to me now than a 20-mask process would have seemed 15 years ago. High yields release both the product designer and the process designer to exert their creativity. I think this is going to have a major change in the thought process. That's going to have an important impact on the overall industry over the next several years.

Another trend that is having a significant impact is cost. Leading edge technology has gotten very expensive. One way to look at it is the cost of the equipment. Here I've picked three different pieces of equipment more or less at random. The random access being the ones I could get the data for easily, and you can see each of those grows essentially exponentially again with time. When we started Intel, the standard increment of wafer fab equipment was $12,000; you could buy a lithography machine or an evaporator or whatever, it cost about $12,000. That increment now is closer to the $1.2 million; that is a hundred fold increase in the time we have been in business. This can't continue because it is growing more rapidly than our ability to support it. With this increase in equipment cost and the increase in process complexity, a minimal facility now with an adequate clean room for doing development in state-of-the-art technology costs on the order of $100 million. An economical production plant is a significant multiple of this. This equipment gets replaced, or at least half of it or so gets replaced, every generation of technology and the facility is adequate for two, possibly three generations of technology if it's upgraded significantly inbetween. At Intel the cost of developing a new technology generation is of the order of $60 to $80 million now and growing at a rapid rate. And the pace of new generations is not slowing. I think a state-of-the-art oriented semiconductor start-up ought to look forward to its ability to support $100 million a year on technology improvement if it plans on living with that kind of a strategy.

In fact technology leadership is much more expensive. I show a curve that graphically tries to depict what it takes to stay ahead of where the general leaders of the industry are as compared with what it takes to drag behind. If we say unity is what it costs the leading half dozen semiconductor companies in the world to stay where they are, trying to get a year ahead of that is a significant multiple of expenses. You have to develop a lot more equipment and do a lot more driving of the technology in order to get there. This curve in fact goes to infinity in something less than two years, as near as I can see. On the other hand, the company willing to live a year or two behind the nominal leading edge of the technology find it is relatively inexpensive. The blind alleys have been eliminated and the equipment has generally become available and been debugged so it can practice this level of technology. To follow is relatively cheap, to lead is tremendously expensive.

Another view of what's happening is the amount of revenue, the fraction of the revenue, that the industry has found necessary to invest in R&D and capital. Technology . . . and technology is not only the development, it's generally the capital to put it into production . . . consumes a growing fraction of the available resources. This curve can't continue to grow at the slope it's averaged over the last decade or clearly we will be spending more to develop the technology than we get by exploiting it.

Another way to look at the limitations we're seeing here financially is to look at the growth in the semiconductor market versus the growth in the collective GNPs of the developed countries. You see a line with a sigficantly steeper slope, a few flucuations on it I'll have to admit that seem very severe at the time, but if you extrapolate this looking at a forty year time scale, you see that the semiconductor industry passes the GNP of the various countries in a relatively short period of time. Now this clearly cannot happen. One of two things has to occur: the growth of the economy has to sharpen dramatically; or the growth of the semiconductor industry has to moderate. Unfortunately, I think the blue curve is going to have a tough time changing the slope of the red curve enough to keep us on the cycle we've been on before. This is going to result in a slowing of the ability of the industry to invest, I think no matter how it comes about. So what I've accumalated here are several different reasons why the economics of the semiconductor industry are going to have to change. It's gotten very expensive, it cannot continue at its growth rate, and we're all going to have to learn to adapt to whatever changes these bring about.

A third change I want to talk about, and take your pick on the way it's described, but basically we have become very good users of exactly the technology that we have created. We mentioned earlier how the design technology has developed significantly more rapidly than our need to use it, so we can do much more complex products actually more efficiently than we could do simpler ones ten or fifteen years ago. I want to give you some nonclassic views on how we are using this technology. One thing I like to take look at first are some of the things that are going on in modeling of processes. And I will admit that this is an area I never really expected to get much from, I frankly thought that we would always lag in capability to model the real world, but that hasn't proved to be the case.

To pick a simple example, this is the way a model of the cross section of a polysilicon layer on top of an oxide might look coming out of the computer. In fact this is exactly a model of one of the things we were doing. Then you can put that model along side the reality and in fact the undercutting is very accurately shown; the slopes and the sidewalls get shown very accurately. This is not a very good photograph to see that on, but we can essentially adjust the parameters in the model to fit what happens essentially exactly and use that as a very good tool for looking at deviations from the standard process.

Another example, take photoresist. This shows the profile of a very narrow line in thick photoresist for a variety of different exposure levels. The scalloped edges show interference fringes from the light reflected up from the underlying surface which is a function of exactly the films that are on it. When I first saw this simulation, I thought it was ridiculous until people started showing me electron micrographs that show exactly those fringes. Now we find it's very important if you have a node or an antinode at the bottom of the photoresist layer. It can affect the line width by plus or minus ten percent down in this kind of a range. Without the ability to model this kind of thing, it would take forever to figure out what we were doing experimentally.

Another one, and one that I really didn't believe in initially, shows putting an insulating layer over a structure that has a couple of metal layers on it. It says as this insulating layer gets thicker and thicker you eventually close the top of the hole and leave a void inbetween the two metals. Lo and behold you take a look at the photomicrograph of the somewhat thicker layer, and the void actually exists exactly as modeled. We have gotten to the point where we do at least ten process experiments on the computer for every one that's done in the lab. They're quicker, cheaper, and there is less chance of making mistakes. Certainly I was surprised here. I never really believed that process modeling would get ahead of our ability to perform the processes themselves. I look forward to the time when we can model our P&L as well.

Another nonconventional use of the technology relates to our ability to improve what we are doing from the point of view of taking advantage of the information that's available. A factory is built to produce products, but it produces a lot more data than it does products. In the past very little of the data produced by the factory could actually be used in improving the processes. Increasingly, with automatic data collection and the ability to summarize and analyze it effectively and essentially in real time, we have been able to use this data to improve our processes dramatically. The kind of things we can see now is this map of a wafer showing particular parameters over the course of several runs. You look at that immediately and you say, "Gee, the left side is not like the right side." That kind of information can be very hard to find just by conventional data analysis techniques. Having this data available, historical with all the parameters that go along with it, and the ability to analyze it, the ability by which processes can get improved dramatically. I think that's one of the important reasons that we are getting ahead of our process generation in eliminating defects. I believe that we already have by a large margin, the most complex industrial technology in existence. But there is still a lot yet on the microelectronics technology plate where it can be developed in several different directions. I think it's moving very rapidly, driven by huge investment and rampant paranoia. As long as we can afford it, we're going to all try to keep up.

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THE FUTURE OF MANUFACTURING TECHNOLOGY

Hiroe Osafune
Corporate Adviser
NEC Corporation

Dr. Osafune is Corporate Adviser at NEC Corporation and is consulting on semiconductor technology. Previously, he was Chairman of the Board of NEC Electronics, Inc., and NEC Yamaguchi. Before that, he was Vice President of the Electron Device Group at NEC Corporation and was responsible for technology, strategy, and overseas business in the semiconductor area. Dr. Osafune started his career as an engineer at NEC developing phosphor materials, and has been involved in starting semiconductor studies in both discrete and integrated circuits. He received B.S. and Ph.D. degrees in Applied Chemistry from Tokyo University.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

Technology over the Next 40 Years

DR. HIROE OSAFUNE

Corporate Adviser
NEC Corporation

THE FUTURE OF MANUFACTURING TECHNOLOGY

Hiroe Osafune

Advisor

NEC Corporation

PAST 40 YEARS

After Second World War in Japan

- 90% of industrial activity was destroyed
- Shortage of foods
- Occupation period (1945~1952)
  limitation of R & D, microwave techn.
  limited international trade

Transistor

- Information of invention (1948)
- Study of semiconductor (1949, fall)
  no Ge, no budget
- First Si mixer diode (1950)
- Crude Ge powder 1 oz (1951)
  ⟶ point contact diode
- Point contact transistor (1953)
- Alloyed and grown junction transistor (1954)

Today NEC is NO.1 (Data Quest Ranking)

SEMICONDUCTOR INDUSTRY

- **Driving Force**

  Popularization of computer and communication
  Home electronics

- **Growth Rate of Semiconductor Industry**

～2000	15～20 %/year
2000～	10～15 %/year

- **Market Needs by 2027**

  Automatic Interpretation Telephone System
  Super microcomputer for AI

DEVICE TECHNOLOGY

Device Design Features till 2000

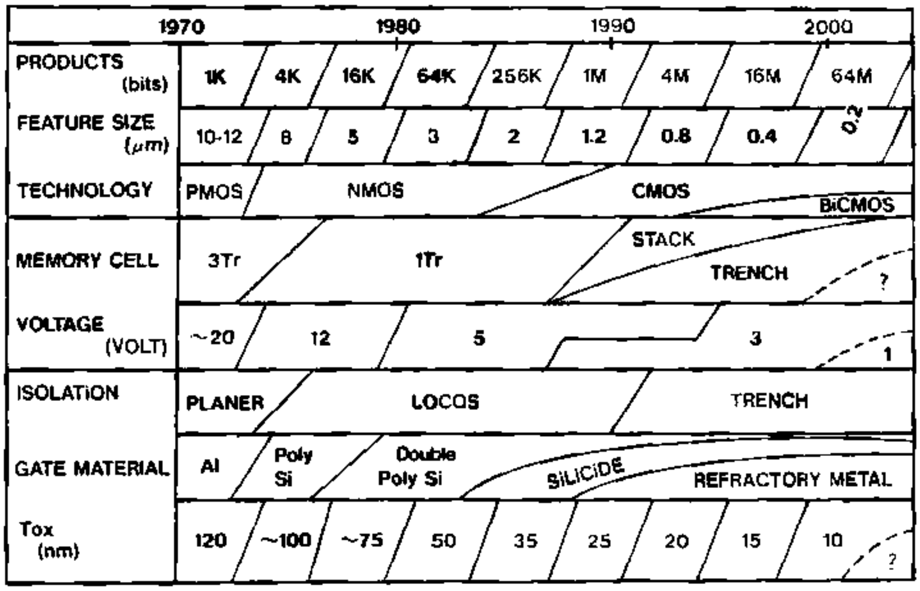
• High integration	by MOS	DRAM, MPU etc.
• High speed	by Bipolar	main frame & super-computer
• **High frequency**	**by GaAs**	**communication, satellite broadcasting**

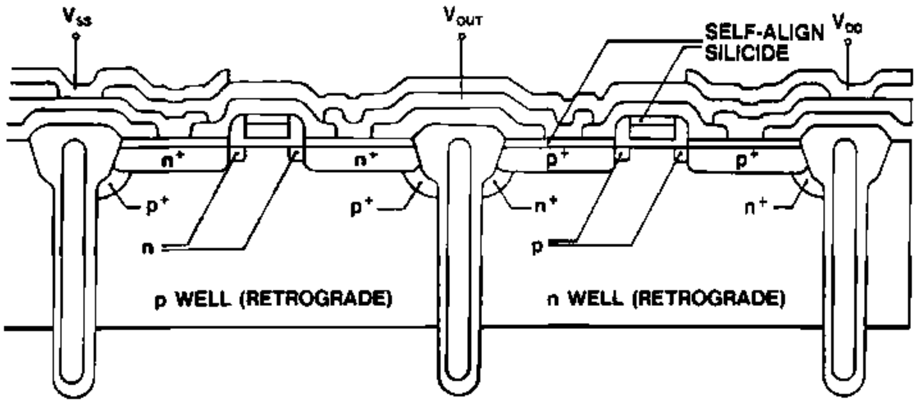
- **Operation of 0.1μm devices are verified**
- **Super-conductor transistor**

1. MICROPROCESSOR TECHNOLOGY TRENDS

A.C.	Application	MPU bit	Clock MHz	Geometry μm	Device	Main Memory Byte	File Memory Byte
1975 ~1980	Calculation English Word Processing Home Electronics	4~8	1	~5	N-MOS	64K	0.5M FD
1980 ~1985	Japanese Word Processing MS-DOS (single task)	16	5~10	2~3	N-MOS	125 ~640K	1M FD
1985 ~1990	UNIX-OS (multi task) 3 dimensional graphics CAD/CAM W.S. Data-base terminal	32	10 ~30	1~2	C-MOS	5M	2~20M FD, HD
1990 ~1995	Pattern Recognition Voice Recognition High Performance Robot Factory Automation	32	30 ~50	0.8	C-MOS Bi-C-MOS	20 ~30M	100M HD, Si File, MO
1995 ~2000	Image Recognition Speech Recognition 3D Movie LSI Pattern Inspection	32 ~64	50 ~100	0.5	Bi-C-MOS	20 ~100M	1G HD, MO Si File
2000 ~	AI	32 ~64	100~	0.3	Bi-C-MOS	1G	10G

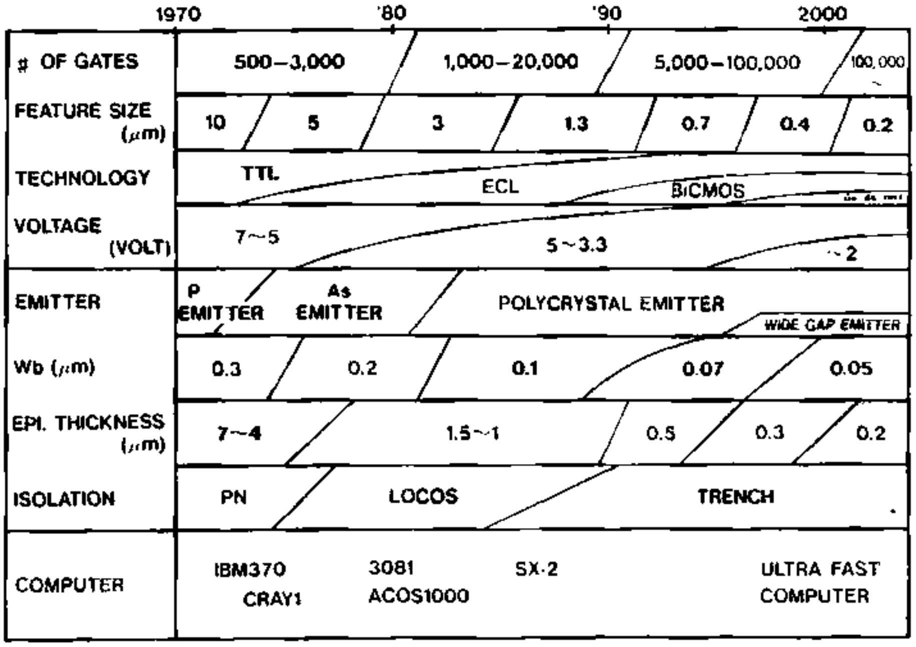
2. DRAM TECHNOLOGY TRENDS





n⁻ or p⁻ Substrate Si

3. BIPOLAR LOGIC TECHNOLOGY TRENDS



4. **MMIC (monolithic linear)**

- **<5GHz** **Si**

- **>5GHz** **GaAs**

5. OEIC

- Fiber optical communication system
  SSI for transmitter & receiver

- **Optical interconnection**
  data-high-way (system to system)

- **Optical data-processing**
  2000~

- **Phased array radar**

PROCESS TECHNOLOGIES

Crystal

1. Silicon

   - Continues to dominate in the foreseeable future
   - Unique Features
     - Economical, abundant source
     - Perfect single crystal
     - SiO_2 film (MOS device, diffusion mask, passivation)
     - Thermal diffusion
     - Si_3N_4 film (Oxidation mask, high dielectric const., passivation)
     - High yield, high volume production, high reliability

2. Ga As and Compound Semiconductors

- Merits
  - Coupling to the optical processing
  - High speed, low power
  - Semi-insulating crystal
- Demerits
  - Lack of stable passivation film
  - Dislocations by thermal treatment
  - Difficult to grow dislocation-free crystal
  - Higher cost

3. Future Technologies

- Artificially structured crystal by computational physics
- Hetero-junction
- Super lattice
- Super conductor

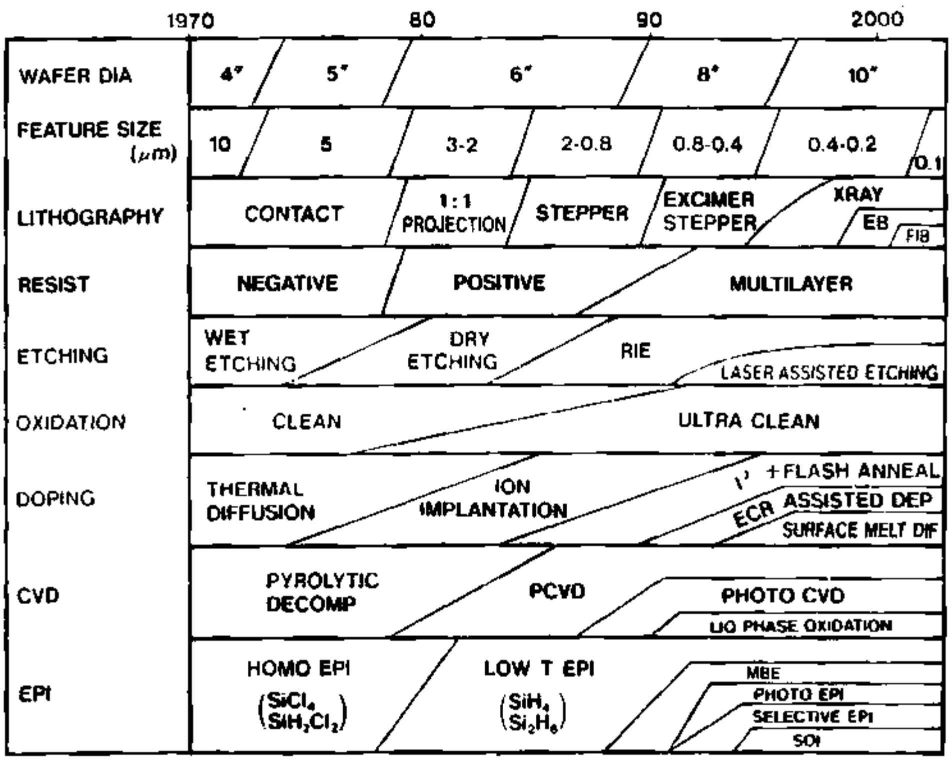
4. 3D IC

- Trench capacitor and isolation
- Stacked transistor and capacitor (SOI)
- Multi-layered chip IC

cycle time	1nsec	$(10cm)^3$
"	0.1nsec	$(1cm)^3$

5. ASIC

- Manufacturing various sorts of products in small quantity



1970
80
90
2000
WAFER DIA
4"
5"
6"
8"
10"
FEATURE SIZE (μm)
10
5
3-2
2-0.8
0.8-0.4
0.4-0.2
0.1
LITHOGRAPHY
CONTACT
1:1 PROJECTION
STEPPER
EXCIMER STEPPER
XRAY
EB
FIB
RESIST
NEGATIVE
POSITIVE
MULTILAYER
ETCHING
WET ETCHING
DRY ETCHING
RIE
LASER ASSISTED ETCHING
OXIDATION
CLEAN
ULTRA CLEAN
DOPING
THERMAL DIFFUSION
ION IMPLANTATION
+FLASH ANNEAL
ECR
ASSISTED DEP
SURFACE MELT DIF
CVD
PYROLYTIC DECOMP
PCVD
PHOTO CVD
LIQ PHASE OXIDATION
EPI
HOMO EPI
(SiCl4 SiH2Cl2)
LOW T EPI
(SiH4 Si2H6)
MBE
PHOTO EPI
SELECTIVE EPI
SOI

MANUFACTURING TECHNOLOGIES

1. Automation and Flexibility

    - Increase through-put (productivity)
    - Fine control of device parameters
    - Self-diagnosis and feedfoward system
    - Short TAT in spite of increasing process steps
    - Needs for high-sensitive monitoring equipments
    - Reproducibility and reliability
    - Flexibility for update equipments & design change
    - Eliminate human error/Saving labor cost

2. Super Clean Room

- Site location
- Building construction — vibration proof/floor plan for flexibility
- Airconditioning and decontamination
  laminar flow, Na free
  class 0.0001 (0.17μm)
- Temperature and humidity control
- Ultrapure water piping system
  high-sensitive resistivity testing
- Gas supply system
  vacuum melt metal tube + electrolytic polishing
- ESD-control
  conductive wall, ceiling, floor, paint and wafer carrier
- Reduce people in clean room → people-less

3. Ultra Clean Meterials

- purer chemicals and gases by two orders of magnitude (small particle free)

- ultra pure water and its control (temperature, surface tension etc)

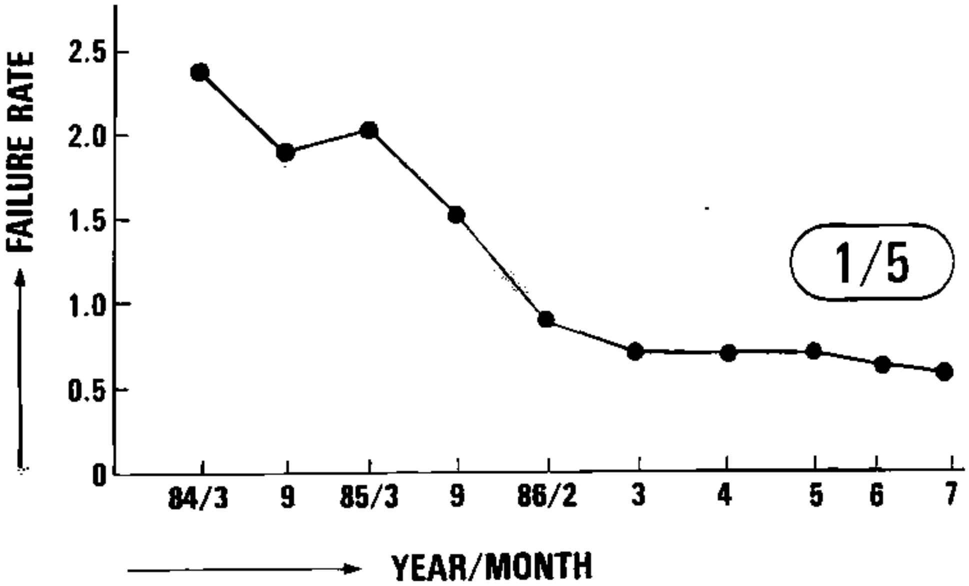
WAFER FABRICATION EQUIPMENT MAINTENANCE

KEY TO SEMICONDUCTOR MANUFACTURING PRODUCTIVITY

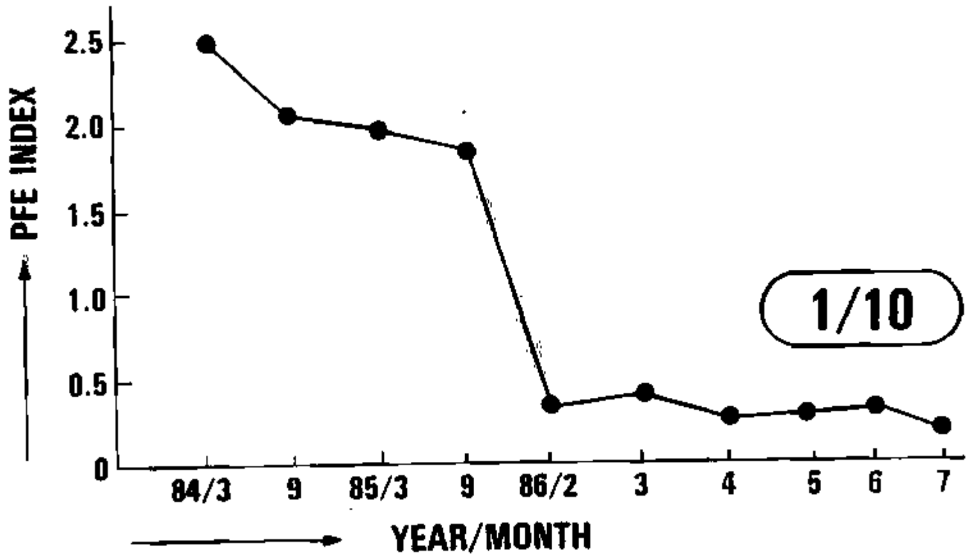
1) PRESENT : TPM

2) FUTURE TRENDS

(1) OVERALL FAILURE RATE



(2). VACUUM SYSTEM



THE 5 PILLARS OF TPM IMPLEMENTATION

1. SELF-DIRECTED MAINTENANCE BY OPERATORS

2. ITEM-BY-ITEM IMPROVEMENT OF PRODUCTIVITY

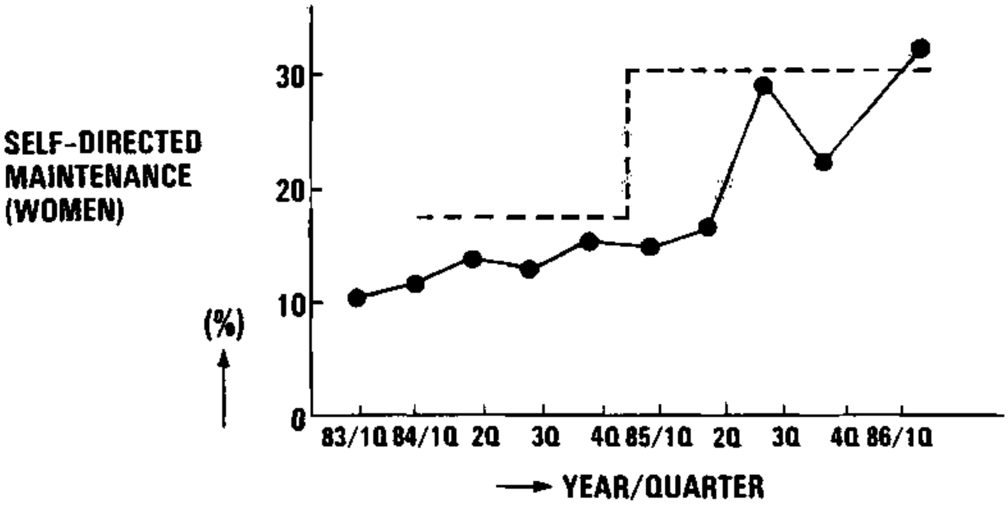
3. PLANNED MAINTENANCE

4. MAINTENANCE PREVENTION SYSTEM

5. EDUCATION AND TRAINING

PROGRESS BY OPERATORS

SELF-DIRECTED MAINTENANCE



HOW TO CONDUCT PLANNED MAINTENANCE

(1) TIME-BASED MAINTENANCE

TIME-BASED INSPECTIONS ARE MADE OF 800–900 EQUIPMENT UNITS. COMPLETENESS IN THE CONTENT OF THE INSPECTIONS PRODUCE SIGNIFICANT BENEFITS.

⇩

A LARGE PORTION OF THE INSPECTION CRITERIA WAS DETERMINED AT THE TIME OF EQUIPMENT DELIVERY. AIM FOR COMPLETENESS IN INSPECTION CONTENT BY REVISING INSPECTION CRITERIA BASED ON EQUIPMENT FAILURE HISTORY.

(2) CONDITION-BASED MAINTENANCE

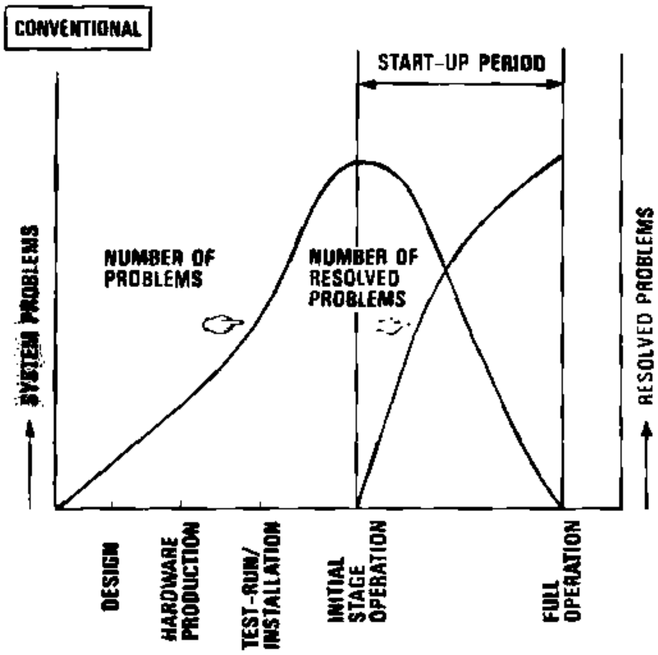
THERE ARE MANY PARTS WHOSE WEAR-DOWN IS UNAVOIDABLE. AN EFFECTIVE STEP IS TO REPAIR OR REPLACE THEM THROUGH CONDITION-BASED MAINTENANCE.

⇩

CREATE MANY EXAMPLES FROM SITUATIONS NEAR AT HAND. REINFORCE IMPORTANCE OF CONDITION-BASED MAINTENANCE AND SPREAD THROUGHOUT ORGANIZATION.

MAINTENANCE PREVENTION (1)

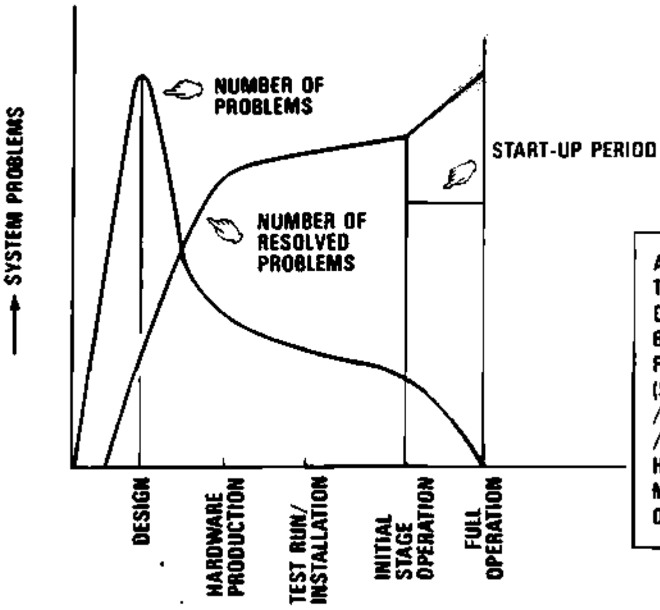
RELATIONSHIP OF DESIGN AND EARLY STAGE START-UP



OCCURRENCE OF SYSTEM PROBLEMS REACHES ITS PEAK AT TIME OF INITIAL STAGE OPERATION RESULTING IN A LONG START-UP PERIOD.

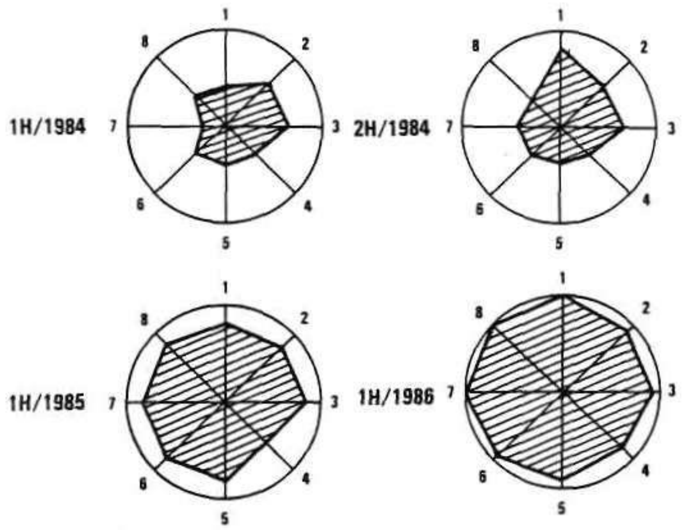
MAINTENANCE PREVENTION (2)

PRESENT



AT DESIGN STAGE MOST OF THE SYSTEM PROBLEMS ARE DETERMINED THROUGH FEED-BACK OF MP INFORMATION FOR SYSTEM IMPROVEMENT (SELF-DIRECTED MAINTENANCE /ITEM BY ITEM IMPROVEMENT /PLANNED MAINTENANCE). HENCE, PROBLEMS ARE MINI-MIZED BEFORE INITIAL STAGE OPERATION.

TECHNICAL KNOW-HOW LEVEL (OPERATORS)



1	EQUIPMENT OPERATION
2	COMPREHESION OF SYSTEM
3	EQUIPMENT INSPECTION
4	PREDICTIVE MAINTENANCE, EQUIPMENT
5	EQUIPMENT TROUBLE-SHOOTING
6	EQUIPMENT CORRECTION
7	SIMPLE REPAIRS
8	LUBRICATION/CLEANING/TIGHTENING

WAFER FABRICATION EQUIPMENT MAINTENANCE

FUTURE TRENDS

1. ON-LINE FAILURE DIAGNOSIS
2. STANDARDIZATION ON RELIABLE PARTS (SEMI)
3. SELF-CLEANING CAPABILITY
4. IN-SITU SELF-DIAGNOSTICS

   (PARTICLES, PLASMA GENERATION, RESISTIVITY, THICKNESS)
5. MAINTENANCE-PREVENTION DESIGNS
6. EDUCATION AND TRAINING

THE ROLE OF PEOPLE IN EQUIPMENT MAINTENANCE

PRESENT : PEOPLE PERFORM ALL CLEANINGS, INSPECTION, MODIFICATION, REPAIR FUNCTIONS

FUTURE :

- CLEANING AND INSPECTION FUNCTIONS WILL BE INCREASINGLY AUTOMATED.
- PEOPLE WILL UPGRADE ROLE TO ANALYSIS, PROBLEM-SOLVING, MODIFICATION AND STANDARDIZATION ACTIVITIES.
- RESULT = IMPROVED UPTIME OF WAFER FAB EQUIPMENT.

CONCLUSION

- Industry will grow perpetually till 21st century
- Design feature size will shrink to 0.1μm
- Process operation, process monitoring will be automated
- Maintenance of manufacturing equipments will be most important
- Management will be very difficult even if computer will assist

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Semiconductors' Midlife Crisis

Surviving in the Land of the Giants

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SURVIVING IN THE LAND OF THE GIANTS

David L. Angel
Managing Director
DQ Alliances

Mr. Angel, Managing Director of DQ Alliances (DQA), is responsible for business development, administration, and management of DQA's merger, acquisition, and corporate alliance projects. Mr. Angel joined DQA during its start-up phase as a part of Dataquest Incorporated, before DQA was established as a separate, but still closely affiliated, entity. 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 start-up companies. Before joining DQA, Mr. Angel was founder and senior partner of Almaden Venture, a seed fund and venture capital consultation firm. Earlier, he was a founder of Signetics Memory Systems and the Director of American Microsystems Inc.'s (AMI's) Image Technology Center. He is considered an expert in semiconductor lithography and is responsible for much of the imaging technology in use today. Mr. Angel has authored more than 50 publications relating to high technology, funding new businesses, strategies for success in high technology, and managing high-technology companies. Mr. Angel's academic background is in Physical Chemistry, Business, and Law. He was educated at Marietta College, Williams College, and LaSalle University.

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Surviving in the Land of the Giants

DAVID L. ANGEL

Managing Director
DQ Alliances

SURVIVING IN THE LAND OF THE GIANTS

An associate of mine provides the counsel that one should testify in public and confess in private. Perhaps unwisely, I will choose to ignore that sage advice for the moment and confess to this group that I from time to time wake up in the middle of the night having lost the ability for restful sleep. Whether it is the onset of middle age or just too many years of trying to solve yield problems, the peaceful slumber of my youth has vanished. As of late, I find myself knotted up with 3:00 a.m. musings over the future of the American semiconductor industry. Not so much the issue of foreign competition or the bad state of the market; those matters appear to be taking a turn for the better. Rather, my head seems to be filled with worries over the survival of the small IC company—the start-up company that is now a few years old. The American entrepreneural spirit and the drive to create these new young, niche-oriented, highly flexible, technology-intensive, bureaucracy-free companies has been the very genesis of the American, and hence, ultimately, the worldwide semiconductor industry. Today, however, there is a mounting groundswell of opinion that the small integrated circuit semiconductor company can no longer survive in the land of the giants.

Reviewing only the events of the past few months, we have witnessed the merger of Thompson and SGS, the merger of Advanced Micro Devices and Monolithic Memories, and now the absorption of Fairchild Semiconductor into National. Six have become three in just two months. Some very wise individuals with credible credentials advise us in the industry that this is indeed the trend and an early look at the future. Are these individuals imbued with unique prescience?

Pasquale Pistorio, the head of the new SGS/Thompson consortium, advises without hesitation that "to play this game you need $1 billion in annual revenue. This is the minimum critical mass. In a few years it could rise to $2 billion depending upon the value of the dollar. If one cannot achieve this level, it is better to change and become a niche supplier." Mr. Pistorio goes on to state that today there are about 300 semiconductor firms but within 10 years that number will be halved.

Consequently, we are faced with the dilemma of growing our company through some means or manner to $1 billion plus annual sales or of redirecting our strategy toward niche markets. If for the moment I can imagine myself as the CEO of a young IC company who has just, through every event and action conceivable, finished my third year of operation with sales of $20 million, the thought of ever reaching $1 billion in annual sales within the span of my mental acuity and physical stamina is remote. Let's look at that another way. A company that had scratched and fought its way to the $100 million annual sales level would have to increase its size by 25 percent every year for the next ten years to grow to $1 billion in annual sales. Or, in other words, the company would have to grow at about twice the industry average. So what about niche markets? Tom Peters in his lectures and wonderful books regarding excellence in American business gives us one cardinal rule of niche market businesses. You must dominate the niche if you ever expect to make money with that business strategy. But let's look at our markets. Since 1980, 130 semiconductor companies have opened their doors. About 20 have ceased to exist either through acquisitions, mergers, or business failures. Of the remaining 110 that are still in business, nearly 50 are focused on the ASIC niche market, 9 are determined to be the DSP niche market leader, another

10 believe that they will ultimately dominate the microprocessor business, while 25 are plotting to rule the memory free-for-all. These niche market strategies are not to be confused with the niche strategies of the major, well-established semiconductor houses like AMD, Intel, Motorola, National, Texas Instruments, and the other giants, all of which have focused their niche gun sights on these markets. Simple logic tells us that not all of these participants are going to dominate or even reasonably control their niche markets of choice. Simple mathematics tells us that when the strongest of the niche market leaders takes its disproportionate share of the market off the top, there isn't going to be enough market left for viable (translate profitable) existence by the remaining participants.

In our role of high-tech investment bankers, we see a large number of business plans for new and existing semiconductor companies that are seeking funding. Each plan, almost without exception, appears to be prepared with what I call the Lotus template. Almost irrespective of the market or technology, each company expects to lose money for the first two or three years, and then rocket up to $50 million in revenue by year five. If we overlay this projected sales growth onto the 110 or so surviving companies that have started up since 1980, we find that this produces $5.5 billion in revenue, which, when integrated with the probable revenue of the established semiconductor companies for the given time frame, produces projected revenue for the total group of semiconductor companies that substantially exceeds the forecast revenue for total semiconductor shipments for the given time period. While admittedly this is an abstract model, the conclusion is that a fair number of the young companies will never achieve their projected revenue growth.

There is a third and perhaps much more serious factor that the small companies must deal with. Dataquest has tracked the amount of capital that semiconductor companies historically have invested in Plant, Property, and Equipment in order to produce incremental revenue. Or, restated, the amount of capital for plant, property, and equipment that one must invest to produce one dollar of incremental revenue. Commencing with a low point of approximately $0.30 in 1974 to produce $1.00 of new revenue, the capital requirement rose steadily until 1985 when $1.00 of capital was required to produce each incremental dollar of new revenue. Dataquest reports that this situation eased up a bit in 1986, when only $0.90 was needed for each incremental dollar of revenue. Dataquest does not believe that the 12-year trend will reverse itself for long and that the capital requirement will hover around $0.90 to $1 for the near future, unless there is a dramatic change in the nature of this business. To make matters worse, like the man who has just received a letter that the IRS wants to stop by the office to chat, we haven't heard all of the bad news yet. Traditionally, much of revenue growth has come from new products and new technologies. Consequently, we must invest in research and development to create the new technologies and products. Dataquest reports that semiconductor companies, on average, have invested $0.11 in R&D to create each new dollar of incremental revenue. So we are faced with a scenario that says that for each dollar of new incremental revenue we must somehow find the capital resources to invest somewhere between $1.00 and $1.20 in plant, property, equipment, and R&D resources. And the tragedy of this situation is that in an industry where profit margins are so slim and so difficult to come by except in the very best of years, it is a rare company that can drive enough to their bottom line to fuel their own growth. It is as if we are trapped in some algorithmic destiny where the capital intensity constant has become so large as to obviate any of the other components of the equation.

To illustrate this point more dramatically, since 1984 60 semiconductor start-up companies have opened their doors for business. Virtually all of these companies are through their early development phase and are now enjoying sales in the $5 million to $25 million range. If we conclude that the average sales for this group of companies is $15 million, and that their clear plan is to be at $50 million in revenue in two to three years, then using the knowledge of required capital investment for plant, property, equipment, and R&D that we discussed previously, some $2.5 billion in additional capital investment will be required in this group of companies to produce the incremental revenue growth that each company has assured its original venture investors will surely occur. Will the venture capital and public equity industry support this level of following-on investment in these companies? The consensus seems to be that the venture community is not prepared to step up to this level of support, and it is dubious that the IPO market will sustain desire or valuations that will generate all of the needed capital resources.

So we begin to understand the death watches for the technology-rich but financially weakened young semiconductor ventures. Perhaps after 30 years of negative cash flow the U.S. chip industry must slow down, and the deacceleration will come at the expense of the younger, less well-positioned companies that are just a little short on critical mass. Things do not look good my friends, OR . . . . . .

Am I wrong? . . . Are these just the midnight anxious worries of somebody who got a little too close to the arsene gas doping bottle a little too often a few too many years ago . . . .? Today, we have the CEOs of four young, niche-oriented semiconductor companies who absolutely believe that their companies will be well-positioned among the survivors. They are here to prove me wrong, and to tell this group how they are beating the system with new strategies and tactics that will inject fresh life into the U.S. semiconductor industry and erase the wrinkles in the venture capitalist's brow. I am anxious to hear what they have to say. When they are through, I hope that we will all feel better, and, maybe, just maybe, I can finally get a good night's sleep.

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THE LAND OF THE GIANTS

- Consolidations to achieve "critical mass"
- $1 billion minimum annual revenue to be a "player"
- Others relegated to niche roles

THE LAND OF THE GIANTS

- $1 billion critical mass
- Model: $100 million sales in 1987
  - Must grow more than 25% per year to achieve $1 billion in 10 years
- Twice predicted industry growth rate

THE LAND OF THE GIANTS

- To succeed in a niche strategy, you must dominate the niche
- ASICs: 50 entities
  DSPs: 9 entities
  Microprocessors: 10 entities
- Only one can be Number 1

THE LAND OF THE GIANTS

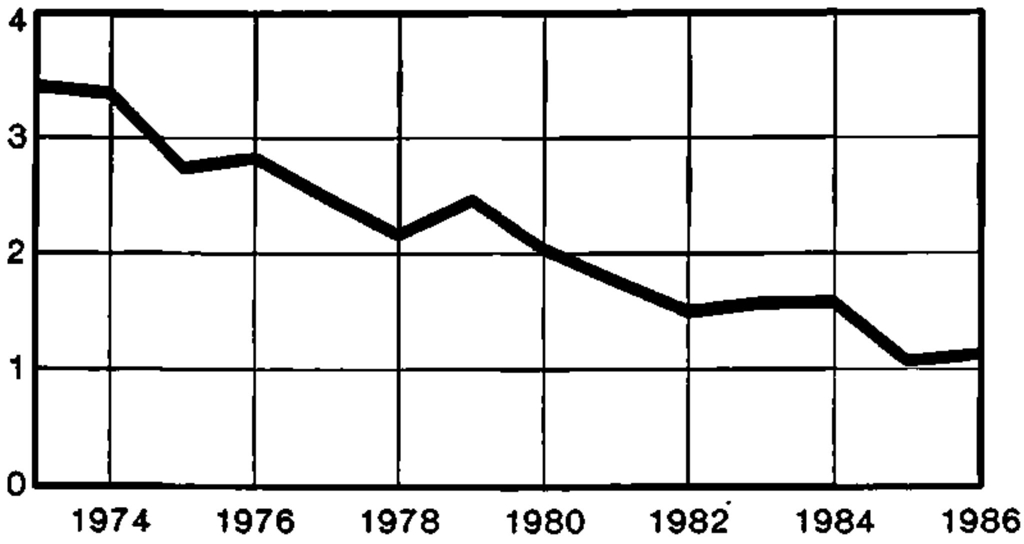
Mom's Memories, Inc.

Sid Start-Up, CEO

Capital by
Wash-Out Ventures
Sand Hill Road
Menlo Park, California

	Year 1	Year 2	Year 3	Year 4	Year 5
Projected Revenue	$ 0.5	$ 4.0	$7.2	$26.5	$47.8
Income	$(3.5)	$(2.5)	$0.7	$ 3.5	$13.0

PLANT, PROPERTY, AND EQUIPMENT INVESTMENT PER $1.0 INCREMENTAL REVENUE



Source: Dataquest

THE LAND OF THE GIANTS

For each incremental dollar of new revenue:

PPE:	$0.90	→	$1.10
R&D:	0.11	→	0.30
	$1.01	→	$1.41

THE LAND OF THE GIANTS

- Are we entering the last days of the entrepreneur–driven semiconductor venture, or
- Are we wrong?

Let's see.

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SURVIVING IN THE LAND OF THE GIANTS

J. Daniel McCranie
President and Chief Executive Officer
SEEQ Technology Incorporated

Mr. McCranie is President and Chief Executive Officer of SEEQ Technology. Previously, he was a Vice President at SEEQ and was responsible for marketing and sales. Prior to joining SEEQ, he served as Group Vice President of Sales at Harris Semiconductor Corporation and held various sales positions at Advanced Micro Devices. Mr. McCranie holds a B.S.E.E. degree from the Virginia Institute of Technology.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

Surviving in the Land of the Giants

J. DANIEL McCRANIE

President and Chief Executive Officer
Seeq Technology

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SURVIVING IN THE LAND OF THE GIANTS

Michael Burton
President and Chief Executive Officer
Triad Semiconductors International B.V.

Mr. Burton is President and Chief Executive Officer of Triad Semiconductors International B.V. based in The Netherlands. Prior to joining Triad, he was Director of Finance and Administration for INMOS International and was a key member of the company's start-up and management teams. Earlier, he spent 14 years at Texas Instruments in various senior financial and operating management positions both in Europe and the United States. Mr. Burton was educated in the United Kingdom and holds a master's degree in Business.

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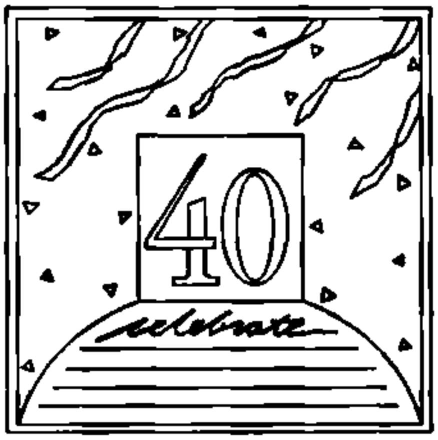

Semiconductors' Midlife Crisis

Surviving in the Land of the Giants

MICHAEL BURTON

President and Chief Executive Officer
Triad Semiconductors International B.V.

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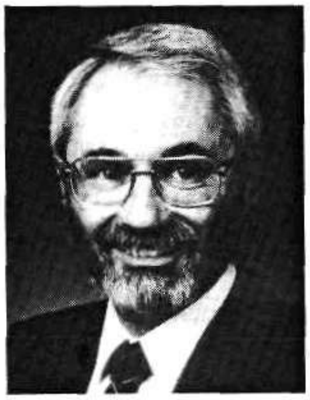

James V. Diller
President and Chief Executive Officer
Sierra Semiconductor Corporation

Mr. Diller is President and Chief Executive Officer of Sierra Semiconductor Corporation. Prior to founding Sierra, he spent 14 years at National Semiconductor Corporation, most recently as Vice President of MOS Memory and Custom MOS. Earlier positions at National included Vice President of the Consumer Products Division, Managing Director of Southeast Asia Manufacturing Operations, Group Director of Linear Circuits, and Managing Director of European Operations. Previously, he worked at Fairchild Semiconductor and Transitron Electronics. Mr. Diller holds a B.S. degree in Physics from the University of Rhode Island and has completed graduate work in Physics at the Massachusetts Institute of Technology.

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JAMES V. DILLER

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SURVIVING IN THE LAND OF THE GIANTS

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

Mr. Hackworth is President and Chief Executive Officer of Cirrus Logic, Inc., and has more than 20 years of experience in the semiconductor and electronic component industries. Before joining Cirrus Logic, he was Senior Vice President at Signetics, where he was responsible for staffing and directing that company's entry into MOS technology and had P&L responsibility for three product divisions. He also directed the design, launch, and operation of an advanced CMOS plant, guided a series of joint development programs with Motorola and Intel, and was responsible for developing Signetics' bipolar LSI logic and memory marketing effort. Prior to joining Signetics, Mr. Hackworth held a variety of marketing and sales management positions at Motorola and Fairchild Semiconductor. Mr. Hackworth holds a bachelor's degree in Electrical Engineering from the University of Santa Clara.

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Surviving in the Land of the Giants

MICHAEL L. HACKWORTH

President and Chief Executive Officer
Cirrus Logic, Incorporated

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Semiconductors'
Midlife Crisis

Technical Competitiveness

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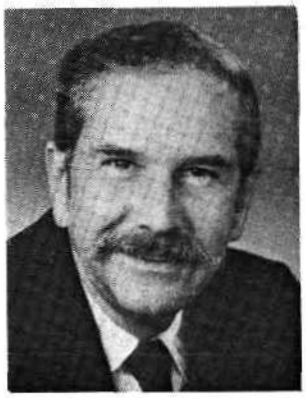
MANUFACTURING COMPETITIVENESS



Charles E. Sporck
President and Chief Executive Officer
National Semiconductor Corporation

Mr. Sporck is President, Chief Executive Officer, and Director of National Semiconductor Corporation. Under his direction, National has grown from a small manufacturer of discrete transistors to one of the largest high-technology companies in the United States. Prior to joining National, Mr. Sporck was General Manager at Fairchild Camera and Instrument Corporation, and before that, held various manufacturing positions at General Electric. Mr. Sporck is a founding member of the Semiconductor Industry Association. He holds a B.S. degree in Mechanical Engineering from Cornell University.

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Semiconductors' Midlife Crisis

Technical Competitiveness

CHARLES E. SPORCK

President and Chief Executive Officer
National Semiconductor Corporation

MEETING THE GLOBAL INDUSTRIAL CHALLENGE

Remarks by
Charles E. Sporck
President and Chief Executive Officer
National Semiconductor Corporation
Dataquest's Semiconductor Conference
October 20, 1987

(Slide 1: Industrial Competitiveness)

Introduction

Good morning. Today I want to speak to you about the international competitive challenge to American industry -- a challenge which I believe represents a major threat to both our standard of living and our position as a world economic and political power.

As a people, Americans have earned a well-deserved reputation for responding to major challenges with real intelligence and ingenuity. But ironically a vital prerequisite for many of our triumphs has been our fear of tragedy. We split the atom, for example, because we felt we had to do it to win World War II. We put a man on the moon only after we were jolted by the launching of Sputnik.

The challenge of increased foreign competition to U.S. industry has been called "the quiet challenge." It has been called "quiet" because it is not the result of some traumatic event that jolted us into action. Instead, it's been the result of many subtle events that have happened over a long period of time. You can't compare it to a car crash. But you can compare it to the process of rust slowly -- but surely -- eating away a car's underside.

Because it has come up on us in such a quiet way, it has been easy for many Americans to deny, dispute, misinterpret, trivialize, or ignore altogether. And for a long time, this is exactly what was happening.

Fortunately, in recent years, the negative trends have become so pronounced and the negative statistics so ominous that a much greater number of us are beginning to understand the severity of the situation and to look for solutions. The quiet challenge is getting louder. And in our's and other industries -- and even in government -- we are seeing significant positive movement.

As someone who's been concerned about our nation's growing inability to compete in world markets for the last 15 years, this is a very hopeful sign. But it would be foolish of me to think that this growing recognition is anything more than the beginning of a beginning. And it would be foolish for any of us to think that we have anything but a long and hard road ahead of us.

Today, I'd like to speak to you about the chief problems the international competitive challenge has created for us, how I think we need to address it, and what I think is ahead for us both as a semiconductor industry and as a nation.

I. The Challenge

First, let's look at the challenge.

(Slide 2: U.S. current account balances 1970-86)

In its most apparent form it is represented by our disasterously negative balance of trading accounts. This is the measure of total trade with other countries, including manufactured goods, services, royalty payments, capital exchanges, and other remittances. It was pretty much even during the 1970s. But, since 1981, it has gone to hell in a handbasket. Last year, it was about $150 billion. And this year, it will be comparable.

It's important to remember, too, that these negative balances are cumulative. Every year -- in fact, every month -- billions of dollars are leaving our country "with our IOUs". And this, I think, has tremendously important implications.

(Slide 3: U.S. net international investment position)

In 1981, we were the world's largest creditor. But since then we have declined rapidly to become the world's largest debtor nation, closing last year at about $250 billion.

While we can handle this amount of debt pretty well, the continuing downward spiral holds many disturbing implications. This estimate from Shearson Lehman, for example, shows that by 1990, we will have to handle about $800 billion. Some other forecasters are even gloomier, predicting amounts of nearly $1 trillion.

Consider how times will be changing. From 1914 to 1984, the rest of the world owed us. We were receiving interest on money loaned out. We were making a great deal of money <u>in addition to</u> the money we made from our many trade surpluses. Now, just to offset the interest costs of carrying the $800 billion debt Shearson Lehman expects in 1990, we will have to sell an additional $75 billion in products worldwide.

(Slide 4: current account components, 1986)

Now, let's look at the components of our current accounts.

Of all these segments, the largest, aside from our IOUs, by far is merchandise. The overwhelming majority is in manufacturing. And of all these, the largest trade deficit by far is in merchandise. Last year, it was about $150 billion. The overwhelming majority of our trade deficit in is merchandise.

These figures also conflict with the widely held perception that it's not detrimental to our trade position to lose manufacturing jobs because they'll just be replaced by service jobs.

It's true that we've been able to create about 35 million service jobs in America over the last 20 years. And it's true that many people, once in merchandise, are now in service industries. But it's not true that more service jobs will have any significant positive impact on our position as a world trader. It is true that these displaced people are in lower-skilled and lower-paid service jobs.

Services are -- and are expected to remain -- a very small part of our total international trade. In addition, we've generally run a negative trade balance in services. And this trend is also expected to continue.

What are the components of trade balances?

(Slide 5: merchandise trade balances, 1986)

This is the most important part when looking at components of trade. As a manufacturer, this is the most disturbing news to me. Within the merchandise segment, the vast majority of the trade deficit is in manufacturing. In fact, manufacturing alone accounts for about 80 percent of our entire trade deficit.

This evidence leads to the inescapable conclusion:

* manufacturing is the critical element in our international trade performance, and

* it is imperative to improve our position here if we ever want to solve our trade problems. The only way to solve it is to manufacture and export manufactured goods.

(Repeat): It is imperative to improve our position here if we ever want to solve our trade problems. The only way to solve it is to manufacture and export manufactured goods.

(Slide 6 - Making America More Competitive Through Manufacturing)

How have we gotten ourselves into such a mess?

I can think several major reasons, all to some extent interrelated and all growing out of our inability to come to grips with changing world economic realities.

The first is the difficulty we've had in defining a national economic role for ourselves that's more compatible with today's world. In many respects, we're still trying to play the same role we played at the end of World War II. Then, we were clearly the economic masters of the world. We could afford to pour money into other nations. We could afford to be the recipient of last resort -- (explanation) anyone who chose to strengthen its industrial base could count on shipping the resulting product to the United States. We could afford to be the military protectors of the entire free world. More appropriately, we have become the receptacle of last resort.

It's to our credit that we took on these responsibilities. We helped many nations -- including our former enemies -- immeasurably. But now the world has greatly changed. We need to understand this, stop pretending we're still as affluent as we once were, and realize that it's not right to penalize our own people for the sake of others forever. It is time to consider what is in the best interest of our own people -- finally.

Related to this is a second reason -- the gross neglect of trade issues on the part of our government. World trade now represents an annual opportunity in excess of $2 trillion, and it is growing faster than our own economy. But today we remain the only major world trader without a real trade strategy -- without a clear picture of how we can best seize that trade opportunity.

Another reason is our national focus on living for the moment without much concern for the future. The issue is consumption versus investment.

I remember that a few years ago someone came out with a bumper sticker that read: "I owe, I owe, so off to work I go." And, to me, this epitomizes our dilemma.

As a country, we don't take the future nearly as seriously as we should. Our financial system encourages short-term focus.

* Our tax system is designed to encourage consumption and to penalize savings.

* And, partly because our tax system is set up this way, we have the lowest rate of personal savings of any of the major industrial countries. The average Japanese, for example, saves nearly 20 percent of his earnings while the average American saves less than five percent and dropping.

I would love to see a bumper sticker that read: "I invest, I invest, so off to work I go." But I think that's a long way away. Even if we change our business practices, tax laws, and personal habits -- even if we find some way to overcome our seeming indifference for the future and our compulsion for consumption -- we'll still be owing the rest of the world for a long time.

And a final reason has been the ability of our trading partners to find intelligent -- and often quite innovative -- ways to exploit our weaknesses.

Japan, for example, has pursued a new economic formula -- one which clearly obsoletes the 200-year-old model of much of the Western world. This is a formula which understands the importance of a industrial base --

* targets and then subsidizes industries deemed key to its economic growth,

* restricts home market access,

* aggressively pursues foreign trade opportunities, and

* incentivizes savings, thereby reducing interest rates and the cost of capital to industry.

I admire the Japanese approach. They are doing what's in the best interest of their people. It is clearly a formula which gives Japan decided advantage and, because it does, it has changed forever the world trade order. Yet, years after it has become apparent, we still don't know how to deal with it. Japan has introduced new rules, and we're still playing by the old ones.

The U.S. semiconductor industry's problems today are, of course, closely tied to all of this.

So far, we have done more than many other U.S. manufacturing industries to adjust to the new trade realities. This is perhaps because we have been the object of a long, extremely aggressive effort of our trading partners to penetrate our industry.

But it's abundantly clear to us that we cannot save ourselves by ourselves. Because we are so intimately linked with the entire system of U.S. industry, government, and finance, we are dependent on the whole system changing in order to secure the kind of future we want.

And getting it to change, as we all know, will be no easy matter.

II. What We Need to Do

After looking at the problems in some detail, the overall solutions seem quite apparent. As a nation united, we have to recognize that every day we fail to take charge of our destiny, we make it easier for our trading partners to take charge of it for us. Then, as a nation united, we have to attack our trade problem on a wide variety of fronts.

We have to use our economic leverage to open closed or severely restricted foreign markets to our goods.

We have to think seriously about all the goods coming into our country and how they affect our overall trade position. If we conclude that restricting some goods will in some ways help us, then we must consider it.

And we absolutely must reorganize our entire system of industry, government, finance, and education to more effectively address current competitive realities.

We must, for example, find more new ways to make the most of our R&D resources. We need to better coordinate government R&D and to coordinate it with commercial R&D and university research. In addition, we need to make commercial R&D more attractive through tax incentives and other measures.

We must, for example, develop a cohesive and coherent trade policy. So far, U.S. trade policy has been <u>not</u> to have a policy. And today, this is a luxury we can no longer afford. Many of us have talked about a Cabinet-level Department of Industry that would define trade objectives and carry them out, and I'm all for it.

Such a department could work:

* to change our antitrust laws to more appropriately reflect the new global trade realities,

* to balance the need for industrial strength with national security and foreign considerations, and

* to bring before the country the importance of a strong, industrial base.

We must, for example, reduce the cost of capital to U.S. manufacturing businesses. This, of course, means making the transition from a consumption-driven to an investment-driven society by:

* reducing the budget deficit quickly and significantly,

* restructuring the tax system to encourage -- rather than discourage -- savings,

* giving industries more incentives to invest in new facilities and capital equipment, and

* pursuing a more stable overall monetary policy.

And we must, for example, improve the quality of our technical education. By this I mean providing more education relevant to business and industry. I would especially like to see a growing emphasis on manufacturing technology and more prestige for those who specialize in it. In the Japanese semiconductor industry electrical engineers who go into it are considered the top of their profession. In the U.S., however, they often have to settle for less prestige than application, process development, and design engineers. And I believe the current state of manufacturing in each country reflects these values.

When we hear all of this, there is a tendency to be overwhelmed -- to wonder where we can even think of beginning. And I understand. As an industry, and as a nation, we have a massive challenge ahead. But, both as an industry and a nation, I believe there is a very logical place to begin -- improving our manufacturing techologies and techniques.

In ours and many other U.S. manufacturing industries, there has been a tendency to place all our eggs in our R&D baskets.

Now, don't get me wrong. I think placing an emphasis on R&D is an excellent practice, and I've always considered a high-R&D-as-a-percentage-of-sales figure as a sign of a company's health and solid future prospects.

But I also don't think it's healthy for us to support basic research and development and reduce manufacturing to the place of illegitmate stepchild. The two are vital ingredients in the success equation, and both have to be nurtured with equal commitment.

In fact, when considering the strength of a nation's industrial base, I might give R&D in manufacturing and support of manufacturing a higher priority over R&D.

Certainly, there has been an inverse relationship between the number of Nobel prizes awarded to the U.S. for science and technology and the strength of our industrial base. And, the lack of the same has not hurt the Japanese position.

This is why I believe that pumping more and more money into basic R&D will not help us improve our trade situation nearly so much as committing more heavily to manufacturing will.

And this is why, as many of you know, I am currently working with people both inside and outside our industry to form SEMATECH, a consortium committed to helping the U.S. regain its leadership position in semiconductor manufacturing technology.

Drawing upon industry, government and academic resources, SEMATECH will develop and test advanced manufacturing processes, materials, and equipment on an actual production line, and to transfer those technologies to its member companies for commercial application. Its goal is to ensure manufacturing parity with overseas competitors by 1990 and the lead by 1993. And its plan is to meet this goal with funds from both member companies and the government.

At the moment, SEMATECH is well along:

* The formal organization has been established and incorporated.

* A board of directors has been selected.

* We have received strong support from both the Department of Defense and the U.S. Congress.

* We have been making real progress toward defining the work to be done.

* The choice of a permanent CEO will be announced shortly.

* And the site for our manufacturing facility will also be selected very soon.

We are on our way. How far we've come as an industry from five (5) years ago. And we are very excited about it. In fact, to show you how far we've come, while I am not in the habit of quoting competitors, I'd like you to hear what AMD's Vice-Chairman Irwin Federman recently said about our effort: "It's a marvelous privlege to be involved with a group that, though small in number and resources, has chosen to forge its own destiny rather than submit to the currents of change."

I couldn't agree more.

III. What's Ahead

Despite the trade problems we have both as a nation and as an industry, I am feeling more confident about the future.

As I said earlier, it sometimes takes a shock to jolt us into action. And I think that the increasingly grim trade news is beginning to have a jolting affect on the public. We are talking about this issue more and more, it's receiving much more play in the press, and it's finally become a top concern among some of our politicians. In fact, when the seven Democratic candidates appeared on William F. Buckley's "Firing Line" show last July, they spent more time talking about trade than they did talking about military spending, the Soviets, the Contras, or even Ronald Reagan.

I also think that we in the U.S. semiconductor industry will gradually be seeing improvements in our trade position.

We have finally convinced the federal government that it's in America's interest for its semiconductor industry to have:

* greater access to restricted foreign markets,

* protection from the unfair trade practices of others,

* tax incentives for R&D, and

* intellectual property protection.

And we see our relationship with government becoming closer and more constructive in the years ahead.

We have also come to understand much more clearly the importance of manufacturing excellence to a strong competitive position in world markets. And both organizations such as SEMATECH and efforts within and between individual companies will help us return to our position as the world's semiconductor manufacturing leader.

Further, I believe a basic change has occurred in the balance between capacity and demand in our industry.

While some of our greatest challenges lie ahead, we also have much to look forward to.

Conclusion

In the book, Re-inventing the Corporation, the authors, John Naisbitt and Patricia Aburdene, quote one executive, well aware of the difficulties involved in re-inventing an established company as opposed to creating a new one. "Birth," said the executive, "is infinitely easier than resurrection."

Clearly, changing the culture, environment, values, and vision of an established company -- especially one that has been successful in the past -- is an awesome challenge.

But the task we, as a nation, have before us dwarfs this by comparison. To more effectively address the new trade order, we have to re-invent our entire national economic system -- a system which also worked extremely well for us for decades. We have to forge a massive partnership of business and industry, government, banks, and schools -- one which will turn our national shortcomings into national triumphs.

I believe that the place to begin this process is by focusing on our most urgent problem: the deterioration of our manufacturing base. And we can best do this by understanding the importance of manufacturing technology to competitiveness and making the appropriate commitment to it.

I also think that, while this issue has long been ignored, an increasingly ominous outlook is finally forcing more Americans to take our trade problems much more seriously. I expect the national debate on trade to intensify greatly in the coming months and years. And I expect much positive movement by both industry and government to eventually come out of it.

For us in the semiconductor industry, there are several hopeful signs ahead. Among them will be:

* greater responsiveness to our needs by government,

* a much higher level of manufacturing expertise made possible both by SEMATECH and by efforts within individual companies, and

* an easing of our traditional capacity problems.

All of these should greatly help our trade and overall earnings prospects.

Thank you very much.

