1983 CAD/CAM INDUSTRY CONFERENCE

The Technology Challenge: Linking CAD/CAM with Integrated Manufacturing

September 26–28
The Newporter
Newport Beach, California

Nielsen Dataquest

The Technology Challenge:

Linking CAD/CAM with Integrated Manufacturing

SUNDAY, SEPTEMBER 25

5:00 p.m. to 8:00 p.m.	Registration
8:00 p.m.	Cocktails

MONDAY, SEPTEMBER 26

8:00 a.m.	Buffet Breakfast
8:00 a.m.	Registration Continues
9:00 a.m.	**Welcome**
	SESSION I—INDUSTRY OVERVIEW
9:15 a.m.	**CAD/CAM Industry Overview** **Timothy O. Gauhan, Vice President and Director** **CAD/CAM Industry Service** **Dataquest Incorporated**
9:45 a.m.	**CAD Market Review and Forecast** **Beth W. Tucker, Research Analyst** **CAD/CAM Industry Service** **Dataquest Incorporated**
10:15 a.m.	Coffee Break
	SESSION II—PRODUCTION AND CAD
10:45 a.m.	**Introduction**
11:00 a.m.	**Manufacturing Is Not a Button on the Design Data Base** **Michael Sterling** **Vice President Research & Development** **CADLINC**
11:45 a.m.	**The Role of Automated Test Equipment in the Automated Factory** **Harold McAleer** **Senior Vice President and General Manager** **GenRad Incorporated**
12:30 p.m.	Luncheon

2:00 p.m. **Trends in Distributed Workstations in CAD**
Joseph F. Gloudeman, President
MacNeal-Schwendler Corporation

2:45 p.m. **Robotics—Today and Tomorrow**
Steve Volm, Western Region Manager
Industrial Automation
IBM Corporation

6:00 p.m. Cocktails

7:00 p.m. Dinner

8:30 p.m. **Productivity and Education**
Dr. Robert Noyce, Vice Chairman
Intel Corporation

TUESDAY, SEPTEMBER 27

7:30 a.m. Buffet Breakfast

SESSION III—PRODUCT STRATEGIES

8:30 a.m. **CAD/CAM Workstation Trends**
Edward L. Busick, President
Spectragraphics Corporation

9:15 a.m. **Computer-Integrated Manufacturing—Technological Imperative**
Philips W. Smith
Corporate Vice President and General Manager
Marketing Division
Computervision Corporation

10:00 a.m. Coffee Break

10:30 a.m. **Computer Companies and Integration**
John W. Poduska, President
Apollo Computer

11:15 a.m. **The Impact of Engineering Workstation Networks on CAD Productivity**
David E. Weisberg, Manager, Market Analysis
Auto-trol Corporation

12:00 noon Luncheon

SESSION IV—ELECTRONICS ISSUES

1:30 p.m. **Impact of Computer-Integrated Manufacturing on a Company**
Wilfred J. Corrigan, President
LSI Logic Corporation

2:15 p.m. **Making Engineers More Productive**
Harvey Jones, Vice President, Marketing
Daisy Systems Corporation

3:00 p.m. **The Role of a Modern Custom Supplier in the Field of VLSI Design**
Graham Shenton
Vice President of Marketing and Engineering
International Microelectronics Products Inc.

4:30 p.m. Regatta

6:00 p.m. Cocktails

7:00 p.m. Dinner

WEDNESDAY, SEPTEMBER 28

8:00 a.m. Buffet Breakfast

SESSION V—REALITY OF THE FACTORY FLOOR

9:00 a.m. **Introduction**

9:15 a.m. **CAM on the Manufacturing Floor: Products There Today**
Al Libbey
Vice President, New Business Development
Modicon Programmable Control Division
Gould Incorporated

10:00 a.m. **Integrated CAD/CAM: An Achievable Goal**
Richard L. Justice, Director
Engineering and Manufacturing Computer Coordination
General Motors Corporation

10:45 a.m. Coffee Break

11:00 a.m. **Role of Start-up Companies in Computer-Integrated Manufacturing**
Laura Conigliaro, Vice President
Prudential-Bache Securities

12:00 noon Luncheon

CONFERENCE INFORMATION

WHO SHOULD ATTEND

The conference is aimed at CAD/CAM industry executives, market research and product planning managers, and financial analysts/portfolio managers.

LOCATION

The site of DATAQUEST's CAD/CAM Industry Conference will be The Newporter, Newport Beach, California.

Address: The Newporter
1107 Jamboree Road
Newport Beach, California 92660
Telephone: (714) 644-1700

CONFERENCE FEE

The fee for the CAD/CAM Industry Service (CCIS) conference is:

- Subscriber (or designee) from CCIS client company . . . . No Charge
- Each additional attendee from CCIS client company $550
- Each attendee who is a client of any other DATAQUEST Industry Service $650
- Each attendee from a nonclient company $795

REGISTRATION

REGISTRATION DEADLINE IS FRIDAY, SEPTEMBER 16, 1983.

To register, please **complete** and return the registration form. **We cannot register you until we have your arrival and departure dates**. You will receive a confirmation packet with additional information shortly before the conference begins.

CANCELLATION POLICY

All cancellations received by DATAQUEST after September 16, 1983, are subject to a $100 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 $100 service charge. Notice of cancellation should be made to Gail van Tubergen, Conference Coordinator, telephone: (408) 971-9000.

FOOD AND LODGING

PLEASE NOTE THAT ALL HOTEL RESERVATIONS MUST BE MADE THROUGH DATAQUEST.

Room rates at The Newporter for the nights of September 26 and 27 are $135.00 single occupancy and $207.00 double occupancy (per room, per night). Rates include all meals taken with the group, beginning with breakfast on Monday and ending with lunch on Wednesday. For those arriving on Sunday, September 25, the rate will be $75.00 single occupancy and $87.00 double occupancy. In addition, charges of 21 percent on food and beverage (gratuity and tax) and 8 percent tax on rooms will be added to your bill.

TRANSPORTATION

The Newporter is 10 minutes from the Orange County Airport and approximately 60 minutes from Los Angeles International Airport. Complimentary limousine service is available from the Orange County Airport to and from The Newporter, and coach service is available from Los Angeles International. No reservations are necessary from Orange County Airport. Simply call upon arrival from the direct telephone in the baggage area of the airport. Taxis and rental cars are also available.

RECREATION

For tennis buffs, California's number-one-rated tennis club, the John Wayne Tennis Club, is located on the property. This excellent facility has sixteen lighted tennis courts, a jacuzzi, and a sauna. There are swimming pools and a 9-hole golf course. The Irvine Coast Country Club is also available for golf. The beach is only minutes away, where you may sunbathe, swim, or surf.

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A.C. Nielsen Company

DATAQUEST INCORPORATED
1290 Ridder Park Drive
San Jose, California 95131
Phone: (408) 971-9000
Telex 171973

1983 DATAQUEST CONFERENCE SCHEDULE

Industry Service	Date	Location
☐ Copying and Duplicating	January 27-28	Hotel Intercontinental Geneva, Switzerland
☐ Small Computer	February 16-18	Silverado Country Club Napa, California
☐ Electronic Printer	March 9-11	Silverado Country Club Napa, California
☐ Telecommunications	April 27-29	The Doubletree Inn Monterey, California
☐ European Semiconductor	May 18-20	Hotel de Paris Monte Carlo, Monaco
☐ Semiconductor	May 24	Tokyo American Club Tokyo, Japan
☐ Copying and Duplicating	June 8-10	Rancho Bernardo Inn San Diego, California
☐ Electronic Printer	June 16-17	Noga Hilton Hotel Geneva, Switzerland
☐ Copying and Duplicating	June 22	Tokyo American Club Tokyo, Japan
☐ Display Terminal	June 22-24	Hyatt Del Monte Monterey, California
☐ CAD/CAM	September 26-28	The Newporter Newport Beach, California
☐ Semiconductor	October 17-19	Rancho Las Palmos Palm Springs, California
☐ Electronic Printer	October	Tokyo American Club Tokyo, Japan
☐ Computer Memory	November 2-4	Silverado Country Club Napa, California
☐ Word Processing	November 16-18	Hyatt Del Monte Monterey, California

Please check box(es) if you would like to receive information regarding any of our conferences.

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San Jose, California 95131
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☐ Please register me for the 1983 CAD/CAM Industry Conference
(please attach business card or print)

Last Name_________________First _____________M.I. ____

Title ______________________________________

Company ___________________________________

Street ______________________________________

City_________________State ____________ Zip ________

Telephone (   )_______________

For invoicing purposes, please check the appropriate box. (If you are attending in the place of a binderholder, please fill in their name or you may be invoiced for a conference fee.)

☐ CCIS client ______________________________
Binderholder's name

☐ CCIS additional attendee

☐ Client—Other DATAQUEST service

☐ Client—Prudential Bache

☐ Client—FSP

☐ Nonclient company attendee

☐ I cannot attend, but I would like more information on DATAQUEST's CAD/CAM Industry Service.

We need the following information to register your reservation.

My spouse will accompany me. ☐ Yes ☐ No

Name of Spouse_______________________

Please reserve: ☐ single room
☐ double room

Arrival Date _______________ Time_________

Departure Date _____________ Time_________

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1290 Ridder Park Drive
San Jose, CA 95131

CAD/CAM Industry Service Conference

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The Newporter
Newport Beach, California

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1290 Ridder Park Drive
San Jose, California 95131
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Telex: 171973

Sales/Service offices:

UNITED KINGDOM
DATAQUEST UK Limited
144/146 New Bond Street
London W1Y 9FD
United Kingdom
(1) 409-1427
Telex: 266195

GERMANY
DATAQUEST GmbH
In der Schneithohl 17
D-6242 Kronberg 2
West Germany
(061) 736921
Telex: 410939

FRANCE
DATAQUEST SARL
41 rue Ybry
92522 Neuilly Sur Seine Cedex
France
(1) 758-1240
Telex: 630842

JAPAN
DATAQUEST Japan, Ltd.
Azabu Heights, Suite 410
1-5-10, Roppongi, Minato-ku
Tokyo 106, Japan
(3) 582-1441
Telex: J32768

Nielsen Dataquest

CAD/CAM Industry Conference

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Final List of Attendees

Adage	Len Keene, Manager, Market Planning
American Microsystems, Inc.	James R. Tobias, Director, Technical Information Systems
Analog Design Tools, Inc.	Martin Walker, President
Apollo Computer	Richard Gimbel, Marketing Manager
Apollo Computer	John Robotham, Engineer
Apple Computer	Matt Slavik, Program Manager
Applicon, Inc.	Russell Doty, Manager, Market Analysis
Arthur Young & Company	Michael Dulion
Auto-Trol Technology Corporation	David P. Hanna, Director of Marketing Robert Stevenson, Director of Product Marketing David Weisberg, Manager, Market Analysis
BA Investment Management Corporation	Rupert Grimm, Vice President
BULL SEMS	M. Jean Paul Carcel Francois DeBelenet Michel N. Sauvage, Manager, Marketing and Plans
Bank of America	Indre M. Bauza, Assistant Vice President
Bank of America	Donald Cvietusa, Vice President - Group Head

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Bank of Boston	Mark MacLennan, Vice President Daphne Strong, Banking Associate Jeffrey Wellington, Loan Officer Peter White, Loan Officer
Bank of California	Bob Bourke, Vice President
Bell Laboratories	J. E. Iwersen, Director Joe Sitarik, Supervisor
Burroughs Corporation	Morrie Binder, Regional Marketing Specialist Ron Budacz, Senior Marketing Manager, Int'l Group Stan Eaton, Director of LOB Manufacturing/Distribution Robert D. Merrell, Vice President, Industrial Products David Rumsey, Director, Coml. LOB Marketing Planning
CADAM Inc.	Howard Wilczynski, Member of Technical Staff Rhonda Lindsey, Product Planning Administrator
CADLINC	Michael Sterling, Vice President, Research & Development John West, President
CADTRAK Corporation	Jim Callan, Director of Marketing
CAE Systems, Inc.	Kamran Elahian, Director/Founder
Cad/Cam Specialists, Inc.	Daniel Garms, Vice President Michael McDonald, President
Cadimation, Inc.	Chad Alber, Senior Staff Scientist
Cadtec Corporation	Steve Schopbach, Vice President, Marketing & Sales

California Automated Design, Inc.	Randy Smith, Vice President Kayo Smith
California Computer Products, Inc.	Richard A. Peters, Vice President
Calma Company	John Allum-Poon, Manager of Customer Education Robert Kuhling, Director, Domestic Business Development Suki Nakamoto, Market Research Analyst Donald C. Stewart, Vice President, Corporate Development Thomas R. Teeters, Director, Marketing Information Planning
Cascade Graphics Development	Steve Ball, Executive Vice President
Cericore, Inc.	Ed Allred, Vice President David Bailey, President
Computervision Corporation	Henry Kellogg, Manager, Competitive Analysis Susan B. Ray, Market Research Philips W. Smith, Corporate Vice President & General Manager
Consultant	Frank Gianattasio
Continental Illinois Bank	Leon McMillan, Senior Investment Analyst, Equity Research
Control Data Corporation	Michael E. Sokolski, Manager, Engineering
Daisy Systems Corporation	Harvey Jones, Vice President, Marketing Lucio Lanza, Customer Marketing Manager
Data General Corporation	Sherman L. Rutherford, Director, Industrial Automation Dave Rome, Marketing Manager of CAE/CADCAM

Dataquest Incorporated	Steve Cottrell, Manager, Consulting Activities O. Ralph Finley, Senior Vice President Frank Florence, Marketing Manager Timothy Gauhan, Vice President & Director Howard Hagen, Director, Small Computer Industry Svc. Sally Hasson, Conference Assistant John Jackson, Marketing Manager David Jorgensen, Chairman of the Board Wendy Ledamun, Research Associate Cathy Marvin, Conference Assistant James R. Newcomb, Associate Director Laura Nichols, Industry Analyst Gayle Phillips, Conference Assistant Donna Plath, Graphics Supervisor John Randall, Marketing Manager James Riley, Senior Vice President Frank Sammann, Vice President, Marketing Robert Speicher, Marketing Manager Beth W. Tucker, Research Analyst Gail Van Tubergen, Conference Coordinator Ed Washington, Senior Industry Analyst
Digital Equipment Corporation	Bob Barnes, Engineering Mgr., Storage Technical Ops Wes Brown, Technical Operations Manager Richard Cook, Engineering Services Manager

Digital Equipment Corporation	Paul Kruger, Market Development Specialist Donald McGinnis, Senior Corporate Planner Bill Seaver, Manager, Manufacturing Engineering Sri Sriram, CAEM Marketing Specialist Irv Winters, Manager, Plant Manufacturing Engineering Douglas Wood, CAEM Electronic Marketing Group Manager Art Worsh, Manager, Manufacturing MIS
Dreyfus Corporation	Tom McManus, Securities Analyst
EDS Nuclear/Impell	Chuck Rosselle, Manager Joan Rosselle
Evans & Sutherland Computer Corporation	Steve Artick, Marketing Research Analyst Diane Artick Ginny Banerjee, Project Manager
Fairchild Test Systems	David Birnbaum, Product Marketing Engineer
First Pennsylvania Bank	John Maxwell, III, Securities Analyst
Fujitsu America, Inc.	Satoru Hayashi, Senior Engineer Katsuhide Hirai
Fujitsu Microelectronics, Inc.	Jim Coe, Vice President, Custom Product Operation
GenRad, Incorporated	Harold McAleer, Senior Vice President
General Dynamics Corporation	John G. Heit, Senior Engineering Specialist
General Electric Company	Anthony Corsi, Program Manager, Corp. Info. Systems

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General Motors Corporation	Richard L. Justice, Director Engineering & Manufacturing Computer Coordination
Genisco Computers Corporation	Daniel R. Jones, Director of Product Marketing
Gould Distributed Systems	Kenneth Brody, Product Line Manager CAE
Gould Incorporated	Al Libbey, Vice President
Hewlett-Packard Company	Pat Castro, Lab Director Calvin Cobb, Marketing Evaluator Tom Newsom Mihir Parikh, Department Manager
Hill Partnership	Paul Kirby, General Manger
Honeywell, Inc.	David P. Peters, Manager, CAE Product Marketing Lillian Peters
Hughes Aircraft Company	Frank Goebels, Portfolio Manager Kevin Shambrook, Technical Director, Automation Lawrence Schmitz, Manager, MOS Design
IBM Corporation	David Durish, Advisory Engineer Richard Ma, Senior Marketing Analyst Bob Olmsted, CAD/CAM Market Support William Quigley, Program Manager Steve Volm, Western Regional Manager Judith Volm Fred Wagner, Consultant, General Engineering
IDS Growth Spectrum Advisors	Edward Hartmann, President
Intel Corporation	Robert Noyce, Vice Chairman

InterWest Partners	Scott Hedrick, General Partner
International Microelectronics Products	Bob Gardner, Manager, Marketing Monique Gardner David Lucas, Manager CAD Graham Shenton, Vice President, Marketing
IntraWest Bank of Denver	Leo Beserra, Vice President & Trust Officer
Jennison Associates	David T. Poiesz, Vice President
Kemper Financial Services, Inc.	Bruce Ebel, Research Analyst
LSI Logic Corporation	Wilfred Corrigan, President Richard Perry, Marketing Manager
MacNeal-Schwendler Corporation	Joseph Gloudeman, President Jan Gloudeman
Mayfield Fund	A. Grant Heidrich, Associate Glenn Mueller, General Partner
McDonnell Douglas Automation Company	Brush Bradley, Consultant, Product Marketing Bob Daugherty, Principal Specialist
Megatek Corporation	Susan Harvey, Planning Manager Nancy Savinelli, Director of Product Marketing
Mentor Graphics Corporation	Mike Bosworth, Director of Marketing
Metheus Corporation	Chong C. Lee, Vice President & General Manager, VLSI Michael Sisavic, Vice President Terry Smith, Manager, Product Marketing James C. Towne, President
Micro Component Technology	Ward T. Bell, General Manager

Mostek Corporation	Frank Hope, Graphics Marketing Manager
NCA Corporation	Barry Goss, Vice President, Operations
NUTECH Engineers, Inc.	George Groves, General Manager Gary Kost, Executive Consultant Judy Kost
Nissho Iwai American Corporation	Edmond Murphy, Consultant, Computer Graphics
Nixdorf Computer Corporation	Philip D. Wilson, Product Line Manager Dora Freidman
Parallax Systems Inc.	Martin Picco
Polaroid Corporation	Phillip Mestancik, Senior Administrator, Business Planning
Prime Computer, Inc	Rod MacDow, Marketing Manager Bob Sanchez, Manager, CAD/CAM Relations Robin Sanchez Barry Wolman, Director, Manufacturing Systems
Prudential Insurance Company	Dana O'Brien, Investment Analyst
Prudential-Bache Securities	Steven Colbert, Vice President Laura Conigliaro, Vice President Carol E. Muratore, Vice President Mitch Quain, Vice President David Stueber, Technology Strategist Michael Weisberg, Vice President
Pyramid Technology Corporation	John Hime, Director Product Marketing
Quantel Business Computers	Milo F. Miras, Manager Marketing Technical Support

Qubix Graphic Systems	Bob Harmison, Director of Marketing Jim Lucas, Vice President, Marketing
Qume Corporation	Han Park, Product Marketing Manager/CRT Terminals
R & D Funding Corp.	Hugh McClung, President
Racal-Redac Ltd.	Richard Barrett, Technical Director Ian Orrock, Manager Director Susan Orrock
Raster Technology Inc.	Stephen Coit, Director of Marketing
Schlumberger	Thomas Schaefer, Marketing Manager, Manufacturing Systems
Seattle First National Bank	Joseph Suty, Vice President
Seiko Instruments USA Inc.	Robert Coats, Director of Sales Tom Hutchins, Marketing Analyst
Siemens AG	E. Baltin, Diploma Engineer
Silicon Compilers	Ann Doerr, Marketing Sales
Silicon Graphics, Inc.	Vernon R. Anderson, President James Clark, Chairman & Chief Technical Officer
Silvar-Lisco	Thomas O. Binder, Vice President, Marketing & Sales
Skantek Corporation	Roger Paradis, President
Spectragraphics Corporation	Robert Blumberg, Chairman of the Board Edward L. Busick, President Alan Kaechele, Applications Engineer John Moreland, Director of Marketing

Tektronix, Inc.	Norman B. Acker, Competitive Assessment Manager Cathy Cramer, Product Marketing Manager, Logic Design Systems John Crist, Information Manager, Design Automation Division Robert Martin, Manager, Engineering Jerry Sullivan, Director, Computer Science Group Joe Yesenofski, Program Manager, Graphic Design System
Teradyne, Inc.	Jim Fogle, Engineer
Texas Instruments, Inc.	Bob Myers, Strategic Planner
The Putnam Mangement Company, Inc.	Richard Jodka, Vice President
Toyo Denki Seizo K.K.	Kazuhiko Yoshinaga, Manager, Software Dept.
Triad Systems Corporation	Steve LaCommare, Vice President, Engineering & Manufacturing Ed Morgan, Manager, Manufacturing Ray Osofsky, Manager, Engineering Sheldon Toso, Manager, Quality Services
Trust Company of the West	James Jeffs, Research Associate
VLSI Technologies Inc.	Henri Jarrat, President Douglas G. Fairbairn, Vice President, User-Designed Technology
Valid Logic Systems	Frank Lynch, Director of Marketing
Vectron Graphics	Charles Simon, President Cathy Simon
Versatec	Edwin Saunders, Manager, Market Research

WICAT Systems	Glenn Stewart, Industry Marketing Manager Kay Stewart
Weitek Corporation	Timothy Neuland, Western Regional Mgr, Graphics Products
Western Asset Management Company	Lisa Hammersly, Research Analyst
Wisconsin State Investment Board	Jean Ledford, Investment Officer
Xerox Corporation	Michael Nagel, Product Manager
ZyMOS Corporation	Bob Lorentzen, CAE Tools Marketing Manager

CAD/CAM Industry Conference

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<u>Final List of Attendees</u>

Norman B. Acker	Tektronix, Inc.
Chad Alber	Cadimation, Inc.
Ed Allred	Cericore, Inc.
John Allum-Poon	Calma Company
Vernon R. Anderson	Silicon Graphics, Inc.
Steve Artick Diane Artick	Evans & Sutherland Computer Corporation
David Bailey	Cericore, Inc.
Steve Ball	Cascade Graphics Development
E Baltin	Siemens AG
Ginny Banerjee	Evans & Sutherland Computer Corporation
Bob Barnes	Digital Equipment Corporation
Richard Barrett	Racal-Redac Ltd.
Indre M. Bauza	Bank of America
Ward T. Bell	Micro Component Technology
Leo Beserra	IntraWest Bank of Denver
Morrie Binder	Burroughs Corporation
Thomas O. Binder	Silvar-Lisco
David Birnbaum	Fairchild Test Systems
Robert Blumberg	Spectragraphics Corporation
Mike Bosworth	Mentor Graphics Corporation

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Bob Bourke	Bank of California
Brush Bradley	McDonnell Douglas Automation Company
Kenneth Brody	Gould Distributed Systems
Wes Brown	Digital Equipment Corporation
Ron Budacz	Burroughs Corporation
Edward L. Busick	Spectragraphics Corporation
Jim Callan	CADTRAK Corporation
M. Jean Paul Carcel	BULL SEMS
Pat Castro	Hewlett-Packard Company
James Clark	Silicon Graphics, Inc.
Robert Coats	Seiko Instruments USA Inc.
Calvin Cobb	Hewlett-Packard Company
Jim Coe	Fujitsu Microelectronics, Inc.
Stephen Coit	Raster Technology Inc.
Steven Colbert	Prudential-Bache Securities
Laura Conigliaro	Prudential-Bache Securities
Richard Cook	Digital Equipment Corporation
Wilfred Corrigan	LSI Logic Corporation
Anthony Corsi	General Electric Company
Steve Cottrell	Dataquest Incorporated
Cathy Cramer	Tektronix, Inc.
John Crist	Tektronix, Inc.
Donald Cvietusa	Bank of America
Bob Daugherty	McDonnell Douglas Automation Company
Francois DeBelenet	BULL SEMS

Ann Doerr	Silicon Compilers
Russell Doty	Applicon, Inc.
Michael Dulion	Arthur Young & Company
David Durish	IBM Corporation
Stan Eaton	Burroughs Corporation
Bruce Ebel	Kemper Financial Services, Inc.
Kamran Elahian	CAE Systems, Inc.
Douglas G. Fairbairn	VLSI Technology, Inc.
Phil Fernandez	Tektronix, Inc.
O. Ralph Finley	Dataquest Incorporated
Frank Florence	Dataquest Incorporated
Jim Fogle	Teradyne, Inc.
Dora Freidman	Nixdorf Computers
Bob Gardner Monique Gardner	International Microelectronics Products
Daniel Garms	Cad/Cam Specialists, Inc.
Timothy Gauhan	Dataquest, Incorporated
Frank Gianattasio	Consultant
Richard Gimbel	Apollo Computer
Joseph Gloudeman Jan Gloudeman	MacNeal-Schwendler Corporation
Frank Goebels	Hughes Aircraft Company
Barry Goss	NCA Corporation
Rupert Grimm	BA Investment Management Corporation
George Groves	NUTECH Engineers, Inc.
Howard Hagen	Dataquest Incorporated

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Lisa Hammersly	Western Asset Management Company
David P. Hanna	Auto-Trol Technology Corporation
Bob Harmison	Qubix Graphic Systems
Edward Hartmann	IDS Growth Spectrum Advisors
Susan Harvey	Megatek Corporation
Sally Hasson	Dataquest Incorporated
Satoru Hayashi	Fujitsu America, Inc.
Scott Hedrick	InterWest Partners
A. Grant Heidrich	Mayfield Fund
John G. Heit	General Dynamics Corporation
John Hime	Pyramid Technology Corporation
Katsuhide Hirai	Fujitsu America. Inc.
Frank Hope	Mostek Corporation
Tom Hutchins	Seiko Instruments USA Inc.
J. E. Iwersen	Bell Laboratories
John Jackson	Dataquest Incorporated
Henri Jarrat	VLSI Technologies Inc.
James Jeffs	Trust Company of the West
Richard Jodka	The Putnam Mangement Company, Inc.
Harvey Jones	Daisy Systems Corporation
Daniel R. Jones	Genisco Computers Corporation
David Jorgensen	Dataquest Incorporated
Richard L. Justice	General Motors Corporation
Alan Kaechele	Spectragraphics Corporation
Len Keene	Adage

Henry Kellogg	Computervision Corporation
Paul Kirby	Hill Partnership
Gary Kost Judy Kost	NUTECH Engineers, Inc.
Paul Kruger	Digital Equipment Corporation
Robert Kuhling	Calma Company
Steve LaCommare	Triad Systems Corporation
Lucio Lanza	Daisy Systems Corporation
Wendy Ledamun	Dataquest, Incorporated
Jean Ledford	Wisconsin State Investment Board
Chong C. Lee	Metheus Corporation
Al Libbey	Gould Incorporated
Rhonda Lindsey	CADAM Inc.
Bob Lorentzen	Zymos Corporation
David Lucas	International Microelectronics Products
Jim Lucas	Qubix Graphic Systems
Frank Lynch	Valid Logic Systems
Richard Ma	IBM Corporation
Rod MacDow	Prime Computer, Inc
Mark MacLennan	Bank of Boston
Robert Martin	Tektronix, Inc.
Cathy Marvin	Dataquest Incorporated
John Maxwell, III	First Pennsylvania Bank
Harold McAleer	GenRad, Incorporated
Hugh McClung	R & D Funding Corporation
Michael McDonald	Cad/Cam Specialists, Inc.

Donald McGinnis	Digital Equipment Corporation
Tom McManus	Dreyfus Corporation
Leon McMillan	Continental Illinois Bank
Robert D. Merrell	Burroughs Corporation
Phillip Mestancik	Polaroid Corporation
Milo F. Miras	Quantel Business Computers
John Moreland	Spectrgraphics
Ed Morgan	Triad Systems Corporation
Glenn Mueller	Mayfield Fund
Carol E. Muratore	Prudential-Bache Securities
Edmond Murphy	Nissho Iwai American Corporation
Bob Myers	Texas Instruments, Inc.
Michael Nagel	Xerox Corporation
Suki Nakamoto	Calma Company
Timothy Neuland	Weitek Corporation
James R. Newcomb	Dataquest, Incorporated
Tom Newsom	Hewlett-Packard Company
Laura Nichols	Dataquest Incorporated
Robert Noyce	Intel Corporation
Dana O'Brien	Prudential Insurance Company
Bob Olmsted	IBM Corporation
Ian Orrock Susan Orrock	Racal-Redac Ltd.
Ray Osofsky	Triad Systems Corporation
Roger Paradis	Skantek Corporation
Mihir Parikh	Hewlett-Packard Company

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Han Park	Qume Corporation
Richard Perry	LSI Logic Corporation
Richard A. Peters	California Computer Products, Inc.
David P. Peters Lillian Peters	Honeywell, Inc.
Gayle Phillips	Dataquest, Incorporated
Martin Picco	Parallax Systems Inc.
Donna Plath	Dataquest Incorporated
David T. Poiesz	Jennison Associates
Mitch Quain	Prudential-Bache Securities
William Quigley	IBM Corporation
John Randall	Dataquest Incorporated
Susan B. Ray	Computervision Corporation
James Riley	Dataquest Incorporated
John Robotham	Apollo Computer
Dave Rome	Data General Corporation
Chuck Rosselle Joan Rosselle	EDS Nuclear/Impell
David Rumsey	Burroughs Corporation
Sherman L. Rutherford	Data General Corporation
Frank Sammann	Dataquest Incorporated
Bob Sanchez Robin Sanchez	Prime Computer, Inc.
Edwin Saunders	Versatec
Michel N. Sauvage	BULL SEMS
Nancy Savinelli	Megatek Corporation
Thomas Schaefer	Schlumberger

Lawrence Schmitz	Hughes Aircraft, Inc.
Steve Schopbach	Cadtec Corporation
Bill Seaver	Digital Equipment Corporation
Kevin Shambrook	Hughes Aircraft Company
Graham Shenton	International Microelectronic Products
Charles Simon Cathy Simon	Vectron Graphics
Michael Sisavic	Metheus Corporation
Joe Sitarik	Bell Laboratories
Matt Slavik	Apple Computer
Randy Smith Kayo Smith	California Automated Design, Inc.
Philips W. Smith	Computervision Corporation
Terry Smith	Metheus Corporation
Michael E. Sokolski	Control Data Corporation
Robert Speicher	Dataquest Incorporated
Sri Sriram	Digital Equipment Corporation
Michael Sterling	CADLINC
Robert Stevenson	Auto-Trol Technology Corporation
Donald C. Stewart	Calma Company
Glenn Stewart Kay Stewart	WICAT Systems
Daphne Strong	Bank of Boston
David Stueber	Prudential-Bache Securities
Jerry Sullivan	Tektronix, Inc.
Joseph Suty	Seattle First National Bank
Thomas R. Teeters	Calma Company

James R. Tobias	American Microsystems, Inc.
Sheldon Toso	Triad Systems Corporation
James C. Towne	Metheus Corporation
Beth W. Tucker	Dataquest, Incorporated
Gail Van Tubergen	Dataquest, Incorporated
Steve Volm Judith Volm	IBM Corporation
Fred Wagner	IBM Corporation
Martin Walker	Analog Design Tools, Inc.
Ed Washington	Dataquest Incorporated
David Weisberg	Auto-Trol Technology Corporation
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Barry Wolman	Prime Computer, Inc.
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Joe Yesenofski	Tektronix, Inc.
Kazuhiko Yoshinaga	Toyo Denki Seizo K.K.

MANUFACTURING IS NOT A BUTTON ON THE DESIGN DATA BASE

Michael W. Sterling
Vice President
CADLINC, INC.

Mr. Sterling is Vice President of Engineering for CADLINC, INC., a CAD/CAM company. Prior to the company's acquisition by CADLINC, he was President of System Associates, Inc. Previously, he was a Senior Mathematician and Senior Development Engineer for General Motors Corporation, specializing in CAD/CAM. Mr. Sterling received B.A. and M.A. degrees in Mathematics from the University of Detroit.

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MANUFACTURING IS NOT A BUTTON ON THE DESIGN DATA BASE

INTRODUCTION

It is a shock to buyers of $100,000.00 per seat CAD/CAM systems when they realize that they are not saving money. The reasons for this are complex and our industry must be blamed, not so much for over-sell as for lack of understanding of the mechanical CAD/CAM problem set itself.

We hope to shed some light on the problems and point out some areas of development that will lead to solutions.

The evidence that we will bring out will support the thesis that a certain CIM architecture and a methodology can be gently placed on current manual methods in a fashion that will accelerate productivity. Along the way we will have to illustrate solutions by pointing out problems. (See Figure 1)

The architecture we will illustrate will be the now emerging Local Area Network scheme. The idea here is to put personal engineering workstations on a very high-speed communication channel. Each node will be a powerful self-sufficient computer with no degradation in performance.

Each network will communicate to brother and sister networks via telecommunication gateways or other high-speed internet gateways. We will show that this architecture is the proper one because it has good characteristics:

1. Simplicity
2. Low Cost
3. Functionality
4. Mimics the well-established conventional world.

HISTORICAL BACKGROUND

The mechanical engineering portion of the CAD/CAM industry is complicated. Most successes and economic advantages have taken place elsewhere, such as electrical engineering.

The reasons for this are:

- New technology is easiest to apply in a new industry.
  - Lack of past manual methods help make new ideas more acceptable.
  - If the industriy is new, then organizations grow with technology: Technology is not imposed on the organization.

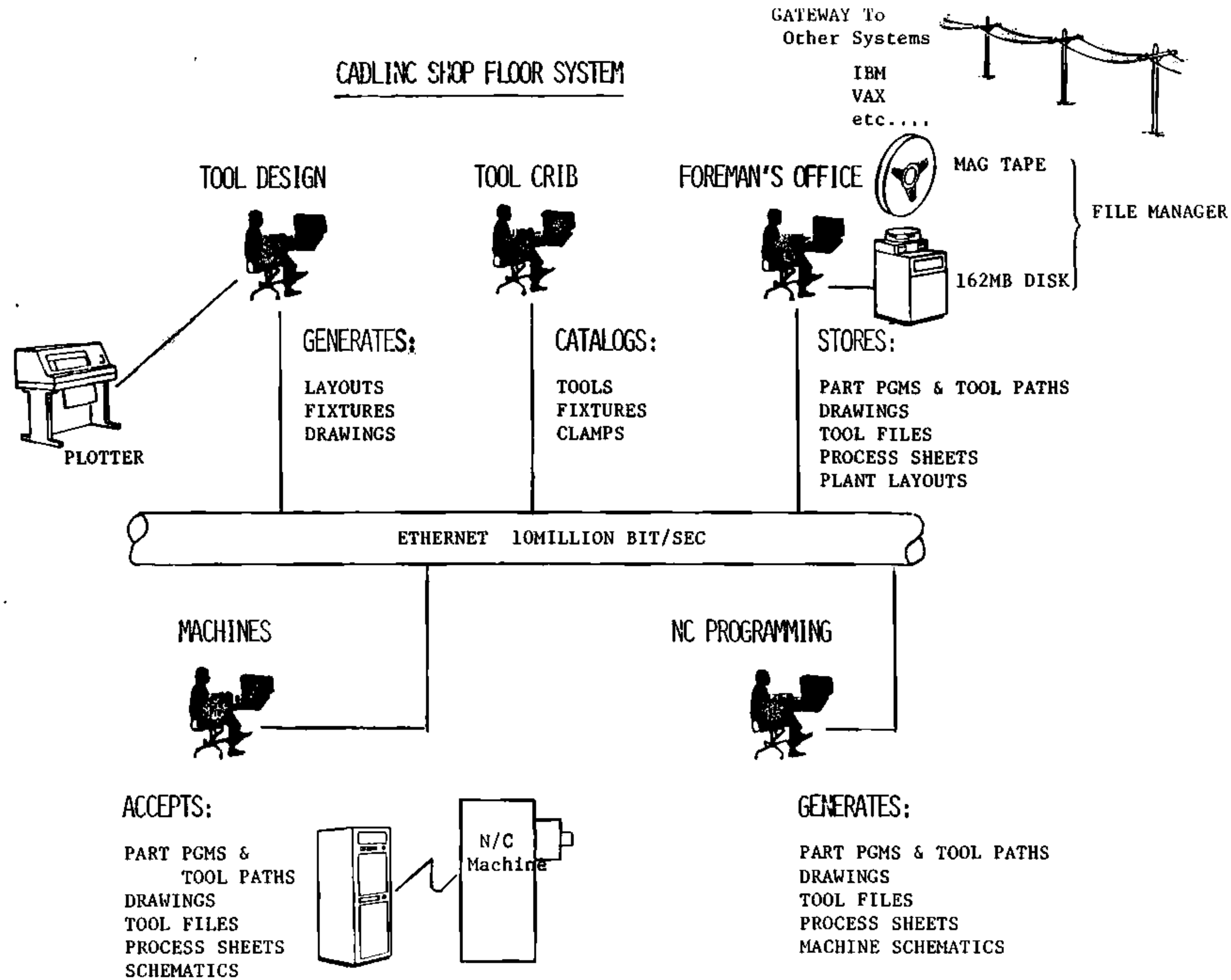

CADLINC SHOP FLOOR SYSTEM
GATEWAY To
Other Systems
IBM
VAX
etc....
TOOL DESIGN
TOOL CRIB
FOREMAN'S OFFICE
MAG TAPE
FILE MANAGER
162MB DISK
GENERATES:
LAYOUTS
FIXTURES
DRAWINGS
PLOTTER
CATALOGS:
TOOLS
FIXTURES
CLAMPS
STORES:
PART PGMS & TOOL PATHS
DRAWINGS
TOOL FILES
PROCESS SHEETS
PLANT LAYOUTS
ETHERNET 10MILLION BIT/SEC
MACHINES
NC PROGRAMMING
ACCEPTS:
PART PGMS &
TOOL PATHS
DRAWINGS
TOOL FILES
PROCESS SHEETS
SCHEMATICS
N/C
Machine
GENERATES:
PART PGMS & TOOL PATHS
DRAWINGS
TOOL FILES
PROCESS SHEETS
MACHINE SCHEMATICS

Figure 1

- Mechanical Engineering and Manufacturing are ancient disciplines. They have their roots in antiquity. Therefore, as chaotic as they may seem at times, these manual methods are surprisingly efficient. One only has to spend a few weeks with a die or mold maker to be impressed with this fact. Toolmakers are smart people !!

- The field is very broad. A designer cannot be expected to grasp the manufacturing technology of the spectrum of parts he or she designs.

- It takes about ten (10) years to develop a good mechanical designer. It also takes ten (10) years to mold a manufacturing engineer. To combine these two into one individual is asking too much over an entire industry.

- The CAM portion of electrical engineering is so new that it has grown up with the design technology. For example, VLSI designers are thinking about most of the details of the manufacturing process as they design. As this field matures and the manufacturing techniques become more exotic, then they, too, will have trouble with the CAD/CAM connection in its entirety.

- Since most computer science people know little about manufacturing engineering, the systems they produce place little emphasis on CAM.

FUNCTIONS OF DESIGN

We should reflect on the purpose of design in order to clarify our thoughts about Computer Integrated Manufacturing. The first fact that is apparent is:

"DESIGN IS NOT AN END IN ITSELF"

This simple idea is often not understood. Designers are sometimes frustrated artists. This is especially true with draftsmen.

The functions of design should be:

- Designs make ideas clear to others. Designs are ideas that function in time.

- Designs are great vehicles to work out problems. The problems are usually spatial in nature like clearances. Many times engineering properties need to be analyzed by the designer.

- Designs might be clear to other designers, but not to manufacturing. In order to make them clear to manufacturing, one needs to add notes. So designs are not all geometry.

- Designs represent a product that can be manufactured.

TYPES OF DESIGN

There are two basic kinds of design - product and tool. Tool design is much richer since it includes automation. A tree of design shows far more branches on the manufacturing side than on the product side. (See Figure 2)

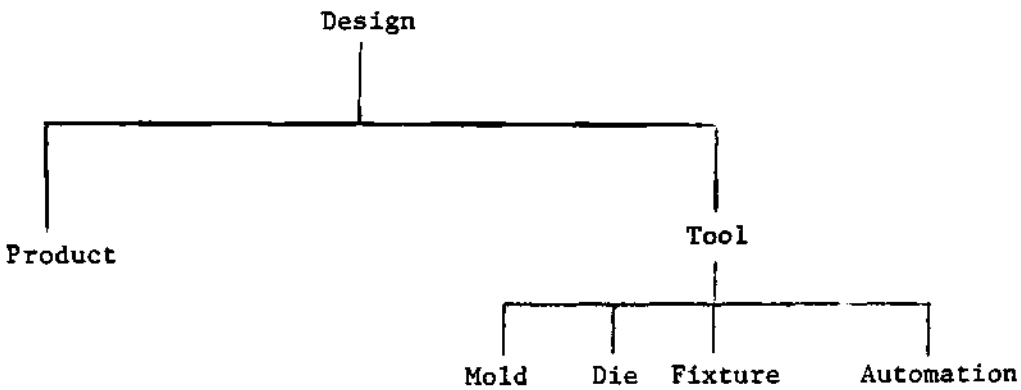


Figure 2

For every product designer, there are five designers on the tooling end of the spectrum. They think of themselves as manufacturing engineers.

We should notice that a product design may remain quite constant over a long duration, while the manufacturing process changes many times underneath it.

- Most people have thought of CAM in terms of numerical control. This is only part of a vast CAM process. In order to appreciate it we must think in terms of CIM - Computer Integrated Manufacturing.

In major companies product and tool design activities are organizationally distinct. The information network they encompass reaches across the main arteries of the organizational charts of the companies. It also extends to satellite companies that serve the industrial giants.

The conventional world is a Local Area Network and we should recognize it as such.

DATA BASES

We need to look at a conventional data base that is maintained on paper with the human being as the relational integrator.

The CIM equation will be similar, with the man being the initial integrator of technology.

Therefore, we should try to define the conventional data base. The product design data base consists of a number of items:

- Geometric Indicators
- Notes and Dimensions
- History of Development
- Relation to Other Products

GEOMETRIC INDICATORS

Drawings of products contain geometry. This is apparant to everyone. The drawing indicates the entire geometry and is very precise about part of it.

For example, no draftsman will draw every tooth on a gear hub. He will be precise about one and indicate the others.

No draftsman will draw a full thread. He will only be precise about it if it is the first of its kind. Otherwise, the geometry will not be shown at all.

In many complicated parts, the non-essential geometry is indicated only with notes such as "blend from .5R to .25R" over a given distance. This gives a toolmaker latitude without hindering functionality. In this case, the designer is using good sense.

Good product designers are very stingy with precision. They know that precision must only be used when it is necessary. Over use precision and it will dramatically increase cost because manufacturing tries to produce what is drawn.

NOTES AND DIMENSIONS

Notes are great refiners of geometry, yet they in fact do much more. A note indicating "heat treat" can greatly change the total geometry configuration of a part and its functionality. The designer relies totally on the manufacturing engineer in this case.

For example, many turned parts are heat treated. Parts that are turned often serve in mechanisms that have mating rolling surfaces. The designer who says "heat treat" in a note should be cognizant of the manufacturing process, but most times is not.

Heat treating, dimensional tolerancing, possible grinding operations, numerical control, metallurgy and tolerance charting may be influenced by that one note.

The manufacturing process highly influences functionality of mechanisms. In molded or formed parts a note that says "maintain sharp corners on decorative trim design" can have the effect of greatly increasing tooling cost.

The manufacturing engineer must now consider a whole new set of problems because of such a note. If the volume is modest, then he may be able to get away with low cost aluminum tooling. If the volume is medium, say 20,000 parts, then that one note can add weeks and $100,000.00 and more to tooling costs.

The reason is that soft tools may not be able to do the job and tool steel may be necessary to maintain sharp corners on a decorative trim. Tool wear becomes important at 20,000 parts.

Going back to the geometric side for a moment, hundreds of thousands of dollars are added to tooling cost by small product geometry differences.

The simplest die is the one that has a neat, clean mating between male and female pieces with little or no binder development. Minute differences in the product cause dramatic changes in the geometry of the die.

In plastic parts this is also true. The simplest mold is the best one. The biggest cost increment often comes from a small change in geometry. Consider the terminal housing shown in Figure 3 (Black Housing).

The geometry for the bezel is OK, since a simple two-piece mold is sufficient. The housing itself is made with two molds - one for the top and one for the bottom. In the top mold, there is a back draft of just a few millimeters. This no longer is a simple two piece mold. Two courses of action are open to the manufacturing engineer:

1. Build a multiple pull mold with the backdraft area opening via separate cylinder. This will add weeks to mold production and almost double its cost.

2. Go back to the designer and ask "Is this backdraft essential?"

What we always have to keep in mind is that this type of expensive tooling is the essence of high production American manufacturing. It used to be that volume overcame the cost in captive markets. This is no longer true, since we must respond to change that much faster.

Before we leave this terminal design, let's examine it from the standpoint of the impact of dimensions on economic production.

The product designer took about six weeks using CAD techniques to design the enclosure. The design included:

- Esthetics - The surfaces are all free-form and pleasing.

- Fit - The bezel fits the tube, and the housing, the base.

- The production of a full scale wood model for evaluation and possible external tooling.

The completion of this phase would constitute about 1/5 of the total time to production and at least five other designer/manufacturing engineers would have to become involved before final tooling would be done.

Only about 1/5 of the CAD methods are complete. The other 4/5 are consumed in the design of the tool. Since the original design culminated in the production of a fully NC generated model, the geometric information is available. If the design had not gone to a model, it would have required much more work.

If the conventional world, the human being fills in the gaps. Lines drawn on paper jump out to form parts and tools in the manufacturing engineer's mind set. The CIM equation has to do this also. This is not done easily by most system.

In order to drive cutters around objects, the geometry must make digital as well as visual sense. We will call this topological integrity.

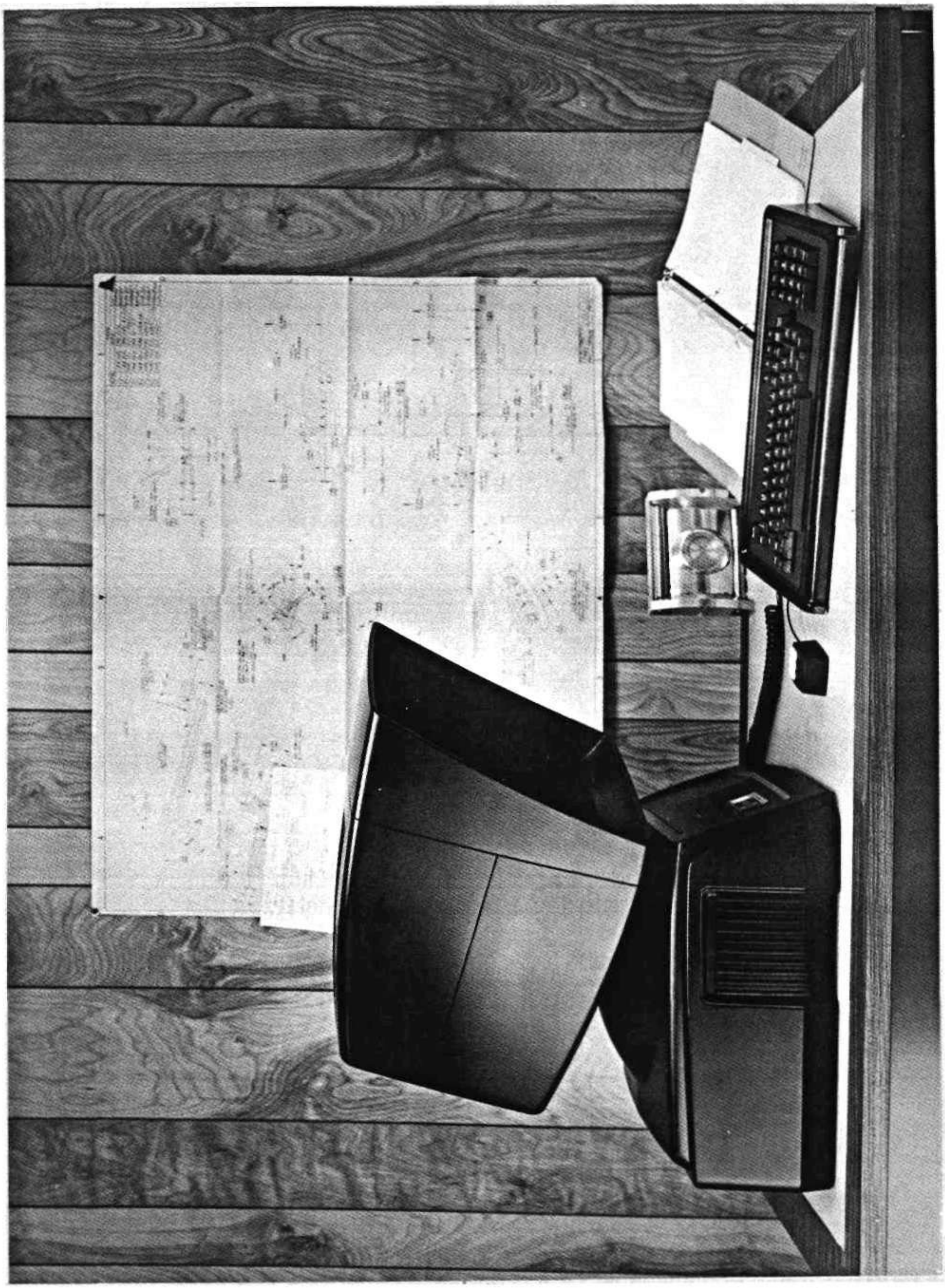
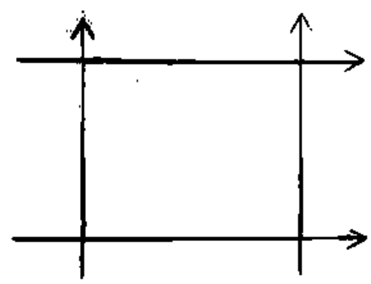


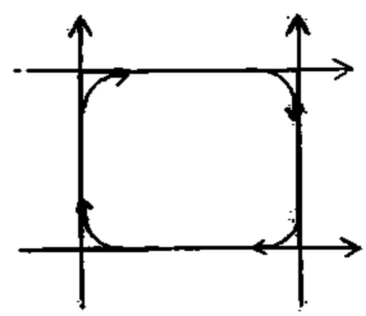
Figure 3

Very few designs hang together topologically. Let me give a simple example of creating an oblong in CAD.

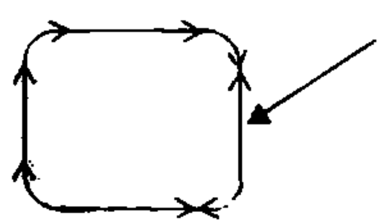
Step 1 -- Construction Lines



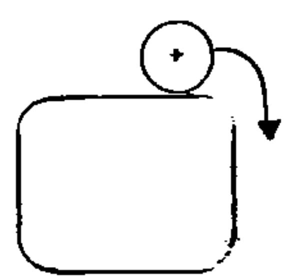
Step 2 -- Fillets



Step 3 -- Trim



Step 4 -- Profile Cut



I have kept the line directions to show you how the design is visually complete, but is topological nonsense. In order to profile cut this shape with a tool, we must have one geometrically complete entity.

MOST DESIGN SYSTEMS WORK FOR VISUAL COMPLETENESS

ALL MANUFACTURING SYSTEMS REQUIRE TOPOLOGICAL INTEGRITY

Herein lies the dilemma. More integrity means more man hours in the design. To add integrity to the design means adding more to the design budget.

Remember, we are trying to lay a new process gently on an old discipline that is quite efficient. The CIM local area net must not produce gross budgetary bumps on the conventional network.

As soon as chief draftsmen are asked to do more work, they rebel. They are responsible for drawings (visuals). Stitching things together for data integrity is not their job. Organizationally they never worried about it and they want it to remain so.

Notes and dimensions can be very confusing to manufacturing. For example, we have seen many aerospace parts with notes that say "spline" and then give a table of (x,y) values. On the same drawing, we might see a table of five (x,y) values and a note that says "conic".

Spline is imprecise since splining techniques are as varied as the wind. For example, did the designer mean cubic spline, rotated cubic spline (Fowler-Wilson), quintic spline, etc..?

Now five point conics are exact, since they define a general conic: but the note is somewhat obscure for most manufacturing engineers.

Here is a case where conventional and CIM techniques have come together to produce nonsense. The writer of such a note was a west coast aerospace firm while the receiver was a midwest tooling firm trying to use CIM tooling methods.

HISTORY OF DEVELOPMENT

Normal drafting room practice dictates that a drawing have a change record or block on it. The purpose of this is to track a design record from its creation to the present. This serves as an audit trail so that related parts can be checked to see how they have been influenced by changes.

The assembly drawing is usually the court of last resort because it will often show a "bubble" of the latest change of a piece part.

All this is well known. What is not apparent is that changes that occur once manufacturing has started literally influence an average of five (5) drawings. Once the manufacturing process has started, change is the big money loser. This is one of the reasons that manufacturing engineers try to wait as long as possible to begin tooling that which is close to the product surface itself.

What they do is get an idea of the product and start on the auxiliary areas, knowing that if they move too close to the product structure too early they will be ruined by change.

Change has become such a strong influence in American industry that it has created an entire sub-industry. This is known as the model and prototype tooling industry.

Models and prototype tooling are absolutely essential to high volume manufacturing. The computer industry has helped to create prototypes, but has done little to eliminate them.

Two things are apparent:

- Our computer data bases are not rich enough today to support going to hard tools without intermediate steps for complicated parts.

- Models and prototype tooling are valuable as communicators of information and ways to work out fit and form, fixture, automation and all sorts of manufacturing problems.

We have been fooled by going directly to product via NC. This is sensational when it is possible. We should seek out every instance where it is possible and automate the process to as high a degree as possible. There is, however, an area, a large area, where major tooling is required that is very hard to get to directly. This is the heavy metal cutting business, so vital to our world industrial economic power.

This area is the vital one for the computer industry to look at because it involves the most potential for savings.

WHAT HAS HAPPENED TO THE DATA BASE IN THE SKY?

In the early 1970's, I thought that the next decade would yield useful geometric data bases running from initial design to the shop floor. This has not happened. Corporate commitment has taken the blame. "They did not understand", "They were not ready", "They stuck to the old ways", "They" meaning the Universal Corporate ogre.

They did slow things down, but the reasons are a lot deeper than superficial slow stepping. These are the reasons, I think, that the design manufacturing data base has not taken hold:

- Manufacturing has been left out. Software and hardware has been allocated to a small cadre of superior designers in the engineering office.

- Manufacturing problems are too little understood.

- Display technology has been too expensive for high quality pictures for the masses.

- Too much emphasis has been placed on large host machines because this was thought to be the way to capture and channel data (corporate data base control).

In short, we have been working with the wrong basic architecture because the corporate data base centered around huge machines cuts across the bias of the conventional world. We must mimic the conventional world and bring the innate abilities of the man back into the CIM equation.

We really did not know enough about data to channel or capture it. We certainly did not know that our machines would not support relational data bases in a meaningful way. Our present architecture is set up to compute, not store and rapidly retrieve masses of pointer-based data structures.

Every manager who is a non-professional computer person should ask his computer staff to tell him how their present CAD/CAM system can support a manufacturing data base in full. Ask them to compute the number of characters required to store the data sequentially. Do not have them bother with the relational aspects.

Ask them to have a report ready two weeks from Tuesday. The CAD/CAM manager is in for a surprise! His staff is unlikely to return two years from Tuesday with any good answers if the company is a Fortune 1000 company with any manufacturing capability at all. No wonder manufacturing data bases have been so hard to grab onto. The organizations that are charged with building it do not have any manufacturing people in them. Where they do, they are picked because they know how to program the company's latest NC equipment, not because of their expertise in the manufacturing process.

How, then, does one go about building a decent data base.

We have to use two primary management tools:

1. Put the right people on the problem.

2. Give them some tools that fit the problem set.

Here is an outline:

1. Put in the proper computer architecture. This means one that mimics the current manual process. This will be Local Area Networks.

2. Get someone on your staff who knows the organization from design through manufacturing. This might be hard to get because manufacturing data base design is not the key to the executive suite.

3. Establish a large block diagram of organizational working units.

4. Find out 10 inputs and outputs of these groups.

5. Order the I/O in priority in each block of the diagram.

6. Create sequential ASCII files to represent each part of the organization.

7. Let the individual groups use their own local area networks and ask them to enter the data as they see fit so it can be looked at by people in their local area, as well as remotely using communication techniques that are standard.

8. Allow communication to take place. People will find ways to use the data effectively if they can look at it on their terminal.

9. Rather than force everyone to one standard before we know what the standard is, establish some guidelines for the data that are easy to achieve. Later, ASCII data stored in an orderly fashion is easy to transfer to a "proper" data base if it warrants it. IGES is a good start here.

The reason we should do all this is that it is an orderly approach to the problem that saves money. It does so by getting the whole organization working the quickest. This is the CIM approach.

THE MYSTERY OF THE 3D DATA BASE

In over 20 years of working with designers and skilled tradesmen, it has become apparent that most designers design in multiple 2D views while tool-makers work in 3D. Maybe the analogy of the painter vs. the sculptor is proper. The difference in thought process can cost us big dollars if we do not have a system that can deal with it.

Toolmakers get to be journeymen with two skills:

1. The ability to visualize 2D drawings as 3D complements. Most tools are in a sense the geometric complemenet of the product to be made.

2. Manual dexterity.

Exceptions to this are loftsmen, who are natural 3D thinkers.

Mechanical designers are "flat-land people". The design problem that might help you understand this is the design of a copying machine. This is a problem of a mass of mating and inter-related mechanical parts. The design is primarily a two-view design --

- Side view for lever movement.

- Plan view for interference and clarity.

The parts are primarily swept shapes. That is, 2D profiles pushed through a third axis.

I make this claim today in September 1983 -- "To use a CAD system to design a copier in full 3D with a set of good mechanical designers will add to the cost of the design."

This is a testimony to the capability of current CAD systems and the state of skills that mechanical designers have.

Another statement of fact -- "The tool designer would not benefit by the '3D-ness' of the data base because the product data base is not the tooling data base." If it were simpler to design in 3D and it cost less, then great. If it benefitted tooling, then also great.

There are some items in the design that would benefit by the use of full 3D. These are items that may undergo some sort of engineering analysis or those for which special tooling may be required.

You can get more benefit out of an early tooling input to the design than you can the 3D aspects of it. The tooling engineer is capable of saving great sums of money if they are available for early design review.

Let us look at another part of the mechanical industry that has been touted as a source of savings -- Die Design.

The product itself may be as 3D as can be with all sorts of sculptured surfaces, but die designers primarily design in plan view looking down at the die. The extent of their 3D-ness, once the product complement surface is positioned in the male or female die, is to add bumps on the binder surface so that proper forming will take place.

About 65% of all machining of these surfaces is 2-1/2D. This means the tool-maker needs profiles and hole locations at Z depths to build the tool.

One of the largest industrial companies in the world worked long and hard at 3D die design. Their findings were:

1. The cost of design went up dramatically.

2. The best designers said it was not needed.

3. The system response slowed dramatically with a topologically complete data base.

4. The tooling engineer had more work undoing the ornate topology to do 65% of their work.

So what they have opted to do is revert to 2-1/2D design and use 3D only when it will directly save money as dictated by tooling.

FUTURE OF 3D

Of course, 3D is here to stay. It has so many benefits whether it be wire frame or solid, but I am amazed that two facts are not realized about where we are today.

1. 3D costs more.

2. 3D has trouble competing with conventional methods in any way across the broad spectrum of applications.

So what can we do. I propose the industry do two things:

1. Recognize the problem and work on it so we can afford full 3D. This means data base research and architectures to run them on suitably.

2. Companies should adopt structured design techniques.

STRUCTURED DESIGN TECHNIQUES

The software industry has found that top down design is the way to go. All this means is:

1. Generalize the problem into gross block diagram form.

2. Only break down the blocks when the whole process is understood.

3. Have regular and consistent design reviews.

Mechanical CAD/CAM could use this approach, involving a tooling engineer from design inception.

It usually works the other way. A contact person from design works with tooling after the design is done. Usually, contact people are not top quality. They are put in this job either when too inexperienced or when they are not competent in a more useful role. They serve as couriers of bad news -- "We're late, you're late, there is a problem they say" etc...

If the tooling engineer were present at early design reviews, then all sorts of problems would disappear. Early consensus is more vital in the CIM process than it is in the conventional world because the data base in the sky is obscured by clouds much longer.

OUT SOURCING

Forty to fifty percent of tooling is outsourced by our industrial giants. Since bids for tooling are done late in the design process and are competitive, how do we involve manufacturing at early stages ?

The Japanese have solved this problem. They tacitly recognize that dominant industries create captive satellite shops. They buy shares in them, sit on their boards and try to keep them profitable. These satellites participate in the famous Japanese consensus.

U.S. companies cannot do this, but they can alter their purchasing procedures in a way that recognizes what is apparent to everyone:

1. The satellites are cleverly run by skilled people.

2. The head count and, therefore, the cost profiles of these companies are much more attuned to boom - recession economy.

3. These companies need to make a profit.

Purchasing agents of high quality recognize all these while others exercise the disposable vendor philosophy, which says:

1. Make them invest in CIM equipment to get the work.

2. Work them against others for price.

3. Dispose of them if their price rises above conventional processes.

I am sure that major tooling programs can be thought out better for the long haul.

Now if this is solved, then we will have to extend the Local Area Network concept to small shops. This has been done in the Detroit area. We call this CIM VENDOR. The idea is to be able to send data from a dominant industrial giant to a tooling shop.

Ideally, it works like this:

1. The shop is called in early to bid on a portion of a major tooling program.

2. The manufacturing engineer knows what kind and type of data he will receive.

3. The bid is accepted by the dominant company.

4. The data is electronically sent via a gateway utility from the large corporate network to the small shop.

5. The shop manufacturing engineer processes the data to produce the tools.

CONCLUSION

My experience tells me that we can really step up productivity by using simple strategies that are at the essence of the CIM philosophy.

- Put in Local Area Networks.

- Do not overdo the data base too early.

- Allow data to flow.

- Use the innate computing and visualization power of the human beings in the organization.

The key idea is to allow the technology to settle on top of the existing organizations. Maybe we should call this technology CIM-M -- Computer Integrated Manufacturing with man as the integrator.

We need to get this technology into American heavy industry in order to revitalize it and allow us to compete in world markets where other countries compete with lower labor rates and the benefit of new technologies growing up with new organizations.

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CAD MARKET REVIEW AND FORECAST

Beth W. Tucker
Research Analyst
CAD/CAM Industry Service
Dataquest Incorporated

Ms. Tucker is a Research Analyst for DATAQUEST's CAD/CAM Industry Service. Prior to joining DATAQUEST, Ms. Tucker was Market Planning Manager of Calma Company's Microelectronics Division, where she was responsible for identifying market opportunities and developing marketing strategies for the company's electronic CAD product line. She later contributed to the development of marketing information systems at Calma's corporate level. Prior to that, she was a Senior Market Research Analyst with Monroe Systems for Business, where she was responsible for market research and development of small business computer products. Ms. Tucker holds an A.A. degree in Computer Technology from Morris County College in New Jersey and is doing course work in Business Administration at San Jose State University.

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CAD/CAM INDUSTRY CONFERENCE
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INTRODUCTION

Computer-aided design and computer-aided manufacturing play key roles in contributing toward productivity gains in most major U.S. industries. The complexity of automating the engineering, manufacturing, and testing of products of all types is being addressed by CAD/CAM vendors and their products. Users of such products are demanding, and their level of sophistication is increasing almost exponentially.

MARKET SIZE

DATAQUEST estimates that CAD/CAM industry worldwide revenue will reach $9 billion by 1987, increasing from $2 billion in 1983. This represents a compound annual growth rate of 43 percent.

The industry comprises five major segments: mechanical; architecture, engineering, and construction (AEC); printed circuit (PC); integrated circuit (IC); and mapping and other. The mechanical segment is the largest, with 1983 revenues expected to reach $1.1 billion, growing at 44 percent per year to almost $5 billion in 1987. The fastest-growing segments are IC and PC, with compound annual growth rates of 47 and 46 percent and estimated 1987 worldwide revenues of $863 million and $1,551 million, respectively. The AEC segment is growing at 39 percent per year, and represents 15 percent of the CAD/CAM market with 1983 revenues of approximately $326 million.

Analyzing industry revenue is a traditional and significant approach to determine market size and market share. However, because system selling prices vary considerably, it is perhaps more meaningful to determine market size by analyzing the number of "seats," or workstations sold. A workstation, in this case, is defined as a single-user station and may be standalone or host dependent.

DATAQUEST estimates that during 1983, approximately 17,000 workstations will be shipped and that this number will increase by 63 percent per year to 119,000 workstations shipped in 1987. Workstation shipments are increasing significantly faster than our revenue estimates, indicating that the average cost per workstation is decreasing. Sales of workstations for designing integrated circuits and printed circuit boards will experience the fastest growth rate, followed closely by workstations for mechanical engineering.

For this analysis, the average cost per workstation or seat includes the cost of the CPU, peripherals, stations, and all software spread between the average number of workstations per system. The average cost also takes into account standalone and host-dependent stations. DATAQUEST predicts that the average cost per workstation will decrease a total of 40 percent, from $126,000 in 1983 to $75,000 in 1987. The IC segment will experience the largest cost decline, at 16 percent per year. This decline is largely due to the electronic design automation (EDA) subsegment's wide use of low-cost 32-bit standalone systems.

SYSTEM USE

DATAQUEST's CAD/CAM Industry Service recently conducted a survey of 4,000 CAD/CAM users. Among other things, we were interested in determining what percentage of system time is spent on drafting, on design/modeling, on analysis, and on manufacturing applications. A preliminary analysis indicates that the percentage of system time spent on each of these applications is 60 percent for drafting, 27 percent for design/modeling, 5 percent for analysis, and 8 percent for manufacturing applications for all market segments. As expected, the percentage of system use varies by segment. For example, AEC systems are not used for manufacturing applications and so the largest percentage of system time is spent on drafting. In contrast, manufacturing applications for mechanical systems comprise 11 percent of system time. PC systems are used mainly for drafting, due to the wide use of systems for to creating artwork. As better and easier routers become available, DATAQUEST anticipates a shift from straight drafting toward more system time spent on design/modeling. By 1987, DATAQUEST predicts a shift in system use, toward more design/modeling, analysis, and manufacturing, with less emphasis on drafting.

CAD/CAM TRENDS

These changes will occur for many reasons. First, and perhaps most importantly, the market demands it. CAD systems originally filled the need to automate drafting and the associated changes and documentation. This need has been successfully filled by many vendors in each of the CAD/CAM market segments. As users and vendors become more sophisticated in using and designing CAD systems, a higher level of sophisticated application programs is being developed with a shift toward more analytical programs and more integration of manufacturing applications.

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Second, significant trends in hardware design, software development, and systems integration philosophies are helping to make the goal of providing a true end-to-end systems approach a reality.

Distributed processing provides each seat with local intelligence, enabling the user to perform interactive, creative, and analytical processes locally. Relatively young companies are dominating the distributed processing market with low-cost 32-bit workstation products. The more well-established computer companies that have traditionally supplied CAD/CAM hardware are also developing or introducing distributed processing systems. The user can now purchase a CAD/CAM system at a relatively low initial purchase price and expand the system without spending hundreds of thousands of dollars. Distributed processing provides a consistent level of performance, regardless of the number of seats, and if one workstation crashes, only that user is affected.

Improved communications capabilities and data base management systems go hand in hand with distributed processing. The size and complexity of CAD/CAM data bases is increasing to the point where local area networks (LANs) and data base management systems (DBMSs) are needed to manage the engineering and design processes. LANs and DBMSs support clusters of local systems so that data and system resources can be shared among users. Manufacturing design functions, i.e., numerically controlled machines and factory robots, tooling, and group technology data bases, are dependent on communicating with the same design data base created in engineering.

The innovative designs and applications of VLSI technology have made it possible to increase CPU performance by 200 percent every two to three years. Circuits are being designed with over 400,000 transistors, and smaller is not necessarily better, according to the start-up company Trilogy. At the same time performance is dramatically increasing, the cost of hardware is decreasing at 15 percent per year.

Companies are developing microprocessor-based graphics stations, with 1,000-line, 60 Hz, noninterlaced technology, offering users the resolution and speed needed for displaying complex designs. Fast graphics processors that can display complex solid models in real time are available. End-user pricing of graphics stations is also declining at approximately 15 percent per year.

The CAD/CAM industry is software intensive, with development time running into thousands of man-years for a single applications program. Third-party software agreements are prevelant in this highly competitive environment. The race to provide full-system design capability requires vendors to provide as much applications software in as little time as possible. Virtually all major vendors have joint marketing or development agreements with software houses, have merged or acquired such companies, or provide interfaces to existing software. Third-party-developed software is typically not the core of a CAD vendor's product, however, but is usually large, number crunching, analytic programs, such as solids modeling, finite element modeling and analysis, or simulation software.

Companies using an end-to-end CAD/CAM systems solution are able to automate their product development cycle, from concept and engineering, to manufacturing and testing, thus enabling them to compete effectively and profitably in worldwide markets.

EDA--AN INTEGRATED SOLUTION

The electronic design automation (EDA) subsegment of the IC CAD market is one example of the successful implementation of the CAD/CAM trends discussed above. DATAQUEST believes EDA is the fastest-growing market segment, and that sales will reach $500 million by 1987, growing at 65 percent compounded annually. To date, the majority of companies in this market (Daisy Systems, Mentor Graphics, and Valid Logic, to name just a few) are less than three years old; yet, together, they have invested millions of man-years worth of state-of-the-art product development.

Distributed processing is prevelant in the EDA marketplace, with low-cost 32-bit workstations being used by electrical engineers. The traditional 16-bit IC CAD physical layout system's average cost per workstation is declining, from $121,000 in 1983 to $78,000 in 1987. However, the electrical engineer is not able to justify this cost; it is too high and does not offer the necessary 32-bit performance.

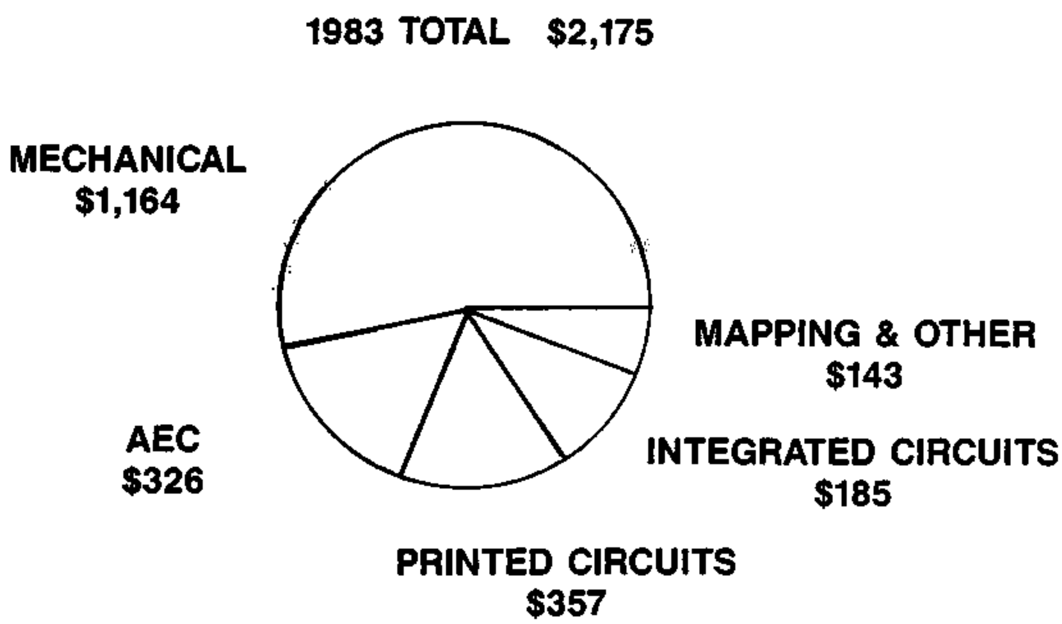
An EDA system must handle massive amounts of electrical and graphics data, so that the engineering design functions are integrated among themselves, as well as with the physical layout and manufacturing functions. Most EDA vendors have formed many third-party software agreements, ranging from interfaces to circuit simulators, to mergers with software companies, to providing a front end to a PCB router.

Manufacturing integration is achieved by providing a front-end design system to a silicon foundry's routing and placement programs for standard cells or gate arrays. In this manner, companies developing electronic systems can afford to develop customized and proprietary circuits. The design data is electronically transmitted to the foundry for fabrication. Although the electronic design automation market is young and not yet fully developed, clearly the EDA vendor's goal is to provide electronic components and systems manufacturers an integrated, end-to-end systems solution.

CONCLUSION

The EDA market is just one example of integrating the design, engineering, and manufacturing phases of the product development cycle to provide CAD/CAM users an integrated solution. As the total available market is penetrated with low-cost, powerful systems capable of integrating design with manufacturing, CAD/CAM users will have the tools to increase productivity, and the reasons for spending nearly $25 on CAD/CAM products during the next four years.