CHARLES E. SPORCK

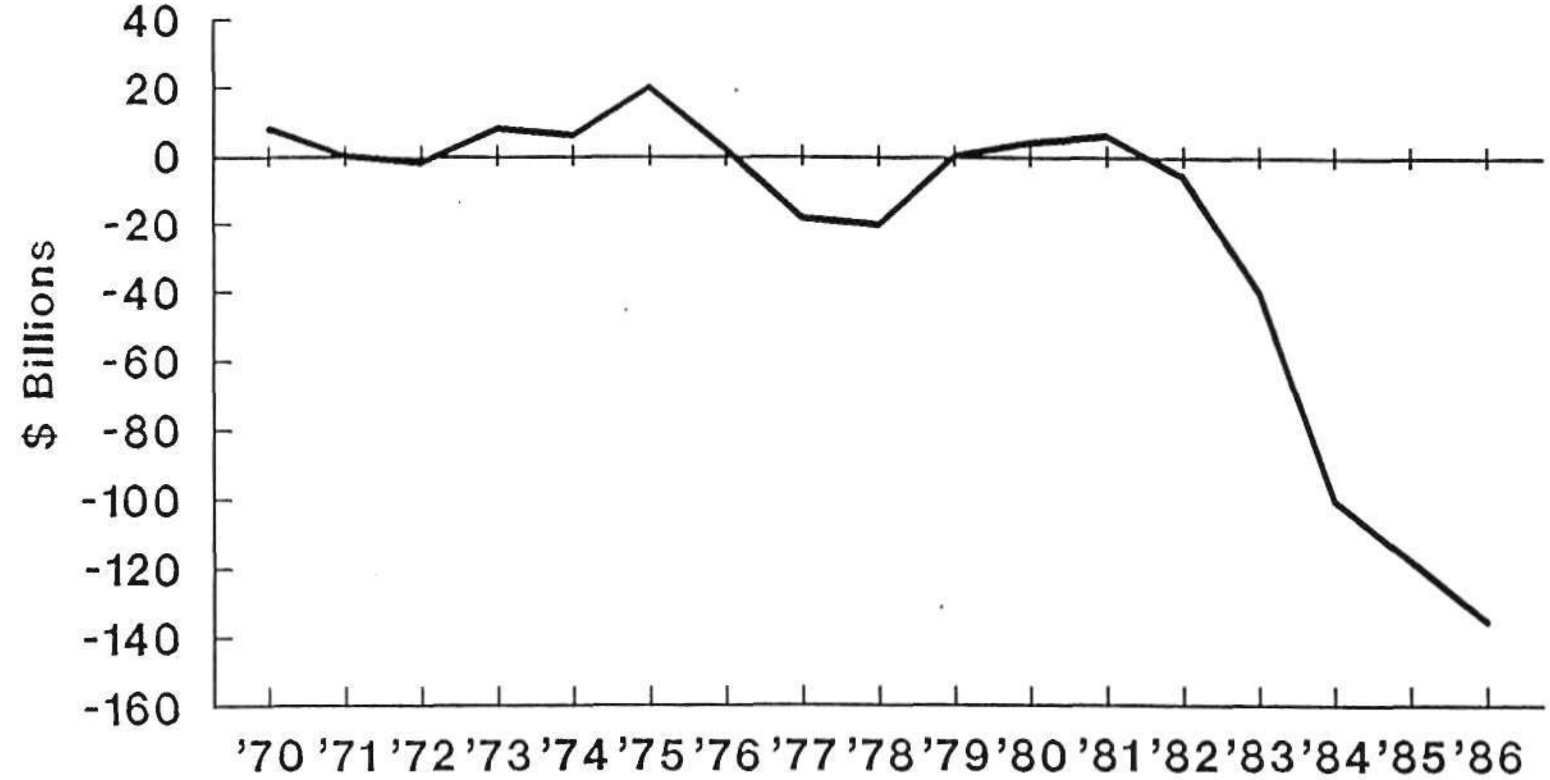
President and C.E.O.

National Semiconductor

National Semiconductor

U.S. CURRENT ACCOUNT BALANCES

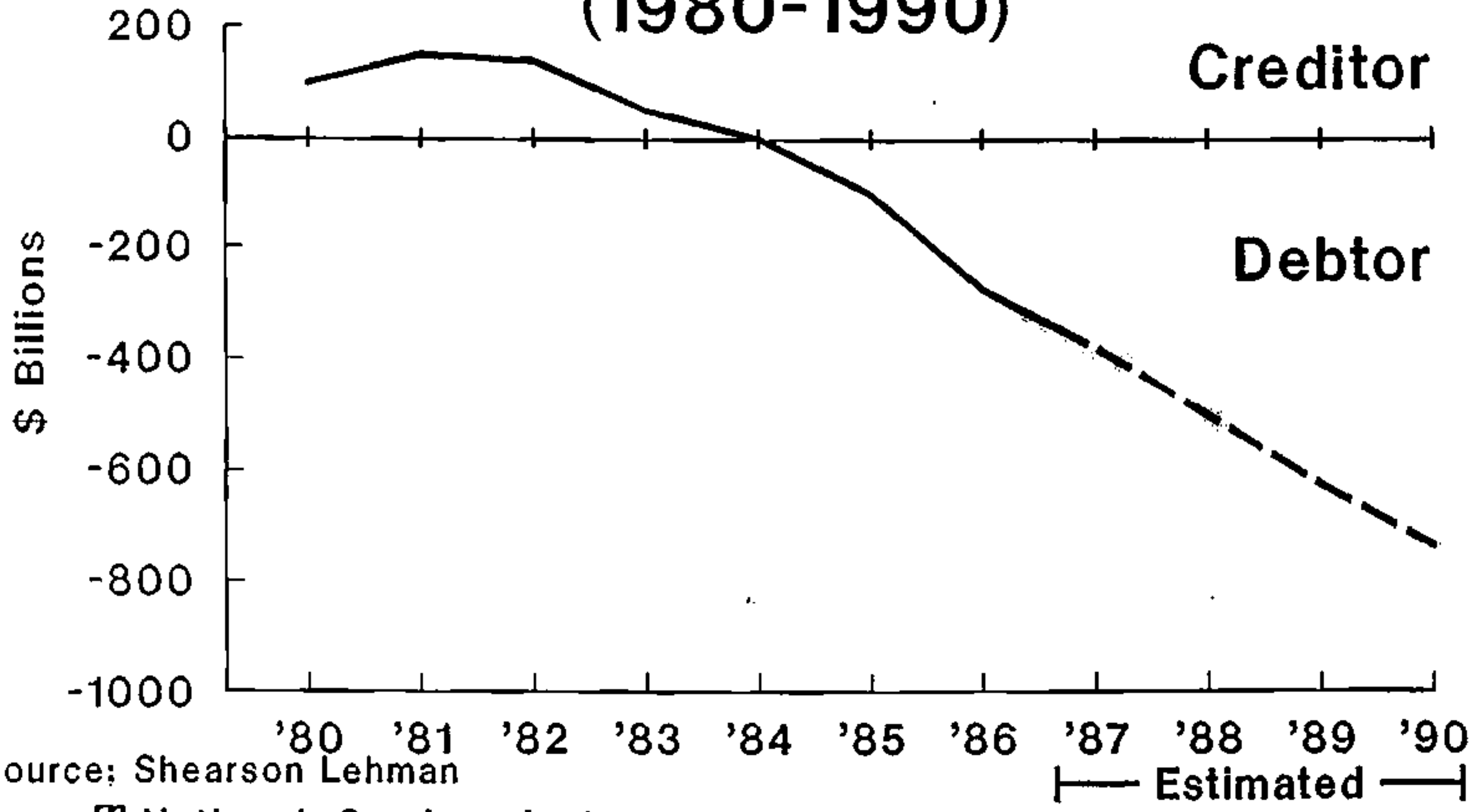
(1970 Through 1986)



Source: Dept. of Commerce

National Semiconductor

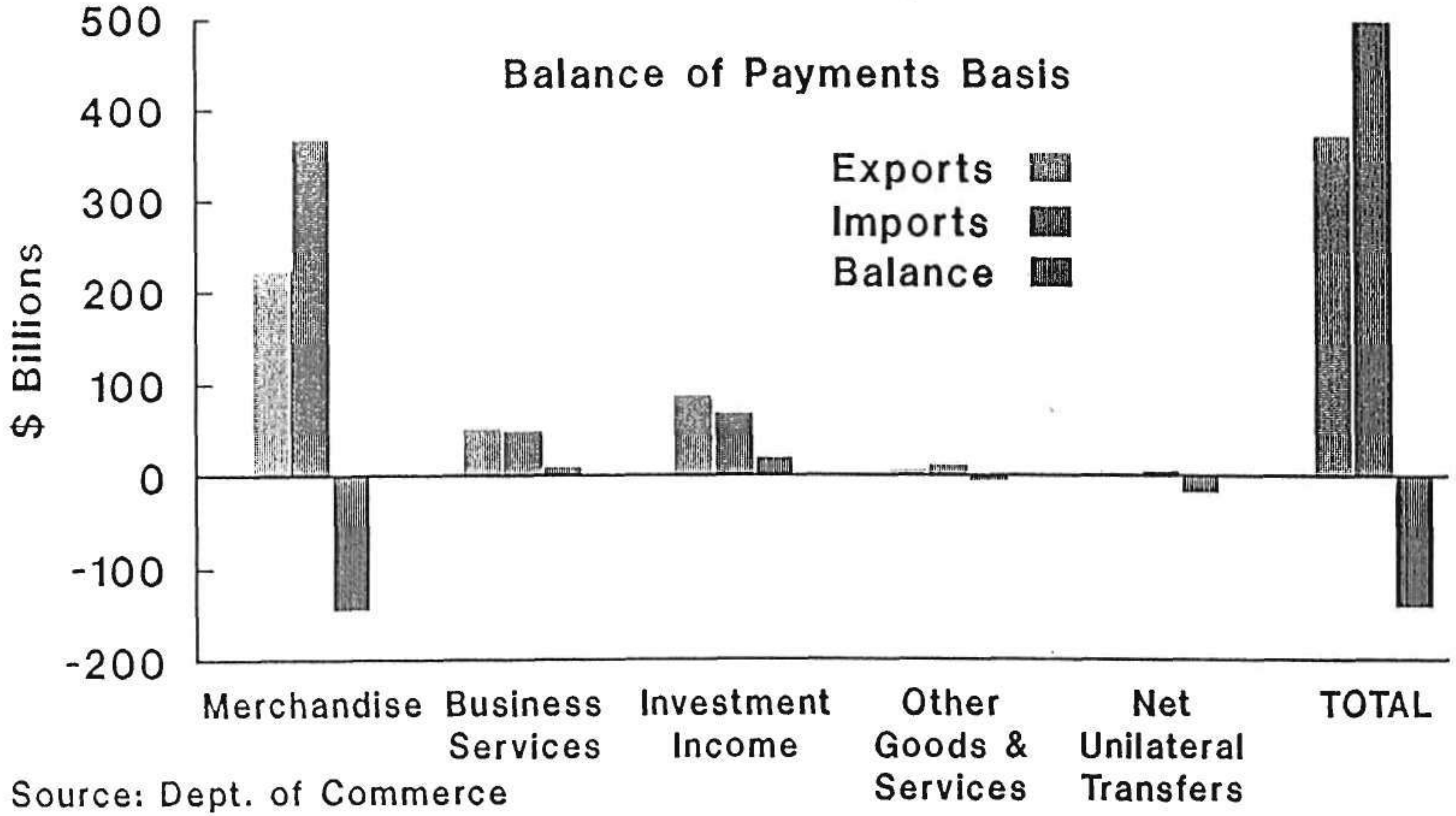
U.S. NET INTERNATIONAL INVESTMENT POSITION
(1980-1990)



Source: Shearson Lehman

National Semiconductor

U.S. CURRENT ACCOUNT COMPONENTS (1986)



Source: Dept. of Commerce

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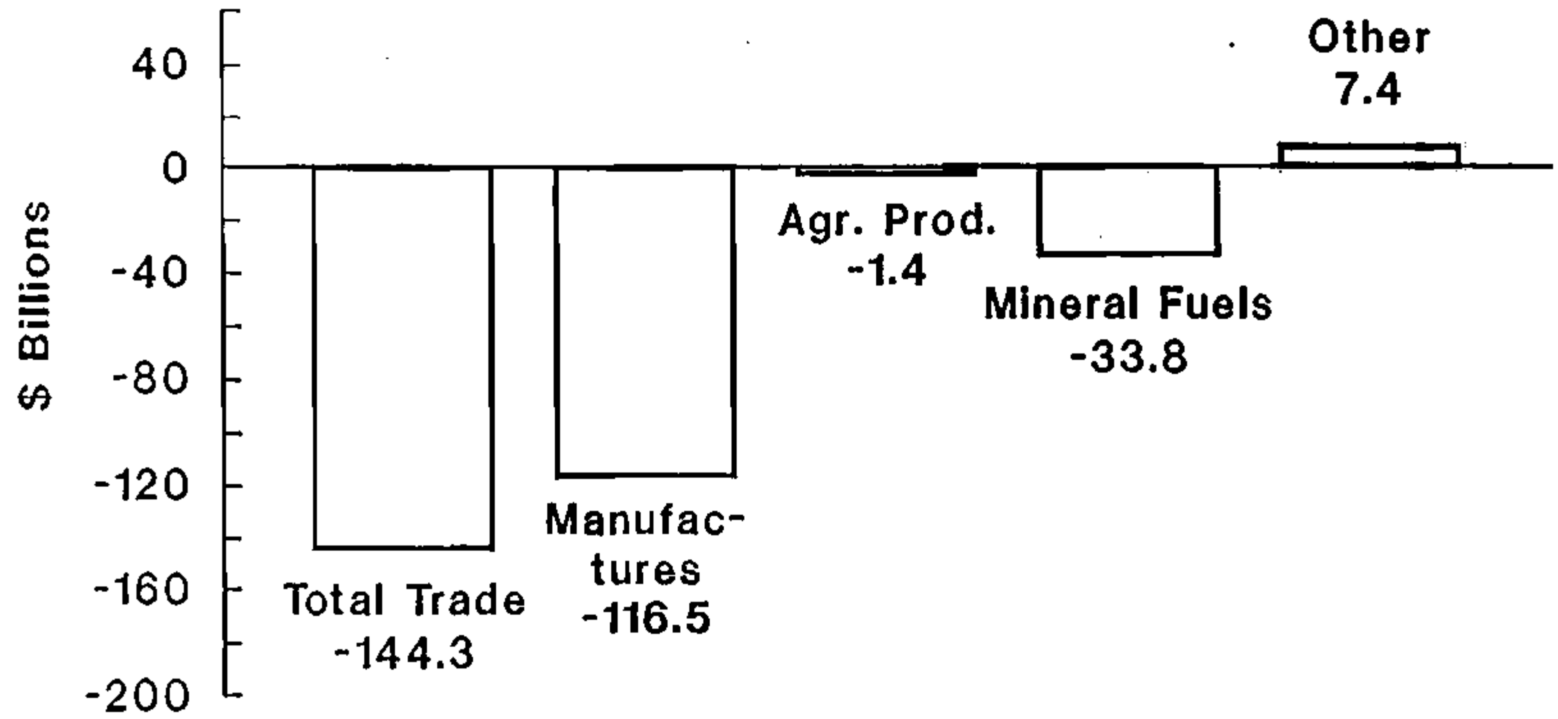
U.S. MERCHANDISE TRADE BALANCES (1986)



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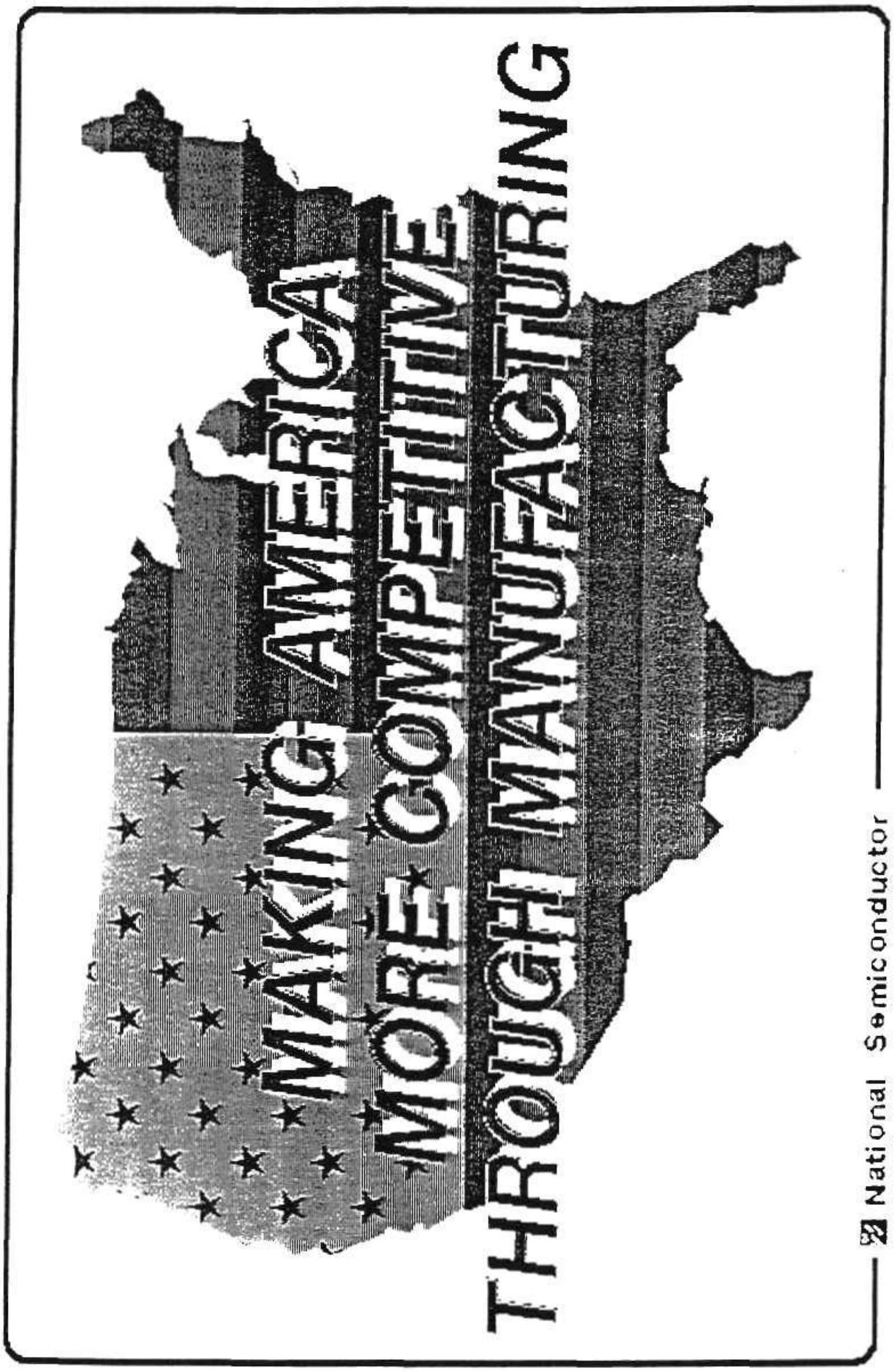
National Semiconductor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FORMULAS FOR SUCCESS OF THE U.S. SEMICONDUCTOR INDUSTRIES

Sanford L. Kane
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Mr. Kane is Vice President of Industry Operations for IBM Corporation. In this capacity, he is IBM's external interface in the area of technology dealing with the semiconductor industry and its support structure, the government, and customers. In previous positions at IBM, he worked as GTD Controller, Manager of Business Controls, and Controller of the East Fishkill Manufacturing and Development facility, after having served in various control, planning, and pricing assignments. Mr. Kane received a B.S. degree in Industrial Engineering from New York University and an M.S. degree in Engineering Administration from Syracuse University.

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Semiconductors' Midlife Crisis

Technical Competitiveness

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FORMULAS FOR THE SUCCESS OF THE U.S. SEMICONDUCTOR INDUSTRY

I can't tell you how pleased I am to be here today. Those of you who are avid readers of Electronic News know that I am just recovering from some abdominal surgery just six weeks ago; and I must say I was very surprised to read about that. But, somebody put it in proper perspective by saying that if President Reagan can have is prostate on the front page of the New York Times, I can make Electronic News with my gall-bladder.

But seriously, it is really a pleasure to be here today. I must say that with IBM stock sitting at around $100, you have to redefine your definition of pleasure. But, I really do appreciate the opportunity to participate in this conference and to play a part, and I must say that I think the theme that has been selected of Semiconductors' Mid-Life Crisis is one that is neither overly dramatic nor far-fetched if you really think about where we have been and where we are going. At stake, in this kind of an environment, is this country's technological leadership and whether or not in the next forty years since we're talking about the next forty years, the United States will play a subservient or a leadership role not just in the technology business but in the world economy.

As we very well know, all of us, either as observers or participants in this industry, semiconductors power much more than a $400 billion or so electronics industry and all the millions of jobs that are related to that. Semiconductors affect nearly every variety of human enterprise including, of course, our national defense. And more and more every day, they help to determine our way of life today and in the future. I don't think it's exaggerated at all to say that unless we find the means of keeping this industry of ours competitive, we are going to end up dependent on others outside of the United States and, as a nation, face a weakened and diminished role. It has been said that if you permit an industry of developing technology to get away from you, then you've clearly let the future get away from you as well. Now, some of you may say it's a picture that's terribly bleak. I think the facts are a matter of public record. We have talked about some of them over the last day or so. And when I talk to people who say that I am unduly alarmed about this, I usually find that they really haven't spent the time examining that record.

Some people are also pointing to the fact that in relatively recent times we have had somewhat of a recovery in this industry, and that is an indication that things have turned around, things are getting better again, the problem is behind us. I would argue that that's not really the case. And to explain why it isn't, I think it is important to start with a brief look at how we arrived where we are in the history of the semiconductor industry.

For most of the forty years that this conference celebrates, the domestic U.S competition did whatever it was supposed to do, whatever we thought was the right place for it to be moving. It drove down the size and the cost of computers that we have learned to know and love, and clearly spread their use. That created an ever increasing demand for advanced and more circuitry. Every product cycle that the electronics industry went through and the semiconductor industry went through seemed able to take advantage of just another semiconductor major technological breakthrough. Concurrently, while these things were happening in the semiconductor industry, these achievements created a terrific infrastructure of top-notch U.S. materials and equipment companies, more than 600 of them around the United States. And they frankly were virtually unchallenged around the world as late as 1979.

Throughout the late '70s and the early '80s, American microchip manufacturers were phenominally successful. They led the world in innovation by far and seemed on their way to dominating the global markets, as we saw them, forever. As late as 1984, less than three years ago—how time flies, the U.S. semiconductor industry had the best year in its history if you measure it in terms of revenue and profit growths. But not since that time has the chip demand of the world exceeded our supplies. Then in 1985, just one year after 1984, that same industry that we talk about had its worst year in history in terms of both revenues and profits. And frankly, 1986 wasn't a hell of a lot better, either!

What was happening to us? It took us, frankly, a while to understand the new situation, if you will. We knew that there was offshore competition, principally from Japanese companies. But so, what! Wasn't this the industry built in America? Didn't the United States lead the world in semiconductor innovation and techniques, and by such a great lead that nobody, frankly, could overtake us? Gradually, we began to understand, I think all of us, that the world was changing. We began to understand what was happening, especially, as Charley puts it, we've gotten some jolts. We've seen some U.S. chip makers close their doors. We've also found that there are less and less companies that can compete in areas such as the higher density dynamic random access memory business. It also dawned on us that the Japanese companies are not doing this on price alone. They are no longer relying simply on U.S. technology, copying our techniques, and building products. What they are doing is investing heavily in their own technology development, especially in the manufacturing areas.

Believe it or not, in spite of those kinds of things, and the things I've said I don't think you need to be rocket scientists to pick up, seem to be rather obvious. Believe it or not, there are still those people out there who don't get that picture. They say, "Well, that's really not bad news, might even be terrific, because what we're going to do is continue to determine the technology with our designs, developments, and implementations, and we will allow the Japanese companies to manufacture the chips that we design, and therefore, we will maintain our lead in the technology." Well, I'm here to tell you, it's just not going to work that way! We need to understand that as Class A manufacturers, and I mean that with a capital "A", the Japanese companies are already producing much of the specialized equipment that is necessary for the ultraclean and sensitive processes that chip fabrication requires. Their process equipment business in Japan has more than doubled since 1980. When you fall behind in the state-of-the-art equipment and materials for chip making, you are sliding into a non-competitive situation and that's lethal in this business. There's no way to really establish and maintain a leadership position in semiconductors unless you lead in all three aspects of the industry—design, development, and manufacturing. What we need to do is to agree that that's a problem that faces all of us.

I must tell you that sometimes, as I have had an opportunity in the last year and a half or so to talk on this subject, I have been asked why on earth does a so-called captive semiconductor manufacturer like the IBM company, which frankly makes plenty of chips, but makes them all for its own use, why are we so concerned about the health of the U.S. industry; why do we take the time to make such an effort to get that message across?

If you really think about it, the answers to that question are similar to those that you would get from most of the merchant companies in the United States. First of all, it is very clear to us that the semiconductor industry is a major driver of the U.S. economy, and innovation from this industry is going to continue to drive and effect the U.S. economy at an exponential rate. There are many economists who say that before long, as this industry goes so will go the nation. IBM's largest single marketplace is in this country. Its health clearly depends on the health of its customers and the success of all of us is tied to the state of the national economy.

Next, IBM continues to go outside and buy chips that it doesn't make because we can't make all our needs, and because there are some chips that we either are not set up to make or choose not to make. Consequently we, in addition to being a large manufacturer, are one of the largest purchasers of semiconductors in the world. And like everybody else, we want to beat down our costs by finding the best we can in price performance. We prefer the option of buying our products and our needs for our end-products locally. By choice, our IBM European manufacturing operations buy much of their chips in Europe. Our Asian manufacturing operations buy many chips from Asian merchants as well. Here at home in the United States we would like to have that same choice and continue to have that same choice.

Finally, IBM is not only a volume purchaser of chips, but as I mentioned, we are clearly a volume manufacturer around the world for use in our products. We do that because we believe that it gives us a technological edge in turning out what we believe to be the best packaged electronics that you can buy in the world. But in order to support that large chip making capability, we are very dependent on other companies for the tools, equipment, and the materials needed for the fabrication business. These companies could not, I assure you, stay in business or keep pace with the technology if they didn't have a viable, healthy, domestic semiconductor market in which to sell. We frankly would be very concerned as a company if we lost our ability to buy the most advanced tools and equipment from U.S. sources.

The factors I described that are IBM's reasons for being concerned about this frankly touch on all of us. Each of our stories would vary depending upon circumstance and scale of magnitude, but we are really all in the same boat. So I can tell you very frankly that IBM very much shares your concerns as an industry. And these concerns are more and more justified by all of us with every passing day.

What are the answers? How does the American semiconductor industry make sure that we survive this crisis and that we are here to talk about it again forty years from now?

Such things as political redress, protectionism, penalties for dumping chips on our market at less than cost, frankly make us feel quite good momentarily. But they are really stop-gap measures, and in the end I think all of us will find that they demand a price that is one that we really can't afford to pay. There are clearly better long-term answers to these problems.

One thing we should do is look at what the Japanese have been doing, learn from what we see, and do it better than they do. The first thing that we ought to look at is to note that the Japanese have an industry-wide strategy.

Frankly, we don't. We have clearly focused on our own individual situations. We have each put together, some of us haven't, but most of us have put together wishful company plans of what ought to happen over the next five years and we will presume that it will. But we have simply ignored in that process the great areas of commonality that exist among us, areas that lend themselves to joint uses of our resources, both material resources and intellectual resources. So, first, we need to consider forming all kinds of specialized industry groups amongst ourselves, launching joint efforts of various types, fostering various university and industry alliances and appropriate government industry cooperation as well. And these are activities that frankly have not in the past been at home in our culture, and we need to change that.

On that last recommendation, government as a supporting player, for example, may sound quite strange; especially from us. It's even a little scary to some of us. But frankly the fact is that government and industry are no longer thought of as instinctive adversaries; they can't be. Government is very much aware, and we've seen the evidence of this, of their need to work constructively with this industry. And we view this as another very clear, promising way for all of us to make up for a lot of lost time.

Again, let us look at the results of the years of that type of coalition that has taken place between public and private sectors in Japan. We sometimes forget that the Japanese semiconductor business has been hit almost as hard as we have in the last few years by slackened world capital investment, by sluggish marketplaces, and clearly by a weakening dollar. U.S. firms, as we know, over the last few years had been operating at as low as 50% capacity, but the Japanese were not doing a lot better than that. In many places they were operating at 60%. Yet the Japanese have financed a momentum of development and growth that no single American company could match and stay in business if they wanted to.

Today, Japan is spending more on semiconductor R&D than the United States is. Its strategy is market penetration with advanced products including such things as 1 Mb and 4Mb DRAMs. We believe that the Japanese companies have a larger installed manufacturing base than the U.S. manufacturers, and their capacity is typically more advanced and more automated, in spite of the fact that for the last two years the U.S. industry has spent more on plant and equipment than the Japanese have. What the Japanese have learned, and what we clearly must learn, is the value of great interdependence.

If our industry is to remain a truly progressive industry in the United States, it must involve the interaction of minds and ideas from all sectors of our society. Other countries have already caught on to this idea—Korea, France, Britain, and Germany. All of them have semiconductor development and manufacturing cooperative efforts between industry and government, and there are even some joint semiconductor enterprises amongst European countries; so its going even beyond common country borders in those cases.

I don't think for a minute that such collaboration amongst government, industry, and academia, would spell the end of private competition. If you just look one more time at Japan, you can see that the Japanese firms who are in these kinds of cooperative efforts remain fiercely competitive today. So it's important for us to acknowledge that we can't deal with this problem entirely as separate business entities. When Ben Franklin signed the Declaration of Independence a couple hundred years ago, an act that clearly made him guilty of treason in the eyes of the British government, he said to his fellow participants, as we all know, "We must all hang together or assuredly we will hang separately." I propose, and I don't mean to be trite about it, that we hang together in this enterprise. If we want to survive this mid-life crisis to the semiconductor industry, we are going to do it together as an industry as opposed to simply thinking that we can survive as individuals without having to deal with one another.

How do we develop that industry clout, if you will, to take on world competition as we through to the future? We do it through a strategy of maintaining and heightening our lead that we have in chip design and development across the board, and by recapturing that very important lead in the manufacturing process. And how do we do that? First, I briefly mentioned and others have said as well, we need to form various specialized industry groups, we need to undertake joint efforts amongst us, and seek appropriate government participation. What we also need to do is to more than match the Japanese in research. We need to find ways to blend the various mechanical, chemical, and optical processes to arrive at the greatest yields, at the highest qualities, at the lowest costs, so that our products from a manufacturing standpoint will be the best in the world.

Research cost to get us there demands tremendous investments of money, of resources, and no guarantee of an equitable return--which is sometimes kind of frustrating for us. But in order to avoid the costly redundancies that would exist if we went at this alone, it's important that there be a cooperative pooling of the talents and the resources that are required through government, industry, and university laboratories.

The focus, it seems clear to me, must be on finding new and unconventional methods in manufacturing processes. We need to focus our concentration as well on conducting some basic research in areas of materials, gases, and environmental control techniques, frankly areas that we have taken for granted for far too long in this country. We also need to develop process, design, and test modeling techniques to support the various manufacturing technology improvements that we are working on.

And last, but not least, on these lists of things we need to do, and I don't think I would get any disagreement here, we need to significantly improve the development of industry standards which frankly in my view is today bordering on a state of chaos.

As you probably already know we, as an industry, have started putting our money where our mouth is on some of these things. It's a vital first step in our strategy for success, and it's called Sematech. A few of us have talked a little bit about it but I just want to focus on a few points relative to that, that you may not be total aware of, sort of an update on where we have been going.

Just this past August after talking about it for an awfully long time--those of us who have been involved in it from the beginning really feel that it has been a long time--Sematech was legally incorporated in the State of Delaware as a non-profit, not for profit, corporation. Its mission plainly and simply was designed to help revitalize the U.S. semiconductor industry through a manufacturing excellence. As you probably know, it's a consortium of U.S. semiconductors manufacturers and equipment suppliers. We already have 13 initial members, committed to be members and putting in their resources in dollars. They include most of the best known names in the U.S. semiconductor industry including IBM. Sematech's full operation is getting under way; we have people physically located out in California in temporary offices doing a lot of the planning and technical work to get us started. Even while that is going on, we are still awaiting the government's final decision with regard to their investment in this consortium. At this stage in the vagaries of the way the process works in Washington, I think it's fair to say that we're quite confident with everything we've seen. I think we're past the stage of wondering whether we will get government funding; we are now at the stage of wondering when we will get it, because we are tied into the entire budget process in Washington. We are very optimistic about that process and our prospects in it. To get going we are also looking for a facility around the country that will accommodate a professional staff of about 700 folks, and we are not quite ready to announce where that will be, but I can assure you that we are getting close to that decision.

The schedule that we have laid out for ourselves is clearly a demanding one. We want to have wafer starts in the facility that I just described by the second half of next year. And we want to achieve world leadership in a world class manufacturing environment within two years after that.

Sematech's product will not be chips or output if you will; it will be knowledge shared by the member companies which they can then apply to their own manufacturing techniques and processes. The strategy of Sematech is to take advantage of the U.S. industry's important strengths in product designs, skills, and customer relationships. Each company will have to establish its own strategy to emphasize their own strengths in these areas, with their own customer sets in mind. Member firms will contribute an annual fee as well as assignees to the resource pool, and they will also enter into extensive joint research and process technology and tool requirements. The collaboration of industry, university, and government not only will provide resources and foster creative synergism, it will provide also a set of checks and balances. Research will not become lopsided in favor of one aspect of the commercial industry, or military, or academic ends.

We clearly have a long way to go in this process, but we are encouraged, very encouraged, by the obvious dedication of all of the participants that we have seen to date. One reason we get that encouragement is the people that the members are assigning to Sematech. You go to any of these meetings, you go to any of these workshops, and what you see sitting around the table are the top notch engineers and scientists from the member companies. We are sending our best people because we are convinced that it is in our best interests to do so, because they will have something to add to the equation and they will be able to learn better than if we don't send our best people. We have seen that consistently across the board, and that is a very encouraging sign to all of us.

None of anything I have described along those lines will put a damper on competition. In fact, we believe that it will be just the opposite. One objective is to make sure that a lively and healthy competition continues both domestically and internationally. All parties agree that it is absolutely essential to lead in the technology. Unless they do, the products that we make become commodities with unacceptable profit margins and that will then limit the available resources for R&D investment; then you go into a spiral. It then becomes easy for competitors to leapfrog over you with the next generation of processes and tools and manufacturing science and new products. So clearly in order to keep that up at the forefront, Sematech will plan to have a low volume manufacturing facility where we will have the ability to prove out the various new techniques and tools and processes that we will work on and verify that their performance is accurate before we transfer those new techniques back to the members.

The focus, quite frankly, on this whole process is on reclaiming the edge in semiconductor manufacturing and to keep our vital materials and tool suppliers healthy. Our knowledge that we derive from Sematech will be shared with all the member firms. We think by this we can avoid costly redundancies in experimentation, or of re-inventing the wheel over and over again. Intellectual property and proprietary information of the individual members will be protected. Sematech deliverables that we give out, if you will, to our members will include, amongt other things, the equipment and process modules that the members can then integrate into their own proprietary processes and products.

I must tell you that some people, both from what I have read and heard from some comments, have expressed some skepticism about IBM's involvement in Sematech. They point to the fact that we have continued rather publicly to make heavy investments in our own semiconductor research laboratories, and they ask how much of that activity is ever going to be shared with the Sematech partners. Let me try to answer that.

Our labs are busy working on new materials and techniques as a means of finding ways for us to design and develop new chips and products. How we will manufacture those chips will very well depend, at least in part, on knowledge that we think we can gain from our participation in Sematech. At the same time we fully expect to bring more than just our money to the table in Sematech. We expect to provide our fair share of people and technological know-how to this endeavour. I will tell you that whatever the outcome, IBM's commitment to Sematech is total, sincere, and frankly a highly expectant one. By no means is Sematech a research lab in competition with individual company labs. It extends only to where the members have common manufacturing interests. It doesn't include planning, designing, or producing specific products. Nobody's strategy or product planning in this endeavour is going to be compromised.

Beyond all that we believe there is a greater benefit from the Sematech operation than its list of deliverables to the industry. Frankly, I would strongly encourage all those of you who are manufacturers or users of semiconductors here today to join us in this terribly important venture. We already see evidence that Sematech will serve as a catalyst. Since Sematech was conceived just a year ago we find that a lot of things have begun to happen; uncharacteristic of our industry in the past. More people are talking to one another across corporate boundaries, exchanging information, understanding the sense of pooling talents, taking advantage of assembled resources; at the same time respecting this country's historic concern for preserving competition. I personally believe that just these types of spin-offs of Sematech will transform the nature of the business, and clearly do it for the betterment of all of us.

Sematech is not intended to be the be-all/end-all for this equation. We mean it to be a way to point the way to the technical collaboration of other company groups and not just expedient short-term ventures, but on going ones that are the only way to develop the momentum of the expertise and comfort of working with one another. We believe that as Sematech progresses, a lot of other things will happen as well. We expect that by the time we have achieved the goals we have set for ourselves as an organization in Sematech, we will have clearly written new ones to achieve. So it's an ongoing process.

Perhaps one of the most useful results of this entire Sematech experience will be a successful pattern for others to follow in the future. I must admit, as I close, that I have come upon some pockets of synergism every now and then; fortunately, less and less. Those who say, "Why are you guys involved in this", not just IBM but the whole industry, "the game is already lost, why throw good money after bad?" They make a list that's more or less the standard list of, "we've already seen U.S. steel making, ship building, appliances, consumer electronics industries curtailed by off-shore competition, and why should the U.S. semiconductor industry assume that it's going to prevail and be any different?" Well, I'll tell you why. I believe that the U.S. semiconductor is unique in a number of ways that many of these other industries are not. First, our strength as an industry continues to be in the design of new products, and the rewards there are clearly apparent. Second, we are consistently, and in good times and bad, achieving significant productivity improvements. Third, it is clear as we look to the future that new market opportunities will always exist, assuring our growth as an industry. Fourth, we have managed in good times and bad to recognize our shortfalls and our problems and we are taking action to correct them. And last, it is clear to me that no other industry has the tradition of the strong and resilient entrepreneurship that this one has. That history of ours shows a willingness to respond rapidly to new opportunities. In short, if we simply remember how we got to where we are today from forty years ago, and continue to exploit the characteristics that I've listed, we will clearly continue to be the pioneers over the next four decades, and lead the way into the new technological adventures that are ahead of us. With the willingness to work together, we can ensure that this nation of ours and the world will enjoy all the economic and social benefits that this industry is capable of providing, and I would suggest that we just meet here forty years from now and see if I was right and we don't all agree on that.

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OPPORTUNITIES FOR GIGASCALE INTEGRATION

James D. Meindl
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Dr. Meindl is Vice President for Academic Affairs and Provost of Rensselaer Polytechnic Institute (RPI) in Troy, New York. Prior to joining RPI, he was with Stanford University where he was the John M. Fluke Professor of Electrical Engineering, Associate Dean for Research in the School of Engineering, Director of the Center for Integrated Systems, and Director of the Electronics Laboratories and the Integrated Circuits Laboratory. He has also served as Director of the Integrated Electronics Division at the U.S. Army Electronics Laboratory. He is a cofounder of Telesensory Systems, Inc., and has served as a member of the Board. In addition, he is a Fellow of the IEEE and the American Association for the Advancement of Science. Dr. Meindl received B.S. and M.S. degrees and a Ph.D. in Electrical Engineering from Carnegie Mellon University. He has authored a book on micropower circuits and more than 300 technical papers on integrated circuits, micropower circuits, and medical electronics.

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Semiconductors' Midlife Crisis

Technical Competitiveness

DR. JAMES D. MEINDL

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OPPORTUNITIES FOR GIGASCALE INTEGRATION (GSI)

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Abstract

Gigascale integration (GSI) of more than one billion components in a single silicon chip is likely to be the mainstream of electronics technology early in the next century. The one-quarter micron geometries associated with GSI will press the physical limits of future MOS technology.

I. Introduction

Gigascale integration of more than 10^9 components in a single semiconductor substrate will be governed by a hierarchy of limits. The levels of this hierarchy can be codified as 1) fundamental, 2) material, 3) device, 4) circuit and 5) system [1]. Fundamental limits are immutable laws of nature; they cannot be changed although new laws are discovered occasionally. Material limits are specific to chemical composition and structure but do not change frequently in practice. Silicon has been the keystone material of integrated electronics for more than the past two decades and this is unlikely to change during the next two. However, compound semiconductors and perhaps superconductors offer outstanding long term promise. Device limits depend upon both the material properties and geometric configuration of GSI components. Consequently, these limits are useful in estimating the smallest possible dimensions of devices such as MOSFET's. Circuit limits are unique because they retain both a complete physical description and a useful definition of the information processing function of a group of transistors and interconnections. Therefore, the circuit level of the hierarchy is the most appropriate one for accurately projecting limiting dimensions of GSI structures for particular purposes. System limits depend strongly on the specific application or end use of a chip. They must account for such factors as packaging and architecture. A new and compact system-level circuit model predicts the impact of changes in material, device, circuit and packaging parameters as well as architecture on system performance. A key issue which can be addressed using this model is how best to partition a system for maximum performance using a selected technology.

The following discussion is divided into five sections which treat fundamental, material, device, circuit and system limits in a sequence corresponding to the hierarchy of limits on ultra large scale integration (ULSI) of 10^7 - 10^9 components per chip and gigascale integration of greater that 10^9 components per chip. Contrasting features of Si and GaAs technology are considered. An explicit purpose of the discussion of system limits is to provide technologists with a helpful perspective for assessing the potential impact of a proposed technology on overall system performance.

Fundamental Limits

Fundamental limits on GSI are closely related to basic physical laws. By definition, these limits are material, device, circuit and system independent. Consequently, fundamental limits must represent extreme boundaries beyond which lie only forbidden zones of operation. Thermodynamics, quantum mechanics and electromagnetic theory impose the three most important fundamental limits on GSI.

Thermal fluctuations enforce a limit on the energy required to switch a node in a digital system, e.g. from a "0" to a "1" state. This switching energy W must be greater than nkT where $n > 1$, k is Boltzmann's constant and T is absolute temperature. Clearly, both k and T are independent of the material, device or circuit associated with the node and decreasing temperature results in a reduction of the switching energy limit. Larger values of n increase the mean time between failure of a switching operation.

The uncertainty principle of quantum mechanics also imposes a limit on switching energy. A measurable energy change W occurring in a time t must be greater than $h/2\pi t$ where h is Planck's constant.

Finally, from classical electromagnetic theory the velocity of propagation v of a high speed pulse along an interconnection line cannot exceed the speed of light in free space c. Even the fundamental limits on switching energy described above are subject to question if reversible logic elements are postulated [2].

The principal value of fundamental limits is that they provide a set of boundaries which indicate the extent of potential opportunities for improvements in the performance of a switching device or an interconnection.

MATERIAL LIMITS

Material limits depend on the chemical composition and structure of a substance but not on any particular device configuration. Compared with fundamental limits, the number of material limits is quite abundant. Examples of such limits for a semiconductor include its energy band gap, intrinsic carrier concentration, Debye length, intrinsic resistivity, mean free path, mobility, breakdown field strength (E_c), scattering limited carrier velocity (v_s), thermal conductivity, etc.

Currently, the two most important semiconductor materials for electronic devices are Si and GaAs while GaAs and InP are most useful for photonic devices. The principal reason for the importance of GaAs in electronic devices is its superior electron drift mobility. Typical values for intrinsic mobility are given in Figure 1.

At high electric field intensity, electron velocity, of course, saturates. Typical values are given in Figure 1.

An interesting carrier transit time limit for comparing Si and GaAs is the time t required for carriers traveling at the scattering limited velocity v_s in the presence of a near breakdown field strength (E_c) to undergo a potential drop V which is given in Figure 1. Regardless of the type of bipolar or field effect transistor in question, carrier transit times cannot be smaller than those cited.

A somewhat more sophisticated material limit can be formulated by deriving the minimum allowable switching time t_s for a device whose power dissipation P_s is limited by thermal spreading resistance. An expression for this time is given in Figure 1 where K is the thermal conductivity, v_s the electron saturation velocity and T the temperature difference between the device and its heat sink.

The preceding material comparisons of mobility, saturation velocity, transit time and thermally limited switching time indicate that although GaAs offers a substantial advantage of about six times in electron (but not hole) mobility, its saturation velocity is only about twice that of Si. These features have long been recognized. This is not the case for the thermally limited switching time which indicates that for extremely small devices GaAs may lose its mobility or speed advantage entirely since higher power dissipation can be tolerated in Si due to its three-fold superior thermal conductivity.

The key material limit for an insulator is its breakdown electric field strength.

The most important parameter of an interconnect material is its resistivity. Recent discoveries of high temperature (e.g. $100^{o}K$) superconductors suggest extremely promising opportunities for cryogenic GSI.

Device Limits

Device limits encompass all material limitations in addition to factors related to geometric configurations and dimensions. To illustrate device limits consider the MOSFET illustrated in Figure 2. As indicated in Figure 3, scaling or reducing the dimensions of a MOSFET begins with the definition of a device scaling factor $S > 1$. Then all lateral and vertical dimensions of the MOSFET are scaled down by the same factor $1/S$. In addition, the supply voltage is scaled as $1/S$ in order to maintain a constant electric field strength and hence equal safety margins in the operation of the device.

The advantages of this constant electric field scaling are illustrated in Figure 4. Device operating speed increases so that gate delay is reduced by $1/S$. Packing density or the number of transistors per unit area increases as S^2 and power-delay product or the energy consumed per switching transition decreases as $1/S^3$[3].

The issue of course is how large can S become? This question is essentially equivalent to asking what is the minimum allowable value of channel length or L_{min}. A rough approximation to L_{min} can be calculated by imposing two conditions on the MOSFET.

1) L_{min} must be greater than twice the depletion width d of a one-sided planar step junction and,

2) the substrate doping concentration N_a must not lead to breakdown of the drain-substrate junction nor the gate insulator for the required drain supply voltage. For a typical substrate doping N_a = $1.5x\ 10^{17}/cm^3$ and a drain supply voltage V_{DD} = 0.5V, L_{min} = 0.18 microns.

A more refined estimate of the device limit on L_{min} can be made by imposing the arbitrary criterion that L_{min} is reached when the change in threshold voltage due to short channel effects ΔV_T (Figure 5) equals 10% of the long channel threshold voltage V_T[5]. A similar criterion has been applied to enhancement mode MESFET's [5].

Following the pattren established for MOSFET's, interconnect scaling also begins with the definition of a "device" scaling factor $S > 1$. In addition, it is useful to define a chip scaling factor $S_c > 1$ since chip dimensions tend to increase with time. To illustrate scaling issues, it is helpful to recognize two different categories of inteconnections: local and long distance. Local interconnections can be viewed as extending from a logic gate to a nearest neighbor and therefore tend to scale in length as 1/S. Long distance interconnections may extend from corner-to-corner of a die and consequently tend to scale in length as S_c.

Assuming cross-sectional dimensions of local interconnects scale as 1/S, Figure 6 summarizes salient results. A concern is that the interconnect time constant RC does not scale as 1/S following MOSFET delay but rather RC remains constant. This indicates increasing impact on circuit delay time of local interconnects as scaling continues. In addition, IR drop does not scale, current density increases as S and contact resistance increases as S^2. Clearly, the conclusion is that whereas scaling benefits transistor performance, it has the opposite impact on interconnections. The impact of scaling on long distance interconnections will be discussed as a circuit limit.

Commonly available Si components include enhancement and depletion NMOST and PMOST, NPN & PNP bipolar, JFET, EPROM and E^2 PROM devices as well as CCD's. The most widely used GaAS devices are MESFET's, modulation doped field effect transistors (MODFET's) and heterojunction bipolar transistors (HBT's), both of which incorporate GaAs-(AlGa)As heterojunctions, as well as diode lasers. The purpose of this listing is to underscore the complimentary features of the Si and GaAs technologies. Clearly, the insulated gates of Si devices are crucial to their superior logic and memory circuit capabilities whereas the direct band gap of GaAs is crucial to its superior operation in diode lasers leading to lightwave interconnections e.g., from chip-to-chip.

Circuit Limits

Circuit limits depend jointly on device capabilities and system requirements. Perhaps the two most important questions to be explored at the circuit level of the hierarchy are: 1) what is the minimum supply voltage at which a logic gate can provide useful operation and 2) what is the minimum channel length L at which an MOSFET can operate effectively in a logic gate?

The most basic form of logic gate is a simple inverter. The requirement that a chain of inverters be able to quantize input signals to restore "0" and "1" levels leads to the conclusion that the incremental voltage amplification of the inverter at the transition point (i.e. where input voltage equals output voltage) must be greater than unity. Imposing this system/circuit requirement on a CMOS inverter in a rigorous analysis leads to the result that the minimum possible value of supply voltage is approximately 4kT/q or about 0.1v at 300^{0}K[6].

The quintessential requirement of an incremental amplification greater unmagnitude than unity at the transition point of the transfer characteristic of a logic gate also provides the basis for assessing the minimum allowable channel length of a MOSFET. Basically, as short channel effects and drain induced barrier lowering reduce the output impedance of an MOSFET, the amplification of a logic gate in the transition region degrades. Studies of circuit transfer characteristics for very short channel MOSFET's have indicated that useful minimum allowable channel lengths appear to lie in the 0.1-0.2 micron range for CMOS gates and in the 0.40-0.50 micron range for E/D NMOS gates with reasonable and equal design margins and a supply voltage of 2.0V [7]. Assuming a fan-out of two, the corresponding gate delay times are 20 and 100psec for CMOS and E/D NMOS respectively.

In many complex chips such as random access memories, the cross-sectional dimensions of long distance interconnections are scaled at the same rate (i.e. 1/S) as local interconnections. Layout and processing requirements influence this practice strongly. The salient results are illustrated in Figure 7. The principal concern is that the interconnect time constant scales as the rapidly increasing function $(SS_c)^2$ [1]. This result raises the question of limiting values for S and S_c for long-distance interconnections. To insure that long distance interconnect delay is not severely degraded, the total distributed resistance R_{int} of the interconnect must be less than 2.3 times the output resistance of its driver circuit [8]. In order to meet this requirement as chip size or S_c increases, it may become necessary to scale the cross sectional dimensions of long distance interconnects more slowly than 1/S. Alternatively, reducing the temperature to 77^oK to decrease the resistivity of Al interconnections or perhaps to enable superconductive interconnections are conceivable possibilities.

In considering circuit limits for GaAs MESFET logic using enhancement drivers and depletion loads (i.e. DCFL), it is interesting to observe that in order to obtain equal static design margins for CMOS and E/D NMOS logic, it was necessary to use MOSFET's with channel lengths of 0.45 microns for NMOS while the circuit advantages of CMOS permitted 0.15 micron channel lengths [7]. This suggests that due to the similarity of E/D NMOS and DCFL circuitry, MESFET channel lengths in DCFL may be required to be substantially larger than MOSFET channel lengths in CMOS. This, of course, could compromise the potential speed advantages of GaAs DCFL.

Epitaxial deposition of GaAS on Si offers the opportunity to combine the best devices and circuits of both technologies. This combination may be internal CMOS logic and memory with GaAS interface circuits and chip-to-chip lightwave communication. The necessity of a "fiber optic printed wiring board" or its equivalent appears to present itself in this scenario.

System Limits

The great challenge in defining system limits on ULSI and GSI is creating a model which links lower level material, device and circuit parameters to system packaging technology and above all to system architecture. To create this new model, Rent's rule is helpful. It is an empirical logarithmic relationship which gives the number of connections to a logic block and by extension the average interconnect wire length as a function of the gate count of the block [9]. Pin counts of actual chips and modules are displayed in Figure 8. Clearly, high performance CPU's require more connections than gate arrays and microprocessors because they have greater concurrency and parallelism and cannot tolerate multiplexing of signals and pins.

Average interconnection length can be determined by partitioning the logic design into hierarchical divisions, and calculating the number of connections between the partitions via Rent's rule.

The overall system model is shown in qualitative form in Figure 9. Material, device and circuit parameters are reflected in the nine "chip technology" descriptors whose key is F, the minimum lithographic feature size. These descriptors are supply voltage V_{DD}, gate oxide thickness t_{gox}, linear region MOSFET output resistance R_{tr}, interconnect resistance R_{int} and capacitance C_{int} per unit length, number of wiring levels n_w, wiring pitch p_w and a wiring area utilization factor e_w. System packaging is described by the nine "module technology" descriptors. These are wiring pitch P_W, number of levels N_W, area utilization factor E_W, insulator relative permittivity ξ_r, interconnect resistance R_{INT} and capacitance C_{INT} per unit length, module interconnect characteristic impedance Z_0, pad capacitance C_{pad} and pad pitch P_p. The remaining eight descriptors of the model reflect a) chip architecture via the logic depth f_{ld}, gate fan-out f_g and Rent's exponent for the chip p; b) chip integration level via the number of gates per chip N_g; c) system architecture via Rent's exponent for the module pin count π, Rent's coefficient for the module pin count K_p and Rent's exponent for module interconnections β; and d) system size via the total number of gates N_{gToT}. Using this 26 parameter model one can calculate for the system the maximum clock frequency f_s, the optimal chip size D_s (corresponding to f_s) and the power dissipation P_s. A sample of model predictions compared with commercial microprocessor specifications are given in Figure 10 [9].

The key point to recognize regarding this new system-level circuit model is that it can be used to address the issues of a) how to determine the impact of a proposed device or packaging technology on overall system performance; b) how best to partition a CPU to exploit a new technology; and c) how to optimize the number of transistors on a chip for maximum system throughput.

CONCLUSION

The number of components per chip N can be expressed in terms of three variables as $N = F^{-2} \cdot D^2 \cdot PE$ where F is the minimum feature size, D^2 is the chip area and the packing efficiency PE is defined as the number of components per minimum feature area F^2. The historical and projected behavior of each of these three variables has been analyzed [1].

Updating this analysis results in the prediction illustrated in Fig. 11. Segments E & F correspond to a 0.5 micron limit on minimum feature size; segments D and G to a 0.25 limit; and segment H to a 0.125 limit. The likelihood of GSI early in the next century is strongly suggested by these projections.

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	Si (T = 300°K)	GaAs
Mobility [cm^2/V-sec]		
electrons	1,500	8,500
holes	450	400
electrons (77°K) -	20,000	~100,000
Electron Velocity [cm/sec]		
peak	1×10^7	2×10^7
saturation	1×10^7	0.6×10^7
Electron Transit Time Limit [psec/V]		
$t/V = 1/v_s \mathcal{E}_c$	0.33	0.125
Thermally Limited Switching Time [psec/mw]		
$t_s/P_s = 1/\pi K v_s T$	0.21	0.23
Thermal Conductivity [w/cm°K]	1.5	0.46

Figure 1. Properties of Si and GaAs.

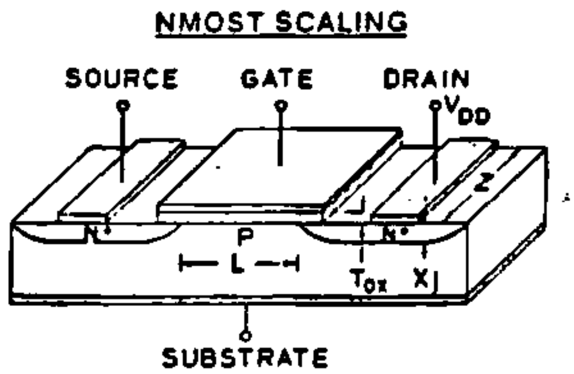


Figure 2. A Device Limit for an MOST

Scaling Factor

$S > 1$

Lateral Dimensions

$L \rightarrow L / S$

$Z \rightarrow Z / S$

Vertical Dimensions

$T_{ox} \rightarrow T_{ox} / S$

$X_j \rightarrow X_j / S$

Supply Voltage

$V_{DD} \rightarrow V_{DD} / S$

Figure 3. Scaling Factor

NMOST DEVICE SCALING FOR CONSTANT FIELD

DEVICE/CIRCUIT PARAMETER	SCALING FACTOR
GATE DELAY	$1/S$
CAPACITANCE	$1/S$
POWER DISSIPATION/DEVICE	$1/S^2$
POWER DENSITY	1
PACKING DENSITY	S^2
SPEED POWER PRODUCT/DEVICE	$1/S^3$

Figure 4.

$$\Delta V_T = \frac{8\, t_{ox}}{d_1}\{2(\phi_{bi} - V_{BS}) + V_D\} \exp\left(-\frac{\pi L}{4 d_1}\right)$$

t_{ox} = gate oxide thickness, d_1 = gate depletion region depth.
ϕ_{bi} = built-in potential of source-to-bulk junction.
V_{BS} = source-to-bulk bias voltage. V_D = drain-to-bulk bias voltage, and L = effective channel length.

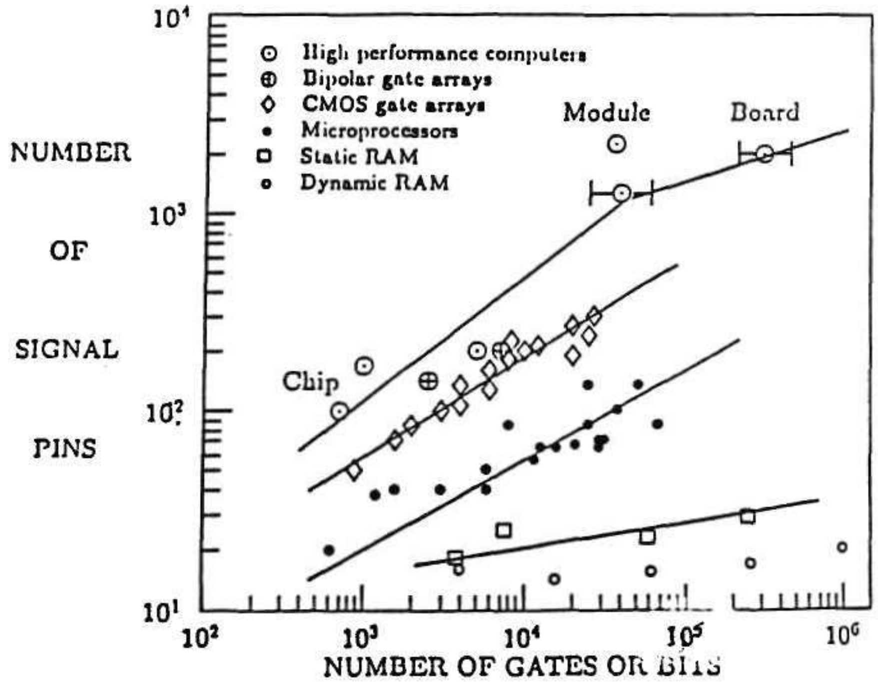
Figure 5. Change in threshold voltage due to short channel effects.

	"Ideal"		"Ideal"
Length	L -> L/S	Resistance	R -> SR
		Capacitance (line to substrate)	C_{LS} -> C_{LS}/S
Width	W -> W/S	Capacitance (line to line)	C_{LL} -> C_{LL}/S
Thickness	T -> T/S	Time Constant	RC -> RC
Spacing	Z -> Z/S	Voltage Drop	IR -> IR
Insulator Thickness	D -> D/S	Current Density	J -> SJ
		Contact Resistance	R_C -> S^2R_C

Figure 6: Local Interconnect Scaling

	"Ideal"		"Ideal"
Length	$L \rightarrow LS_C$	Resistance	$R \rightarrow S^2 S_C R$
Width	$W \rightarrow W/S$	Capacitance (line to substrate)	$C_{LS} \rightarrow S_C C_{LS}$
Thickness	$T \rightarrow T/S$	Capacitance (line to line)	$C_{LL} \rightarrow S_C C_{LL}$
Spacing	$Z \rightarrow Z/S$		
Insulator Thickness	$D \rightarrow D/S$	Time Constant	$RC \rightarrow S^2 S^2_C RC$

Figure 7: Long Distance Interconnect Scaling



High performance computers
Bipolar gate arrays
CMOS gate arrays
Microprocessors
Static RAM
Dynamic RAM
Module
Board
Chip
NUMBER OF SIGNAL PINS
NUMBER OF GATES OR BITS

Figure 8.

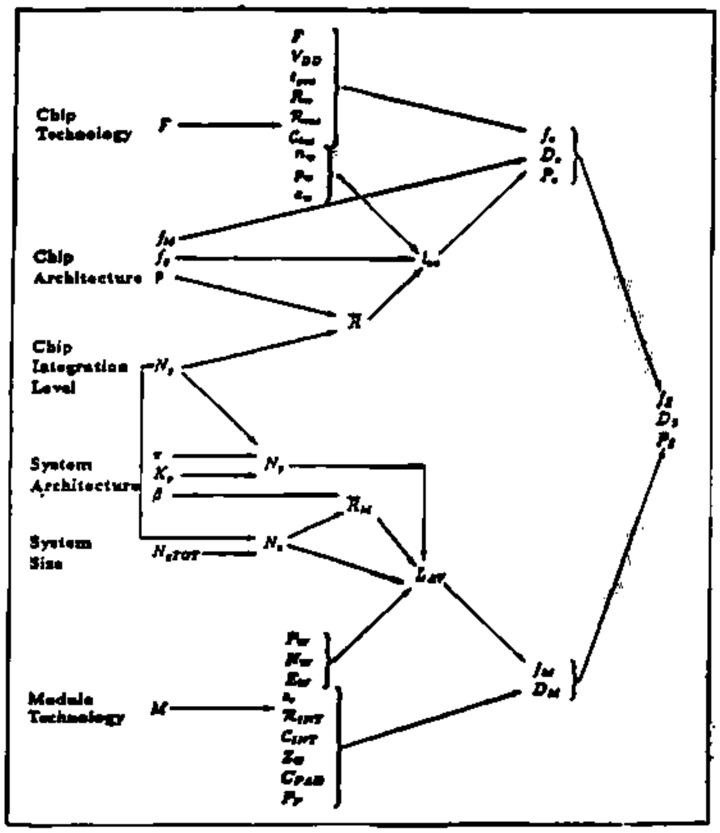
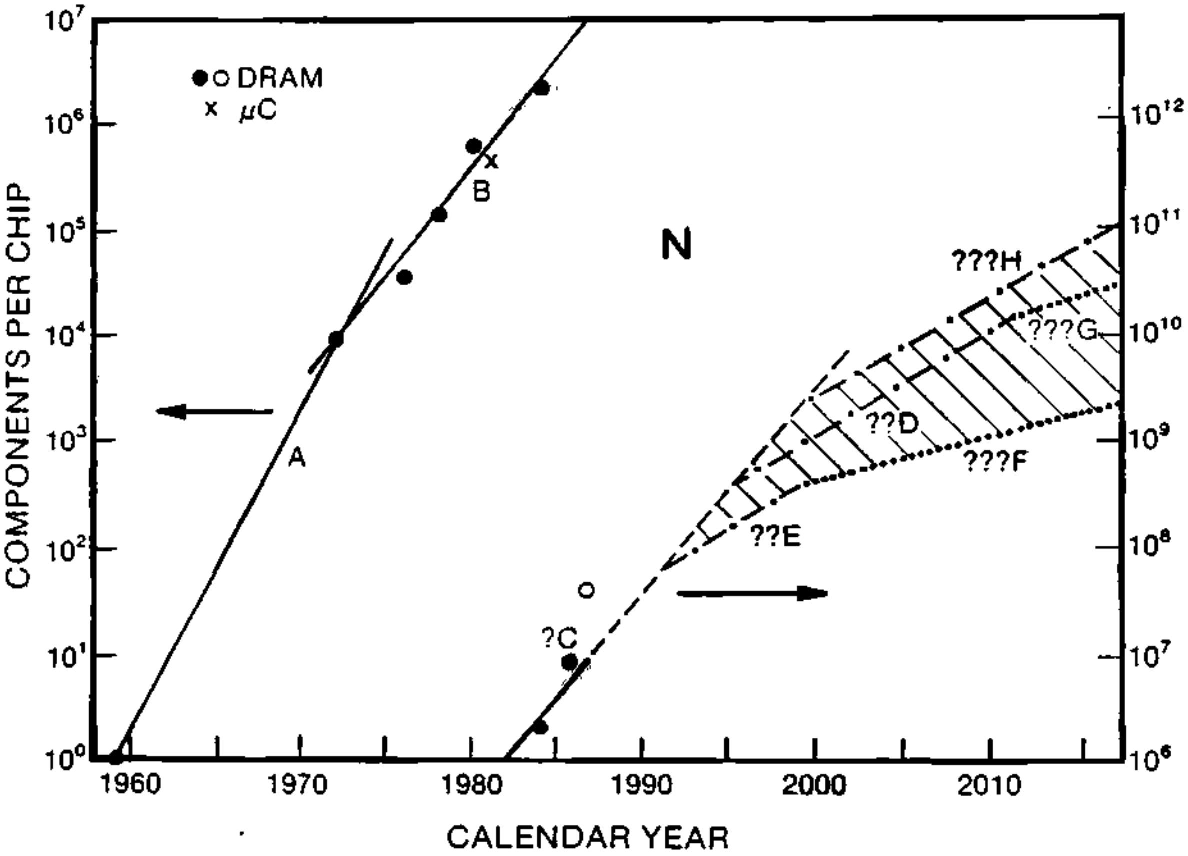

Chip Technology
Chip Architecture
Chip Integration Level
System Architecture
System Size
Module Technology

Figure 9.