WORLDWIDE CAD/CAM REVENUE
(Millions of Dollars)



Source: DATAQUEST

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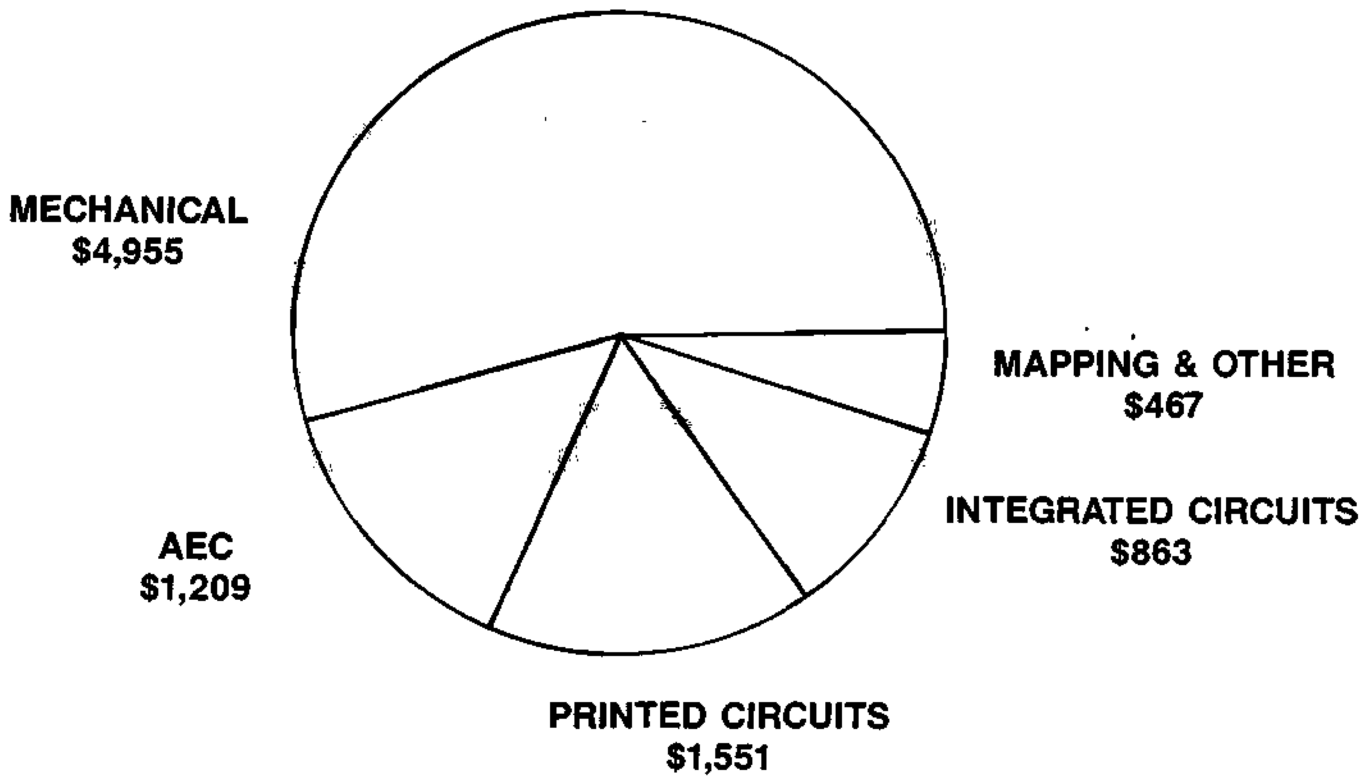
WORLDWIDE CAD/CAM REVENUE
(Millions of Dollars)

1987 TOTAL $9,045



Source: DATAQUEST

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DEFINITION

WORKSTATION — A SINGLE USER STATION, EITHER STAND-ALONE OR HOST-DEPENDENT

AVERAGE COST — AVERAGE TOTAL SYSTEM PRICE, INCLUDING CPU, PERIPHERALS, STATIONS AND SOFTWARE, DIVIDED BY AVERAGE NUMBER OF STATIONS

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WORKSTATION SHIPMENT FORECAST

APPLICATION	1983 UNITS	1987 UNITS	CAG
MECHANICAL	8,317	59,822	64%
AEC	3,023	18,091	56%
PC	2,853	21,594	66%
IC	1,558	12,959	76%
MAPPING & OTHER	1,197	6,370	44%
TOTAL	16,948	118,836	63%

Source: DATAQUEST

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AVERAGE COST PER WORKSTATION

APPLICATION	1983 COST	1987 COST	PERCENT CHANGE
MECHANICAL	140,000	83,000	−41%
AEC	108,000	67,000	−38%
PC	119,000	70,000	−41%
IC	127,000	62,000	−51%
MAPPING & OTHER	97,000	73,000	−25%
TOTAL	126,000	75,000	−40%

Source: DATAQUEST

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DATAQUEST USER SURVEY

PERCENTAGE OF SYSTEM TIME SPENT ON...

DRAFTING

DESIGN/MODELING

ANALYSIS

MANUFACTURING

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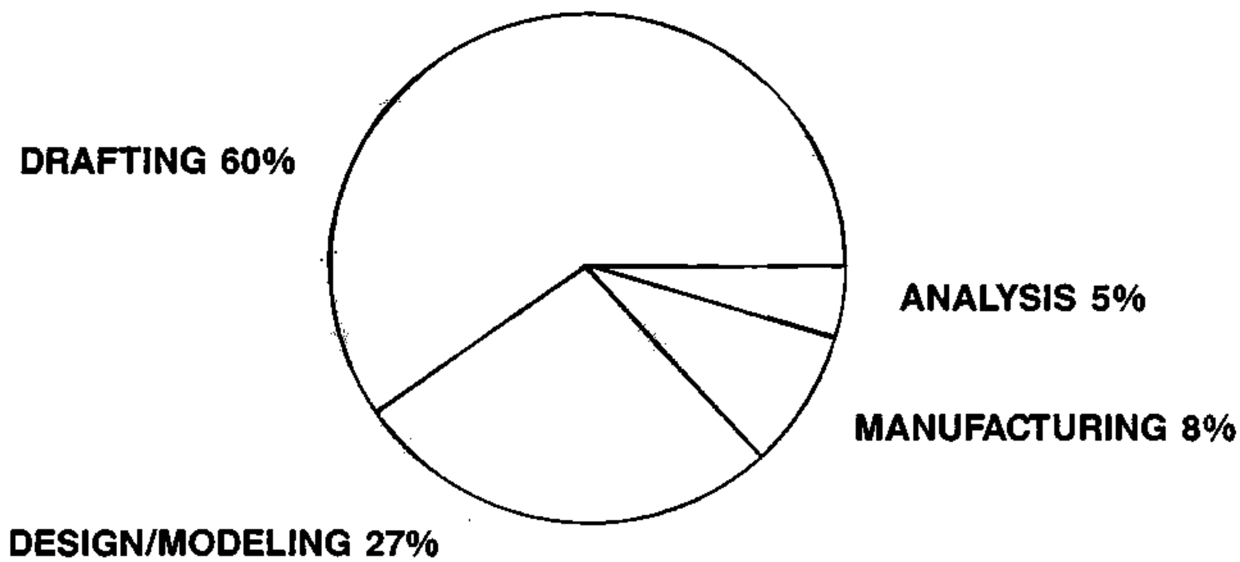
1983 CAD/CAM SYSTEM USAGE



Source: DATAQUEST

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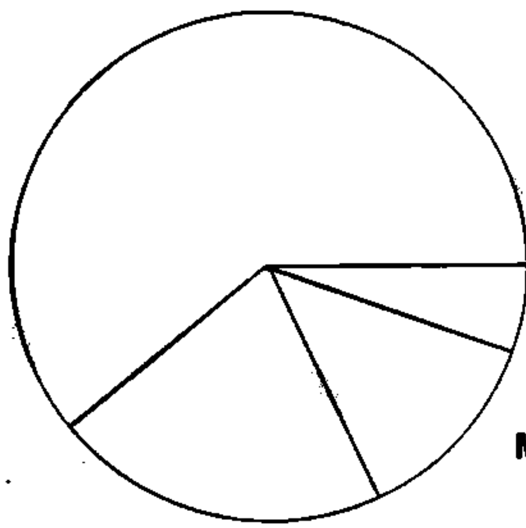
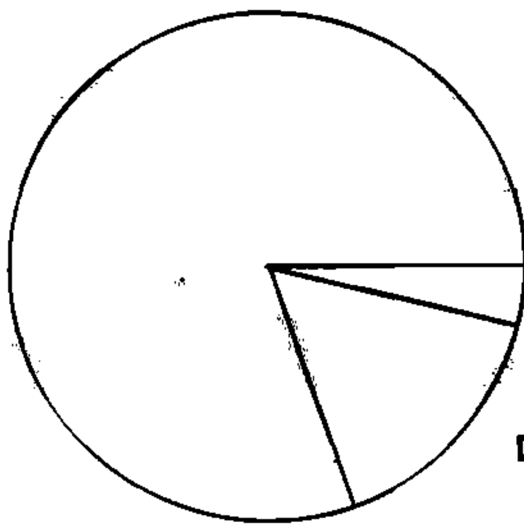
MECHANICAL CAD/CAM SYSTEM USAGE



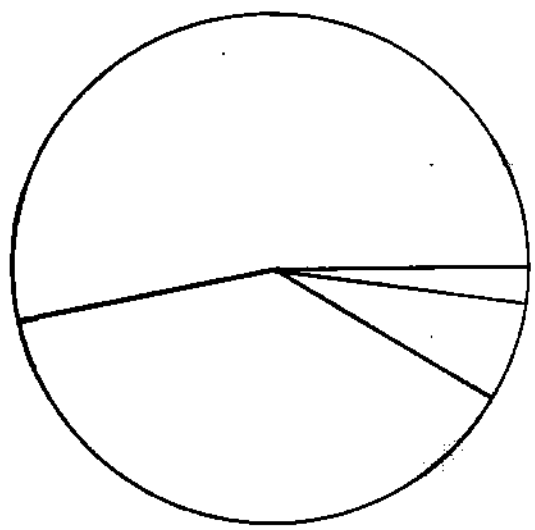
Source: DATAQUEST

AEC CAD/CAM SYSTEM USAGE



Source: DATAQUEST

PC CAD/CAM SYSTEM USAGE



Source: DATAQUEST

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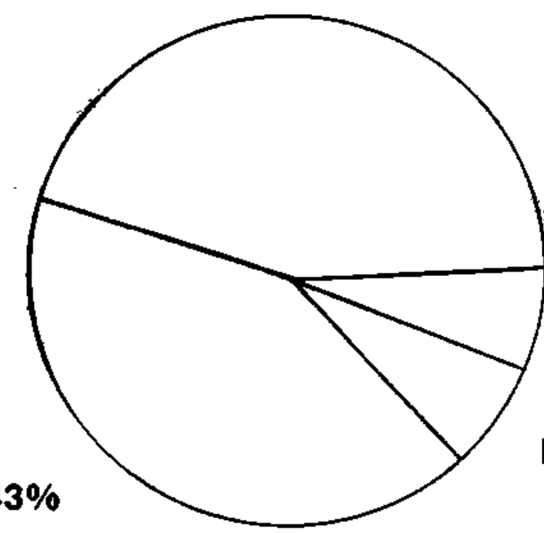
IC CAD/CAM SYSTEM USAGE



Source: DATAQUEST

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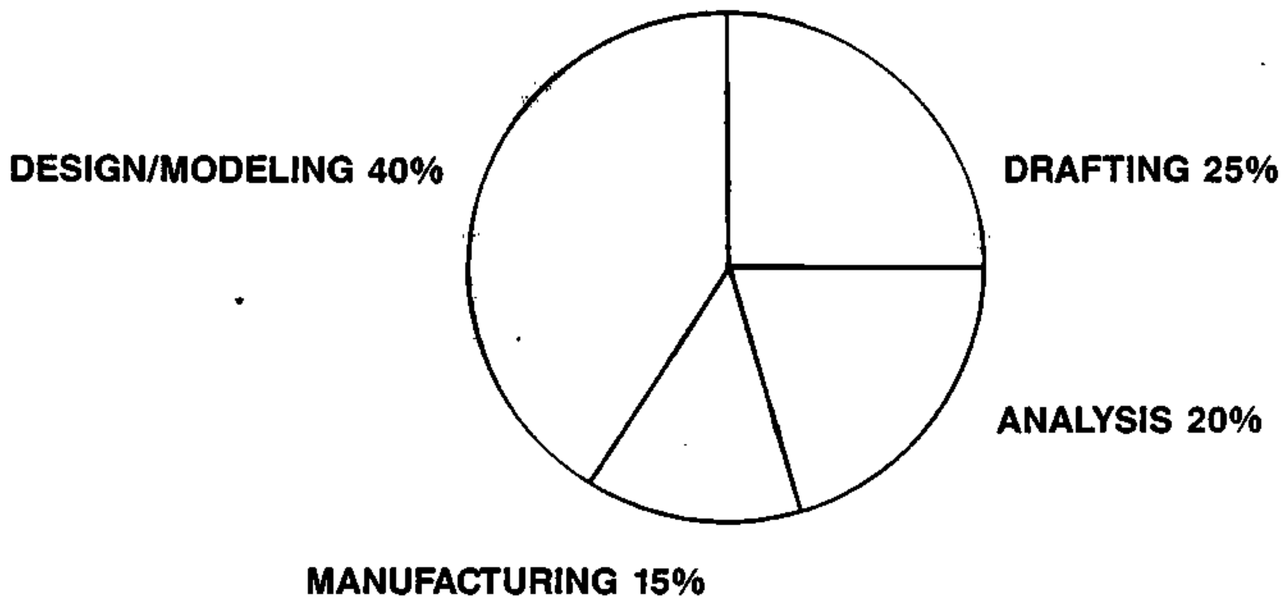
1987 ESTIMATED CAD/CAM USAGE



Source: DATAQUEST

WHAT WILL MAKE THESE CHANGES POSSIBLE?

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CAD/CAM TRENDS

- DISTRIBUTED PROCESSING
- IMPROVED COMMUNICATIONS/DATA BASE MANAGEMENT
- IMPROVED PRICE/PERFORMANCE
- THIRD PARTY SOFTWARE
- INTEGRATED SYSTEMS

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DISTRIBUTED PROCESSING

- LOCAL INTELLIGENCE
- CONSISTENT LEVEL OF PERFORMANCE
- SYSTEM DOWNTIME AFFECTS SINGLE USER
- LOWER ENTRY PRICE
- INCREMENTAL GROWTH
- SHARED RESOURCES

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IMPROVED COMMUNICATIONS/DATA BASE MANAGEMENT

- CLUSTERS OF LOCAL SYSTEMS
- SHARED DATA AND RESOURCES
- EFFICIENT WORK FLOW
- INTEGRATE AND MANAGE DATA BASE
- PROJECT MANAGEMENT AND CONTROL

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IMPROVED PRICE/PERFORMANCE

- SEMICUSTOM VLSI
- CPU PERFORMANCE INCREASING 200% EVERY 2-3 YEARS
- HARDWARE DECREASING 15% EVERY YEAR
- INTELLIGENT, POWERFUL GRAPHICS STATIONS
- REAL-TIME DISPLAYS

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THIRD-PARTY SOFTWARE

- NO NEED TO REINVENT THE WHEEL
- MAXIMIZE RESOURCES
  - PEOPLE
  - MONEY
  - TIME
- ACQUISITIONS, MERGERS, JOINT AGREEMENTS

INTEGRATED SOLUTIONS

- COMPUTER-AIDED ENGINEERING
- DESIGN AUTOMATION
- COMPUTER-AIDED DESIGN
- COMPUTER-AIDED MANUFACTURE
- COMPUTER-AIDED TESTING

COMPUTER INTEGRATED MANUFACTURING

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EDA —

AN INTEGRATED SOLUTION

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WHAT MADE EDA POSSIBLE?

- PHYSICAL LAYOUT, SATURATION/PRICE
- NEED: ELECTRICAL ENGINEERING, DESIGN AUTOMATION
- TECHNOLOGY

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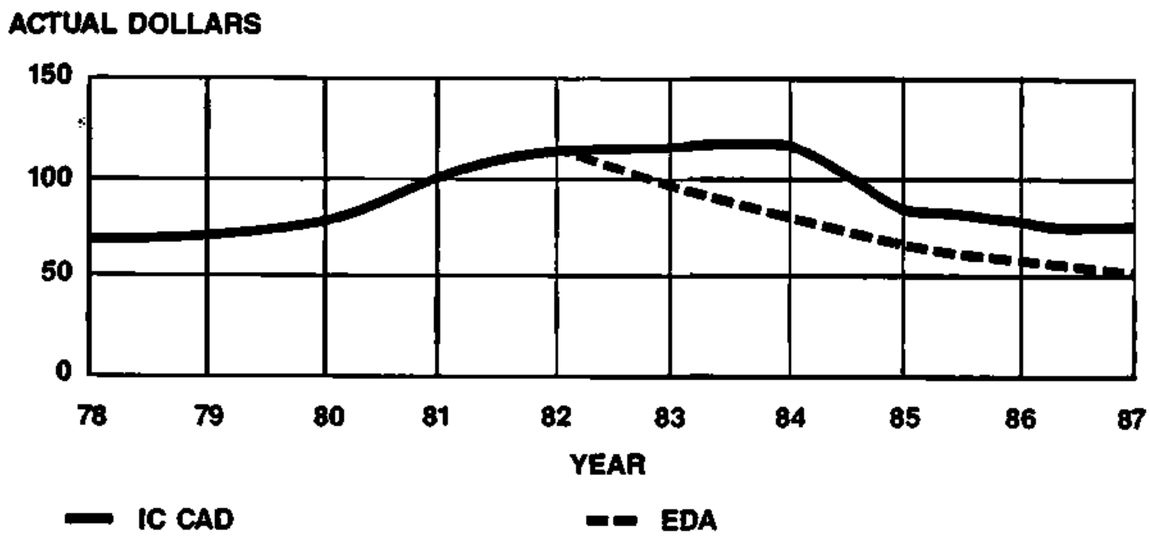
AVERAGE COST PER WORKSTATION
IC CAD AND EDA APPLICATIONS



Source: DATAQUEST

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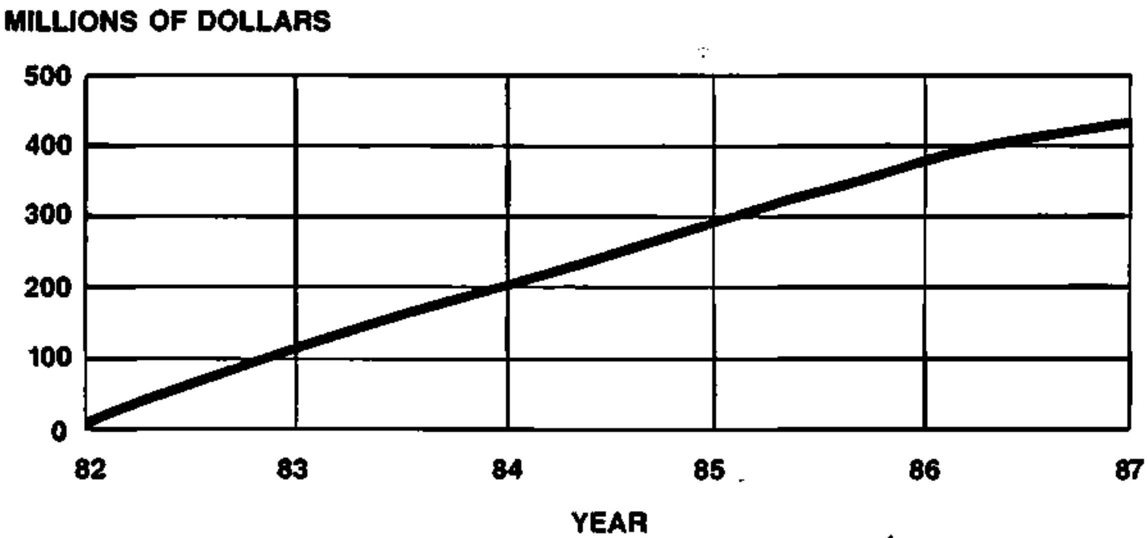
EDA REVENUE FORECAST



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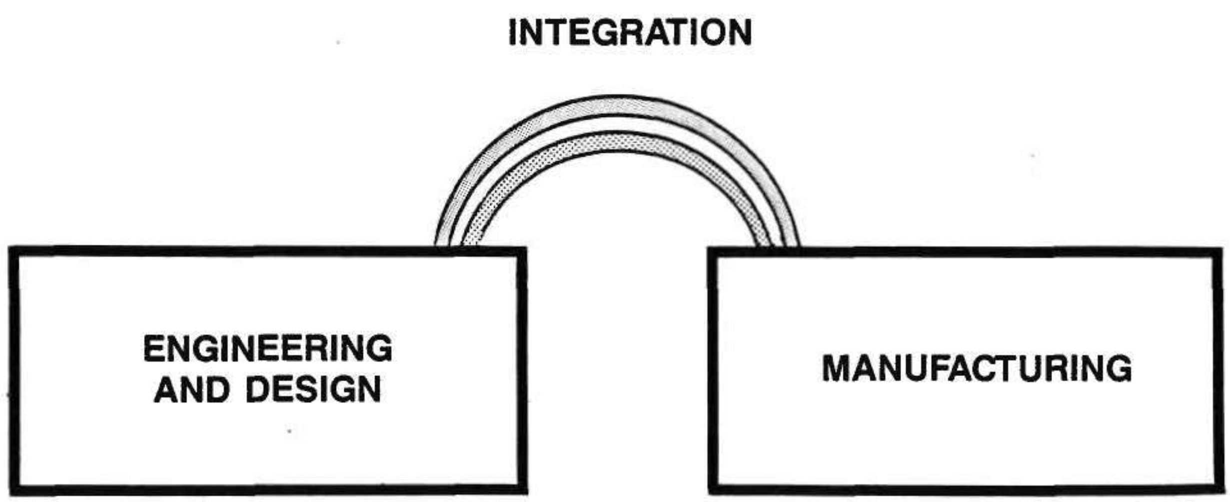
CLOSING THE GAP



Nielsen Dataquest

CAD/CAM INDUSTRY OVERVIEW

Timothy O. Gauhan
Vice President and Director
CAD/CAM Industry Service
Dataquest Incorporated

Dr. Gauhan is Vice President and Director of DATAQUEST's CAD/CAM Industry Service. He was formerly with Calma Company, where he served as Manager of Marketing for the Mechanical Products Division and as Director of Marketing and Technical Publications. Earlier, he served on overseas research projects sponsored by the National Science Foundation and the U.S. Agency for International Development. Dr. Gauhan has taught courses in Research Methodology at Rice University and Arizona State University, and courses in International Business at the American Graduate School of International Management. He received a B.A. degree in International Relations from San Jose State University and M.A. and Ph.D. degrees from Rice University.

Dataquest Incorporated
CAD/CAM INDUSTRY CONFERENCE
September 26-28, 1983
Newport Beach, California

As all of us who work in the CAD/CAM industry fully appreciate, this is a very complex business, full of interesting but oftentimes perplexing problems. Being successful in this business often requires equal parts of hard work, luck, and aspirin. Consider for a moment this list of technical buzzwords that confront CAD/CAM marketing people on a daily basis.

- 3-D Modeling
- Communication
- Data base management
- Design rule checks
- Graphics software
- Microprocessors
- Minicomputers
- NC/FEM
- Networking
- Plotters
- Routing and placement
- Solid modeling

Having mastered these little tidbits of technology (spanning the disciplines of computer science, mathematics, electronics, and heaven knows how many branches of engineering) the CAD/CAM marketeer must then turn to this list of issues in order to make sure his or her products are successful in the marketplace.

- Advertising
- Benchmarks
- Corporate agreements
- Demos
- Marketing agreements
- PR
- Product literature
- Product management
- Sales proposals
- Technical centers
- Tradeshows
- User's groups

I won't bother you with the list of manufacturing, financial, accounting, and personnel woes that confront CAD/CAM companies, but suffice it to say, while the rewards can be great, so can the bills for Bufferin.

In February of 1981, DATAQUEST began its efforts to help CAD/CAM professionals make sense out of this oftentimes confusing world. We spent the following months meeting the necessary contacts throughout the industry, collecting and analyzing what data there were available, and on August 31 of that year we sent our Marketing Analysts' Source Book to our first clients, some of whom are in this room this morning.

We are often accused of being compulsive keepers of statistics (and rightly so, I suppose). Beth Tucker will report a number of statistics on the industry in a few minutes, but I would like to take just a brief time to share some statistics that DATAQUEST's CAD/CAM Industry Service has collected on itself after two years of serving the industry.

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While I thought there were only six companies in the business when we first started, I am pleased to note that our client list now consists of some 95 companies. In terms of types of clients that we serve, 67 percent of our clients are in the manufacturing and marketing of CAD/CAM equipment, 32 percent are in the financial community, and 11 percent are end users of CAD/CAM equipment or are other types of companies.

Obviously the vendors of CAD/CAM equipment constitute the largest user group of DATAQUEST's CCIS. I thought it would be interesting to see what kind of companies these are. The following breakdown will give you some idea of the types of vendor companies that DATAQUEST provides information to.

- Turnkey--34 percent
- Computer--20 percent
- Software--8 percent
- Graphics--21 percent
- Other--17 percent

In order to keep track of the information these companies require from us, we currently have files on over 350 companies.

In our two years of existence we have published over 2,000 pages of information for our clients, the number of statistics that can be found in our volumes is in the tens of thousands.

As those of you who use CCIS are aware, a very important aspect of our business is answering inquiries from our clients. No matter how much information we publish in our books, we could not possibly publish enough information to suit our clients' needs. Consequently, we have responded to about 7,000 inquiries from our clients since the inception of the service; and as I have said in the past, in this business, every answer seems to raise five more questions. While we may not have been right 100 percent of the time, I think our staff has provided the industry with a very valuable service, which we plan to improve year after year.

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Gathering these numbers is a difficult enough task in itself, but because of the dynamics of the industry over the past few years, I have found that figuring out where to put the numbers is even more difficult. When we first published our numbers two years ago, we estimated that the minicomputer-based turnkey companies constituted well over 90 percent of the total CAD/CAM market. So we published our estimates and forecasts of the revenues and shipments of the six major turnkey companies and discussed the fact that computer companies were becoming a more and more important factor in the business. Our most recent estimates indicate that computer companies constitute over 30 percent of the CAD/CAM market, so that we have now expanded our coverage to include detailed information on such companies as IBM, Prime, Digital, and Sperry.

As usual, the industry has not stood still long enough for our categories to be the "final word," and new products like microprocessor-based workstations and even CAD systems running on personal computers have now come on the scene. As if that weren't confusing enough, companies like Daisy, Mentor, Valid Logic, Silvar Lisco, Metheus, and others, have virtually created a new market, which we have dubbed Electronic Design Automation (EDA), that addresses a whole set of application issues not previously addressed by the CAD/CAM industry.

We are busy reorganizing our data base to accommodate these new products and approaches, but it is not the easiest job in the world. Here is a brief list of categories that have been suggested thus far:

- CAD/CAM
- CAE
- CIM
- Computer
- EDA
- Engineering workstations
- Software
- Terminal
- Turnkey

After we have developed the categories that are useful in helping us present our data in a meaningful way to the industry, that's really just where the fun begins. I have had what I thought were semiconductor companies tell me they were more accurately described as CAD companies, software companies tell me they were turnkey companies, and turnkey companies say they were actually into CIM.

If you are the "scorekeepers of the industry," which is a part of DATAQUEST's role, it is a lot easier if you know whether the players think they are playing racquetball or rugby!

In the years to follow, though, we promise to do our best to provide accurate information on the industry by product type, company type, application area, and region of the world.

Before turning to a discussion of the major issues that confront the CAD/CAM industry today, I thought I would give you just a brief glance at some of the work that we have in progress that DATAQUEST subscribers can expect to see from us in the coming year.

For example, we have just completed a major survey of users' groups which will reveal a good deal of information on their patterns of usage of CAD/CAM. Beth Tucker, who will give you a summary view of the industry in a few moments, has just begun to work on a survey of 27 systems for printed circuit board design. This survey will provide us with much needed data in what has turned out to be a very strong marketplace for PCB design.

On the international scene, DATAQUEST's staff has taken two trips to DATAQUEST Japan this year. Preliminary analysis of the work we did there reveals some very interesting facts, which we will report on in the coming year.

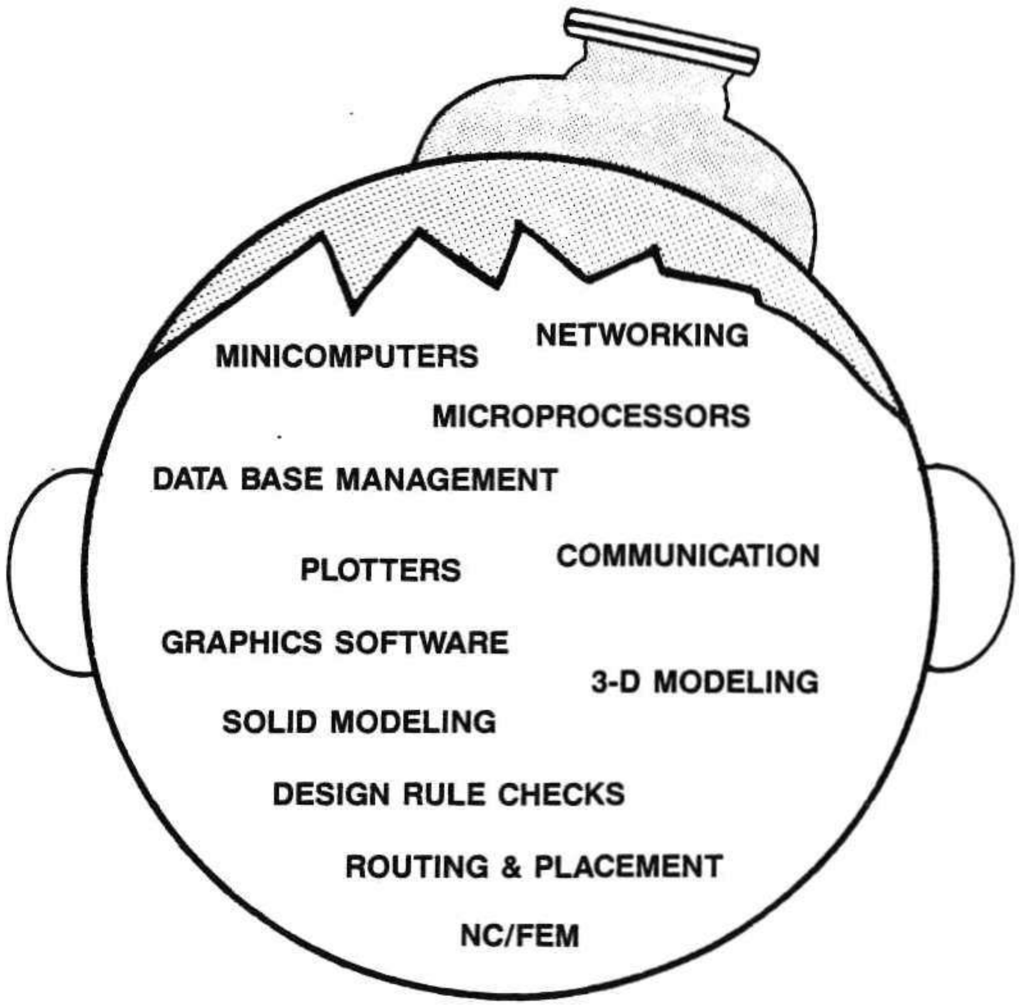
We were able to unearth 27 firms that are in the CAD/CAM business in Japan, although some of them have sold few or no systems. The installed base in Japan is much smaller than the base in the United States, both in a relative and an absolute sense. As we noted in a newsletter this year, given its industrial base, Japan is effectively five to six years behind the United States in implementing CAD.

Looking at the spread in application use, however, we are finding that the Japanese seem to be more intensive in their use of systems for mechanical and electronic circuit design. This probably reflects the emphasis in the Japanese economy on heavy industry and consumer and system electronics.

While the Japanese have gained a reputation in the area of manufacturing automation, robotics, and the like, it appears as if Japan is lagging in the area of computer-aided design.

These are but a few of the areas that we will be researching for our clients over the next year. As we look at the changes that have taken place in the industry since the DATAQUEST CAD/CAM Industry Service was begun just over two years ago, we cannot help but foresee that we will be kept very busy keeping track of the events that take place in the CAD/CAM Industry next year and in the years to follow.

TECHNICAL HEADACHES



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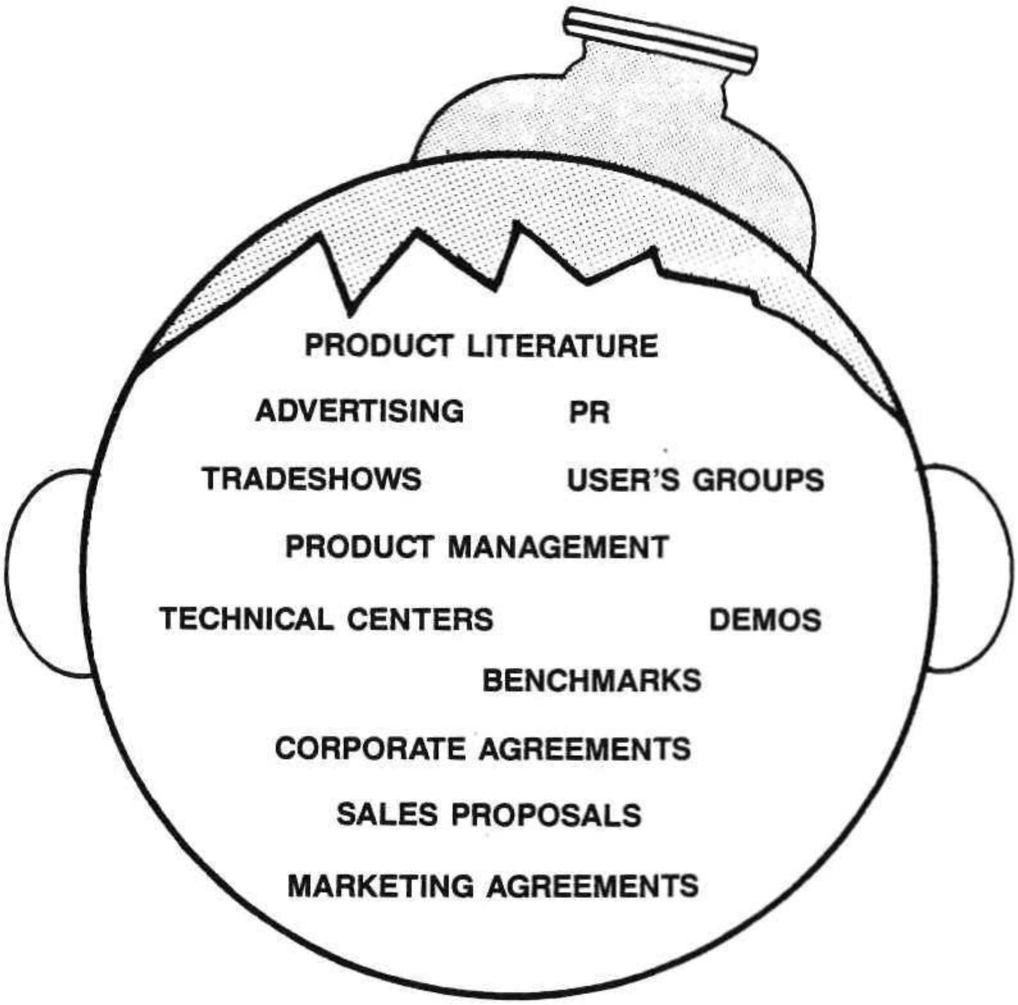
MARKETING HEADACHES



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CAD/CAM INDUSTRY SERVICE
CLIENT LIST

Agence de l'Informatique
Alpha Fund
American Microsystems Inc.
Arthur Andersen & Company
Apollo Computer
Applicon
Assigraph
Auto-trol Technology
Bank of America
Bank of California
Bank of the West
Banque Nationale de Paris
Bell Laboratories
BULL-SEMS
Burroughs Corporation
CADAM, Incorporated
Cadlinc
Cadnetix
Cadtec Corporation
Cadtrak Corporation
CAE Systems, Incorporated
CALCOMP
California Automated Design Inc.
Calma Company
CGX Corporation
Churchill Group
Holley Carburetor
Computervision
Crocker Bank
Daisy Systems

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CAD/CAM INDUSTRY SERVICE CLIENT LIST

Data General
Dept. of Industry
Digital Equipment
EDS Nuclear/Impell
Evans & Sutherland
Fairchild
First Interstate Capital
First National Bank of Boston
Fuji Xerox
Fujitsu America
General Electric
GE Industrial Automation Ltd.
Genisco
GenRaD
GTE Automatic Electric Labs
Hewlett-Packard
IBM Corporation
IBM World Trade Asia Corporation
International Microelectronics Products
InterWest Partners
ITT Engineering Support Centre
Landmarks Group
LSI Logic Corporation
Matrix Partners

CAD/CAM INDUSTRY SERVICE
CLIENT LIST

Mayfield Fund
MCAUTO
Measuronics
Megatek
Membrane Ltd.
Metheus
Moody's Investor Service
Motorola Semiconductor
Murray Electronics PLC
Nutech
Oak Management Corp.
OCE Nederland B.V.
Oxford Venture
Phoenix Leasing
Prime Capital Management
Prime Computer
Qubix
Racal Ltd.
Racal-Redac
Ramtek
Rank Xerox Ltd.
Sanders Associates, Inc.
Scientific Calculations
Seiko Instruments USA
Siemens AG
Silicon Compilers
Silicon Graphics
Silvar-Lisco
Spectragraphics
Tektronix

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CAD/CAM INDUSTRY SERVICE
CLIENT LIST

Telemecanique Electrique
Telesis
Toyo Corporation
Valid Logic Systems
Vector Scientific
Vectron Graphics
VLSI Technology, Inc.
Union Bank
Xerox
Arthur Young & Company

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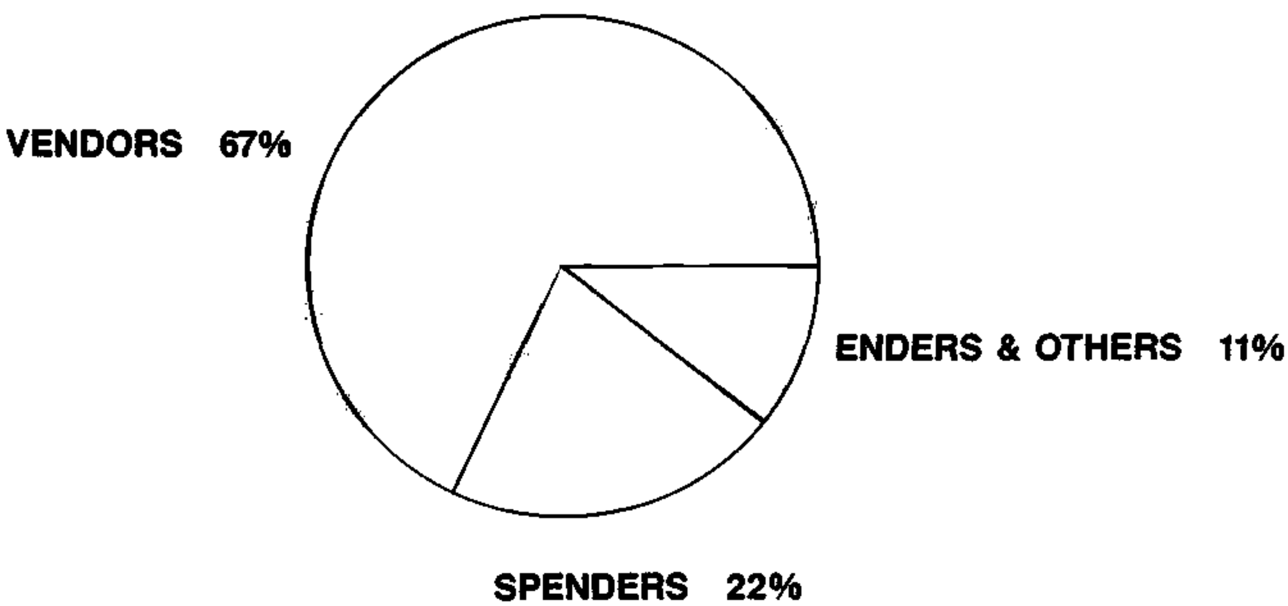
DISTRIBUTION OF CCIS CLIENTS



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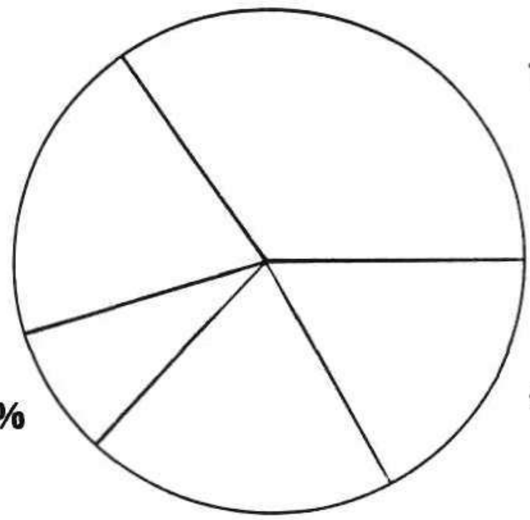
CCIS VENDOR COMPANIES



Source: DATAQUEST

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CAD/CAM INDUSTRY
SERVICE COMPANY COVERAGE LIST

Advanced Electronics
Andromeda Systems
ASK Computer
Bausch & Lomb
Bridgeport Machines
Boeing Aerospace
California Automated Design
Control Data
Cray Research
Datapoint
Digital Engineering
Display Interface
Efficient Engineering
Evans & Sutherland
Everett-Charles
Fairchild
Florida Computer Graphics
Fujitsu
General Motors
Genrad
Graphic Construction
Hewlett-Packard
Hitachi
Honeywell
IBM
Integrated Computer Systems
Intersil, Inc.
Jacobs Engineering Group
James River Graphics
Jupiter

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CAD/CAM INDUSTRY
SERVICE COMPANY COVERAGE LIST

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Kinegraphics
KOH-I-NOOR
Lear-Siegler
Lockheed
LSI Logic
MacNeal-Schwendler
Morgan Fairchild Graphics
Metrex Management
National Computer Systems
Northrup
Numeritronix
Oce Industries
Omnitech Graphics
Orcatech
Phoenix Computer Graphics
Precision Visuals
Pyramid Technology
Quality Micro Systems
Quadrex
Raster Technology
RCA
ROLM
Scientific Calculations
Seiko Intruments
Sperry-Univac
Tandem
Teradyne
Texas Instruments
Trilog

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Unimation
United States Robots
Varian
Vector Automation
VLSI Technology
Wang Labs
Western Electric
Westinghouse
Xerox
Xiphias
Zilog
Zonic Corporation
Zytronix

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DATAQUEST CCIS DATA SUMMARY

- 2,000 PAGES PUBLISHED
- 7,000 INQUIRIES
- 10,000 CAD RELATED DOCUMENTS
- 95 CLIENTS
- 346 COMPANIES TRACKED

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SUGGESTED CATEGORY NAMES

- TURNKEY
- COMPUTER
- ENGINEERING WORKSTATION
- CLUSTER NETWORK
- GRAPHIC TERMINALS
- SOFTWARE
- CAE
- EDA

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SUGGESTED CATEGORY NAMES

- HOST DEPENDENT
- MAINFRAME
- MINI
- MICRO
- PERSONNEL
- YELLOW
- ORANGE
- BLUE

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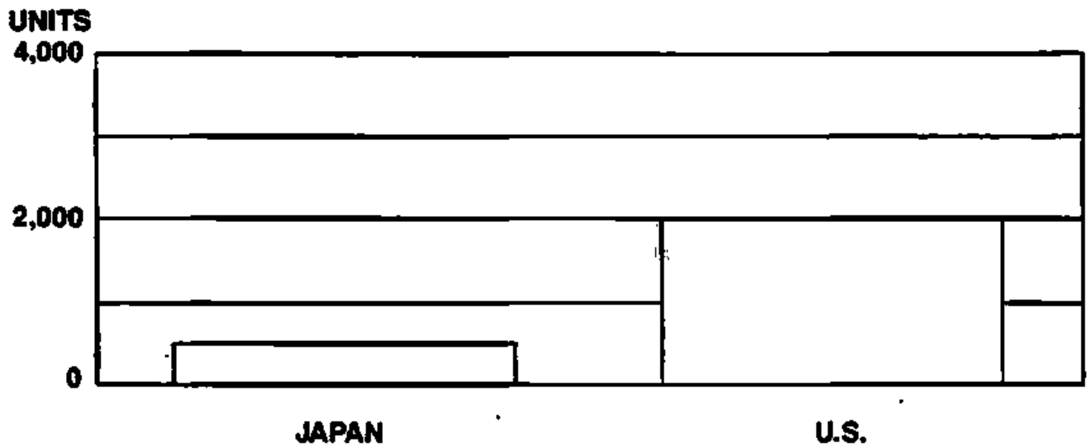
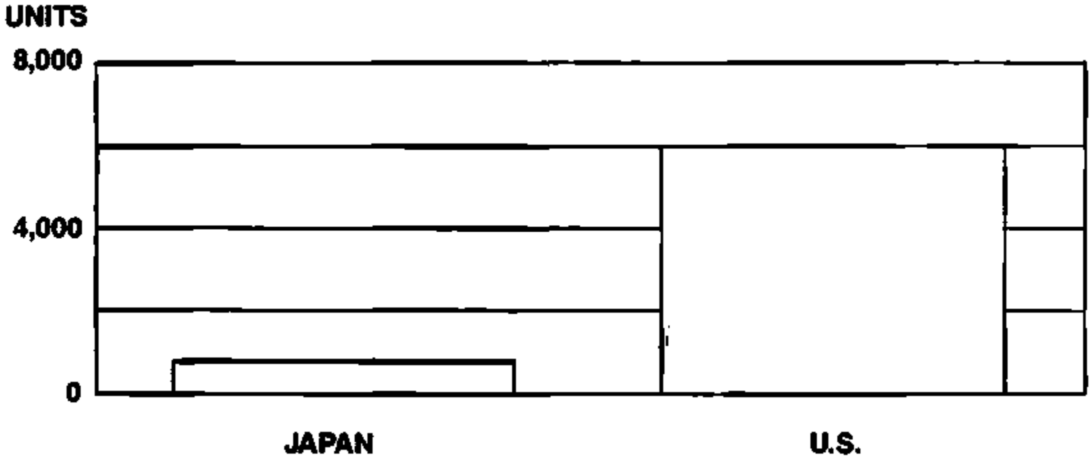
ESTIMATED SYSTEM INSTALLATIONS 1982



Source: DATAQUEST

ESTIMATED
TOTAL INSTALLED BASE OF SYSTEMS
1982



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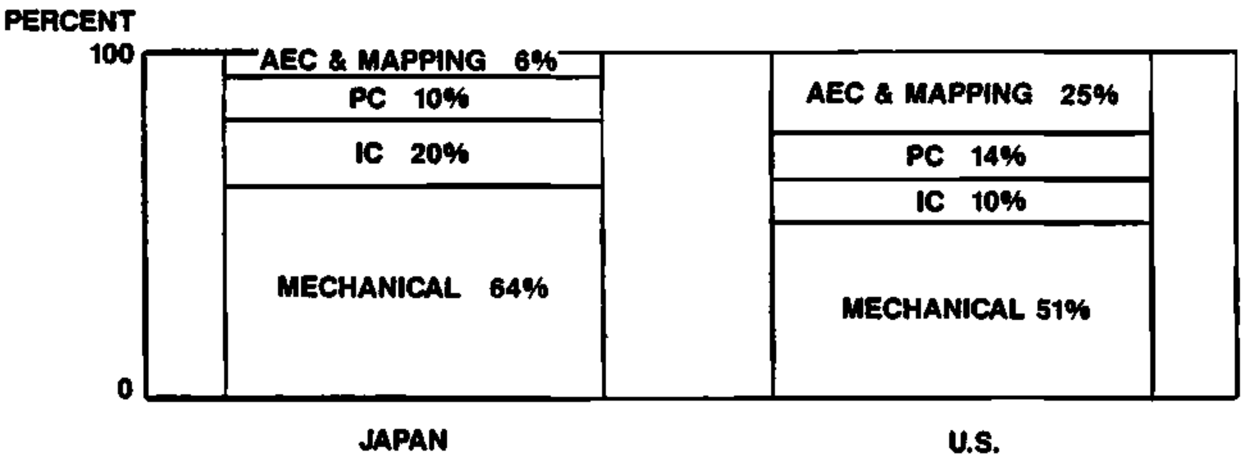
APPLICATION DISTRIBUTION OF CAD/CAM SYSTEMS IN U.S. AND JAPAN 1982



Source: DATAQUEST

CAD/CAM
THE BIG ISSUES
OF THE '80s

TURNKEY COMPANIES

- LEADING EDGE IN:
  - GRAPHICS INTEGRATION
  - GEOMETRIC MODELING INTEGRATION (SOLID MODELING)
  - APPLICATIONS SOFTWARE DEVELOPMENT
- NEW EMPHASIS ON THE "CAM" IN CAD/CAM
- A BROADER LINE OF PRODUCTS

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COMPUTER COMPANIES

- PROVIDING ENGINEERING TOOLS FOR INSTALLED BASE
- PROVIDING A WIDE VARIETY OF THIRD PARTY SOFTWARE
- PROVIDING GOOD GRAPHICS HARDWARE SOLUTIONS
- PROVIDING COMPANY-WIDE INTEGRATED SOLUTIONS

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SOFTWARE COMPANIES

- TRACKING WITH ADVANCES IN HARDWARE TECHNOLOGY
- PROVIDING "HOOKS" TO EXISTING TURNKEY AND SOFTWARE SOLUTIONS
- RESPONDING TO THE NEED FOR PORTABILITY

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ENGINEERING WORKSTATIONS

- DEFINITION
  - CPU DEDICATED TO SINGLE USER
  - OPERATING AS A STAND ALONE, IN A NETWORK, AND/OR INTERACTING WITH A HOST
  - SPECIALIZED HARDWARE CAPABILITIES FOR ENGINEERING TASTS (E.G., GRAPHICS)
  - COMPATIBILITY WITH ENGINEERING SOFTWARE

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ENGINEERING WORKSTATIONS

- TRENDS
  - CONTINUING PRICE/PERFORMANCE IMPROVEMENT
  - DISTRIBUTED PROCESSING AS A WAY OF LIFE IN THE ENGINEERING ENVIRONMENT
  - MORE THAN JUST "HIGH TECH ETCH-A-SKETCH"
- STANDARDIZATION?

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NEW APPLICATIONS

- ELECTRONIC DESIGN AUTOMATION (EDA)

ARCHITECTURE → LOGIC → CIRCUIT → ¦ PHYSICAL LAYOUT → MANUFACTURE

- CAM
- DOCUMENTATION AND PUBLICATION
- DRAWING STORAGE AND RETRIEVAL

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NEW SOFTWARE TECHNOLOGY

- STRUCTURED DESIGN OF ELECTRONIC CIRCUITS AND SYSTEMS
- SOLID MODELING
- CIM

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NEW HARDWARE TECHNOLOGY

- THE "SUPERMARKET APPROACH TO TECHNOLOGY"
- THE "CAROUSEL OF CAD/CAM"

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START-UPS —
HAS THE FEVER BROKEN?

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CAD/CAM AND WALL STREET

- OLD FRIENDS
- SOME NEW KIDS ON THE BLOCK

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CAD/CAM INDUSTRY SERVICE
SECOND ANNUAL CONFERENCE

"THE TECHNOLOGY CHALLENGE: LINKING CAD/CAM WITH INTEGRATED MANUFACTURING

- PRODUCTION AND CAD
- PRODUCT STRATEGIES
- ELECTRONICS ISSUES
- REALITY OF THE FACTORY FLOOR

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Nielsen Dataquest

THE ROLE OF AUTOMATED TEST EQUIPMENT IN THE AUTOMATED FACTORY

Harold McAleer
Senior Vice President
GenRad Incorporated

Mr. McAleer is a Senior Vice President of GenRad and General Manager of its Component Test and Quality Management Divisions. A 30-year veteran at GenRad, he has had a variety of engineering and management positions, such as Manager of Custom Products, Vice President of Engineering, General Manager of the Electronic Instruments Division in Massachusetts, and General Manager of the Vibration Analysis Division in California. He received B.S. and M.S. degrees in Electrical Engineering from MIT and is a member of IEEE and Tau Beta Pi.

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September 26-28, 1983
Newport Beach, California

THE ROLE OF TESTING IN THE AUTOMATED FACTORY

The industrial revolution is still raging all around us as we struggle to satisfy the insatiable demand of society for the products of technology--vehicles and machines and computers and video games. Several waves of this revolution are taking clearer shape--the thrust to factory automation to improve productivity and, of ever-increasing importance, to improve quality. As John Naisbitt says in his book "Megatrends" the industrial-machine nature of the revolution has changed to an information-processing revolution--and that, I believe is the key to factory automation.

I hope to give you a view of factory automation from the perspective of the ATE industry--Automatic Test Equipment for manufacturing of electronic equipment--and describe a few points of thought and language to expand your own viewpoint, I hope to convince you that a network of automatic test equipment linked together with information processors and applications software can provide the missing link in factory automation--an integrated quality management system to join with the cost and schedule systems to produce true improvements in quality and productivity. But first a few words about ATE.

This slide shows the ATE market as a Subset of Factory Automation, along with CAE and CAD/CAM. The acronym CAT, Computer-Aided Testing, would probably fit the jargon better.

The commercial ATE industry is an outgrowth of the older Test and Measurement industry which included laboratory instruments for electronic engineers. These instruments found their way to the factory floor and the industry boomed. In the late 60's and early 70's the minicomputer combined with electronic instruments to form automatic test systems and a new ATE industry was born.

This figure shows past and projected growth rate for the ATE industry. It doubled every two years through the seventies, slowed down a bit during the recent recession, and is predicted to pick up again to a rate of doubling every three years through the eighties.

The next slide shows the rough magnitude of ATE sales last year. The slide also gives a view into the process for electronic manufacturers which is not so different from the process of any manufacturer. Components are produced by component manufacturers--in this case the basic components are integrated circuits from the magic kingdoms of the West, and empty printed circuit boards. These components are combined into assemblies and these into systems to be shipped to end users.

ATE is used at just about every step in this process in an attempt to weed out defects before more value is added and to diagnose and repair failures. Component testers are used by semiconductor manufacturers and also by electronic manufacturers at incoming inspection, testers are used for both bare and stuffed printed-circuit boards and also for finished assemblies. After products are in use, testers are used to repair them when they fail.

The fundamental motivation for the use of ATE has been relatively simple economic payback. The yield in electronic processes has been notoriously poor. Even after careful screening, burn in, and testing by semiconductor manufacturers drop-out rates of 1 to 5 percent are not uncommon at incoming inspection—depending on the maturity of the component and its own manufacturing process.

If you stuff a PC board with 100 IC's from a population with 1 percent defects, statistics tell us that 64 percent of the boards will be bad from that cause alone not to mention bent pins and solder blobs. So manufacturers attempt to cull out bad units as early in the process as possible. The theme being "don't add value to bad parts." This is also summarized in the "rule of ten". It cost you about ten times as much to find a defect as it moves from step to step in your process. Thus it may cost 50 cents to find a bad component at incoming, $5 at board test, $50 at final test, and, heaven forbid, $500 to send a service technician to your customers' site--not to mention the embarassment and loss of good will.

Because of the poor yield, ATE is used not so much as an off-line sampling-inspection tool to gather data on the statistics of the process, but rather as an essential part of the process to get the darn things working. Testing therefore is a major element of manufacturing costs and a critical factor in throughput. I suspect that that is true in areas of manufacturing other than electronics.

Changes are occurring, however, in the role of ATE (especially regarding factory automation) caused by competitive necessity and new converts to the religious wave of Quality. As I mentioned, the classical role of ATE has been to find and fix bad product-defect detection. That role is now being expanded to include defect prevention and we can look forward to an even greater role in an integrated quality management system. Here's how it works:

As I said, the automatic test equipment is used at several phases of the production process. In keeping with the new language we refer to these as <u>workstations</u> and we call the activity, <u>Level 1</u> where the tester finds the faults and separates the bad from the good. It turns out that the tester gathers a lot of data that is often not used; the tester knows more than we ask it. In fact, in a relatively low-yield operation, like electronic manufacturing, the tester is the only thing that really knows what's happening. Other management systems--the cost system, the MRP system, etc., are predicated on high and uniform yields. They assume a "standard" cost, a "standard" lead time, a "standard" processing time, etc. These standards are corrected very slowly. The result can be significant pileup of excess inventory-components, faulty boards. But the tester really knows the yield and the time, if we can only figure out how to ask it the right questions and how to use the answers.

It has been said that most electronic manufacturers are running two factories--one to make the good stuff, and one to make the bad stuff. The cost to run the bad factory is wasted, since nothing comes out. If the bad factory can be shrunk, tremendous savings can be realized. Enter a new concept--Level 2, wherein data acquired by the tester is turned into information about the process so that action can be taken to improve the yield. The role of the tester (and an associated data processor) is augmented beyond just finding faults--fault detection--to stopping the faults--fault prevention. We call this activity Level 2, an automated work center--a combination of automatic workstations, a central processor, and the proper mix of peripherals and, of course, software, to provide information to control and improve the process.

The automated ATE work centers--islands of automation--are beginning to appear more frequently and are producing effective results. We see them in incoming-inspection departments where several component testers are networked to a common host computer to produce reports of inspection yield, vendor performance, etc. We also see them in the printed circuit test and repair center where board testers are linked to a host computer and video terminals display instructions to repair technicians while, all the while, the host gathers information on the activity of the center. We will likewise see similar automation in the depot and field-service areas even as we see it already in the CAE/CAD centers of engineering departments.

The trick now is to tie all these automated work centers together into yet another level of the hierarchy that we call Level 3, Integrated Quality Management Systems. In this new world, the ATE networks join their fellow islands of automation and tie to the big-brother systems of MIS to provide something new that wasn't there before--Essentially, we're talking about moving information throughout all parts of an organization in four possible directions. Backward, forward, up and down.

First, Feedback. In an automated factory, the quality monitoring and management system is an essential element in a real-time servomechanism-sensing and feeding back information on quality that is vital to the productive operation of the entire manufacturing process and the essence of automation. The whole purpose for automating the factory is to achieve greater productivity, greater control, and greater manufacturing economies. Real-time quality management makes these goals achievable.

Second, feedforward. Feedforward means to move information automatically from one stage in the process to a later stage. This capability can avoid duplication of effort, avert errors, reduce time to market, and increase the return on investment. A good example here is what happens today in most operations before a new pc-board can be tested. A test program must first be developed. Before that can happen, the circuit description must be laboriously entered into the board tester. With a CAD station linked directly to the tester, the circuit description, already housed in the CAD station, can be fed directly to the tester. It's faster, more accurate, and no manual intervention is involved.

Let's look at the other two directions feed up and feed down. Here information flows automatically up from production and down from management. The result? Better overall business control. For example a link between a higher-level local-area network and the test network can provide a more direct and more timely connection between "plan" and "actual" results: you feed plans down, feed actual results up. Information is more timely; results are more productive. This is where the real link between quality, cost, and schedule happens.

Automatically feeding information forward/back/up/down throughout this organization is a capability that has begun to emerge, but clearly, we're not there yet. Much more remains to be done before comprehensive quality management tools can assume this central role in the automated factory. Much depends on the growth of the automated factory itself, the larger universe of which quality management is only a part. George Gagliardi of Arthur D. Little has cited two obstacles that have slowed down implementation to date.

First, most corporate managers tend to view short-term payback as the only justification of capital investment, despite the long-term productivity improvements that factory automation promises. We all need to look farther down the road than next quarter's or next year's earnings statement. Our successful counterparts in Japan are doing just that, with spectacular results in several industries, including semiconductors and consumer electronics.

And second, there are no general standards for integrated computer-aided manufacturing. This complicates the task of building bridges between the many islands of factory automation that already exist on the market.

As a result, it is both tempting and convenient to take a wait-and-see attitude toward implementing the automated factory.

But another set of forces is gradually overcoming these obstacles, and presenting opportunities that are pushing the entire electronics industry toward greater automation:

- As more companies adopt automated manufacturing, we all move further down the learning curve. The risks of obsolescence diminish and the rewards for automation grow.

- The trend toward shorter product lifetimes requires flexible manufacturing systems to permit quicker implementation of new designs and smoother transitions from prototype to production.

- Increasing production costs, for energy, materials, and labor, require better productivity to maintain profit margins. Better automated quality management means higher product yields, which in turn means lower unit costs.

The conclusion is: We can't affort to wait. Companies that are moving toward automation <u>now</u> are the companies that will get quality products to market more cost-effectively and ahead of the competition to establish and maintain leadership positions. And this is not an unprecedented development--it fits the historical pattern perfectly.

The automation of electronics manufacturing has taken giant strides over the past 25 to 30 years, and developments in test instrumentation have played an increasingly important role. As the level of integration of electronic devices has increased, so has the level of integration of the test equipment used to manufacture both those devices and products that incorporate them. As a result, the testing function has also provided better and better information.

When the basic electronic device was the discrete component the basic testing tool was the dicrete instrument. It tested specific device parameters, but it required manual sequencing of tests and manual interpretation of results. With the advent of the integrated circuit--which is a system of components--came the integrated test system, which is a system of instruments. These systems tested many parameters much more quickly than discrete instruments; they featured automatic sequencing of tests and, in most cases, automatic interpretation of results.

Today, we not only have components integrated into circuits and circuits integrated into systems, we now have systems integrated into networks of systems, distributed systems. The parallel phase in ATE's evolution is the network of test systems--distributed testing. And the scope of ATE's role has grown accordingly. Where once the test instrument was called upon only to check parameters in the development laboratory, the role of the test network is no less than to monitor and manage quality over the product's entire life cycle--from design to production to field service.

It's a change in testing's role--and in your perception of that role. Testing can provide a powerful lever for improvement--or it can define the limit of how good the operation can ever hope to be. The testers themselves will create the information that will fuel the process to turn out high-quality products. Strategic decisions will determine--and are today determining--how to leverage that information--how good that process can become.

And there's nothing futuristic about it. That's what we mean when we say "the factory of the future ain't what it used to be." It's here today: conceptually, strategically, substantively.

I realize that many of my remarks are like preaching to the choir--you already believe. My purpose will have been served, however, if, when you run into some brash members of the ATE fraternity thrashing around in what you may have viewed as your exclusive territory you don't think, "what are those turkeys doing here--this town ain't big enough for both of us", but rather, "oh, wow, welcome guys. What can we do to help each other to bring the fruits of technology to this wonderful marketplace of ours?"

TRENDS IN DISTRIBUTED WORKSTATIONS IN CAD

Joseph F. Gloudeman
President
The MacNeal-Schwendler Corporation

Dr. Gloudeman is President and Chief Operating Officer of The MacNeal-Schwendler Corporation (MSC). In addition to a bachelor's degree from Marquette University and a master's degree from the University of Southern California, he holds a Ph.D. degree in Aerospace Engineering from the University of Stuttgart (West Germany).

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CAD/CAM INDUSTRY CONFERENCE
September 26-28, 1983
Newport Beach, California

TRENDS IN DISTRIBUTED

WORKSTATIONS IN CAE

Joseph F. Gloudeman
The MacNeal-Schwendler Corporation
815 Colorado Boulevard
Los Angeles, CA 90041

INTRODUCTION

This paper addresses the expected trends in engineering workstations. This is done with some trepidation because in today's highly dynamic computing environment the price, performance and technology of computing hardware are changing so rapidly that even last month's forecasts are somewhat obsolete.

Contributing to the confusion of this highly dynamic environment is the proliferation of acronyms and terminology. In the interest of improved communications, the first part of this presentation will deal with some definitions of the terminology used, as well as a discussion of the scope that the author is attempting to cover.

Next, a brief history of the technology related to engineering workstations is presented in order to place the recent sequence of events into proper prospective. Emphasis is, of course, placed on events of the past few years leading to the current status of engineering workstations. This background makes it possible to offer some guesses as to the future directions. For the sake of sanity and self-preservation, some of the challenges and open issues that require attention and correction will be presented in the event that hard copies of this presentation come back to haunt the author more than six months from now.

DEFINITIONS AND SCOPE

This presentation places emphasis on engineering workstations used primarily to conduct engineering analysis. This type of activity generally falls within the category of Computer-Aided-Engineering (CAE). The diagram shows the relationship of CAE to the CAD/CAM environment. At the risk of over-simplification, let's assume the primary thrust of CAD is in the area of Computer-Aided-Design Drafting; it is not necessary to further discuss the scope of CAD/CAM for this audience.

The spectacular development of the microprocessor in the early 1980's now provides the engineering community with a most attractive opportunity to use low-cost workstations for analysis including the further integration of various engineering analyses. While representing one of the most dramatic breakthroughs of the past 30 years of engineering computing, this opportunity also presents a major challenge due to both the large number of diverse computers on which today's analysis programs operate and the differences in these systems and their operating system and applications software programs. The new engineering workstations provide capability that was only provided by large processors in the mid-1960's and exceeds the power of the computers available in the 1950's.

This explosive change in microprocessor technology comes at a most opportune time for the engineering community. For engineers, whose main activity is analysis, the promise of a personal-level, high-powered computer seems to offer the best of all worlds - most of the advantages of the large-scale processor without suffering poor turn-around because of the overloading of resources usually encountered in the multi-user environment. Microprocessors are also well received by engineering management who continually look for innovative ways to improve engineering productivity, especially in those situations in which the computational process directly affects the engineering activity. However, because engineers tend to work as a team, especially on large projects, there is a need to have efficient means of communicating technical information from one engineer to another - frequently outside of the local engineering organization. Significant improvements in telecommunications show signs of resolving this difficulty.

The recent advances in local area networks (LAN), are best exemplified by those provided through coaxial cable connections or fiber optics such as the Xerox Ethernet and the Apollo Domain network. These networks provide a network transfer rate in the 10 to 12 megabit per second range. The file transfer time is not noticeably different whether the engineer is using a disk attached directly to his own workstation or one somewhere else in the network. This capability allows the local workstation to have very rapid access to other servers in the network which specialize in services that are too expensive or too infrequently used to justify locally. These servers are usually 1) A high speed computer server with a speed of ten to one hundred times the workstation; 2) A high quality laser print server with both higher speed and quality than is available on the local low cost dot matrix printer; 3) A large disk server with capacity that is one hundred to several thousand times the local disk; 4) A plotting server that provides both larger sizes and higher resolution. Clearly the disk server will also provide various data bases of engineering, financial, and procedural information which includes computer programs for general usage.

Software improvements have tended to lag the explosive advances of hardware. Very little has been done to significantly improve programmer productivity via improved Higher-Order-Languages in real life environments. FORTRAN is still FORTRAN. Rather than dwell on other shortcomings, which usually stem from the labor-intensive nature of software development, it now seems appropriate to try to define the basic software needed for both individual workstations and distributed systems in general.

FUNDAMENTAL SOFTWARE NEEDS

Every workstation has a need for a fundamental set of generic software that can be classified in seven classes. These can be most easily remembered by the use of the neumonic WCGOLDS which stands for:

W - Word Processing
C - Communications
G - Graphics
O - Operating System
L - Languages
D - Data Base System
S - Spread Sheet Systems

Each class is discussed briefly below:

W - Word Processing. Most engineers spend a lot of time writing reports, memos, letters, etc., both at home and in the office. Many currently available word processing programs provide outstanding capabilities for both short memos and long complicated technical reports. The effective use of these tools will be a mandatory skill for every future engineering graduate. Even the Apple offers such extras as left- and right-hand justification, page formatting, hyphenation, and checking of spelling. The future offers syntax and grammatical correction. Also to be looked for is the ready incorporation of graphics into text.

C - Communications. A fundamental job of most engineers is to communicate his designs and analysis to other people. In order to do these tasks much information is required from the customer or other engineers. A workstation with the appropriate communications hardware and software provides the ideal tool for receiving and transmitting technical information. Graphical information still provides some difficulties which will be discussed in the next paragraph.

G - Graphics. Low to medium resolution graphics is now available on CRT displays and dot matrix printers at very low cost. These very recent developments have jumped ahead of both the two and three dimensional geometric model theory and the software to support this low-cost new hardware. Rapid progress in the software is being made and many very useful programs for both engineering and business graphics are now beginning to appear. The new proposed CBEMA standard for videotext called NAPLPS offers a very powerful tool for elementary graphics displays.

Although the recently adopted GKS graphics standard may be useful in providing an interim set of tools, it needs major revisions and will probably be totally replaced.

O - Operating System. The operating system provides the primary user interface and the utility programs for management of files and programs. This then makes software most important as it is the foundation on which all other programs depend. Most workstations designed for the engineering market are providing UNIX-like operating systems. The recently delivered PC/DOS 2.0 has most of the key UNIX concepts and assures, by its popularity, that these will become the basis for most operating systems in the late 1980's.

L - Languages. FORTRAN has been the principal programming language for engineers and scientists. Neither BASIC nor Pascal will replace FORTRAN. Ada remains an unknown quantity, but early implementations show some promise. C is an interesting combination of structured concepts and bit manipulation capability which provides both good portability and efficiency. All future engineers should know FORTRAN and a second language still to be determined.

D - Data Base System. The critical nature of data base systems in engineering has long been recognized but such systems are still primarily designed for business use. As a result, most systems do not adequately support various engineering needs such as floating point, graphics, vectors, matrices, etc. Recent systems such as RIM and

INGRES have attempted to overcome some of these deficiencies. Most engineers will develop their own data bases which will become as important to them as their collection of technical books and papers. This accumulation will start in college and continue throughout their careers.

S - Spread Sheet System. Manpower and financial planning is something that most engineers do from the day they go to work until they retire. Initially the planning may be very simple and only involve individual efforts, but it usually grows quickly to a more complicated activity. Spread sheet systems provide a most effective tools for handling this otherwise tedious function. Recent programs such as VisiCalc and Lotus 1-2-3 provide excellent tools for performing this key activity.

The above discussion summarizes the seven pieces of software that most engineers should know and use frequently regardless of the nature of their technical duties which are discussed below.

ENGINEERING DESIGN AND ANALYSIS

Engineers are usually engaged in either design or analysis. Let's consider the mechanical engineer since that activity is more closely related to this conference. The design engineer typically receives a conceptual input in written or graphic form depending on the status of the project in the design cycle. This concept or preliminary design should either be available on a disk to which the engineer has ready access with the other engineers on the same project or transmitted to a local disk storage if the project is small. Further detailed design or analysis is performed with the results transmitted or made available to others on the project. The critical concepts then are 1) Who has the need for and access to information?; 2) What analysis programs are available and should be used? A complex, multi-faceted program like MSC/NASTRAN has great capability in the hands of a skilled structural analyst. However, it must be available and understood by the involved engineers. Further, the geometric model describing a part needs to be augmented with instructions telling the engineers what analysis needs to be done prior to that part being accepted and released.

The three key concepts discussed in the above paragraph are 1) The management of design information; 2) The management of the analysis programs to be used and; (3) The management of the resulting output information from the analysis programs. Currently, much of this information is available in various computers throughout a typical high-tech company. Unfortunately, the incompatibility of the various data formats, the lack of high-speed local area networks, and the lack and use of good engineering data base systems make the integration of the information difficult. Also few companies have yet to consider an engineering workstation and associated network as a mandatory tool for every engineer.

A BRIEF HISTORICAL REVIEW

The introduction of the stored program computer in the early 1950's enabled engineers to better perform their analysis, especially in high technology areas. IBM's first stored program computer (the IBM 701) was originally called the Defense Calculator since it was intended primarily for use in aerospace and related engineering industries. Initially these engineering computing efforts were highly fragmented and offered virtually no computer intercommunications of engineering analysis or integration of the various analyses except through human communications.

While the majority of computers used in support of engineering retained their fundamental batch orientation, improvements were made over the years to make the central computing facility more accessible to the engineer. For example, IBM's Time Sharing Option (TSO) came into being in the late 1960's and did offer improved accessibility, but was not without its shortcomings. It was often expensive because of the premium prices for on-line users set by the central computing organizations. The limitation of the number of simultaneous users affected both turnaround and accessibility, especially during peak usage hours. This was further aggravated by self-serving abuses of the log-on procedures. The communication lines, especially public telephone lines, were not always the most reliable - and were over-priced for what the user actually received.

The introduction of minicomputers for handling distributed time-sharing environments and microcomputer-based systems as stand-alone workstations represented an attempt to resolve the extant problems. These systems, which started to appear in the early 1970's, suffered a common problem of inadequate processing power, word length and addressing, data handling limitations, weaknesses in their operating systems and programming languages, and lack of low-cost passive and interactive graphics. Many of these deficiencies were overcome in the late 1970's as 32-bit minicomputers made great strides.

This brings us to today's environment in which such technologies as the Motorola 68000 chip have made possible very powerful micro-computers at very reasonable costs, as discussed earlier.

FUTURE ENGINEERING WORKSTATIONS

First, let's discuss the hardware required - CPU, memory, disk, CRT, keyboard, and printer. Thirty-two bit microprocessors with a speed of one million operations per second will be available in 1984. This then provides each engineer with the capability of today's best selling superminicomputer at his desk. A one to two megabyte memory should provide more than enough capability for the individual workstation. Winchester disks of forty to several hundred megabytes provide adequate local read/write storage when combined with removable cartridges of similar capacity. Such units are just becoming available at costs of one to five thousand dollars for the smaller units with larger, more cost effective units to be available next year. CRT's with low to medium resolution are available now at under one thousand dollars with high resolution (1024 x 1024) at two or three times that cost. The costs for the high resolution units should drop in 1984 and 1985 as higher resolution units become available from commercial television. Keyboards will be supplemented with mouses this year and will make the input of graphics and the general interfacing by engineers easier. Low-cost dot matrix printers with graphics are currently adequate for most engineering work and improvements in the next year or two will make quality better with no significant increase in cost.

In addition to the above hardware, communications interface hardware is required. This hardware is now available and the cost will be significantly reduced as better microprocessors become available.

By as early as 1985 an engineering workstation with all of the above key features should be available for a cost of around five thousand dollars. Most future engineers will expect one, and engineering companies will tend to base their activities around the workstation and associated network.

Engineering software costs will not change as rapidly due to the smaller market. The more general software as described above will be very low in cost as some of it is today; but, the more limited specialized engineering analysis programs will not significantly decrease in price because of the more limited distribution and great complexity of the code. However, compatibility between various engineering software will be greatly enhanced by the establishment of various standards such as IGES.

In finite element modeling, the semi-automatic generation of meshes from geometric models will begin to make some inroads. This process will require good human interfacing to allow the adjustment of the automatically generated meshes in a rapid and effective manner. Such code can be written but will require much experimentation to make it cost effective.

Recent advances in geometric modeling research give hope that solid modeling is the wave of the future for defining mechanical parts and assemblies. As industry begins to design parts using geometrical modeling systems, the semi-automation of finite element mesh generation becomes more desirable. Recent research in octrees provide hope that this type of process is economical and technically feasible.

CURRENT EXPERIENCE IN USING WORKSTATIONS

During the past several years, both Hughes Aircraft Company and The MacNeal-Schwendler Corporation have been studying and evaluating various workstations. Included in this evaluation have been the DEC 350, DEC Rainbow 100, Dynalogic Hyperion, Altos 68000, Apollo DN 420 and DN 300. Apple Lisa, NEC APC, Compaq, IBM PC, Onyx 8002, HP 9816, HP 9000, Columbia PC, SUN, and Victor.

To date two units have stood out as candidates for finite element use: the Apollo Domain and the IBM PC. The Apollo DN 420 is a computer in the one quarter megaop class. It has four outstanding features: 800 x 1024 hi-speed bit mapped mapped graphics, 12 megabit per second interprocessor communications, virtual memory, and floating point hardware. Its disadvantages were only noise, size, and cost. The Apollo DN 300 remedies significantly improves all three deficiencies and should be an outstanding engineering workstation when the floating point hardware becomes available in the fourth quarter of 1983 at a cost in the $20,000 range.

At a significantly lower cost the IBM PC and the various IBM look-alikes offer outstanding value with lower capability. The lack of virtual memory, the low resolution graphics and the the lack of good support for the recently announced 8087 floating point chip are major defects in an otherwise most-promising workstation. These defects should all be overcome by late 1983 and this will then allow the engineer to have a truly outstanding low-cost workstation. The speed of the unit will probably be improved by the new Intel 286 microprocessor in 1984. The price of the improved unit is not expected to increase since the cost of the microprocessor and associated chips are less.