$F = 2\ \mu m$, $V_{DD} = 5\ V$, $t_{gox} = 400\ A$, $R_{NMOS} = 10\ k\Omega$, $R_{PMOS} = 20\ k\Omega$,
$C_{int} = 2\ pF/cm$, $p_w = 6\ \mu m$, $n_w = 1 + 2$, $e_w = 0.4$,
$p = 0.4$, $r = 0.45$, $K_p = 0.82$, $f_g = 3$, $f_d = 0.5$

Parameter	Intel 80386		Fairchild Clipper	
	SUSPENS Prediction	Actual Design	SUSPENS Prediction	Actual Design
N_{tr}		180,000		132,000
N_g	30,000		22,000	
$\bar{R}$	4.2		4.1	
$d_g\ (\mu m)$	63		62	
$D_c\ (cm)$	1.1	0.96	0.92	1.0
$R_{gout}\ (\Omega)$	5000		5000	
$C_{gin}\ (fF)$	108		108	
$C_{int}\ (fF)$	53		52	
$T_g\ (nsec)$	2.4		2.4	0.5-3.0
f_{ld}	25 (CISC)		15 (RISC)	
$f_c\ (MHz)$	16.6	12-16	28	33
$\sum C_{tr}\ (pF)$	9,720		7,128	
$\sum C_{int}\ (pF)$	4,800		3,356	
$C_c\ (pF)$	14,520		10,486	
$P\ (W)$	1.5	1-2	1.6	0.5
N_p	85-106	120	73-93	132

Figure 10. Suspens Calculations for two Microprocessors



DRAM
μC
COMPONENTS PER CHIP
CALENDAR YEAR
A
B
?C
??D
??E
???F
???G
???H
N
1960
1970
1980
1990
2000
2010

Figure 11.

Semiconductors' Midlife Crisis

Managing the Cost of Technology Growth

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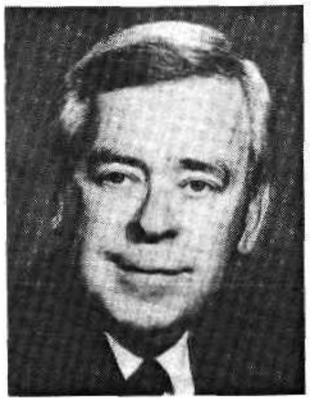
U.S. COMPETITIVENESS IN THE 1990s



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U.S. COMPETITIVENESS IN THE 1990S

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October 21, 1987

Summary

Perhaps in the ambiance of today's improved business climate and the SIA's assurance that growth rates will return to the 20 percent level of yesteryear, the spectre of overseas competition may be fading. Let me assure you, however, that it is still there. I would like to offer you a few observations from the perspective of the semiconductor equipment and materials industry.

The formula for success in the worldwide semiconductor industry has been continually evolving as the market place and the players in it have changed and grown. The semiconductor industry is no longer the localized business that it once was. Instead of pockets of industry in regions such as Silicon Valley and Route 128 around Boston, major customer bases now exist throughout the world. And it takes an international approach to do business in today's industry, not only for the companies in the various markets but also for their support organizations.

SEMI itself is an international trade association, representing companies which supply semiconductor-manufacturing equipment and materials worldwide. Our membership roster includes over 1,100 member companies in 18 countries around the world. As an international organization, SEMI is a leading advocate for strong national semiconductor industries around the world--in the U.S., in Japan, in Korea and throughout Europe.

Our membership's international distribution reflects the worldwide scale of the semiconductor equipment and materials industry today. And the same is true of the device manufacturers. NEC, a company based in Japan, has a facility in Roseville, California, and recently opened another plant near Livingston, Scotland. Thomson, a French company, has established a U.S.-presence with the acquisition of Mostek last year.

The globalization of the semiconductor industry has made it harder, if not impossible, for most companies to "go it alone." Competition throughout world markets has grown too intense for companies to play it strictly solo. To succeed in today's global industry, a company must make use of all its available resources and have a business strategy that remains intact for more than six months.

In many respects, the current position of the U.S. semiconductor industry in the world market can be attributed to a failure to utilize all of its available resources and maximize its competitive potential. On the other hand, the Japanese semiconductor industry stands out as an example of a national industry that has dramatically improved its market position.

Why has the Japanese semiconductor industry enjoyed such landmark success while the U.S. industry has been in decline? The search for an answer must begin with a comparison of these two national industries.

In the past few years, the U.S. has lost its financial position as number one in total semiconductor sales. Dataquest figures reveal that from 1979, when the U.S. held 40.8 percent of total market revenue, to 1986, when that share slipped to 32.9 percent, the U.S. has given up its market position to Japan. Over this seven year period, Japan gained almost 15 percent in worldwide market share--largely at the expense of the U.S., which lost nearly eight percent. Europe's share of the world market also diminished over this period, slipping from 27.1 percent to 17.8 percent. It should be noted that these figures are somewhat distorted by the impact of exchange rates and the unavailability of captive output in the U.S., which some say has increased faster than merchant production.

I am sure that this market swing is not news to any of you. However, you may not realize that during this same period when the Japanese were making major advances in global market share, they were also dramatically increasing their capital expenditures. From 1979 to 1985, capital investment in Japan jumped 15 percent--doubling in size as a percentage of semiconductor production--compared to a capital spending increase of only five percent in the U.S. Capital spending fell in all regions in 1986, undoubtedly influenced by the prolonged industry recession.

But the overall trend toward increased capital investment in Japan not only reflects the Japanese business philosophy, but also points out their strategy regarding the importance of market share. The Japanese purchase of capital equipment has enabled them to increase market share. They have found that for every dollar invested in capital equipment, they will see a two-dollar return. They also have a strategic view and do not emphasize short-term returns on their capital equipment investments.

What exactly are the financial factors associated with wafer processing? Dataquest's figures show that wafer-processing costs have risen steadily since 1980. That trend is projected to continue into the next decade. However, it is important to remember that today's equipment offers many more functions and capabilities than the previous generation, and tomorrow's equipment will offer even more.

Once again, the increased cost reflects a greater product value.

For example, advances in manufacturing technology have led to increases in both wafer diameters and device densities. Although production costs are rising, so is the value of the final product. In fact, Dataquest's price analysis for DRAMs indicates that the price per bit is dropping and will continue to decrease through at least 1990.

These two trends--increasing production costs coupled with decreasing price per function--present very persuasive arguments for increased cooperation among the two segments that makeup the semiconductor industry: the equipment and material manufacturers and the device manufacturers. A look into the recent past leaves no doubt about the interdependence of these two industries.

In 1982, the top three merchant semiconductor manufacturers were, in order, Texas Instruments, Motorola and NEC. By 1986, the rankings had dramatically changed with NEC, Hitachi and Toshiba leading the pack. These results were influenced by exchange rates.

Just five years ago, the top 10 device manufacturers were heavily weighted toward U.S. companies. The four U.S. firms in the top 10 accounted for $3.87 billion in sales, while the five Japanese entrants totaled just $3.15 billion in sales--19 percent less. By 1986, top 10 sales were dominated by its six Japanese companies with a total of $10.86 billion. The three U.S. companies accounted for only $5.3 billion in sales, less that half of the sales generated by the Japanese firms. Again, exchange rates were a factor.

The story is not so different for equipment manufacturers. In 1982, Perkin-Elmer, Varian and Schlumberger were the leading semiconductor equipment companies. In 1986, Perkin-Elmer maintained its lead, but Advantest (formerly Takeda Riken, the number four company in 1982) and Tokyo Electron moved into the second and third positions. The population of the top 10 equipment companies has experienced a demographic shift that is very similar to the one seen among the top 10 device manufactuers. In 1982, the top 10 equipment companies included six U.S. companies, three Japanese companies and one European firm. But by 1986, the top 10's make-up had nearly flip-flopped with five Japanese companies, four U.S. firms and one European company.

Why did both the Japanese device manufacturers and Japanese equipment vendors experience similar gains in market position over the same period of time? Because they understood their interdependence and had learned to work together to help each other gain the competitive edge.

Gordon Moore of Intel understands this industry interdependence very well and, in a realistic light, put it very succinctly: "It is important for device manufacturers to work closely with equipment manufacturers, but each such cooperative relationship requires major commitments to be successful. No device company has sufficient resources to interact at this level simultaneously with many equipment manufacturers. Accordingly, some cooperative venture is required."

Most of us are very aware of the relative advantages that the Japanese semiconductor industry has worked hard to achieve, including manufacturing excellence, economies of scale, large captive markets, domination of certain key semiconductor components and an excellent leading-edge infrastructure, namely Japan's equipment and material suppliers.

The equipment and materials industry provides the manufacturing technologies and capabilities that make semiconductors possible. This $8-billion-a-year worldwide business is the foundation that supports the semiconductor device industry and, in turn, each successive tier of the global electronics industry. The Japanese recognize the importance of the equipment and materials industry in providing the technological cornerstone for the device industry. By promoting interaction between the two industries, Japanese vendors and users of semiconductor equipment and materials have helped each other to succeed.

Strategic alliances, developing cooperative relationships between equipment and material suppliers and device manufacturers, has been very successful in Japan. The Anelva/NEC venture has enabled NEC to move from the number three position in 1982 to number one in 1986. The arrangement has also allowed Anelva to develop leading-edge sputtering systems for mass producing megabit VLSI devices. The relationship has been beneficial to both companies.

Hitachi has played an important role at Kokusai, funding much of their wafer fabrication research.

Advantest has gained a technological edge over its competitors due to its alliance with NTT. And the list goes on.

Strategic alliances in the U.S. are not as easy to identify. However, the ventures that do exist have resulted in some very succesful alliances and results for the companies involved. Perkin-Elmer has allied itself over the years with companies that were able to help it advance technologically. It has managed to maintain its number one position from 1982 to 1986 as the top equipment manufacturer. Over the years, Perkin-Elmer worked with Intel on their first-generation Micralign projection system and with IBM on the second generation. The commitment of orders and money for research and development by these device houses gave Perkin-Elmer the same edge that many of its Japanese competitors have had over the years.

Development of E-beam technology at AT&T is another excellent example of a large research group offering a brand new technology to semiconductor equipment companies on a licensing basis. ETEC and Varian were offered this opportunity and commercialized it. Even though Varian lost interest in the technology, ETEC marketed it and eventually sold their business to Perkin-Elmer.

Finding other examples of strategic alliances in the U.S. is difficult, if not impossible. Perhaps these question marks in the U.S. semiconductor industry indicate a lack of cooperative ventures in the past. I hope that in the near future, these blanks will be replaced by a long list of strategic alliances.

Another issue that I would like to address is the different emphasis placed on education in the U.S. and in Japan, and the comparative advantage that Japanese industry has over the U.S. in this area. A recent article in <u>The Wall Street Journal</u> comparing Japanese and American high school students revealed that Japan exceeds the U.S. in literacy, high school completion rate, length of high school year and the amount of time that students study. It also showed that high school teachers in Japan are much better compensated than their U.S. counterparts.

In another study by a professor at Stanford University on the differences in education between U.S. and Japanese high school students, it was shown that the type of subjects studied and the quality of education required and offered during the high school years was very different. In Japan, high school students are required to take four years of science and four years of math. American high schools rarely require more than one year of science, two years of math and two years of a foreign language to graduate. In U.S. schools, neither English nor social studies are required in all years. Japanese high schools typically offer a choice of 25-30 subjects over one year. An American school offers about 200 courses over one year--in other words, we offer students a curriculum rich in electives and poor in basics. The Japanese offer and demand basic knowledge.

Specifically addressing the comparison of math and science education is enlightening. In the U.S., the average high school student takes one year of science and two of math. The average Japanese students takes four years of each. Draw your own conclusion about the human resource base that industry has to choose from in the U.S.

Americans are concerned about a comprehensive high school education, and have an acute sensitivity to individual differences in talents and interests. The Japanese are more concerned about the separation of academic and vocational schooling, and have a preoccupation in keeping up with international standards as they reflect on Japan's security and national pride.

Education is, and will continue to be, the foundation for success in the Information Age. The U.S. must immediately set to work on building the solid educational system needed to shape its future--a future that demands a well-educated, flexible workforce capable of adjusting to and taking advantage of the U.S. economy's rapidly changing market opportunities. Today, the literacy rate in the U.S. is a handicap to its competitive position in the global marketplace. That situation must be corrected at local levels now.

It stands to reason that the average Japanese fab line worker would be better educated than the average U.S. worker. Because the Japanese employee brings more to his job, he is entitled to and does receive a better compensation package than his U.S. counterpart. An average fab line worker in the U.S. makes approximately $1,135 a month. In Japan, the average fab line worker makes $2,700 a month. This amount includes his basic salary, a yearly bonus (whether the company makes money or not), educational and recreational activities as well as money for transportation and housing.

In Japan, companies usually hire students directly from high school and train them on the job. They provide job security and opportunities for advancement. They have very little problem with maintaining a good employee base.

It is obvious that the U.S. faces many challenges in the future if it is to develop and maintain its semiconductor industry in these competitive times. In the past few months, many people have offered their strategy for the future. Many good ideas have emerged, and a new awakening has begun throughout the U.S. semiconductor industry. To me, it is an exciting time. It is a time when I see two very dynamic, related industries beginning to work together, looking at ways to strategically ally themselves with each other. I would like to offer some strategies from my perspective.

First, I suggest that communities provide better education so that we in the semiconductor industry can hire smarter. By hiring better educated employees, there will be a better opportunity to obtain reliable information regarding equipment performance.

Providing workers with better training in how to operate and maintain their equipment would undoubtedly contribute to better uptime and performance rates.

Dedication to customer service must be emphasized and re-emphasized.

Both the vendors and the users of equipment and materials need to exchange information. Finding ways to do this will be an important step. The establishment of productivity councils or some other forums made up of users and vendors could be very beneficial to all involved.

Any nation's semiconductor industry will not be able to survive in the 1990s unless the collective "we"--the semiconductor equipment industry and the device industry--find ways to maintain technological leadership on a worldwide basis. To reach this goal, we need the tangible commitment that can only be provided by long-term contracts. Long-term supplier-customer contracts are needed at all levels, from the end-product manufacturers--the consumers of semiconductor devices--to the device manufacturers to the equipment and materials suppliers. Only when the semiconductor industry has accepted and implemented long-term and binding business commitments can we say that we have begun to establish the necessary strategic alliances.

Long-term contracts will also help the members of our industry to smooth out wide fluctuations in business conditions, thereby introducing a greater degree of certainty to our business and instilling greater confidence among the investment community, both public and private.

This industry-wide commitment also means developing closer ties with various research groups, government and university projects as well as establishing new groups for this purpose. SEMATECH and SRC are excellent examples of our industry working toward this goal.

We all acknowledge the importance of industry standards, but we must also accept the responsibility of working hard to maintain those standards in a changing, dynamic and international industry such as ours. At SEMI, our basic goal as an association is to provide market access opportunities for all our members throughout the world. We have found that industry standards provide an important vehicle to reach this goal.

SEMI has been working on standards since 1973, and has developed over 100 internationally accepted standards in the areas of materials, photomasks, equipment automation, chemicals, packaging and safety. SEMI has over 3,500 volunteers worldwide from device and equipment companies working on these specifications. There has been much support and involvement from device manufacturers, and in the past few months we have been pleased to see that 10 major device manufacturers have joined SEMI's Standards Corporate Membership Program. To us, this means that senior management at major device houses see the benefits of standardization and are encouraging their employees to participate--a positive sign of the collective "we" working.

Obviously, there are many other strategies that could be put into place, but I feel that whatever the strategy, we must all buy into it and support each other if we are going to be competitive in the 1990s.

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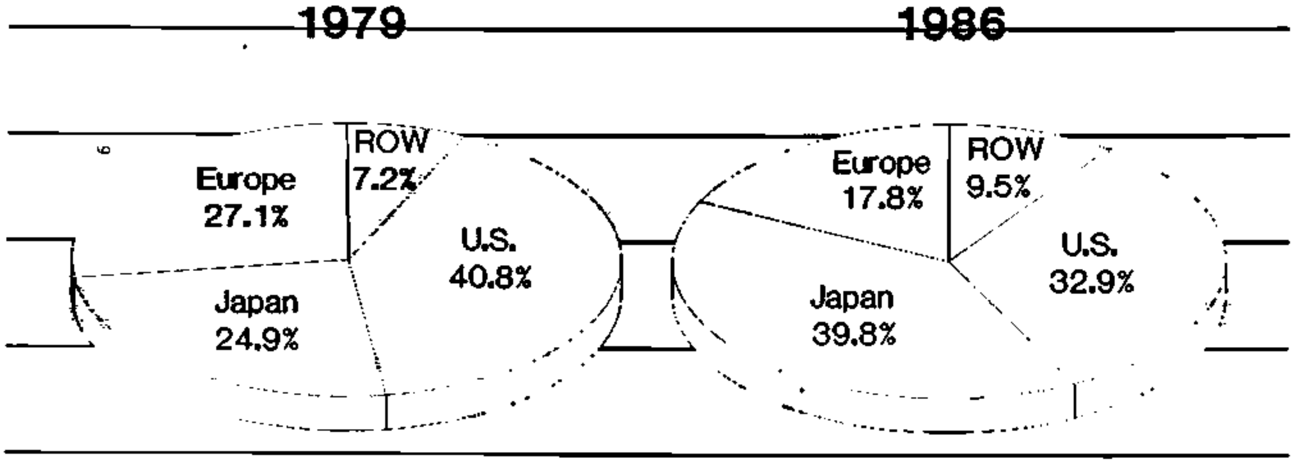
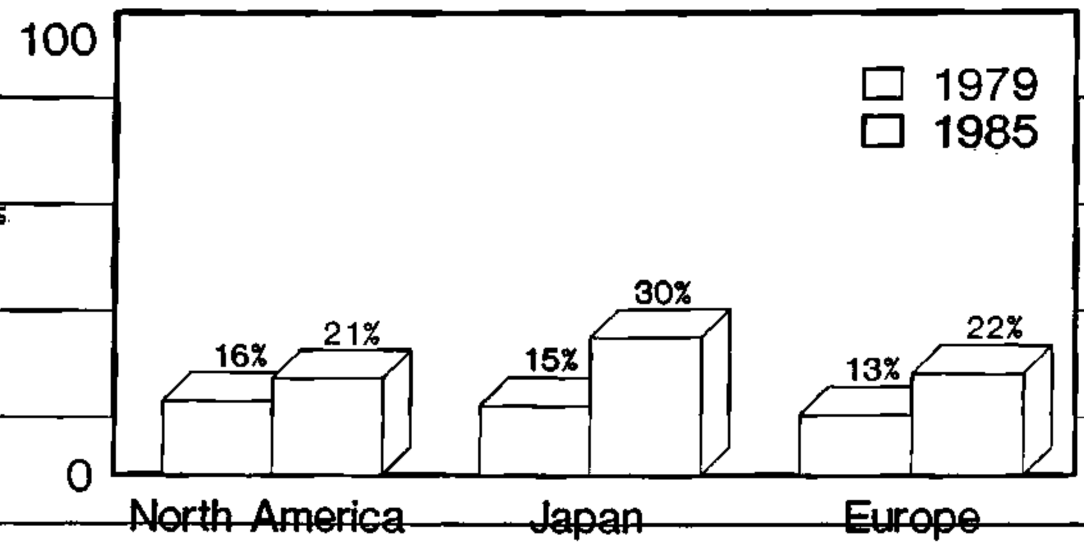
U.S. Competitiveness in the 1990's

Geographical Distribution
% of Semiconductor Sales



Source: DataQuest

Capital Expenditures as a % of Semiconductor Production



Source: DataQuest

Increasing Costs and Decreasing Prices

	1980	1985	1990
Wafer processing cost/square inch	$4.75	$8.48	$11.48
Depreciation/square inch	$0.33	$3.26	$4.31
Percent of total	7%	38%	38%
DRAM price per bit (millicents)	30.4	1.6	0.3

Source: DataQuest

Top Ten Merchant Semiconductor Suppliers Worldwide

Worldwide Sales ($ millions)

	1982
Texas Instruments	$1,310
Motorola	1,220
NEC	1,080
Hitachi	880
Philips/Signetics	800
Toshiba	720
National Semiconductor	710
Intel	630
Fujitsu	470
Matsushita	430

Source: DataQuest

Top Ten Merchant Semiconductor Suppliers Worldwide

Worldwide Sales ($ millions)

1982		1986	
Texas Instruments	$1,310	NEC	$2,640
Motorola	1,220	Hitachi	2,300
NEC	1,080	Toshiba	2,270
Hitachi	880	Motorola	2,030
Philips/Signetics	800	Texas Instruments	1,780
Toshiba	720	National Semi./Fairchild	1,490
National Semiconductor	710	Philips/Signetics	1,360
Intel	630	Fujitsu	1,310
Fujitsu	470	Matsushita	1,200
Matsushita	430	Mitsubishi	1,140

Source: DataQuest Source: DataQuest

Top Ten Semiconductor Equipment Manufacturers and Suppliers Worldwide

Worldwide Sales ($ millions)

	1982
Perkin-Elmer	$162.1
Varian	99.5
Schlumberger	96.4
Takeda Riken (Advantest)	83.8
Applied Materials	83.4
Eaton	79.9
Teradyne	78.7
Canon	77.7
General Signal	76.9
Nikon	57.7

Source: Electronic Business, May 1984

Top Ten Semiconductor Equipment Manufacturers and Suppliers Worldwide

Worldwide Sales ($ millions)

1982		1986	
Perkin-Elmer	$162.1	Perkin-Elmer	$264
Varian	99.5	Advantest	238
Schlumberger	96.4	Tokyo Electron (TEL)	166
Takeda Riken (Advantest)	83.8	Canon	155
Applied Materials	83.4	General Signal	155
Eaton	79.9	Applied Materials	149
Teradyne	78.7	Nikon	148
Canon	77.7	Schlumberger	139
General Signal	76.9	Varian	137
Nikon	57.7	Ando	136

Source: Electronic Business, May 1984 — Source: Electronic Business, May 1987

"It is important for device manufacturers to work closely with equipment manufacturers, but each such cooperative relationship requires major commitments to be successful. No device company has sufficient resources to interact at this level simultaneously with many equipment manufacturers accordingly, some cooperative venture is required."

Gordon Moore, Intel

Current Japanese Comparative Advantage in Semiconductors

- Manufacturing excellence
- Economies of scale
- Large captive markets
- Domination of certain key semiconductor components (DRAMs, bipolar memory, optoelectronics)
- Leading-edge infrastructure (equipment and materials manufacturers)

Strategic Alliances In Japan

- Anelva/NEC
- Kokusai/Hitachi
- Advantest (Takeda Riken)/NTT
- Oki/Denkoh
- Nikon/Matsushita
- TEL/Mitsubishi
- Cambridge/Fuji

Strategic Alliances in U.S.

- Perkin–Elmer/IBM/Intel
- Perkin–Elmer/ATT/Varian
- Ultratech Stepper (General Signal)/Intel
- ?
- ?
- ?

Education in the U.S. and Japan: A Comparison

	United States	Japan
Literacy rate	80%	99%
High school completion rate	72.7%	90%
Length of school year	180 days	240 days
High school seniors spending less than five hours per week on homework	76%	35%
Financing of education:		
National	6.2%	47.3%
State	49.0%	28.1%
Local	44.8%	24.6%
Teacher salaries	Determined locally	By national law, must be paid 10% more than the top civil servant
Salary compared to other wage earners	Approximately average among all wage earners	In the top 10% of all wage earners

Source: U.S. Department of Education; Japanese Ministry of Education

A Comparison of High School Students' Math and Science Education

(Education in Years)

	United States	Japan
Science	1	4
Math	2	4

Source: Japan's High School; Thomas P. Rohlen

Average Fab Line Worker

	United States	Japan
Education	Literate	High School
Compensation	$1,135	$2,700

Strategy for the Future

- Hire smarter
- Invest in training
- Improve service
- Exchange information (productivity council)
- Develop new technology
- Develop closer ties on strategic projects
- Expand government and acedemic research projects
- Develop and implement industry standards

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THE TECHNOLOGY OF PARTNERING

Irwin Federman
Vice Chairman of the Board
Advanced Micro Devices, Inc.

Mr. Federman is Vice Chairman of the Board of Advanced Micro Devices, Inc. Before the company's recent merger with Monolithic Memories, Inc. (MMI), he was president and CEO of MMI. During his tenure, MMI grew almost eightfold. Previously, Mr. Federman was Vice President of Finance and cofounder of an OCR equipment manufacturer. Prior to that, he was Chief Financial Officer of a Palo Alto, California, company that pioneered early developments in lasers, fiber optics, and optical thin films. Mr. Federman holds a B.S. degree in Economics from Brooklyn College and an honorary Doctorate of Engineering Science from Santa Clara University.

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SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

Managing the Cost of Technology Growth

IRWIN FEDERMAN

Vice Chairman of the Board
Advanced Micro Devices, Inc.

Dataquest Semiconductor Industry Conference
October 20, 1987
Presentation by
Irwin Federman
Vice Chairman of the Board
Advanced Micro Devices, Inc.

The Technology of Partnering

One out of two marriages ends in divorce. I read somewhere that first marriages last an average of seven years, while the second survives for only about three. Obviously, experience doesn't count for much.

I have lately been more than casually interested in the history of corporate combinations. According to a Hay study, no less than one-third of acquired companies are sold off within five years of acquisition, while 90% fail to meet expectations. Acquisitions in the semiconductor industry have left a bloody trail -- over $2 billion in losses. Of the four major deals prior to ours, two acquiring CEOs have since lost their jobs and one has died. The history of second-source agreements, technology exchanges and other so-called partnering relationships has not been significantly better. It seems then, that while we know what we have to do, the doing of it appears to need a little work.

Clearly, there is a compelling rationale for companies to combine forces where high capital risk, narrow market windows, and/or insufficient individual expertise exist. Combinations to force new product ideas do not usually make much sense. If handled carefully, however, the innovative product of one company can be traded off against unaffordable capital or market risk. The object of the exercise is to mitigate redundant, and often pedestrian, investment in favor of better returns for all participants.

It should be clear to all of us that the long-term profit prospects are not very attractive for an industry that insists on investing 15% of its annual sales in R&D, and another 20% in capital equipment.

Having convinced ourselves, either intuitively or by analysis, that partnering is a strategic imperative, semiconductor companies are now plunging headlong into new relationships. I believe that many of these will not meet expectations, and some are likely to be costly failures. In my view, our high-technology business now needs to develop yet another skill set: something one might call The Technology of Partnering.

The semiconductor industry has matured in many respects over the years. That we have joined together in the SRC, in Sematech and the present flurry of deals, is evidence that we are capable of subordinating ego to reason. Perhaps this is true because the managements of our companies are not as young as they were in the past. That is true for both established companies and startups. Most of the familiar names are still around and in the business. And all are thus ten years older than they were in 1977. Whether wiser or more mature is problematic, but, unquestionably, our perspectives have evolved.

Although the stakes have grown, the pace of our business has not slowed. The perils of accelerating capital intensity are now amplified by narrower market windows and the need for more precise product definition. To cope with rapid change, a renaissance of determined entrepreneurial intensity now characterizes even the larger companies. But we must be wary of this entrepreneurial zeal, for, whatever its attributes, it carries attendant burdens. By its very nature, a startup venture is consumed with itself. It is parochial, ego-driven, fiercely competitive in attitude, and frequently has the unfortunate inclination to denigrate the achievements of others while being very tolerant of its own weaknesses and limitations.

This baggage is poison to partnerships. Yet this is what small companies have, and what entreprenurial business units in larger organizations are in danger of acquiring.

The proper conduct of any relationship is cultural in nature. Individual behavior traits frequently reflect one's upbringing, the values imprinted in our developing years. It is not much different between and within organizations. The behavior patterns implicitly or explicitly encouraged within any company are no doubt good indicators in assessing the probable success of its partnerships.

The need to seek out an external set of talents or resources is usually driven from a strategic perspective. Frequently, this broader view derives from an executive or group which sits at one or more levels above the people who, ultimately, will be charged with implementation. Therefore, the partnering notion is often advocated by individuals who will have little responsibility for making it work. That's a problem. Dictated deals usually don't have the complete support of a tough-minded manager who has had little involvement in the decision process.

Therefore, to get things off on the right foot, operating managers on both sides must be brought into the process before the objectives, scope and logistics of any deal are cast in concrete by the initiating parties. Negotiation of terms and conditions is best left to others. There is little sense in creating adversarial attitudes between and among the people who will be responsible for working together to make the relationship a success. At MMI we have had partnering experiences which are cogent examples of what happens with and without the appropriate people's involvement. In 1983 we did a marvelous technology/product exchange with Cypress Semiconductor. T. J. Rodgers and I did that deal--other MMI people came in much later. The Cypress relationship was viewed within MMI as a Federman deal. And I did a poor job of internal selling. As a result, our engineers pulled back, were cynical, and, in general, exhibited acute NIH. Not surprisingly, the technology benefit to our company suffered an unnecessary two-year delay. I am pleased to report that our people have since seen the light, and MMI is now turning out very fast CMOS product in production quantities. In contrast to that experience, MMI's E^2 logic program with SEEQ Technology went just the other way. Although Dan McCranie and I started it off, Mike Callahan, Bob Bortfeld and many of our engineers were involved almost from the first. The net result was first-pass working silicon on a very fast E^2 programmable logic device in eight months from a standing start.

Even though early involvement of those charged with producing results is an obvious prerequisite, it doesn't happen often enough. The internal selling of a partner program should take place well in advance of working the deal structure. My observation is that more often a deal is struck and then the troops are recruited. You all know from personal experience that your commitment to a program with which you reluctantly go along but don't fully support, simply does not have the quality to endure and overcome the rough spots which inevitably develop. A successful partnership requires commitment not merely involvement. There's a big difference. In a plate of bacon and eggs, the chicken is involved -- but the pig is committed.

The essential element of a service mentality is that one puts oneself in the other fellow's shoes, feels the way he feels and then acts in a way which will make those feelings very good. Service is received, not delivered. Therefore, the only way to achieve it is to adopt the perspective of the recipient. That is an acculturation process. It does not come naturally. Understanding the meaning of service excellence is germane to partnering, because companies that have ingrained service mentalities can be exceptionally good partners. Organizations in which those characteristics are absent are likely to think in terms of deliverables and will probably prove to be disappointing partners. The most important deliverables are almost never spelled out in the agreement, no matter how carefully written. Intent is everything. Frequently, companies partner with hidden agendas. They want "paper" second sources. Or they intend to milk their partner and scheme to minimize their own contributions. Or they have pre-interpreted the fine print and thus have identified and focused on all the escape hatches. Sometimes one partner will boast about how he took advantage of the other, got a better deal, or how incompetent his partner is or was.

One must think long and hard about doing a deal with such organizations. Why risk the probability that your company will be similarly short-changed and castigated?

Since, in any significant relationship, both partners are giving up something of value, a great deal of paranoia usually invades the mentality. You need the other guy, but are frightened of the potential damage he can cause you with what you give him. This paranoia is acute in smaller companies, particularly in a deal with a larger entity.

It is incumbent upon the larger partner to be extraordinarily sensitive to these concerns. Any behavior which reinforces the initial mistrust will simply harden the small company's fears and get in the way of free and open exchange. The larger company must deliver more than the contract calls for, should extend its hand in areas outside the scope of the agreement, and consciously develop personal relationships at various levels in both companies. It helps to like and respect the people you're doing business with. If you have the notion that they should like and respect you, your behavior will reflect that priority and you will have gone a long way.

Frequently, however, the more powerful organization takes a power position. It describes its own wonderfulness instead of expressing its sense of good fortune to be associated with such a great partner. People like to hear about themselves, not about you. And that goes double for a startup. So if you want to conduct a successful courtship--and have it consumated in an enduring relationship--you should take pains to assure that your people maintain the appropriate sensitivities.

If partnering is to be a structural element of our business, then we must teach and prepare ourselves to do it successfully. Unfortunately, the thinking of operating managers is not likely to change merely because of changing times. Fully-integrated semiconductor companies have traditionally been heavily weighted towards the "make" side of any make-or-buy decision. Not only because of installed capacity. There's also such a thing as installed ego. Our designs are always better, our product architectures are always more clever. Their company always pre-releases products, their devices are always marginal to the spec. We sell real products, they sell vaporware.

Under those conditions, how can one reasonably consider having "them" do something which is important to us?

Well, us is them and them is us and we can't all be right. The correction of ill-conceived baseline notions must come from a company's leaders. Respect for the partner is an important first step in any cooperative venture.

The development of a service mentality and its concommitant virtues, in partnering, and in many other aspects of our business, will not occur as the result of laundry lists or company credos on how to deal with customers. If a company promotes respect and interdepartmental support and human consideration within its own organization, it will not have to teach anybody how to deal with customers or partners. Such an organization will have practiced and developed those skills in its day-to-day internal dealings.

The huge risks in our business have made partnering essential. Partnering, in turn, has raised the issue of company acculturation to a new level of importance. There will be companies with whom you should not, and in the future, will not ever do a deal. Others will have a line outside the door. Certainly, a prospective partner must have the desired capabilities. But, beyond that, it must have both the intent and the institutionalized capability to deliver on its implied promises.

Partnering between competitors in the marketplace is fraught with conflicts of interest. Reconciling those issues is difficult enough even if both parties have mutual interests and operate with complete candor. Should either of those factors be absent, we will just be kidding ourselves.

Mutual trust is the underlying bedrock of any significant long-term relationship. It seems to me that we are generally inclined to be cynical as to the other fellow's motives, and too sanctimonious relative to our own. In any interpersonal relationship, if you consistently treat your partner in a fashion which reflects a lack of trust, ultimately he will prove you to be correct. the challenge in successful partnering is to overcome those inclinations and to force ourselves to participate with an almost naive faith that our partner is as well-intentioned as are we. And then we must make certain that we are well-intentioned and reinforce that level of integrity throughout our organization. I submit to you that this is virtually impossible in an organization that encourages internal politicking, or, in general, operates in an adversarial manner towards its vendors, customers or employees. The only way to assure that we get what we want out of any deal, is to make certain that the other guy perceives that his interests are being faithfully served, and thus will be inclined to reciprocate. This is the essence of service, and a fundamental of human motivation.

It is my absolute conviction that partnering is not merely another project technique which a company can casually include in its cafeteria of alternatives. Unlike the purchase of a piece of equipment, or foundry services, or any transaction in which the consideration is cash, partnering is a process in which the value of the consideration has many qualitative aspects. The technology of partnering requires a corporate re-think. How do we really operate? Do we reward results, however obtained? And if we do, are we convinced that the processes thus tacitly endorsed will ultimately inure to our benefit? And if not, how can we modify our culture?

There are enormous potential rewards in eliminating redundancy and leveraging upon each other's strengths. Taking advantage of this latent treasure will not be easy for all companies. As in any technology, there will be leaders in the technology of partnering. This leadership will not be accidental. It will take a tremendous amount of top management effort, in setting behavioral standards, in the inculcation of those standards deep into the ranks. It will take persistence and patience. I believe the potential returns on that investment are worth the effort.

Thank you for your kind attention.

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PERSPECTIVES ON TECHNOLOGY ACCELERATION

Walden C. Rhines
Senior Vice President
Semiconductor Group
Texas Instruments, Inc.

Dr. Rhines is Senior Vice President of the Semiconductor Group at Texas Instruments, Inc., with responsibility for its system components businesses including microprocessors, MOS logic, and application-specific ICs (ASICs). Before assuming his present position, Mr. Rhines held a wide variety of technical and business management positions at TI, primarily in the Semiconductor Group, but also in the Consumer Products Group, Central Research Laboratories, and Data Systems Group. Dr. Rhines holds a B.S.E. degree in Metallurgical Engineering from the University of Michigan, an M.S. degree and a Ph.D. in Materials Science and Engineering from Stanford University, and an M.B.A. degree in Finance and Marketing from Southern Methodist University. He has served as Chairman of the Semiconductor Technical Advisory Committee of the Department of Commerce and is currently a member of the board of the Corporation for Open Systems.

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Semiconductors' Midlife Crisis

Managing the Cost of Technology Growth

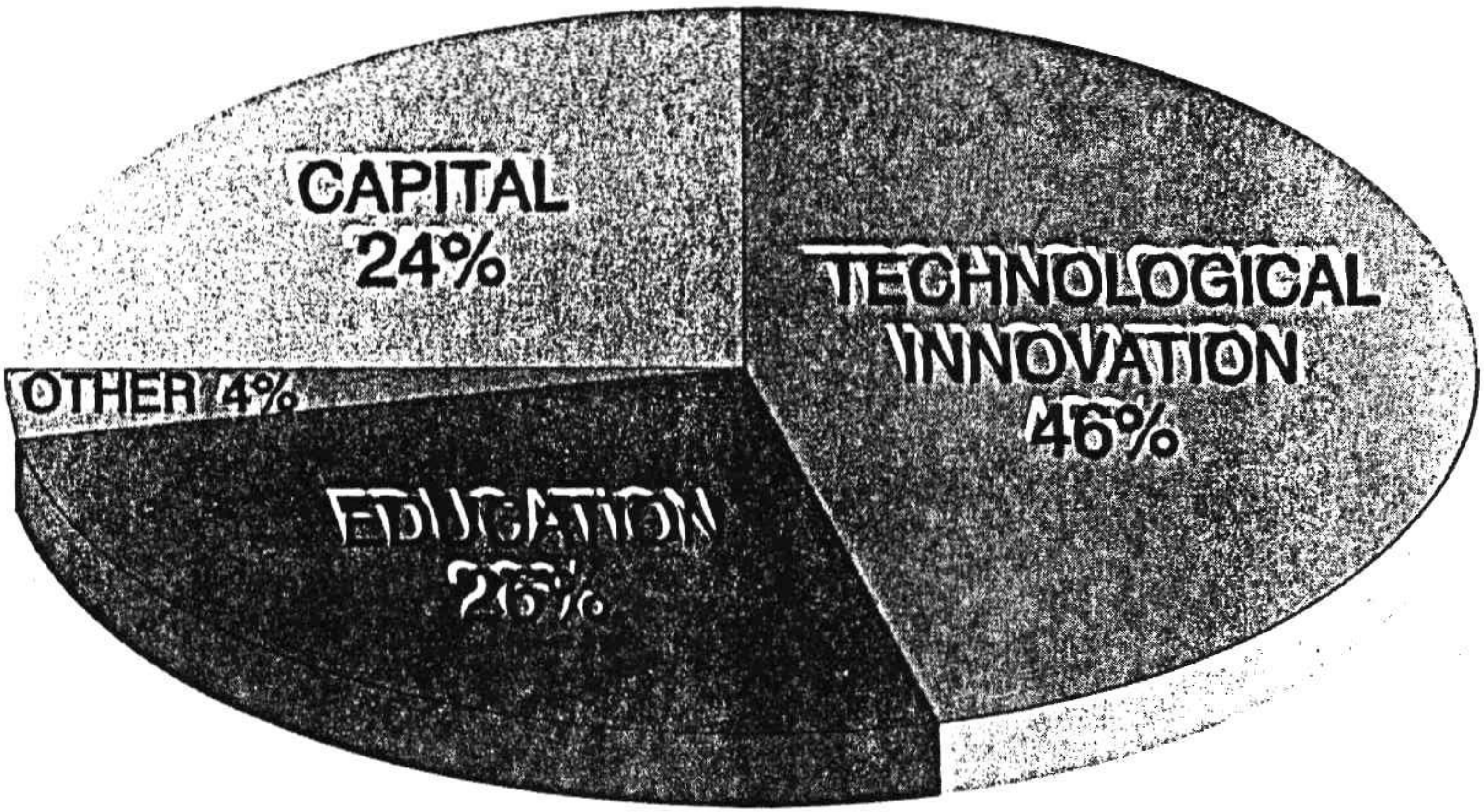
WALDEN C. (WALLY) RHINES

Vice President
Senior Vice President
Semiconductor Group
Texas Instruments, Incorporated

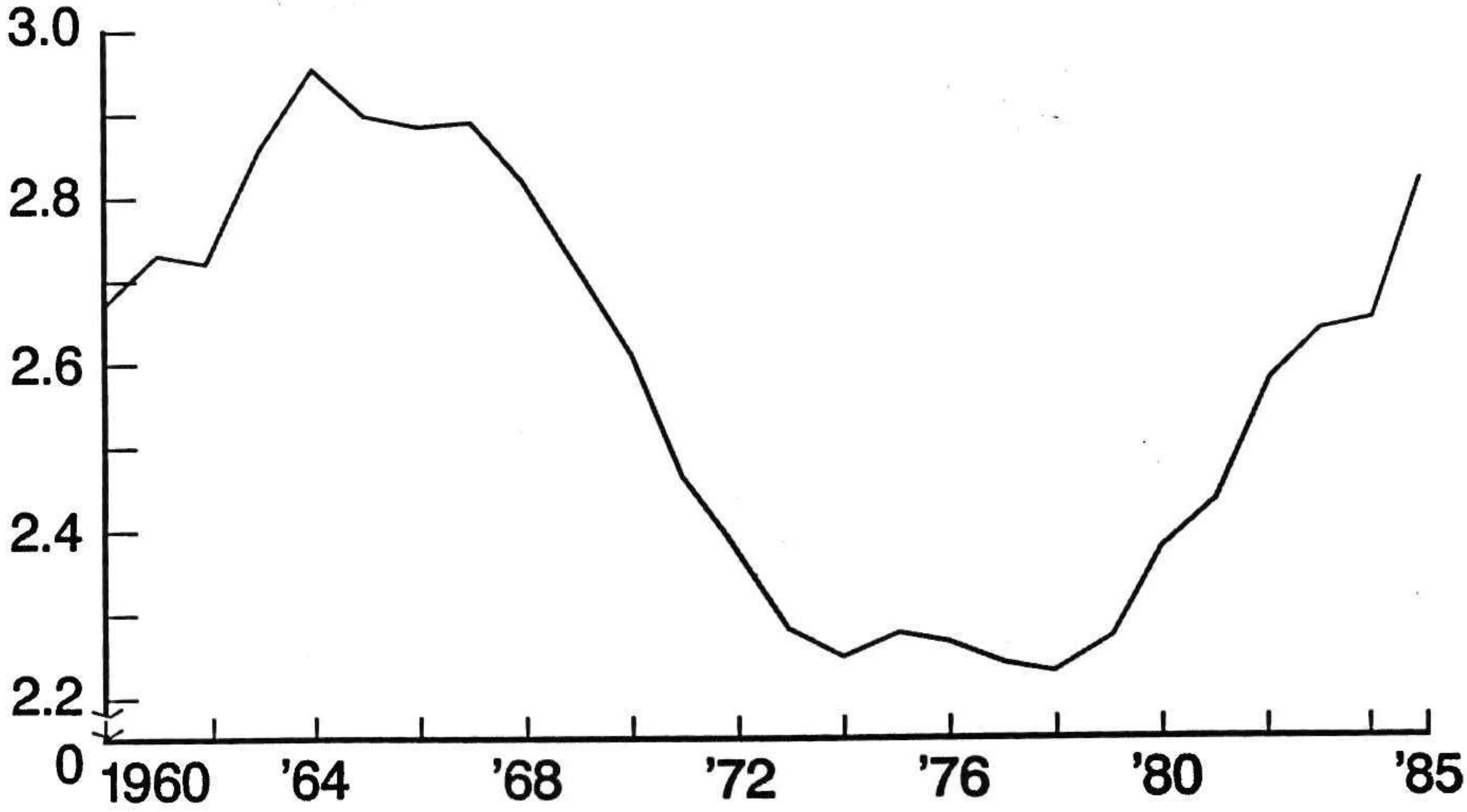
TEXAS INSTRUMENTS

SOURCES OF U.S. PRODUCTIVITY GROWTH

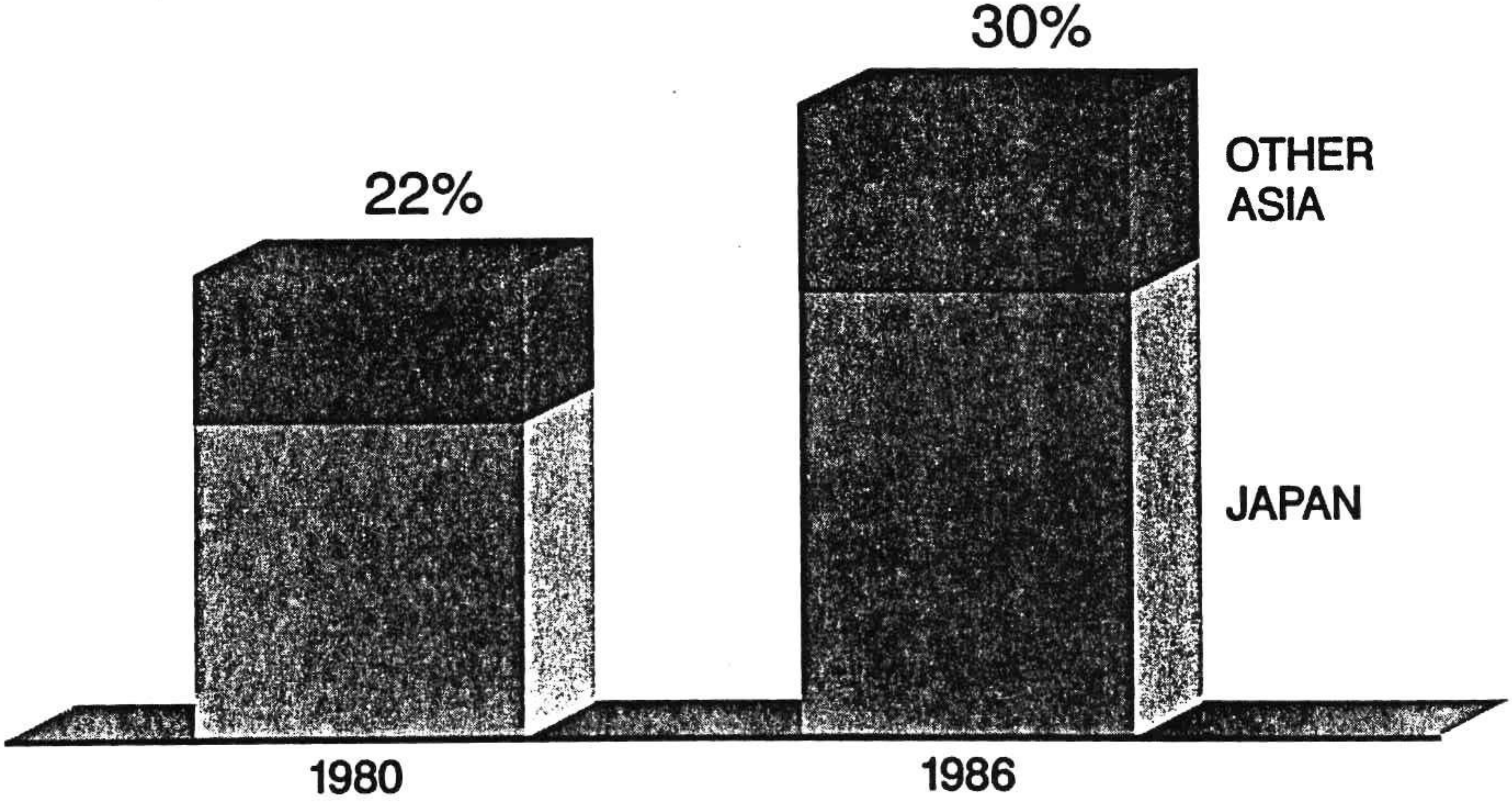
1929 – 1985



R&D SPENDING
(As a percentage of GNP)



SHARE OF WORLD ELECTRONIC END-EQUIPMENT PRODUCTION



MANAGING THE COST OF TECHNOLOGY

- More capability from fewer basic processes
- Share the design effort
- More derivatives from standard products
- Protection of intellectual property rights

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- **More capability from fewer basic processes**
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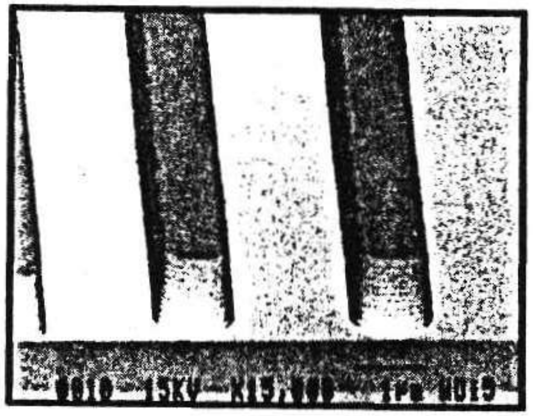
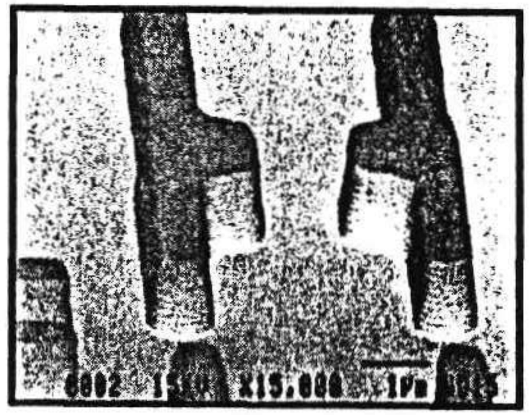
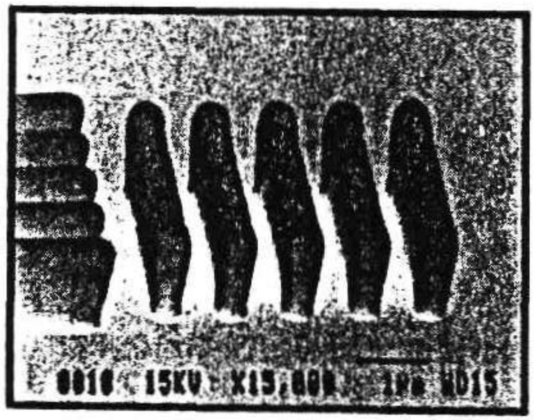
PHOTOLITHOGRAPHY FOR SUBMICRON VLSI



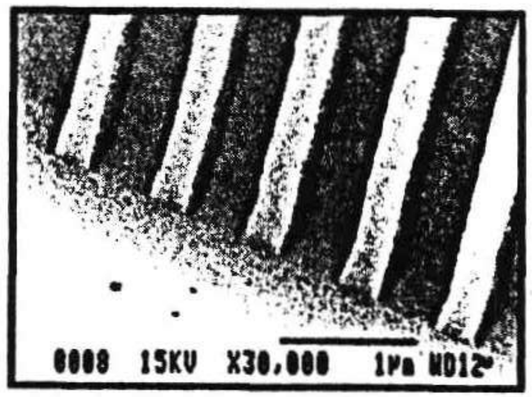
G-Line Stepper (1μ)



High NA G-Line (.8μ)



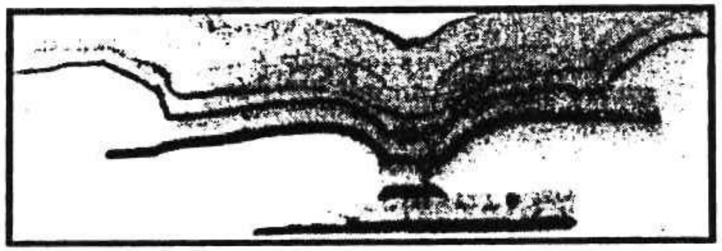
Advanced Resist (.8μ)

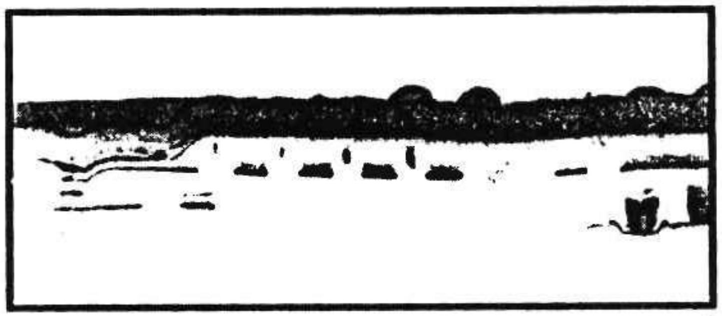


Excimer Laser Stepper (.5μ)

INTERCONNECT TECHNOLOGY

Triple Level Metal





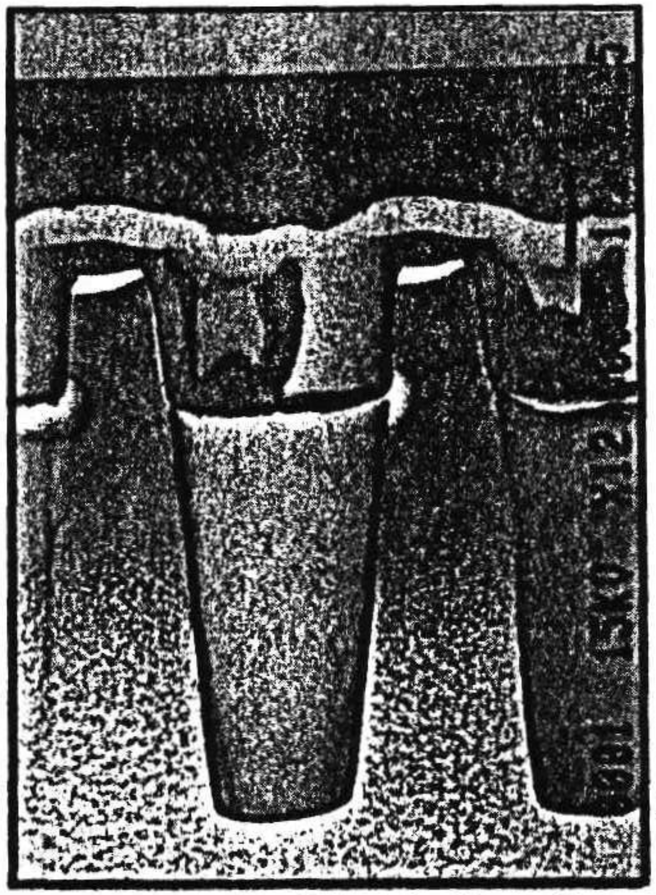
What is it?

- Three levels of Ti:W/AL:Cu layered metal
- Fully planarized interlevel and filled contacts/via

Benefits

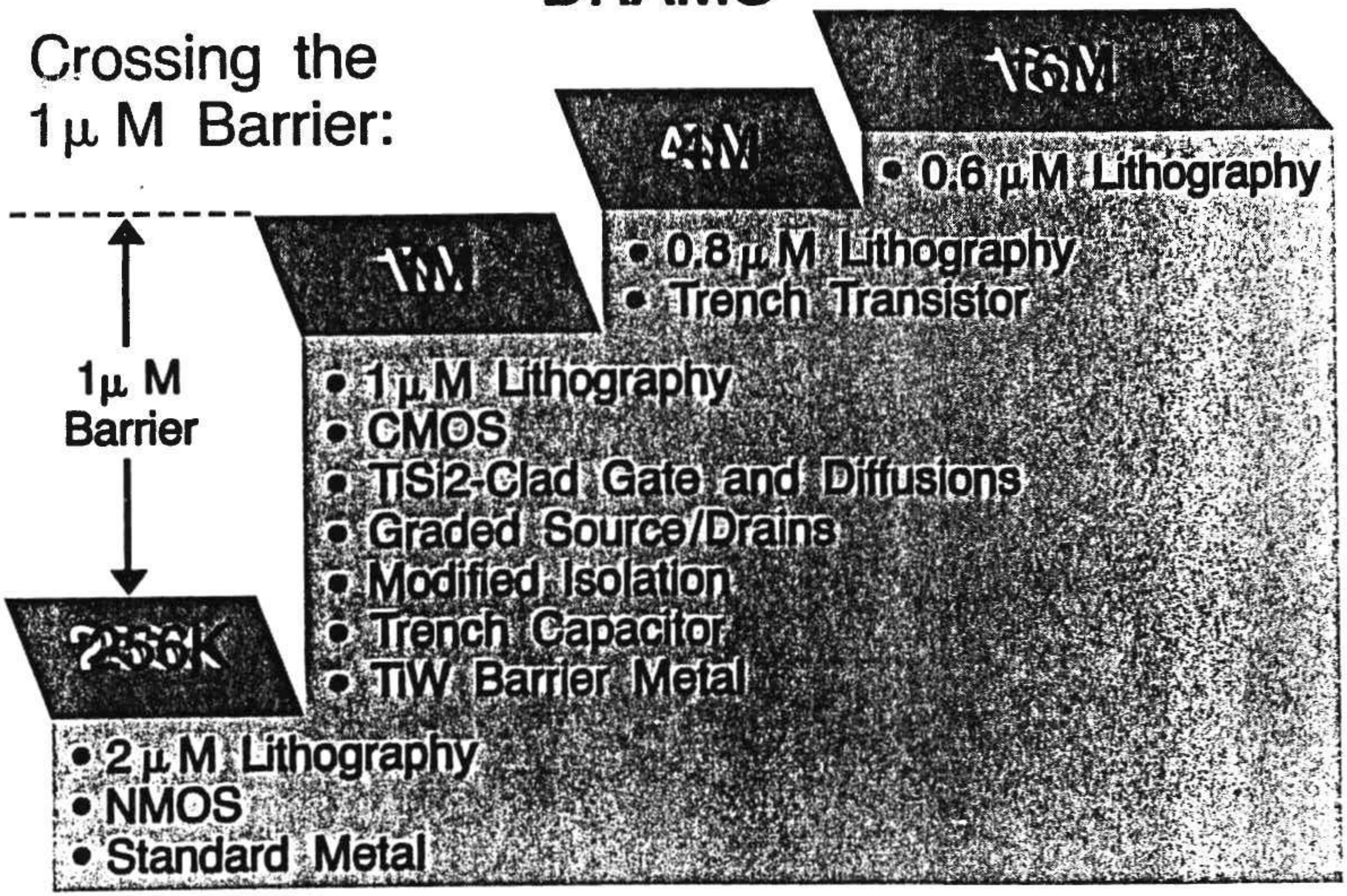
- Ultra high performance for ASIC, ECL and VLSI
- Automatic synthesis and routing without performance/ area penalty

HIGH PERFORMANCE/SCALABLE TRENCH TRANSISTOR CELL FOR 4 MEGABIT AND 16 MEGABIT DRAMs

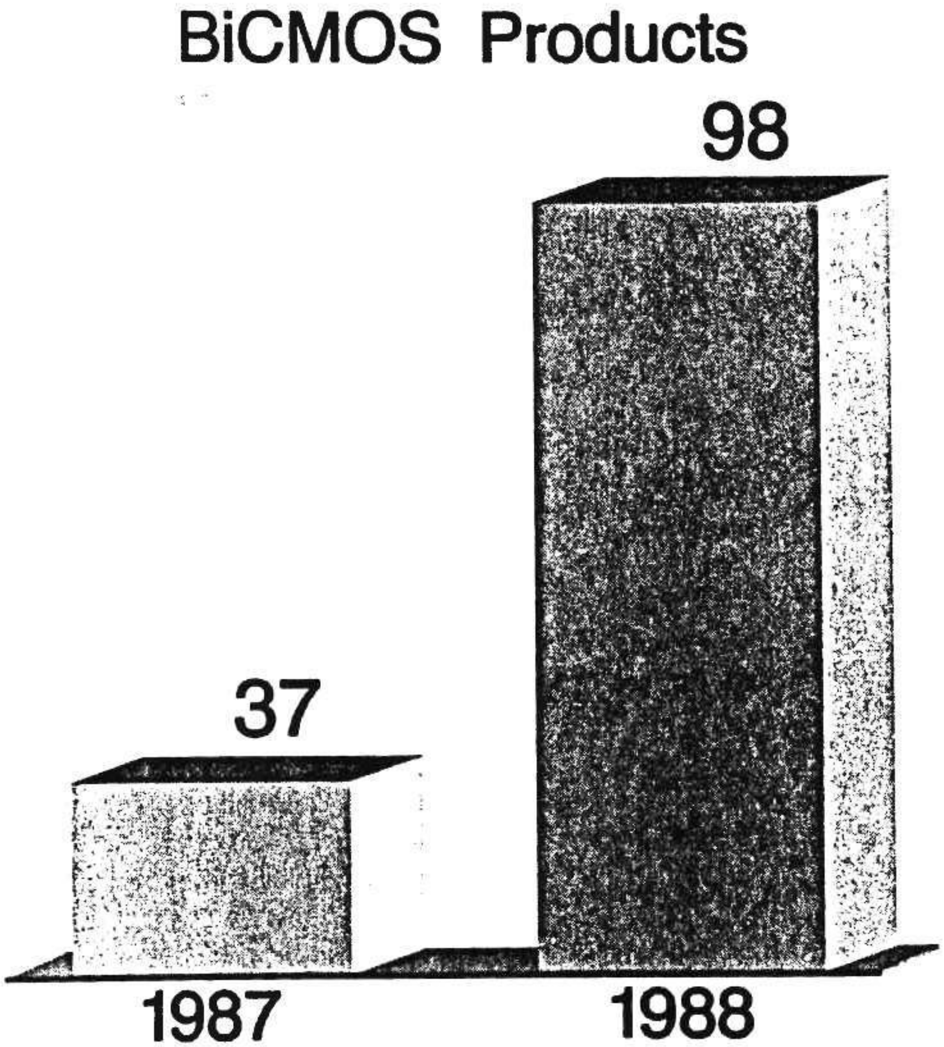


TECHNOLOGY DRIVERS
DRAMS

Crossing the 1µ M Barrier:



BiCMOS TECHNOLOGY



- Low-power dissipation of CMOS
- Speed and current drive of Bipolar
- Broad Application:
  - Standard logic
  - Memories
  - ASICs
  - Linear

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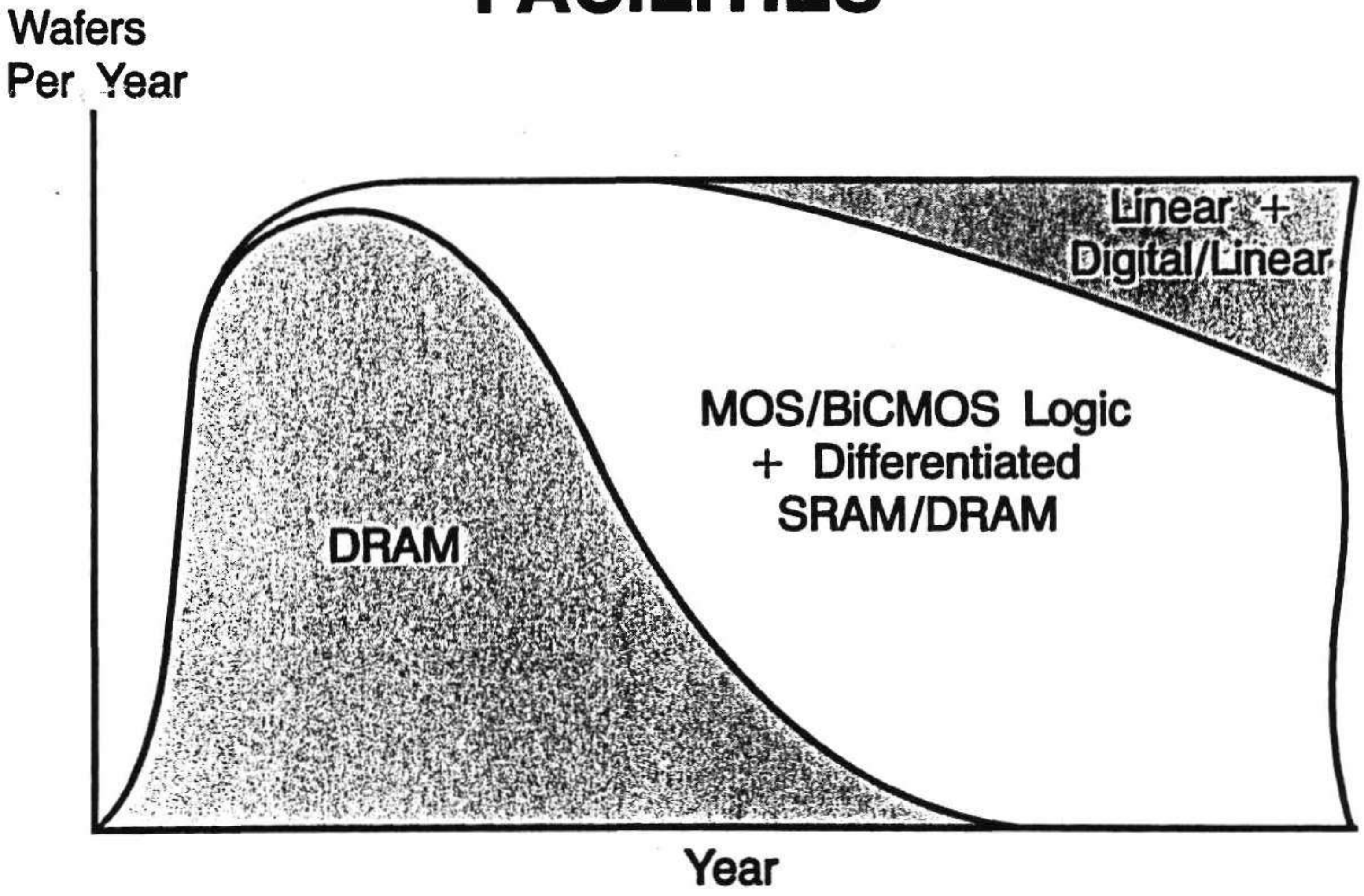
EVOLUTIONARY WAFER FAB FACILITIES