CONCLUSIONS

In the next five years, many engineers will have a workstation in their office and one in their home. These workstations will be of the one million instructions per second (mips) class with a one-tenth to one-fifth of a million floating point instructions per second (megaflops) capability. They will have color graphics with a resolution of approximately 1,000 by 1,000 pixels on a 15 or 17 inch CRT. The primary memory will be one or two megabytes with a Winchester-type disk providing another 40 to 100 megabytes of auxiliary storage. This workstation will include a color dot matrix printer with a resolution of better than 250 dots per inch. There is some strong indication that this could become available sooner than earlier anticipated.

The communication capability will include a local area network with a speed of at least several megabits per second for distances of up to several thousand feet and a global network in the range of more than 100 kilobits per second. Included in this local area network will be computer engines with speeds that are 10 to 10,000 times the speed of the local workstation. Also available in the LAN will be large disk farms with large data bases which will include graphic images and geometric models. High quality, high-speed laser printers will also be available for volume printing.

The current heterogeneous unfriendly interface problem will hopefully have been eliminated by integrating interface programs and use of mouses and menus will make the use of the workstation easy and fun.

In the late 1980's we will begin to see the use of techniques now being developed in Artificial Intelligence research. The most significant of these seems to be those concerned with machine learning. By this is meant the modification or construction by program of stored information structures, so that the machine-deliverable information is more accurate, larger in amount, cheaper to obtain, or some combination of these. The implications that the computer will provide some part of the engineering analysis in a more accurate, rapid, and cost-effective manner are staggering. The current research leaves no doubt of this ultimate capability, the question is can we learn to integrate this with effective use of human engineers and to benefit mankind through its use.

The challenges of both using workstations effectively in the near-term and then to incorporate A.I. techniques into these provides a tremendous technical and management challenge for the rest of this century.

TRENDS IN DISTRIBUTED WORKSTATIONS IN CAE

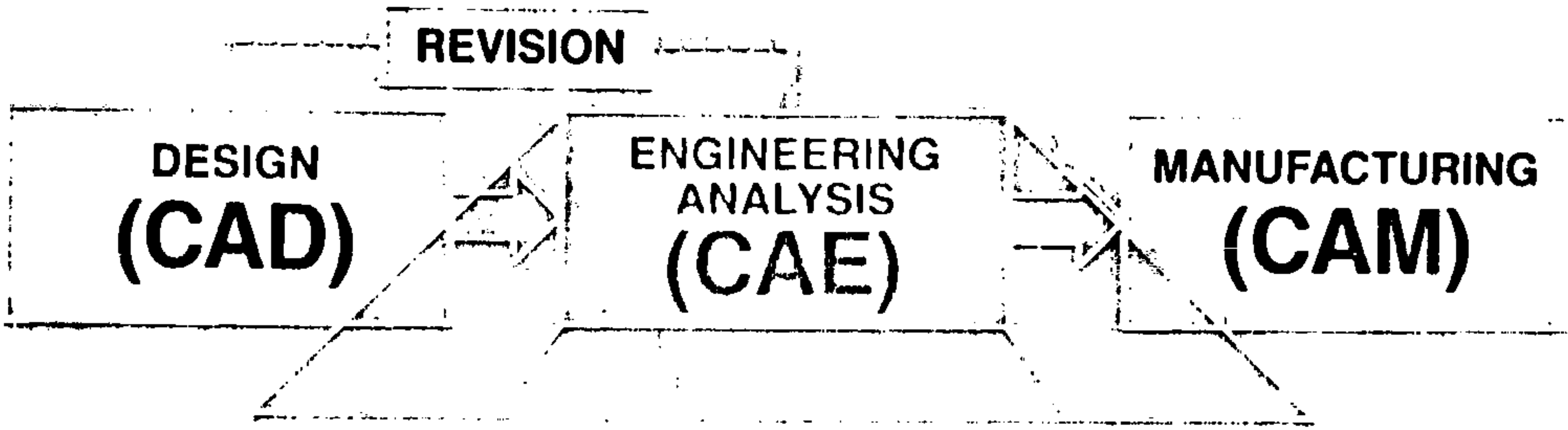
1983 CAD/CAM INDUSTRY CONFERENCE

Newport Beach, California
September 26 - 28, 1983

Joseph F. Gloudeman
President
The MacNeal-Schwendler Corporation
815 Colorado Boulevard
Los Angeles, California 90041

MSC

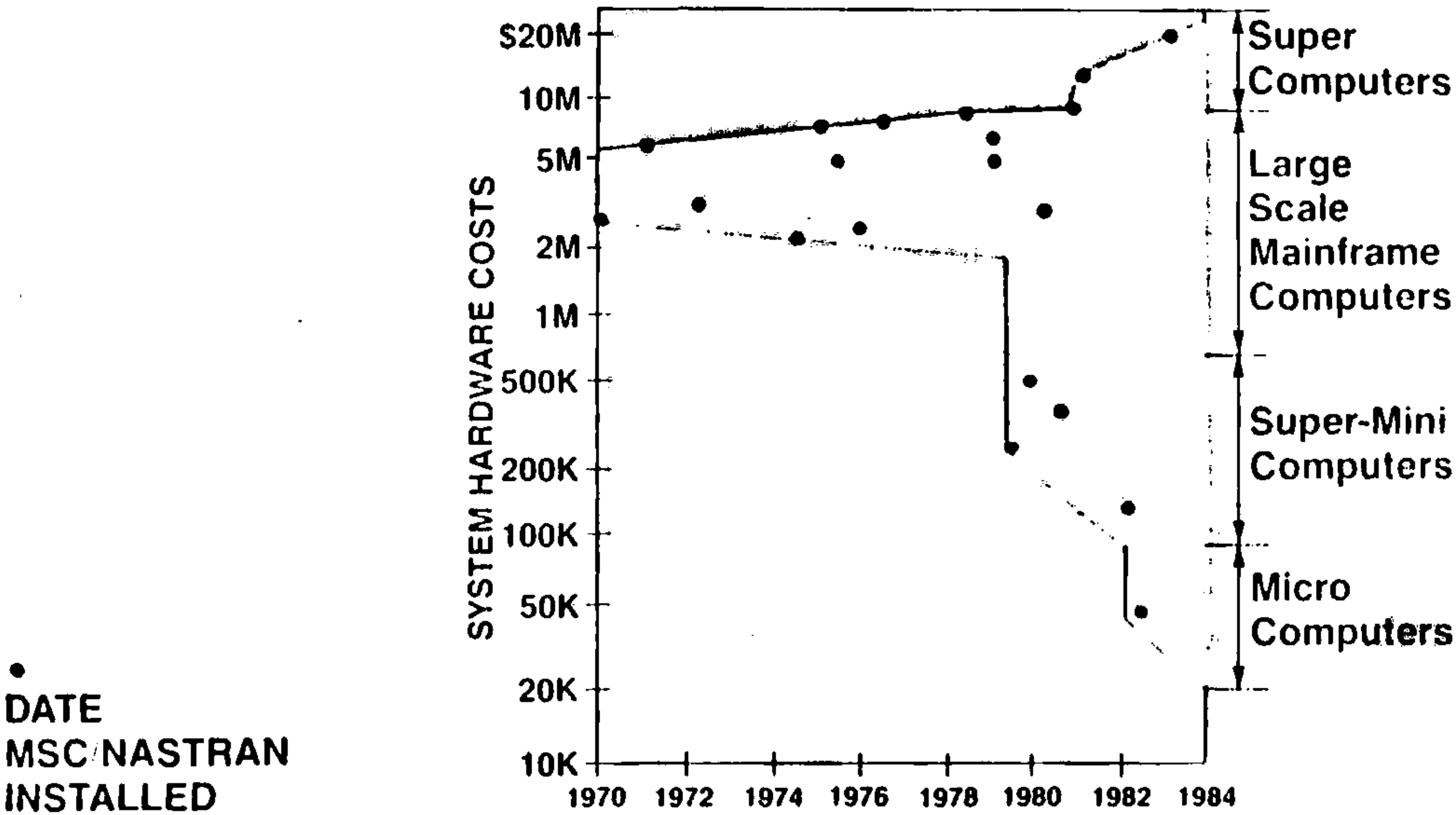
The Role of the Company's Products in Computer-Aided Engineering



Company Products

MSGMESH MSC/GRASP	MSC/NASTRAN	MSC/GRASP
Input Preparation	Data Processing	Output Display

Computer Hardware Cost Trends



TRENDS IN COMPUTING SYSTEMS

- CPU SPEED
- MEMORY SIZE
- STORAGE DEVICES
- TRANSMISSION AND DISPLAY
- COMPUTER HARDWARE COST TRENDS
- SUPPLY AND DEMAND TRENDS FOR PROGRAMMERS/ANALYSTS

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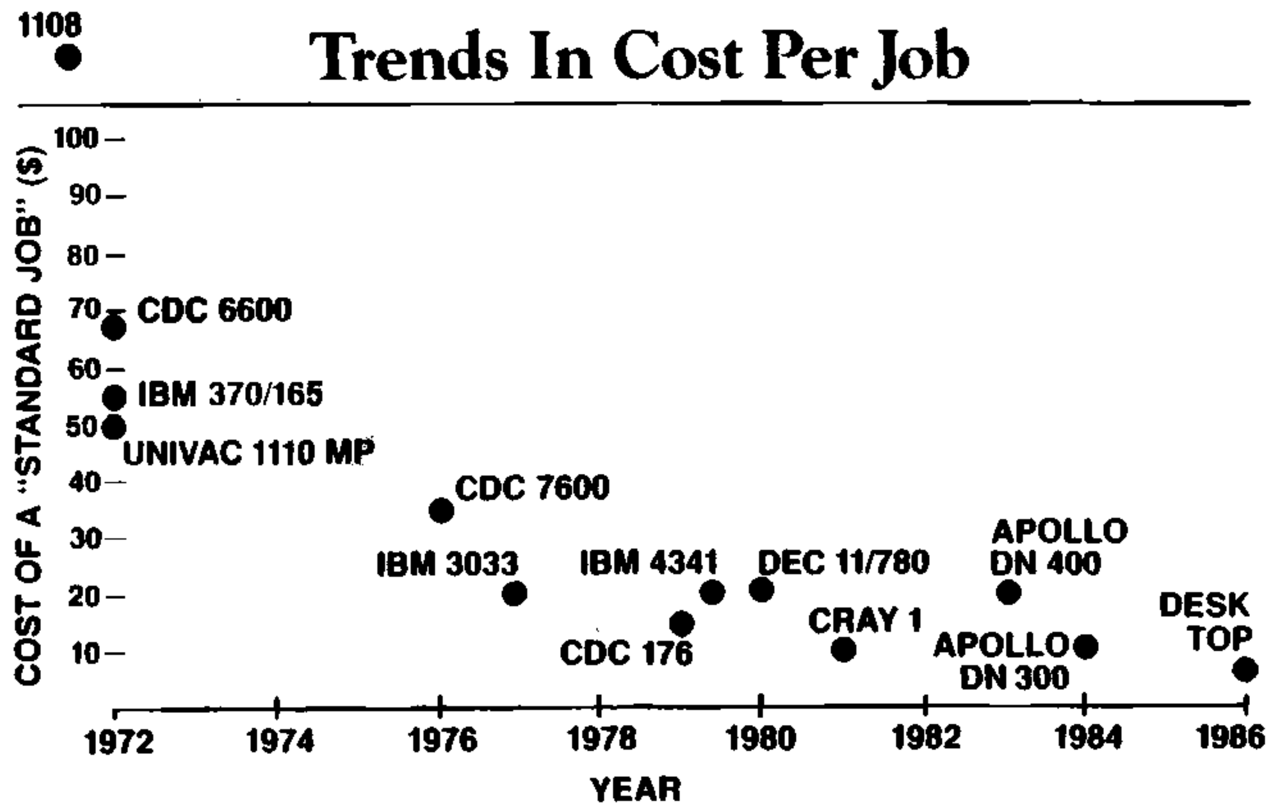
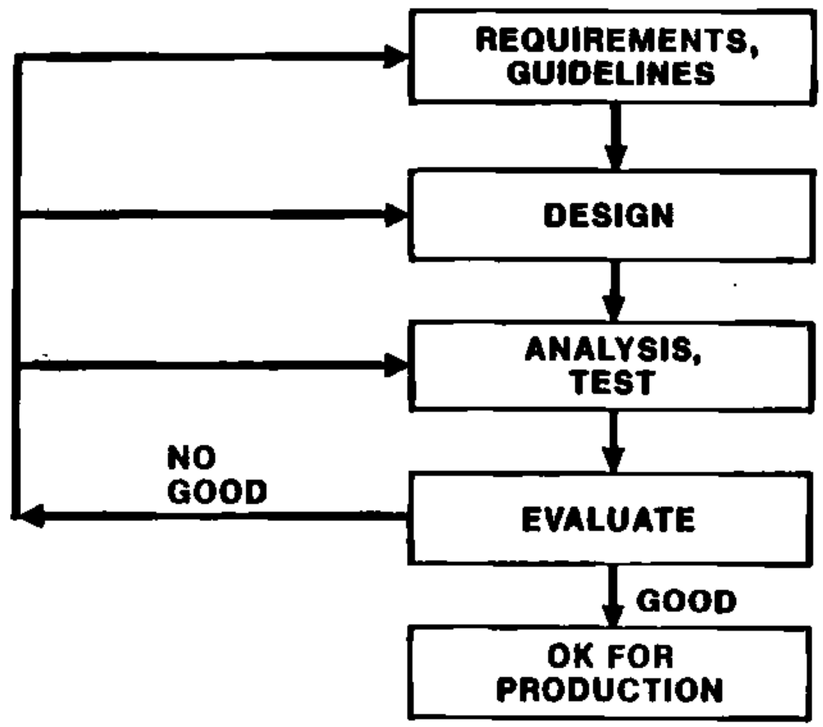
Trends In Cost Per Job



WORK STATION CONCEPT

- ECONOMICS OF MICROPROCESSORS
- POWERFUL COMMAND LANGUAGE (USER ORIENTED)
- COMPILERS FOR HIGHER LEVEL LANGUAGES
- TEXT PROCESSING (MECHANIZED REPORT GENERATION)
- TECHNICALLY ORIENTED RELATIONAL DATA BASE MANAGEMENT SYSTEM
- GRAPHIC FUNCTION
- WINCHESTER DISK TECHNOLOGY
- CO-AXIAL CABLES

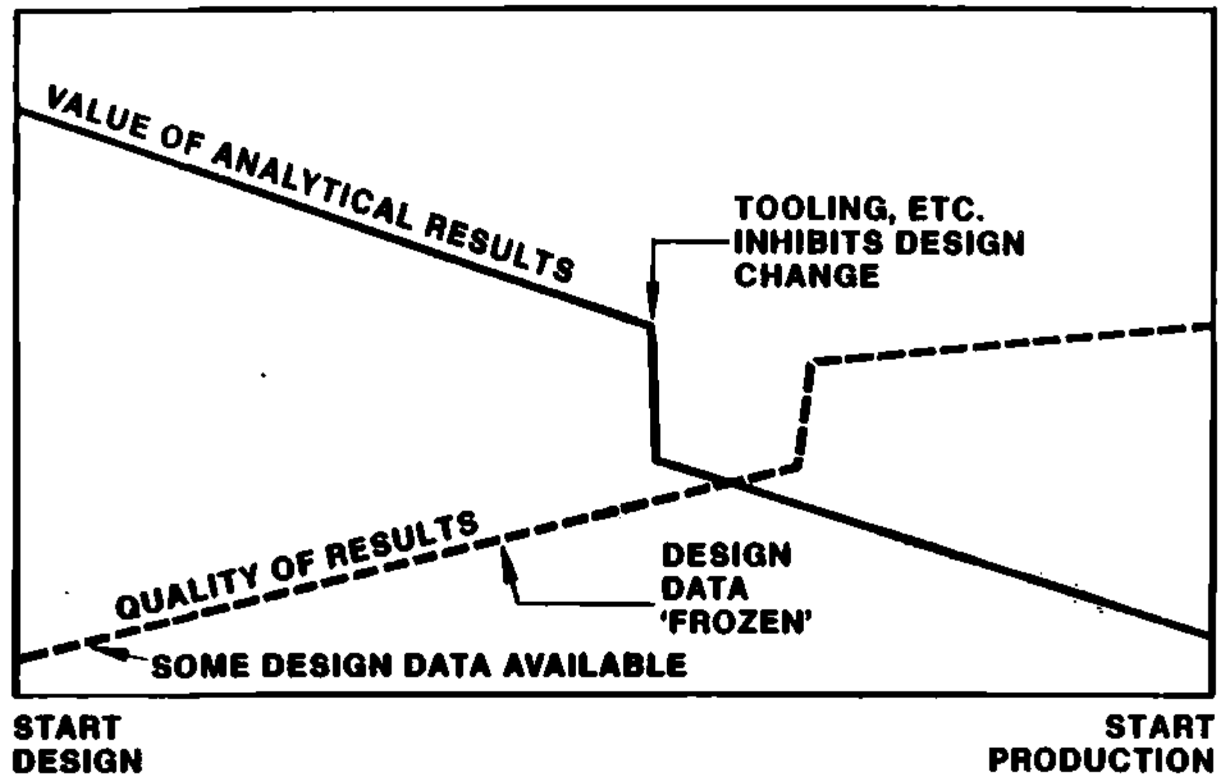
ROLE OF ANALYSIS IN DESIGN



EXISTING TOOLS FOR ANALYSIS

- **POWERFUL COMPUTER HARDWARE**
  - — HIGH SPEED PROCESSORS
  - — LARGE MEMORY, STORAGE DEVICES
  - — FILE MANAGEMENT
  - — REMOTE TERMINALS
- **WIDE SELECTION OF ANALYTICAL PROGRAMS**
  - — FEM POPULARITY, GENERALITY

A MAJOR CHALLENGE IN ANALYSIS



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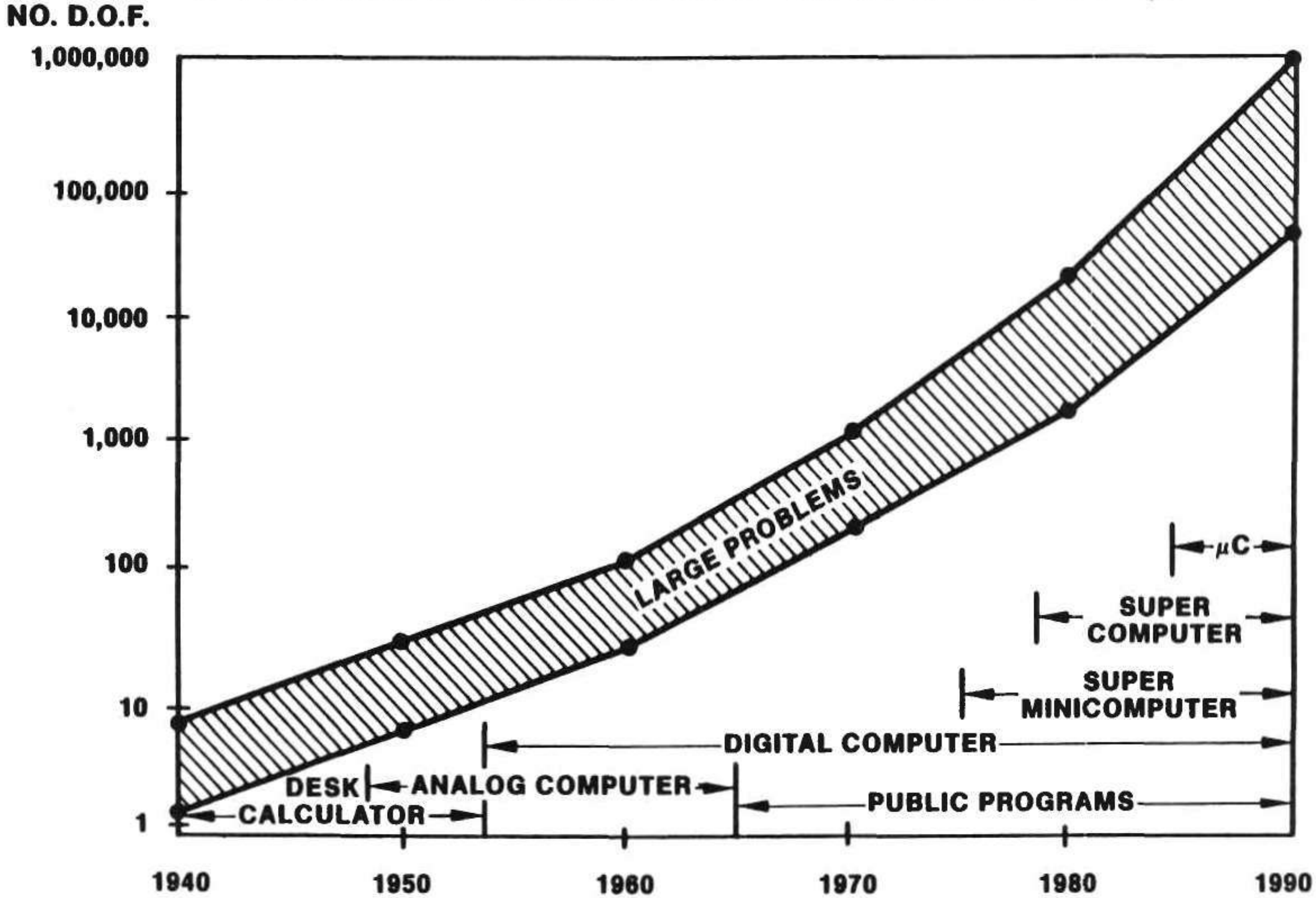
DYNAMIC ANALYSIS GROWTH TRENDS



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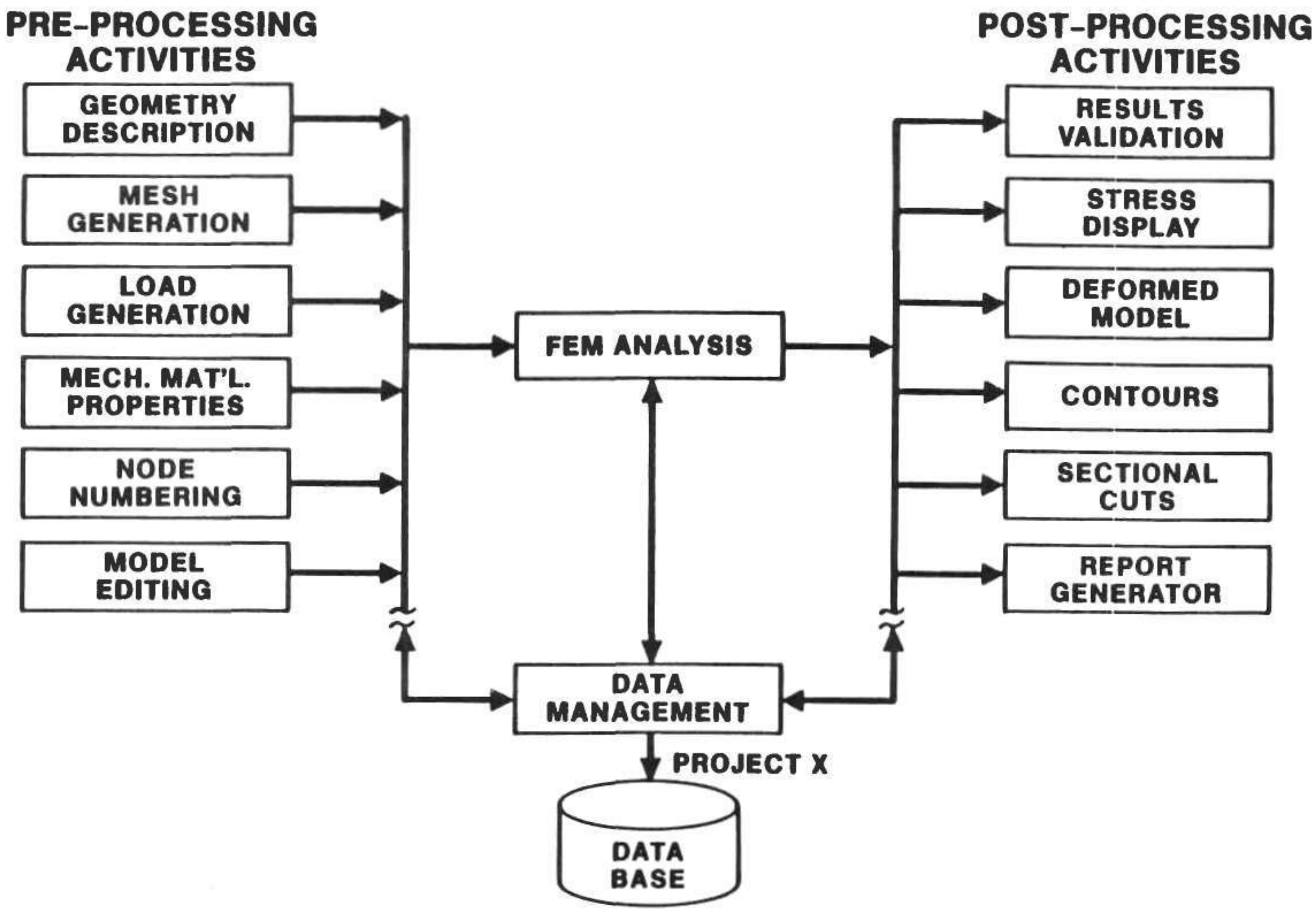
HORIZONTAL INTEGRATION

- **FINITE ELEMENT METHOD USED IN MANY APPLICATION AREAS**
  - STRUCTURAL ANALYSIS
  - HEAT TRANSFER
  - FLUID MECHANICS
  - ACOUSTICS
  - ELECTROMAGNETIC FIELDS
  - AEROELASTICITY
  - FLUID - STRUCTURE - INTERACTION
  - NON-LINEAR MECHANICS

VERTICAL INTEGRATION OF APPLICATIONS

- **BETTER INTERFACES BETWEEN DESIGN AND ANALYSIS ORGANIZATIONS**
    - — DIGITIZED GENERATION OF GEOMETRY AND TOPOLOGY
    - — GEOMETRY MODELING (SOLIDS)
- **FINITE ELEMENT METHOD OPPORTUNITIES: PRE- AND POST-PROCESSORS**
    - — ACCURACY, PRODUCTIVITY

AN INTEGRATED SYSTEM



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TRENDS IN INTERFACING CAD AND ANALYSIS METHODS

PHASE I: STANDALONE

- EACH APPLICATION "INDEPENDENT"
- SUBSTANTIAL MANUAL INTERVENTION + ERRORS + DELAYS

PHASE II: INTERFACING KEY SYSTEMS

- SOME COMMON DATA
- MECHANICAL TRANSLATION OF MUCH DATA
- MANUAL INTERVENTION TO ACTIVATE COMPUTER PROGRAMS

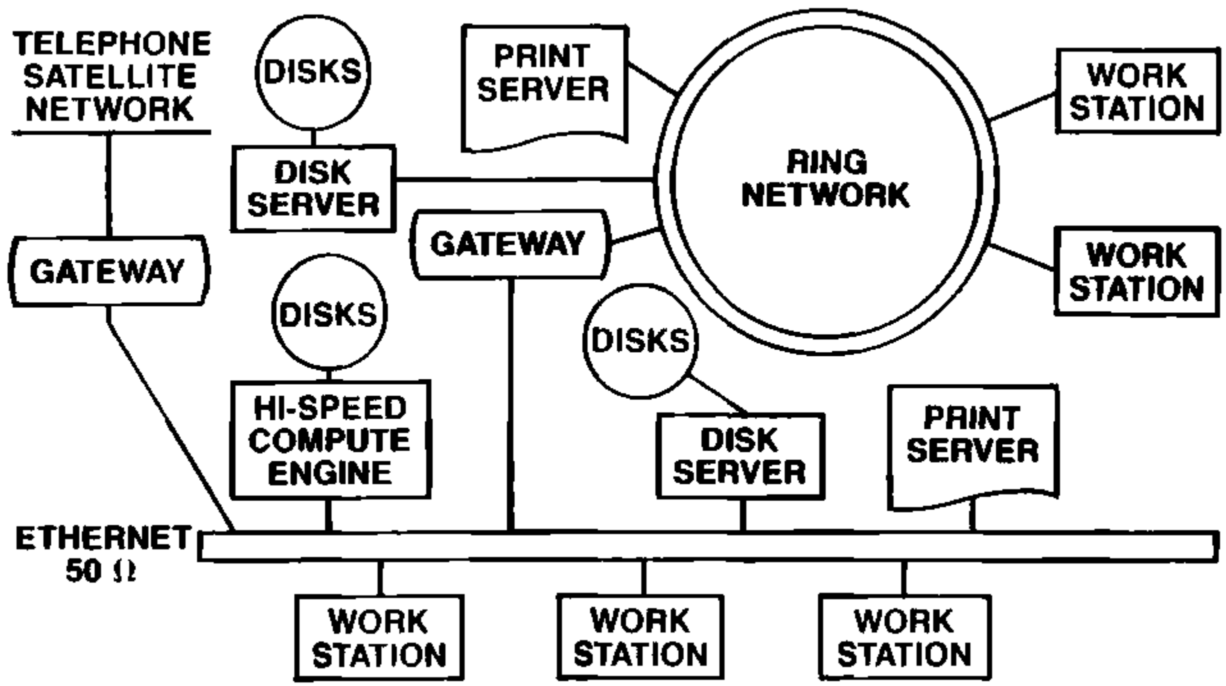
PHASE III: THE SEEDS OF INTEGRATION

- MUCH COMMON DATA
- SOME MECHANICAL TRANSLATION
- SEMI-AUTOMATED PROGRAM ACTIVATION

PHASE IV: INTEGRATED SYSTEMS

- COMMON DATA BASE (DBMS)
  - CONFIGURATION MANAGEMENT
  - CONSISTENT DATA AND RESULTS
  - EASE OF ACCESS FOR QUALIFIED USERS, PROGRAMS

Distributed Engineering Work Stations



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CHALLENGES IN DATA INTERCHANGES

- **LARGE VOLUMES**
  - BILLIONS OF DATA ELEMENTS
- **TIME LAG BETWEEN DESIGN AND ANALYSIS**
- **DESIGN CHANGE ACTIVITY**
  - CONFIGURATION MANAGEMENT
- **PROJECT LEADER VISIBILITY AND CONTROL**
  - RECORD KEEPING
  - ARCHIVING

SOME OF THE CHALLENGES IN COMPUTER SYSTEMS

- **DATA BASE MANAGEMENT SYSTEM**
  - RELATIONAL/NETWORK DATA BASE
  - GRAPHIC AND GEOMETRIC REPRESENTATION
  - EFFICIENCY, ACCESSIBILITY
  - CONTROL
- **DISTRIBUTED ENVIRONMENT**
  - DIS-SIMILAR PROCESSORS (E.G. WORD SIZE, ARCHITECTURE)
  - MICROPROCESSORS ⟶ SUPERCOMPUTERS

⋮

WORK STATIONS!

AREAS REQUIRING DEFINITION, DEVELOPMENT

- TECHNICALLY-ORIENTED DBMS
  - — LOGICAL SCHEMA DEFINITION AN OPEN ISSUE
- "STANDARD" INTERFACES
  - — MULTI-VENDOR COMPUTERS
  - — GRAPHICS DEVICES
- "UNIVERSAL" NETWORKING, TELECOMMUNICATIONS
- USER-ORIENTED LANGUAGES; STANDARDS
  - — DATA HANDLING
  - — GRAPHICS
  - — GEOMETRY

SOME ALTERNATE PATHS

- **INTERMEDIATE GRAPHICS EXCHANGE STANDARD**
  - EXTENSION TO NEUTRAL DATA BASE
  - TRANSLATION/TRANSMISSION OF DATA
  - NEED PEOPLE, MONEY, SPONSOR
- **NASA'S IPAD**
- **DOD'S ICAM**
  - RFP FOR PRODUCT DEFINITION DATA SYSTEM

AN ARGUMENT FOR INTEGRATION
(PRE- AND POST-PROCESSORS)

	% OF COST	% OF SCHEDULE
PREPARE INPUT	50	60
COMPUTER PROCESSING	30	20
INTERPRET, DOCUMENT RESULTS	20	20

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Nielsen Dataquest

ROBOTICS--TODAY AND TOMORROW

Stephen P. Volm
Western Region Manager
Advanced Manufacturing Systems
IBM Corporation

Mr. Volm is Western Region Manager for IBM's Advanced Manufacturing Systems business unit. AMS has responsibility for developing, manufacturing, and marketing IBM's robotic systems. During his 14 years with IBM he has held various marketing and management positions. He has concentrated in marketing manufacturing control systems, plant automation, and CAD systems. Prior to joining IBM, he held several design engineering and factory management positions with International Harvester. Mr. Volm received his degree in Mechanical Engineering from Marquette University.

Dataquest Incorporated
CAD/CAM INDUSTRY CONFERENCE
September 26-28, 1983
Newport Beach, California

ROBOTICS TODAY & TOMORROW

STEPHEN P. VOLM
I B M CORPORATION
ADVANCED MANUFACTURING SYSTEMS
SAN DIEGO, CALIFORNIA 92108

In February 1982 IBM formed a new organization called Advanced Manufacturing Systems to develop, manufacture and market IBM's robotic products.

The organization was set up as an independent business unit which operates independently of any existing IBM marketing organization. Our organization consists of a General Manager who reports to a Board of Directors made up of IBM group executives. The business unit is still apart of IBM, but its independency gives it an opportunity to react to changing market conditions with this new technology. IBM's internal automation group (SEDAB-Special Engineering Design And Build) is also part of our AMS organization. This group has responsibility for both hard and flexible automation projects at IBM plant sites worldwide. This adds additional skill to our new organization that is very helpful when working with prospects on flexible automation requirements. The AMS organization is headquartered at the IBM Boca Raton, Florida facility.

This site was chosen because it is the location of our manufacturing organization that builds the Personal Computer and the IBM Series 1 Computer which drive the robotic products. In addition, our SEDAB organization is also located at this facility.

The interest and use of flexible automation is accelerating rapidly in the United States. However, when compared to the robotic usage in Japan, the United States is very far behind. Recent surveys have estimated that Japan has three-fourths of the world's robots installed. They have been implementing robots for the past ten years or longer, and are now implementing computer integrated factories.Increasing interest in this country can best be described by recent attendance at the National Robot Shows. Two years ago, about 4,000 people attended the National Robot Show. The Robot VII Show this year in Chicago had over 20,000 attendees.

There are many reasons why companies must begin to make widespread use of robotics and flexible automation. Competition has increased significantly on a worldwide basis over the past ten years. If you examine some of the causes of increased competition particularly from overseas businesses, you will find that the expenditures for plant modernization and flexible automation have far exceeded those in the United States. This has increased productivity at a rapid rate in other countries and created a condition where our productivity improvement and output per manhour in the United States now lags all major industrial nations along with the United Kingdom.

In absolute terms, the United States still leads the rest of the industrialized world in productivity, but in productivity growth, we are last. This is a trend that must be reversed in the near term if we are to regain our industrial leadership. Our rate of productivity growth over the past decade has been about 2½%. Japan's has been 7.3%. Much has been written about large corporations in the United States beginning to take an aggressive attitude towards automation. General Electric, for example, is building one of the world's most advanced locomotive factories in Erie, Pennsylvania. Using new manufacturing technology, robots and computer control, the new factory will bring a dramatic gain in productivity. Where it now takes 68 skilled machine operators 16 days to build a locomotive motor frame, the new factory will turn them out in one day with one-tenth of the operators. Japan's Yamazaki machine works is one that has been written up in a number of publications. They are building a new 15 million dollar machine tool parts plant in Florence, Kentucky. This factory will be one of the world's first entirely automated factories, and when they complete it in 1983, it will require 6 workers to tend to the master controller and the robots in the factory.

Continued inflation creates additional justification for robotic opportunities into the decade of the '80's. Labor costs have risen about 48% over the last 6 years in the United States, and that trend is expected to continue. Robots can help stabilize these costs.

In many businesses we have seen a growing requirement for improved product quality. Items made in Japan used to be very inexpensive and of low quality. Today that trend has been reversed where their products are now the standard of quality. The demand for quality will be achieved with flexible automation and robotic systems that can produce with repeatability and impact on the overall product quality.

We have also found that many of the assembly operations in the United States are being switched to small batch lot assembly. With the recent rising cost of carrying inventory and the volatile market conditions, it is very difficult to predict volume requirements of any one product in a time period. As a result, manufacturers are shifting their operations to produce in smaller lots to reduce the amount of inventory and be more responsive tc market fluctuations. Programmable robots give companies a tremendous opportunity to change lines and manufacture multiple products over a single flexible automation line. The changeover of these lines that are designed for flexibility is minimal and permits manufacturers to produce in smaller lots.

The evolution of the robotic industry can be traced back to the initial implementation in the early '60's of mechanical arms. By mid 70's there were computer controlled robots. In the early '80's we saw the introduction of sensory feedback robots. By 1985 the robotic systems will be integrated into an automated factory. IBM has focused its efforts on the intelligent robots with sensory feedback and integrated systems for assembly and test.

This is a very new area for robotic automation because it requires sensory capability in the robot and requires the computer that is driving the robot to handle many other tasks besides controlling the manipulator.