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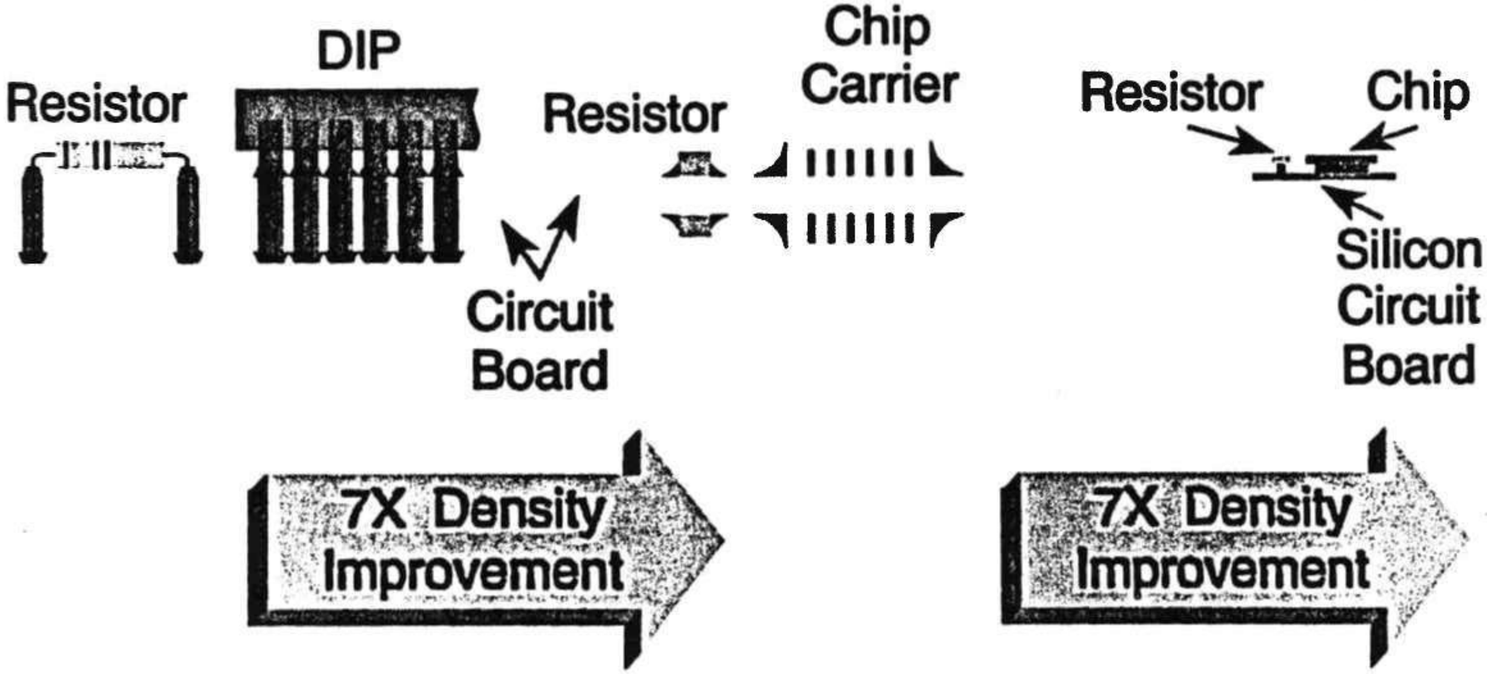
PROGRESSION OF HIGH DENSITY PACKAGING

PAST	PRESENT	FUTURE
Thru-Board DIP packages	Surface mounted Chip carriers	Orthogonal FLIP-Chip Mount



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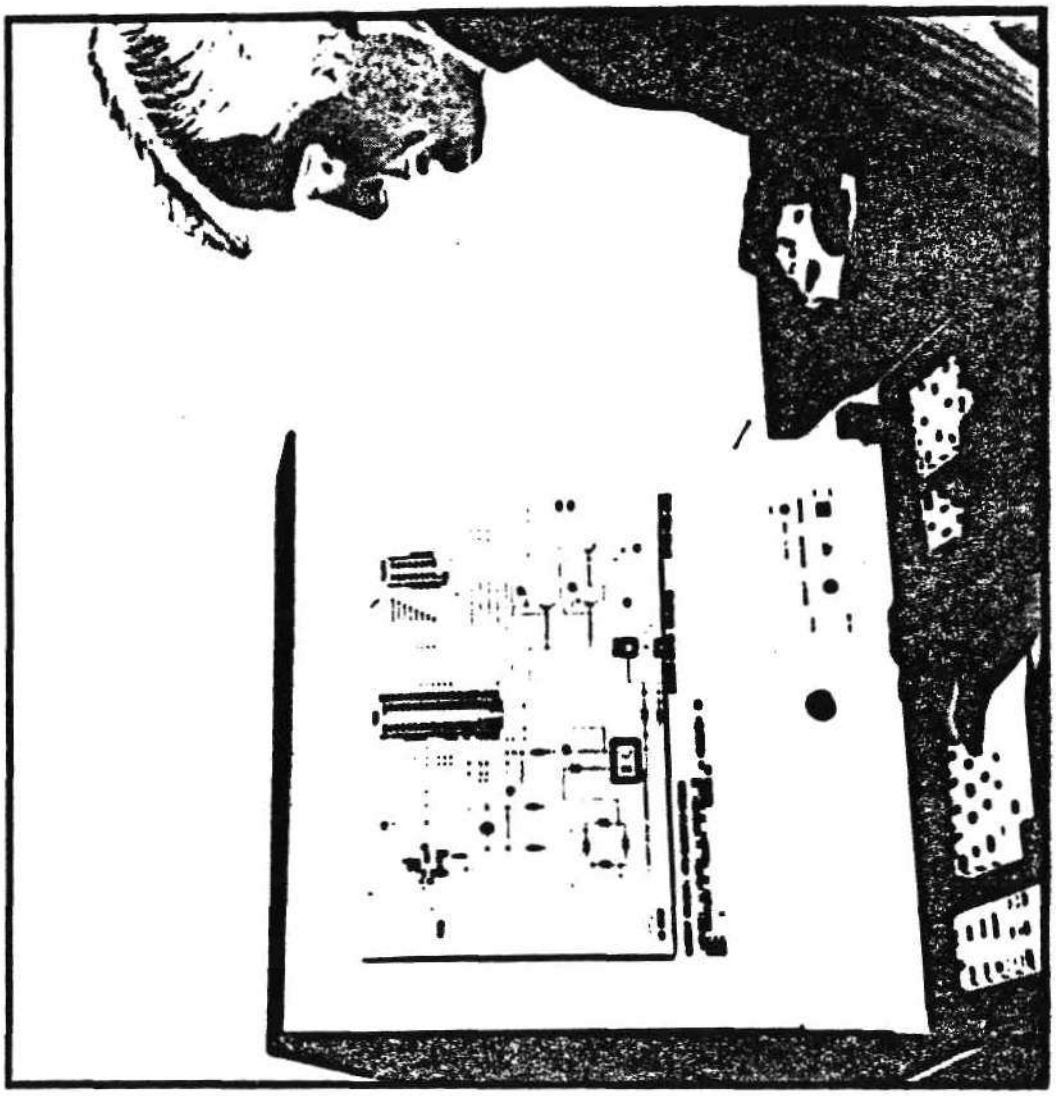
MANAGING THE COST OF TECHNOLOGY

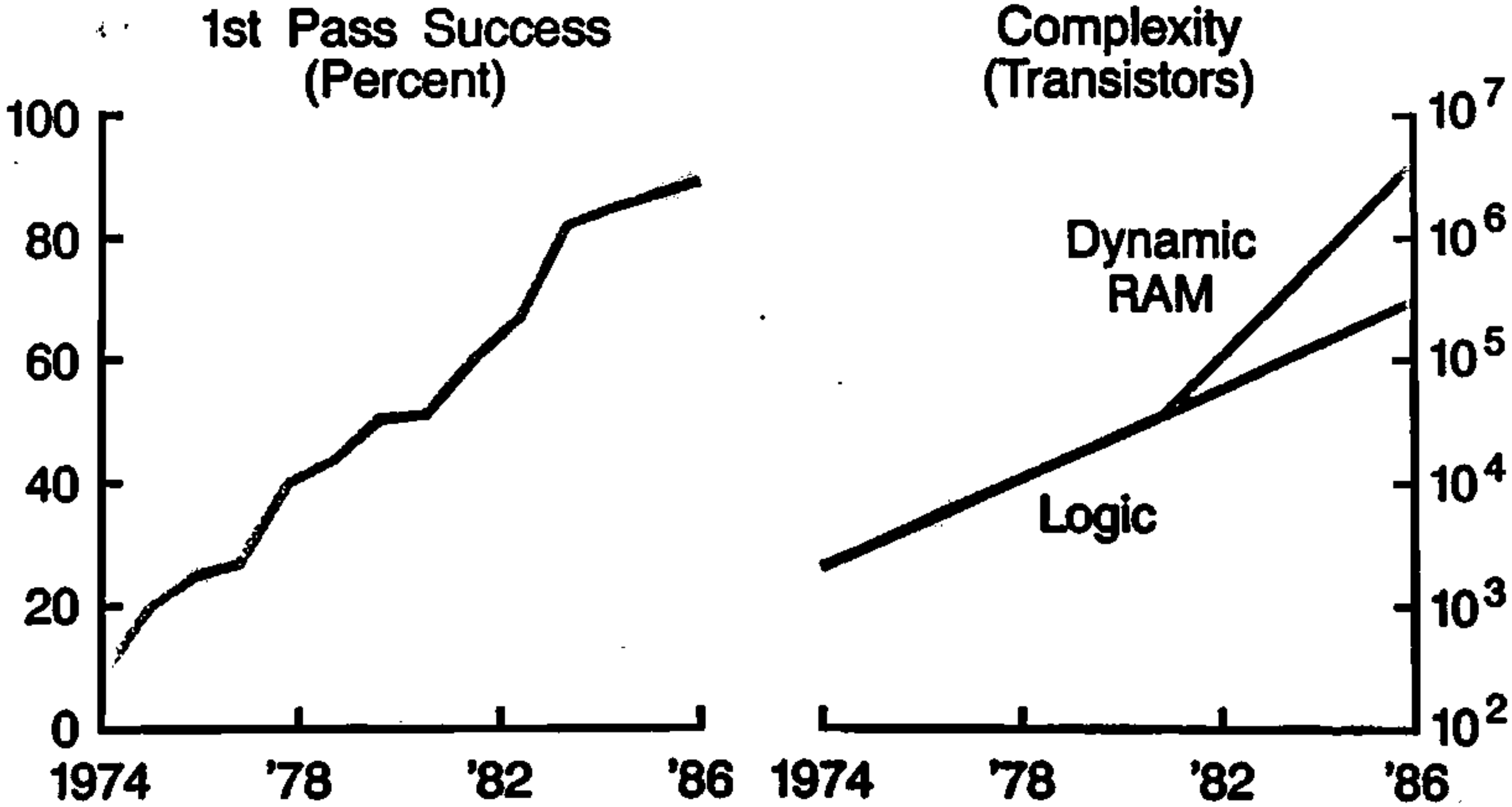
- More capability from fewer basic processes
- Share the design effort
- More derivatives from standard products
- Protection of intellectual property rights

DESIGN AUTOMATION



DESIGN AUTOMATION

Design Success Versus Complexity



"Design for Reliability" Emphasis

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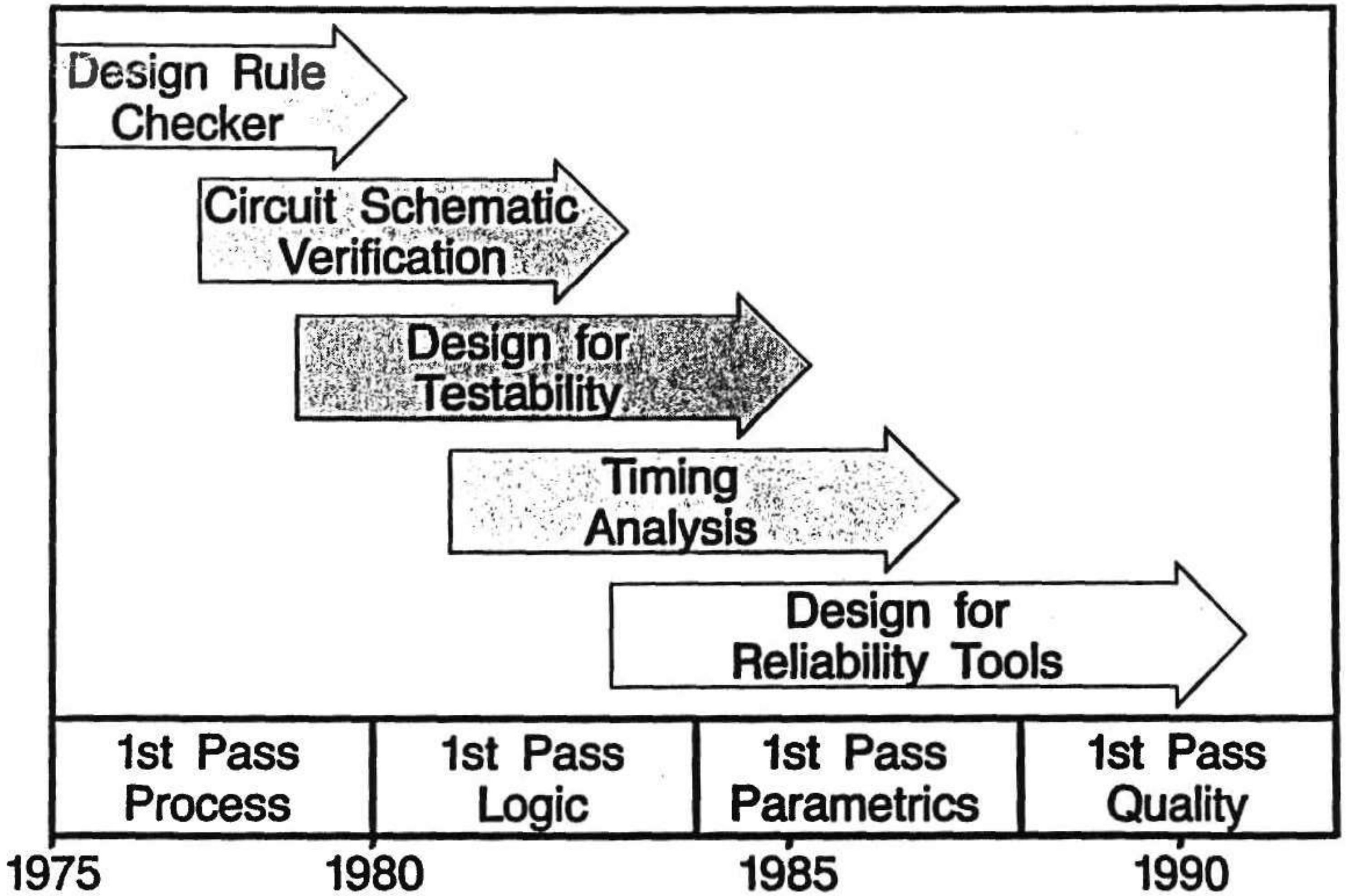
KNOWLEDGE-BASED DESIGN VERIFICATION



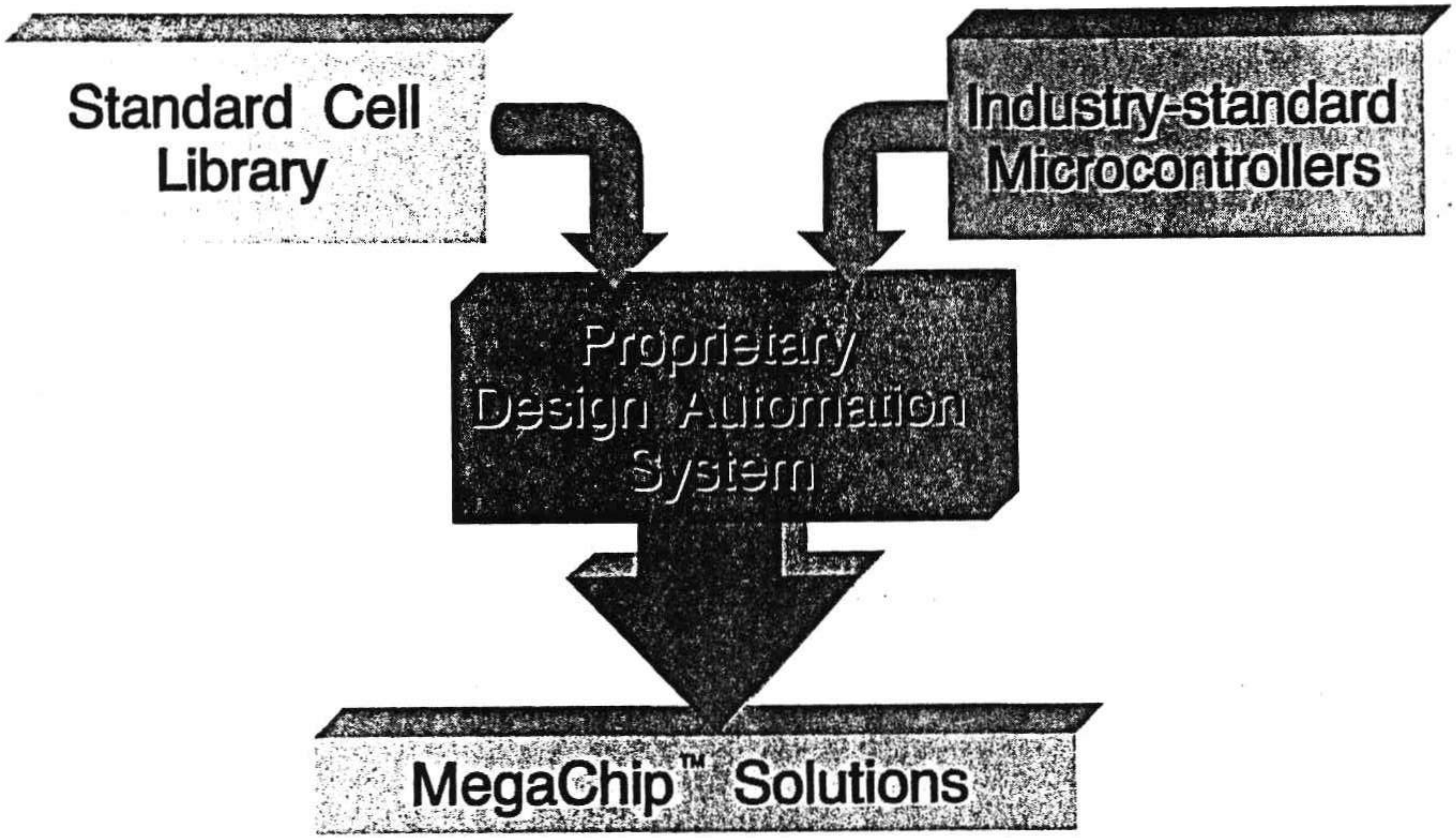
KNOWLEDGE BASED DESIGN AUTOMATION

SYMBOLIC COMPUTING IN DESIGN AUTOMATION

ADVANTAGES

- HIGH PRODUCTIVITY ENVIRONMENT
- LISP IS VERY WELL SUITED TO REPRESENT AND MANIPULATE DESIGN INFORMATION
- BUILD ON OBJECT-ORIENTED SOFTWARE TOOLS
- SHARE CODE
- INTEGRATED TOOLS

SYSTEMS INTEGRATION ROADMAP



TI/INTEL ASIC AGREEMENT

Alternate source agreement aimed at promoting standards in the area of libraries, packaging, test, and CAE

- Common gate array libraries/base bars

TI Contribution	Intel Contribution
SSI/MSI	SSI/MSI
I/O	I/O
Register Files	8237A
FIFOs	8254
29xx Family	8259A
Compilers	82284
	82288

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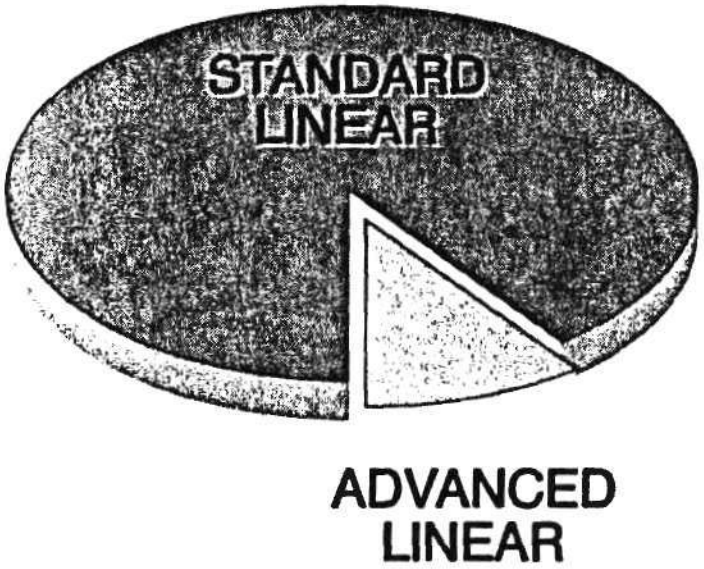
INTEL AND TI ASIC AGREEMENT

- Common cell library
- Common gate array Macro library
- Common ASIC testing, packaging and design rules
- Compatible ASIC CMOS process
- Framework for additional LSI/VLSI cells

ADVANCED LINEAR THRUST

LINEAR MARKET

1986 WORLDWIDE TAM
$5.1B



ADVANCED LINEAR

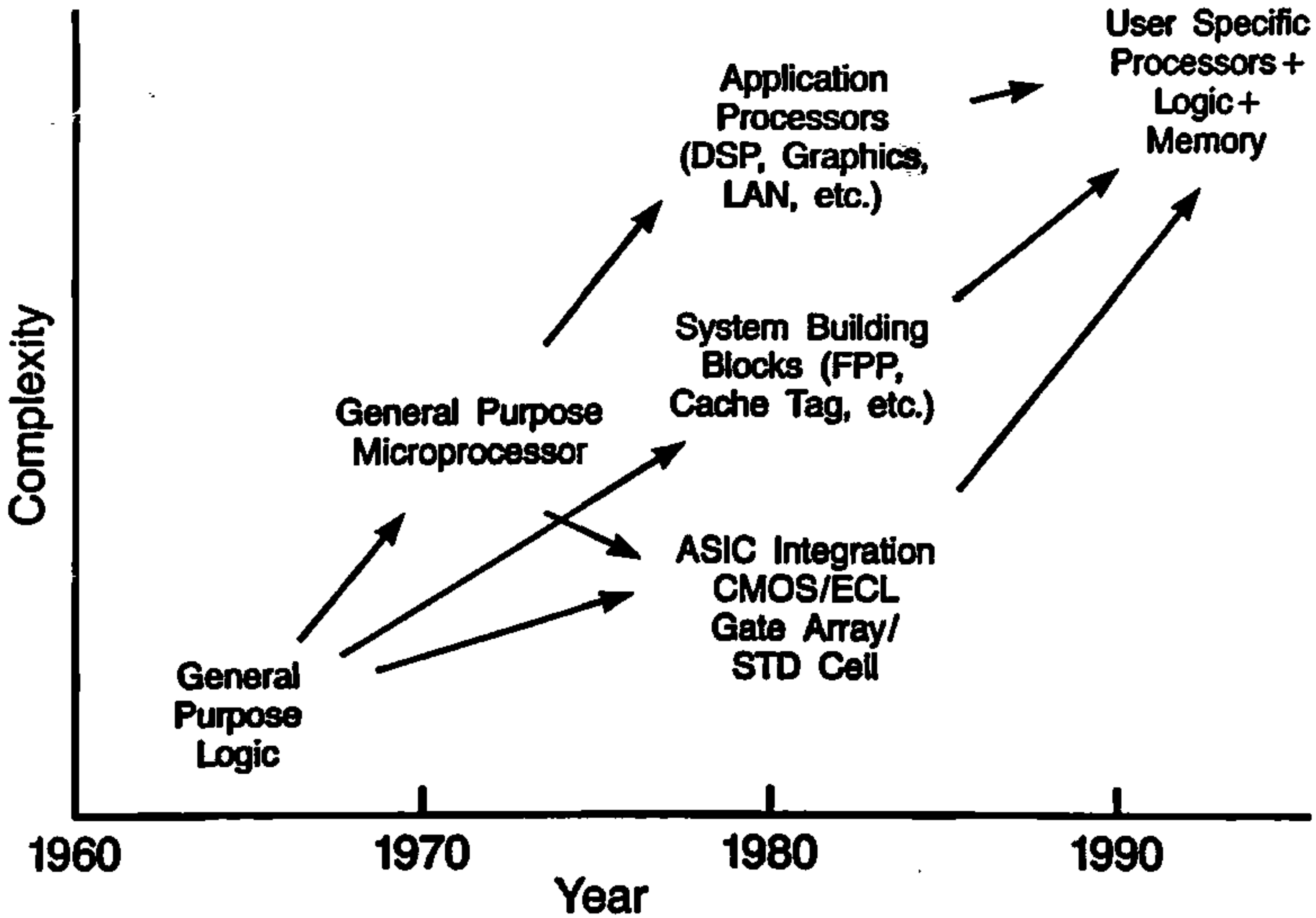
- High-Performance Data Converters
- Custom Linear
- High-Precision Amplifiers
- Networking Interface Products

Source: World Semiconductor Trade Statistics

MANAGING THE COST OF TECHNOLOGY

- More capability from fewer basic processes
- Share the design effort
- **More derivatives from standard products**
- Protection of intellectual property rights

SYSTEM INTEGRATION TREND



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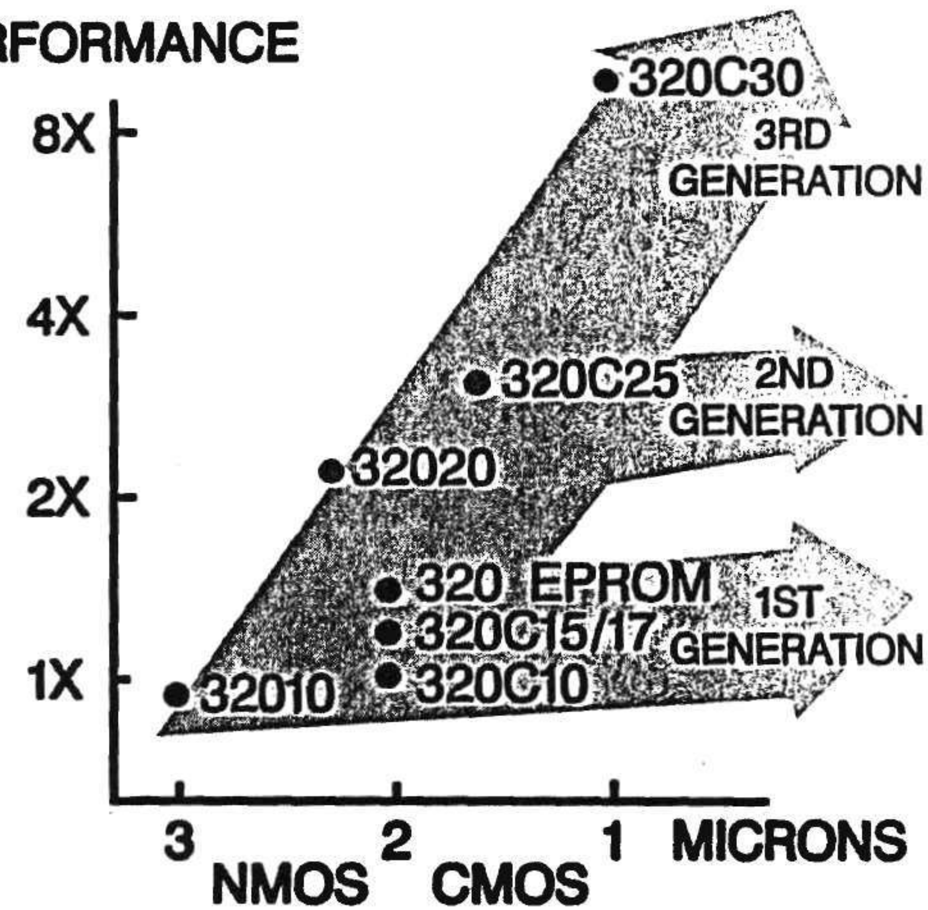
APPLICATIONS PROCESSORS THRUST

TMS320 DIGITAL SIGNAL PROCESSOR FAMILY



SOURCE: ELECTRONIC BUSINESS PUBLICATIONS

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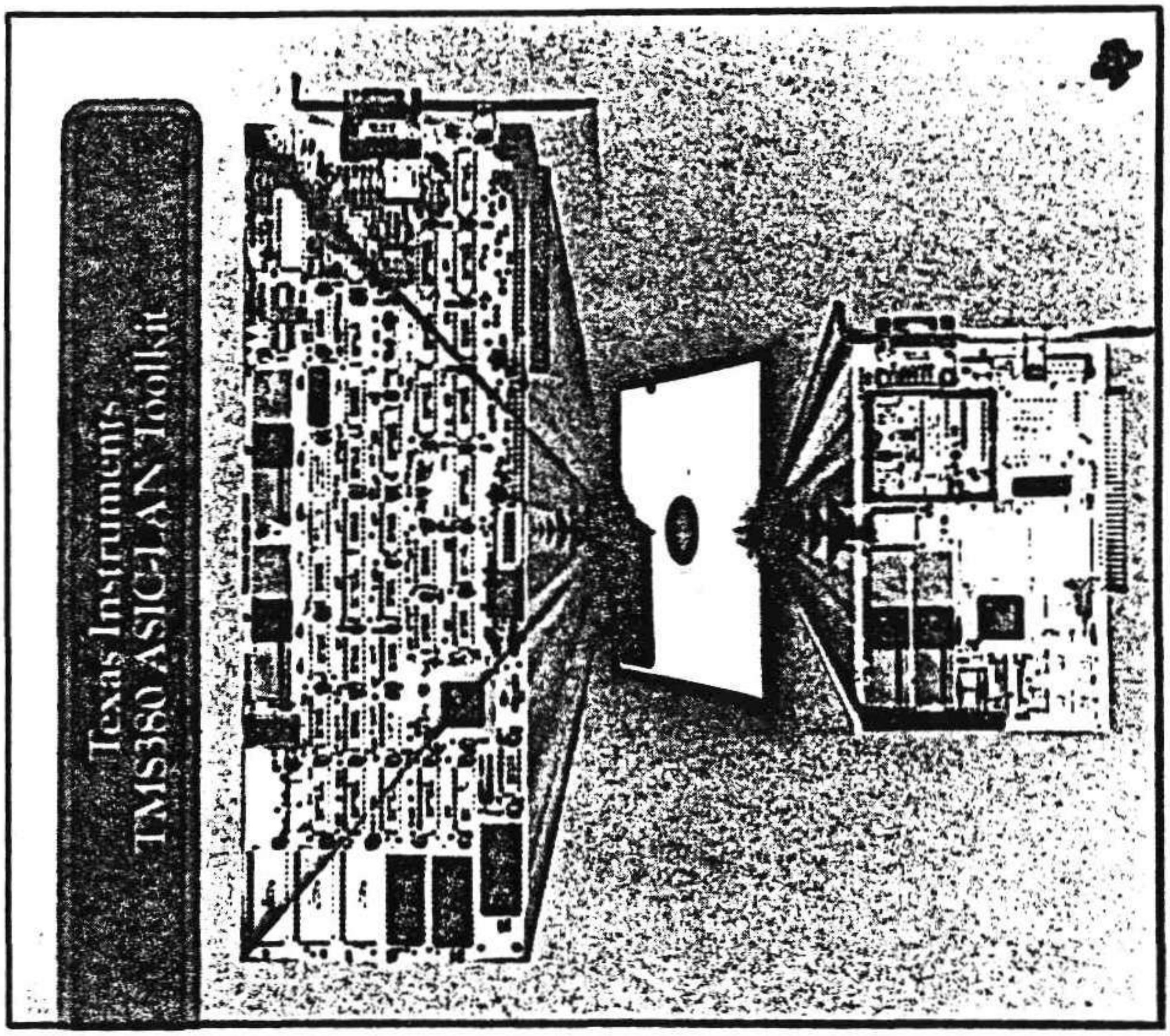
Texas Instruments
TMS380 ASIC-LAN Toolkit

APPLICATION SPECIFIC MEMORY

DRAM DERIVATIVES

Driver	Application Specific Memory	Typical System Application
64K DRAM (NMOS, 3 µM)	64K VRAM	• Graphics • Imaging • High-Speed Telecommunications
256K DRAM (NMOS, 2 µM)	256K VRAM	
1Mb DRAM (CMOS, 1 µM)	1Mb VRAM	
	1Mb FRAM	• Digital TV • VTR • Broadcasting • Facsimile/Printer

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MANAGING THE COST OF TECHNOLOGY

- More capability from fewer basic processes
- Share the design effort
- More derivatives from standard products
- **Protection of intellectual property rights**

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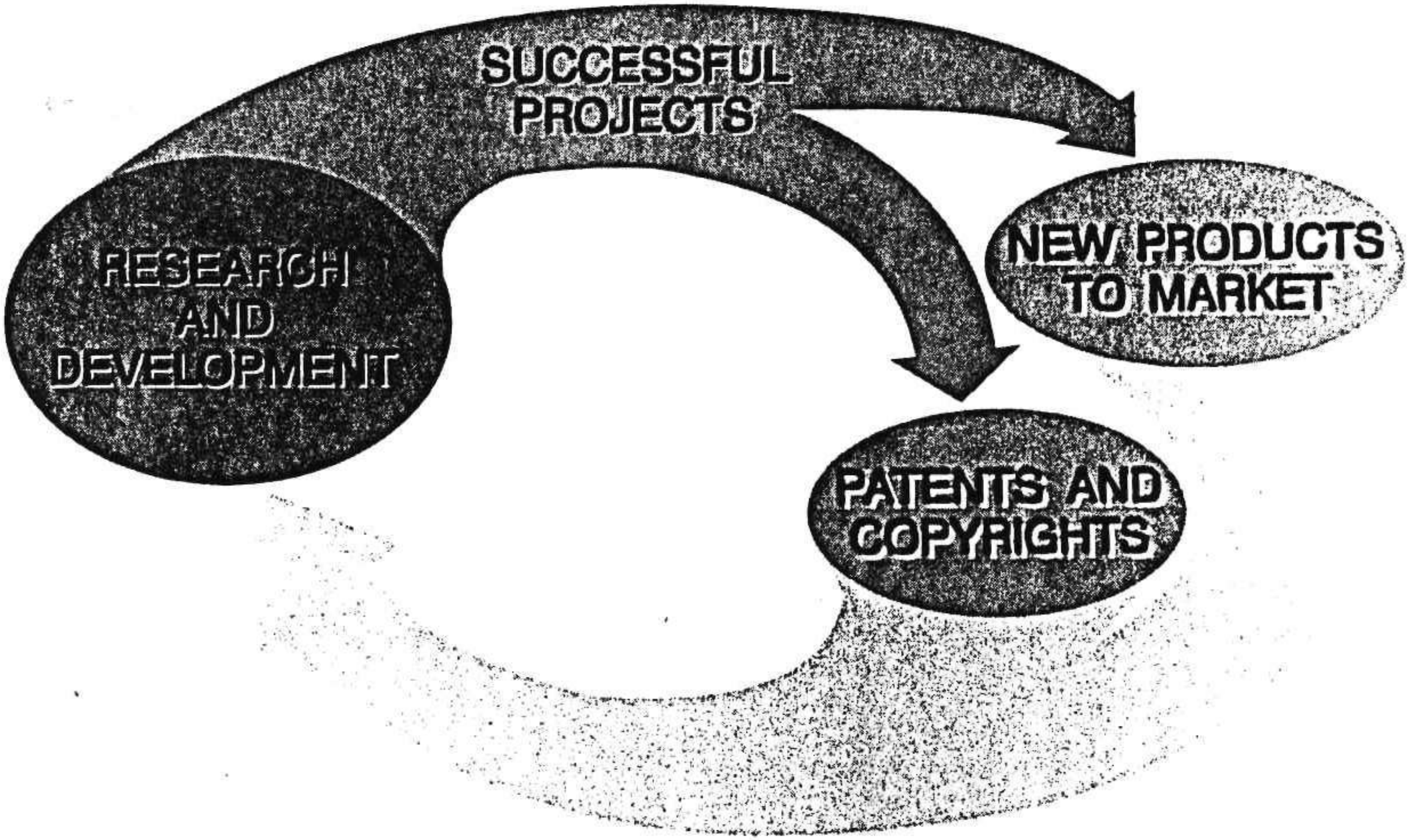
INTELLECTUAL PROPERTY



OPERATING PROFITS AND ROYALTIES

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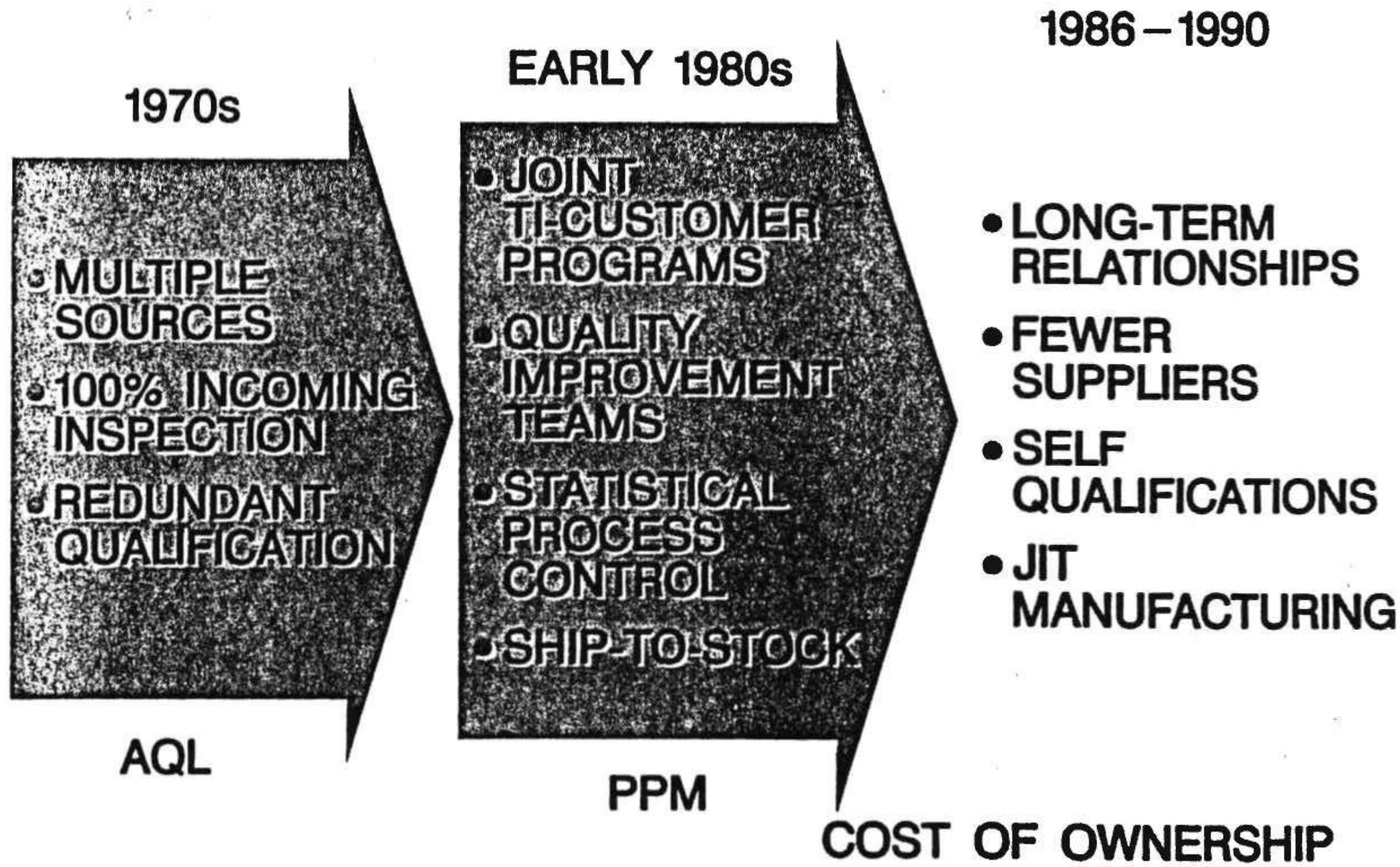
TI QUALITY — SERVICE PROGRAM



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Semiconductors' Midlife Crisis

Alliances and Acquisitions

Dataquest

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MERGERS AND ACQUISITIONS--
THE FORCES THAT ARE SHAPING OUR INDUSTRY

Donald W. Brooks

Mr. Brooks is former President and Chief Executive Officer of Fairchild Semiconductor Corporation. He came to Fairchild from Texas Instruments, where he was Senior Vice President, Digital and Military Group. Prior to that assignment, he was Vice President of the MOS Memory Division at TI. During his 25 years at Texas Instruments, Mr. Brooks also held several other key management positions. Mr. Brooks received a B.S. degree in Electrical Engineering from Southern Methodist University in Dallas, Texas.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

Alliances and Acquisitions

DONALD W. BROOKS

MERGERS & ACQUISITIONS -
THE FORCES THAT ARE SHAPING OUR INDUSTRY

AGENDA

I. GLOBAL DYNAMICS

II. SEMICONDUCTOR INDUSTRY

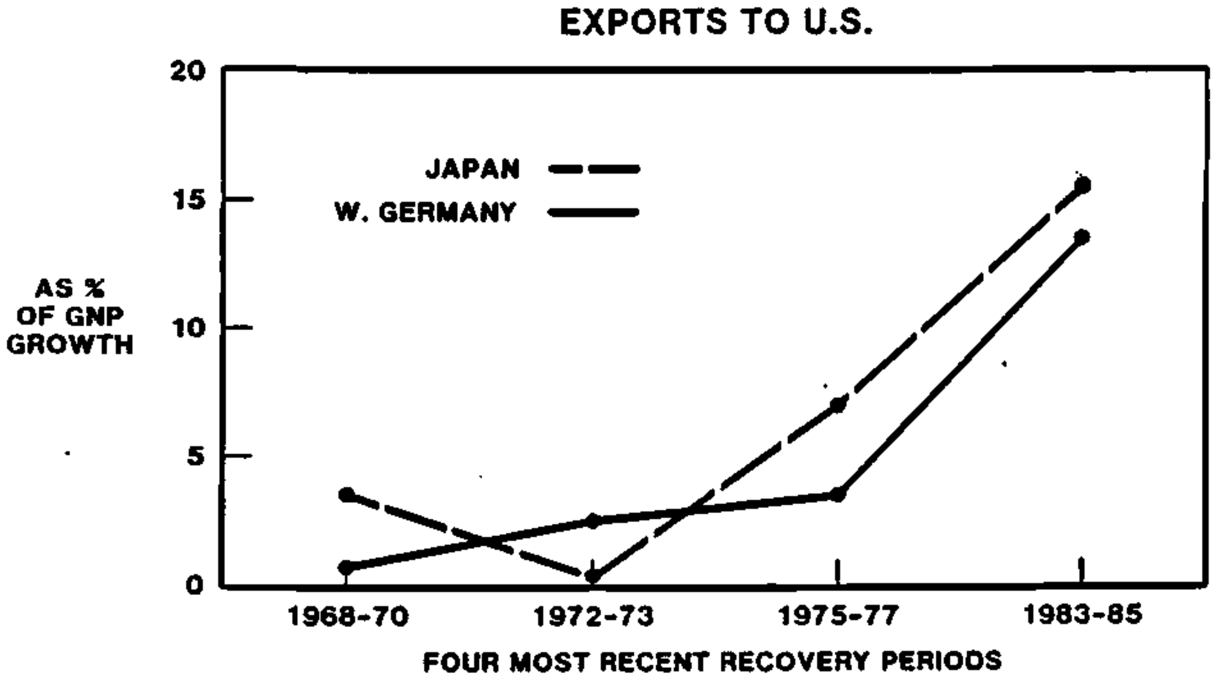
III. IMPLICATIONS FOR MANAGEMENT

GLOBAL DYNAMICS

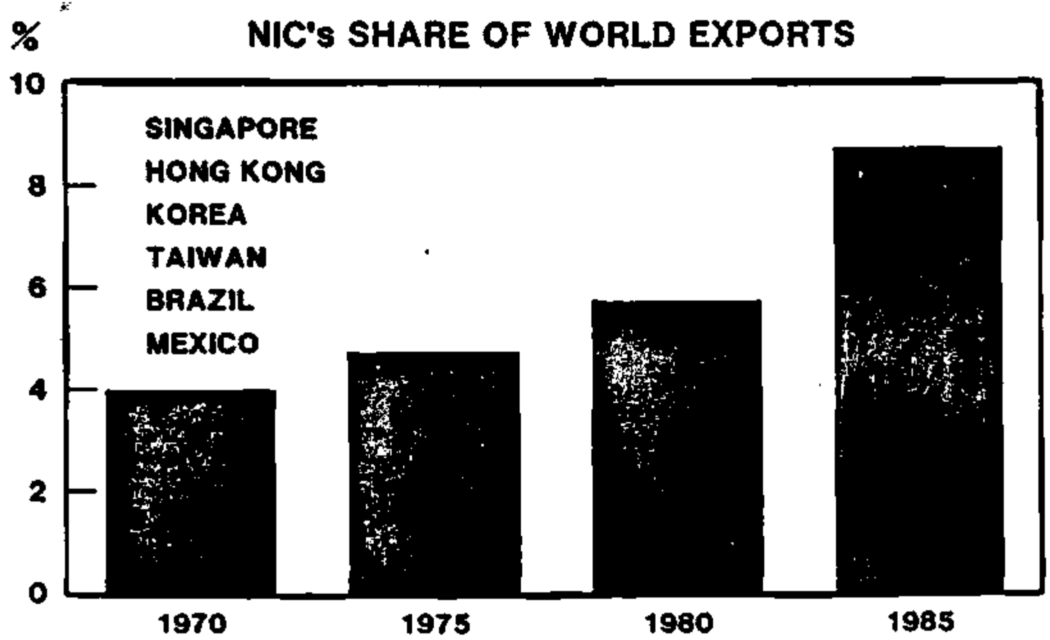
THERE IS SUBSTANTIAL OVERSUPPLY...OF EVERYTHING

SUPPLY FACTORS

- POST WAR RE-INDUSTRIALIZATION OF JAPAN AND EUROPE WAS EXPORT BASED
- CONVERSION OF U.S. WARTIME OUTPUT TO SATISFY CIVILIAN DEMAND
- EMERGENCE OF NEWLY INDUSTRIALIZED COUNTRIES (NIC's)
- EASY AVAILABILITY OF DEBT TO FUEL EXPANSION

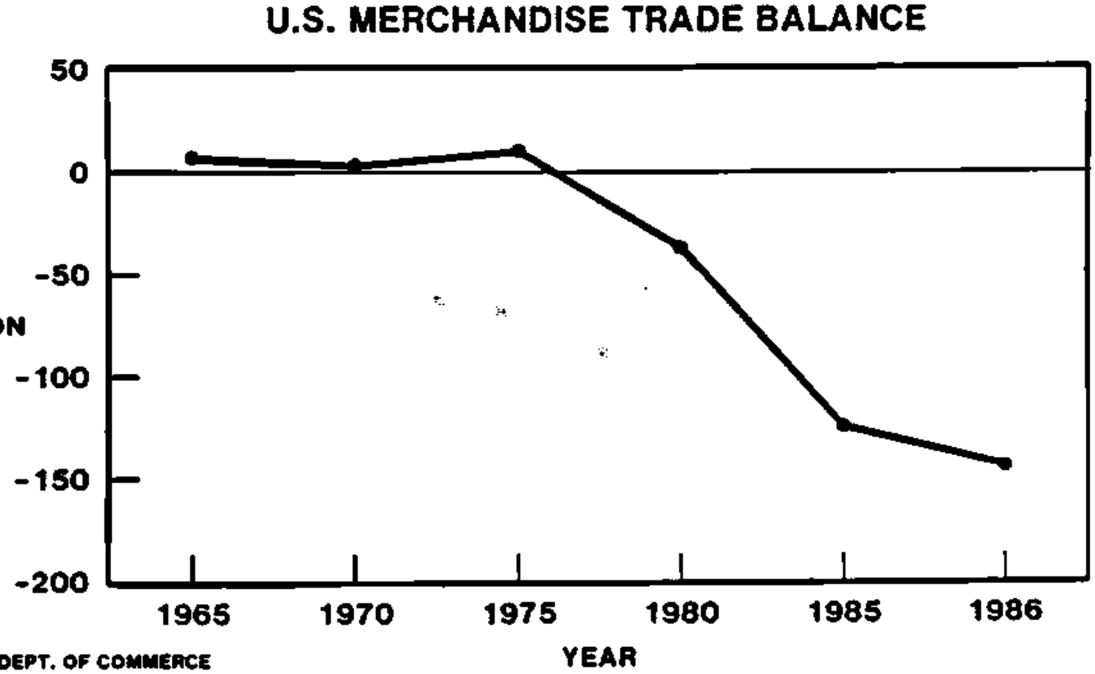

EXPORTS TO U.S.
20
15
10
5
0
AS %
OF GNP
GROWTH
JAPAN
W. GERMANY
1968-70
1972-73
1975-77
1983-85
FOUR MOST RECENT RECOVERY PERIODS

GLOBAL DYNAMICS



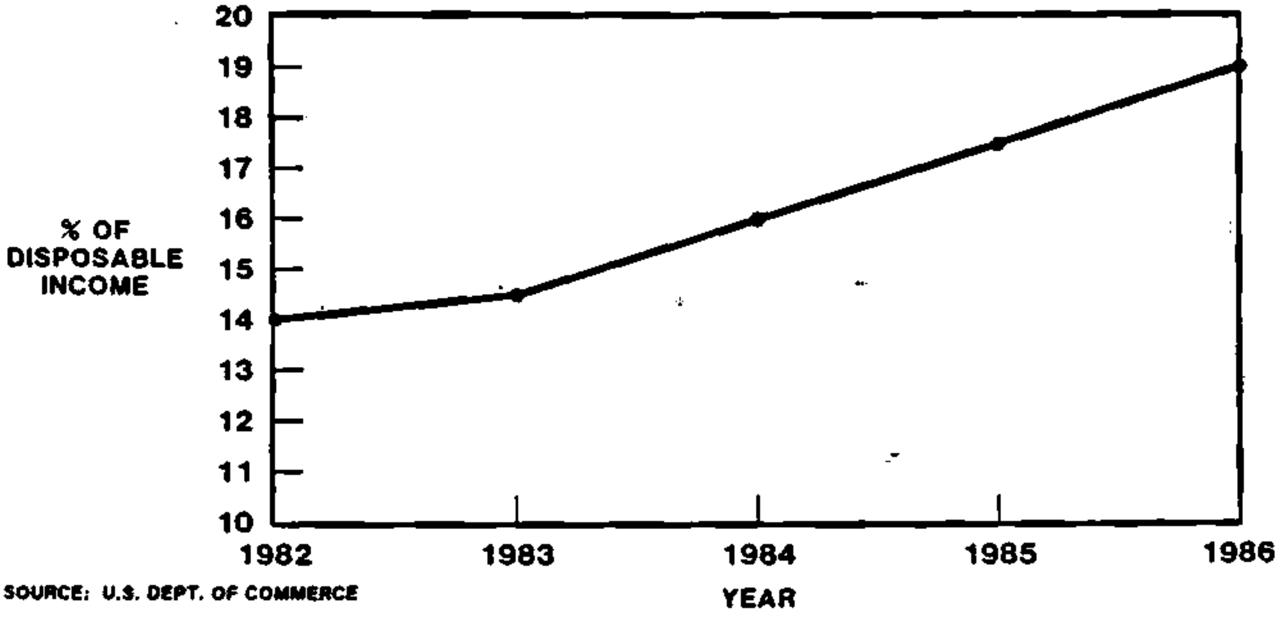
SOURCE: IMF

GLOBAL DYNAMICS



SOURCE: U.S. DEPT. OF COMMERCE

U.S. CONSUMER DEBT



SOURCE: U.S. DEPT. OF COMMERCE

BUT, WHAT ABOUT CHINA?

"ALTHOUGH MANY REGARD CHINA AS, POTENTIALLY, A MARKET OF 1 BILLION CONSUMERS FOR WESTERN GOODS, WE VIEW IT AS 1 BILLION POTENTIAL PRODUCERS OF INDUSTRIAL EXPORTS."

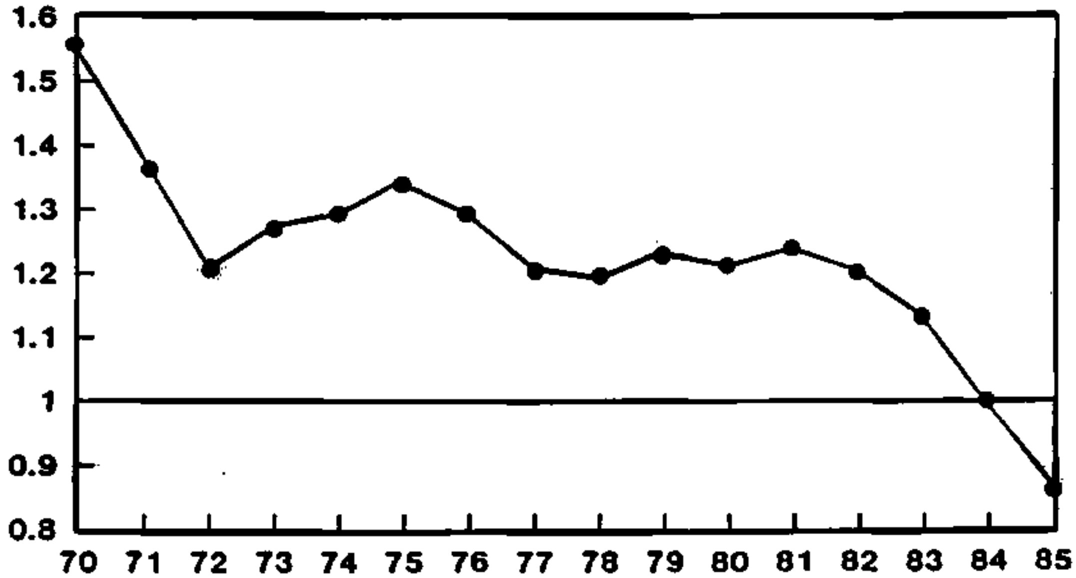
A. GARY SHILLING

CONCLUSIONS

- GROWING PROTECTIONIST SENTIMENT IN CONGRESS TO PRESERVE U.S. DEMAND FOR U.S. PRODUCTION
- DOLLARS STEEP DECLINE WILL ENCOURAGE THIS BUT WILL NOT STOP NIC's
- U.S. INDUSTRIAL BASE NOT LIKELY TO RESPOND EFFECTIVELY IN SHORT TERM
- FOREIGN INVESTMENT HAS AND WILL CONTINUE TO POUR INTO THE U.S., EUROPE AND JAPAN TO GET A PIECE OF THE LOCAL DEMAND

GLOBAL DYNAMICS

RATIO OF U.S. ASSETS ABROAD TO FOREIGN ASSETS IN THE U.S.

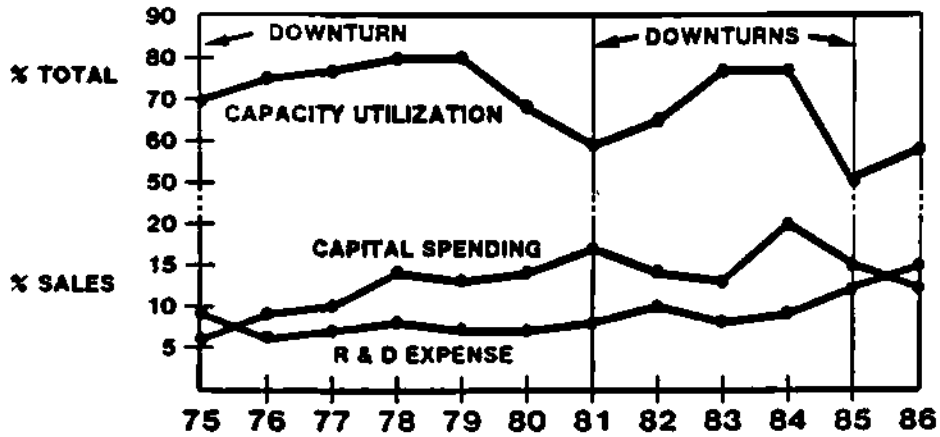


SOURCE: FEDERAL RESERVE BOARD

WHAT'S DRIVING GLOBALIZATION IN THE SEMICONDUCTOR INDUSTRY?

- SUSTAINED OVERSUPPLY HAS WEAKENED FINANCIAL STRUCTURE
- NEED TO FUND EXPANDING TECHNOLOGY ENVELOPE
  - MANUFACTURING FACILITIES
  - MANUFACTURING EQUIPMENT
  - SOFTWARE
  - R & D
- NEED FOR VERTICAL INTEGRATION
  - SYSTEMS EXPERTISE
  - VALUE ADDED
- REGIONAL MANUFACTURING, DESIGN, TEST, SALES AND SERVICE
  - CUSTOM/SEMICUSTOM
  - PROTECTIONISM

U.S. BASED SEMICONDUCTOR INDUSTRY FINANCIAL CHANGES



- GROSS OVERCAPACITY HAS CREATED FIERCE INTERNATIONAL PRICE COMPETITION
- LOW ASSET UTILIZATION, HIGH CAPITAL INTENSITY HAS SHARPLY INCREASED COST
- R & D, S G & A HAS PUSHED UP EXPENSE
- PROFITABILITY HAS DETERIORATED MORE SEVERELY WITH EACH DOWN CYCLE
- THE INDUSTRY IS IN CONSOLIDATION AND SEEKING ECONOMIES OF SCALE TO RESTORE PROFITABILITY

SEMICONDUCTOR INDUSTRY OPPORTUNITIES FOR ECONOMIES OF SCALE

- PROCESS IMPROVEMENT, DEVELOPMENT
  - EXPANDING TYPES
    - CMOS
    - BiMOS
    - ECL
    - GaAs

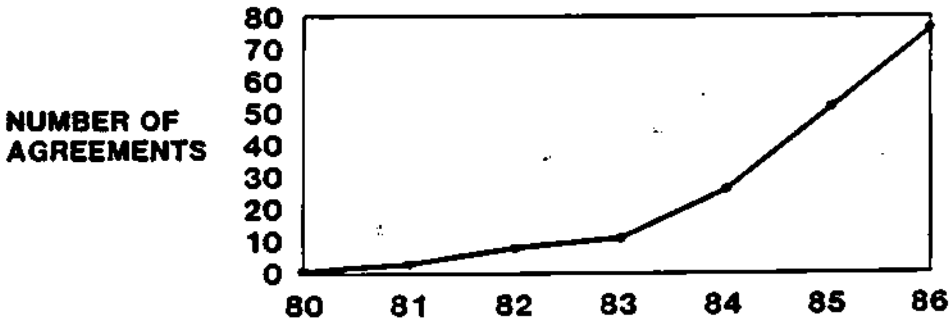
    BOTH ANALOG AND DIGITAL
  - SIMULTANEOUS PRODUCTION REQUIREMENTS
    - 3.0u
    - 2.0u
    - 1.5u
    - 1.0u
    - 2.2u
    - 1.8u
    - 1.2u
    - .8u
- FACILITY RATIONALIZATION
  - LOCATION, COST STRUCTURE
  - PROCESS, PRODUCT MIX
  - TURNAROUND TIME, THROUGHPUT
- EQUIPMENT DEVELOPMENT, MODIFICATION
  - WAFER MANUFACTURING
  - ASSEMBLY
  - TEST
- PRODUCT DESIGN AND DEVELOPMENT
  - APPLICATIONS EXPERTISE
  - CAD
  - PACKAGING
  - CELL LIBRARIES
- MARKETING AND SALES
  - GEOGRAPHICAL DEPLOYMENT
  - APPLICATIONS EXPERTISE
  - TRAINING AND TOOLS

SEMICONDUCTOR ECONOMIES OF SCALE THROUGH STRATEGIC ALLIANCES

- **RESOURCE SHARING**

PROCESS	←→	PROCESS
PROCESS	←→	DESIGN
PROCESS	←→	MANUFACTURING
MANUFACTURING	←→	DESIGN
DESIGN	←→	DESIGN
DESIGN	←→	SALES

- **RECENT SEMICONDUCTOR ALLIANCE ACTIVITY WITH JAPAN:**



- **THESE RELATIONSHIPS REPRESENT A GROWING CONSOLIDATION OF INDUSTRY PHYSICAL AND INTELLECTUAL ASSETS**

AGENDA

III IMPLICATIONS FOR MANAGEMENT

IMPLICATIONS FOR MANAGEMENT

MANAGEMENT'S ROLE HAS CHANGED

- COST CONTROL, CONSOLIDATION, RETURN ON ASSETS ARE KEYS TO SURVIVAL
- WITH MANUFACTURING BECOMING GLOBALIZED, WHITE COLLAR PRODUCTIVITY IS THE NEW FRONTIER
- JOINT VENTURE MANAGEMENT IS AN UNFOLDING CHALLENGE REQUIRING NEW SKILLS
- POST CONSOLIDATION PROFITABILITY WILL BE STRONG

DO YOU REALLY HAVE A GLOBAL STRATEGY?

"THOSE WHO DEFINE INTERNATIONAL COMPETITIVENESS AS NO MORE THAN LOW-COST MANUFACTURING ARE AIMING AT THE WRONG TARGET."

"GLOBAL COMPETITORS MUST HAVE THE CAPACITY TO THINK AND ACT IN COMPLEX WAYS. IN OTHER WORDS, THEY MAY SLICE THE COMPANY ONE WAY FOR DISTRIBUTION INVESTMENTS, IN ANOTHER FOR TECHNOLOGY, AND IN STILL ANOTHER FOR MANUFACTURING."

HARVARD BUSINESS REVIEW
JULY-AUGUST 1985

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ALLIANCES: REQUIREMENTS FOR LEADERSHIP

Thomas D. George
Senior Vice President and
Assistant General Manager
Semiconductor Products Sector
Motorola, Inc.

Dr. George is Senior Vice President and Assistant General Manager of the Semiconductor Products Sector of Motorola, Inc. Previously, he was responsible for managing special circuits operations, internal operations, bipolar integrated circuits, standard logic and integrated circuits, and wafer manufacturing at Motorola. Prior to joining Motorola, Dr. George worked at Texas Instruments, where he was involved in neutron activation analysis and productivity improvement programs and was responsible for all calculator assembly manufacturing and support functions. Dr. George received B.S. and M.S. degrees in Chemistry from Texas Technological College and a Ph.D. in Materials Science from Northwestern University. He is the author of 11 publications in scientific journals.

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DR. THOMAS D. GEORGE

Senior Vice President and Assistant General Manager
Semiconductor Product Sector
Motorola, Inc.

DATAQUEST SEMICONDUCTOR INDUSTRY CONFERENCE

PHOENIX, ARIZONA

OCTOBER 20, 1987

"ALLIANCES: REQUIREMENT FOR LEADERSHIP"

THOMAS D. GEORGE, PH.D.

SENIOR VICE PRESIDENT

AND ASSISTANT GENERAL MANAGER

SEMICONDUCTOR PRODUCTS SECTOR

MOTOROLA INC.

GOOD AFTERNOON, LADIES AND GENTLEMEN.

THE TERM "MID-LIFE CRISIS" USUALLY CONJURES UP IMAGES OF A FORTY-YEAR OLD HAVING WILD AFFAIRS, PERFORMING SEEMINGLY IRRATIONAL ACTS, OR MOVING THROUGH A PERIOD OF DEPRESSION OR ANXIETY. IT CAN ALSO BE A PERIOD OF INTROSPECTION, FOCUS AND PERHAPS REDIRECTION AT THE MIDPOINT IN ONE'S LIFE. ORGANIZATIONS AND ENTERPRISES SEEM TO FACE THE SAME DILEMMAS AND DOUBTS ASSOCIATED WITH THE ONSET OF MID-LIFE MATURITY.

WITH OUR INDUSTRY NOW AT THIS CRUCIAL AGE, THE DECISIONS WE MAKE AND THE COURSE OF ACTION WE CHOOSE - AS INDIVIDUAL COMPANIES AND ASSOCIATED FIRMS - COULD PROFOUNDLY AFFECT THE TEXTURE OF THE SEMICONDUCTOR INDUSTRY FOR MANY YEARS TO COME.

MY REMARKS THIS AFTERNOON WILL OFFER A MOTOROLA PERSPECTIVE ON SOME OF THE FORCES SHAPING OUR INDUSTRY TODAY. THEN, I WILL LOOK AT SOME OF THE REASONS WE ARE SEEING A GROWING NUMBER OF ALLIANCES, USING MOTOROLA AS AN EXAMPLE, AND FINALLY, I'LL SHARE SOME THOUGHTS ABOUT THE FUTURE.

LET'S START BY LOOKING AT CURRENT DYNAMICS WITHIN OUR INDUSTRY, FOCUSING ON SOME OF THE MAJOR ELEMENTS WHICH ARE SHAPING OUR BUSINESSES AND OUR RESPONSES TO THESE DYNAMICS.

THE FIRST ELEMENT IS THE <u>GLOBALIZATION</u> OF OUR INDUSTRY.

OUR PRODUCTS ARE VERY MUCH LIKE ANY OTHER COMMODITY WITH IDENTICAL APPLICATIONS AND USES IN VIRTUALLY ALL PARTS OF THE WORLD. STRONG CAPABILITY IS REQUIRED IN EACH OF THE WORLD'S MAJOR MARKETS -- EUROPE, NORTH AMERICA AND THE PACIFIC BASIN -- IN ORDER TO BE A LEADING CHIP SUPPLIER. FACTORS INCLUDE A GROWING CUSTOMER BASE IN ALL REGIONS; O.E.M. SPECIALIZATION IN VARIOUS REGIONAL MARKETS, SUCH AS THE CONSUMER SEGMENT IN EUROPE AND THE PACIFIC BASIN; STRONG PREFERENCE FOR LOCAL PRODUCTION; AND MANY LARGE, TRADITIONAL CUSTOMERS EXPANDING GLOBALLY.

THE PRIMARY FACTOR, OF COURSE, IS THE GROWING SIZE AND IMPORTANCE OF THE JAPANESE MARKET - NOW THE WORLD'S LARGEST - WHICH CANNOT BE OVERLOOKED BY ANY SEMICONDUCTOR SUPPLIER HOPING TO BE A LEADER IN THIS INDUSTRY.

ALL OF THESE DEVELOPMENTS HAVE CREATED THE NEED TO HAVE THE FULL SPECTRUM OF DESIGN, MANUFACTURING AND MARKETING CLOSE TO OUR CUSTOMERS, REGARDLESS OF THEIR GEOGRAPHIC LOCATION. AN IMPORTANT FACTOR IS THE NEED TO MINIMIZE RISK BY MAINTAINING A GOOD BALANCE AMONG THE MAJOR REGIONS, THEIR MARKET SEGMENTS AND CUSTOMER BASES.

(PAUSE)

THE SECOND MAJOR ELEMENT SHAPING OUR INDUSTRY TODAY IS THE LARGE AND GROWING COST OF STAYING TECHNOLOGICALLY CURRENT. CONSIDER THAT WE NOW CAN SPEND UP TO A QUARTER OF A BILLION DOLLARS BUILDING A STATE-OF-THE-ART WAFER FABRICATION FACILITY OR DEVELOPING A MAJOR NEW TECHNOLOGY. THE STAKES ARE STRATOSPHERIC, AND THE RETURNS ARE NOT ASSURED. INCREASINGLY, IT APPEARS THAT LARGE, VERTICALLY INTEGRATED PLAYERS HAVE THE BEST CHANCE TO BE SUCCESSFUL. MOREOVER, THE ODDS APPEAR TO FAVOR COMPANIES WHOSE SEMICONDUCTOR BUSINESS DOES NOT DOMINATE THEIR REVENUES.

OF COURSE, DESPITE THE HIGH PRICE OF ENTERING OR STAYING IN THE GAME, EACH PLAYER IS EXPECTED TO BE A CONSISTENT WINNER, BY DEMONSTRATING ACCEPTABLE FINANCIAL PERFORMANCE - REGARDLESS OF THE CYCLICALITY OF OUR INDUSTRY.

THE THIRD ELEMENT AT WORK IS CUSTOMER EXPECTATIONS. TODAY, MORE AND MORE OF THE CUSTOMERS' SYSTEM IS EMBEDDED IN SILICON.

THIS TREND LIKELY WILL ACCELERATE IN THE YEARS TO COME - DRIVEN BY RAPIDLY GROWING CUSTOMIZED CIRCUIT TECHNOLOGIES, INCLUDING STANDARD CELLS, CORE-BASED CELLS AND GATE ARRAYS, THAT ARE BRINGING PROFOUND CHANGES IN OUR INDUSTRY.

CUSTOMERS ALSO ARE AGGRESSIVELY REDUCING THEIR SUPPLIER BASE, AS A MEANS OF BETTER MANAGING THEIR COSTS AND THE COMPLEXITY OF THEIR BUSINESS. THEY ARE DEMANDING NOT ONLY PRODUCT LEADERSHIP BUT A BROAD PORTFOLIO IN ORDER TO ELIMINATE THE NEED TO DEAL WITH HUNDREDS OF VENDORS.

MOREOVER, CUSTOMERS INCREASINGLY ARE PLACING MUCH MORE STRINGENT SERVICE REQUIREMENTS UPON THEIR SUPPLIERS, SUCH AS ELABORATE, REAL-TIME DATA LINKS, THE INTRODUCTION OF JUST-IN-TIME DELIVERIES, AND NUMEROUS PERSONALIZED SERVICE ELEMENTS. THIS REQUIRES SUPPLIERS TO ESTABLISH COMPLETE, REGIONAL MANUFACTURING CAPABILITIES TO FULLY SERVE THEIR CUSTOMERS.

JUST AS WE ARE SEEING MORE ALLIANCES AMONG SUPPLIERS, WE INCREASINGLY ARE SEEING THE DEVELOPMENT OF TRUE PARTNERSHIPS WITH KEY CUSTOMERS, NONE OF WHOM CAN BET THE FUTURE OF THEIR COMPANY ON A QUESTIONABLE SILICON SUPPLIER.

THE FOURTH MAJOR ELEMENT AT WORK IS MANUFACTURING EXCELLENCE. AMERICAN INDUSTRY NOW REALIZES THAT TO BE GLOBALLY COMPETITIVE IT MUST HAVE THE FULL SPECTRUM OF CAPABILITY, INCLUDING WORLD-CLASS MANUFACTURING. MOST U.S. SEMICONDUCTOR SUPPLIERS CERTAINLY HAVE REALIZED THIS, AND WE ARE MAKING A MONUMENTAL EFFORT TO REGAIN MANUFACTURING LEADERSHIP THROUGH INDIVIDUAL EFFORTS, TEAMING, AND IN BROAD COOPERATIVE VENTURES SUCH AS SEMATECH.

TAKEN TOGETHER, THESE ELEMENTS AND MANY RELATED FACTORS ARE PRODUCING A GROWING NUMBER OF ALLIANCES WITHIN OUR INDUSTRY, AS DISTINGUISHED FROM SECOND SOURCES OR NARROWLY FOCUSED AGREEMENTS. I WON'T ATTEMPT TO SUMMARIZE HISTORY, EXCEPT TO NOTE THAT MANY AGREEMENTS IN THE PAST HAVE NOT WORKED AS EXPECTED.

HOWEVER, I BELIEVE THAT ALLIANCES WILL CONTINUE BECAUSE THEY ARE A REQUIREMENT FOR LEADERSHIP IN THIS INDUSTRY. BY THE WAY, THE SAME PHENOMENON HOLDS TRUE FOR THE ACQUISITION OF SMALLER COMPANIES, WHICH MAY OFFER A TECHNOLOGY OR A CAPABILITY DEEMED VALUABLE BY A LARGER SUPPLIER. LET'S LOOK AT THEIR ATTRIBUTES, USING MOTOROLA'S ALLIANCE WITH TOSHIBA AS THE EXAMPLE, SINCE THAT'S THE ONE I KNOW A LOT ABOUT.

THE CHIEF MOTIVATOR FOR ALLIANCES IS THE ACQUISITION OF TECHNOLOGY, EITHER DESIGN OR PROCESS, OR A COMBINATION. IN THE CASE OF MOTOROLA, WE NEED TO DEVELOP WORLD-CLASS MEMORY TECHNOLOGY AND TOSHIBA NEEDS WORLD-CLASS MPU CAPABILITY. THIS IS A REALIZATION THAT NO SINGLE ENTITY CAN BE THE BEST AT EVERYTHING AT THE SAME TIME. TECHNOLOGY ACQUISITION IS GENERALLY DRIVEN BY CUSTOMERS' DEMANDS FOR A SUFFICIENTLY BROAD PORTFOLIO TO SERVE THEIR NEEDS. THE FACT IS THAT MANY OF OUR CUSTOMERS WANT MOTOROLA AS A MEMORY SUPPLIER, AND WE INTEND TO DELIVER.

THE SECOND MAJOR MOTIVATION FOR ALLIANCES IS COST SAVINGS, WITH PARTNERS SHARING THE RISK AND COST OF PRODUCT AND PROCESS DEVELOPMENT, AS WELL AS NEW FACILITIES. A CASE IN POINT IS THE MOTOROLA-TOSHIBA JOINT VENTURE FACILITY NOW BEING CONSTRUCTED IN JAPAN. AN ADDED BEEFIT IS THAT WE'RE BLENDING THE BEST FEATURES OF BOTH COMPANIES' DESIGN, CONSTRUCTION AND EQUIPMENT CAPABILITIES IN THIS LEADING-EDGE FACILITY, WHICH WILL BE IN PRODUCTION BY MID-88.

THE THIRD MOTIVATION FOR THE FORMATION OF ALLIANCES IS REGIONAL STRENGTH, AS ONE LEVERAGES THE CREDIBILITY AND CAPABILITY OF THEIR PARTNER IN A PARTICULAR MARKETPLACE OR REGION. THE MAJOR FOCUS, OF COURSE, IS JAPAN; AND AS I STATED EARLIER, COMPANIES SIMPLY MUST SUCCEED IN JAPAN IN ORDER TO REMAIN A LEADER IN THIS INDUSTRY.
WE BELIEVE MOTOROLA'S ALLIANCE WITH TOSHIBA WILL BE VERY BENEFICIAL IN THIS REGARD.

AS ATTRACTIVE AS ALLIANCES HAVE BECOME, EXPERIENCE HAS SHOWN THAT THERE ARE SOME KEY REQUIREMENTS FOR AN ALLIANCE TO SUCCEED.

FIRST, THE GOALS OF EACH PARTY MUST BE COMPLETELY UNDERSTOOD AND FULLY SUPPORTED BY THE OTHER PARTY, AT ALL LEVELS OF THE ORGANIZATIONS. HIDDEN AGENDAS AND QUESTIONABLE MOTIVES WILL SURELY DOOM ANY ARRANGEMENT OR AGREEMENT, REGARDLESS OF THE STATED PURPOSE. THE GOALS MUST BE SUCH THAT WIN-WIN-WIN OCCURS: EACH PARTNER MUST WIN AND THE CUSTOMER MUST WIN.

NEXT, IS THE REQUIREMENT FOR MANAGEMENT COMPATIBILITY, TRUST, AND FREQUENT INTERACTION. THE MOST SENIOR LEVELS OF BOTH COMPANIES MUST BE INVOLVED IN DEVELOPING THE ALLIANCE AND IN ENSURING ITS SUCCESS ON A CONTINUING BASIS.

THE THIRD REQUIREMENT FOR SUCCESS IS THE PROVISION OF PROPER RESOURCES IN SUPPORT OF THE ALLIANCE. THIS INCLUDES NOT ONLY THE FINANCIAL REQUIREMENTS, BUT ALSO ADEQUATE HUMAN RESOURCES. ALLIANCES NEITHER MANAGE THEMSELVES, NOR ARE THEY SELF-PERPETUATING. THEY REQUIRE WORK. THERE MUST BE A PROCESS OF CAREFUL MONITORING AND EVALUATION, AND A CLEARLY DEFINED AND ACCEPTED MEANS OF RESOLVING ANY DISPUTES THAT MAY ARISE.

MOTOROLA'S EXPERIENCE WITH TOSHIBA SHOWS THAT A COMPREHENSIVE ALLIANCE CAN BE A REWARDING ENDEAVOR. WE BELIEVE THE ATTRIBUTES FAR OUTWEIGH THE POTENTIAL RISKS, AND EACH COMPANY IS COMMITTED TO MAKING THE ALLIANCE A LONG-TERM SUCCESS.

(PAUSE)

I BELIEVE SIMILAR ALLIANCES WILL CONTINUE TO OCCUR IN THE FUTURE ... WHICH BRINGS ME TO THE OUTLOOK FOR "LIFE AFTER 40" IN THE SEMICONDUCTOR INDUSTRY.

THE MAJOR FORCES SHAPING OUR INDUSTRY'S MID-LIFE CRISIS WILL REMAIN FOR THE FORESEEABLE FUTURE, DRIVING FURTHER RESTRUCTURING, CONSOLIDATION, AND COMPREHENSIVE ALLIANCES.

THE RESULT WILL BE FEWER, LARGE INDEPENDENT SEMICONDUCTOR PRODUCERS DURING THE NEXT TEN YEARS. THE SMALL AND MEDIUM-SIZED COMPANIES WILL CONTINUE TO MERGE OR BE ACQUIRED BY LARGER PLAYERS. THERE WILL BE FEWER START-UPS, GIVEN THE HIGH PRICE OF ENTRY AND QUESTIONABLE RETURN, ALTHOUGH I DO BELIEVE THAT NEW VENTURES ALWAYS WILL BE PART OF OUR INDUSTRY.

SOME LARGE, DIVERSIFIED COMPANIES WITH A WEAK SEMICONDUCTOR CAPABILITY LIKELY WILL DIVEST THEMSELVES OF THEIR MERCHANT SEMICONDUCTOR OPERATIONS. ON THE OTHER HAND, A FEW LARGE NON-ELECTRONICS COMPANIES WITH LARGE FINANCIAL RESOURCES MAY ACQUIRE SMALLER SEMICONDUCTOR FIRMS IN ORDER TO ENTER THIS STRATEGIC TECHNOLOGY ARENA. THESE ACQUISITIONS LIKELY WILL BE MOTIVATED BY THE NEEDS OF THEIR OWN END-EQUIPMENT BUSINESSES FOR PROPRIETARY SILICON TECHNOLOGY AND RELIABLE INTERNAL SUPPLY, AS OPPOSED TO LARGE, MERCHANT SALES ASPIRATIONS.

REGIONAL ALLIANCES LIKELY WILL REMAIN A FACTOR, ESPECIALLY IN EUROPE AND JAPAN.

HIGHER LEVELS OF AUTOMATION, ASIC TECHNOLOGIES AND SERVICE REQUIREMENTS LIKE JIT WILL RESULT IN A LARGER NUMBER OF INTEGRATED, RAPID CYCLE TIME FACTORIES TO SERVE MAJOR MARKET REGIONS.

THE WORLD'S MAJOR ECONOMIC POWERS AND NEWLY INDUSTRIALIZED COUNTRIES WILL CONTINUE TO VIEW SEMICONDUCTOR TECHNOLOGY AS A STRATEGIC RESOURCE FOR BOTH COMMERCIAL AND MILITARY MIGHT.

SUCH NATIONALISTIC CONSIDERATIONS BY THE INDUSTRIAL GIANTS WILL CONTINUE TO INFLUENCE OUR INDUSTRY, BUT IT'S DOUBTFUL THAT SMALLER NATIONS CAN MUSTER THE COMMITMENT, TALENT AND FINANCIAL RESOURCES TO PLAY IN THE BIG LEAGUES. TAIWAN PROBABLY WILL SERVE AS THE TEST CASE FOR THESE TYPE OF ENDEAVORS.

BY THE END OF THE CENTURY, CHANCES ARE WE WILL SEE 12 OR LESS MAJOR SEMICONDUCTOR SUPPLIERS, EACH PART OF A LARGER, DIVERSIFIED ENTERPRISE. HOW WELL WE MANAGE OUR AFFAIRS DURING THE INDUSTRY'S MID-LIFE CRISIS WILL DETERMINE THAT LINE UP WHEN WE WELCOME A NEW CENTURY. ONE THING IS CERTAIN, ALLIANCES WILL BE A KEY ELEMENT IN THE STRATEGIES WE PURSUE.

THANK YOU.

SEMICONDUCTOR PARTNERSHIPS--KEY TO SUCCESS

Alfred J. Stein
Chairman of the Board and Chief Executive Officer
VLSI Technology, Incorporated

Mr. Stein is Chairman and Chief Executive Officer of VLSI Technology, Inc., a company that specializes in ASICs. Before joining VLSI Technology, Mr. Stein was President and Chief Executive Officer of Arrow Electronics. Prior to that, he was Assistant General Manager of the entire Semiconductor Sector of Motorola Corporation. There, he was instrumental in the development of a vast spectrum of new products, including the 68000 microprocessors, high-density memories, the low-power Schottky TTL digital logic family, and high-speed bipolar gate arrays. Earlier, he held numerous management positions with Texas Instruments. Mr. Stein holds a B.S. degree from St. Mary's University in San Antonio, Texas, and an M.S. degree in Mathematics from Southern Methodist University in Dallas.

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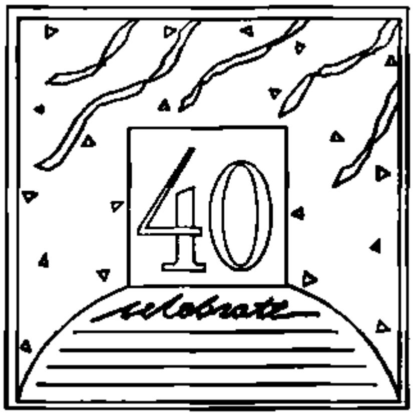

Semiconductors' Midlife Crisis

Alliances and Acquisitions

ALFRED J. STEIN

Chairman and Chief Executive Officer
VLSI Technology

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SEMICONDUCTOR PARTNERSHIPS

SEMICONDUCTOR PARTNERSHIPS

- CHANGING VIEWS ON INDUSTRY COOPERATION
- CHANGING INDUSTRY CONDITIONS - 1980's
- STRATEGIC PARTNERSHIP SPECTRUM
- SUCCESSFULL TECHNOLOGY PARTNERSHIPS
- THE FUTURE OF PARTNERSHIPS

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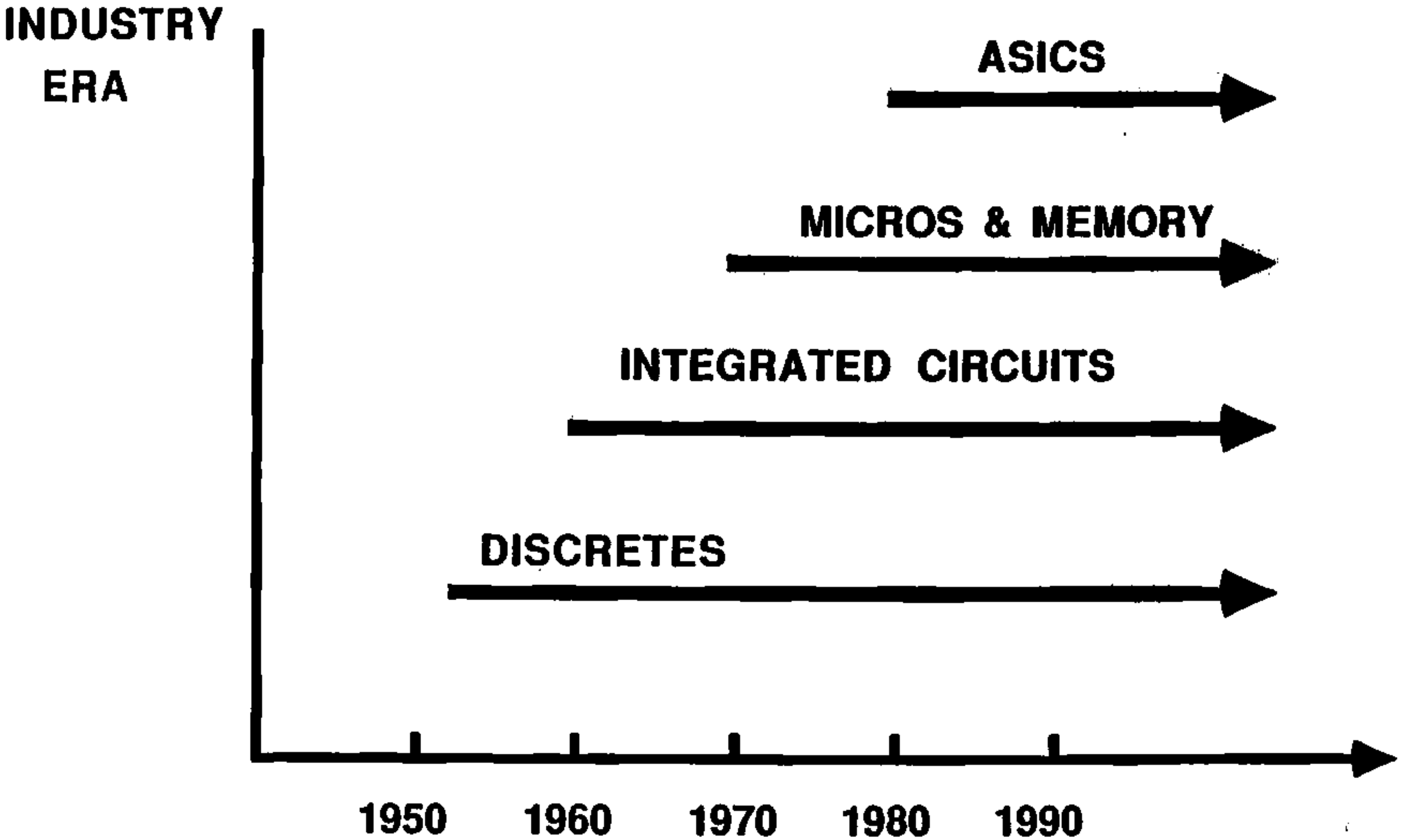
SEMICONDUCTOR INDUSTRY EVOLUTION



INDUSTRY COOPERATION - 1950s AND 1960s

- O AT&T LICENSES TRANSISTOR PATENTS - 1949

  MOTOROLA, TI, ETC.

- O SUPPLIERS COMPETE FIERCELY
- O SECOND SOURCING ABSENT
- O LICENSING TO JAPAN

  FAIRCHILD - NEC

  TI - SONY

INDUSTRY COOPERATION - 1970s

- O CUSTOMERS DEMAND ALTERNATE SOURCES
- O MARKET STANDARDS DEVELOPMENT
- O EUROPEANS ACQUIRE AND INVEST IN US
- O EXAMPLES

  MOTOROLA - SIGNETICS (MARKET STANDARD)

  PHILIPS - SIGNETICS (ACQUISITION)

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CHANGING INDUSTRY CONDITIONS - 1980s

- O INCREASING CAPITAL REQUIREMENTS
- O SHIFTING INDUSTRY LEADERSHIP
- O DECREASING LIFE CYCLES
- O INCREASING IMPORTANCE OF DESIGN AUTOMATION

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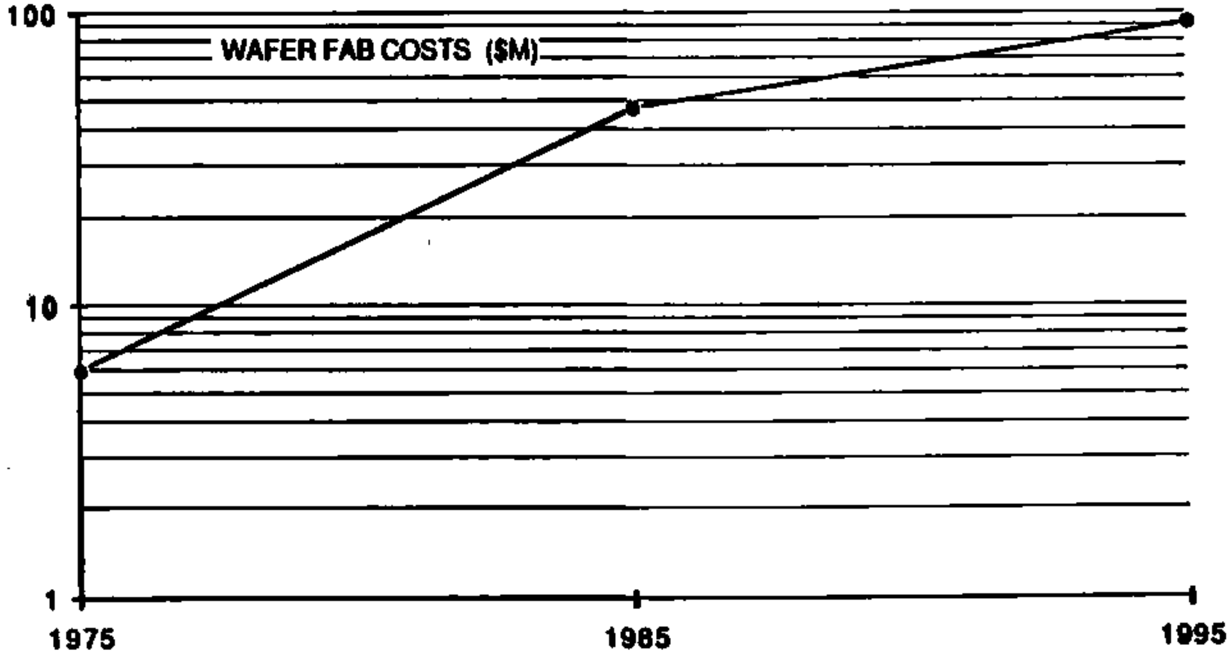
INCREASING CAPITAL REQUIREMENTS



Source: Dataquest

SHIFTING REVENUE LEADERSHIP

1955	1965	1975	1985
HUGHES	TI	TI	NEC
TRANSITRON	MOTOROLA	FAIRCHILD	MOTOROLA
PHILCO	FAIRCHILD	NATIONAL	TI
SYLVANIA	GI	MOTOROLA	HITACHI
TI	GE	SIGNETICS	TOSHIBA

SOURCE:: DATAQUEST (2/29/80, 1984), IEEE SPECTRUM (6/76), ICE CORP

SHIFTING REVENUE LEADERSHIP

1985	1986
NEC	NEC
MOTOROLA	HITACHI
TI	TOSHIBA
HITACHI	MOTOROLA
TOSHIBA	TI

SOURCE:: DATAQUEST

DECREASING PRODUCT LIFE CYCLES

LOGIC FAMILIES	MICRO FAMILIES	ASIC LIBRARY FAMILIES
5.6 YEARS	4 YEARS	1.3 YEARS
1965 54/74	1970 4004	1983 Cell Compilers (3u HMOS)
1971 54/74S	1974 8080	1984 Standard cells (3u HMOS)
1980 54/74AS	1975 8085	1986 VSC10 cell-based (2u CMOS)
1982 54/74F	1978 8086	1987 VSC100 cell-based (1.5u CMOS)
	1982 80286	
	1986 80386	

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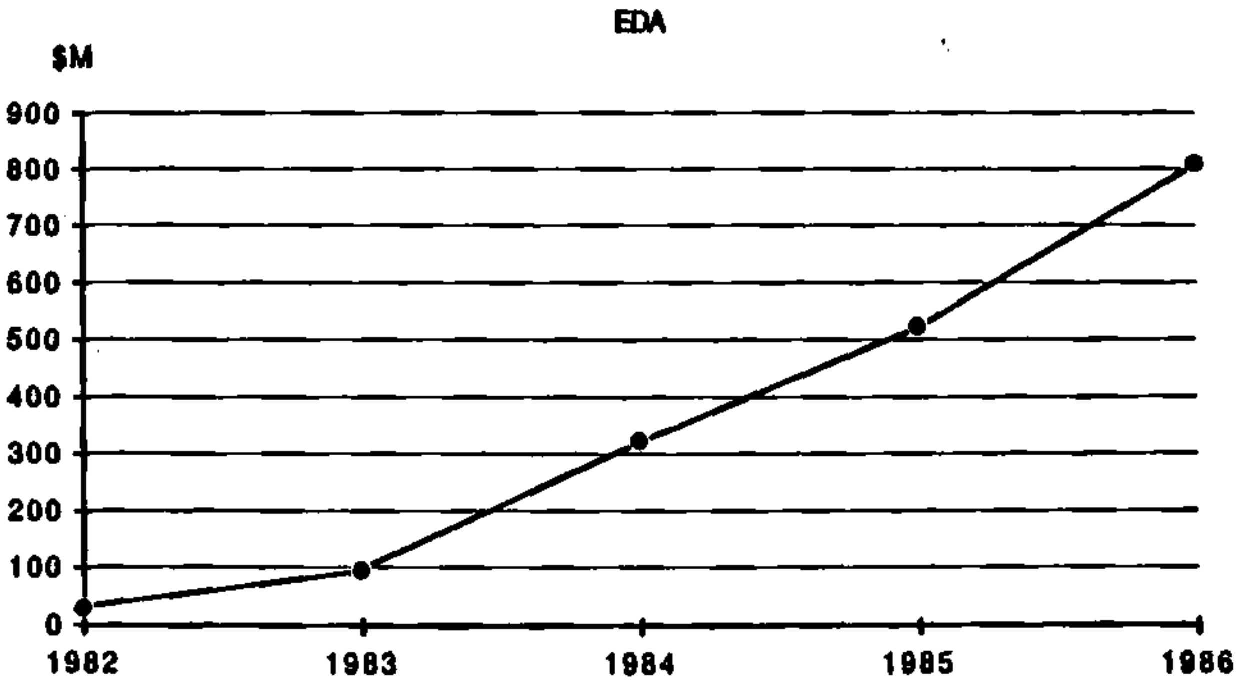
INCREASING DESIGN AUTOMATION



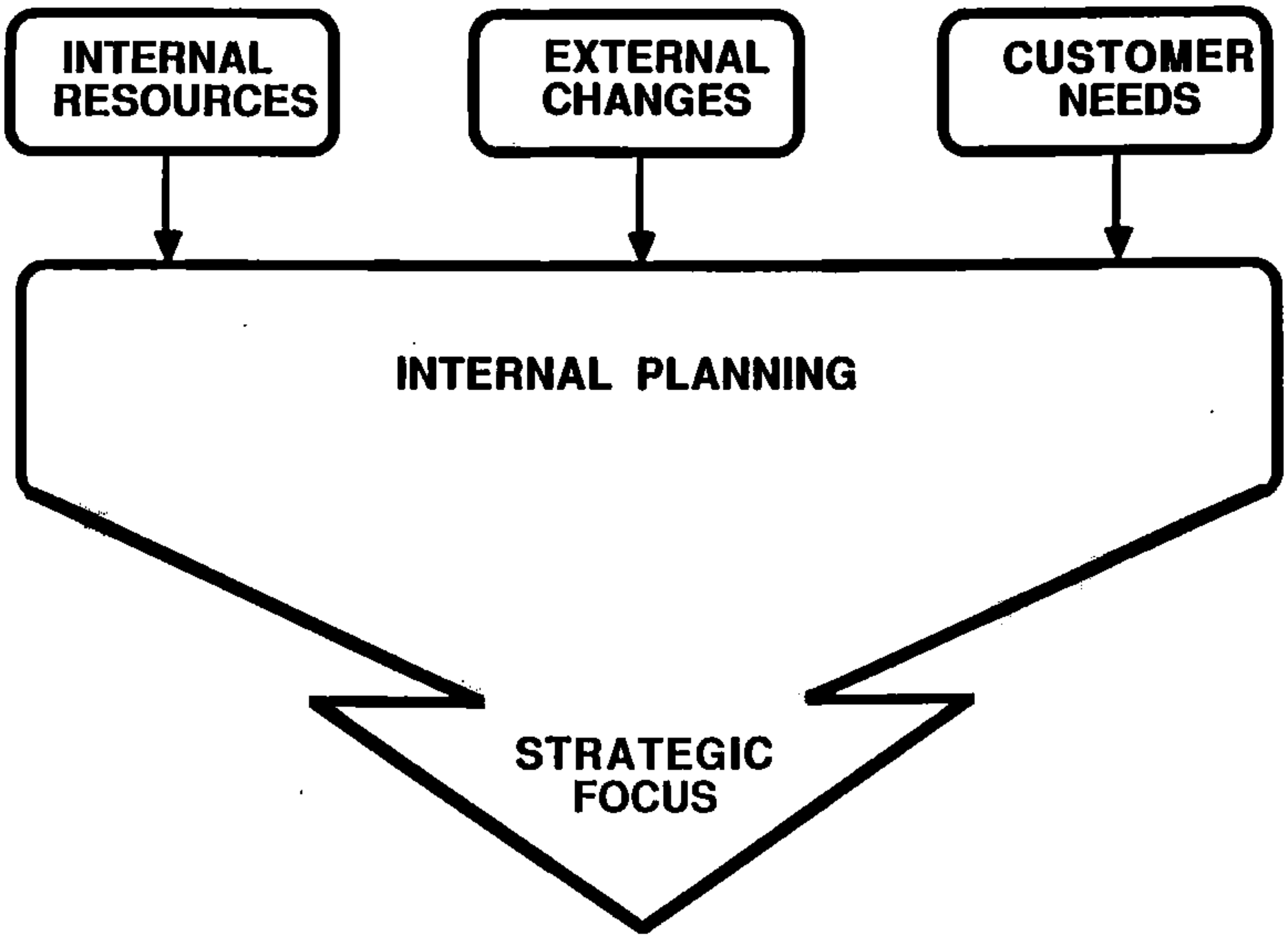
Source: Technology Research Group

INDUSTRY COOPERATION - 1980s & 1990s

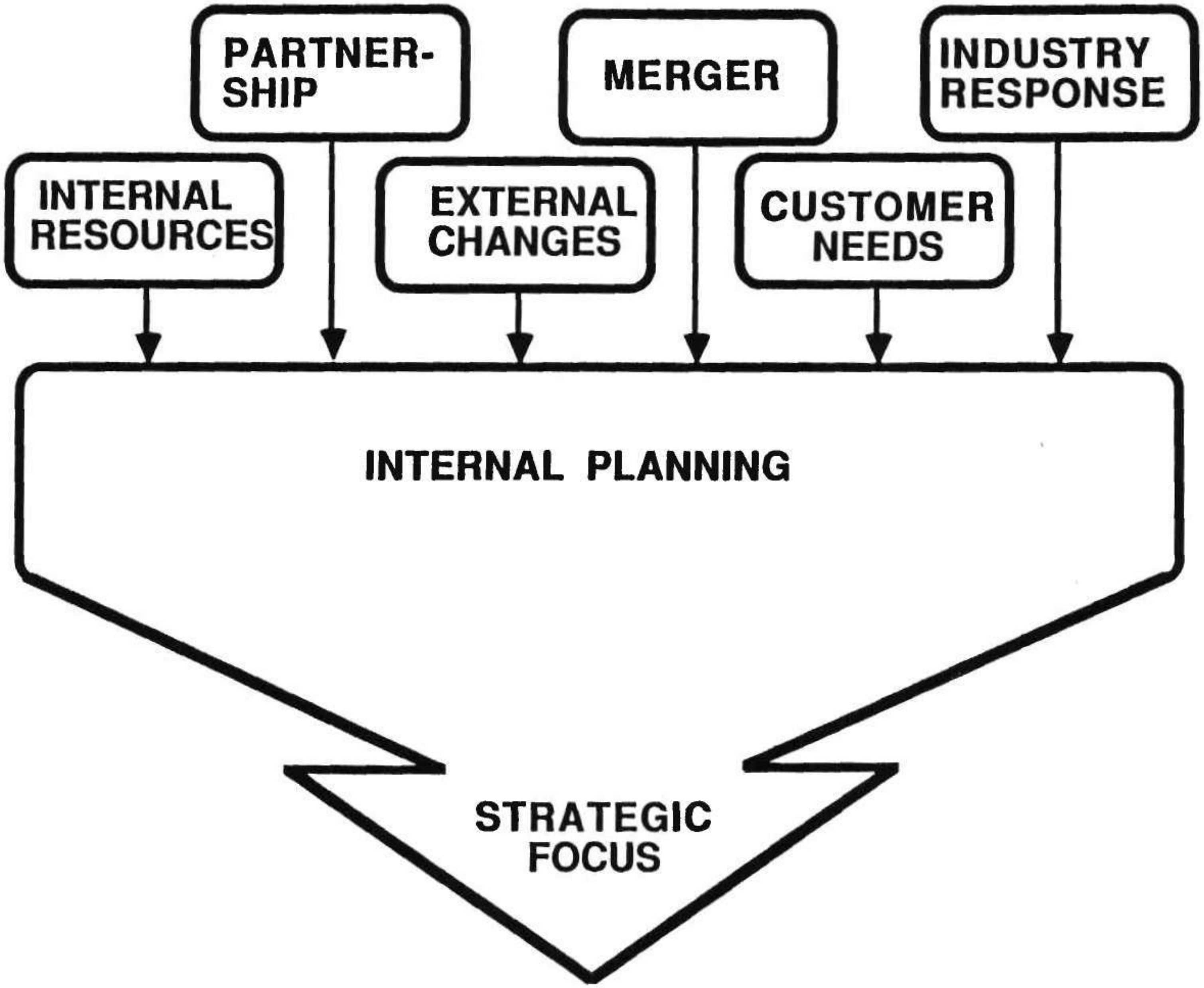
- O PREVIOUS RELATIONSHIP FORMS CONTINUE
- O NYU STUDY: STRONG RISE IN AGREEMENTS IN 1981
- O US FIRMS LICENSE FROM JAPAN
- O NEW EMPHASIS ON LONG TERM R&D RELATIONSHIPS

VLSI - ROCKWELL	(ASIC SOFTWARE)
LSI LOGIC - TOSHIBA	(GATE ARRAYS)
PHILIPS - SIEMENS	(MEMORY PROCESS)

YESTERDAY'S STRATEGIC RESPONSE



TODAY'S STRATEGIC RESPONSE



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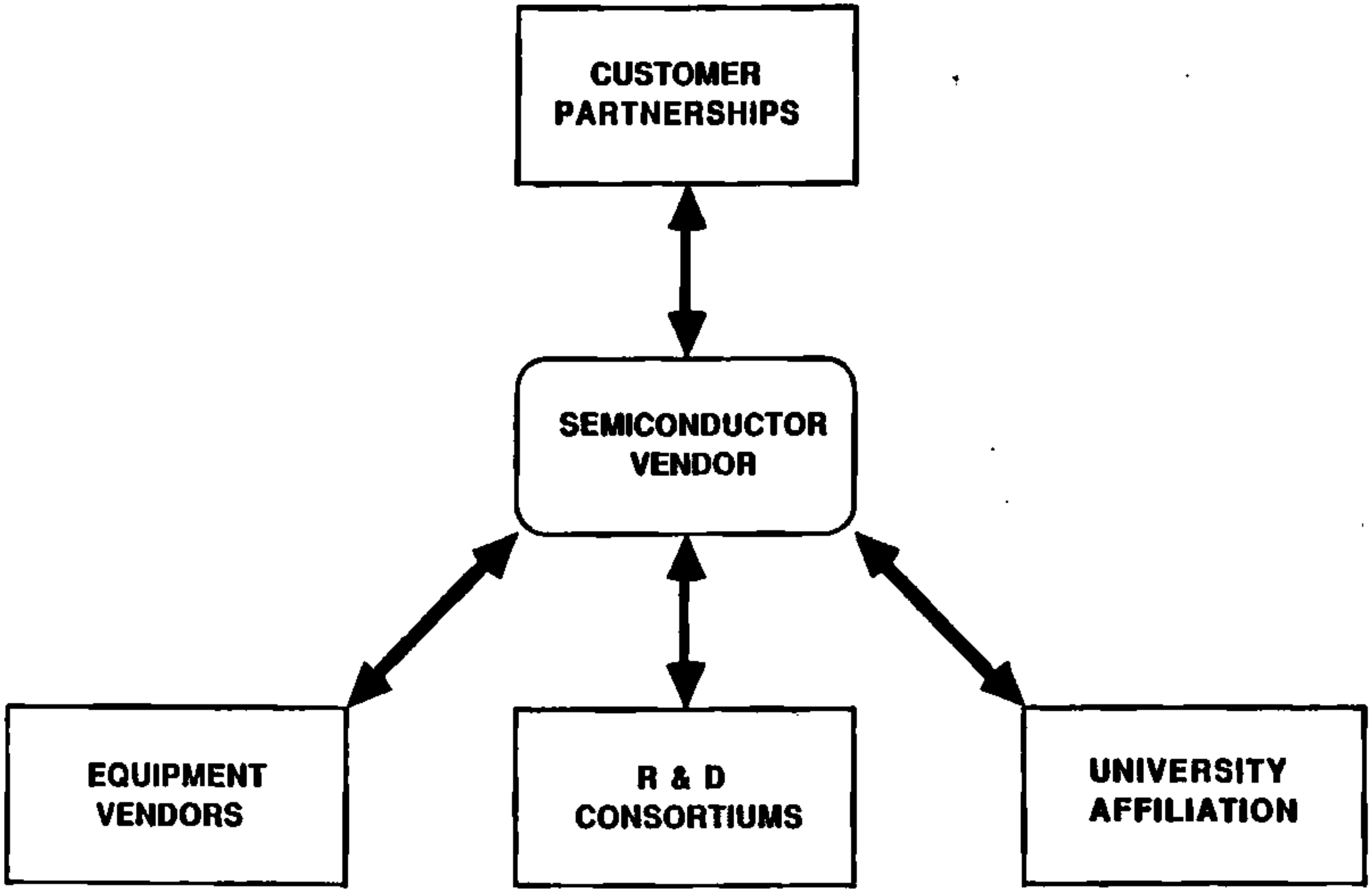
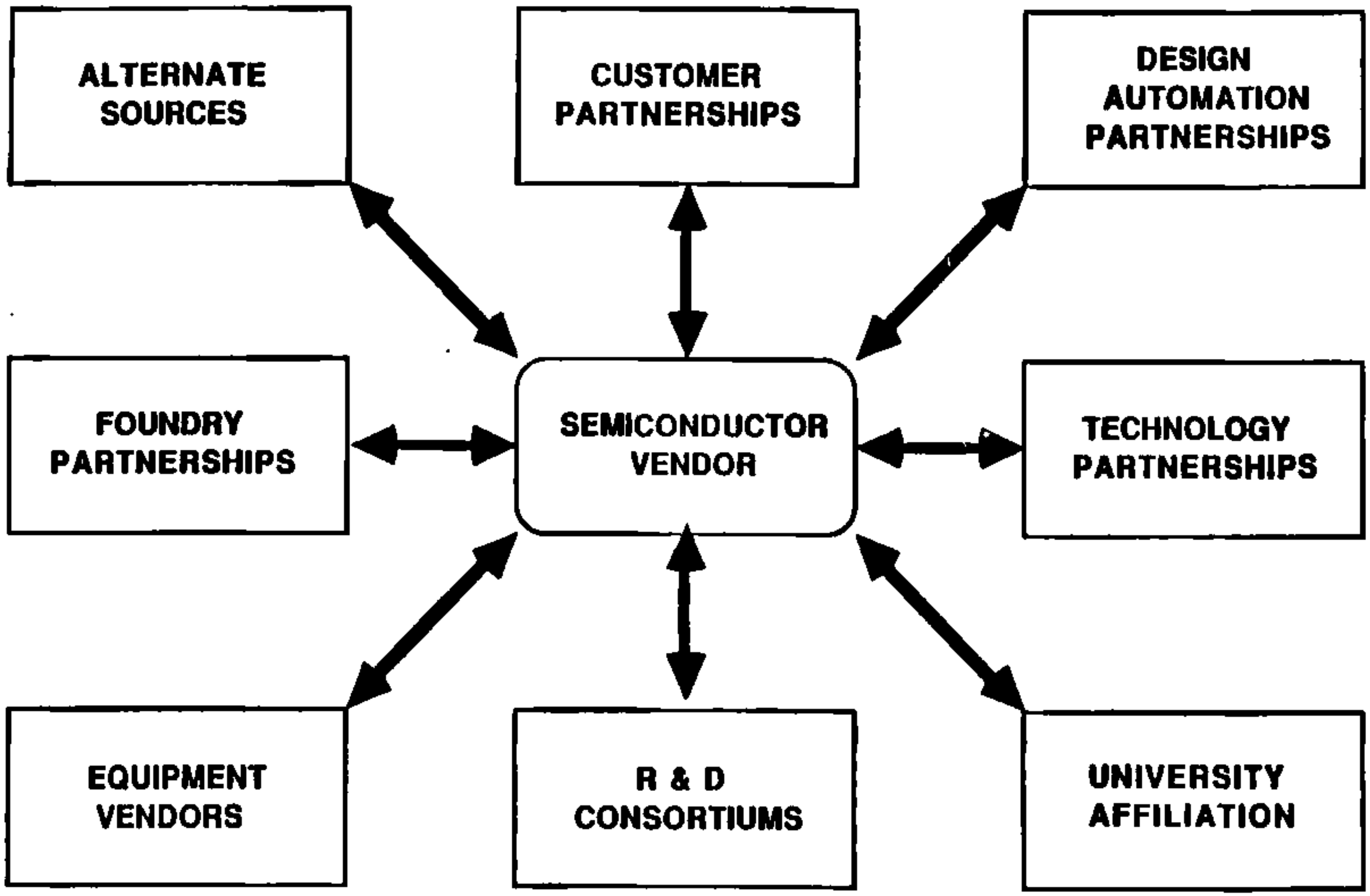
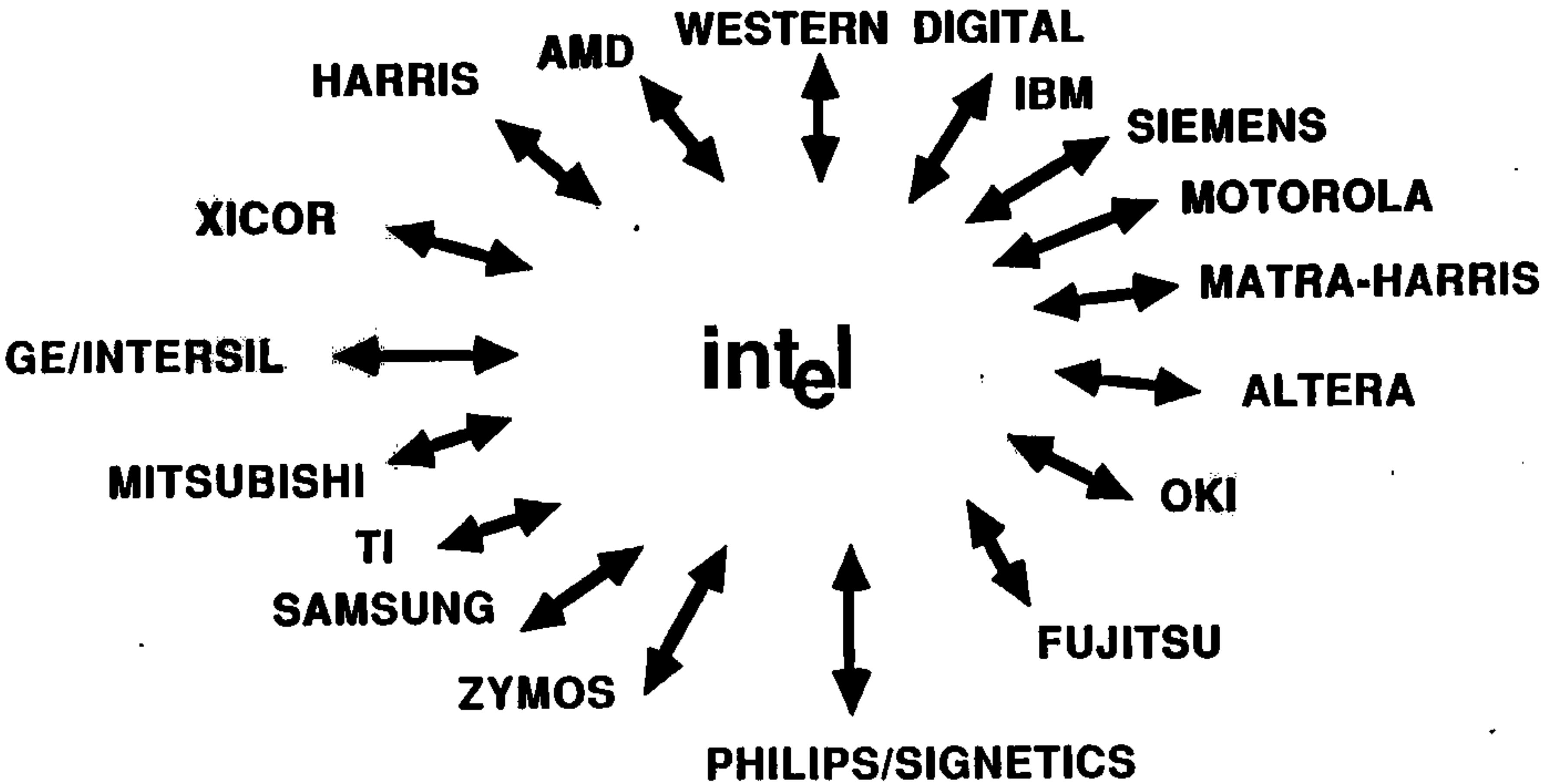
YESTERDAY'S STRATEGIC PARTNERSHIP SPECTRUM



TODAY'S STRATEGIC PARTNERSHIP SPECTRUM

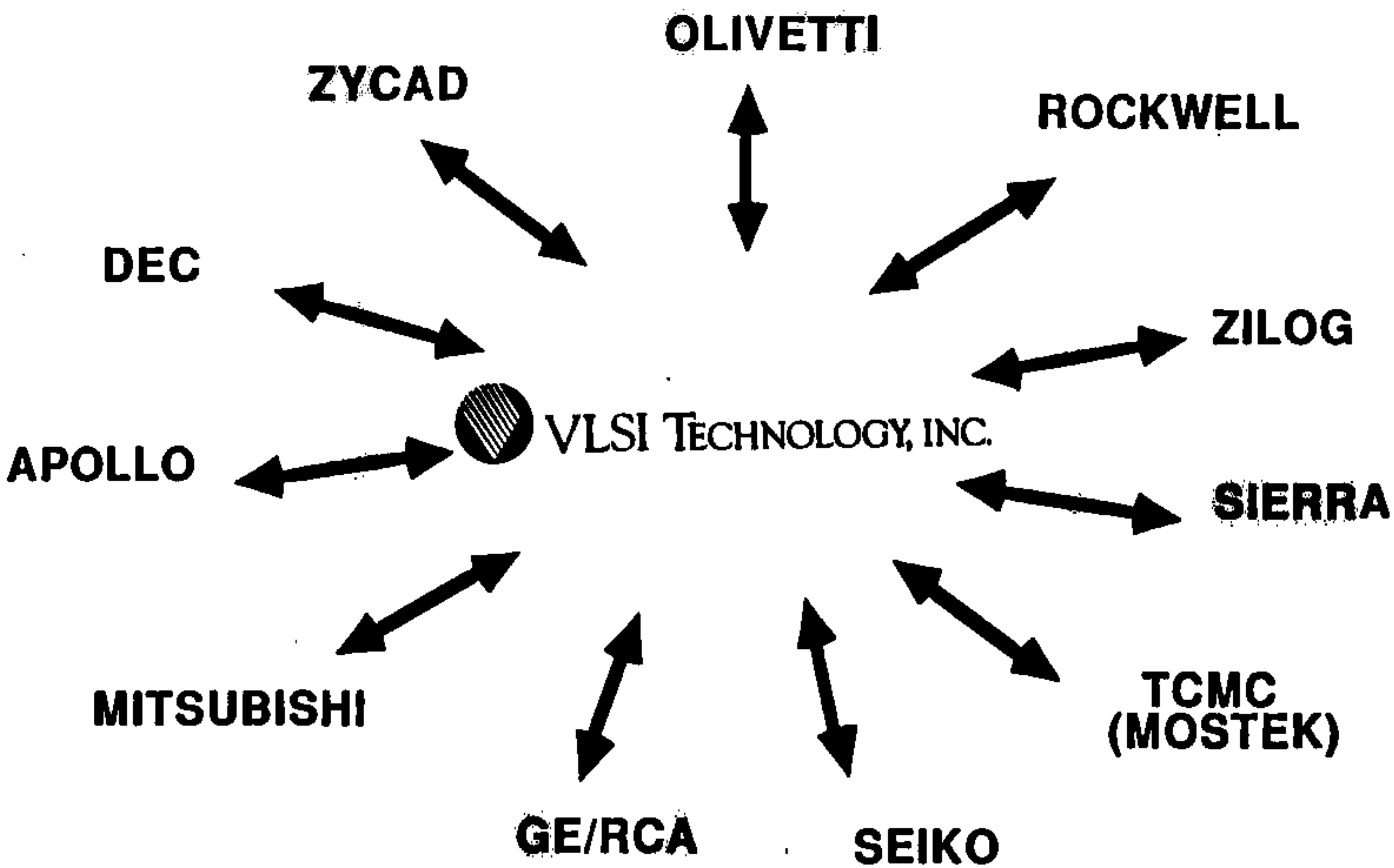


INTEL'S PARTNERSHIPS



Source: Dataquest

VLSI'S PARTNERSHIPS



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TECHNOLOGY PARTNERSHIP SUCCESS FACTORS

- O MUTUAL BENEFIT THROUGHOUT PARTNERSHIP LIFE
- O COMPLEMENTARY MARKET GOALS
- O COMMON PROCESS ROADMAP
- O GOOD WORKING RELATIONSHIP AT ALL LEVELS
- O ACTIVE MANAGEMENT

A SUCCESSFULL PARTNERSHIP: VLSI & ROCKWELL

- O COMMON NEED FOR DESIGN TECHNOLOGY
- O COMPLEMENTARY APPLICATIONS (INTERNAL/EXTERNAL)
- O JOINT PROCESS ROADMAP
- O QUARTERLY MANAGEMENT REVIEWS
- O SUCCESSFUL LIBRARY AND COMPILER DEVELOPMENT

THE FUTURE OF PARTNERSHIPS

- CONTINUE TO PROLIFERATE
- INTERNATIONAL IN SCOPE
- BIASED TOWARD ASIC

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THE FUTURE OF ASIC PARTNERSHIPS

- DEFINE LIBRARY STANDARDS
- SHARE TECHNOLOGY DEVELOPMENT
- ALTERNATE SOURCING WILL INCREASE
- RICHER DESIGN ENVIRONMENT FOR THE ASIC DESIGNER

THE MOST IMPORTANT PARTNERSHIP

- VENDOR AND CUSTOMER

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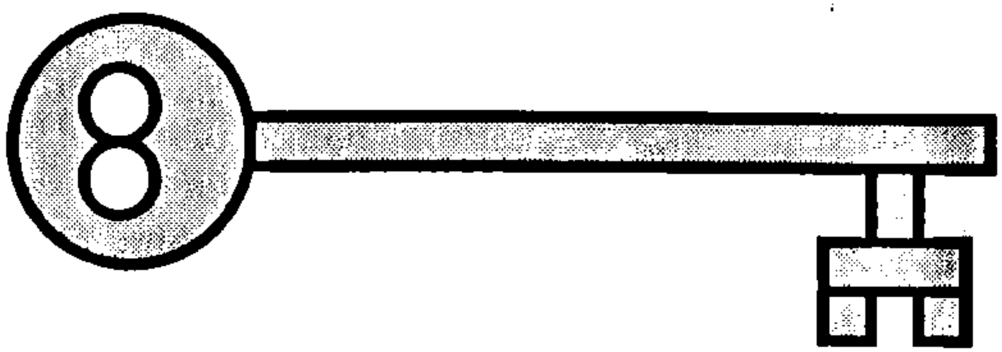
SEMICONDUCTOR PARTNERSHIPS:



KEY TO SUCCESS

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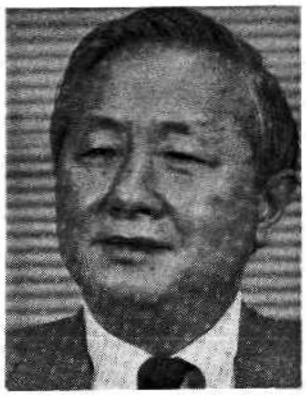
ROLE OF SILICON FOUNDRY IN THE FUTURE SEMICONDUCTOR INDUSTRY



Morris Chang
President
Industrial Technology Research
Institute (ITRI)

Dr. Chang is President of the Industrial Technology Research Institute in Taiwan and oversees its five major divisions. Prior to joining ITRI, Dr. Chang held positions as President and Chief Operating Officer of General Instrument Corporation, Senior Vice President of Texas Instruments, and Senior Engineer and Engineering Manager in the Semiconductor Division of Sylvania Electric Products. While at Texas Instruments, Dr. Chang was responsible for making the TI Series 74 TTL a standard and established the company as a leader in MOS memories. Low-cost calculators and digital watches became a reality under his leadership. Dr. Chang attended Harvard University before transferring to Massachusetts Institute of Technology, where he obtained B.S. and M.S. degrees in Mechanical Engineering. He later received a Ph.D. in Electrical Engineering from Stanford University.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

International Perspectives

DR. MORRIS CHANG

President
Industrial Technology Research Institute (ITRI)
Chairman of the Board
Taiwan Semiconductor Manufacturing Company

ROLE OF SILICON FOUNDRY IN THE FUTURE SEMICONDUCTOR INDUSTRY

Ladies and Gentlemen, today I want to talk about an idea whose time has come and a place whose time has come. The idea is a semiconductor manufacturing company. It will perform manufacturing services for customers, it will do silicon wafer processing, packaging, and testing. It will not do any design. It will not do any marketing except, of course, to customers who want these manufacturing services. It will not compete with the semiconductor companies. It will collaborate with them. The place whose time has come is Taiwan. In conventional wisdom it's one of the four tigers on the Asia Pacific Rim. In actual fact, I think it's one of only two tigers. In 1985 and 1986, when all the world's semiconductor industries were sweating blood, the Taiwan IC market grew by 40% each year and I think you have seen Gene Norrett's estimates yesterday; at least in the foreseeable future, for the next five years or so, we expect the growth to continue at an average of about 30% per year.

The idea and the place have met. The result is the Taiwan Semiconductor Manufacturing Company, and I will talk more specifically about that company later. But first, let's review the reasons why the time of the pure semiconductor manufacturing company has come: first, the capital cost of wafer fab and the ongoing R&D cost of a processing development. Several speakers have already referred to that in the last day and a half. A modern minimum size fab costs more than $75 million. An economic size wafer fab costs two or three times that. In addition, it costs tens of millions of dollars per year to keep up with a process development. That magnitude of investment is certainly beyond the means of startups. It is even beyond the means of some established smaller companies. Where do they go? They have to team up with foundries. Now that problem is not limited to just startups or small companies. Large companies, of course, have enough financial resources, but the risk of large investment has also caused them to increasingly seek manufacturing partners. In fact, some of the companies in the very large class already have a policy of using outside wafer fabs for a certain percentage of their own production. Second, the growth of ASICs has fostered the growth of IC design activities in traditional users of ICs, such as computer companies and systems companies. With the exception of IBM and AT&T, few of those companies have the need or the inclination to invest in wafer fabs. Yet those companies can and want to benefit from their own ASICs. They then become natural customers for the semiconductor manufacturing company.

You may comment, while the points I have made are valid, that there are many IC companies that provide foundry services. Indeed there are. But to the best of my knowledge, the Taiwan Semiconductor Manufacturing Company (TSMC) is the first pure manufacturing company. It is a fundamental part of the company charter that it remain a pure manufacturing company. Doing business with TSMC is simple: we charge a price for the manufacturing services that a customer wants us to perform. We want no product rights. We want no second sourcing. And since we have no products of our own, the customer need not fear that our own products will have a priority claim on our capacity. Nor does he need to fear that we may come out later with a similar product to compete with him in the marketplace.

Now, let's talk about Taiwan. For TSMC to succeed, it must have good yields. What will give us good yields? The audience does not lack wafer fab experts. I will not insult your intelligence by going into any detail on what would give us good yields. But let me just summarize the important points in my view that will give us good yields. First, a skilled and stable work force. Here, I am thinking primarily of direct labor. I believe that perhaps a minimum degree of education is required for the direct labor force: perhaps high school education or higher. When I say stable, I mean low turnover rate. Second factor: quality of manufacturing supervisors. Third factor: quality of repair and maintenance technicians. Dr. Osafune, I believe, mentioned that very prominently yesterday in his talk. Fourth factor: team work between the manufacturing supervisor and the process engineers and the technicians and direct labor. Fifth: solid process engineering. And last but not least, good management, which provides motivation and leadership. How does Taiwan fit into the picture of these criterion? As an aside, one of the great assets of Taiwan, I believe, is its education system. Of 450,000 people in college or equivalent level of educational institutes, half of them are technical. Taiwan graduates about 4,000 electrical engineers per year, which is a factor of 5 less than what the United States graduates per year. Taiwan graduates about one-fifth of the electrical engineers with a population that's one-eleventh of the size of the United States. On a per capita basis, you might say that Taiwan graduates 2-1/2 times more electrical engineers per capita than the United States.

Direct labor force - it is still relatively easy to insist on a high school minimum education on the direct labor force in Taiwan. In fact, a fairly significant percentage of the direct labor force has college degrees.

Manufacturing supervisors - it is still relatively easy to recruit engineers. For years I thought it was a major problem in the United States not to be able to get good quality manufacturing supervisors. In Taiwan, it is still relatively easy not only to get manufacturing supervisors with technical college degrees, but even with electrical engineering technical college degrees.

Rapair and maintenance technicians and process technicians - Taiwan has three types of trade schools: a three year trade school, which starts at high school graduation (equivalent to three years of college); a four year trade school which starts again at high school graduation (equivalent to a full four years of college except its training and curriculum is more specialized, tailored toward a trade); and a five year program, which starts at the end of the sophomore year in high school (equivalent, again, to a three year college education). The reason there are these three kinds of trade schools is because not everyone at all can get into the college in Taiwan and those people who fail to get into college then, of course, do the next best, which is to enter a trade school. And the companies in Taiwan normally draw their technicians from these trade schools and the supply is expected to remain good.

Work ethic - dedication to job at hand - I believe those qualities are in abundance in the people in Taiwan. And notice I did not mention wage level. Of course, that's a very important factor in cost but that is no longer a dominant consideration. Of course, in wafer fabs, yields are always more important than pure wage levels, anyway. But looking at the wage level, it still gives Taiwan an advantage. For the new graduates, it's a factor of 3 to 1 compared to the United States. For the good engineers with about 10 or 15 years' experience the gap between the U.S. scale and the Taiwan scale is about a factor of 1.5 to 2. So it's still an advantage.

Summarizing what I've just said about Taiwan, I think necessary conditions exist to enable a semiconductor manufacturing company in Taiwan to achieve as high a yield as anywhere else in the world and this is not just theory. In fact, in the fabs that have operated in Taiwan for several years now, the yields that have been achieve, I believe, are as high as any achieved in the world on a like product.

Two years ago, when I first assumed the presidency of the Industrial Technology Research Institute in Taiwan, I was asked to propose a strategy to stimulate the semiconductor industry in Taiwan, both the manufacturing and the yields and also the design activities. At that time, no state of art processing capability existed but the market was growing rapidly. There were a number of local design groups. Some were independent companies and some were groups of parent system companies. And those design groups, by and large, went to Japan or Korea for foundry services. My recommendation was to create a modern semiconductor manufacturing capability, yet I felt it was foolhardy to compete head on with U.S. and Japanese giants. Thus, the idea of a pure manufacturing company was born and TSMC was born. TSMC was capitalized at $188 million. The government has 48%, Philips has 27% and other investors have 25%. Initially we expect to operate with a conservative 70% equity, 30% loan financial structure. Thus, with $188 million of equity capital, we have a total financial resource of around $250 million. Philips plays three roles in TSMC. It is a major investor, it is a technology partner, and we expect it to be an important customer.

TSMC has been in operation half a year now; it has 250 employees at present; we have recruited a top management team that's predominately American. Jim Dykes, formerly the GE semiconductor general manager, is the president and CEO of TSMC. Klaus Wiemer, formerly of Texas Instruments and the Thomas Consulting Group, is the vice president of operations of TSMC. Steve Pletcher, who is in the audience now, formerly of RCA and GE, is the vice president of marketing and sales in the United States and Europe.

When we launched TSMC, we felt that by introducing state-of-the-art manufacturing capability in Taiwan, we would automatically stimulate IC design activities and IC users in Taiwan. What happened has exceeded our fondest expectations. More than 15 design companies have been started in Taiwan in just the last year. The Taipei/Hsinchu axis (Hsinchu is where TSMC is located) is beginning to look like the Silicon Valley.

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THE STATUS OF SEMICONDUCTOR TECHNOLOGY AND THE ASIC MARKET IN KOREA

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Senior Managing Director
R&D and Business Development Group
GoldStar Company, Ltd.

Dr. Min is Senior Managing Director of the R&D and Business Development Group, Computer and Communications Sector, at GoldStar Company Ltd. Previously, he was Senior Managing Director for Communications Systems, Semiconductors, and Computer Systems at GoldStar Semiconductor, Ltd. Before that, he was Executive Director of Information and Communication Systems at GoldStar Tele-Electric Co. Before joining GoldStar, Dr. Min was Program Manager, Office Systems Products, at Xerox Corporation and Senior Manager of the Service Support System at IBM Corporation. He has also worked as a Researcher for the Information System Lab and Remote Sensing Lab at Purdue University and as an Engineering Manager at Tong Young Electric Company of Korea. Dr. Min holds a B.S.E.E. degree from Yonsei University of Korea and an M.S.E.E. degree and a Ph.D. in Computer Science from Purdue University. He received five IBM Contribution Awards, is the author of numerous technical publications, and has taught Computer Science and Engineering at IBM and at various universities.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

International Perspectives

DR. P. JUNE MIN

Senior Managing Director
R&D and Business Development Group
GoldStar Semiconductor, Ltd.