What are we trying to achieve with robotic automation, and why is this an advantage? If you examine the opportunities for automating assembly prior to intelligent robots, there were basically two options: 1) manual labor; and 2) fixed or hard automation. Manual labor was the most flexible being easily taught, very adaptable to change, required little tooling, and would automatically inspect its work. The negatives associated with manual labor were fatigue, quality could vary, speed could vary, and costs were increasing. With fixed automation, it was very repeatable, reliable and was usually very fast. However, in many cases, it was built for a single purpose; you could not vary the product; it was not flexible; and it was expensive compared to flexible automation. The key question that we are asking is how do we achieve breakthroughs in productivity where we can get the best of both manual labor and fixed automation. Robotics fits in this middle ground between manual labor and fixed automation. Intelligent robots offer an opportunity to realize the advantages of manual labor and hard automation while eliminating the negatives associated with each.

IBM has addressed the assembly market with two types of intelligent robots. The 7535 is an intelligent robot which is quick and precise.

The 7565 is a very intelligent robot with tactile sensing that can adapt to its work environment. The key to intelligent robots is the software language. IBM developed the language used to drive its robotic products called AML in the early '70's. This language was put to use with robotic systems in the IBM plants in the mid '70's and has been continually enhanced since that time. An intelligent robotic language must have several capabilities which AML has, such as: robot control, data processing capabilities, calculational capabilities, debugging, program development, error handling. In addition, the language must be extendable. AML has the capability to design your own interface; you can develop a higher level language within the AML language to customize subroutines for your own use; and IBM has added a high level language for manufacturing engineers called PROBE which stands for Programming Robot By Example. This easy-to-use language allows people who are not programming professionals to gain access to the system and do productive work. AML is a single step interpretive language which allows you to make program changes line by line and execute them. This interpretive language capability is very important in making it easier to put robotic applications in production.

The 7565 and 7535 basic systems were intended to cover the spectrum of assembly operations. The 7535 is used for simple assembly operations and can be used to service many hard automation devices such as loading and unloading auto insertion equipment, test stands, etc. The 7565, on the other hand, is intended to address the more complex assembly operations where tactile sensing is required to duplicate the assembly process. The types of applications performed by these robots are stacking, component insertion, fitting, palletizing, testing, load and unload, parts handling, kitting, and light metal removing and fabrication such as drilling, tapping, deburring.

IBM developed its robot technology and the AML language in 1972 and 1973 and installed the first prototype system at Lexington and Poughkeepsie in 1976 and 1977. This first application was used to test the back panels of the IBM large scale processors. There were about 30,000 pins on these back panels that had to be tested for continuity. It took about 92 hours to test each system. We put 2 arms in the 7565 frame and rotated it 90 degrees and did the probe testing on those panels in about 14 hours with the robot. Since the first system was installed in 1976, we have continued to expand this testing system. IBM's latest large computers are 100% tested in a cell that now consists of 16 2-armed 7565 robotic systems. Many other tests are now performed on circuit quality in addition to circuit continuity. The major benefit from this system was improved testing which made a major contribution to improved product quality. It has also produced substantial labor savings. The new modules are tested in about 3 hours and are performing many more tests that would have been uneconomical to do manually.

The IBM 7565 adaptable robot system has a workspace about the size of a workbench. The longest axis is about 58 inches in length with an 18 inch X-axis and a 17 inch Y-axis. It is driven by the IBM Series 1 Computer that has the capability of storing up to nine million bytes of data. A CRT and printer are available for programming and operator control. This system is a hydraulic unit with a speed of 40 inches per second and has 6 degrees of freedom (X, Y, Z, roll, pitch and yawl) in addition to the gripper. The linear hydraulic motors are a special design and operate along the parabolic cam for each linear axis. They have proven to be very reliable in all the installations both in IBM plants and in customer locations. The configuration gives us a very high force to wait ratio and a very reliable system that can adapt to its surroundings. The system's adaptiveness is due to the strain gauges that are built into the fingers of the gripper that detect X, Y and Z forces. These highly sensitive gauges that can detect force in 10 gram increments along with the software that monitors the pulse beat of the robot every 20 miliseconds are the basic ingredients that allow the 7565 to adapt to a variety of changing conditions that occur in its working environment. For example, if a drift builds up in the tooling of the fixtures, the robot can sense this and take corrective action and then re-register all the points of the new location to accommodate for the drift. In addition to the tactile sensing in the gripper, there is also a light emitting diode that allows presence sensing to occur between the fingers. This feature is very useful in calibration.

The operator merely has to move the gripper near the calibration post and execute a subroutine called "Find Post", and the 7565 through an AML software routine will calibrate itself on the alignment post. This makes setting up a job very easy for the operator.

The other major robotic system being offered by IBM is the 7535 SCARA robot. This system was designed for precision assembly and is specified with a repeatability of ±.002 inches across the entire workspace with up to a 13 lb. payload. It has 4 basic degrees of freedom (X, Y, Z, and roll) in addition to the gripper. This system does not have tactile sensing but does have 14 points of digital input and digital output sensing that are useful in moving conveyor systems or detecting part presence. It is programmed with the IBM Personal Computer, and one Personal Computer can service many 7535's by downloading the programs into the 7535's controller. The system is very flexible and can be located over existing conveyor linesor workbench areas.

Management's focus has been on payback when justifying robots. This thinking is changing as it becomes obvious we do not understand all the benefits of this new technology prior to installation.

The major components of robotic justification are: labor displacement, quality improvement, reusable tooling, cost stability, reduced tooling costs, manufacturing flexibility and shorten the design-to-build cycle.

Users that have installed intelligent robotic systems have learned the following: it requires an upfront investment; it takes dedicated people; you should start with simple applications; intelligent robots can reduce tooling; they learned how to design the product for automated assembly; and they had to learn by doing.

The steps necessary to expand into the computer integrated factory are: the first step could be a robot assembly cell; the second step could be moving the work flow to several of the automated assembly cells; the third step is the integration of both the work flow and the data flow, achieving a computer integrated manufacturing system. The technology is there today to implement computer integrated manufacturing. It requires management commitment and an initial investment of resources and capital to begin the implementation process. Computer integrated manufacturing and flexible automation will help manufacturers become "low cost producers" and improve their level of product quality.

HISTORY OF IBM ROBOTICS

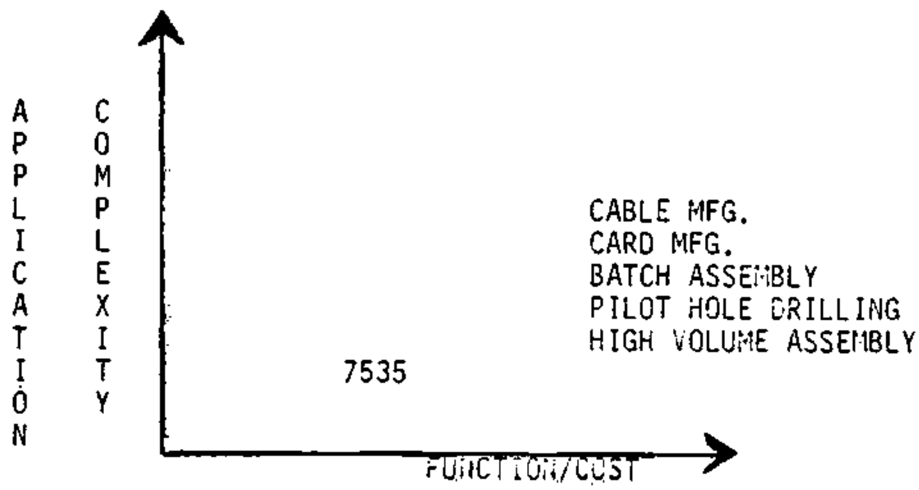
1972	RESEARCH DIVISION (YORKTOWN,NY) CHARTERED TO DEVELOP ROBOT TECHNOLOGY
1973	FIRST ROBOT BUILT
1976-1977	PROTOTYPE SYSTEMS INSTALLED AT LEXINGTON AND POUGHKEEPSIE PLANTS
1978	ROBOTICS GROUP FORMED IN BOCA RATON
1979	ROBOT SYSTEM INSTALLED AT JOINT STUDY SITE
1980	IBM ROBOTS INSTALLED THROUGHOUT IBM PLANTS AND LABORATORIES
1981	FIRST TEST MARKETING ROBOT CUSTOMER SHIP
1982	FEBRUARY - IBM ROBOTIC ANNOUNCEMENT MARCH - ROBOTS VI EXPOSITION
1983	JANUARY - IBM 7565 MANUFACTURING SYSTEM

KEYS TO ROBOTIC JUSTIFICATION

INTELLIGENT → VERY INTELLIGENT

- LABOR DISPLACEMENT
- QUALITY IMPROVEMENTS
  - UNIFORM PERFORMANCE
  - TEST WHILE BUILD
- REUSE
  - RETOOL
  - REPROGRAM
- COST STABILITY
  - STEADY RATE
- MANUFACTURING FLEXIBILITY
  - ASSEMBLE TO "NEED"
  - PRODUCT MIX CHANGES
- REDUCED TOOLING COST
  - ADAPT WITH SENSING/SOFTWARE
- SHORTENED DESIGN/BUILD CYCLE

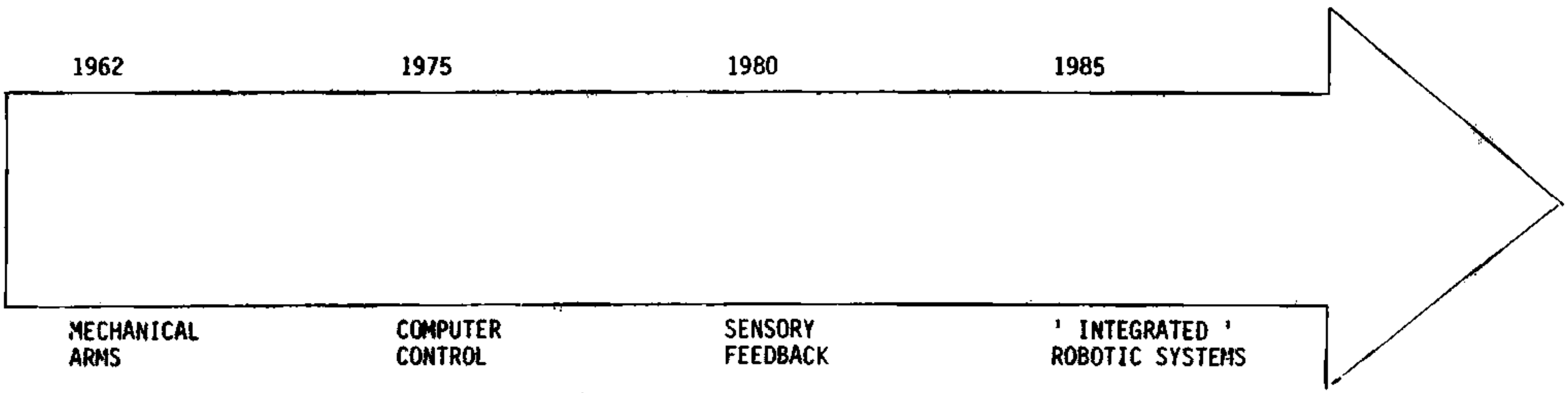
7535 APPLICATION POTENTIAL



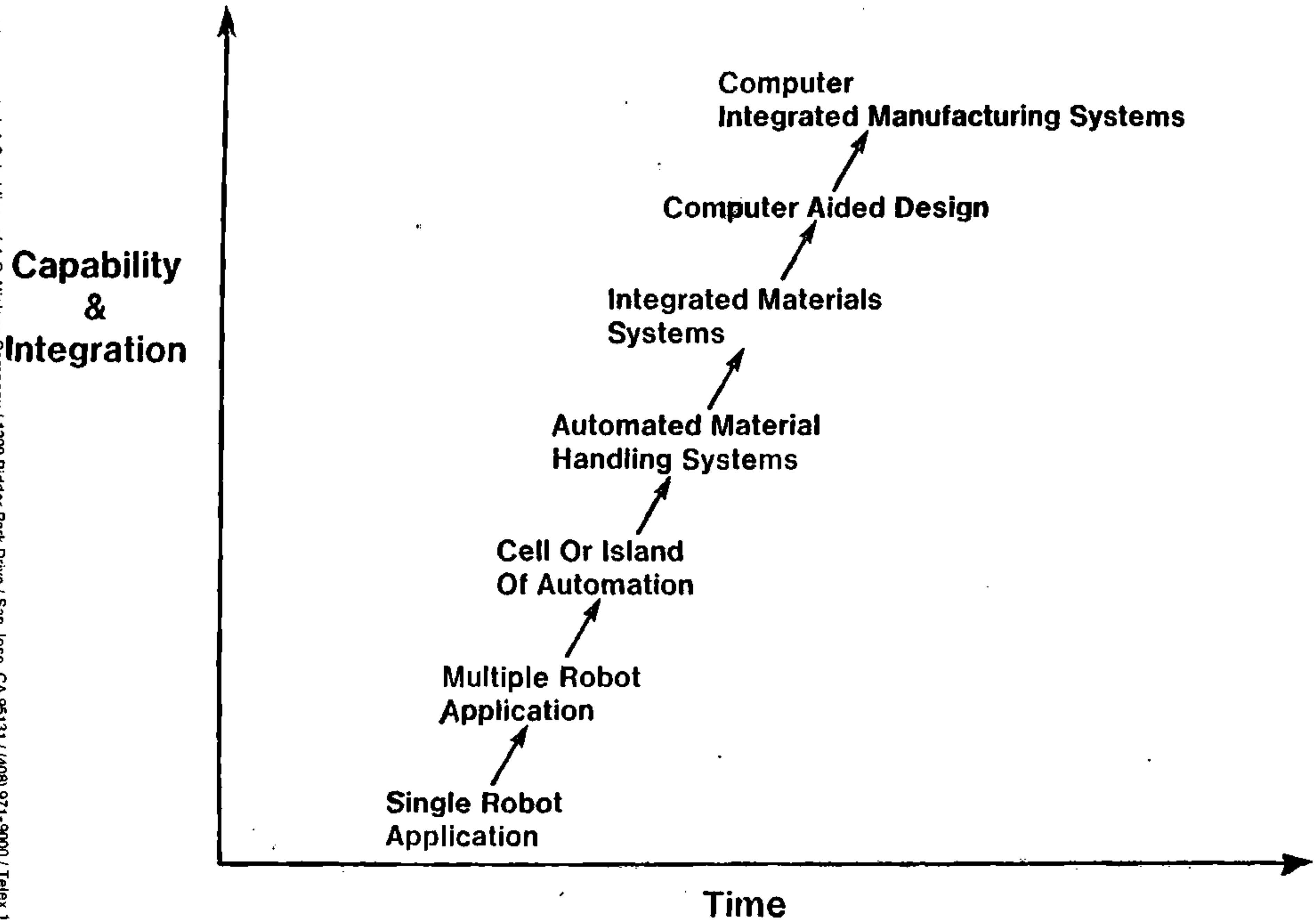
INTELLIGENT ROBOT REQUIREMENTS

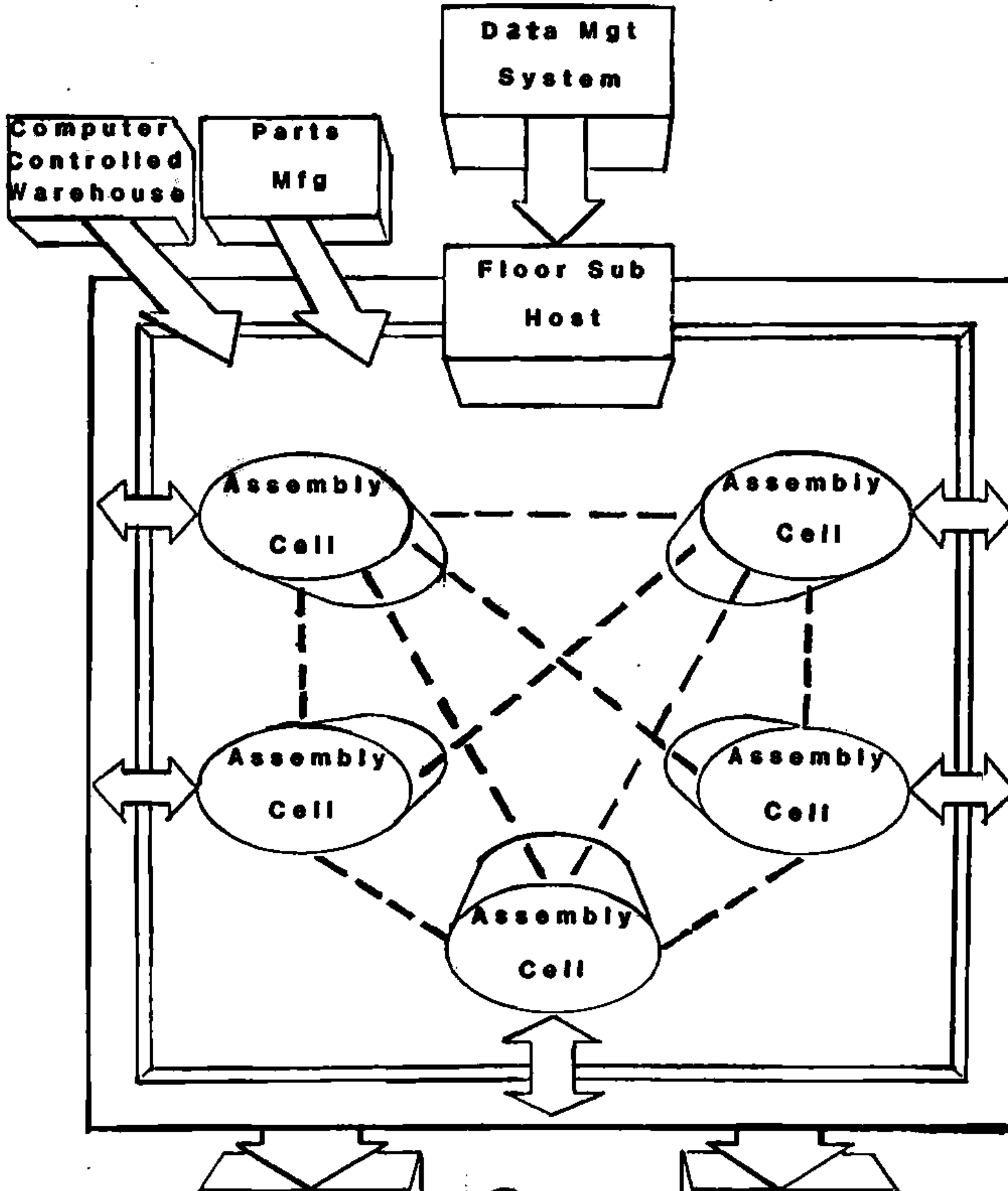
- °PRICE PERFORMANCE
- °SPEED
- °PAYLOAD
- °PROGRAMMING SIMPLICITY

ROBOTICS EVOLUTION

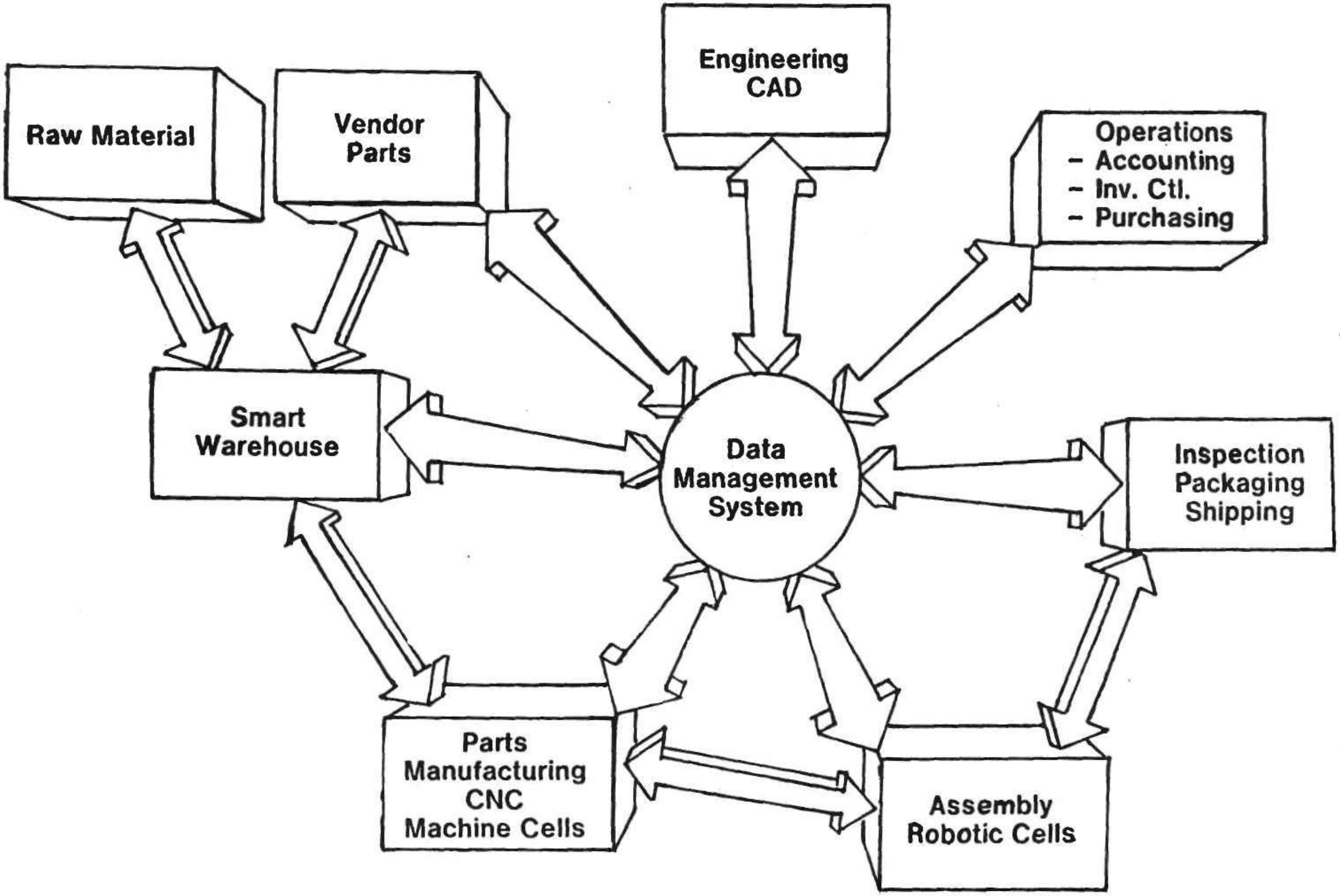


Automation Migration




Data Mgt
System
Computer
Controlled
Warehouse
Parts
Mfg
Floor Sub
Host
Assembly
Cell
Assembly
Cell
Assembly
Cell
Assembly
Cell
Assembly
Cell

Computer Integrated Manufacturing



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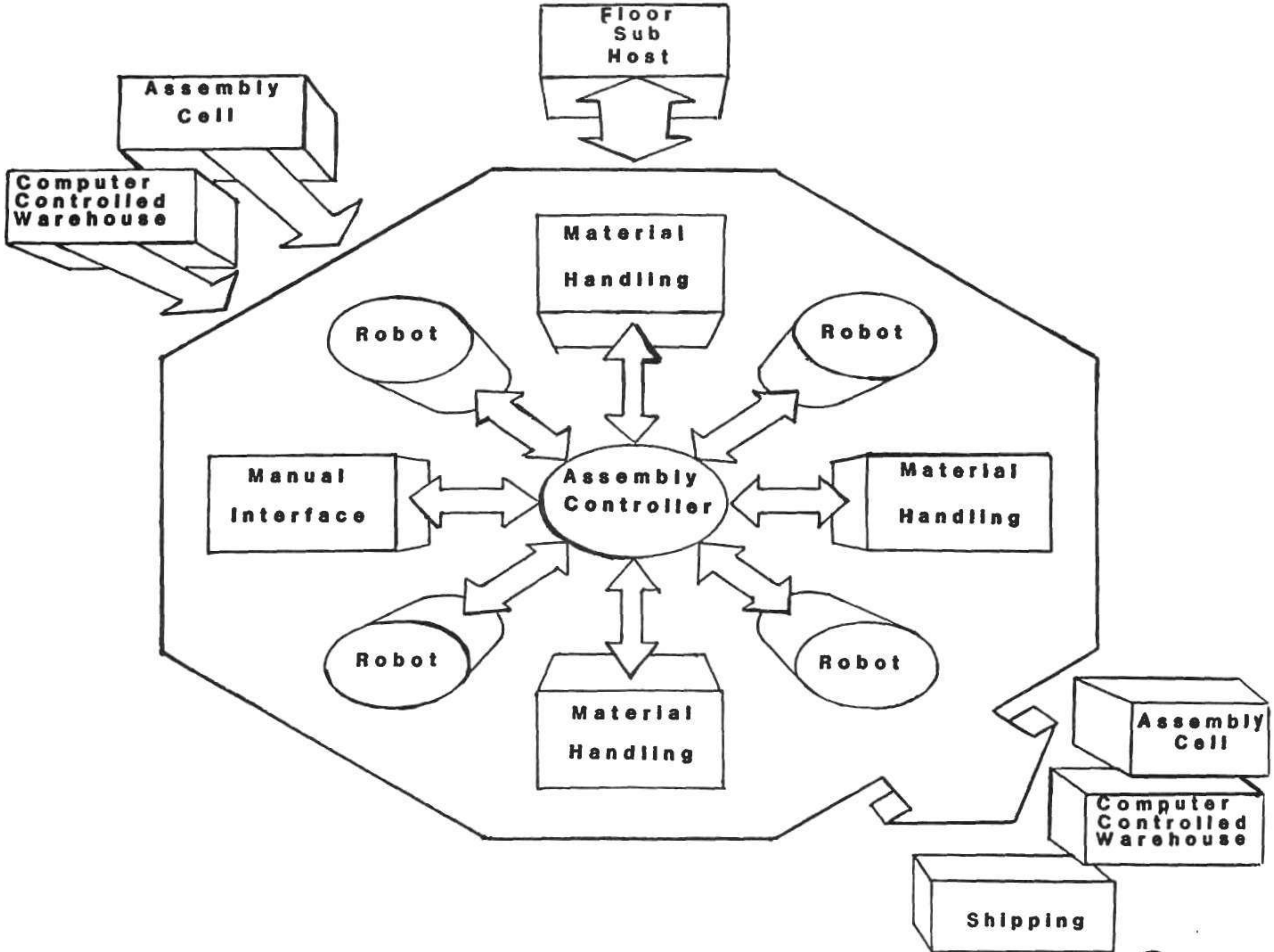
ROBOT ASSEMBLY CELL



Nielsen Dataquest

PRODUCTIVITY AND EDUCATION

Robert N. Noyce
Vice Chairman
Intel Corporation
Santa Clara, California

A cofounder, with Gordon Moore, of Intel Corporation in 1968, Dr. Noyce was President until 1975 and Chairman of the Board from 1975 to 1979. Dr. Noyce is co-inventor of the integrated circuit with Jack Kilby. They jointly received the Ballantine medal of the Franklin Institute, and the Cledo Brunetti Award of the IEEE for this work. He has also received, with Gordon Moore, the AFIPS Harry Goode award for leadership in computer science. Dr. Noyce was awarded the National Medal of Science and the I.E.E. Faraday Medal in 1979, and the IEEE Medal of Honor in 1978. He is a member of the National Academy of Science, the National Academy of Engineering, the American Academy of Arts and Sciences, and is a Fellow of the IEEE. Dr. Noyce holds 16 patents for semiconductor devices, methods, and structures. He did research at Philco Corporation before joining Shockley Semiconductor Laboratory, Palo Alto, California. In 1957, Dr. Noyce cofounded Fairchild Semiconductor Corporation, Mountain View, California. He was Research Director until early 1959, when he became Vice President and General Manager. Dr. Noyce received a B.A. degree from Grinnell College (Iowa), where he was elected to Phi Beta Kappa. He received a Ph.D. in Physical Electronics from the Massachusetts Institute of Technology.

Dataquest Incorporated
CAD/CAM INDUSTRY CONFERENCE
September 26-28, 1983
Newport Beach, California

PRODUCTIVITY and EDUCATION

R. N. Noyce

There is probably no better statement of our national goals than the preamble to the American Constitution. I'd like to read it to you as a reminder, and use it as a point of departure in talking about productivity and education.

> "We, the people of the United States, in order to form a more perfect union, establish justice, insure domestic tranquility, provide for the common defense, promote the general welfare, and secure the blessings of liberty to ourselves and our posterity, do ordain and establish this Constitution for the United States of America."

Our history, with some periods of backsliding, has indeed been in pursuit of these lofty goals. Most of us would agree that we have not met them yet, and that we have a lot of work left to do. It is the sum total of our efforts to meet these goals which I would like to define as productivity in the broadest sense. There are many facets to the issue of productivity--the provision of the best quality of life possible--and for the most people in a democracy. Clearly, there are many conflicts to be resolved in striving toward these goals. Effort to resolve these conflicts has been at the center of the political process since politics began.

Essential to reaching these goals, however, if we have not yet reached the optimum, is change. Although this simple fact should be self evident, many of the voices raised in our society would seem to say that although we must improve the quality of life, change is deleterious. As an example, some of our most liberal thinkers seem to say that we must preserve the jobs in the older industries which are no longer neede. They decry change in these traditional industries, or in the use of our national resources. Yet they advocate raising the standard of living for Americans. which clearly cannot be done without changing what we are doing. Even the labels we apply to these viewpoints are exchanged as liberals work for the conservation of the environment, and those we call conservatives would see expanded use of the national forests and primitive areas.

These apparently conflicting positions arise from wishful thinking, from the refusal to admit that the objectives of our society call for continuous compromise, hoping we can have our cake and eat it too. There is a need to think about accommodating the change necessary to approach our goals more closely.

It is indeed through change that we have been able to achieve the highest standard of living humankind has ever known, and it will be through further change that we can improve more. A century and a half ago, more than half our population was engaged in agriculture, in the provision of the food necessary for survival. I'm sure that if, at that time, a politician projected that most of the farmers would lose their jobs, and that less than three percent of the population would provide the food for all Americans, he would have been ridden out of town after being tarred and feathered, and furthermore would have lost the next election. It is precicely because that farm labor was available to provide for other needs or wants of the society that the American productivity increased so rapidly. It was that labor which built the highways and the hospitals, built the automobiles and the refrigerators, built the jet airplanes and computers which we have come to expect.

This massive improvement in the productivity of agriculture was undertaken as America's first, and perhaps only, successful industrial policy, if we put it in the language of today's debate. That policy was carried out through the establishment of the Land Grant colleges, with the consequent massive upgrading of the skills of our farmers and farm management, and the subsequent establishment of major agricultural research centers. Those centers were directed toward finding better varieties of grain to grow, or better stock to raise. It may be useful for a minute to speculate about the debate that might have been carried out at that time if those engaged in the debate could have forseen some of the effects of their policy.

"My constituents are farmers--I can't support a policy which will eliminate their jobs."

"How can we ever hope to retrain the farm population to make tractors or develop hybrid corn?"

"This policy will cause massive technological unemployment."

The policy would clearly have failed if only that part of its effect could have been envisioned. Only with a better vision of the future impact could it have been enacted. I suspect that none of the displacement effects were forseen, but that the improvement in knowledge was seen as benefitting the more than half the population who were farming.

The makeup of our workforce has, as you know, gone through a massive shift since that time. Now more than half of the population is involved with the creation, handling, and dissemination of information. Is it possible today to implement a policy similar to that implemented for agriculture so long ago? That might involve the establishment of schools directed at the improvement of the performance of, and the tools available to the knowledge worker. We could establish research centers which would examine the methods used by those workers. New equipment might be developed in concept, as is being done in the Japanese fifth generation computer project. We might even establish incentives for the adoption of new methodologies, such as computer-aided design or computer-aided manufacturing.

A rational man could easily think that such a program which would enhance the productivity of more than half the workforce would be quickly adopted. Unless, and until we understand our other national goals and make due accommodation for them, they won't be. Clearly there are many conflicts which must be resolved. At the same time, there are many forces which are driving us to accommodate the technology available to us. Primary among those are the aspirations we all have to lead a better life. Advancing technology is simultaneously the cause of, and the response to many of these aspirations.

We can easilyidentify some of the changes which are changing our historical response to these aspirations:

We have seen the disappearance of our western frontier. Those seeking new opportunity and challenge must seek it not on a homestead, but in a new activity.

Our population is aging as a result of improved public health and medical intervention, and the drop in the birth rate. An ever increasing fraction of our population will be dependent on the working population either as they are being trained for productive activity, or after their retirement.

Improvements in communication and transportation have made competition global, whether it be for markets, or for adoption of ideas. Wars in Ireland or in Lebanon are concerns for all, and the establishment of the fifth generation computer project is seen as a threat to our own industry.

America has raised the priority of establishing justice for those of all races or economic background, sacrificing short term benefit for longer range and higher objectives.

In the broadest sense, increasing productivity is our attemt to more nearly optomize the solution to the broadly stated problem: "How can we best meet our conflicting national goals?" The answer clearly includes the improvement in the hourly output of everyone in the workforce, but it includes many other things as well, which enhance our quality of life. This leads me back to the subject of this talk, and the relationship between education and productivity. The basic role of education is the preparation of our people to optomize the solution to this problem.

The current debate on education is many-faceted. The American Electronics Association is concerned with the short term availability of scientists and engineers necessary for the rapidly growing electronics industry, a concern all of us share. The recent report of the U. S. Commission of Higher Education decries the deterioration of the quality of our institutions of higher learning, particularly in the sciences and mathematics, but in communication skills as well. Congress is asking what role education must, or should play in the solution to problems of international competitiveness, or retraining the technologically unemployed. At the same time, articles are being written suggesting that the increasing use of computers and automation of the production process will require lower skills from our workforce rather than higher skills.

As an example of this line of thinking, let me quote from a recent article by Henry Levin and Russell Rumberger of Stanford:

> "Just as ominous is the possibility that high tech will eliminate more jobs than it creates. Researchers at the Robotics Institute at Carnegie-Mellon University estimate that in the next twenty years, robotics could replace up to three million manufacturing positions involving operating machinery, and potentially eliminate all eight million of these positions by the year 2025. The widespread use of computer-aided design may virtually eliminate the occupation of drafter in the not-too-distant future, a potential loss of 300,000 skilled positions. A recent study from the Upjohn Institute estimated that robots could eliminate three times as many jobs as they create, and the Director of Advanced Products and Manufacturing at General Motors predicts the 'factory of the future' will employ 30% fewer workers per car because of robotics. Even if laid-off production workers are retrained for high tech positions they may not be able to achieve a comparable income level."

That is a powerful call to arms to the draftsmen and the auto workers. We can speculate that the farmers of 1850 should still be on the unemployment roles. That it is seen as "ominous" that jobs can be eliminated while achieveng the same output indicates the enormous resistance to change and lack of understanding of how our society progresses. That resistance to change is institutionalized in the power structure in our society. Just as the congressman resists change in the rules which let him be elected, the industrialist seeks to preserve the competitive environment in which he built hiscompany, and the engineer would like to continue to work in the field in which he has enjoyed his success. Clearly we have our work cut out for us.

Education and basic research occupy a unique position in our society. Both are very long-term investments. In niether case is the benefit of their support very likely to accrue to the individual or group supporting them. To illustrate, consider an industry with two equal competitors, and their considerations about performing basic research. Upon reflection, both will conclude that the winning strategy is to let the competitor pay for the basic research , the results of which are widely disseminated, and exploit those results when appropriate with the funds saved by not paying the bill for the original research. Thus, left to the free market, support for education and research will be at a lower than optimum level for the society. The odds become better when supported by a broader coalition of the society, but failing the power to force everyone to participate, the individual would still decide to let his neighbor support the schools and use those savings to buy a new car which he sees of more direct benefit to himself. How many smog devices would be installed on American automobiles if they were only a consumer option?

The feedback loop around the process of education is very long. The determination of whether or not the process produced the desired result may take twenty years or more. As any control theorist can explain to you, it is very difficult to stabilize such a process, and the system is likely to go into wild oscillations. Educators, as a result, are properly deeply concerned about making changes rapidly for fear of destabilizing the system.

Traditionally, education has sought to prepare the student for the rest of his lifetime of work. Perhaps when the rate of change was slower, that concept was valid. Today, in the technological fields, the concept that training in a narrow field can prepare for his lifetime is clearly erroneous. If that career lasts forty years, (and that time is likely to lengthen with the increasing vitality of the older population) we need only to think of the technology of forty years ago to see how obsolete that education will be. In 1943, the transistor was yet to be invented, the first of the military jets had just begun flying, computers made with relays were calculating shell trajectories, sulfa drugs had been discovered but penicillin was yet to come, and nuclear weapons and space travel existed only in science fiction magazines. Clearly, specific training in the applied technology of the day would not be useful today. The objective of education must be to provide a background such that the student can understand our society, has the basic skills which may be used in a variety of different activities, and can accommodate the inevitable changes which will occur, and, hopefully, contribute to constructive change in his lifetime. We must not sacrifice this broader objective to the short term success of specialized training, even though that is the basis upon which the job applicant is most likely chosen. Such a course would be short-sighted in the extreme.

As we seek to improve the productivity of our society profound change is inevitable. Education is a powerful facilitator for that change. To fulfill that role, whether in the classroom or out, many things need to be accomplished:

First, and perhaps most important, we must establish a common ground for resolving the conflicts which will arise with change. Failing in this task will leave us paralyzed, unable to do that necessary for continued progress toward our goals.

Secondly, basic skills in communication and quantitative thinking must be imparted to the student, in order that he can understand and analyze the potential solutions offered. Language and mathematical skills are essential.

Third, since many, if not most, of the changes which will occur will be based in the advancement of scientific knowledge the student needs to have a basic understanding of the method by which new knowledge is developed, an understanding of how the scientific method distinguishes between truth and falsehood, and an understanding of the limits of todays scientific knowledge.

Fourth, in order to live a satisfying and productive life, he must have an understanding of the culture in which he is to function, which may be inparted through its history, art, or philosophical foundation.

Finally, he should be trained to make a specific contribution to the society, whether as a dental technician or doctor, a repairman or engineer. This "vocational" training may be done within our institutions of learning or outside, but it surely must be done if the student is to be gainfully employed. This is the most transient of the education, likely to be repeated many times in a career.

For the society, education is a highly leveraged investment, providing more than half the inprovement in productivity which we have achieved historically. Yet, because of its long-term nature, it can easily be sacrificed to shorter term goals. Consequently, it needs to be nurtured and supported by all of us if we are to "promote the general welfare" as envisioned by our forefathers.

Nielsen Dataquest

CAD/CAM WORKSTATION TRENDS

Edward L. Busick
President
Spectragraphics Corporation

Mr. Busick is founder and President of Spectragraphics Corporation in San Diego, California. Previously, he was in management with Parson's Engineering and Construction and with other international companies on major construction projects in Australia, Alaska, and Saudi Arabia. Mr. Busick was also with Adage, Inc., a computer graphics workstation manufacturer in Billerica, Massachusetts. He received his B.S. degree from the Sloan School of Industrial Management, Massachusetts Institute of Technology.

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CAD/CAM WORKSTATION TRENDS

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- HISTORICAL PERSPECTIVE
- TECHNOLOGICAL AND COST FACTORS
- CURRENT TRENDS
- FUTURE TRENDS
- FINAL CONSIDERATIONS

HISTORICAL PERSPECTIVE

This year marks the 40th anniversary of the era of electronic computing. In 1943 at the University of Pennsylvania the effort was begun to develop ENIAC, the first vacuum tube computer. In 1951, the Whirlwind computer at M.I.T. utilized the first core memory. Whirlwind filled a large room, had 4K of memory, and less computing power than today's home computer.

One of the first CRT computer systems was the SAGE Air Defense System used to detect and display the location of aircraft throughout the U.S. SAGE became operational in 1953. In 1957, the TX-0 was built at M.I.T. and was the first transistorized computer. The TX-0 had a point plot graphics console with light pen. and could do convincing interactive graphics.

Two events occurred in the early 1960's that can be considered to mark the beginning of the CAD/CAM era. At General Motors, the DAC-1 console was installed by IBM on a 7094 computer. The DAC-1 was used to test man-machine interaction for the first time and showed a 1/3 increase in productivity. The same year, DEC produced its first computer, the PDP-1. These events marked a major point of departure in solutions to the CAD/CAM challenge.

The CAD/CAM Tree (Figure 1) traces the history of major developments over the past four decades. Following the main branch on the left, after the PDP-1, we next encounter the PDP-9 in 1966. This machine had optional storage tube as well as stroke-vector CRT. The PDP-9 and its successor the PDP-15 laid the groundwork for DEC's reputation in engineering graphics support computers. The PDP-11 opened the door to

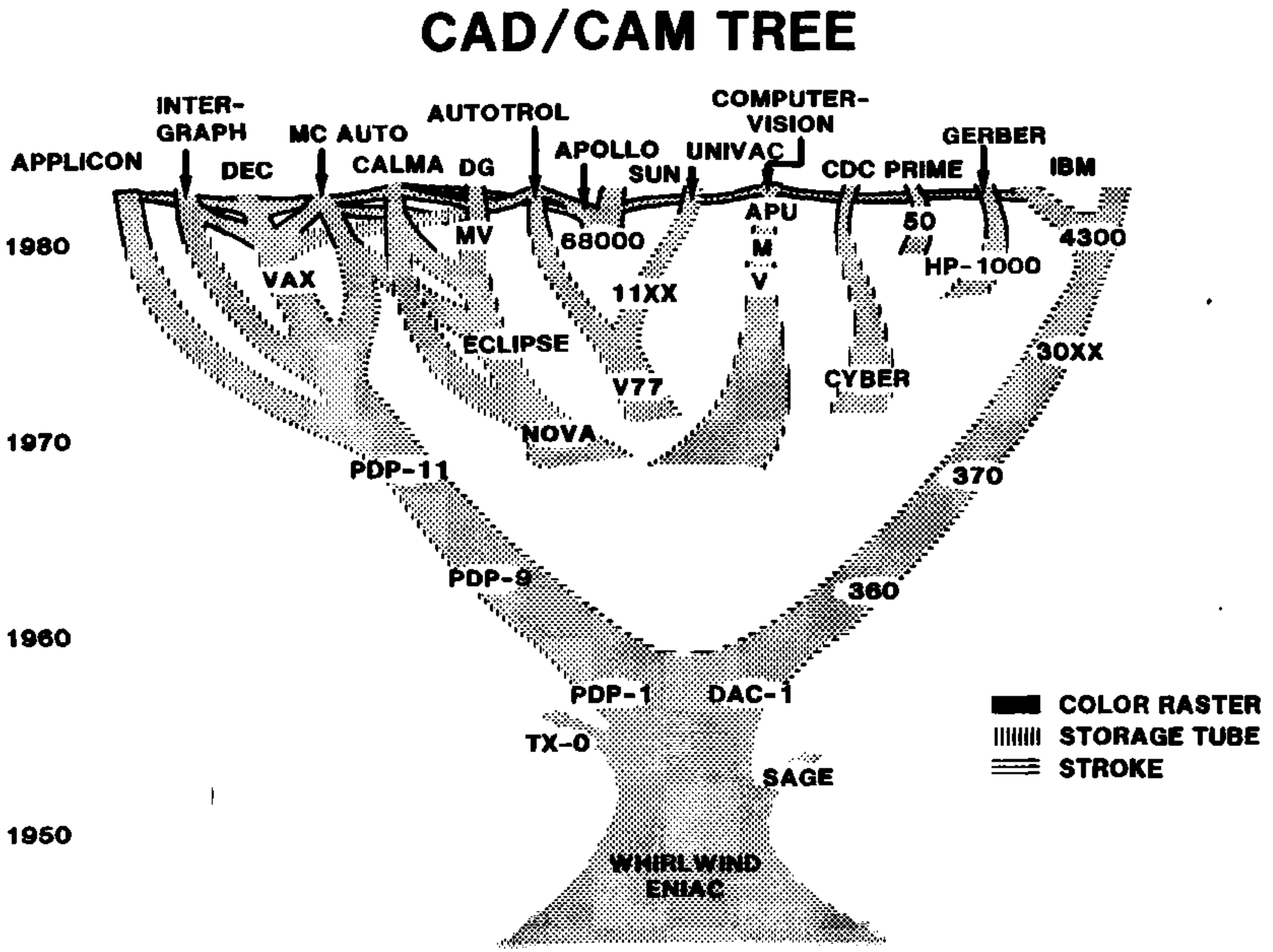
CAD/CAM TREE
APPLICON
INTER-GRAPH
DEC
MC AUTO
CALMA
DG
AUTOTROL
APOLLO
SUN
UNIVAC
COMPUTER-VISION
CDC
PRIME
GERBER
IBM
1980
VAX
MV
68000
11XX
APU
M
V
50
HP-1000
4300
ECLIPSE
V77
CYBER
30XX
1970
NOVA
PDP-11
370
PDP-9
360
1960
PDP-1
DAC-1
TX-0
SAGE
1950
WHIRLWIND
ENIAC
COLOR RASTER
STORAGE TUBE
STROKE

Figure 1

CAD/CAM for DEC. Applicon introduced its first system using the 11 in the early 1970's and was followed a few years later by Intergraph and McAuto. As you can see, all these companies have upgraded to the VAX series and were joined by Autotrol and Calma as DEC-based turnkey suppliers.

The right branch of the CAD/CAM Tree shows the introduction of the IBM 360 in 1964. Lockheed Corporation along with General Motors and McDonnell Douglas were early pioneers in IBM's CAD/CAM effort. Today Lockheed is one of the largest users of CAD/CAM workstations and has many turnkey IBM systems, some with as many as 100 workstations on a single mainframe. Lockheed's subsidiary, CADAM, Inc., is a major third party software vendor. CADAM software is sold under license by IBM. The 370, 30XX and 4300 series round out the past 20 years of progress for IBM in CAD/CAM computer support. IBM is now the second largest turnkey systems supplier.

Computervision is the No. 1 vendor in the industry. With total installations approaching 10,000 workstations, Computervision has set the pace for the industry. Recent product announcements indicate further Computervision innovations. Agreements with IBM and Sun Microsystems epitomize the new trends that CAD/CAM is establishing. The 32-bit mainframe and the 32-bit microprocessor are taking their position along with the 32-bit supermini as major factors in turnkey systems.

Apollo, another manufacturer of networked microprocessor-based systems, has made a significant impact on CAD/CAM. Started in 1979, Apollo supplies workstation hardware to Autotrol, Calma, as well as several of the new Computer-Aided-Engineering (CAE) turnkey electrical vendors. Data General, Univac, CDC, Prime, and Hewlett Packard are also shown as major factors in CAD/CAM. These companies represent a major portion of the industry, but are by no means a complete list. The purpose of the CAD/CAM Tree is to show general trends for vendors over the past few decades.

A second set of information is depicted in the CAD/CAM Tree. The history of the workstation CRT technology used by each vendor is shown. As many of you know, there are three major types of workstation hardware. These include stroke, storage tube, and color raster CRT's. IBM has been and still is the major proponent of stroke technology. Stroke systems offer significant speed-of-response advantages for fast picture update, and are well-matched to the high speed I/O channel and CPU performance of the IBM and Univac mainframes. Stroke systems have limited color capability and the tendency to flicker as the picture content becomes more complex.

The storage tube has been, for the most part, a Tektronix product. The storage tube was the main workstation offering for most turnkey vendors throughout the 1970's. The storage tube offers the advantage of no flicker. Once the picture is written, it remains stored in the screen phosphor without refresh. The disadvantages include slow update rate and limited color capability.

The third workstation alternative is raster scan. Raster resolves both the fast update problem as well as the potential flicker problem. The picture can be refreshed at constant rates exceeding normal television quality. Raster also offers the benefit of full color capability. Raster workstations were first introduced into CAD/CAM in 1980, and today most of the turnkey vendors offer color.

Because of the advantages and disadvantages of the workstation CRT types, certain modes of operation were adopted by various vendors to

WORKSTATION TECHNOLOGIES

STROKE	STORAGE TUBE	RASTER
FAST RESPONSE	SLOW RESPONSE	FAST RESPONSE
FLICKER	NO FLICKER	NO FLICKER
LIMITED COLOR	LIMITED COLOR	FULL COLOR
↓	↓	↓
2D DRAFTING	2D DRAFTING	2D + 3D MODELING
SCREEN MENU	TABLET MENU	TABLET OR SCREEN MENU

Figure 2

match workstation performance. Stroke systems take advantage of fast update and utilize a screen menu for selection of interactive function. In order to circumvent the slow erase and update for storage tubes, a tablet menu with a large set of function alternatives was employed.

The raster workstation offers the flexibility for either screen or tablet update. Secondly, complex images in full color can be presented without flicker. This flexibility has encouraged turnkey vendors and third party software vendors to rapidly expand the number of features available in various applications areas. Three-dimensional solids modeling, robotic kinematics, work cell simulation, and 3-D piping are but a few of the new areas opening up to CAD/CAM with the advent of raster workstation technology. These new opportunities raise questions that should be addressed if the CAD/CAM industry is to take effective advantage of the new technology. Should the CAD/CAM system use specialized workstation features now available in order to reduce the host computer workload? Off-loading the host computer means better productivity and more users per system. This makes a CAD/CAM system easier to cost justify. How should intelligent workstations with local 32-bit microprocessor power be used in the system resource allocation? (Figure 3). The cost benefits available with intelligent workstations must be balanced with the overall corporate CAD/CAM needs and the needs of the user. If these issues are not addressed by turnkey vendors and users, the host computer may become overburdened handling the workstation graphics functions.

The historical summary for CAD/CAM (Figure 4) shows a range of computing alternatives in the 32-bit arena -- mainframes, superminis and microprocessors -- that can provide growth potential and flexible, cost-effective solutions tailored to user needs. Raster workstations can provide similar growth potential and a migration path to more functionality. The technology and cost factors must be understood to balance CAD/CAM system resources. We will return to the system resource question after looking at these factors.

WORKSTATION TECHNOLOGY AND COST FACTORS

Turning now from the historical to the present, let's look at some of the technological factors of workstation design. Figure 5 enumerates some of the typical graphics functions that can be applied to the interactive geometric data base. I have included a brief glossary of terms in the Appendix to help you remember these graphics functions. Let's examine the task allocation implications of using the host computer vs. the workstation for these functions. Each of the graphics functions has a required level of processing power for execution. This graph shows that the range of computing power varies by a factor of nearly 1,000 from the simplest graphics function to the most complex. The figure is intended to show order-of-magnitude relationships. Specific functions such as shading are dependent on the algorithm used. The simplest functions, pan and zoom, are becoming a standard feature of most workstations being offered today. The medium performance functions are being offered by many workstation manufacturers. The more complex functions are being addressed by custom VLSI chip manufacturers and a few workstation manufacturers. The highest performance function shown, point light source shading, can require significant computing power for execution and is only being effectively addressed with mainframe computing.

THE CAD/CAM SYSTEM RESOURCE QUESTION

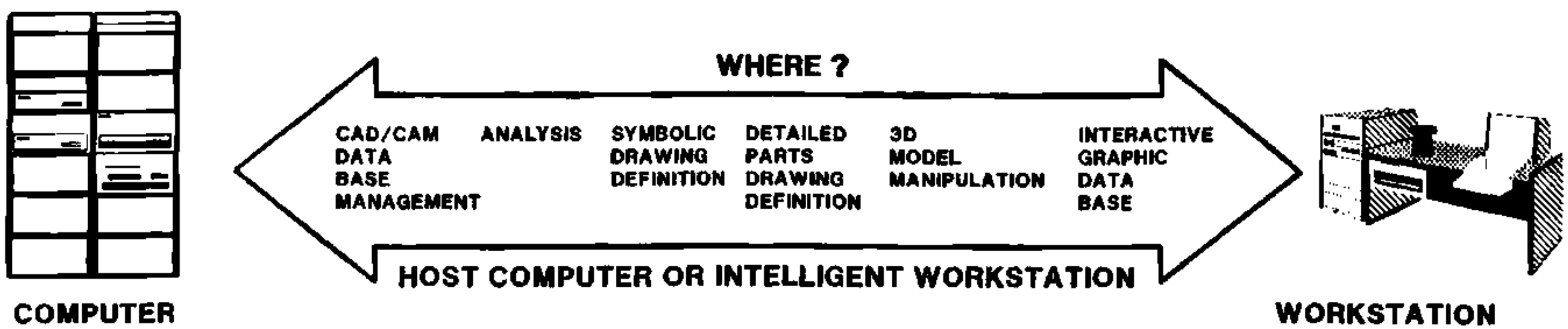

Figure 3

HISTORICAL SUMMARY

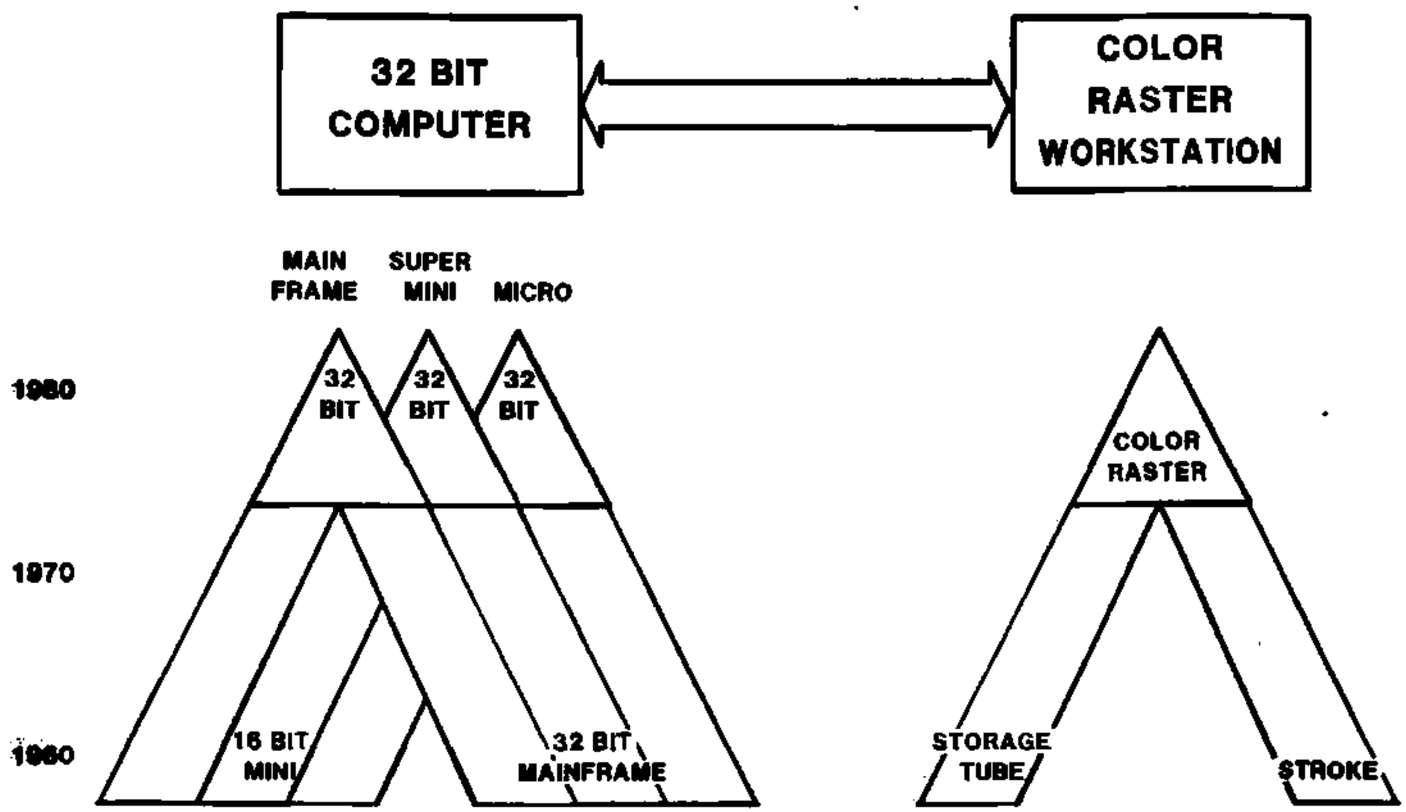

Figure 4

TYPICAL GRAPHICS FUNCTIONS VS ESTIMATED NUMBER REQUIRED MACHINE INSTRUCTIONS TO EXECUTE FUNCTION

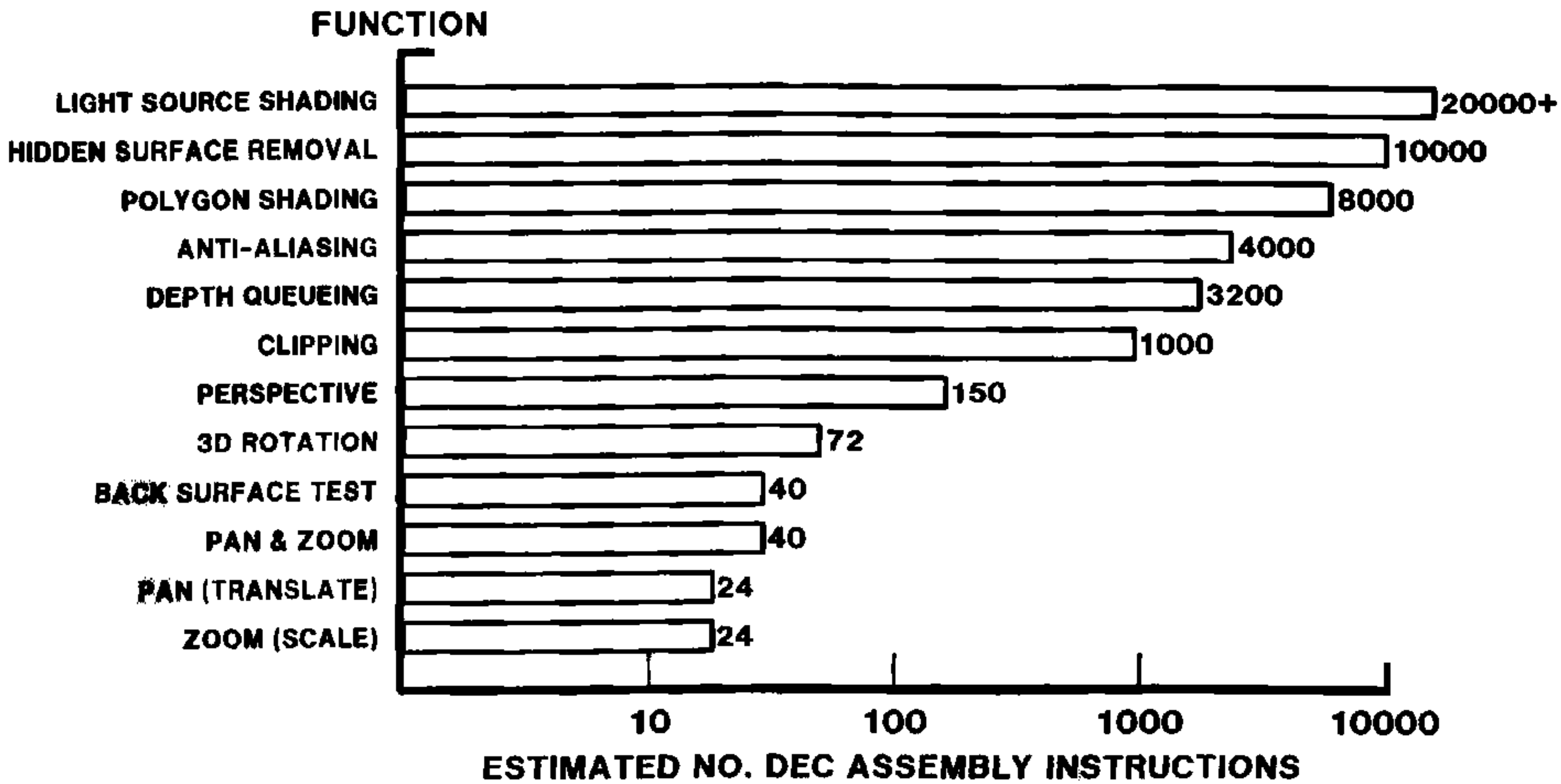

Figure 5

Turnkey vendors are moving toward the 3-D data base as the standard. Parts drawings and symbolic drawings are 2-D projections of the 3-D model. The drawings are closely related to the model data but with added information for the drafting or analysis requirement. The 3-D model or the 2-D drawings can be changed and the changes reflected in either data base. The Computervision CADDS-4 and IBM-CADAM 3-D Wire Frame are examples of these new directions.

Let's take a look at 3-D graphics manipulation as a specific example of the cost/performance trade-off available in workstation design. Figure 5 tells us that in order to execute an assembly language 3-D rotation routine in a DEC VAX will require 72 instructions. This routine will be executed once for each line in the 3-D model. A typcial 3-D image is composed of approximately 5,000 lines. A simple calculation tells us that in order to do a single rotation of this image will require 72 X 5,000 = 360,000 instructions. Now, let's assume that the host CAD/CAM computer supports 16 users and half of them need this 3-D capability at any given time. We further assume that these 8 users will utilize the 3-D function an average of once every 10 seconds. The calculation in Figure 6 gives the result that 14% of the computing capacity of a 2 MIPS host computer will be used in supporting the 3-D rotation graphics function. The alternative is special purpose graphics hardware in the workstation. Available workstation technology can off-load this graphics function from the host computer. The 3-D rotation graphics function can be executed by special purpose hardware, at a performance throughput of 72 MIPS. The cost per user in current systems is as low as $2,000/workstation or $16,000 for our assumed eight-user requirement. A 2 MIPS host machine is generally priced in the $400,000

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SAMPLE CALCULATION
HOST COMPUTER 3D SUPPORT

72	INSTRUCTIONS PER LINE IN 3D-MODEL
X 5,000	LINES IN 3D MODEL
360,000	INSTRUCTIONS TO ROTATE MODEL
X 8	USERS
2,880,000	INSTRUCTIONS
÷ 10	SECONDS AVERAGE INTERACTION TIME
288,000	INSTRUCTIONS/SECOND

$$\frac{288{,}000}{2{,}000{,}000} = 14\% \text{ OF 2 mips HOST COMPUTER CAPACITY}$$

Figure 6

range and up. The final cost calculation is shown in Figure 7. Off-loading this graphics function will allow an increase in the number of users of the CAD/CAM host machine, making for easier system cost justification.

The reason that special purpose graphics workstation hardware is more suited to the problem solution is that the graphics functions can be executed most effectively with parallel-pipelined processing. Mainframes, superminis and microprocessors are not designed for this type of parallel processing.

The polygon shading feature is a much more dramatic example of the potential cost/performance advantages of special purpose workstation hardware. If this "solids" feature is required by the same number of users as in the example above, and utilized once every two minutes, 67% of the 2 MIPS machine capacity would be required (Figure 8). If these features are to become truly useful in the future of CAD/CAM, most of the graphics functions will become workstation hardware requirements.

The next technological issue is local processing power in the workstation. The Motorola 68000 has started a major trend in this industry. The Computer-Aided-Engineering (CAE) workstation is expected to rapidly increase its market share in CAD/CAM over the next few years. New microprocessors from National Semiconductor, NCR, Intel, and others will add to this lower cost computing alternative. There are some who see the microprocessor as the ultimate solution to the CAD/CAM problem. Every engineer will have his own workstation and the need for the mainframe will disappear. The reality of the situation does not match this dream. The intelligent workstation can solve a sizable piece of the CAD/CAM problem but many problems are beyond its reach. For instance, some of the large aerospace companies have on-line access to nearly one

COST COMPARISON
HOST COMPUTER VS. WORKSTATION

HOST COMPUTER TOTAL COST:	$400,000
CAPACITY REQUIRED FOR 3D-ROTATE FUNCTION (14%):	.14
TOTAL HOST COMPUTER RESOURCE ALLOCATION COST (8 USERS):	$ 56,000
WORKSTATION 3D-ROTATE FUNCTION HARDWARE COST (8 USERS):	$ 16,000

COST RATIO 3D-ROTATE FUNCTION

HOST COMPUTER : WORKSTATION
3.5 : 1

Figure 7

SAMPLE CALCULATION
HOST COMPUTER POLYGON SHADING SUPPORT

8,000	INSTRUCTIONS PER POLYGON IN 3D-MODEL (1/4" x 1/4" POLYGONS ON 1024 x 1024 RESOLUTION CRT)
2,500	POLYGONS IN 3D-MODEL
20,000,000	INSTRUCTIONS TO SHADE POLYGON 3D-MODEL
X 8	USERS
160,000,000	INSTRUCTIONS
÷ 120	SECONDS AVERAGE INTERACTION TIME
1,333,333	INSTRUCTIONS PER SECOND

$$\frac{1{,}333{,}333}{2{,}000{,}000}$$ = 67% OF 2 mips HOST COMPUTER CAPACITY

Figure 8

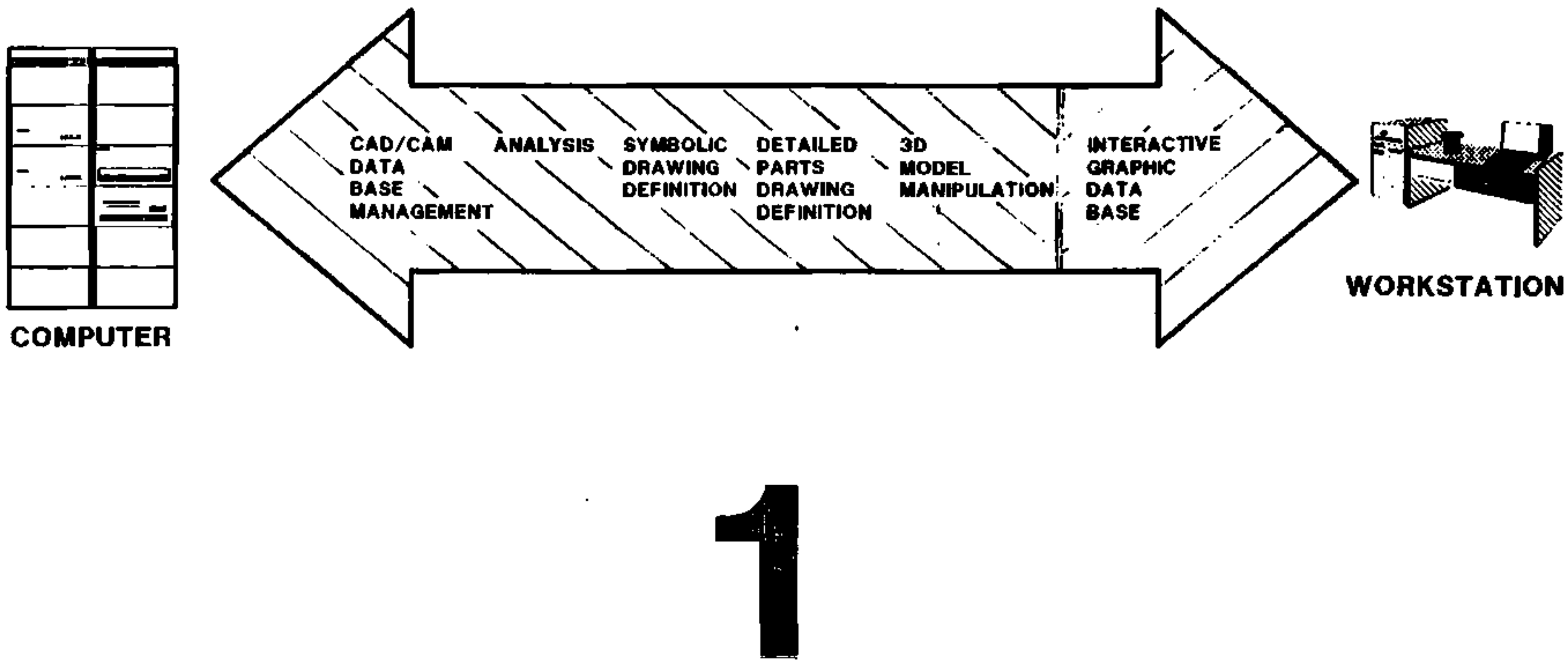
million CAD/CAM drawings. The mainframes that manage this data base are located in different parts of the country. It is with this major data base management challenge that the local area network (LAN) falls short. Secondly, the analysis portion of the CAD/CAM problem can be compute intensive and mainframes will continue to outperform micros. Mainframe power will maintain its role in these areas.

Let's address the range of three possible performance levels for a CAD/CAM workstation. The basic workstation has 2-D capability with a complement of interactive devices. It is attached directly to the host computer over serial or high-speed parallel interface. Workstation Number 1 needs full host support. Only the interactive graphic data base is processed by the basic workstation. A second workstation with expanded hardware to handle the 3-D or Solids graphics function can solve more of the problem and off-load the host computer. Workstation Number 2 performs 3-D model manipulation without host support. Finally, a workstation with 32-bit microprocessor can function as a stand-alone intelligent system. Workstation Number 3 can be used in symbolic and detailed parts drawing definition. There is an important point to understand in this migration path. Going from Step 1 to Step 3 is not possible without Step 2. The microprocessor system without the option for expanded workstation hardware functions will provide limited growth potential for 3-D modeling requirements in the coming years. Step 3 without Step 2 does not have a "solid" future.

CURRENT TRENDS

In covering the historical and current technology, we have mentioned several of the more obvious CAD/CAM workstation trends. These include

THE CAD/CAM SYSTEM RESOURCE QUESTION

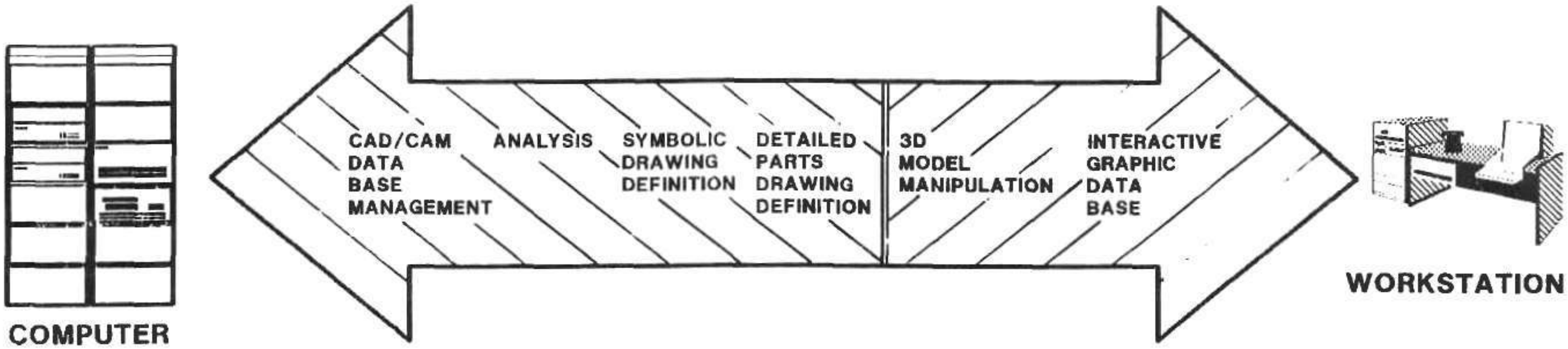


BASIC WORK STATION

NEEDS FULL HOST COMPUTER SUPPORT

Figure 9

THE CAD/CAM SYSTEM RESOURCE QUESTION

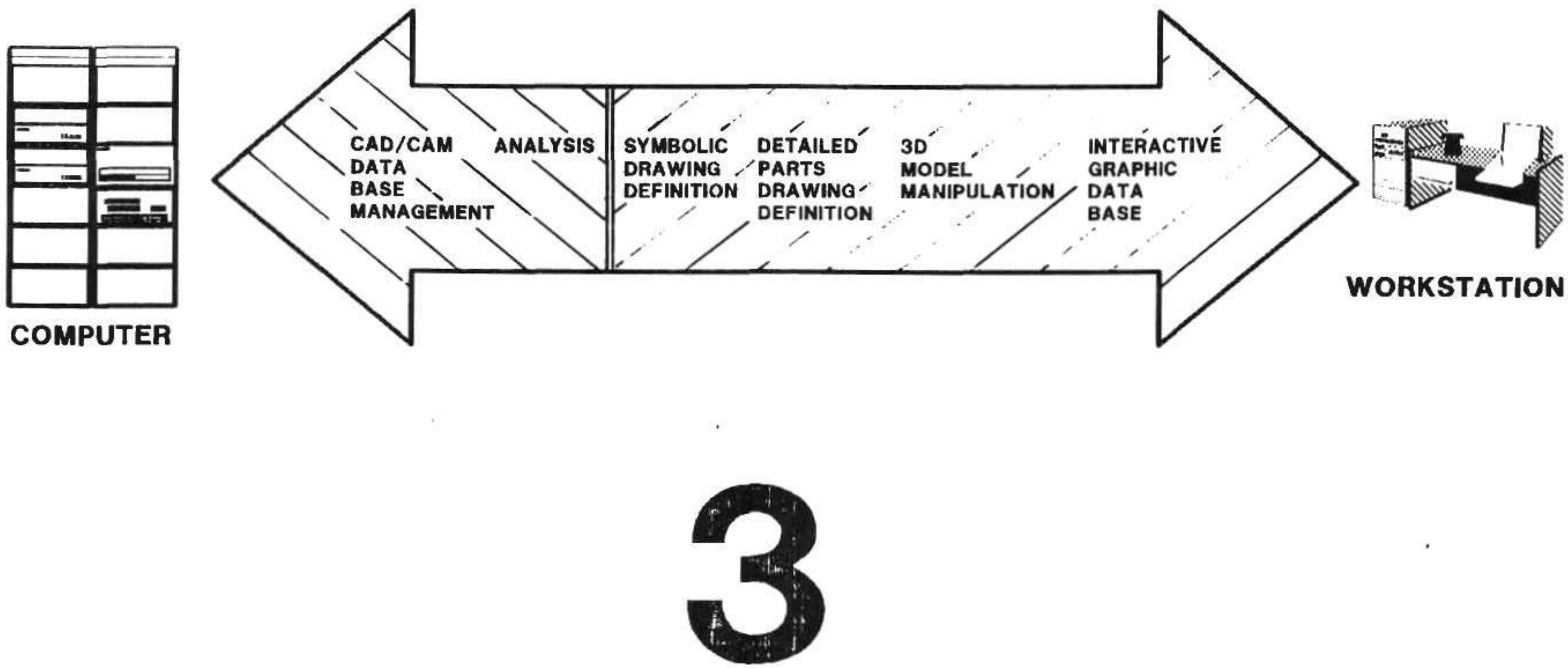


2

WORKSTATION WITH EXPANDED GRAPHICS FUNCTIONS
OFF-LOADS HOST COMPUTER
PERFORMS WORKSTATION 3D-MODEL MANIPULATION

Figure 10

THE CAD/CAM SYSTEM RESOURCE QUESTION



32-BIT MICROPROCESSOR-BASED WORKSTATION
STAND ALONE CAPABILITY
3D MANIPULATION + DRAWING DEFINITION

Figure 11

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GRAPHICS WORKSTATION MIGRATION

BASIC FUNCTIONALITY	EXPANDED FUNCTIONALITY 3D MODELING	STAND ALONE LOCAL INTELLIGENCE 3-D MODELING

Figure 12

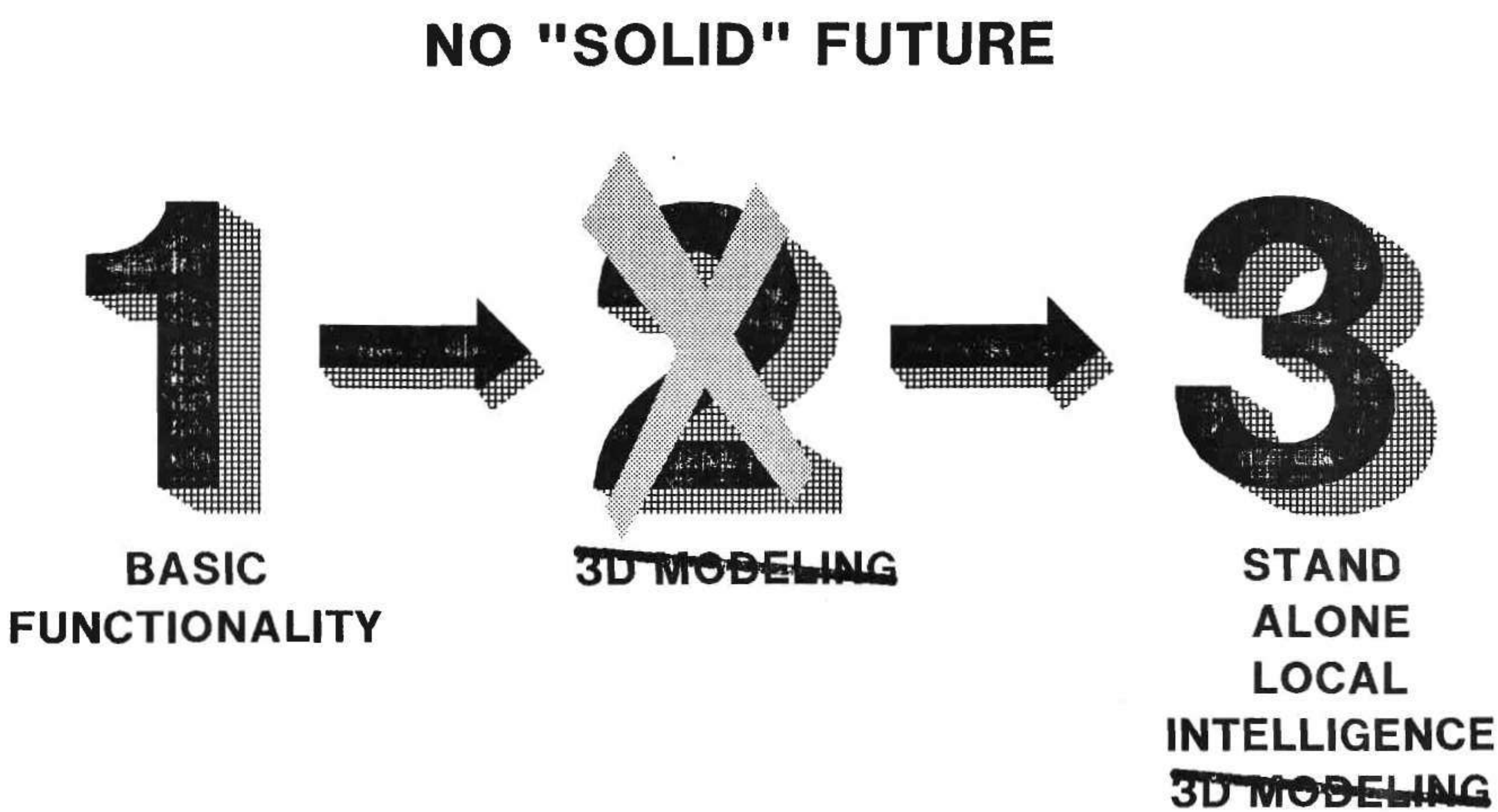
NO "SOLID" FUTURE
1
2
3
BASIC FUNCTIONALITY
~~3D MODELING~~
STAND ALONE LOCAL INTELLIGENCE
~~3D MODELING~~

Figure 13

dominance of color raster in CRT technology, 32-bit microprocessor-based intelligent workstations, local area networks, and expanded workstation graphics functions. An important new trend is workstation compatibility with the proposed Graphics Kernal System (GKS). GKS is being evaluated by the American National Standards Institute as the standard for graphics communication between the host computer and the workstation. At least eight companies have announced GKS compatibility. Recent articles and technical presentations seem to indicate that Tektronix and IBM plan to join this group. GKS is the result of a world-wide cooperative effort to establish a method for transportability of graphics applications from one workstation to another. Commitment to this standard will have to be addressed by the major turnkey vendors. GKS presents an opportunity for the turnkey vendors to minimize future development costs. Once an application is GKS compatible, the migration costs to another type of workstation will be minimized. For the user, GKS also offers benefits. The user will be able to take advantage of GKS compatible applications from multiple vendors and independent third-party software companies.