THE STATUS OF SEMICONDUCTOR INDUSTRY & ASIC MARKET IN KOREA

OCT. 1987

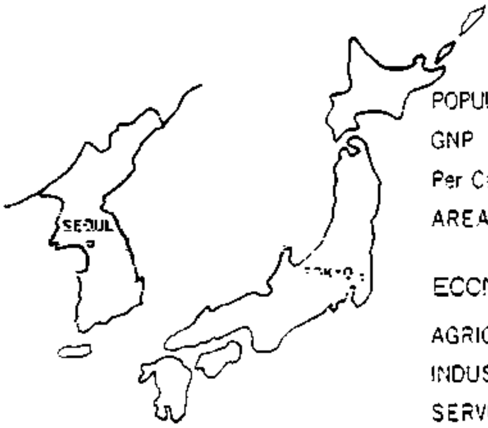
P. JUNE MIN

GoldStar Semiconductor Ltd.
SEOUL, KOREA

PRESENTATION OUTLINE

- INTRODUCTION
- INDUSTRY ANALYSIS & FORECAST
- TECHNOLOGY STATUS
- CAPITAL INVESTMENT
- ASIC MARKET & TREND

KOREA(SOUTH): THE DEMOGRAPHY IN 1986

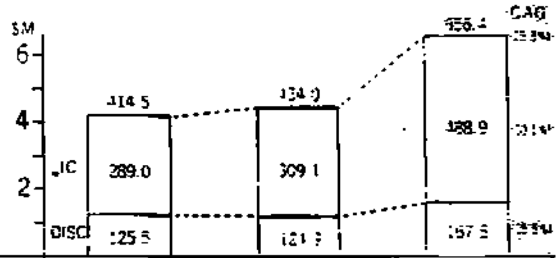


POPULATION	41,569,000
GNP ($B)	95.3
Per Capita GNP ($)	2,296
AREA (miles²)	38,200

ECONOMY STRUCTURE

AGRICULTURE	14.3%
INDUSTRIAL	30.6%
SERVICE	55.1%

MARKET TREND & DISTRIBUTIONS



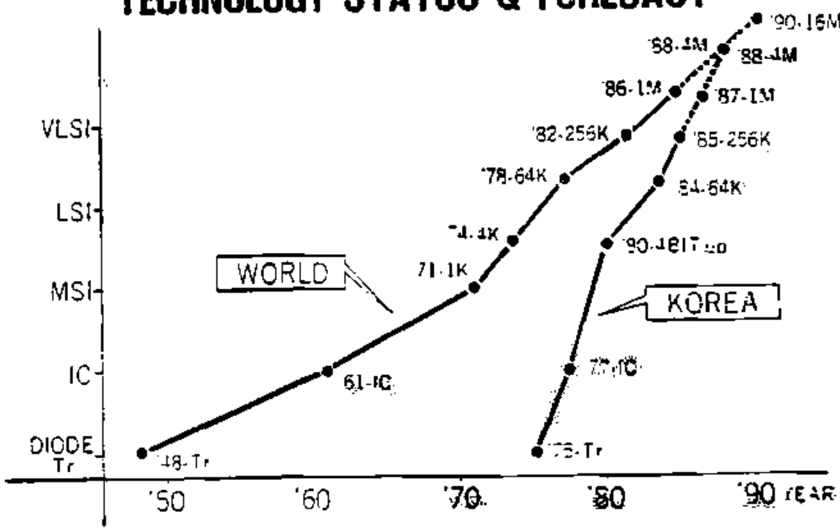
	'84	'85	'86
MOS IC	34.5%	33.5%	38.8%
BIPOLAR IC	23.7	27.8	26.7
HYBRID IC	11.5	9.9	9.0
DISCRETE	30.3	28.8	25.5

MAJOR PLAYERS & BUSINESS ARRANGEMENT

GSS –	AT & T	AMD	LSI LOGIC	
	ZILOG	BRI	FAIRCHILD	
SST –	SHARP	INTEL	MICRON TECH.	ITT DITT
	UNISYS	ZYTREX	IXYS CO.	MTA
HEI –	TI	INMOS	ICT	MOS ELEC.
	VITELIC	ALTO CORP(J)		
KEC –	TOSHIBA			
DWT –	ZYMOS			
ANAM –	VTI			

(1983~1987. 6)

TECHNOLOGY STATUS & FORECAST



TRANSACTION ANALYSIS

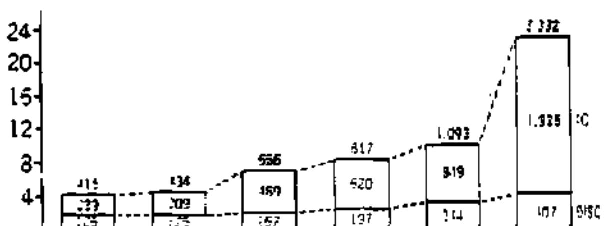
PRODUCTION + IMPORT = DOMESTIC + EXPORT

($M)

	PRODUCTION	IMPORT	TOTAL	DOMESTIC	EXPORT
1984	1,268	337	1,605	415	1,190
1985	1,155	341	1,496	434	1,062
1986	1,473	542	2,015	656	1,359

MARKET TREND & FORECAST

(Unit $M)



COMPOSITION	'84	'85	'86	'87	'88	'91
MOS IC	34.5%	33.5%	38.8%	40.6%	43.0%	49.8%
BIPOLAR IC	23.7	27.8	26.7	25.4	26.0	24.7
HYBRID IC	11.5	9.9	9.0	8.8	8.5	8.0
DISCRETE	30.3	29.3	25.5	24.2	22.1	[illegible]
CAG	25.8%			29.?%		

TECHNOLOGY STATUS

RAW MATERIAL
- SI/POLY SI GROWING
- SIZE: 3~5 INCHES
- PARTICIPATING COMPANIES
  - KORSIL: J/V WITH MONSANTO
  - LAMI : T/A WITH SILTEC

DESIGN
- POOR CELL LIBRARY AND CAD TOOLS
- SEMI-CUSTOM VLSI DESIGN (T/A)
- 1.5 MICRON TECHNOLOGY (64K & 256K DRAM)
- 1M DRAM

TECHNOLOGY STATUS

MASK MAKING
- AUTOMATIC PATTERN GENERATION
- NO CAPABILITY FOR SUB-MICRON

WAFER PROCESSING
- 1.2~1.3 MICRON PROCESSING TECHNOLOGY
- DRY ETCHING TECHNOLOGY
- THIN FILM TECHNOLOGY
- DEFUSION TECHNOLOGY

TECHNOLOGY STATUS

ASSEMBLY

- UP TO 1 BILLION IC/YEAR

TEST & QA

- BIT MAP ANALYZER & SOFTWARE FROM USA.

PRODUCT TECHNOLOGY

- MEMORY : 1.25 MICRON 1M ROM, 1M DRAM
- MICRO PROCESSOR : 16/32 BIT PROCESS TECHNOLOGY
- LOGIC : HCMOS
- LINEAR IC : VTR VLSI, TV IC

CAPITAL INVESTMENT

(UNIT $M [illegible])

	PRIOR '82	'83	'84	'85	'86	'87~'90	CAG '83~'95
FACILITIES	45.5	72.0	332.0	378.9	242.6	987.3	51.7
R & D	4.4	9.1	26.8	82.9	63.1	220.8	93.2
TOTAL	49.9	81.1	358.8	461.8	305.7	1,208.1	57.5
CUMULATIVE	49.9	131.0	489.8	951.6	1,257.3	2,465.4	

JOINT PROJECT PLAN(KSRC)-4M DRAM

($M)

STAGE	TARGET	INVESTMENT
1st YEAR ('86/06-'87/05)	- 1 MICRON 4M DRAM DESIGN - 0.8 MICRON UNIT PROCESS	45.4
2nd YEAR ('87/06-'88/05)	- WORKING SAMPLE (FUNCTIONAL CHIP) - COMPLETE 0.8 MICRON 4M DRAM DESIGN	37.1
3rd YEAR ('88/06-'89/05)	- MATURED PRODUCT - MASS PRODUCTION	[illegible]
TOTAL		100.2

ASIC MARKET IN KOREA

CHARACTERISTICS

- COMPUTERS : ONLY PERSONAL COMPUTERS ARE MANUFACTURED
- COMMUNICATIONS: DOMESTIC MARKET IS RELATIVELY SMALL
- OFFICE AUTOMATION PRODUCTS & OTHERS : NOT MANY PRODUCTS ARE EXPORTED

ASIC MARKET FORECAST

UNIT: $M, %

	'88	'89	'90	CAG
COMPUTERS	90.9	138.4	182.3	43
COMMUNICATIONS	12.7	39.4	77.1	146
OA & OTHERS	8.7	21.8	54.4	150
TOTAL	112.3	199.6	313.8	

PARTCIPANTS

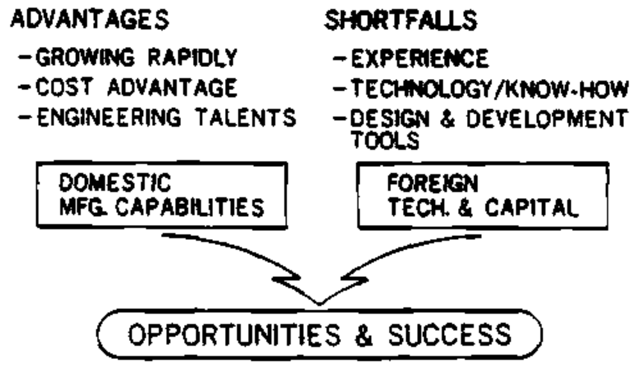
CURRENT

GSS	-GATE ARRAY & STANDAND CELL
SST	-GATE ARRAY
LSI LOGIC	-GATE ARRAY
VTI/ANAM	-STANDARD CELL & MEGACELL
SCS/KOREA SILICON	- GENESIL)
MOTOROLA	-MACROCELL & STANDARD CELL

PLAN

FAIRCHILD	TOSHIBA
NATIONAL SEMICONDUCTOR	SANYO
SGS (ITALY)	HITACHI
TI	NEC

SUMMARY-KOREAN ASIC MARKET



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DR. SHELDON WEINIG
Dinner Speaker, October 20, 1987

As many of you are probably aware, Secretary of Defense Weinberger was originally scheduled to give this speech. But the Secretary had to cancel at the last minute because of a highly sensitive, secret mission to the Middle East. I was suspicious, so I called Bob Woodward, the author of Veil, who knows all Washington's secrets, to get the real story.

He confirmed that Cap Weinberger was truly in the Middle East where the Ayatollah agreed to make Iranian speed boats available to take Cap and some of his staff on a water skiing tour of the Persian Gulf offshore oil platforms.

Cap said that if we were really hard up for a speaker, he would arrange to have Senator Joe Biden read his remarks--but without attribution. However, even in absentia, Secretary Weinberger is a very gracious man with a high regard for our industry and he sent me a letter to read to you this evening.

"Dear Shelly:

Regards from the Straits of Hormuz. The weather is good and there is a large unemployed population in the area, but I do not wish to recommend that any semiconductor company consider opening an offshore facility here.

As you know, we use a lot of electronics at the Pentagon and I have become a reasonable expert on semiconductors. While Dataquest was obviously unable to find a substitute speaker who could match my breadth and expertise in electronics, I see they have remained true to the program and produced a bonafide authority on midlife crisis.

I want to congratulate your industry on an uncanny ability to survive four decades of steadfast government indifference. The U.S. semiconductor manufacturers are the only industry I know that stays alert by shooting itself in the foot. At the Pentagon we like to aim a little higher . . ."

I'm not certain whether that letter was written by Cap Weinberger. I suspect the hidden hand of a member of Senator Dukakis' staff.

Dataquest is not sad that Weinberger isn't here -- He costs $15,000 -- I cost nothing. After you hear me, you will realize you get what you pay for.

Anyway, here we are in the middle of the desert -- in Silicon Central -- to talk about semiconductors and midlife crisis.

Describing our industry in terms of midlife crisis may actually be an optimistic assessment — since it implies that there is more to come. It's like the fellow who said that growing old isn't that bad — when you consider the alternative.

But as a survivor of both corporate and individual midlife crisis, I think what really happens is this: after a period of robust growth and energy, we begin to sense our own mortality. Individually, we react in strange, unpredictable ways.

Men go out with women half their age. Women go out with men half their age. (It is the Universal Law of Physics that the sum of the ages in bed should remain constant). We take lessons and join awareness groups. We search our souls and re-read passages of books long put down.

The patterns are the same as industry. Some of our dreams have been shattered. Things are not the way they used to be — the future may not seem quite as exciting as the past. We've reached that stage in life where the only new thing we feel is a symptom. The transition from youth to maturity brings difficult challenges and new opportunities. How do we make the best of an uncertain future?

Many years ago I remember reading about a glamorous race car driver from Argentina named Juan Fangio who said that he risked his life on the track because he was enthralled by "the exhilaration of acceleration".

Anyone who has been involved with the semiconductor industry during the past forty years has had firsthand experience with the exhilaration of acceleration. Our industry has played a leading role in the most dramatic, exciting period of growth in world history. It was the age of the entrepreneur and they sang our tune. We wrote the book on venture capital and the entrepreneurial spirit. Many of us were millionaires up until yesterday.

In the forty years since Brattain, Bardeen and Shockley invented the transistor, this industry has revolutionized the way the world calculates, communicates and innovates. We can pause at midlife to reflect on the days of wide horizons and incredible growth. This industry has had a very exciting and productive adolescence.

It's fun to look back, but it's equally important to look ahead. As individuals we can turn midlife to our advantage by making it a time for renewal of mind and body, rather than standing by helplessly to watch them both decline.

As individuals, as corporations, as an industry, this is also the time to face reality, make the choices, and plan for the future. We can acknowledge and adapt to new circumstances (Charles Sporck elaborated fully this morning) or we can run the risk of becoming affable old fogies with stories to tell about the good old days.

Incidentally, the importance of confronting reality and attempting to predict future developments, both technically and commercially, is that it permits you to consider actions that will enhance the positive and suppress negative consequences.

For years we complained about the dollar being overvalued, especially in comparison with the yen. That was a valid complaint -- and we believed that it forced us to walk uphill in the quest for world markets. But during the past year there has been a major alignment of currencies and I assure you it is not temporary -- and it has had only a minimal impact on our competitiveness.

For years we complained about other countries violating international trade agreements and dumping chips in our market. In reality, unfair trade is one of the biggest growth industries in the United States. For example, since 1983, the U.S. has initiated more unfair trade actions that any country in the world. This has actually worked as a foreign business excess profits program, forcing some foreign companies to make more money than they anticipated. An example is the auto quota imposed on Japan where the number of Japanese cars imported into the U.S. were limited -- the Japanese added all the horns and whistle accessories and ended up with two times the profits they expected. Nostrums like trade agreements and currency realignments are not the salvation of the semiconductor industry.

A third thing we are seeing is the process of consolidation, or company marriages. This trend is inevitable if the semiconductor industry is to survive. We've seen G.E. and RCA; Fairchild and National; AMD and Monolothic -- and it is only the beginning. This trend will accelerate! Consolidation is not limited to semiconductor companies, for example, Hughes and G.M.

Hughes -- as a major defense contractor -- should bring a dowry of important technology to the marriage. G.M. should bring manufacturing efficiency to Hughes.

All of this sounds great in the abstract but G.M. doesn't operate in the abstract -- as Ross Perrot discovered. If I remember correctly, Ross Perrot found it easier to work his will in revolutionary Iran than to innovate in the structured corporate confines of G.M.

We will see if G.M./Hughes will prosper or whether it will be a futile attempt to force fit a missile guidance system into a Pontiac Fiero.

It's not enough to get <u>bigger</u> through consolidation. We've also got to get <u>better</u>. The Persian General Darius once said, "Know thine enemy and win a thousand battles." Japan may not be the enemy, but they are certainly our competitors, and we can learn a great deal from the way they do business.

I speak with some authority on this subject, because I was the first non-Japanese to receive a Japan development bank loan to build a factory in Japan in order to compete with Japanese companies on their home turf. At the time, many people thought I was crazy -- <u>a kind of King Canute from Orangeburg commanding the tide to turn</u>. But we've learned a lot in the process. For example, we can make equally <u>unreliable</u> machines in Japan as we do in the U.S. So in reality, we also taught them.

Looking to the future, one effect of currency realignment and trade prosecutions is that more Japanese companies will open manufacturing facilities in this country. They're already turning out hundreds of thousands of Mazdas, Toyotas and Hondas in America -- and we can expect precisely the same thing to happen in the electronics industry - Mitsubishi in North Carolina, Fujitsu in Oregon, Toshiba in Moscow, Idaho.

One reason the Japanese have been such effective competitors is the way they use their home markets to get in shape for the world series of international competition.

Countries like Korea and Taiwan really don't have that advantage -- their domestic markets simply aren't large enough to serve as a proving ground for world-class products. They are like the children in a "midlife crisis" family and must look for parental attention in the U.S. market.

Japanese companies battle for preeminence in their domestic market -- which is protected during this period. They get the bugs out, cut the costs, weed out the inefficient, and end up with a lean, state-of-the-art, finely tuned juggernaut ready to take on the world. Then they move over here with quality products and market-entry pricing and they kick the hell out of us.

By the way of contrast, our pattern has been to innovate and compete here in the world's richest, largest and most accessible market. Then, when we're finally in shape, when we're ready for any test ....we sit back and flick on our Japanese TV, open a Canadian ale and dream about owning a Porsche. An example is the American automobile industry which owned the world for decades. But did they go overseas? Did they aggressively pursue world markets? No. They became complacent and, as a result, Germany and Japan ate their lunch. Will a similar scenario evolve for the U.S. semiconductor industry? I don't think so. Consolidation will begin to cross international boundaries and we will have a role to play in the <u>globilization of industry</u>.

It will be discovered that the new technology produced by any one nation will be less than the totality of advances by the other nations.

The trend to consolidation can give the U.S. semiconductor industry the size, the resources, the economies of scale to compete in the world. But, ultimately, success in that competition will be determined by men and women of vision and courage who accept the need for change -- who refuse to sit back and play it safe waiting for Uncle in Washington to solve all of their problems.

If we want to turn Midlife Crisis into Midlife Opportunity, this industry must also be prepared to scrap some of the old mythology that still colors our decision making. For example, the conventional wisdom in America has been that investment in the defense establish will produce great technology. That's nonsense.

There have been spinoffs from NASA research, the $400,000 Pentagon grant, that funded E.N.I.A.C., the grand-daddy of computers of World War II. But I do not believe there is any evidence to suggest that force-feeding the Pentagon geese translates into a "pate" of great technology with commercial applications.

A study of NAE and NAS that will be published later this year found no surprises. The U.S. outspends all other countries:

- o Percentage of expenditures for defense R&D
- o Percentage of G.N.P. for defense R&D
- o Percentage of scientists and engineers engaged in defense R&D

This results in competition for available manpower and resources needed for commercial applications but, more importantly, they found that there is less and less interchangeability of government R&D and commercial R&D.

National defense outlays, I hope, have made America stronger. But they certainly have not yielded the technological breakthroughs necessary to reclaim a position of preeminence in the world.

The Japanese spend considerably less on defense; instead, they concentrate their substantial resources and talents on consumer goods. While we are creating missile systems, they are creating the product technology that has made Japan a winner in the battle for world markets.

We must understand that America faces more than one threat in the world. War is not the only danger to our national security.

Monumental trade deficits and even greater budget deficits are just as dangerous.

Unless we can compete internationally, the Trojan Horse of trade will be within the gates.

There is an economic as well as military threat. We must break with the past and develop a strategy that involves government and academia.

Sematech is of course a giant step in that direction.

There are other possibilities that will evolve.

If we were diagnosed as an industry, we would be found "manic depressive". When things were good we built plants, we innovated, we expanded, we hired people and we spun-off companies. We were on top of the owrld. But when we hit the skids we hung our heads and chanted the mantra of gloom. We forgot how good we really are.

This industry has been on an emotional roller-coaster for forty years, and we're all paying the price. I think we could use a strong dose of lithium to even out the mood swings and modulate the cycles. With maturity, the days of stunning growth may be behind us. But, perhaps, so is the worst of the crisis.

One hundred fifty years ago a preacher from New York studied the scriptures with such diligence that he predicted the precise date of the second coming. Reverend William Miller said the world would end on October 22, 1844, and thousands of people believed him. They donned white robes, sold their worldly possessions, and ascended mountains and rooftops to be nearer to Heaven when the end came.

Well, the world did not end on October 22, 1844, and -- even as we celebrate midlife -- the end is nowhere in sight for the U.S. semiconductor industry. So get down from the rooftops, face up to reality, roll up your sleeves, and get back to work.

If this industry needs inspiration, we can look to the state of Israel which, coincidentally, is also celebrating its fortieth anniversary this year. Israel has also performed miracles with sand. It has been forced to solve problems and overcome a series of crises always against profound odds. But, it has always found opportunity in crisis and this industry can do the same.

Let's not confuse our dawning maturity with stodginess. We can learn a lesson from the American automobile industry. When that industry was young, it was crazy, it had new ideas, new approaches and intense competition. The product had style, verve and personality.

With maturity it went to fat. It reacted to crisis by making cars that all look alike. It lost the drive and spontaneity that was the key to its success in the early years.

Well, this modern day preacher from New York doesn't think that is going to happen to the semiconductor industry, and let me tell you why.

There was a play on Broadway several years ago called Equus, by Peter Shaffer. It was about a troubled young man who was placed under the care of a psychiatrist because he had committed an unspeakable, irrational act. During the play, the psychiatrist explores the young man's dreams, fantasies and passions. And he manages to cure him - he brings him to the point where he has no more dreams...no more fantasies...feels no pain...and has no passion.

The psychiatrist has grave doubts about his accomplishment and he says:

- He is delivered from madness, but what then?
- He will feel no pain, but how will he know pleasure?
- His feelings and passion will be gone, but they can't be reattached like bandaids.

You see, passion can be destroyed, but it cannot be created."

This industry has an entrepeneurial passion for achievement, progress and innovation that has been our greatest asset and remains our best hope for the future.

People have attempted to destroy it!

But none have learned how to create it!

The challenge to this industry is to not forget our entrepeneurial passion and

USE IT!

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GLOBALIZATION: WE'RE NOT TOO OLD TO PLAY

Norman A. Neumann
President and Chief Executive Officer
Signetics Corporation

Mr. Neumann is President and Chief Executive Officer of Signetics Corporation, having joined the company as a member of the Philips executive team when it purchased Signetics. Previously, he was Vice President/Group Executive of North American Philips Corporation and prior to that, President of Amperex Electronic Corporation after four years as Vice President/General Manager of Amperex's semiconductor division. Preceding Mr. Neumann's Philips association, he was Vice President and General Manager of the Semiconductor Division at General Instrument Corporation, and before that, Vice President of General Transistor Corporation and Chief Industrial Engineer for Radio Receptor Company. Mr. Neumann studied industrial engineering at New York University.

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International Perspectives

NORMAN NEUMANN

President and Chief Executive Officer
Signetics Corporation

GLOBALIZATION: WE'RE NOT TOO OLD PLAY

Thank you. Your warm welcome must mean that you have just realized that you are only thirty minutes away from cocktails.

During these two days, we have heard from some of the foremost leaders in the industry, and before we leave tomorrow, we will have shared some 1400 years of experience from the people who have helped shape the semiconductor business. I applaud Dataquest for sponsoring this assembly, for it puts us on the right track.

While it has been an intensive two days, I've found them very worthwhile and informative. Our theme of the industry in mid-life crisis is certainly apropos. Each year, more and more gray hair appears in the audience, and while the industry has done well by this experience, the next 40 years will make even greater demands on the leadership of our industry.

We need to do things, not just differently, but better, if our semiconductor business, and American industry in general, is to flourish.

We have examined a number of trends forecasted for our industry. Some of these have already taken shape, while others are just beginning to impact our business. Many of these trends developed somewhat in spite of us. It is as though we were white water rafting. You believe you are in control of the speed and direction of your raft, when in fact, you are simply being swept along by the river's current.

Looking back for a moment, in the 1950's and 1960's, we achieved new technological milestones almost daily. Applications waited for the next generation of product, and we waited for the process equipment to catch up with the boys in the lab.

The 1970's brought a new focus on manufacturing. Cost leadership became our new watchword and we raced down the learning curve. Then at the end of the decade, quality began to raise its long-ignored head.

Then the 1980's were upon us, and Japan discovered that it had its own talent, that it was capable of doing more than assembling U.S. generated designs, and that it was a formidable competitor.

Low labor costs had already convinced many U.S. companies to establish manufacturing sites offshore. Air travel, telecommunications and the proliferation of computers helped make these remote locations feasible, and together they have accelerated the pace at which the world has been shrinking since the end of World War II. Today, we find ourselves in a global environment. And many of us are not yet prepared to deal with this fact.

By global environment, I do not mean that the world is becoming a single, homogenous market. Clearly there are significant regional differences in terms of industrial base, demand mix, and other market factors. Rather, I mean that it has become necessary to serve our customers wherever they may be located. More and more companies are locating their operations where it makes the most business sense. That is, where they can best meet local content requirements, or achieve lower labor costs. To serve such customers, we must be prepared to meet the special needs of each location with products and services adapted to local market realities.

Not so long ago, what we now refer to as Southeast Asia - on the Pacific Rim - was listed on most marketing charts as ROW - Rest of World. We lumped it together with South America, Africa, the Near East and others. We looked at it as an opportunity, rather than a market. It was referred to as foreign, offshore or international. As always, we looked at it from the U.S. point of view.

Today this market is growing faster than any other. Over the past year, the North American market grew by only 5%, while Europe increased by 18%. During the same period Japan gained 37%. On the other hand, the rest of the world, which primarily means Southeast Asia, jumped almost 65%. These numbers make it impossible for us to ignore this increasingly important segment.

The industry is beginning to realize the parochial, nationalistic views we have traditionally held will not carry us through the 1990's and into the 21st century.

For many industries, the impact of globalization hit years ago. The steel, automotive, oil, footwear and now consumer goods businesses are still reeling from the impact of this aggressive, even ruthless, business environment.

But I hope that our industry is both young enough and determined enough to stay in the game. The test will be in whether we can successfully respond to a new set of standards and accepted rules of play. The global marketplace is not one of fair and open trade practices. Customer mores, accepted margins, government involvement and each country's role in world military, economic and political arenas - all directly affect accepted business practices. These tend to be very different from what we are accustomed to.

A supplier fighting to defend domestic market share against a foreign challenge is at a long-term disadvantage when that supplier cannot respond in the rival's home market, or for that matter, another region of the world.

But protectionism is not the long-term answer. I am not against a hard rap on the knuckles when one of us misbehaves. But tariffs and other legislation only serve to stifle creativity and turn our nation's allies against us. There are other means to overcome these roadblocks to success. The objective must be open access to all geographic regions.

Life was easier when a small group of suppliers called the shots. This industry was born in the United States and for many years, America was the primary producer and the biggest consumer of our products.

Those days are gone. Today our industry seems to be in turmoil. I do not have to dwell on the result of recent changes: loss of market share, loss of cost leadership, loss of technological leadership, and foreign ownership and management of U.S. companies.

Today our customers, many of whom would not exist without our technology, have turned our products into commodities. When major users of integrated circuits no longer care about the source of their components, both the customer and the supplier lose.

A new, long-term view has to be taken by the user, as well as the supplier. Stronger, open relationships must evolve with customers, and even with competitors, where future plans and risks are shared.

As many of you know, Signetics - a 26-year old world supplier of ICs - has been a wholly-owned subsidiary of N.V. Philips of The Netherlands since 1975. That puts us in the position of having been in a true global environment for the past 12 years.

Philips has traditionally managed its numerous businesses around the world by encouraging the entrepreneurial drive of its managers. Today, Philips/Signetics is a respectable $1.3 billion IC business with aggressive growth plans.

Our association with Philips has not been without its rough spots, but over the years we have learned to work together by setting common goals. In the process, we have learned some important lessons about consortiums, partnerships and what it takes to be a global player. I thought it would be of interest to share some of those experiences with you now.

To be a major semiconductor supplier operating on a global level, will take strength in several key areas.

- financial stability
- global marketing excellence
- consistent R&D investment
- more cost-effective manufacturing processes
- a fully-developed customer service orientation
- a commitment to quality
- and effective asset management

Financial health, regardless of company size or geographic arena, means being able to assure customers that will remain viable through tough times, and provide new products and technologies for the future.

Through Philips, Signetics is fortunate to have the backing it needs to expand its technological and marketing positions anywhere in the world.

In addition to deep pockets, operating in a global marketplace requires marketing muscle. Sales and marketing professionals must be intimately familiar with, if not native to, the locales they serve, and our commitment to customer satisfaction must be expanded to a worldwide basis. Translated very simply, that dedication means understanding the customer's needs and wants, in local terms, and delivering products and services to fill those needs.

As a case in point, a number of U.S. and European semiconductor companies met in Washington, D.C. last June to establish a basis for dealing with possible high-tech trade issues and explore areas of common interest. The meeting was jointly sponsored by the U.S. Trade Representative and its European counterpart, the Commission of the European Communities.

Of the major European manufacturers, all were represented by top-level people. But on the U.S. side only one company was present through the entire meeting. What's worse is the American participants didn't seem to be well informed about major European high technology initiatives such as the ESPIRIT and EUREKA programs. Nor were they familiar with the joint Philips/Siemens Mega Project, which is a European version of Sematech.

Unfortunately, this reflects a less than global attitude on the part of the U.S. semiconductor industry. In my view, this outlook can be self-destructive in that U.S. firms fail to have adequate respect for their overseas competitors.

In this day and age, no business effort can be successful without a strong commitment to R&D. For instance, our Sunnyvale lab is part of Philips' network of research laboratories, which is one of the largest private lab facilities in the world, and it provides Signetics with research ranging from detailed materials characterization to computer-aided design to submicron geometry.

The semiconductor industry needs to nurture this kind of incentive to invest in R&D. Protection may be the answer here, but not in the form of trade restrictions. Rather it must be through copyright and patent recognition for silicon and software designs. Only through such legal backing, with worldwide enforcement, can a company ensure that it will be able to recover costs and generate profit from its R&D investments.

Sematech is one approach to the problem, and its progress and eventual success in addressing this issue will be significant. Unfortunately, one of the ironies of this organization is that Signetics is not permitted to participate even though we have been a member of the SIA since 1977 and can make a meaningful contribution.

When the U.S. represented half the world economy, a semiconductor manufacturer could enjoy economies of scale as long as U.S. market share was sufficient. But in the future, these economies will go to those companies that can also exploit high-growth markets in Europe, Southeast Asia, and certainly, Japan.

Sharing equal importance with these programs is the issue of quality. Quality is a universal language, and a zero-defect attitude must travel with us as we expand our operations around the globe.

Finally, the global manager must understand much more than yield rates, new processes and productivity issues. The global manager must also be familiar with the effects of rising interest rates, the falling dollar, the trade deficit, local trade restrictions and foreign investments . . . a global view of managing assets.

Philips/Signetics has implemented a special exchange program to facilitate just this kind of management education. We believe this cross-pollenation invigorates the entire organization.

We are always looking for new talent, and in the U.S., companies have traditionally turned to the universities. But the industry is approaching a major crisis. The academic community is failing to fulfill our need for the kind of creative engineering superstars who have made yesterday's science fiction today's reality.

As a result, the competitive advantage that U.S.-based firms once held, thanks to the American education system, is quickly slipping away. Instead, the U.S. is now educating the world.

According to a recent study by the National Science Foundation, the startling fact is that 57% of all engineering doctorates awarded in this country last year went to foreign nationals. Not only that, but enrollment of foreign students in American universities has been increasing at a rate of 2% per year for the last decade. If this trend continues, foreign students will outnumber their American counterparts by more than 3 to 2 by 1995.

While many of these foreign nations stay to fill positions with American suppliers, many more return to their native lands, creating a talent drain on local industry in crisis proportions.

Semiconductor suppliers in all countries must work together with their local academic systems to strengthen their technical training programs and boost their recruitment efforts.

So as the industry approaches its mid-life crisis, we can be confident that we are not too old to play. That we still have many years of vigor left in us, as well as the foresight to bring in new, young talent to carry us into the 21st century.

Furthermore, the game of globalization is just starting. The People's Republic of China, India, and the U.S.S.R. will soon challenge Southeast Asia's dominance as the world's manufacturing center, and someday, become major consumers of electronics themselves.

We can successfully meet these challenges as long as we continue to learn from our own mistakes, and take advantage of the lessons learned by our colleagues in other industries. Through change we can remain strong and viable. But to do so, we must not only acknowledge its existence, we must also be willing to restructure ourselves to adjust to our ever-shrinking global marketplace. An important part of this will depend on our success in attracting America's brightest young minds to join our exciting industry.

There is just one more thought I would like to leave you with, and that is this: The U.S. cannot live exclusively on a service economy. We cannot maintain world economic leadership only through dependence on industries such as hotels, restaurants, sports teams, health care and financial services. We must take an active role in preserving our country's place as an industrial and technological leader in world society.

GLOBALIZATION
We're Not Too Old To Play

by
Norman A. Neumann

President and Chief Executive Officer
Signetics Corporation
Sunnyvale, California

Presented To:

1987 Semiconductor Industry Conference
"Semiconductors: Midlife Crisis"

The Pointe at Squaw Peak
Phoenix, Arizona
October 19-21, 1987

1947-1987

Globalization

We're Not too Old to Play!

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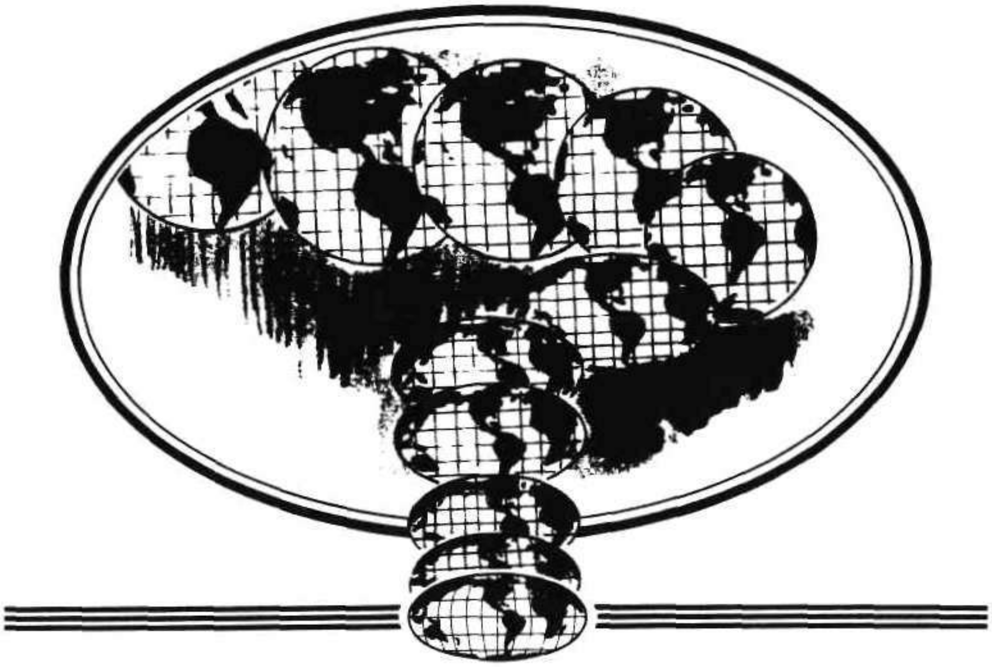
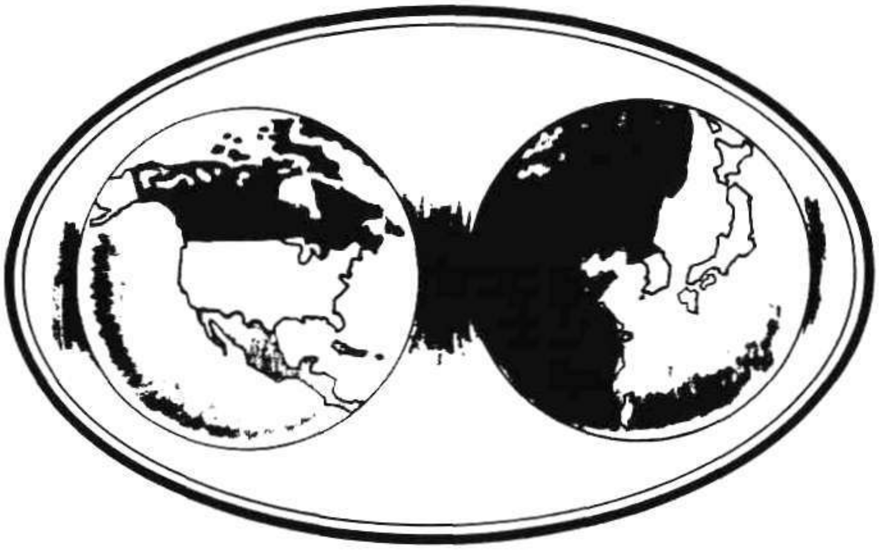
Semiconductor Industry in Retrospect

- '60's: Technological Innovation and Milestones.
- '70's: Focus on Manufacturing, Cost Leadership, Learning Curve, Emergence of Quality.
- '80's: The Customer. Service. Marketing. Global Competition. Japan.

1947-1987.



1947-1987



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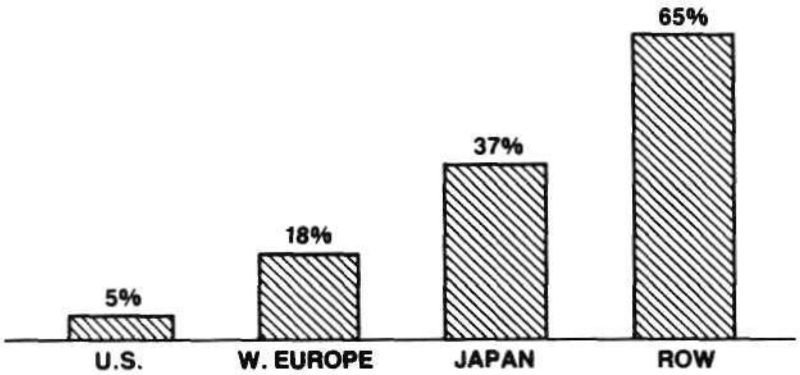
Market Growth '86 vs '85



SOURCE: SIA

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Protectionism

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Signetics

Member of the Worldwide Philips Family

Requirements for Global Operation

- Financial Stability
- Global Marketing Excellence
- Consistent R&D Investment
- Cost-effective Manufacturing Processes
- Customer Orientation
- Commitment to Quality
- Effective Asset Management

Financial Stability

Global Marketing Excellence

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Consistent R&D Investment

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Consistent R&D Investment

- Maintain Adequate Investment
- Protect R&D Investment via copyrights and patents
- Sematech

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Cost Effective Manufacturing Processes

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Commitment to Quality

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Customer Orientation

Effective Asset Management

1947-1987

U.S. EDUCATIONAL SYSTEM

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1947-1987

Semiconductors: Midlife Crisis

- Not too Old to Play
- Infusion of New Talent
- Globalization Just Beginning
- Learn From Mistakes
- Willingness and Ability to Change

- **Cannot Live by Service Alone!**

Semiconductors: Midlife Crisis

- Not too Old to Play
- Infusion of New Talent
- Globalization Just Beginning
- Learn From Mistakes
- Willingness and Ability to Change

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DINNER SPEAKER

Sheldon Weinig
Chairman and Chief Executive Officer
Materials Research Corporation

Dr. Weinig is Chairman and the founder of Materials Research Corporation. Prior to starting the company, he was on the faculty of Columbia University and New York University. Dr. Weinig is a member of President Reagan's Board of Advisors on Private Sector Initiatives, a member of the Columbia University East Asian Institute Visiting Committee, a Fellow of the American Society for Metals, a Fellow of the Polytechnic Institute of New York, and a member of the New York Academy of Sciences. Dr. Weinig holds a doctorate degree in Metallurgy from Columbia University and an honorary doctor of laws degree from Saint Thomas Aquinas College. He received the 1980 SEMMY award for developing the critical materials necessary for the growth of the semiconductor industry and was elected to the National Academy of Engineering in 1984.

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October 19-21, 1987
Phoenix, Arizona

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Semiconductors'
Midlife Crisis

Semiconductor Manufacturing: Strategic Issues for the 1990s

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Semiconductors' Midlife Crisis

Semiconductor Manufacturing: Strategic Issues for the 1990s

ROBERT McGEARY

Director, Semiconductor Equipment and Materials Service
Dataquest Incorporated

Dataquest

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**CAPITAL FORMATION FOR U.S.
SEMICONDUCTOR MANUFACTURING IN THE 1990s**

Wilmer R. Bottoms
Senior Vice President
and General Partner
Alan Patricof Associates, Inc.

Dr. Bottoms is Senior Vice President and General Partner of Alan Patricof Associates, Inc. Previously, he was President of the Semiconductor Equipment Group at Varian Associates. Earlier, he was General Manager of Varian's Extrion Division, after joining the company as Manager of Research and Development. Prior to that, Dr. Bottoms was a Professor of Electrical Engineering at Princeton University. Dr. Bottoms has also served as a member and chairman of several governmental technical advisory groups, and is on the Boards of Directors of several high-technology companies. Dr. Bottoms received a B.S. degree in Physics from Huntington College in Montgomery, Alabama, and an M.S. degree in Physics and a Ph.D. in Solid-State Physics from Tulane University.

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Semiconductors' Midlife Crisis

Semiconductor Manufacturing: Strategic Issues for the 1990s

DR. WILMER R. BOTTOMS

Senior Vice President and General Partner
Alan Patricof Associates, Inc.

"CAPITAL FORMATION FOR SEMICONDUCTOR MANUFACTURING IN THE 1990's"

DATAQUEST SEMICONDUCTOR INDUSTRY CONFERENCE 1987

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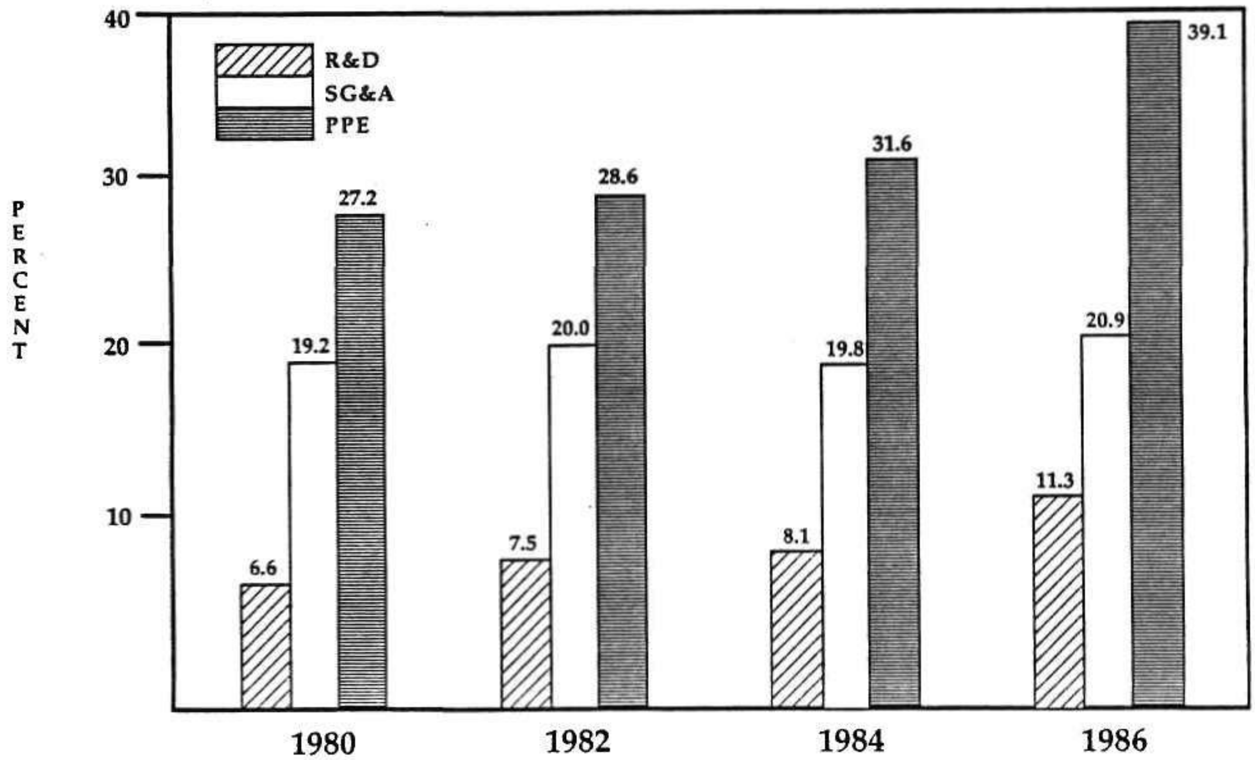
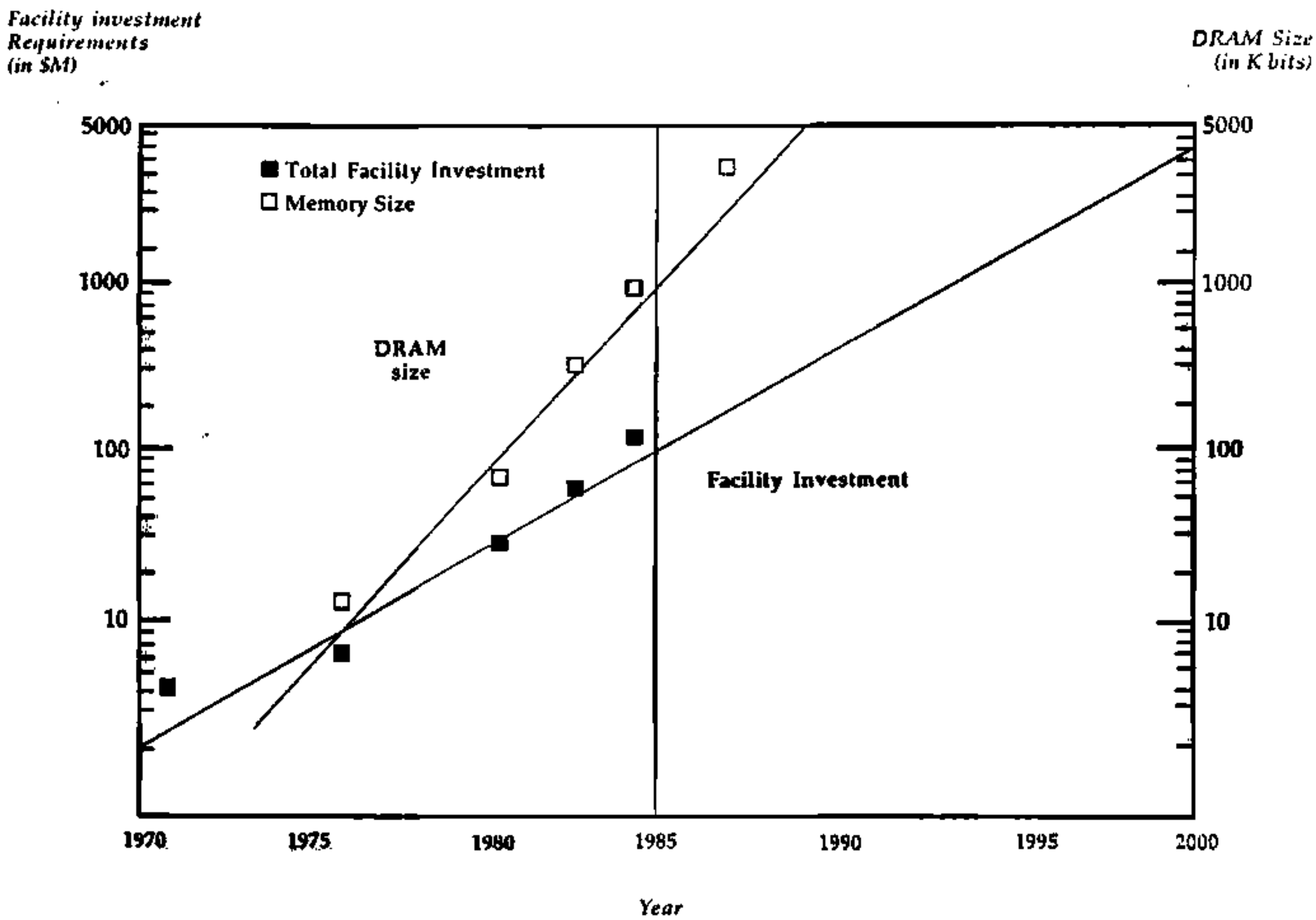
WHAT WILL IT COST?

- TECHNOLOGY
- PRODUCTION CAPACITY
- MARKETING AND SALES

CAPITAL USES AS PERCENT OF SALES MERCHANT MARKET SUPPLIERS





Source: VLSI RESEARCH, INC.

ALTERNATIVES FOR FUNDING TECHNOLOGY

- CONSORTIA (SRC, SEMATECH, MCC, ETC.)
- UNIVERSITIES
- CONTRACT FUNDING (VHSIC, SBIR, ETC.)
- R&D PARTNERSHIP

ALTERNATIVES FOR FUNDING TECHNOLOGY (continued)

- JOINT VENTURE
- LICENSING
- PURCHASE
- IR&D

ALTERNATIVES FOR PROVIDING PRODUCTION CAPACITY

- RENT/LEASE
- PURCHASE
- FOUNDRY
- LICENSE

ALTERNATIVES FOR FUNDING MARKETING/SALES

- DIRECT SALES FORCE
- DISTRIBUTORS AND SALES REPS
- JOINT VENTURE

BOTH COUNTRIES AND COMPANIES WILL BE CAPITALIZING AND SUBSIDIZING THE INTEGRATED CIRCUIT INDUSTRY

SOURCES OF CAPITAL FOR THE IC INDUSTRY

I. GOVERNMENT

- TAX INCENTIVES
- PRODUCT DEVELOPMENT SUPPORT (BOTH DIRECT AND INDIRECT)
- CAPITAL GRANTS
- LOW INTEREST/NO INTEREST LOANS
- CONSORTIA PARTICIPATION

SOURCES OF CAPITAL FOR THE IC INDUSTRY

II. PRIVATE SECTOR

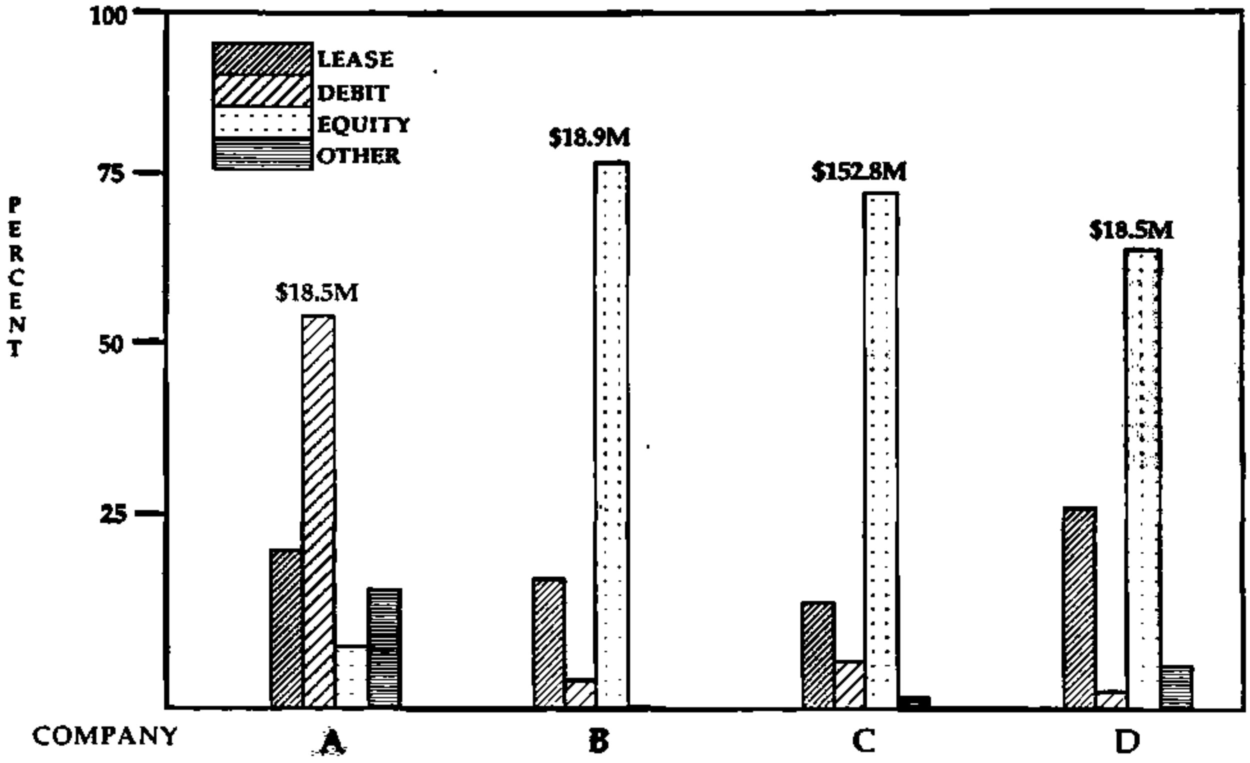
- PUBLIC MARKET (STOCKS AND BONDS)
- VENTURE CAPITAL
- SECURED LENDERS
- JOINT VENTURE
- CONSORTIA PARTICIPATION

SOURCES OF CAPITAL FOR THE IC INDUSTRY

III. CAPITAL EQUIVALENCE/AVOIDANCE

- UNIVERSITY RESEARCH AND DEVELOPMENT
- SUPPLIERS
- CUSTOMERS
- CORPORATE ALLIANCE

Sources of Capital



CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)
FRANCE

I. GOVERNMENT

- SUBSIDIZED LOANS AND LEASES
- QUASI-EQUITY (CONDITIONAL LOANS) TO 50% OF PRODUCT DEVELOPMENT COSTS
- DIRECT GRANTS TO 25% OF PRODUCT DEVELOPMENT COSTS
- NO CAPITAL GAINS TAX ON RISK CAPITAL INVESTMENTS

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)
FRANCE

II. PRIVATE

- SECOND MARKET ESTABLISHED IN 1983
- VENTURE CAPITAL FUNDS ENABLED IN 1983
- STRONG BANKING SYSTEM

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)
GERMANY

I. GOVERNMENT

- GRANTS UP TO 20% OF PRODUCT DEVELOPMENT COST
- 20 YEAR UNSECURED LOANS WITH 10 YEAR GRACE PERIOD
- NO TAX ON CAPITAL GAINS IN MOST CASES

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)
GERMANY

II. PRIVATE

- OTC MARKET ACCESSIBLE RECENTLY (1985)
- LIMITED VENTURE CAPITAL AVAILABLE
- BIG BANKS DOMINATE THE ECONOMY

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)

SPAIN

I. GOVERNMENT (NATIONAL AND REGIONAL)

- SUBSIDIZED LENDING UP TO 60% OF PRODUCT DEVELOPMENT COST
- DIRECT GRANTS UP TO 50% OF PRODUCT DEVELOPMENT COST
- LOAN GUARANTEES

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)

SPAIN

II. PRIVATE SECTOR

- LITTLE NON-GUARANTEED DEBT AVAILABLE TO SMALL COMPANIES
- SECONDARY STOCK MARKET ESTABLISHED IN 1986
- LIMITED VENTURE CAPITAL AVAILABLE

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)
UNITED KINGDOM

I. GOVERNMENT

- NO CAPITAL GAINS TAX FOR PUBLIC COMPANIES
- LOAN GUARANTEES UP TO 70% OF PROJECT COSTS
- GRANTS TO TARGETED INDUSTRIES
- DIRECT EQUITY INVESTMENT BY REGIONAL GOVERNMENTS
- TRAINING GRANTS

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)
UNITED KINGDOM

II. PRIVATE SECTOR

- LARGE AND GROWING VENTURE CAPITAL INDUSTRY
- UNLISTED SECURITIES MARKET FORMED IN 1980
- STRONG BANKING SYSTEM

INVESTMENT ACTIVITY OF BRITISH VENTURE CAPITAL ASSOCIATION MEMBERS

	1985	1986	% change
TOTAL AMT INVESTED (£ MILLION)	324.6	425.9	+31%
NUMBER OF INDIVIDUAL INVESTMENTS	1,021	1,105	+ 8%
NUMBER OF COMPANIES FINANCED	635	708	+11%

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)
KOREA

I. GOVERNMENT

- TAX CREDIT FOR CAPITAL EQUIPMENT
- NO TAX ON CAPITAL GAINS OR DIVIDENDS
- V.C. INDUSTRY CAPITALIZED AT 169.7B WON AS OF 1/1/86

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)
KOREA

II. PRIVATE SECTOR

- NO SECURITIES MARKET FOR SMALL COMPANIES
- LITTLE INSTITUTIONAL FINANCING AVAILABLE
- JOINT VENTURE SUPPORTED BY MAJOR CORPORATIONS (FAMILY OWNED)

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)
SINGAPORE

I. GOVERNMENT

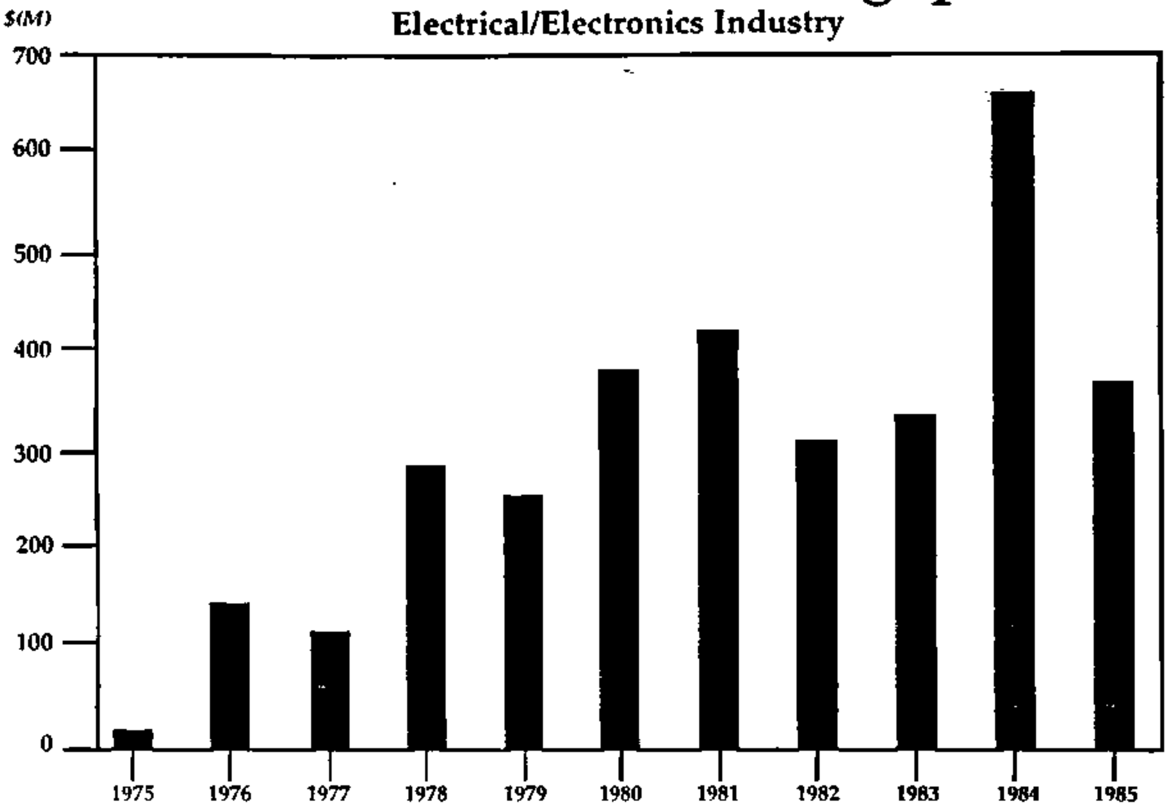
- GUARANTEED SUBSIDIZED LOANS
- TRAINING GRANTS
- GRANTS FOR UP TO 50% OF PRODUCT DEVELOPMENT COST
- COOPERATIVE TECHNOLOGY DEVELOPMENT WITH UNIVERSITIES
- INCOME TAX EXEMPTION UP TO 10 YEARS
- CAPITAL GAINS TAX EXEMPT

CORPORATE FINANCING RESOURCES
(OTHER THAN MARKET RATE SECURED DEBT)
SINGAPORE

II. PRIVATE SECTOR

- LITTLE ACCESS TO STOCK MARKET FOR YOUNG/SMALL COMPANIES
- LIMITED PRIVATE VENTURE CAPITAL AVAILABLE

Net Investment in Singapore



Source: Singapore Econ. Dev. Bd.

U.S. VENTURE CAPITAL INDUSTRY 1986

- $3.05 BILLION INVESTED BY TOP FIRMS IN 1986
- $24.1 BILLION UNDER MANAGEMENT
- 50.5% INVESTED IN ELECTRONICS RELATED INDUSTRIES
- 4421 INVESTMENT OPPORTUNITIES RECORDED IN 1986

Source: Venture Magazine

UNITED STATES STATE TECHNOLOGY DEVELOPMENT PROGRAMS 1986

- OPERATIONAL IN 43 STATES
- $666.2M INVESTED IN 1986
- MOST ARE MODELED AFTER

  SILICON VALLEY

  ROUTE 128

  RESEARCH TRIANGLE PARK

TOP 15 STATES IN EXPENDITURES FOR TECHNOLOGY DEVELOPMENT PROGRAMS FY1986

Pennsylvania	$99,750,000
New Jersey	60,836,000
Michigan	58,300,000
Ohio	38,400,000
Massachusetts	25,148,000
Georgia	31,000,000
Illinois	30,467,000
Arizona	26,000,000
Minnesota	24,339,000
North Carolina	22,050,000
New York	20,979,000
Louisiana	20,000,000
Iowa	15,400,000
Kentucky	13,400,000
Oregon	13,000,000
Total	$509,069,000

Amount represents 76% of total funding by all states.

STATE TECHNOLOGY DEVELOPMENT PROGRAMS 1986

SHARE OF TECHNOLOGY FUNDING BY TYPE OF PROGRAM

Technology/Research Centers	49.8%
Venture/Seed Capital	22.8%
Research Grants	18.1%
Research Parks	5.6%
Incubators	5.2%
Equity Royalty Programs	2.0%
Technical/Managerial Assistance	1.5%
Technology Transfer	1.2%
Technology Office/Commission	1.2%
Technology Training	1.1%

SECURITIES MARKETS ARE NOW INTERNATIONAL

- INTERNATIONAL EQUITY TRADING EXCEEDED $740B IN 1986
- FOREIGNERS ACCOUNT FOR A HIGH PERCENTAGE OF THE SECURITIES TRADING IN MANY MARKETS

  40% WEST GERMANY, 36% BRITAIN, 10% U.S., 9% JAPAN
- U.S. COMPANIES HAVE SUCCESSFULLY USED FOREIGN STOCKMARKETS TO RAISE PUBLIC CAPITAL

Source: The Economist

MAJOR CHANGES IN INTERNATIONAL FINANCIAL MARKETS HAVE OCCURRED SINCE 1980

- PRIVATIZATION
- TAX POLICY
- SECURITIES MARKETS PRACTICES AND REGULATIONS
- INSTITUTIONAL PARTICIPATION
- PUBLIC POLICY AND ATTITUDE

HISTORICAL DISTINCTIONS
HAVE BLURRED

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MASKMAKING:
LIFE AFTER 5EX

Steven K. Dunbrack
Marketing Manager
Ultratech Stepper Inc.

Mr. Dunbrack is Marketing Manager at Ultratech Stepper Inc. He is responsible for technical liaison to maskmakers and Ultratech customers. His area of expertise is in electron beam maskmaking, inspection, repair, and meteorology. Prior to joining Ultratech Stepper, he was Director of Technology for Ultratech Photomask. Earlier, he was technical advisor to the President at Xynetics Corporation. Mr. Dunbrack is a cofounder of BACUS (Bay Area Chrome Users Society). He received a bachelor's degree from the University of California at Irvine and completed coursework in engineering at Harvey Mudd College. He has authored several technical papers at SPIE, Kodak, and SEMI.

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Semiconductors' Midlife Crisis

Semiconductor Manufacturing: Strategic Issues for the 1990s

STEVEN K. DUNBRACK

Marketing Manager
Ultratech Stepper

Ultratech
Stepper

MASKMAKING:

LIFE AFTER 5EX

STEVEN K. DUNBRACK
ULTRATECH STEPPER
Santa Clara, California

Ultratech Stepper

DRAM PROGRESSION

Mature Production

	1st 1/3	Mid	Last 1/3	
1970	1 KBit	4 KBit	16 KBit	1980
1980	64 KBit	256 KBit	1 MBit	1990
1990	4 MBit	16MBit	64 MBit	2000
2000	256 MBit	1 GBit	4 GBit	2010

*** Assumes a new generation in volume DRAM production every 1/3 decade.**

Ultratech
Stepper

LINEWIDTH PROGRESSION

Mature Production

From	1st 1/3	Mid	Last 1/3	To
1970	1 KBit	4 KBit	16 KBit	1980
1980	64 KBit 3.0 µm	256 KBit 1.5 µm	1 MBit 1.0 µm	1990
1990	4 MBit 0.70µm	16 MBit 0.5 µm	64 MBit 0.35 µm	2000
2000	256 MBit 0.25 µm	1 GBit 0.18 µm	4 GBit 1/8 µm	2010

- **MFS reduced by ~√2 for each generation.**
- **Chip introductions preceed production by 1/3 of a decade.**

Ultratech Stepper

CHIP SIZE PROGRESSION
Mature Production

1970	1 KBit	4 KBit	16 KBit	1980
1980	64 KBit	256 KBit	1 MBit 40 mm^2	1990
1990	4 MBit 66 mm^2	16 MBit 116 mm^2	64 MBit 192 mm^2	2000
2000	256 MBit 334 mm^2	1 GBit 588 mm^2 ~ 1 in^2	4 GBit 965 mm^2	2010

* Area increases by ~ 1.7x for each generation (assumes design efficiencies, vertical integration, etc.

Ultratech Stepper

PROJECTED DRAM CHIP PARAMETERS

YEAR	PROJECTED ACTUAL SIZES		COMMENTS
1986	50 mm^2 1.0µ	1M DRAM	308 DICE/150 mm WAFER
1988	100mm^2 0.8µ	4M DRAM	270 DICE?200 mm WAFER
1990	200mm^2 0.5µ	16M DRAM	135 DICE/200mm WAFER
1993 3-DIMENSIONAL?	400 mm^2 0.35µ	65M DRAM	250mm WAFERS?
1996 3-DIMENSIONAL?	800mm^2 0.25µ	256M DRAM	250mm WAFERS?
1999 3-DIMENSIONAL?	1,600mm^2 0.18µ	1G DRAM	300mm WAFERS?

Ultratech Stepper

SPACE BANDWIDTH PRODUCT

(SBP)

- **Combines minimum feature size and chip size in one number.**
- **Helps to define our lithography requirements.**
- **Examples of SBPs:**

EXAMPLE	~SBP
Color T. V.	2.5×10^5
Slide on the Screen	1×10^6
State-of-the-art lenses	4×10^8
1 G Bit DRAM	2×10^{10}

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SPACE BANDWIDTH PRODUCT

(Resolution Elements/Chip)

Period			
1970 → 1980	1 KBit	4 KBit	16 KBit
1980 → 1990	64 KBit	256 KBit	1 MBit 0.40×10^8
1990 → 2000	4 MBit 1.36×10^8	16 MBit 4.62×10^8	64 MBit 15.7×10^8
2000 → 2010	256 MBit 53.4×10^8	1 GBit 182×10^8	4 GBit 618×10^8

- Increases by ~3.4x/generation

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AN OPTICAL 1X PATH STEP-AND-REPEAT

- 1x Catadioptric designs lend themselves to large field sizes at high N.A.s

  (large SBPs)

- A SBP of 50×10^8 is achievable

  Resolution -- $K\lambda/NA$

  $0.28\mu m = 0.65\ (.193)/0.45$

  $0.27\mu m = 0.65\ (.248)/0.60$

  Rayleigh Limited DOF -- $0.5\lambda/NA^2$

  $= 0.5\mu m$

  Field Size $\geq 400mm^2$

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WHY "LIFE AFTER 5EX"?

- **5x lens designs become complex and limited in field size and SBP.**
- **Superchips - may see chips as large as $4in^2$ or larger in the 1990s.**
- **Would require a 5x Reticle as large as 12" x 12".**
- **One can store 25x the information on a 1x reticle -- The HARD DISC of masks.**
- **Such chips will require nx Step-and-Stitch or Step-and-Scan.**

Where $3 \geq n \geq 1$

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LIFE AFTER 5EX

- Conventional 1x Reticles
- nx Reticles for scanning or stitching projection aligners.
- 1x X-ray, Electron, or Ion Reticles.

Parallel imaging of mask information is the most cost effective manufacturing technique.

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PICTURE OF A MASK SHOP

INPUT FROM DESIGN

↓

Data Services Job Programming

↓

Electron Beam Write

↓

Electron Beam Process

↓

Q.A. -- Inspection, Repair, & Metrology

↓

Mask Out to Fab

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MASK MAKING TECHNOLOGY SURGE 1985 -- 1987

SOFTWARE

Calma → ECAD
AT & T
Transcription

INSPECTION

KLA 101 → KLA 208
209
218
219
219HR

REPAIR

Opaque Removal Only → Quantronix
Micrion
Seiko

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ALSO....

Metrology

Leitz IMS -- 2000

Lithography

MEBES™ - III

Process

Maturity of PBS Processing

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PRESENT STATE-OF-THE-ART OF MASK MAKING

- **Both 1x reticles and 5x reticles are being built today for 3/4 μm device work.**
- **This will carry us through 4MBit DRAMs....**
- **and into the 1990's.**

But......

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OUR MASK INDUSTRY IS METROLOGY LIMITED TODAY!!

Mask Overlay Requirements

5x

MFS	≥1.0μm	< 1.0μm	< 0.5μm
Mask Overlay	±0.25μm	±0.10 - 0.15μm	< ±0.10μm

Metrology Precision≅ 0.125 μm (3σ)

1x

MFS	≥ 1.0μm	< 1.0 μm	< 0.5 μm
Mask Overlay	±0.10μm	±0.05 - 0.08μm	< ±0.05μm

Metrology Precision≅ 0.05 μm (3σ)

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PRESENT PRACTICE

- **At a ± 0.25µm overlay spec, fabs will not accept a measurement of 0.26µm.**
- **At a ±0.15µm spec, the mask shops will be working at the noise level of their metrology instrument.**

THESE SPECS NO LONGER HAVE ANY MEANING!!

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THE SPECIFICATION CRISIS

- **Overlay Specs are at the limits of our metrology instruments.**

- **Defect Specs bear little relationship to reality.**
  - **-- What prints?**
  - **-- What kills?**

- **CD Specs have become overly complicated.**
  - **--** $\bar{x}$
  - **-- spread**
  - **-- x vs. y**

- **Customers insist on statistical interpretations of non-random data.**

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DATA HANDLING

- **At the 1 MBit DRAM level, we see single layer data files as large as 100 MBytes.**
- **At the 16 MBit DRAM level, these files will be 1 - 2 GBytes.**
- **An entire circuit will be as large as 10 GBytes.**
- **We will need 20 500 MByte discs to store one circuits worth of data.**

AND WHAT ABOUT ASICs!?!

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THE MASK MAKING CRISIS

ASSUMING THAT WE CONTINUE WITH BUSINESS AS USUAL.......

- At the 16 MBit DRAM level, mask shops will
  - -- no longer be able to meet mask specs
  - -- be a severe front end bottleneck
- Within 3 - 5 years, our semiconductor industry will be mask limited.

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WHAT CAN WE DO?

- PARTNERSHIPS- need to eliminate the adversarial relationship between the mask shop and its customer.

- STATISTICAL PROCESS CONTROL- a must for the mask shop. The only assurance of consistent quality

- SHIP TO STOCK--Reduces Spec Warfare

- INTEGRATION-- we need to integrate the mask shop into the semiconductor process.

WE NEED TO CHANGE THE WAY WE DO BUSINESS WITH OUR MASK SHOPS

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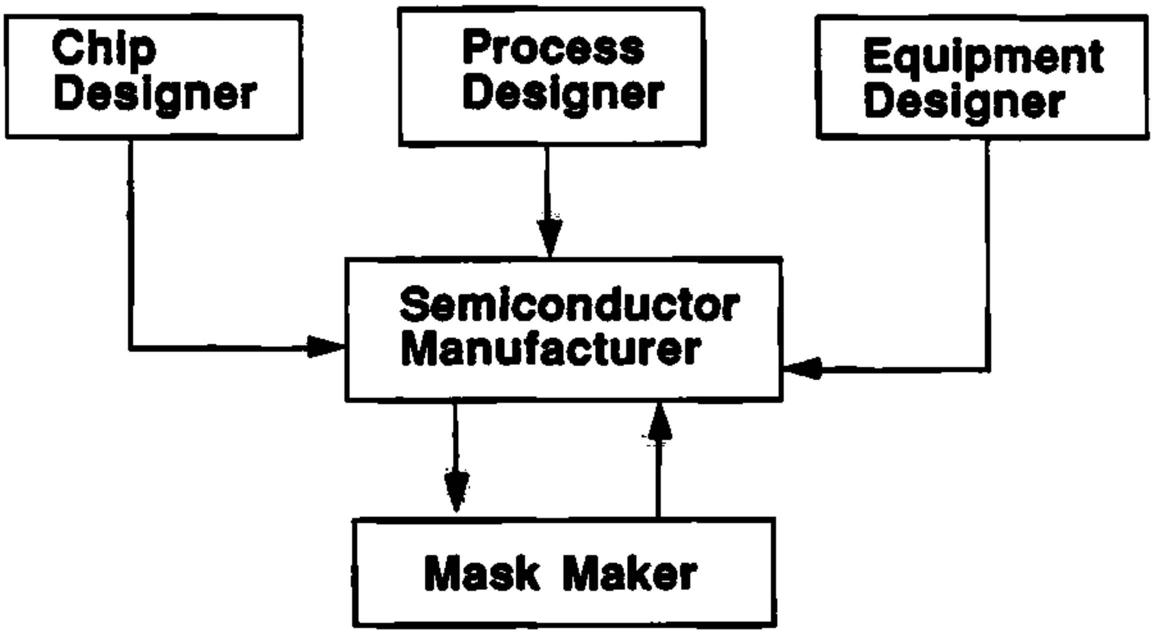
NOW



THE COMPARTMENTALIZED APPROACH

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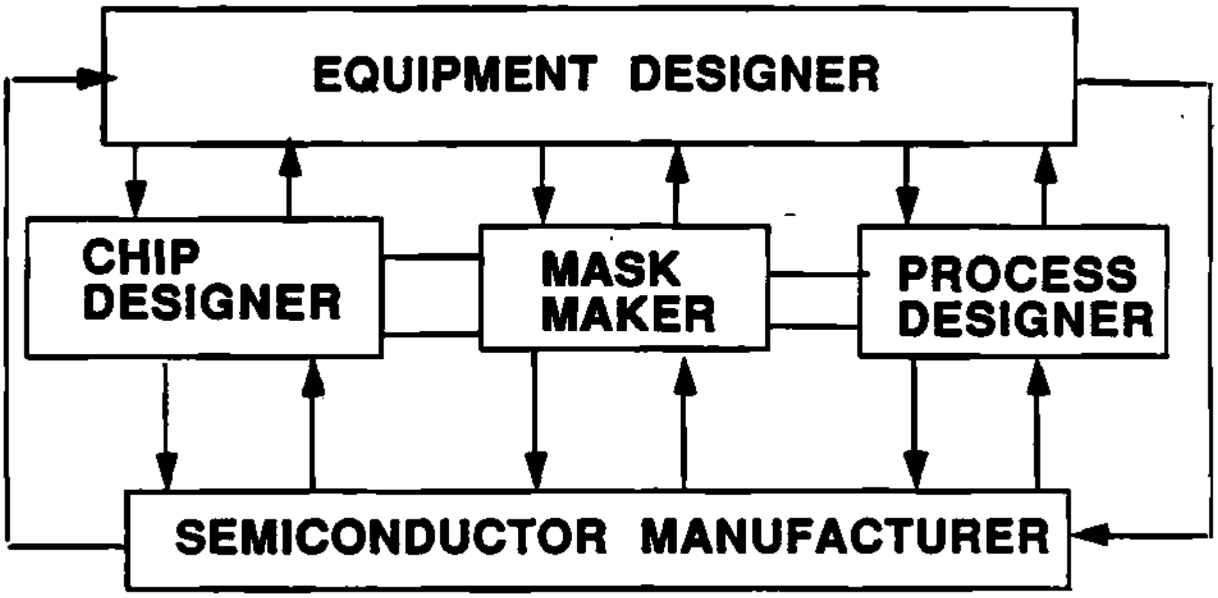
FUTURE



THE INTEGRATED APPROACH

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A NEW FRONT END APPROACH

- **Designers need to design with the mask shop in mind.**

- **Standardize inputs**

  --Use some common ground rules

  --Use a common language

- **We must compress our data.**

  -- Will require software to link design to the mask shop front end.

  -- Will require agreement and standards.

- **Customer needs to assume more responsibility for the integrity of their data inputs and job formats.**

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A NEW APPROACH TO INSPECTION AND METROLOGY

- **We need to integrate defect detection with CD measurement and registration in one system.**
- **The system will emulate both the lithography instrument and the process.**
- **It will have artificial intelligence.**
- **It will be able to determine if the mask fits the requirements of the process.**

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THE INTEGRATING STEP

- The system will accept the following inputs:
  - -- Design rule information
  - -- Lens to lens distortion data
  - -- Alignment models
  - -- Process models

- It will look at every feature on every mask

- It will distinguish between inconsequential defect and distortions and fatal defects.

- It will make intelligent decisions about any mask impact on:
  - -- device performance
  - -- yields

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IS IT PRACTICAL?
WE HAVE TO DO IT!!

- At least three design concepts have already been forwarded.
- System takes advantage of the product of our industry:

  COMPUTATIONAL POWER

- Present cost to do only a fraction of the job:

① State-of-the-art inspection instrument with database capability	$1.25 M
① Metrology instrument with requisite peripherals	$1.25 M
TOTAL	$2.5 M

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$ $ $ $ $ $

- R & D in conventional mask technology has never been an industry priority.
- The mask industry is small and fragmented.
- Mask makers are generally reactionary not visionary.
- Mask shops have had to cut back during the recent recession.
- The market for equipment and materials is small.

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$ $ $ $ $ $

- The semiconductor industry as a whole will need to take ownership of the mask problem.

- SEMATECH!!

- X-Ray R & D dollars!!!

  -- X-Ray masks will have to fit into a mask mfg infrastructure

  -- Should integrate X-Ray mask R & D with conventional mask R & D.

- VHISIC

- SRC

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SOME THINGS WE CAN DO

- **A Sematech Workshop to bring the design community and mask community together.**

- **A Sematech Mask committee to assess the present status of U.S. mask making.**
  - **-- recommend solutions**
  - **-- stimulate developments**
  - **-- act as a liason**

- **Diversion of some % of X-ray R & D $ to conventional mask R & D**

- **More university R & D $ for mask research**
  - **--Esp. process and materials**

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IN CONCLUSION

- We will be using masked lithography technologies well into the 21st Century.
- It is very likely that optical lithography will carry us into the 21st Century.
- Conventional mask making will be needed in the 21st Century, but.....
- We're running headlong into a crisis in mask making.
- We need to start working together today to prevent this from happening.

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SEMICONDUCTOR MANUFACTURING INDUSTRY, ITS ROLE AND ISSUES FOR THE 1990s

Tsuyoshi Kawanishi
Senior Vice President and
Director of the Board
Group Executive of the
Semiconductor Group
Toshiba Corporation

Mr. Kawanishi is Group Executive of the Semiconductor Group and Senior Vice President and Director of the Board of Toshiba Corporation. He began as a production engineer at Toshiba's Transistor Works (now the Microelectronics Center) and has spent his career at Toshiba in the development of its semiconductor business. He has served as Assistant Group Executive of the Semiconductor Group, General Manager of the Transistor Works, General Manager of the Oita Works, and Manager of Production Engineering at the Oita Works. Mr. Kawanishi received a B.E.E. degree from the Tokyo Institute of Technology.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

Semiconductor Manufacturing: Strategic Issues for the 1990s

TSUYOSHI KAWANISHI

Senior Vice President
Director of the Board
Group Executive, Semiconductor Group
Toshiba Corporation

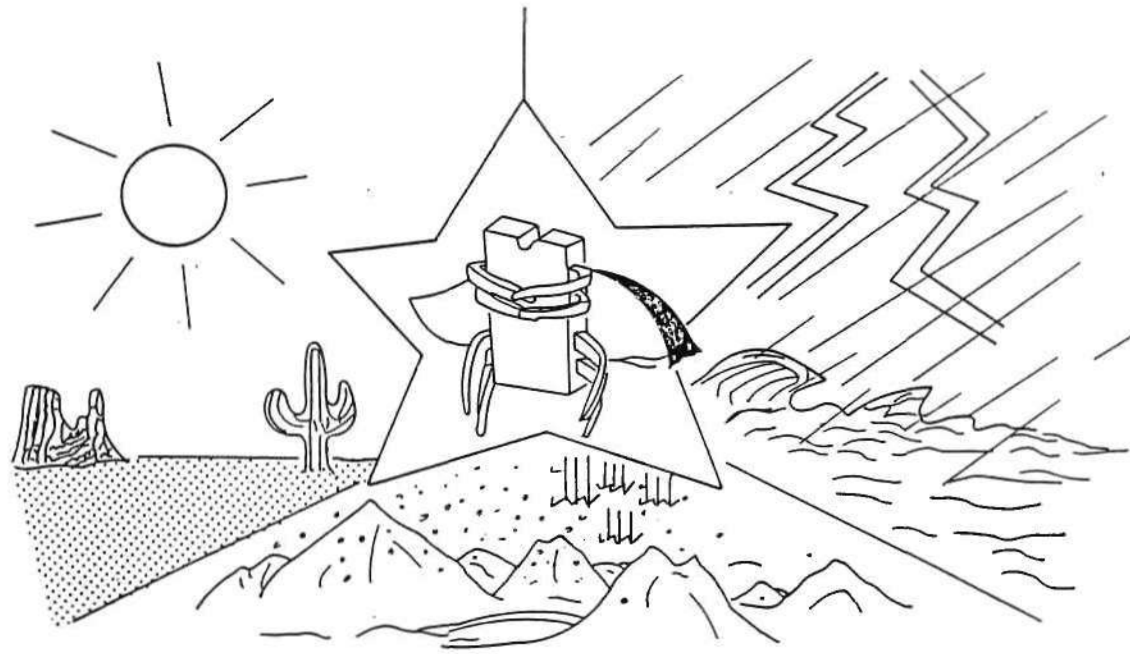
THE SEMICONDUCTOR MANUFACTURING INDUSTRY

ITS ROLE AND ISSUES FOR THE 1990'S

T.KAWANISHI
SENIOR VICE PRESIDENT &
DIRECTOR OF THE BOARD
GROUP EXECUTIVE
SEMICONDUCTOR GROUP
TOSHIBA CORPORATION

TOSHIBA

SEMICONDUCTOR: A SUPER HERO FOR A NEW AGE



TOSHIBA

Dataquest, a company of The Dun & Bradstreet Corporation / 1290 Ridder Park Drive / San Jose, CA 95131-2398 / (408) 971-9000 / Telex 171973

THE HERO HAS 3 MISSIONS

1. THE "CRUDE OIL" OF ALL MODERN INDUSTRY

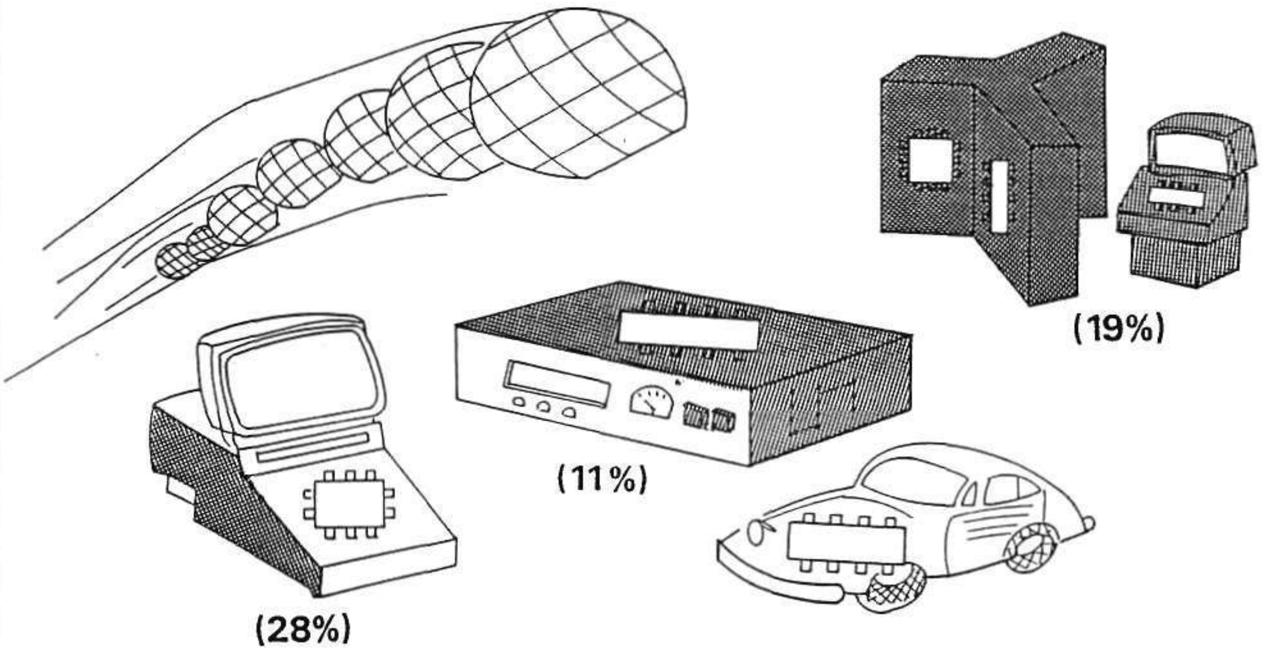
2. THE BEST SUBSTITUTE OF SOME FUNCTIONS OF A HUMAN BEING

3. THE CONDUCTOR FOR TOMORROW'S WORLD OF INFORMATION

TOSHIBA

It is

THE "CRUDE OIL" OF ALL MODERN INDUSTRY



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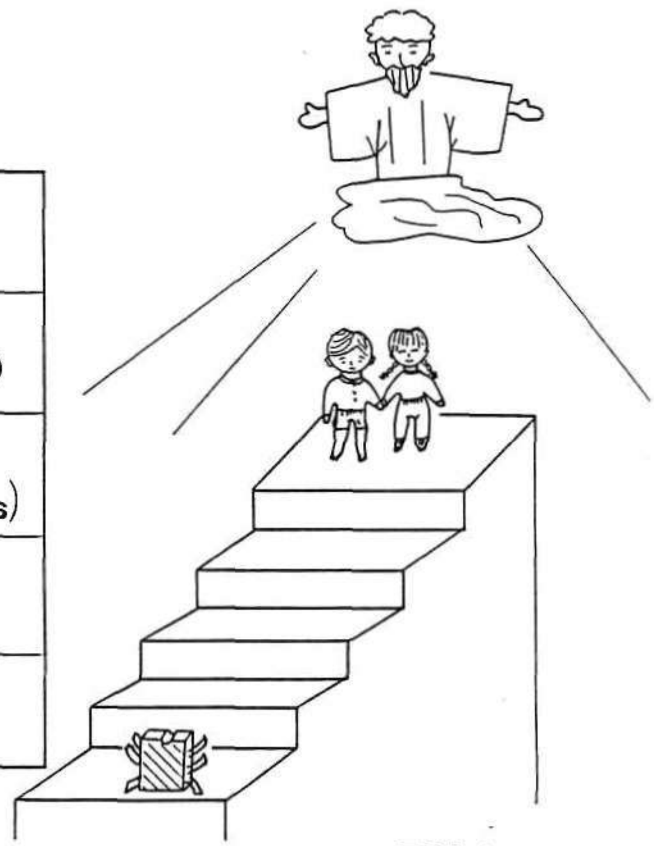
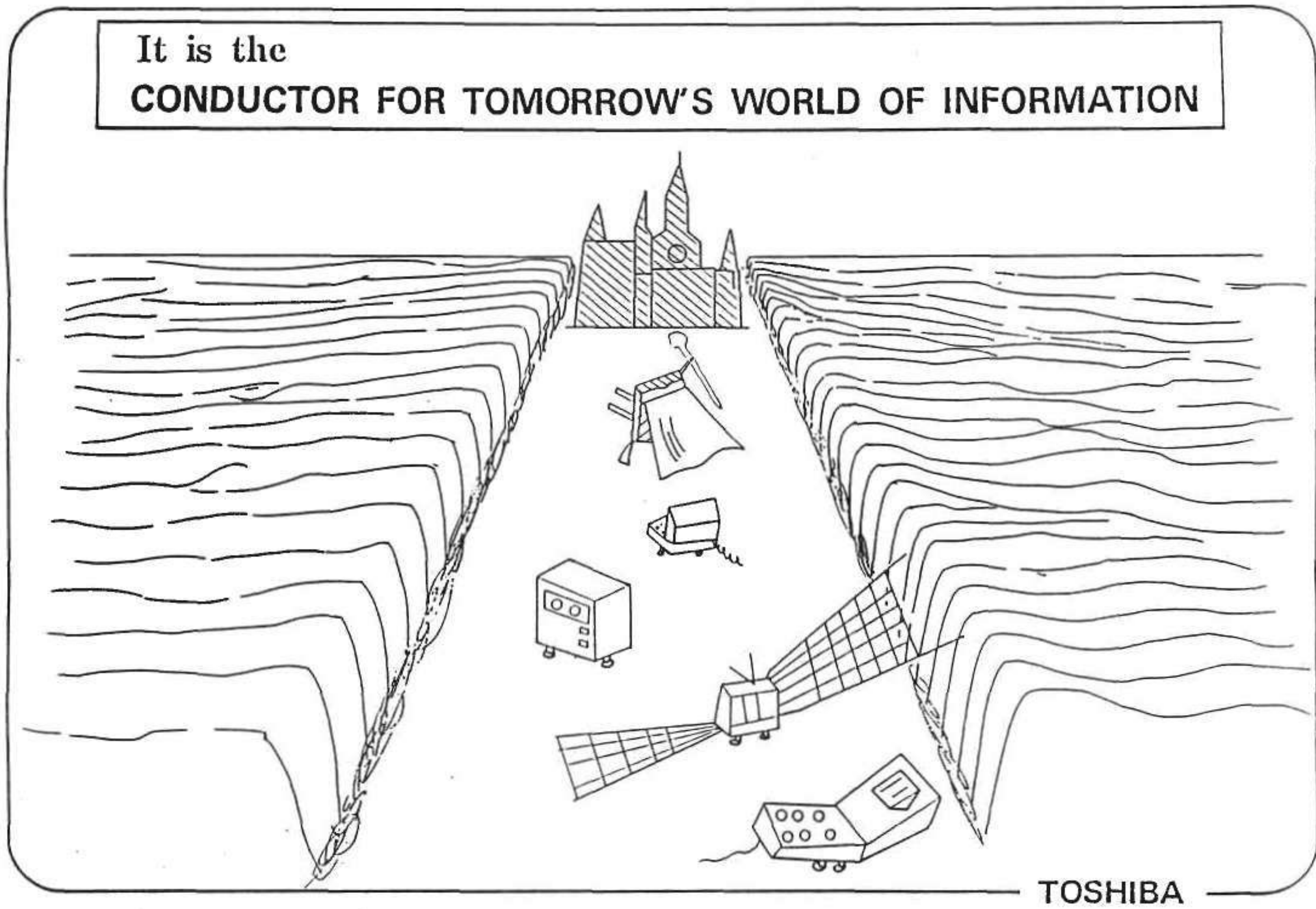
IT TAKES OVER SOME FUNCTIONS OF A HUMAN BEING

SEMI-CONDUCTOR		HUMAN BEING
DRAM (1M BIT)	1/14,000	BRAIN (14B CELLS)
CCD (400K ELEMENTS)	1/300	EYE (120 RECEPTORS)
ROM + CPU	AS SPEECH PROCESSOR	MOUTH
VOICE RECOGNIZER		EAR



TOSHIBA


It is the
CONDUCTOR FOR TOMORROW'S WORLD OF INFORMATION
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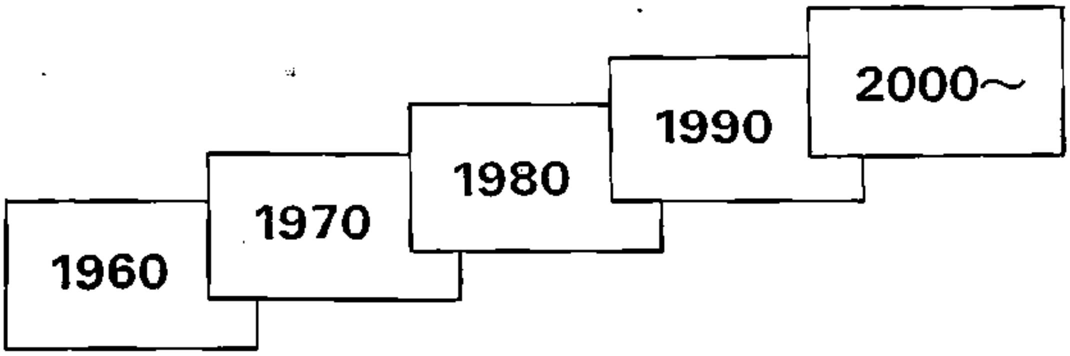
THE HISTORY OF SEMICONDUCTOR



	TR	IC	LSI	VLSI	ULSI	SLSI
ELEMENT PER CHIP	1	2~1K	1K~100K	100K~1M	1M~	100M~

THE SKY IS NO LIMIT TO SEMICONDUCTOR TECHNOLOGY EVEN AT 2000

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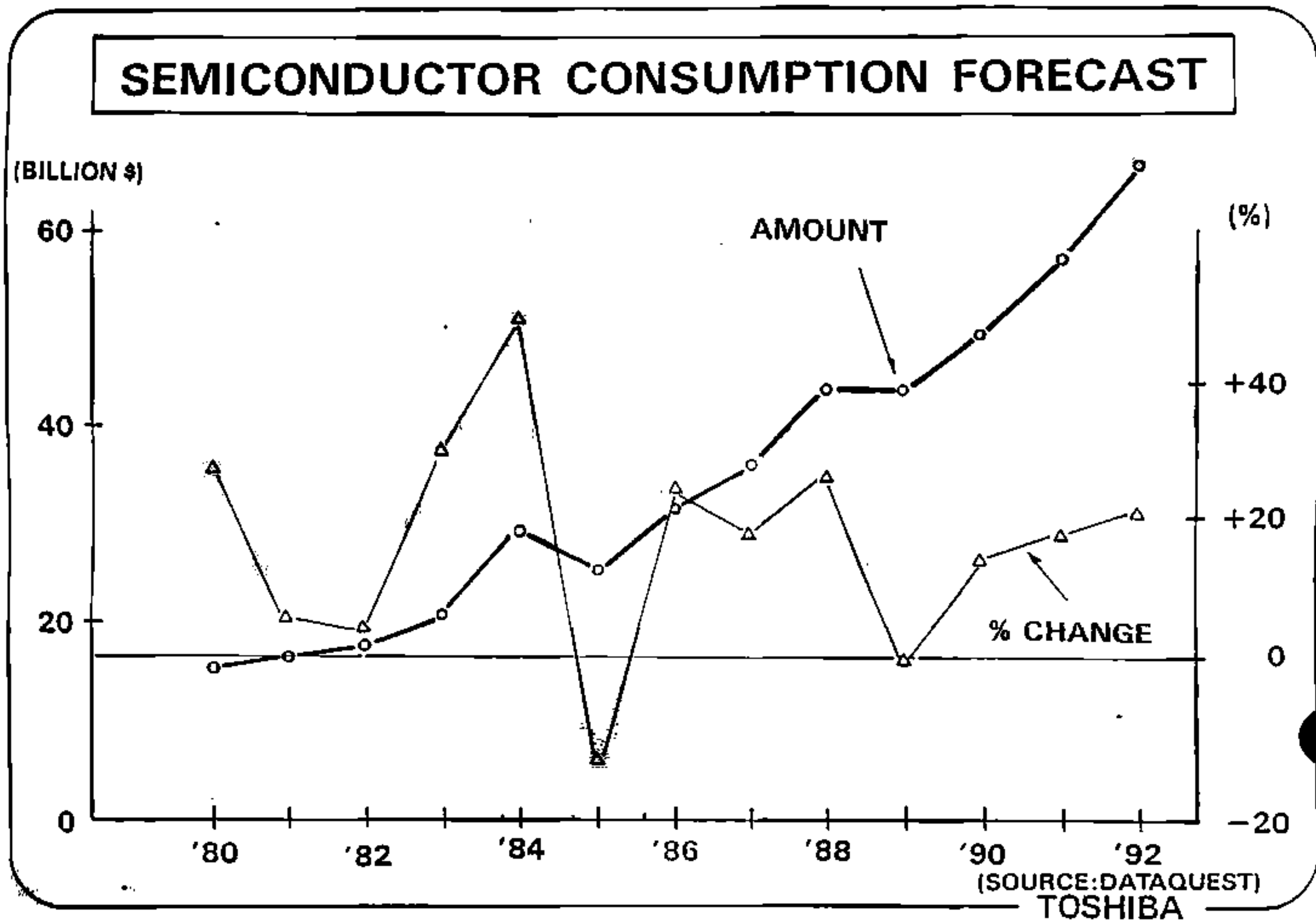

SEMICONDUCTOR CONSUMPTION FORECAST
(BILLION $)
60
40
20
0
AMOUNT
(%)
+40
+20
0
-20
% CHANGE
'80
'82
'84
'86
'88
'90
'92
(SOURCE:DATAQUEST)
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10 KEY BUSINESS AREAS FOR THE 1990'S

1. DIGITAL AV APPARATUS
2. DIGITAL COMMUNICATION EQUIPMENT
3. EXCELLENT COMPUTERS
4. SMART-CARDS
5. ELECTRONIC STILL CAMERAS
6. AUTOMOTIVE ELECTRONICS
7. HOME SECURITY APPARATUS
8. HEALTH CARE EQUIPMENT
9. PORTABLE TERMINAL
10. NEW ENTERTAINMENT

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10 KEY PRODUCTS FOR THE 1990'S

1. MEGA-BIT MEMORY
2. HIGH END CPU/MPR
3. VERY HIGH SPEED LOGIC
4. CCD AREA SENSORS, LINEAR SENSORS
5. LASER DIODES
6. ASIC/CSIC
7. ASMIC
8. ASSP (APPLICATION SPECIFIC STANDARD PRODUCTS)
9. BI-CMOS DEVICES
10. SMART POWER

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THE COMPARISON OF GROWTH RATE
(JAPAN)

	1986	1986/1976	AGR	AGR OF GNP ‖ 1
GNP	330.8	199	7.1	1
ELECTRONICS INDUSTRY	17.7	302	11.7	1.6
SEMICONDUCTOR INDUSTRY	2.3	513	17.8	2.5

(TRILLION YEN)

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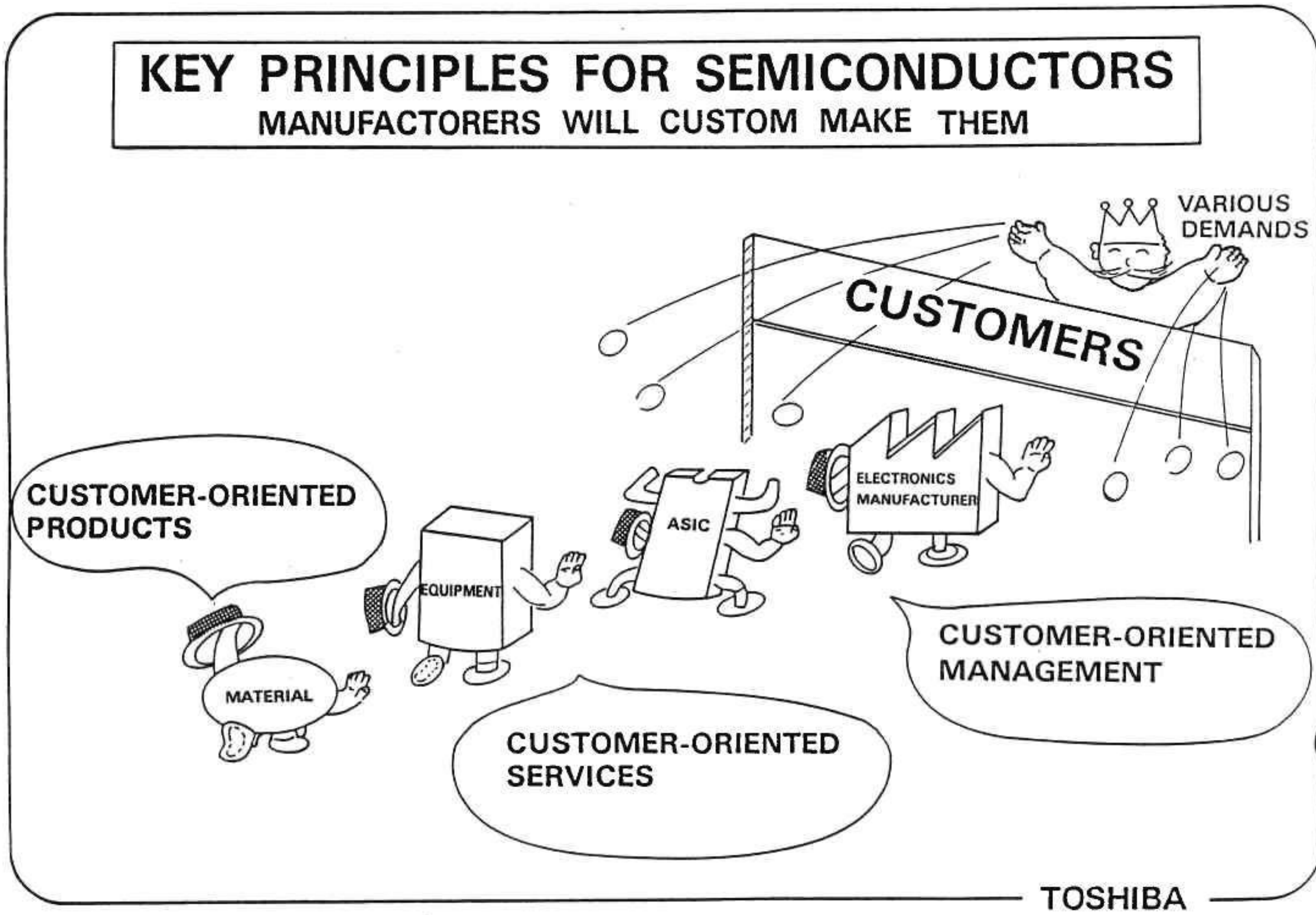
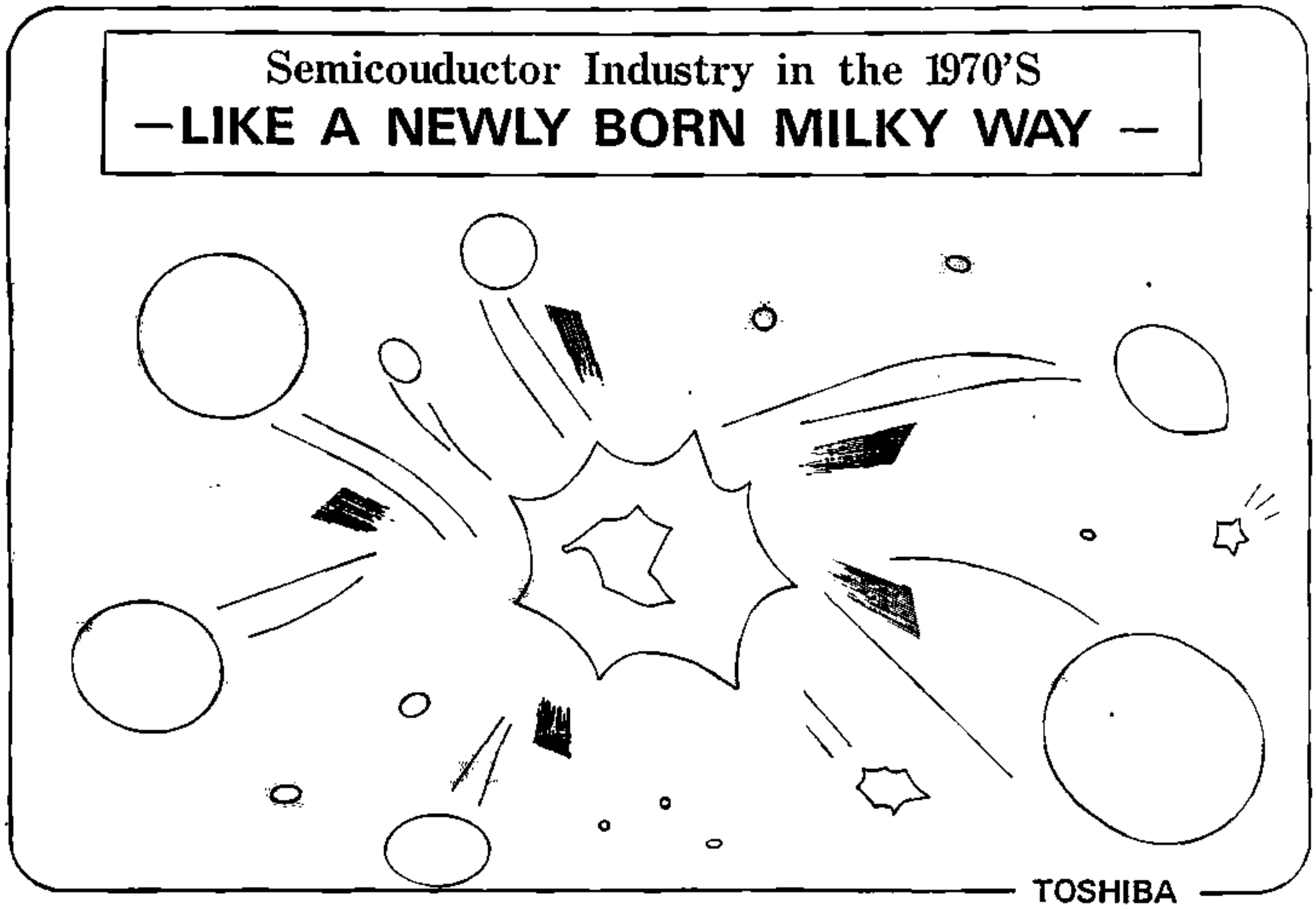
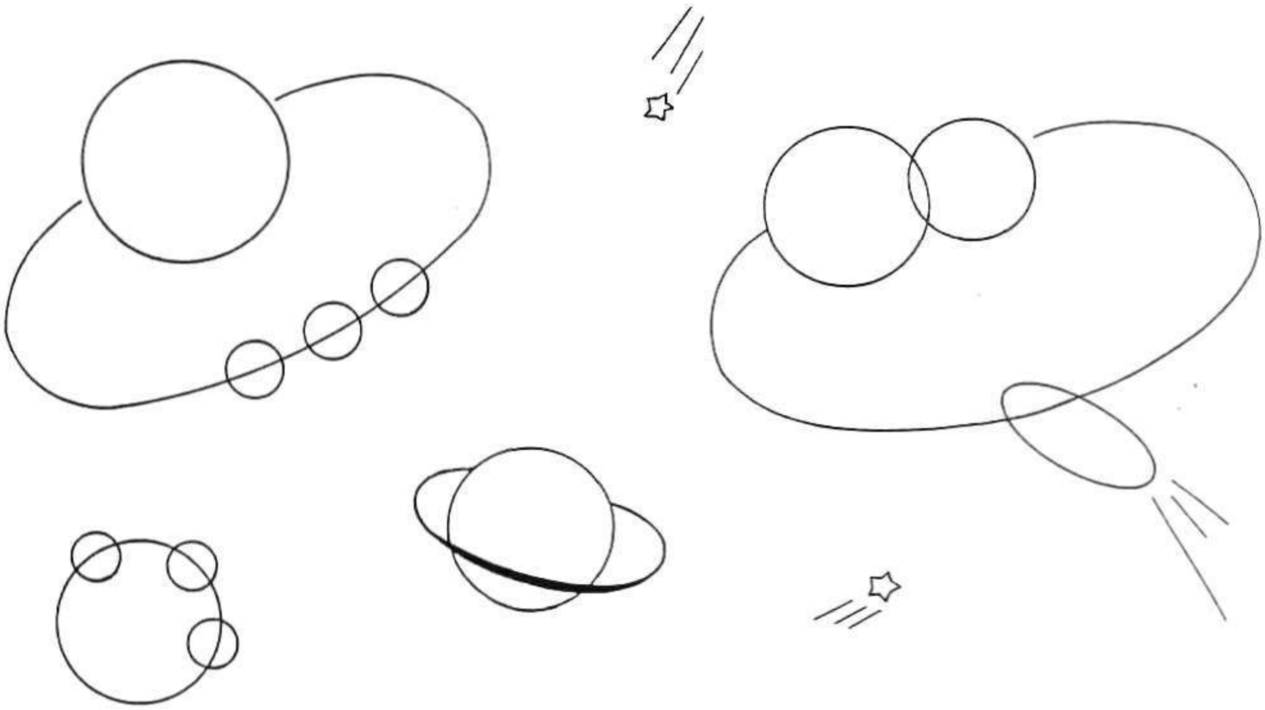

KEY PRINCIPLES FOR SEMICONDUCTORS
MANUFACTORERS WILL CUSTOM MAKE THEM
VARIOUS DEMANDS
CUSTOMERS
CUSTOMER-ORIENTED PRODUCTS
ELECTRONICS MANUFACTURER
ASIC
EQUIPMENT
MATERIAL
CUSTOMER-ORIENTED MANAGEMENT
CUSTOMER-ORIENTED SERVICES
TOSHIBA


Semicouductor Industry in the 1970'S
—LIKE A NEWLY BORN MILKY WAY —
TOSHIBA

Semicouductor Industry in the 1980'S

– SOME BIG STARS START MAINTAINING THEIR ORDER –



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THE GOAL OF THE 1980'S

1. MAKING STEADY CAPITAL INVESTMENT

2. TARGETING MOS MEMORY
   AS FLAG SHIP MERCHANDISE

3. REALIZING THE EXPERIENCE CURVE THEORY

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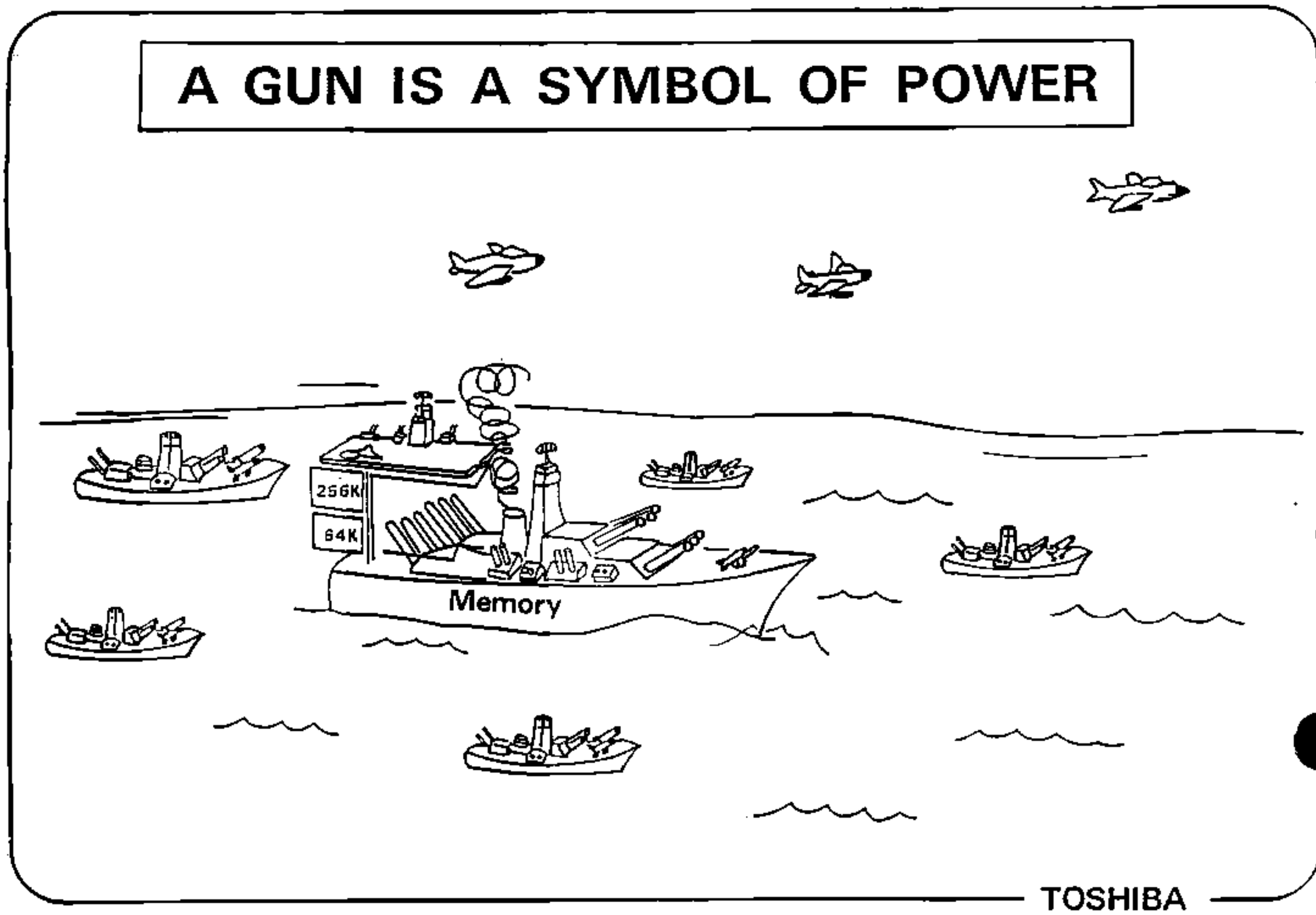
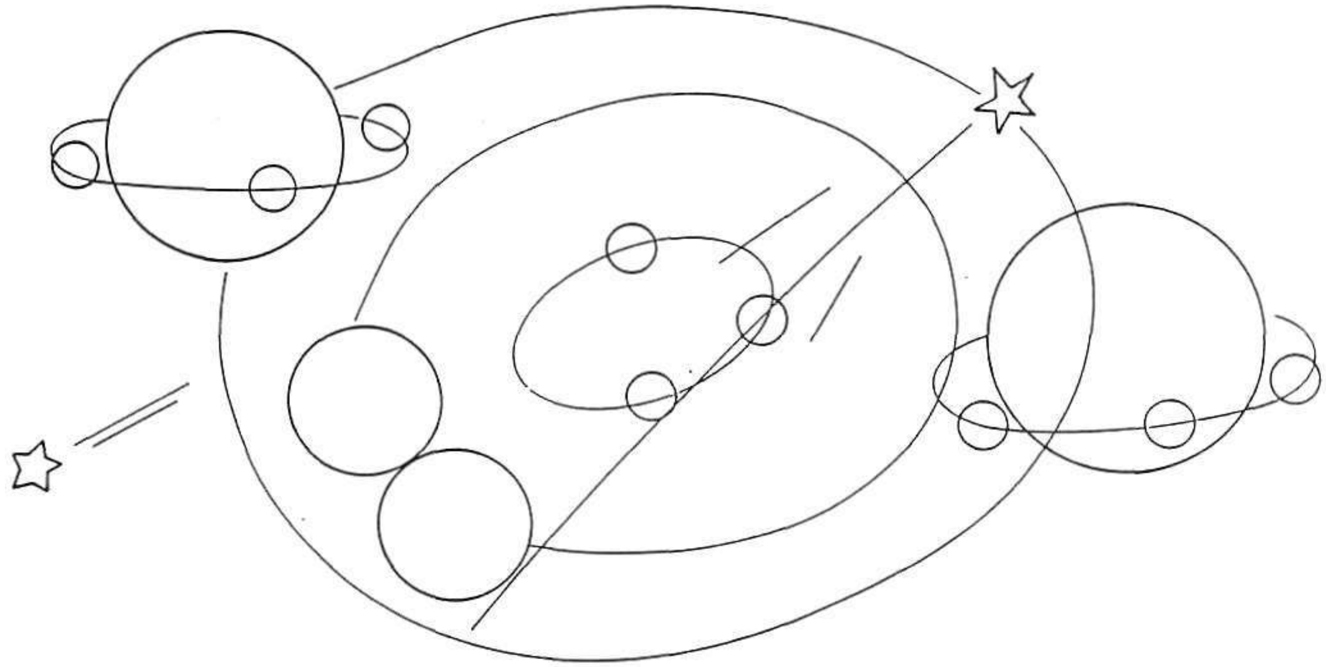

A GUN IS A SYMBOL OF POWER
256K
64K
Memory
TOSHIBA

Semicouductor Industry in the 1990'S

— SEVERAL BIG ONES WILL GLOW —



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WORLDWIDE SEMICONDUCTOR MARKET IN 1986

	MARKET SIZE	U.S	JAPANESE	EUROPEAN	ROW
WORLD	30,311M$	40%	47%	11%	2%
NORTH AMERICA	10,003	77	15	7	1
JAPAN	11,821	8	91	1	0
EUROPE	5,759	46	13	41	—
ROW	2,728	26	48	13	13

(SOURCE:DATAQUEST)

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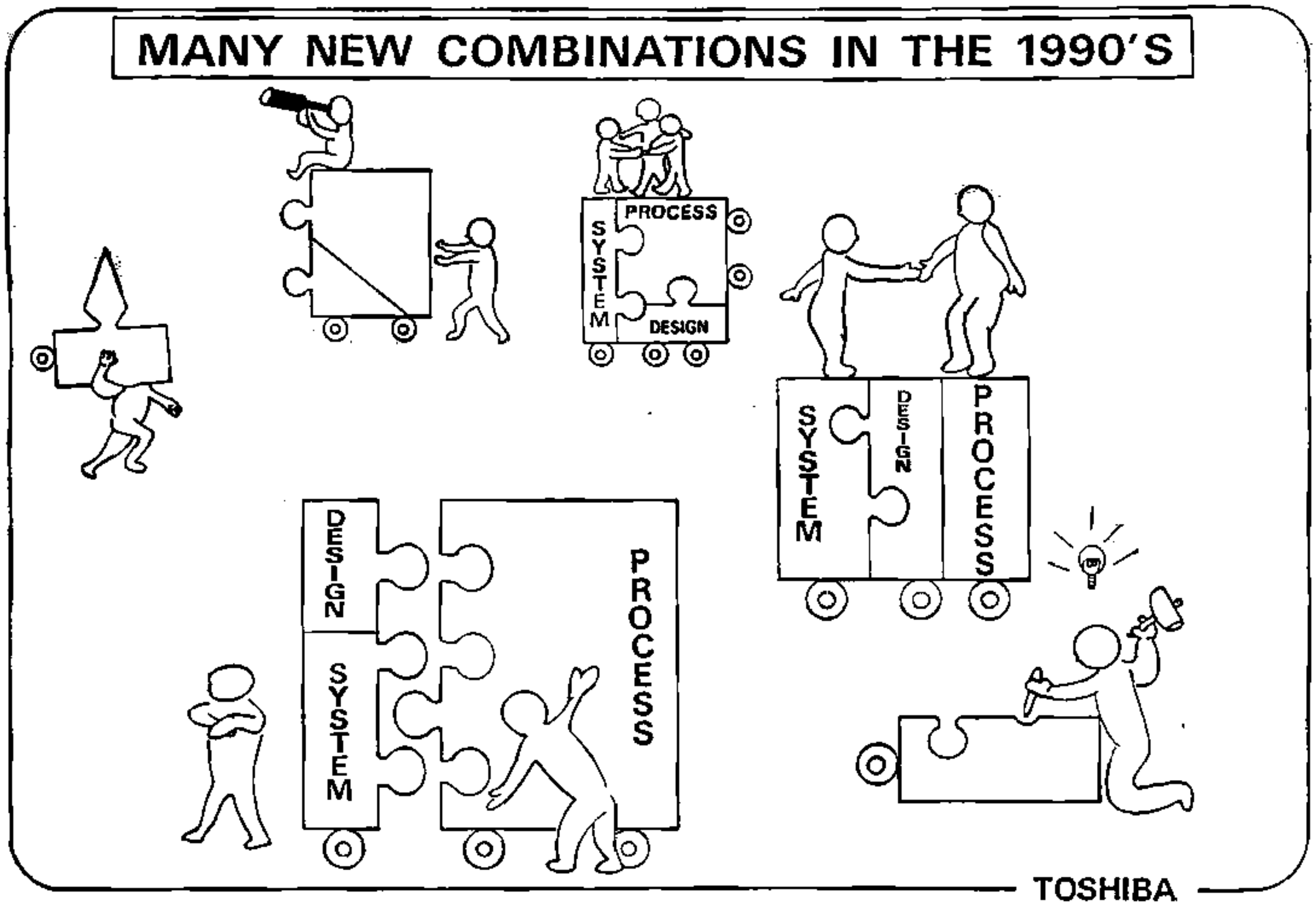

MANY NEW COMBINATIONS IN THE 1990'S
PROCESS
SYSTEM
DESIGN
SYSTEM
DESIGN
PROCESS
DESIGN
SYSTEM
PROCESS
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THE STYLE OF SEMICONDUCTOR MANUFACTURING FOR THE 1990'S

1. EXCELLENT HARDWARE
   VERY HIGH-GRADE PROCESS
2. EXCELLENT SOFTWARE
   PRODUCTION CONTROL
   BY THE COMPUTER & NETWORK
3. EXCELLENT MANAGEMENT
   FLEXIBLE OPERATION

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EXCELLENT HARDWARE

– VERY HIGH-GRADE PROCESS –

1. SUB-MICRON TECHNOLOGY
2. MULTI-LAYER TECHNOLOGY
3. VERTICAL TECHNOLOGY
4. ZERO DEFECT & CONTAMINATION

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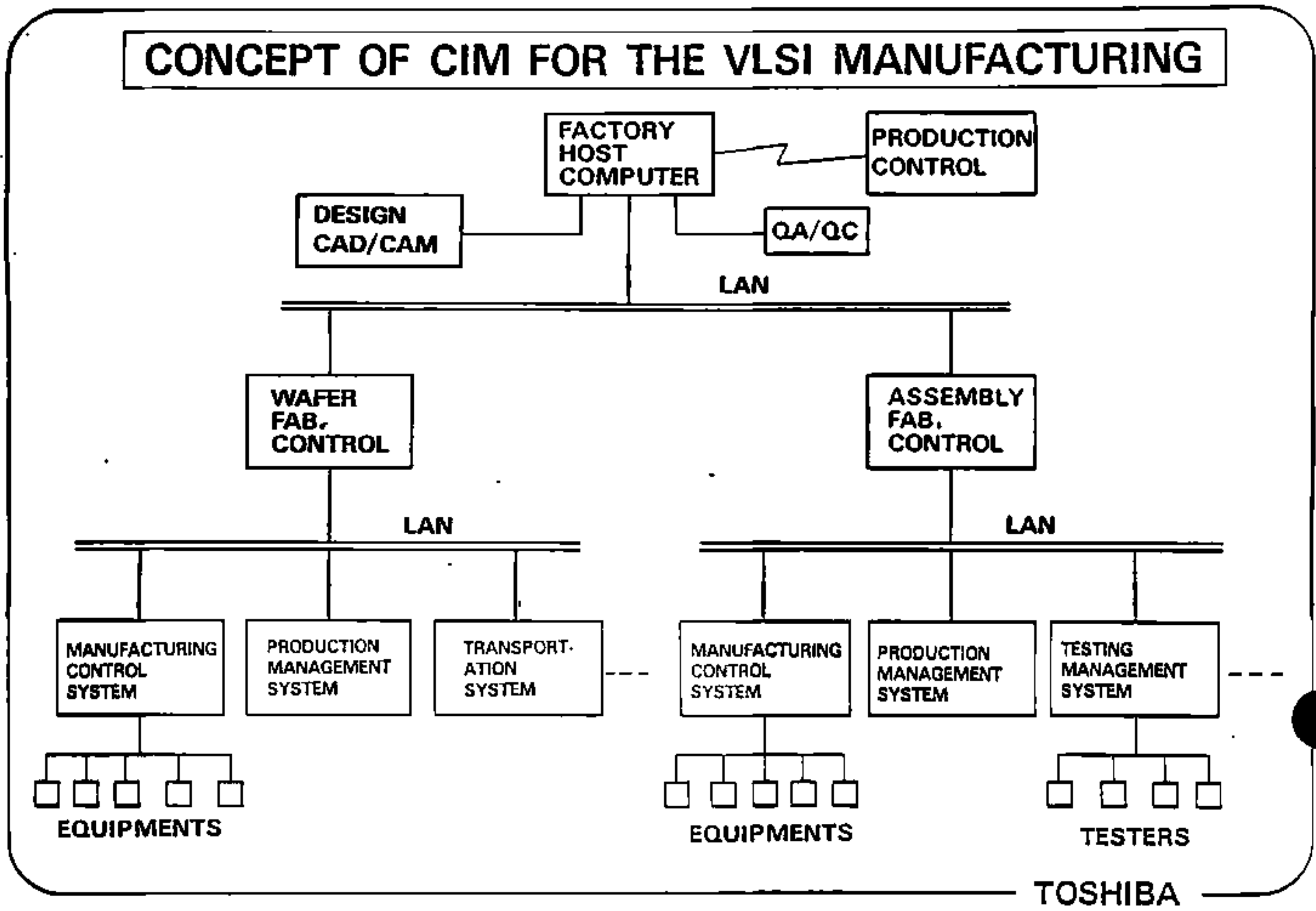
CONCEPT OF CIM FOR THE VLSI MANUFACTURING
FACTORY HOST COMPUTER
PRODUCTION CONTROL
DESIGN CAD/CAM
QA/QC
LAN
WAFER FAB. CONTROL
ASSEMBLY FAB. CONTROL
LAN
LAN
MANUFACTURING CONTROL SYSTEM
PRODUCTION MANAGEMENT SYSTEM
TRANSPORT-ATION SYSTEM
MANUFACTURING CONTROL SYSTEM
PRODUCTION MANAGEMENT SYSTEM
TESTING MANAGEMENT SYSTEM
EQUIPMENTS
EQUIPMENTS
TESTERS
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EXCELLENT MANAGEMENT

— FLEXIBLE OPERATION —

1. TOP-DOWN MOVEMENT
IMPLEMENTATION OF
CONCEPTS AND TECHNIQUES

2. BOTTOM-UP MOVEMENT
TOTAL PRODUCUCTIVITY MOVEMENT

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PROSPECTS FOR THE 1990'S

1. DEVELOP AN EXCELLENT PROCESS
   MEMORY IS TECHNOLOGY'S DRIVER

2. PERSIST IN SYSTEMIZATION
   CAD, DESIGN CENTER

3. CC & C
   WITH CUSTOMER, WITH MANUFACTURER

TOSHIBA

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A WINNING STRATEGY FOR U.S. SEMICONDUCTORS

Edward E. David, Jr.
President
EED Inc.

Dr. David is President of EED Inc., consultants to industry and government on technology and research management. Previously, he was Science Advisor to the President of the United States, Executive Director of Bell Telephone Laboratories, President of Exxon Research and Engineering Company, and Executive Vice President of Gould, Inc. Among Dr. David's many business and professional associations are: the White House Science Council; U.S. Representative to the NATO Science Committee; New Jersey Governor's Commission for Science and Technology; and New York Governor's Commission for Science and Technology. He has received many awards and holds 12 honorary degrees. Among these are degrees from the Polytechnic University, Rensselaer Polytechnic Institute, Rutgers University, New Jersey Institute of Technology, and the University of Pennsylvania.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
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Semiconductors' Midlife Crisis

Semiconductor Manufacturing: Strategic Issues for the 1990s

DR. EDWARD E. DAVID, JR.

President
EED, Inc.

A Winning Strategy for Semiconductors.

Edward E. David, Jr.

ABSTRACT

The American semiconductor industry now faces such severe international competition, principally from Japan, that it poses important issues for U.S. national policy. Hitherto, the industry structure - its diversity and number of small players - has been a source of its strength and innovativeness. Now, especially because of sharply rising R & D and equipment costs, it is emerging as a weakness, too. Because of the vital role the industry plays in our economy and national defense, a consensus is emerging in industry and government that considered actions are necessary to improve the industry's competitiveness. The industry has spearheaded several approaches, including the formation of a consortium, which would focus on manufacturing technology. The success of these approaches hinges upon resolve and support by both industry and government. Given such resolve, decision-makers have sufficient options for action to keep the industry competitive.

Dr. Edward E. David, Jr.
President EED, Inc.
Remarks at
Dataquest Semiconductor
Industry Conference
October 21, 1987
As Given

A WINNING STRATEGY FOR THE SEMICONDUCTOR INDUSTRY

No need to tell this audience that the semiconductor industry has been through the ringer. In the last decade Japan's share of the world semiconductor market has risen from 25 percent to 45 percent, while this country's share has shrunk from 60 percent to about 40 percent. Then the cyclical downturn that began in 1984 created a worldwide overcapacity in production, undermining prices and causing widespread downsizing.

The situation has led to a surprisingly strong reaction, much stronger than in previous downturns, of which there have been many. The reason is that this time Japan has been labelled the villain, whereas before domestic competition was seen as the cause. Many people reacted strongly, and one of the strongest expressions of concern came from the Defense Science Board in a report published last April. I myself have been involved in a study by the White House Science Council.

Meanwhile, the Administration negotiated a "voluntary" trade agreement with Japan limiting semiconductor exports to the U.S., and even slapped a short-lived punitive tariff on Japan for dumping. And, in a dramatic display of unity, the semiconductor industry is forming a consortium--Sematech--to invigorate the semiconductor manufacturing equipment suppliers, set standards, and undertake process development.

In my view, we do need extraordinary action to keep our semiconductor industry competitive. Although I distrust Federal intervention in commercial enterprises, I do believe that there is a role for government, too. That role begins first of all with the Defense Department's need for advanced semiconductors at reasonable prices. More about this role and its legitimacy later. I can go further even, and say that the semiconductor industry is a national economic resource, not matched by the many others that have been in trouble over the years.

Now let me look at the way Washington is approaching the problems of the semiconductor industry. There are three broad questions. First, just why is an internationally competitive semiconductor industry so important that we should single it out? Then, why is the industry in trouble, and, specifically, how and why is it, as it is, falling behind in manufacturing? Finally, what should the industry and the government actually do to make the semiconductor industry more competitive--and, specifically, what about the role of Sematech? In the end, you will find that I do think with resolve on the part of government and industry, we will craft a winning strategy.

IMPORTANCE OF A COMPETITIVE SEMICONDUCTOR INDUSTRY

Now why is our semiconductor industry so important? In Washington today, one of the most telling answers is that semiconductors are essential to our national security. Prudence dictates that the U.S. not depend on foreign suppliers, even the friendliest ones, for the integrated circuits that go into our advanced weapons systems. Yet we do: the Defense Science Board points out that in the newest systems about to be deployed "several tens of percent" of the semiconductors are either entirely made, or packaged and tested, abroad.

Some people suggest that we can solve that problem by stockpiling chips. We can stockpile routine devices and parts, but we can't stockpile tomorrow's integrated circuits, nor can we even count on getting advanced products early. Remember, we are dealing mainly with vertically integrated foreign suppliers. Those suppliers will want to use their most advanced chips in their own systems before exporting them to others. Meanwhile, our designers would lose immediate access to leading edge technology.

What's more we can't afford solutions that fit military needs alone. The days are long gone when military programs drove technological progress in semiconductors. Volume production is the key to leadership in semiconductors, and today commercial applications vastly outnumber military ones. The U.S. military accounts for only about 10 percent of the U.S. semiconductor market. So we reach the somewhat surprising conclusion that military leadership in semiconductors depends on commercial leadership in semiconductors. Should the commercial industry move abroad, domestic military production would have to take place in wildly expensive dedicated facilities operating at low volume--not unlike the military shipbuilding industry.

The second most telling argument about the semiconductor industry in Washington is that a strong semiconductor industry is vital to our economic growth and to creating not just jobs, but high-quality jobs. Technological innovation in semiconductors is the dynamo behind every one of the high technology, high value-added industries that we have been depending on to drive our economy and our exports.

WHY THE SEMICONDUCTOR INDUSTRY HAS FALLEN BEHIND

The Defense Science Board found that Japan now leads the U.S. industry in 12 out of 25 basic semiconductor technologies.

In almost all cases, the culprit is weakness in manufacturing. How and why could we let this happen?

The macroeconomic causes are well-known, because they have affected a wide swath of industry. Let me just name some of them: high U.S. capital costs, anti-investment tax policies, the mushrooming Federal deficit, misguided export controls, perverse product liability laws and, until recently, the Government's lax attitude toward protecting intellectual property. You've heard about all these before.

However, the U.S. semiconductor industry has some specific structural problems, not necessarily shared by the broad sweep of industry. Ironically, one of the greatest strengths of the U.S. semiconductor industry has also turned into one of its greatest weaknesses. Our merchant industry is highly entrepreneurial, highly innovative . . . and highly fragmented.

Our industry is full of niche players. Few or none are vertically integrated, unless you count IBM and AT&T. Most recent start-up companies design here and manufacture abroad. Further, unlike all four major Japanese semiconductor companies, our merchant companies have no guaranteed internal markets; they can't use semiconductors as loss leaders, or as tools for keeping their companies' end products and systems at the leading edge. They have less staying power in downturns. The industry's structure exacerbated another problem as well--namely, that R&D

and capital investment are soaring, while revenues are not keeping up.

We now know that when the U.S. lost the consumer electronics business, it was a fateful blow. In the 60s and 70s, consumer electronics turned into a manufacturing prize, now accounting for 20-to-25 percent of the entire world semiconductor market, and over 50 percent of the Japanese market. My friends at AT&T like to point out that for every laser they build into one of their advanced lightwave transmission systems (1.7 gigabits/sec), the Japanese put over a thousand lasers into CD players. Likewise, they were learning how to design and manufacture reliable circuit boards in high volume using integrated circuits, long before U.S. producers had to. And the Japanese could do such pioneering work under a much more forgiving regime than the ones imposed by systems developed for telecommunications, mainframe computing or the military. This situation helped bring about our decline in semiconductor manufacturing, even though we still lead in logic and design.

ANSWERS AND STRATEGIES

What are the answers? Obviously, some of the most useful steps would would involve balancing the Federal budget, boosting the savings rate, bringing down interest rates . . . all those good things that everyone, including the politicians, knows about, talks about, and can't seem to do much about. For sure, we need to make clear that we won't tolerate the protectionism of others; we need to relax the antitrust laws further; we need to extend and expand the R&D Tax Credit; and so on.

To its credit, the Federal Government has already taken steps to meet specific industry needs, notably the need for strong support in fundamental science and engineering. For example, the National Science Foundation is establishing a network of engineering research centers at universities around the country that include a focus on semiconductors. We may need more such programs, including some that concentrate on manufacturing. Government, with industry, can at the same time work to improve university curricula in manufacturing.

Education is critical--from advanced doctoral programs down to the training of highly skilled technicians. The latter are especially needed in the industry, since operation of a production process demands a high sensitivity to process control and equipment maintenance.

I have already mentioned the structural problems of the industry. Much more restructuring is called for. The Government should not manage this restructuring; the marketplace and the individual players should. But the Government certainly should not interfere through overzealous use of the anti-trust laws. My assignment here is to emphasize the Sematech proposal and assess its viability. But let just say that, if we're going to shape a winning strategy for the semiconductor industry, new horizontal and vertical alliances will play at least as important a role, if not a more important role, than Sematech. I'm talking about mergers such as we've seen between AMD and Fairchild, and about vertical alliances of the sort we've seen between AT&T and Western Digital or between IBM and Intel.

SEMATECH

But let me focus now on our semiconductor industry's newest plan--Sematech. I gauge the importance of the Sematech proposal by the extraordinary degree of consensus that has emerged about it throughout the industry. The small companies back the idea, but so do big merchant houses like Intel and Motorola, and big captive producers like IBM and AT&T.

Sematech's first goal is to close the gap that has opened up between U.S. and Japanese manufacturing, then to keep the industry competitive. People estimate that the U.S. industry has fallen behind by as much as a year in some sectors. We're not accustomed to playing catch-up, but at least it is easier than pioneering.

The plan calls for the Federal government and the semiconductor industry to split the costs, for a total of $250 million per year over five years. Without describing all details of the proposal, let me just say that the goals are consistent with the need. In particular, there is a clear imperative to foster more cooperation both horizontally and vertically in the industry, and Sematech is a way to do it.

This need is especially acute in regard to the upstream semiconductor equipment industry. The merchant semiconductor industry may be fragmented, but it looks like the center of the Chicago Bears line compared to the 800 or so companies competing in the semiconductor equipment industry. Here, one of Sematech's most important roles can be to foster standardization, economies of scale, and the interworking of manufacturing systems from many vendors so that viable processes emerge.

In analyzing the Sematech proposal, two related issues come to mind: first, do consortia of this kind work, and, second, if they do work, what is the best way for the government to support Sematech and under what conditions?

Some R&D consortia do work. Many people don't realize the fact, but cooperative research programs are actually a very old phenomenon. For example, the Electric Power Research Institute is a consortium of power companies started around 1976 that has produced a number of important innovations, including the so-called Cool Water Plant for high efficiency power production with low pollution.

Many people believe that the U.S. can trace superiority in aerospace to R&D that the Federal Government began funding decades ago through an agency known as the National Advisory Committee for Aeronautics, or NACA. NACA was later folded into NASA.

What's new, perhaps, is the scope of the Sematech proposal, and its overwhelming focus on commercial technology. Outside the U.S., of course, companies and governments have been working together for some time, seeking to establish national or regional supremacy, or at least parity, in technologies they perceive as strategic to their commercial futures. Note that both here and abroad, the most prominent involve information technologies--including the Esprit and Eureka projects in Europe, the Fifth Generation Computer Project in Japan, the Microelectronics and Computer Technologies Consortium in our own country, the Semiconductor Research Corporation, and, of course, Sematech.

It is difficult to generalize about the success of such comprehensive projects. Clearly, much depends on your definition of success. It is safe to say that the higher the expectation, the lower the chances. It is also safe to say that, as in any R&D organization, the chances for success depend utterly on having a clear mission and objectives that the receiving parties understand and accept. My perception is that this is one of Sematech's strongest points, because a broad consensus has developed in the industry about what must be done. But let me make a few observations about other conditions that favor success--which I'll define as a flow of useful technology, and trained people, developed at reasonable cost. Underline "trained people."

For modern R&D consortia, the most cited model is Japan's VLSI program in the 70s, which helped drive the Japanese semiconductor industry to parity and beyond. This prompts the initial observation that such programs work best when playing catchup. The Japanese Fifth Generation Computer project is an attempt to leapfrog current technology, and it is apparently in trouble. For the same reason, I question how Japan's new superconductivity project will fare. Thus, to the degree that we're playing catchup, I think we can say with some confidence that Sematech should help. Proprietary advantages in semiconductor manufacturing will be harder to achieve, especially when by everyone's admission they last only about six months or so.

We can say with some confidence, too, that the movement of and training of people will be critical, in my view more critical than the technology. As a matter of fact, in assessing the Japanese programs, people in the U.S. tend to overestimate the importance of developing technology and underestimate the importance of developing (or training) people. Hitachi, Fujitsu, NEC, and Toshiba realized the greatest benefits from the VLSI program when their own people returned and began innovating in their own laboratories.

The people issue is critical to another sometimes overlooked problem--namely, transferring technology into a consortium for it to develop and adapt on behalf of the members. In this and other ways, a big question mark about Sematech is how the big players will behave--companies like AT&T, IBM, TI, or Motorola. These companies create much of their own manufacturing hardware and software. Won't they be loathe to throw their most advanced proprietary technology into the common pot for Sematech to work on? And how will they behave vis a vis the small equipment and materials suppliers--particularly in the standards-setting process? Will they force events selfishly to their own advantage, or will they compromise on standards and other things for the common good?

My instinct is to believe that a successful consortium must transfer technology in. However, the new Chairman of MCC, Grant Dove, told Congress last summer that the members of MCC do not share their technology with MCC. But Sematech evidently does expect to receive member technology, and one goal of Sematech is to develop manufacturing technology for devices with .5 micron features. Will IBM and AT&T be willing to supply the technology they are already developing for this design rule--including resist, etching and epitaxy systems? If not, the outlook for Sematech is bleak.

As any R&D manager will attest, transferring technology out is hard, too, but clearly it is essential to success. Here we might look to MCC's experience, since MCC is serving a related need. Some reports suggest that MCC has had some trouble getting its member companies to use what it has developed. But let's not overlook what MCC has accomplished. MCC has built up a high quality staff starting from scratch. Dove claims that MCC has formally transferred some 30 new technologies to its owners, which include developments in CAD, packaging, software, and advanced computer architecture. What's more, although MCC lost some of its original members, MCC now enjoys a bigger membership than ever--about 20.

For a final assessment of R&D consortia, let me call on the authority of Al Chynowyth. Al Chynowyth is a vice president of Bell Communications Research, or Bellcore, and he should understand the new trend in R&D consortia as well as anyone. With a budget of more than $1 billion a year, Bellcore is by far the biggest R&D consortium in the world. Al knows about Bellcore, and Bellcore is a member of MCC--a consortium within a consortium. So Al knows the issues with MCC as well.

Al's overall view is that economic trends overwhelmingly favor R&D consortia, but that human attitudes and suspicions get in the way. So the main challenge of running an effective consortium is a management challenge. As Al describes it, the challenge does not look a lot different from managing a central R&D function in a large, decentralized corporation like Exxon. You know the kinds of problems: overcoming geographical and organizational remoteness from the customer; achieving consensus on the work program; and transferring technology that will really make a difference to the owner's business.

Al would, I think, support my view that Sematech deserves an enthusiastic try, Federal support, and even state support where it sets up for business. The next question is how and under what conditions should government extend its support? The original Sematech proposal calls for a flat, no-strings-attached Federal grant of $100 million a year for five years. In this age of accountability, no-strings-attached grants are rare birds, but one might be hatched by Congress for Sematech. Regardless, several alternatives exist, including contracts for specific programs and projects, guaranteed government loans, and . . . well, moral support, but I won't consider that alternative.

The key to sorting out the alternatives is to remember the goal--competitiveness for an industry, nothing less. The Defense Department could fund the effort--in fact, the political situation makes it the only possible Federal source, I think. The chances are very good that Congress will give DOD the funds to support Sematech through a series of specific contracts. We need to ensure that DOD does not turn the program into a defense project, however. To ensure this outcome, DOD needs to formulate requirements that are consistent with commercial applications.

Regardless of the mechanism chosen, the government might insist that Sematech follow a few simple guidelines to keep the players honest, including these. The companies should throw their proprietary production technology into the common pot, sharing it through suitable licensing. The consortium should treat all equipment suppliers even-handedly, big and little. It should play a standard-setting role, but that should mean facilitating consensus about standards, not imposing them. And, not least, Sematech should facilitate the industry's consolidation and restructuring, rather than supporting its continued fragmentation.

SUMMARY AND CONCLUSION

In sum, I think a consensus is emerging in this country that we must do something extraordinary to strengthen our semiconductor industry and make it more competitive. The Congress is even convinced to the extent of taking action. Sematech is the industry's chosen instrument to bring itself back to the competitive edge. Yet there are doubts that Sematech can be effective, even doubts within the industry itself. Consortia are not our usual way of competing. Depite these doubts, Sematech is worth a vigorous try if the major players in the industry are committed. The measures of that committment, beyond money, are the caliber of people they are willing to second to Sematech, the level of technology committed to Sematech by its principal members, and the willingness of their managements to engage in a common standards setting process. If that committment is there, then the Federal government, through DOD, should support the effort in its own interest; namely, that of having an industrial base to produce leading edge semiconductor devices economically.

But even a successful Sematech would be only one string to the bow required to project and sustain semiconductor competitiveness. Education of future technological and managerial leaders, and training of high skill technical operators is another. Especially critical will be enlightened private sector efforts to restructure and forge horizontal and vertical alliances in the industry. The goal is to achieve economies through production volume while maintaining our traditional inclinations toward innovation in technology. There are other steps but let me stop here.

In closing let me just note that several knowledgeable people, both observers and participants in the scene, say that it is too late. Some few years hence, it is said, there will be no U.S. semiconductor industry. Let's not let that happen.

# # #

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SEMICONDUCTOR PROCESSING EQUIPMENT COMPETITIVE ISSUES
SEMATECH--POTENTIAL IMPACT

Larry L. Hansen
Executive Vice President
Varian Associates, Inc.

Mr. Hansen is an Executive Vice President of Varian Associates, Inc., and is head of the Office of Technology and President of the Semiconductor Equipment Group. Mr. Hansen started Varian's semiconductor equipment business in 1970. He has served on the Board of Directors of the Semiconductor Equipment and Materials Institute (SEMI) since 1976, and was president of that organization in 1981 and 1982. He has also served as Chairman of the Department of Commerce Technical Advisory Committee on Semiconductor Manufacturing Equipment. Mr. Hansen received a B.S. degree in Electrical Engineering from Utah State University and a Certificate in Business Management from the University of Utah.

Dataquest Incorporated
SEMICONDUCTOR INDUSTRY CONFERENCE
October 19-21, 1987
Phoenix, Arizona

Semiconductors' Midlife Crisis

Semiconductor Manufacturing: Strategic Issues for the 1990s

LARRY HANSEN

Executive Vice President
Varian Associates

varian

SEMICONDUCTOR EQUIPMENT

EQUIPMENT REQUIREMENT TRENDS

- MORE AUTOMATION
- MORE PRECISE MECHANICAL CONTROL
- BETTER TEMPERATURE CONTROL
- MORE FLEXIBILITY
  - PROCESS
  - WAFER SIZE
- SMALLER SPACE NEEDS
- LOWER PARTICULATES
- BETTER RELIABILITY
- LOWER COST OF OWNERSHIP FOR USER

varian

SEMICONDUCTOR EQUIPMENT

TECHNOLOGY TRENDS

- **SMALLER DIMENSIONS**
- **COMPLEX STRUCTURES**
- **MULTI-LAYER STRUCTURES**
- **LOW TEMPERATURE PROCESSES**

varian

SEMICONDUCTOR EQUIPMENT

COMPETITIVE SITUATION

- MANY U.S. COMPANIES HAVE BEEN WEAKENED
  - INVESTMENTS ARE DOWN IN SEMICONDUCTOR EQUIPMENT
- JAPANESE EQUIPMENT SUPPLIERS HAVE BEEN HURT BADLY BY THE RECESSION
  - INVESTMENTS IN ALTERNATE MARKETS
  - JAPANESE COMPANIES ARE BETTER FINANCED THAN U.S. COMPANIES
- EUROPEAN EQUIPMENT SUPPLIERS HAVE ENJOYED A REAL ECONOMIC ADVANTAGE
- OVERALL COMPETITIVE SITUATION HAS NOT CHANGED MUCH IN THE PAST YEAR

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SEMICONDUCTOR EQUIPMENT

R & D COSTS

- EQUIPMENT AND PROCESS COMPLEXITY
- RELIABILITY REQUIREMENTS
- PROCESS DEVELOPMENT
- PROCESS INTEGRATION
- SOFTWARE DEVELOPMENT AND SUPPORT

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SEMICONDUCTOR EQUIPMENT

INDUSTRY OVERVIEW

- FUTURE TECHNOLOGICAL ADVANCES ARE IN DOUBT
  - SMALL COMPANIES CANNOT INVEST
  - LARGE COMPANIES WILL NOT INVEST
- REQUIRED INVESTMENTS ARE VERY LARGE IN SOME PRODUCT CATEGORIES

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SEMICONDUCTOR EQUIPMENT BUSINESS CONDITIONS

PRESENT CONDITIONS

- BUSINESS RECESSION
- PRICING PRESSURES
- SKYROCKETING R & D COSTS
- PROCESS DEVELOPMENT COST BURDENS SHIFTED TO EQUIPMENT MAKERS
- SERVICE AND SUPPORT COSTS

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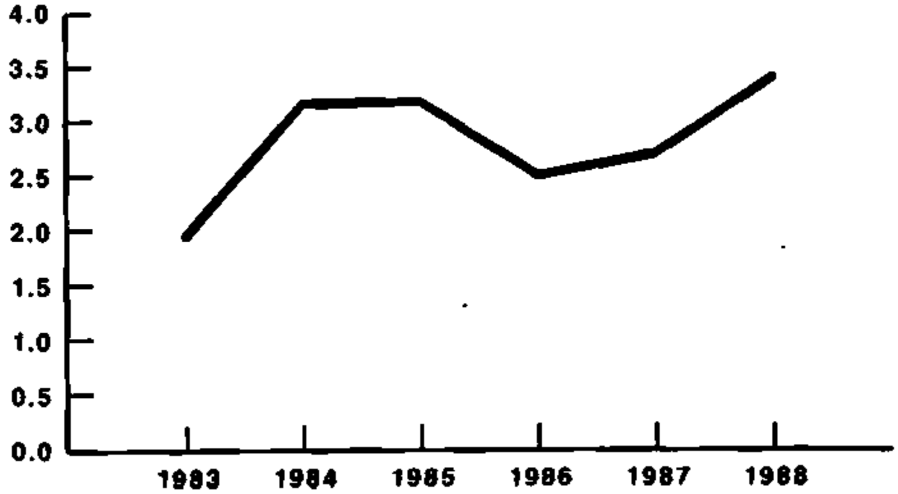
SEMICONDUCTOR WAFER FABRICATION EQUIPMENT SALES
($ BILLIONS)



SEMICONDUCTOR WAFER FABRICATION EQUIPMENT 1986 - 1987 ($ MILLIONS)

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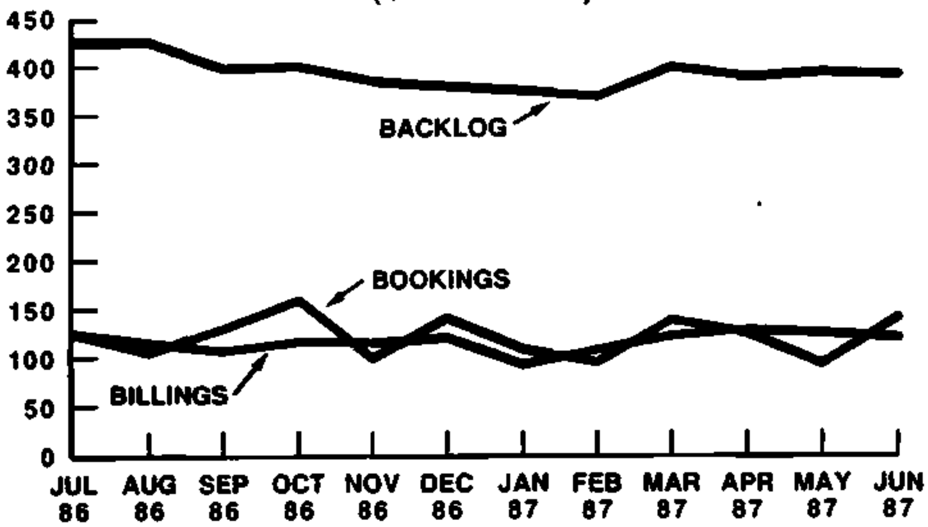

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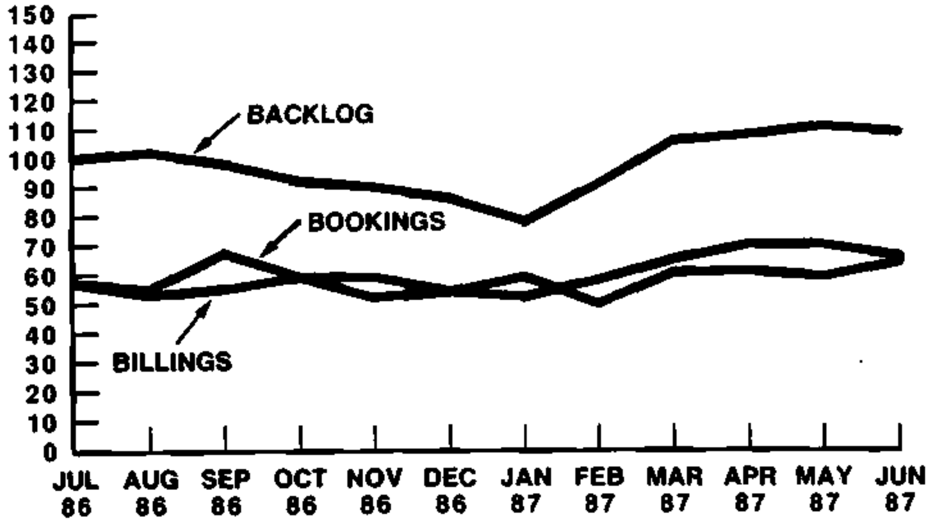
SEMICONDUCTOR MATERIALS 1986 - 1987 ($ MILLIONS)



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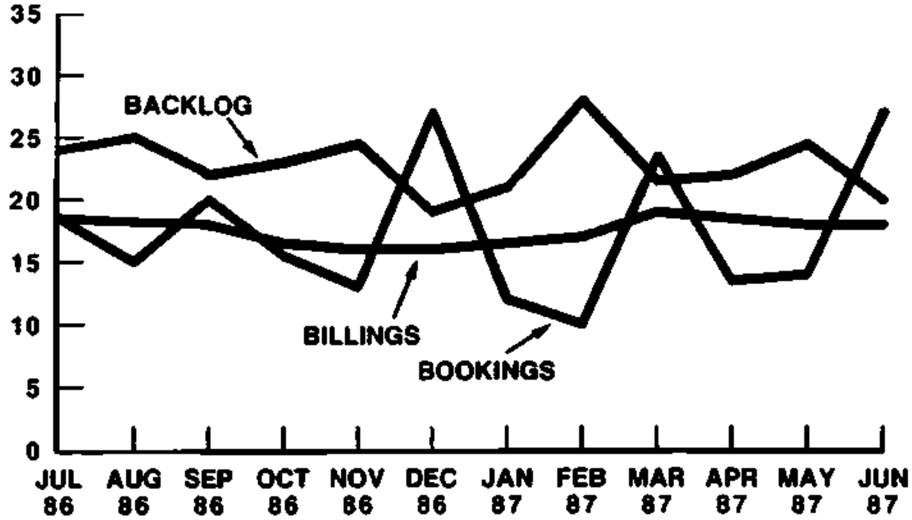
SEMICONDUCTOR ASSEMBLY EQUIPMENT
1986 - 1987
($ MILLIONS)



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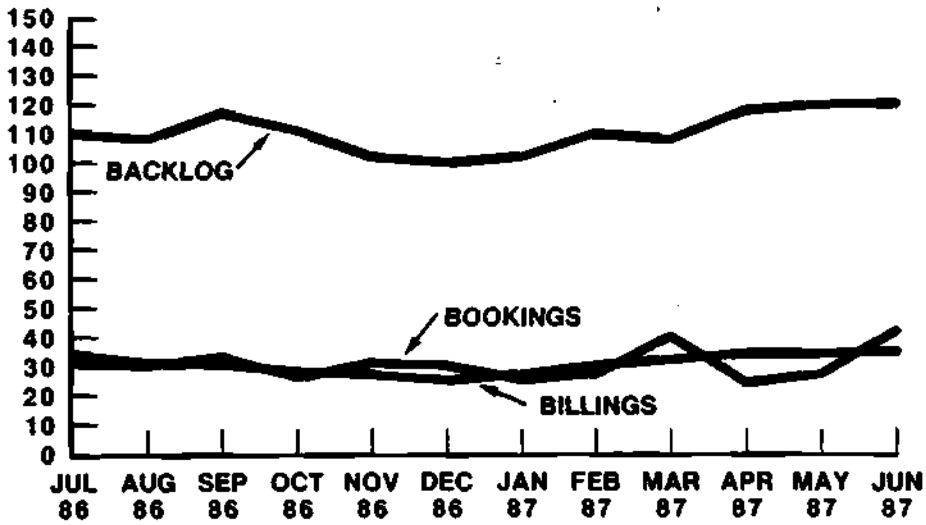
SEMICONDUCTOR TEST EQUIPMENT
1986 - 1987
($ MILLIONS)



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SEMATECH

AN OPPORTUNITY FOR CHANGE

- **A BASIC OBJECTIVE - TO STRENGTHEN THE SEMICONDUCTOR EQUIPMENT AND MATERIALS INDUSTRY**
    - **R & D FUNDING**
    - **GENERIC PROCESS DEVELOPMENT**
    - **PROCESS INTEGRATION**
    - **TECHNOLOGY LEVELING**

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INTERNATIONAL COMPETITION IN ADVANCE PROCESSING

Peter H. Rose
President
Semiconductor Equipment Division
Eaton Corporation

Dr. Rose is General Manager of the Semiconductor Equipment Division of Eaton Corporation. Previously, he was President and founder of Nova Associates, which was acquired by Eaton in 1980. Nova was formed to design and sell high-current ion implantation equipment. Before starting Nova, Dr. Rose was founder and President of Extrion Corporation, now Varian/Extrion. Dr. Rose came to the United States from England as a Fulbright Scholar and Research Associate at Massachusetts Institute of Technology. He spent the early years of his career as a scientist at High Voltage Engineering, and later became President of its subsidiary, Ion Physics Corporation. Dr. Rose received a Ph.D. in Physics from the University of London and has more than 160 publications in nuclear, atomic, and accelerator physics. He received the SEMMY award for developments in semiconductor processing equipment in May 1986.

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Semiconductors' Midlife Crisis

Semiconductor Manufacturing: Strategic Issues for the 1990s

DR. PETER H. ROSE

President
Semiconductor Equipment Division
Eaton Corporation

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International Competition in Advanced Processing

Peter H. Rose, President
Semiconductor Equipment Division
Eaton Corporation

Just as it does now, the future of the semiconductor industry will depend on specialized new materials primarily created by surface modification and the availability of process equipment. The trend will be towards smaller structures embodying different combinations of electronic and optical devices. The processing of the materials needed to make these devices is very difficult and it usually takes years to industrialize a laboratory breakthrough. The fabrication procedures must be capable of controlling material interactions at submicron resolution. High and low energy ion and laser beams, and plasmas as well as epitaxial growth techniques have emerged as essential technologies capable of doping, selective etching or deposition, and of controlling patterning on a submicrometer scale.

A report sponsored by the National Materials Advisory Board entitled "Advanced Processing of Electronic Materials in the United States and Japan" was published in 1986. The author of this publication was privileged to be one of the members of the team that prepared this report, which gives a state-of-the-art comparison of the strengths of the United States and Japan and this talk makes abundant use of it. In the short time since this study was written there has, of course, been technical progress in both countries, but the competitive balance has remained much the same. This presentation will review the situation and emphasize any important those changes that have occurred since 1986 known to the speaker.

Future devices will require new patterning techniques, materials and structures. To make useful developments and to understand what needs to be done requires a considerable investment in R&D which is beyond the individual means of most United States semiconductor manufacturers. Although United States equipment vendors continue to be innovative the lack of coupling with process R&D must in the long run be detrimental.

The United States is strong in University and to a lesser extent in Government Laboratory research. Unfortunately, this research is not close enough to the requirements of the manufacturing processes on which the semiconductor maker depends and needs to influence. To put it another way, the research is not being done to satisfy the commercial needs of a company and it is, therefore, not surprising to find R&D is applied more effectively in Japan where the research is mostly done by semiconductor manufacturers. Some of the processing areas in which Japan appears to lead are discussed in Appendix I which was taken from the NAS Report. These processing areas are vital to the chip manufacturer.

In summary, the future of the United States semiconductor processing equipment industry does not look good. As United States leadership in processing technology declines, so does the technology resource available to processing equipment manufacturers. The result is less competitive equipment and an increasing disadvantage relative to foreign competition. As a result, equipment manufacturers are more vulnerable to competition than their United States customers who can (for a while?) buy equipment from overseas. It should not be necessary to say the demise of equipment vendors would be a trajedy for the United States.

Appendix I - Comments on Key Technologies.

"But what of the key technologies of the future? Submicrometerscale device structures require low-temperature depositions and machining techniques that have spatial definition approaching the atomic scale. Optoelectronic devices require novel combinations of materials and processing techniques to create new device structures. Our assessment is that Japan has within the past two years entered into a stage of accelerated development relative to United States activity. This development activity ranges from the materials scientist to the equipment manufacturer. In the following we list the areas in which we believe United States research and development are lagging behind Japan's.

- Microwave Plasma Processing. Radio-frequency (RF) plasma etching and deposition techniques are widely utilized in present-day VLSI circuit fabrication. The Japanese have developed microwave plasma systems that have significant advantages over RF techniques. These microwave systems provide low-temperature, damage-free etching and deposition capabilities, characteristics that are considered crucial for future devices. This technology is sufficiently developed so that implementation is imminent.

- Lithography Sources. The limit of pattern resolution for optical lithography in current large-scale silicon processing is about 0.5um. The resolution limits arise with present optical sources because of the wavelength limitations dictated by the shortest wavelengths allowed by refractive optics. Advances in the lithographic process require the development of higher resolution. Several Japanese companies are developing X-ray lithographic sources in the form of compact synchrotron radiation sources compatible with device processing.

- Electron and Ion Microbeams. Electron beams are important for the generation of optical masks and direct writing of circuits. The Japanese are now a major force in this equipment market. Finely focused ion beams are more versatile in that they can be used for direct writing and increased resolution, micromachining and etching, and direct implantation without a mask. Japan now leads in the development and use of this emerging technology and is the leading supplier of focused ion beam systems.

- Laser-Assisted Processing. Present circuit processing technologies for etching and thin film deposition do not employ laser sources to enhance reaction rates. Researchers in the United States and Japan are exploring a wide range of applications of lasers and incoherent light sources for low-temperature processing. Although this field is still in the exploratory stage, the potential for new discoveries and improvement of low-temperature CVD techniques is great.

- Compound Semiconductor Processing. GaAs is a potential candidate for the replacement of silicon in some applications that require increased speed and reduced power consumption. In spite of the advantages, application is held up by many processing difficulties. It would appear that Japanese laboratories already have a better understanding of the entire spectrum of processing steps for GaAs, from material growth to self-aligned gate implantations.

- Optoelectronic Integrated Circuits. The successful integration of electronic and optical properties in a single structure is of considerable importance. Complex compound semiconductor materials are required, and the difficult processing problems can only be solved by the most sophisticated techniques. One particularly innovative Japanese approach is the integration of sequential processing steps into one UHV processing system to fabricate complete structures.

- Three-Dimensional Circuits. Novel device configurations can be realized with the stack of silicon active layers. This is being accomplished in Japan using scanned laser or electron beam sources to recrystallize silicon films on insulating layers. Although it is recognized by the Japanese researchers that this work is very exploratory, benefits are expected in terms of new processing technologies and new device architectures."

INTERNATIONAL COMPETITION
IN
ADVANCED PROCESSING

Peter H. Rose, President
Semiconductor Equipment Division

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CAN ANYTHING BE DONE?

Until There Is A Change In Policy And Culture The United States Team Can Continue To:

- **Improve Efficiency And Quality And Reduce Costs Of Manufacture**
- **Provide Incentives To Divert Innovation To Manufacturing**
- **Satisfy The Customer In Terms Of Price, Reliability, And Performance And Automation**
- **Work With Customers To Understand Their Problems**
- **Keep The R&D Activities At As High A Level As Possible**

A POSSIBLE SCENARIO

It Is Easy To See A Scenario In Which All The Best Semiconductor Equipment Companies Are Foreign Or Partly Owned By Foreigners By The Year 2000.

E·T·N

A FURTHER TEST CASE

- The best research on superconductivity is going on in the United States
- Whether it is commercialized here or not will be a test of the United States system

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Equipment

PROCESS REQUIREMENTS

- Future devices must have patterned structures with sub-micrometer lateral and vertical dimensions to achieve the desired speeds and packing densities and many will require entirely new materials, material combinations and device configurations.

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Semiconductor Equipment

COMPETITIVE SITUATION

The United States Is Ahead In:

- **Ion Implantation**
- **Thin Film Epitaxy (CVD, MBE, MOCVD)**
- **Film Deposition And Etching**

EATON
Semiconductor
Equipment

COMPETITIVE SITUATION

Japan Is Ahead In:

- **Optical Lithography ?**
- **Microwave Plasma Sources**
- **Electron And Ion Micro Beams**
- **Laser Assisted Processing**
- **Opto Electronic Integrated Circuits**
- **Three Dimensional Device Structures**
- **Defect Densities**

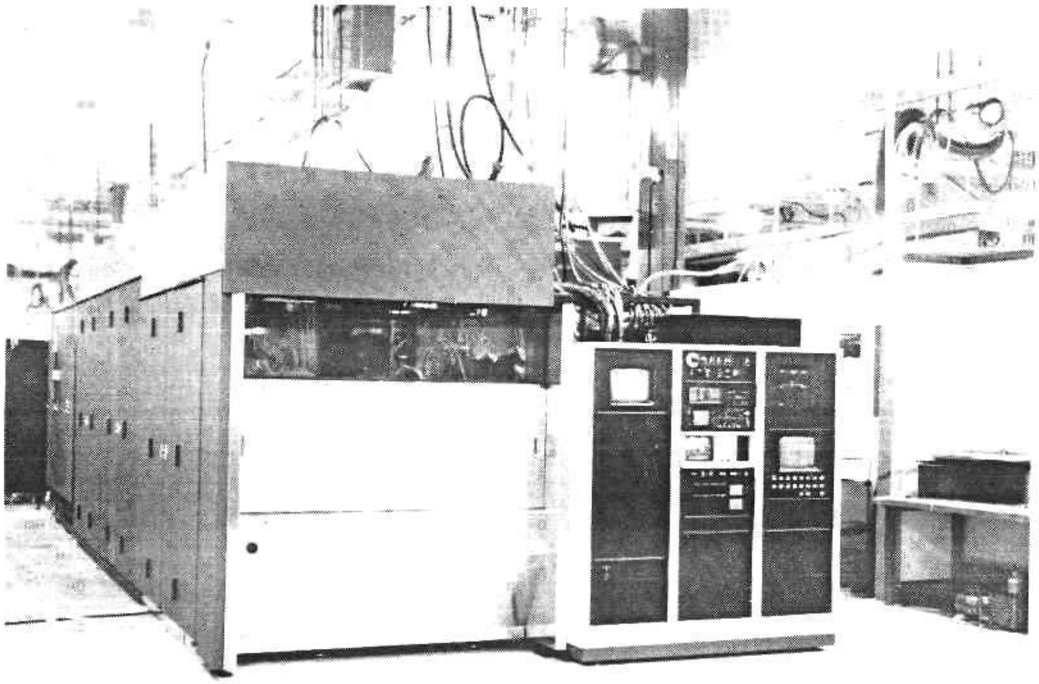
EATON Semiconductor Equipment

ION IMPLANTATION

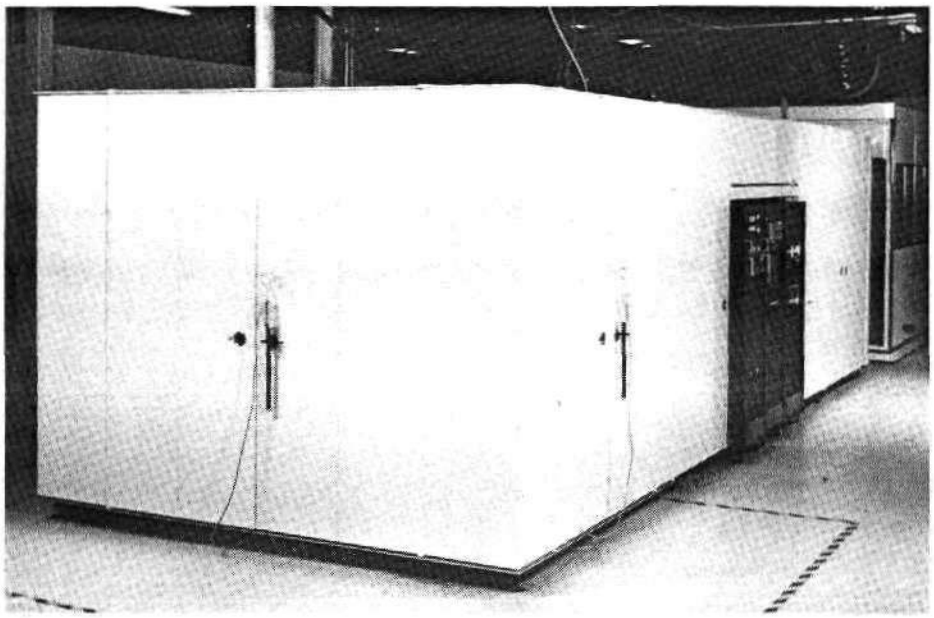
The United States Still Leads The World In Ion Implantation Especially In Equipment Innovation e.g. High Energy And High Current Oxygen Implanters.

The Threat To Their Lead Lies In The Ability Of Japan To Produce A *Reliable* Machine.

EATON
Semiconductor
Equipment



Photograph of the Eaton Linac High Energy Implanter



Photograph of the Ionex Tandem High Energy Implanter

EXAMPLE OF A COMPETITIVE DIFFERENCE

LASER ANNEALING

The United States Is In The Forefront With Regard To Basic Studies Of Solidification And Phase Transformation.

Japan Is Ahead In The Application To Multilayer Structures.

EATON
Semiconductor
Equipment

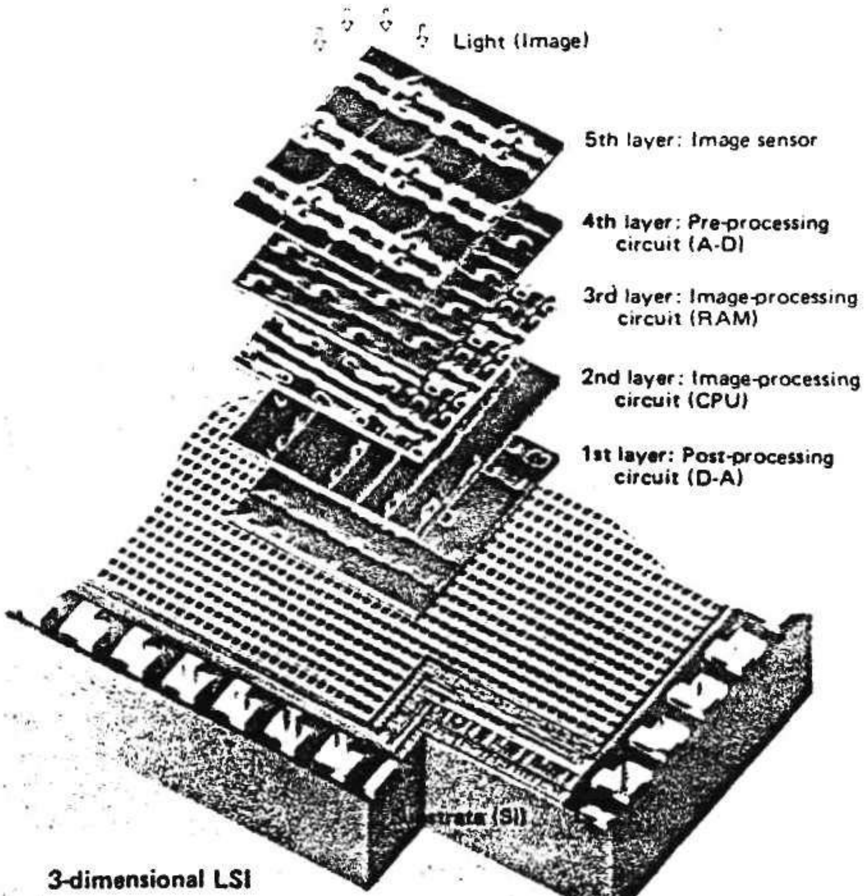
THIN FILM EPITAXY

- MBE And MOCVD Increasingly Important
- United States Is Probably Still Slightly Ahead

HOWEVER

- Japan Is Increasing Efforts To Make Hetero Structures Such As GaAs On Silicon
- Japan Makes Significantly Better Bulk GaAs Crystals
- This Gives Japan A Leading Position In Opto Electronic Technology

EATON Semiconductor Equipment


Light (Image)
5th layer: Image sensor
4th layer: Pre-processing circuit (A-D)
3rd layer: Image-processing circuit (RAM)
2nd layer: Image-processing circuit (CPU)
1st layer: Post-processing circuit (D-A)
3-dimensional LSI

ETCHING AND MACHINING

- United States Leads In The Science And Technology Of Conventional RF Reactive Ion Etching.
- Laser And Ion Assisted Processing Are Being Actively Researched In Both The United States And Japan.
- Japan Makes Much More Use Of Focused Ion Beams.

EATON

OPTICAL LITHOGRAPHY

The situation for the United States may be improving in 1987 with the introduction of Eximer laser steppers capable of being used at 0.5μM and possibly extendable to 0.35μM geometries. The United States may again have taken a lead by innovation.

If true, how long will this lead last?

E-BEAM LITHOGRAPHY

The Story Speaks For Itself

- **There Is One U. S. Vendor Left Out Of Six.**
- **Three Exist In Japan With Active R & D Programs.**

X-RAY LITHOGRAPHY

- **Japan Has Mounted A More Massive Program In X-ray Lithography Than Any Other Country.**
- **The Issue Here May Be A Technical One. With The Improved Resolution Of Steppers, And The Possibility Of Masked Ion Beam Lithography, The Cost Effective Region For X-ray May Be Small.**
- **Japan clearly does not intend to wait and see.**

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Research Newsletter

Conference Newsletter

October 19, 1987

Everyone comes to the Dataquest Semiconductor Industry Conference with plenty of questions in their minds, and this year is no exception. This newsletter, the first of a series to be published daily throughout the conference, answers some of the most widely asked questions.

Semiconductor Consumption

Why is the Dataquest forecast more optimistic than the SIA forecast?

Dataquest believes that North American semiconductor consumption in 1987 will grow 21 percent over 1986, with consumption in 1988 increasing by 23 percent. The Semiconductor Industry Association (SIA) projections for both years are 20 percent growth. Even though orders have slowed, we believe that the current order backlog combined with a projected book-to-bill ratio above parity for the rest of 1987 will result in moderate positive growth in the fourth. Our optimism for 1988 is based on a projection of 15 percent growth in the U.S. computer and communications equipment markets in 1988.

Why does the Dataquest forecast predict a recession in 1989?

Our forecast of a 1.9 percent decline in semiconductor consumption in North America in 1989 is based on our belief that the growth in the computer and communications markets will begin early in 1988 and peak later that same year. We are anticipating that semiconductor production will continue to rise beyond that point and a supply/demand imbalance will result in a correction in 1989.

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Memories

In the memory world, as usual, the questions most frequently asked by Dataquest clients have centered around pricing and supply/demand issues.

What is the ratio of supply to demand for 1Mbit DRAMs?

Right now Dataquest estimates that demand for 1Mbit DRAMs exceeds supply by about 20 percent, although this estimate may be distorted by some double-ordering by users. We believe true worldwide demand in 1988 will be about 350 million units. Semiconductor suppliers, on the other hand, will most likely be able to produce only 260 million 1Mbit DRAMs! Supply is expected to catch up with demand by the second quarter of 1988.

When will 256K DRAM prices begin to decline?

Based on the comments in the previous answer, we expect that 256K prices will remain relatively strong until1Mbit supply becomes adequate.

How does Dataquest foresee trade issues affecting 1Mbit DRAM supply?

Japan's Ministry of International Trade and Industry (MITI) will probably wait until other DRAM manufacturers enter the U.S. market before allowing 1Mbit and 256K prices to come down. MITI will be careful to avoid the accusations of predatory pricing from the U.S. that would likely develop if domestic 1Mbit suppliers were shut out of the market.

Microprocessors

Many of the recent questions that Dataquest has received pertaining to the microdevice market are user-related--particularly regarding the supply of Intel's 80386 and 80286 microprocessors. Other questions regarding the microdevices market include:

Is the adoption of RISC architectures growing? If so, how will this affect the microprocessor market?

RISC is a small segment of today's 32-bit microprocessor (MPU) market. Nevertheless, Dataquest has observed a dramatic increase in the introduction of RISC-based chips. In the long-term, Dataquest does not predict that RISC will displace complex instruction set computer (CISC) architectures. More likely, RISC-based MPU's could enjoy as much as 20 percent of the MPU market by 1992.

Is Dataquest predicting the demise of the 4-bit microcontroller market?

Dataquest no longer supports the notion that 4-bit microcontrollers (MCU) will be completely supplanted by 8-bit devices. Based on our most recent review of the MCU market, we see no sign of a decline in 4-bit MCU unit shipments in the near future.

ASICs

Is Dataquest's April 1987 ASIC forecast still looking accurate?

Our projections for programmable logic devices (PLDs) and gate arrays appear to be close to reality. Our estimates for cell-based ICs (CBICs), however, may be low due to our underestimating the impact of Japanese suppliers.

How will CBICs fare against gate arrays?

The current Dataquest ASIC forecast indicates that worldwide CBIC revenues may exceed gate array revenues late in the 1990s. There are several reasons that CBIC devices may be slower in overtaking gate array products:

--The current installed base of silicon compilers is not very large.

--Existing cell libraries need to be expanded and filled-out.

--CBIC prices are not significantly lower than gate array prices. Gate array prices have, in fact, declined substantially over the past two years.

--Intellectual property issues are a serious concern surrounding the use of cell-based IC design.

How is the E-squared PLD market shaping up?

We believe that our current forecast for E-squared PLDs may be on the low side. While Dataquest has projected 1992 sales of E-squared PLDs to be $150 million, it now seems more likely that this figure will be $200 million. This increase is primarily due to two factors:

--The flash E-squared cell should result in faster E-squared devices than are currently available in today's market. This will eat into the market share of bipolar PLDs.

--The number of players in the E-squared PLD market continues to grow. Among the competing companies are AMD/MMI, Exel, Gould/AMI, ICT, Lattice Semiconductor, National Semiconductor, SGS/Thomson, and VLSI Technology.

What is happening in the area of BICMOS and GaAs ASICs?

One of the Dataquest newsletters you will receive at the conference deals with the BICMOS ASIC market. At present, Dataquest sees GaAs ASICs as a niche market. We have observed good yields of low-density devices from Gigabit Logic, Triquint, and Vitesse. On the whole, suppliers are now realizing that the development of the GaAs ASIC market will most likely come from building products for existing sockets at prices competitive to ECL. The recent agreement between VLSI Technology and Vitesse lends further credibility to the GaAs market.

Semiconductor Manufacturing Equipment

Dataquest's Semiconductor Equipment and Materials Service (SEMS) maintains a detailed database of fabrication facilities around the world. At present the Fab Database has identified 446 fabs in the

U.S., 157 in Japan, 105 in Europe, and 52 in Rest of World (ROW). Many of the questions heard by Dataquest regarding the equipment side of the industry have to do with whether or not the chip recovery is "trickling down" to the equipment suppliers.

Has capital spending recovered?

Dataquest forecasts a worldwide increase in semiconductor capital spending of 10 percent for 1987. The increase for ROW will be more dramatic, with 48 percent growth over 1986! By contrast, Japan's capital spending will be down 4 percent this year over last. We believe, however, that capital spending in Japan hit bottom in the first or second quarter of this year, and will now show continuous growth throughout the rest of the decade.

What is the longer-term outlook for the semiconductor equipment industry?

A lot of semiconductor production capacity was brought on-line between 1983-1985 in anticipation of the worldwide semiconductor boom continuing. Thus, in spite of the increase in semiconductor production this year, the industry is still in a state of excess capacity. Dataquest does not expect orders for production equipment to increase substantially until 1988, when we forecast that capital spending will increase 30 percent over 1986. Dataquest believes, however, that worldwide capital spending will not reach
reach 1984 levels until 1990. This is in contrast to the fact that worldwide semiconductor production has already exceeded 1984 levels, with production in 1987 expected to be 33 percent higher than 1984.

Intellectual Property Issues

The protection of intellectual property by semiconductor companies has certainly received unprecedented media attention during 1987. The way our legal system views intellectual property, and the recourse open to companies in protecting it, will utimately have a significant impact on market share.

Are U.S. companies becoming more aggessive in their protection of intellectual property

Judging from the number of lawsuits recently witnessed in the industry, this would certainly seem the case. There are a number of reasons for this:

--In 1982 the process for hearing patent and copyright violation cases was restructured in a more expeditious manner.

--The interpretation of certain intellectual property issues by the courts has become more favorable to the protection of patents and copyright.

--Companies moving into the cell-based IC market are finding that control over the rights to standard products is strategic to success in the ASIC market.

--With increasing global competition for the microdevice and ASIC markets, controlling the rights to key standard products is tantamount to preserving market share.

What have been the landmark legal events during 1987?

There have been several, including:

--The out-of-court settlement of Texas Instruments' 9 DRAM patent lawsuits against Asian competitors. These settlements yielded TI more than $138 million in fixed royalty payments during the first half of its fiscal year!

--The intervention of the U.S. Customs Service and the International Trade Commission (ITC) in industry lawsuits (TI-Samsung, Zilog-Sharp). Intel has also sought the involvement of the U.S. Customs Service in its lawsuits against NEC and Hyundai.

--The sweeping nature of Intel's recent lawsuits, which apply the protection of intellectual property across the gamut of manufacturers, designers, and distributors.

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Research Newsletter

Conference Newsletter

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One point is certain. No one will forget the first day of Dataquest's Semiconductor Industry Conference. Amid rumors of a crashing stock market, later substantiated at a record-breaking 508 point decline, it was hard to maintain share of mind. But we are in the business of semiconductors, and semiconductors were the focus of the day's discussion.

Despite the economic catastrophe suggested by the stock market tumble, the overall mood today was positive. Joe Duncan predicted that the U.S. economy in 1988 will grow 3.3 percent over 1987--an improvement over this year's predicted 2.5 percent GNP growth. While this may seem modest, Mr. Duncan emphasized that the economy is actually healthier than the GNP suggests. He bases his optimism on the strong performance of final sales to domestic consumers, which he feels more truly reflects the state of the economy. In global terms, economic growth in 1987 is expected to be weaker than 1986, although Joe Duncan expects improvement in the period 1988 through 1992.

In more specific terms, Gene Norrett presented the Dataquest semiconductor industry forecast. Worldwide, Dataquest believes that electronic equipment manufacturing revenue will grow from $470 billion in 1987 to $600 billion in 1990. In 1987, worldwide semiconductor production will account for $42.5 billion, or 9 percent of total electronic equipment. By 1990, semiconductor revenues will reach $60 billion, increaseing to 10 percent of worldwide electronic equipment revenues. Sales of semiconductor manufacturing equipment will grow in the same period from $5.8 billion to $9.5 billion.

The dynamics of the global semiconductor industry will change dramatically over the next five years. Dataquest expects Japan to maintain its newly acquired role as the leading semiconductor producer over this period, but by 1990 Europe will relinquish its third place position to producers in the Asia Pacific countries.

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Dataquest's forecast for North American semiconductor consumption in 1987 and 1988 is more optimistic than that of the Semiconductor Industry Association (SIA). Dataquest predicts growth of 21 percent in 1987, and 23 percent in 1988, compared with the SIA's forecast of 20 percent growth for both years. Dataquest expects worldwide semiconductor consumption to increase by 23.9 percent in 1987, and 23.7 percent in 1988.

How will this growth affect the semiconductor equipment industry? According to Bob McGeary, when capacity utilization reaches 80 percent, capital spending increases. Dataquest believes that worldwide capacity will reach this level in 1987. Worldwide capital spending will reach nearly $6 billion in 1987, an increase of 10 percent over 1986. This represents the first year-to-year increase in capital spending since 1984. In 1988 worldwide capital spending is expected to reach $7.7 billion, an increase of 30 percent over 1987. In summarizing the capital spending outlook, Bob noted that purchases in the next 18 months will be capacity driven, with users buying tried and true products. Beyond the next 18 months, purchases are expected to be technology driven, as semiconductor manufacturers strive to meet the challenges of sub-micron technology.

Technological innovation was the focus of the session entitled "Technology Over The Next Forty Years". Forty years ago, as Mike Thompson pointed out, it would have been as difficult for the inventors of the point contact transistor to have predicted the semiconductor industry of today. The speakers who participated in this session were faced with an equally difficult task. There is not necessarily a direct connection between today's inventions and those forty years hence. It is relatively easier to consider the needs that can be met by future technology.

Michael Thompson addressed the issue of the human-machine interface, and the technological challenges it creates. He defined challenges in three applications areas: speech, vision, and artificial intelligence (AI). While we currently have chips capable of isolated word recognition, and are developing graph search algorithms capable of real-time recognition of connected speech, the understanding of fluent discourse still has no known solution. He offered similar examples in the fields of vision and AI. While we tend to be awed by our advances in this industry, Michael restored our sense of proportion by pointing out that the garden slug is a 120 MIP machine.

While it is difficult to predict where technology is going, it is relatively easier to predict where it is not going. As Dan McCranie said later in the day, "extrapolation is not necessarily destiny". Jack Kilby's speech was eloquent testimony to this fact. Pure extrapolation will predict that the semiconductor products of 2027 will be sub-micron devices 12 inches square with an average selling price of around $3.00.

Dr. Hiroe Osafune emphasized the manufacturing issues that will be faced in the future. He anticipates the automation of process operation and process monitoring. He stressed the importance of adequate maintenance of manufacturing equipment, and the management problems that tomorrow's industry will face. In his predictions for future technology, Dr. Osafune theorized the development of artificially structured crystals using computational physics. Gordon Moore also discussed the future use of computer simulation at the device physics level when he demonstrated the success of defect analysis in process modeling.

Gordon Moore's other predictions touched on a topic close to everyone's heart--the competitive cost of manufacturing semiconductors. Gordon Moore maintains that the equipment costs associated with staying at the leading edge of technology are going up faster than the industry's ability to invest. With the current trend line pointing to 0.1-micron device geometries by the year 2010, remaining competitive will cost a semiconductor company $100 million per year in manufacturing improvements. Under such conditions, how can a small company compete? This was the major issue addressed in the afternoon panel session, "Surviving In The Land of The Giants".

David Angel, session moderator, challenged a group of presidents and CEOs of young semiconductor companies with a number of sobering observations. Assuming that a semiconductor company spends even 10 percent of its annual revenues on capital improvements, meeting Gordon Moore's capital spending target would require sales of $1 billion per year. For a company with current sales of $100 million, reaching the $1 billion dollar level would take growth of 25 percent every year for the next decade. Such growth would no doubt exceed the industry average. Each of the panelists took up David's challenge in a different way.

Michael Burton of Triad Semiconductor rebuffed the challenge with his discussion of the "inefficiencies of scale" facing the industry giants, including organizational impediments, vertical integration, ever changing priorities, corporate and government politics, greater isolation from market fluctuations, and the problems of retaining and developing talent. He described a strategy of alliances which he characterized as "collaborative competition". His final advice was "differentiate of die".

Dan McCranie of Seeq Technology built his case on three major points: stay lean, stay out of multi-sourced commodities, and above all, persist. He argued that "extrapolation is not necssarily destiny" when referring to some of the earlier remarks made concerning industry trends. Jim Diller offerred a classic niche strategy in the ASIC market. His company, Sierra Semiconductor, has formed major alliances with National Semiconductor and VLSI Technology, as well as establishing an independent European operation.

Michael Hackworth of Cirrus Logic stressed the importance of understanding value, and the importance of focusing research. He described three broad areas of expertise that a company might have: process technology, manufacturing muscle, and product innovation. Cirrus Logic's strategy concentrates on the third category.

The semiconductor industry is facing new realities. The day's events in the stock market showed that even these realities are not totally stable. Even seasoned Wall Street analysts can't predict the effect of today's events on industry. We can, however, predict that the semiconductor industry will be spending more time and attention on non-technology issues. Both on and off the podium, the topics of intellectual property protection, trade, and industry consortia were widely discussed. We expect more attention to be focused on these issues in the next two days.

For an industry in mid life crisis, the semiconductor industry continues to exhibit remarkable energy, enthusiasm, and innovative talent.

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Research *Newsletter*

Conference Newsletter

October 21, 1987

Yesterday's conference ended with a discussion of the problems faced by young companies competing in today's semiconductor industry environment. Today's conference began by confronting the problems faced by nations competing in today's semiconductor industry environment.

Charlie Sporck addressed the issue of national competitiveness in his presentation, with specific emphasis on manufacturing. Mr. Sporck listed a number of points weakening the ability of the U.S. to compete on a global scale. Among the problems he cited were the lack of a formal trade strategy, a national preoccupation with consumption, the declining quality of U.S. technical education, and the low level of personal investment by Americans.

With specific regard to the U.S. semiconductor industry, Mr. Sporck called attention to the emphasis placed on basic R&D at the expense of manufacturing technology. Later that morning, Bill Reed reinforced Charlie Sporck's contention that manufacturing in the U.S. is not accorded the respect it deserves when he compared the wages and educational level of fab workers in Korea to those of the U.S.

Both Charlie Sporck and Don Brooks predicted that the national debate on trade would intensify. Along with a several other speakers they were aware that protectionism was not a long-term answer. Sanford Kane, during his presentation, suggested that current efforts to deal with trade problems are stop-gap solutions, and that longer term trade strategy is required. Trade strategy alone, however, does not address the challenge of government and industry alliances facing the U.S. from both Europe and Asia. During his talk, Norman Neuman described Philips-Siemens MegaProject as the European version of Sematech, and expressed his disappointment over U.S. ignorance of this and other European R&D efforts.

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One of the major themes of yesterday's conference session was the high level of investment needed to succeed in today's semiconductor industry. This was underscored once again when Wally Rhines described the costs incurred by Texas Instruments in moving from the 256K DRAM to the 1Mb DRAM, and the need to amortize fab costs by developing manufacturing expertise in high-density CMOS memories. One reason for the high levels of investment required in the current industry environment is the fact that we are pushing technology to its physical limits, and incremental improvement becomes increasingly expensive.

Jim Meindl of the Rensselaer Polytechnic Institute spoke of gigascale integration of more than a billion transistors on a single semiconductor substrate, and the hierarchy of limits--fundamental, material, device, circuit, and system--that the industry must contend with in the future. While Gordon Moore and Jack Kilby had previously described limitations from the standpoint of the industry's ability to invest in innovation, the limitations that Mr. Meindl addressed represent a point beyond which known technology will not pass.

Whatever the effect of such limitations on the industry, they will be experienced most dramatically by the suppliers of semiconductor manufacturing equipment. But is this vital segment of the industry up to the challenge? Effectively, the U.S. electronics industry ultimately rests on the viability of the semiconductor manfacturing equipment industry. Bill Reed maintained that from a technology standpoint, the equipment suppliers could be counted on to keep the industry at the leading edge.

What concerned Mr. Reed, however, was the ability of domestic chip suppliers to make the necessary investments in capital equipment. Drawing on Dataquest data, Bill Reed discussed the relationship between the growing costs per square inch of wafer processing, the accelerating depreciation per square inch as the cost of fab equipment increases, and the declining price per bit of DRAM devices. In common with many others, he expressed concern about current educational levels, and their effect on the future workforce.

Mr. Reed emphasized the need for forming effective alliances as a means of competing in the industry or in the market. Alliances can take two basic forms: those between two or more specific companies, and those between government, universities, and industry participants. Regarding the latter, Sandy Kane gave the Dataquest audience an update on the status of Sematech, the manufacturing consortium of U.S. semiconductor manufacturers, electronic equipment suppliers, and manufacturing equipment vendors.

In spite of some initial pessimism over the consortium's chances, Sandy Kane revealed that the selection of site and CEO for Sematech are close at hand, with actual wafer starts anticipated during the second half of 1988. Mr. Kane assured the conference audience that Sematech would form a vital partnership between equipment suppliers, chip makers, and the federal government. The success of Sematech would mark the end of what Dataquest dinner speaker Sheldon Weinig described as "steadfast government indifference".

The other, more traditional, form of alliance occurs between two or more companies. Such alliances were addressed by a number of today's speakers. Al Stein noted changes over the last thirty years in the reasons for forming alliances. He characterized the alliance climate of the 1980s as one influenced by increasing capital requirements, shifting industry leadership, decreasing product life-cycles, and the increasing importance of design automation. In comparing today's strategic partnership spectrum with that of the past, Mr. Stein illustrated a nexus of relationships linking the semiconductor vendor to customers, alternate source suppliers, foundry and technology partners, design tool and equipment vendors, R&D consortia, and universities.

While Al Stein spoke of the reasons for forming alliances, Tommy George and Irwin Federman described the elements that make them work. Mr. George identified a number of key requirements for a successful alliance.
These included the need for the participants to fully understand each other's goals, to establish a win-win-win solution where everyone, including the customer can win, and for frequent interaction between the companies at all levels. He emphasized that an alliance can only work successfully if both parties allocate adequate resources to the project. Irwin Federman stressed that understanding the meaning of service excellence is necessary to successful partnering, and warned

that organizations that lack this characteristic are " likely to think in terms of deliverables and will probably prove to be disappointing partners."

One of the new realities of the semiconductor industry that Dataquest has been discussing has been the rapid globalization of the industry and the phenomenal growth of the Asia-Pacific region as both a supplier and consumer. But how will countries such as Taiwan and Korea create an electronics infrastructure in the midst of an already highly competitive market? During the afternoon two speakers addressed the strategies of their respective countries.

Dr. Morris Chang spoke about the Taiwan Semiconductor Manufacturing Company (TSMC), the world's first pure foundry operation. Capitalized at $188 million, TSMC is 25% owned by N. V. Philips with 47% ownership by the government of Taiwan. He stressed the importance of the educational level of Taiwanese employees as a significant factor in the potential success of the enterprise. Dr. P. June Min described Korea as part of the future business center of the world. Particularly impressive was the timetable illustrated by Dr. Min showing Korea catching up with the United States in terms of high density memory technology by 1988, despite entering the market only 12 years ago.

As Don Brooks pointed out, Korea and Taiwan may just be the tip of the iceberg. He quoted economist Gary Schilling who observed, "Although many regard China as, potentially, a market of one billion consumers for Western goods, we view it as one billion potential producers of industrial exports."

Reflection on this newsletter shows one important underlying concern by virtually all the participants -- one that is too often overlooked -- education. Just as semiconductors have been acknowledged as the foundation of our high technology economy, educational excellence must be the cornerstone of our future maintenance of technology leadership. Unfortunately for the U.S. there is currently no educational equivalent of Sematech.

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Research Newsletter
Conference Newsletter

October 22, 1987

Larry Hansen said "You can't have a world-class semiconductor industry without a world-class manufacturing equipment industry." Equipment and materials was the topic of the third day of the Semiconductor Industry Conference, and Sematech was seen as a possible solution to some of the problems besetting the U.S. semiconductor equipment manufacturing industry.

In his presentation, Mr. Hansen suggested that a basic objective of Sematech must be the strengthening of the U.S. equipment industry. The industry will require assistance, and "the fundamental form of assistance is money." He cited a number of problems faced by the industry including skyrocketing R&D costs, and the expense of service and support. He also made the point that much of the cost burden of process development is being shifted back to the equipment makers as they work closely with device manufacturers to extend the frontiers of leading-edge technology.

Among the ways in which Mr. Hansen saw Sematech assisting the industry were R&D funding, generic process development, process integration and technology leveling.

Peter Rose painted an extremely dark picture of the possibilities facing the U.S. semiconductor equipment manufacturing. According to Mr. Rose, "It is easy to see a scenario in which all the best semiconductor equipment companies are foreign or partly owned by foreigners by the year 1990." Although he believes that the U.S. leads in ion implantation, thin film epitaxy, and film deposition and etching, Japan leads in a greater number of key wafer processing technologies, including optical lithography, microwave plasma sources, electron and ion micro beams, laser assisted processing, and three dimensional device structures.

One of Mr. Rose's major concerns was the fact that U.S. university and government laboratory research is not sufficiently directed toward

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the needs of industry. As U.S. leadership in processing technology declines, so does the technology resource available to process equipment manufacturers. The result is less competitive equipment and an increasing disadvantage relative to foreign competitors.

Steve Dunbrack's presentation concentrated on the maskmaking industry. He commented that, although present state-of-the-art maskmaking capability can carry us through the 4 Mbit DRAM level and into the 1990s, the semiconductor industry will be mask limited within 3 to 5 years. Mr. Dunbrack expressed concern that conventional mask-making was not an industry priority. Since the maskmaking industry is small and fragmented, and mask makers are generally reactionary rather than visionary, it is impossible for individual companies to solve the industry's problems. Indeed, the semiconductor industry as a whole must take ownership of the mask problem.

Mr. Dunbrack visualizes a Sematech mask committee to assess the present status of U.S. mask making, recommend solutions, stimulate developments, and act as a liaison between the various parties. In particular he feels that it is important to divert some of the money directed toward X-ray R&D and continue research in conventional mask-making.

Sematech was the watchword of today's sessions. Ed David referred to the "extraordinary degree of consensus" that has been achieved both for the concept of Sematech and for its objectives. Mr. David emphasized the importance of the semiconductor industry to both national security and the economic health of the country. Although Mr. David agreed that there are many components to the problem of the U.S. loss of competitive leadership in the semiconductor industry, and many factors that could contribute to the improvement of the situation, he was convinced that Sematech was an essential part of the solution.

But Mr. David also recognized that even a successful Sematech was only "one string to the industry's bow". The major problem facing the industry is the need for capital. Bill Bottoms believes that the survivors of the changed semiconductor industry structure will be the companies that exploit all available resources to obtain the capital that private sources alone cannot generate. Mr. Bottoms divided industry sources of capital into three major categories: government, private sector, and capital equivalence/ avoidance.

Examples of government sources include tax incentives and product development support (such as the VHSIC program). Private sector sources include venture capital and secured loans. Capital equivalence/avoidance is often overlooked as a source of capital but can be very valuable if used effectively. Sources include university research and development. He cited the example of the California Micro Program in which industry could make investments in university research, matched by state government funds, and secure limited rights to resulting technology.

More than at any previous Semiconductor Industry Conference the spirit of cooperation was in the air. In addition to the strong support for Sematech that was voiced by virtually every speaker, the value of alliances was heavily stressed. Alliances between semiconductor manufacturers and equipment suppliers seem to be a logical solution to many problems. Peter Rose commented on the difference in the quality of relationships between vendors and customers in Japan and those in the U.S.

Just as on previous days, the importance of education at all levels in the industry was stressed in several presentations. Mr. Kawanishi described a manufacturing facility of the near future in which production workers will need to integrate into a complex information processing environment. Ed David stressed that highly skilled technicians are needed to make U.S. industry competitive again. Peter Rose elaborated this point when he explained that Japanese companies are able to move workers into different jobs during downturns and therefore do not need to train new workers at the beginning of a recovery, as is the case with U.S. manufacturers.

Perhaps the most profound change that is occuring in the semiconductor industry is that we no longer have the progression where the U.S innovates, Japan commercializes, and the Asia-Pacific countries do low-cost fabrication. We are truly in a global marketplace where all participants are looking to innovate and exploit the technology. As stated by Michael Thompson and Tsuyoshi Kawanishi, the industry is going beyond the mere consolidation of electronic circuits to the emulation of human functions in thought, vision, speech, and voice recognition. Perhaps it will also take the lead in its approach to industrial competition, demonstrating the ability to foster cooperation in technological advances. It will be interesting to see if the lead taken by the semiconductor industry is followed in the commercialization of the superconductor.

If the semiconductor industry is, as we suggested, in a mid-life crisis, it is certainly emerging from it gracefully. With maturity comes the willingness and the ability to cooperate. Sematech and stronger, more cooperative alliances were seen as ways to combat the problems facing all industry participants. The degree of capital intensity inherent in today's semiconductor industry means that industry, universities, and government must work together to achieve future technological advances.

Despite its inauspicious beginnings on the day of the largest stock market loss in history, the mood of the conference demonstrated a basic confidence in the semiconductor industry's near term recovery, and long term potential.