Another recent trend has been the introduction of several low-cost color hard copy printers in the $10,000 range. These devices will be suitable for the LAN microprocessor-based systems, and will have some limited use with superminis and mainframe host computers. The larger host systems will continue to rely on higher performance hard copy such as the Versatec, Benson, and Calcomp devices. Many system developers believe that black and white hard copy will continue to play an important role in predominantly color systems. This line of reasoning is based on the fact that manuals and supporting documentation derived from CAD/CAM

CURRENT TRENDS

- COLOR RASTER CRT
- 32 BIT MICROPROCESSOR BASED INTELLIGENT WORKSTATION
- LOCAL AREA NETWORK
- EXPANDED WORKSTATION GRAPHICS FUNCTIONS-3D, ETC.
- GRAPHICS KERNAL SYSTEM (GKS) COMPATIBILITY
- LOCAL COLOR HARD COPY
- LOW-COST PASSIVE REVIEW (PR) TERMINAL

Figure 14

are printed in black and white. The costs are major for converting this support documentation infrastructure to color.

The final item on our list of current trends is a low-cost graphics terminal that can be used for passive viewing of drawings by the CAD documentation support groups, process planning group, and the manufacturing organization. This concept is being addressed by IBM with the 3279 "softcopy" terminal. This Passive Review (P/R) type terminal will be a necessary part of an Integrated Manufacturing scheme. Target prices under $5,000 will be necessary in order to fulfill this requirement. The number of terminals to be sold in this market may exceed the number of interactive CAD/CAM workstations by a factor of two or three. The market is potentially large.

FUTURE TRENDS

Many of the major Fortune 500 users have progressed to the stage of setting corporate CAD/CAM goals for future growth. The goals often include a requirement for communications among divisions throughout the U.S. and, in some cases, even include European operations. Remote Area Networks will become more commonplace for major users. These requirements coupled with the emerging trend toward process planning and group technology will necessitate expanded communications support from turnkey vendors. Since the turnkey suppliers use a wide variety of CPU's and workstation configurations, a hierarchical network of mainframes, superminis, and 32-bit microprocessors will likely emerge. The network will include Passive Review (P/R) Terminals and Interactive Workstations (W/S) (Figure 16). The Initial Graphics Exchange Specification (IGES) represents part of the solution to this network requirement. IGES allows the exchange of CAD/CAM drawings between otherwise non-compatible turnkey systems.

FUTURE TRENDS

- REMOTE AREA NETWORK (RAN)
- INITIAL GRAPHICS EXCHANGE SPECIFICATION (IGES)
- ERGONOMICS AND AESTHETICS

Figure 15

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IGES/GKS INTEGRATION

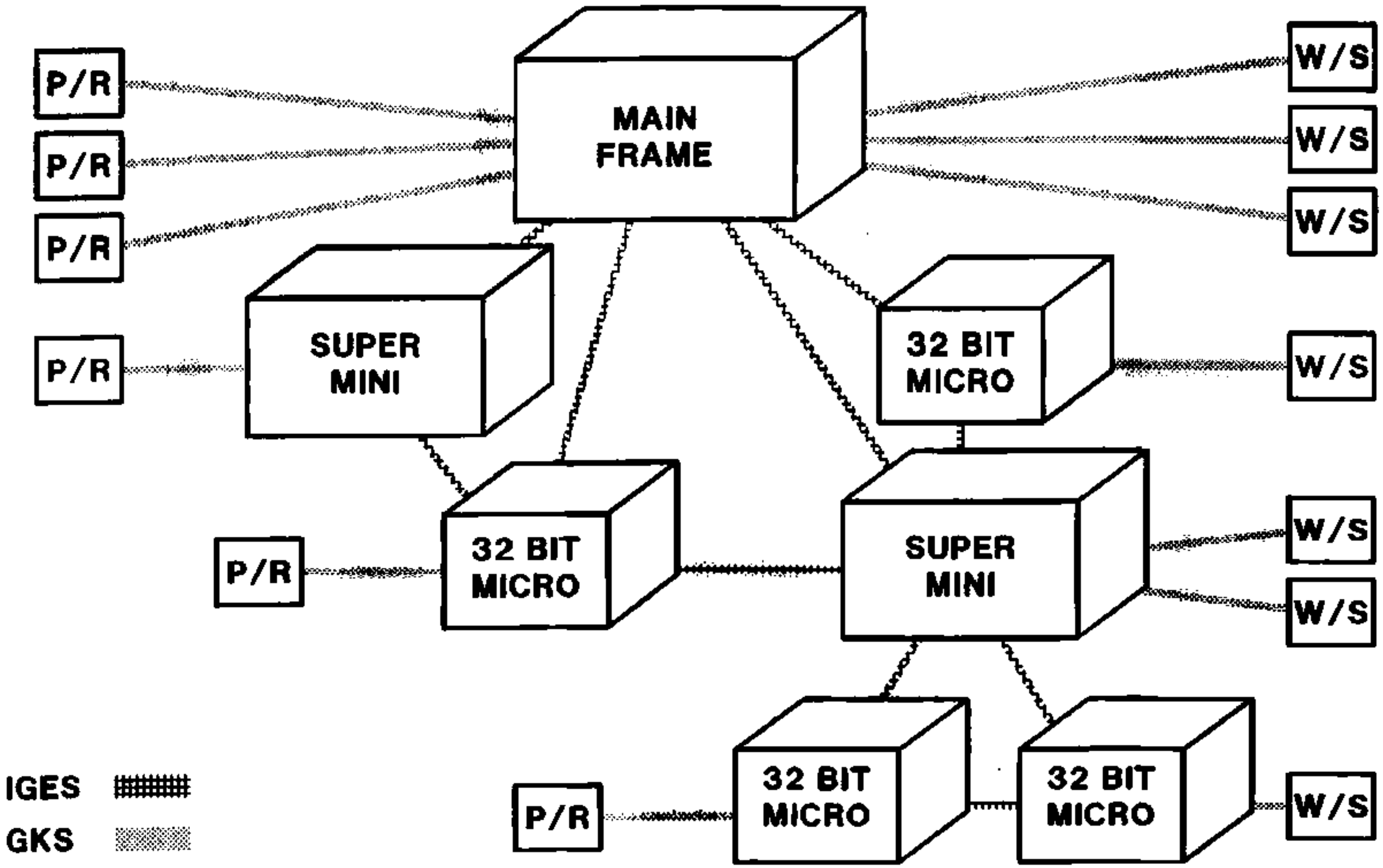

Figure 16

Recent developments by Autotrol and Applicon indicate that unbundling of software may be an emerging trend. Both these companies offer unbundled software on DEC-VAX. If unbundling becomes a trend and GKS is accepted as the workstation interface standard, CAD/CAM software may eventually become independent of both CPU and workstation hardware. The software and workstation could be upward compatible, not only to other CPU's in a single manufacturer's line, but also across lines to CPU's from other major manufacturers. The corporation would be able to choose CPU, workstation, and software based on the merits of each, or choose a packaged turnkey system which includes all three components.

The final item on the list of future workstation trends is ergonomics and aesthetics. The major turnkey vendors and workstation manufacturers will continue to pay increasing attention to workstation ergonomics. Various international standards will make this a necessity. The user will benefit with an improved work environment. Many CAD/CAM users spend a full 8-hour workday at the workstation and deserve maximum consideration in workstation feature design. Aesthetics of the workstation will gain in importance in future years.

FINAL CONSIDERATIONS

Our summary of trends for CAD/CAM workstations in the 1980's focuses on three important areas. The first area is the effective use of emerging new standards such as IGES and GKS. These standards will allow more freedom in moving applications software and data from one CPU to another, and between the workstation and the CPU. Each branch in the CAD/CAM Tree has had major R & D cost implications for turnkey vendors and software companies. There have also been transition cost for the users in taking

SUMMARY

- TRANSPORTABLE APPLICATIONS SOFTWARE
- MAXIMUM USE OF COMPUTER POWER
- WORKSTATION HARDWARE MIGRATION

Figure 17

advantage of available new technology. Product line continuity and user satisfaction will be maximized if future R & D efforts give full consideration to these new standards.

The second area is the utilization of an effective blend of mainframe, supermini, and microprocessor power. Adding to the existing base of CAD design software is only a portion of the challenge to be addressed in this decade. Group technology and process planning will alter the balance of computer resources required for CAD/CAM in the coming years. A flexible network of CPU resources will be an advantage in meeting this challenge.

The third area of importance is workstation hardware migration. Graphics functions require parallel processing which is a different type of problem than the serial processing required for the CAD/CAM data base. Parallel processing is most easily handled within the workstation hardware framework. The workstation hardware migration path leads to full realization of system growth potential. Consideration to all three of these areas is important to final success.

GLOSSARY

ANTI-ALIASING: The process of "smoothing" a line on a raster CRT by providing a more accurate pixel (dot) approximation to the line than provided by the normal CRT pixel addressing.

BACK SURFACE TEST: Removal of any surface (plane) which is located on a rear surface (farthest from viewer) of a displayed image. Gives an approximation to Hidden Surface Removal for convex objects.

CLIPPING: Defining a boundary for a screen image. The clip boundary is often used to eliminate the portion of the image falling outside the boundary, similar to clipping a newspaper article.

DEPTH CUEING: Providing a visual indication of the third dimension by varying the line color or intensity.

*HIDDEN SURFACE REMOVAL: Representation of solid 3-dimensional objects on the screen in which all surfaces not normally viewable are eliminated.

*LIGHT SOURCE SHADING: Representation of a solid 3-dimensional object on the screen depicted as if a light emanating from a single point source were being shone on the object.

PAN: Translation of an object across the screen to a new position.

PERSPECTIVE: Simulation of depth and distance by representing parallel lines merging at a vanishing point.

*POLYGON SHADING: Providing a unique color or intensity for a planar polygon (constant shading). The polygons often form the surface boundary of a 3-D solid object. Polygon shading can be the final step in light source shading.

3-D ROTATION: Alteration of the angle of view. Generally applied to a 3-D "wire frame" model composed of line segments defining the surface boundary.

ZOOM: To scale up or down the size of an image.

*NOTE: The calculation of the number of instructions required for these functions in Figure 5 is based on .25" x .25" square polygons, 1024 x 1024 pixel addressability, and a 19" CRT. Other functions are generally applicable to lines and points.

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COMPUTER-INTEGRATED MANUFACTURING--
TECHNOLOGICAL IMPERATIVE

Phillips W. Smith
Corporate Vice President
Computervision Corporation

Dr. Smith is a Corporate Vice President of the Computervision Corporation and is also a Corporate Officer. His responsibilities include corporate strategic planning, product line management for hardware and software products, pricing, and competitive analysis. He has direct responsibility for the seven vertical industry segments, aerospace, automotive, AEC, mechanical machinery, electrical machinery, fabricated metals, and manufacturing/construction products. Prior to his current assignment, he was President of Applied Research Laboratories, a division of Bausch and Lomb. Previously, he was Division President of Lear Siegler's Environmental Technology Division. His experience includes the general management of high-technology, internationally oriented corporations. Dr. Smith studied Engineering at the U.S. Military Academy (West Point) and received his M.B.A. from Michigan State University and his Ph.D. in Business Administration from St. Louis University.

Dataquest Incorporated
CAD/CAM INDUSTRY CONFERENCE
September 26-28, 1983
Newport Beach, California

COMPUTER-INTEGRATED MANUFACTURING--THE TECHNOLOGICAL IMPERATIVE

Intense competition is forcing manufacturers all over the world to find new ways to increase productivity. One method that has proven particurlarly effective is the application of computer equipment to various manufacturing operations. But to reap maximum benefits, all these computerized operations need to be integrated into one centralized system. The term computer-integrated manufacturing, or CIM, has evolved to describe this integration.

But calling it computer-integrated manufacturing can be slightly misleading. CIM is a global concept that includes far more than the traditional manufacturing processes found in the factory such as drilling, punching or stamping. It integrates all data processing functions within the company, including financial accounting, inventory control and payroll, as well as those traditional manufacturing operations.

In the next half hour or so, I would like to define why I believe CIM is a technological imperative. I'll trace some of CIM's technological roots, talk about some of the future directions I think the technology is heading, use Computervision as an example to show how the marketing strategy of a CAD/CAM company has shifted to accomodate these sweeping changes, and discuss a few of the obstacles that I think are slowing the implementation of CIM technology.

Since the mid-1960s, industrial countries in Europe and Asia have been gaining market share in such industries as steel, automobiles, electronic products and machine tools. These countries have captured market share by offering higher quality products that provide more performance at less cost. While these industrial countries often pay lower labor costs, they have also been very aggressive at installing factory automation systems to boost overall productivity.

By investing in and effectively implementing these automated systems in their plants, Asian and European manufacturers are creating superior products that cost less to produce, providing significant market advantages.

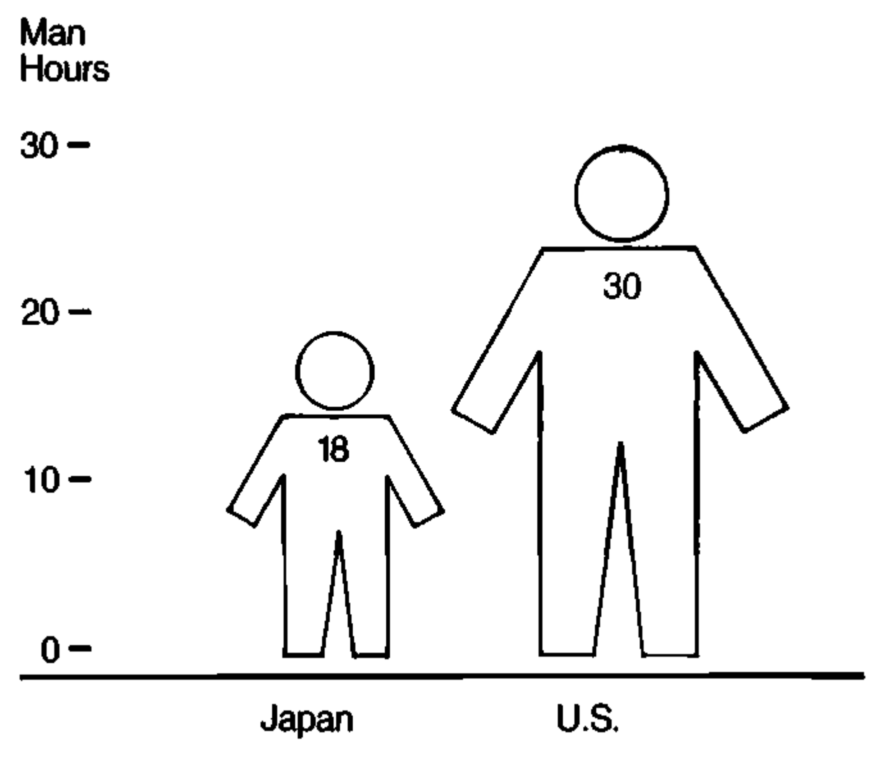
One of the most poignant examples of this advantage can be found in the automotive industry. U.S. automakers, for example, are simply unable to compete effectively against foreign manufacturers in the subcompact market. In a recent WALL STREET JOURNAL article entitled "U.S. Car Industry Has Full-Sized Problems in Subcompact Market", author Amal Nag points out that high production costs are probably Detroit's single biggest problem in the production of small cars. U.S. auto workers are now paid an average of $8.00 more an hour in wages and benefits than their Japanese counterparts. And according to James Harbour, an automotive consultant in Detroit, better factory layouts, more flexible use of workers and automated manufacturing equipment allow Japanese automakers to assemble a small car in approximately 18 man-hours compared with as many as 30 hours for American automakers. (Figure 1) When all the cost advantages are considered, the Japanese have an approximate $2500 cost advantage over U.S. manufacturers on each subcompact they produce.

THE EVOLUTION OF CIM

With the increasing sophistication and decreasing price of microprocessors, factory automation equipment such as computer-aided design and manufacturing (CAD/CAM) systems, robots, numerical control machines, material requirement planning systems and coordinate measurement machines are permeating manufacturing facilities. Rapid advances in a number of areas are pushing the development of increasingly sophisticated manufacturing equipment, including:

1) Computers--from micros up to mainframes
2) Inexpensive electronic data storage
3) Data communications systems
4) Sensors and actuators
5) Machine recognition of visual patterns
6) Voice input and output for machines
7) Electronic graphic displays

Japan vs. U.S. Production Times



Just as the steam engine served as the catalyst for the Industrial Revolution, the microprocessor is playing an analagous role in the automated factory.

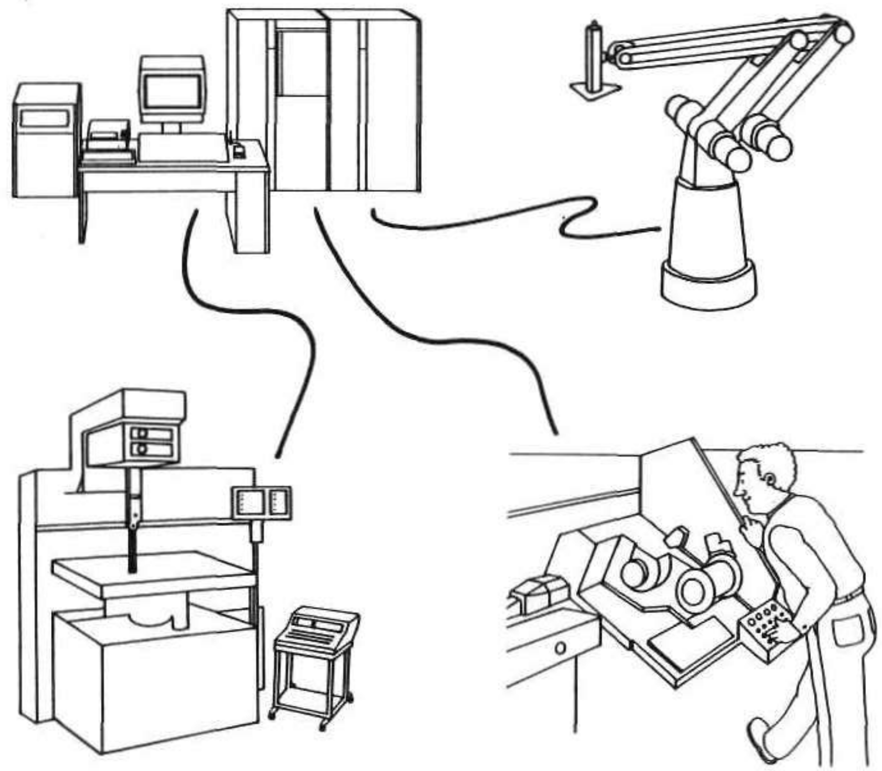
Until recently, these various automation technologies have been developing somewhat independently, creating "islands of automation" in both the office and on the shop floor. But the key to increased productivity in the future will be the successful linking of these independent islands into one centralized computer integrated manufacturing system. (Figure 2)

Two fundamental aspects of manufacturing, originally defined by Dr. Joseph Harrington, Jr. of Arthur D. Little, help to explain why CIM is so important to manufacturing. The first point is the fact that manufacturing--from product design through production to service support--is a monolithic, indivisible function. Because all the various components are interrelated, no single part can be considered singularly, but only by its relationship to the whole. Second, the common denominator for all manufacturing operations is the processing of data. The creation, storing, analysis, transmission and modification of data is key to all the operations of a manufacturing company.

The importance of computer-integrated manufacturing is that it directly addresses these two fundamental aspects. By successfully linking together and integrating all operations through a common data link, CIM maximizes and streamlines the manufacturing process.

The ultimate goal is to link all management, engineering and

CIM Links Islands



production functions, and integrate these into a heirarchical network of computers. This CIM heirarchy provides four major benefits: electronic communications, decision support analysis, automated equipment and database management.

Electronic communication provides decision makers with the ability to access up-to-date information on a wide range of activities, including shop floor operations, new product designs, current orders, process plans and inventory. Decisions based on this information can be rapidly returned to the appropriate area for immediate and timely execution.

With decision support analysis capabilities, managers can easily access and manipulate large amounts of data to make more meaningful decisions based on costs and benefits.

Automated equipment such as numerical control machines and CAD/CAM systems can substantially improve quality and reliability, streamline material flow, and improve inventory control.

Database management is perhaps one of the most important benefits that CIM systems can offer. It helps to store, track, update and retrieve data generated from and required by each area of the automated manufacturing operation.

The heart of database management is the centralized product database. This product database is the central reservoir for all the information about a particular product--the design information needed to actually create it, cost variables and production flow.

Information created in one application area is stored and then easily accessed and used by other applicatons. As each application adds its specific information, the product database becomes more useful to all areas.

Computer-integrated manufacturing technology offers progressively greater benefits as it integrates more and more sectors of a plant's operations. Value added comes from the productivity benefits gained at each step of the operation as a result of sharing and capitalizing on information from the same centralized database. Since data for each area of automation does not have to be re-entered each time, costly redefinition and reformatting errors are eliminated. And because the information is more accurate, product quality and reliability are enhanced. Another important benefit is that communication between design, manufacturing and the other major groups of a company is vastly improved as many of the traditional barriers between groups are broken down. (Figure 3)

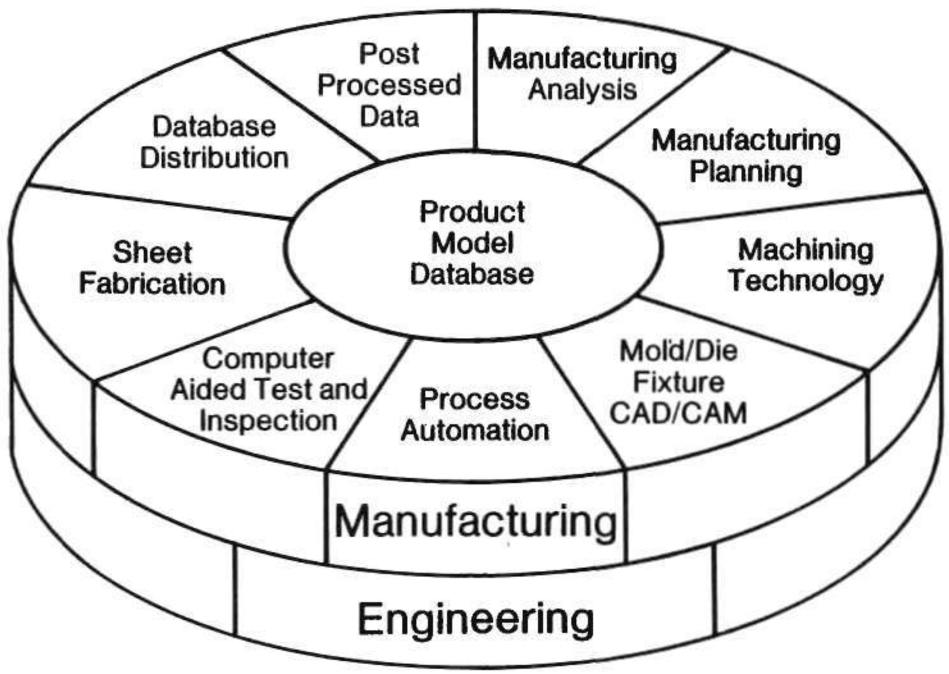
COMPUTERVISION'S CIM STRATEGY

Computervision has recently announced a major change in strategy that is designed to offer companies a wider range of productive CIM solutions.

I would like to use my company as an example to show how the marketing strategy of a CAD/CAM company has changed to maximize the benefits of integrated manufacturing operations.

Computervision has traditionally supplied turnkey CAD/CAM systems for product design and manufacturing processes, including

Centralized Product Data Base



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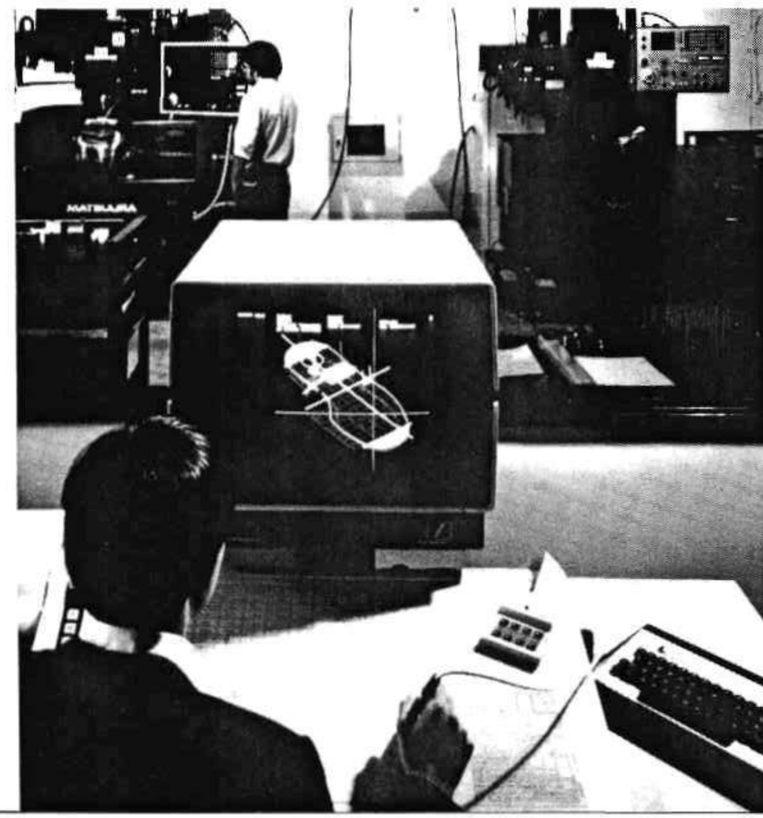
computer-aided engineering, computer-aided design and computer-aided manufacturing. These products and services have established the company as market share leader in these segments of the industry automation market. (Figure 4)

But Computervision has recently chosen to redefine and expand the range of markets it serves from the traditional core of graphics-oriented turnkey CAD/CAM applications to a broader range of engineering and manufacturing activities encompassing total product data management and control.

This strategy was developed in response to market demands for expanded capabilities in several major areas: improved functionality and performance in the core software application areas; enhanced abilities to manage and control expanding product design and manufacturing databases; and greater capabilities to share the benefits of this technology throughout engineering, manufacturing and all other information management functions within a company.

Computervision's new strategy is to provide customers with capabilities in three areas. First, the traditional single-user/focused application enviornment will incorporate intelligent workstations, standard operating systems, and local area networking, and will spread the availability of CAD/CAM technology throughout engineering and manufacturing operations. Engineers will be able to easily access drawings and information from small, intelligent workstations that will be linked together in large networks.

Traditional CAD/CAM Marketplace



Second, the multiuser/multiapplication environment, the core of our traditional offerings, will continue to be enhanced in both functionality and performance. Our new CDS 4000 product line, for example, is the first member of this new product family.

And third, a large scale system that will be linked to large main frame computers and provide total database management for an entire company. Huge databases will be supported on-line, so users can integrate all data processing applications into a single unit for comprehensive manufacturing automation.

This three tier strategy is aimed at providing total CIM capabilities to manufacturing companies of almost every size and need--ranging from standalone engineering workstations to large company wide database management systems.

Computervision has traditionally developed the majority of its products internally, but a part of this new strategy is to address the needs of the expanded marketplace not only through internal product development, but also by joining forces with other industry leaders in CAD/CAM related fields. The company has acquired a number of software firms that provide key application capabilities. Our recent purchase of the Organization for Industrial Research, for example, provides group technology and process planning capabilities--key elements of a CIM configuration.

To begin the implementation of this strategy, Computervision has also entered into a joint development agreement with Sun Microsystems for the development of engineering workstations, and recently signed an ag ment with IBM Corporation for the purchase of IBM products for integration in Computervision systems.

This new agreement with IBM will provide a means to link together all the information resources within a company to create what might be called a configuration management system, and the Sun agreement will provide a series of powerful intelligent workstations.

FUTURE DIRECTIONS

But where will all this lead? When engineers create a product with CAD/CAM today, they typically use a series of part drawings. While all information revolves around this part drawing, there is currently no effective way to relate part drawings with one another. When an engineering change order requires a change in one co, ent of a subassembly, for example, there is no way to determine how that change will affect all the other components in the same assembly. There can often be as many as 20,000 or more part drawings for a particular assembly, creating a logistics nightmare to control and access all the relevant information.

The configuration management system incorporates an ex ive on-line storage capability that will allow all drawings for subassemblies and other components to be integrated and associated. When a change is made on one component of an assembly, the system will quickly identify all part drawings affected by that change. Even with as many as 20,000 drawings on file, the configuration management system will be able to quickly search the entire file. age on-line memory will also make group technology procedures even more effective as the system can search for similar designs, process plans and tooling that may have been previously created, minimizing design redundancy.

The traditional data processing functions of a company have evolved independently from the graphic CAD/CAM functions, but it will be essential that the two databases be linked together if an effective company-wide computer-integrated manufacturing system is achieved. When the traditional data processing functions such as financial accounting, inventory control and payroll are integrated with manufacturing functions such as numerical control, process planning and materials requirement planning, the resultant integrated database can provide a company with an extremely powerful pool of information. This information can be used for a variety of "what if" scenarios to determine optimum economies of scale, and allow companies to accurately project total costs for a specific project.

I would even go so far as to project that the size of the manufacturing database will ultimately be anywhere from 20 to 50 times larger than most current data processing databases. This extensive database will be composed of process plans, fixture and tooling designs, NC programs, quality control and inspection programs, robot programs and process programs. With as many as 48 billion bytes devoted to manufacturing data compared to perhaps two billion bytes for data processing, it is quite conceivable that data processing will ultimately become a subset of the manufacturing operation once a truly integrated CIM operation has been put in place.

Intelligent engineering workstations will also become increasingly important to a wide variety of job functions. Data is already being generated much faster than it can be consumed. Ultimately, the paperless office and factory will become a reality with information accessed on a terminal rather than a piece of paper. Even more documentation and other supporting data will accompany specific part drawings and information. Working at an engineering workstation, an individual will be able to combine documentation, word processing, business graphics, reports and a variety of additional information and have it all tied directly to a specific part drawing.

For example, a part design might be sent to a finite element modeling specialist for analysis. The specialist would generate a mesh on the engineering workstation, and then access a larger processor to run an analysis on the part using Strudl or some similar analysis package. He would then write a summary of the analysis, perhaps defining a structural problem in a specific area of the part. When he sends his report back, he would include a file showing the mesh and the actual dynamic deformation of the part to support his summary and conclusions.

Many networking and communication problems still must be resolved before the integration of the alphanumeric data from data processing and the graphics CAD/CAM data can take place. But significant progress is being made in this area, and it is likely that these problems will soon be resolved.

OBSTACLES TO CIM IMPLEMENTATION

With all of the tremendous advantages CIM systems can offer, why aren't more of them currently in place? The reasons are complex and wide-ranging. But an understanding of the problems is usually one of the best ways to begin to solve them. Most manufacturers will agree that CIM offers significant advantages in terms of increasing productivity, lowering costs for materials, labor and energy, and improving product quality. But because of its integrative nature, CIM technology is having and will continue to have a profound impact on a company's industrial organization, occupational structure and labor relations.

One of the major roadblocks to the implementation of CIM systems is the apparent lack of long-term planning in American industry. Up to and during World War II, the movers and shakers of American industry were individuals from manufacturing and production. Production specialists showed their genius during World War II, and were largely responsible for quickly and radically stepping up production during the war and in the economic boom years that followed.

With the proliferation of new products during the 1950s and 1960s, companies shifted their central focus to marketing as a means to gain attention for their products.

A few years later, with the advent of conglomerates and mergers, the central focus changed again to lawyers and financial experts. Manufacturing companies soon began to give in to the pressure of steadily increasing revenues each quarter to insure glowing financial reports. Long range planning was largely forgotten in the scramble for consistent quarterly increases.

Today, when companies consider large capital investment decisions, the financial people are usually there asking how soon a return on the investment can be expected, what effect the investment will have on earnings, and how they can justify it to stock holders. This short term thinking is pervasive in American industry, and while still important, it fails to take into consideration the essential long term question of whether the company will even be able to compete in the international marketplace in five to ten years. The financial representatives typically are unfamiliar with manufacturing processes and naturally gravitate toward options with the lowest perceived risk- a classic case of not being able to see the forest for the trees.

A recent article in the HARVARD BUSINESS REVIEW by Bela Gold, entitled "CAM Sets New Rules for Production", states several more specific reasons why American managers have been slow to realize the significance of CIM:

1) They don't realize that CIM is a special kind of technology, whose adoption requires a broader level of analysis than is normally applied to the purchase of equipment and facilities.

2) They rely on bottom-up impetus for the generation of new equipment proposals.

3) They still depend on traditional capital budgeting techniques to evaluate proposals.

CIM provides a systematic capability by integrating adjacent and interrelated operations, so neither the purchase or the performance of CIM systems should be evaluated in the traditional way a single piece of equipment such as a machine tool is evaluated. When managers insist on evaluating CIM systems with these narrow attitudes, it becomes very difficult to make meaningful decisions about a new technology that has implications for the entire company.

The existing manufacturing organization often presents significant barriers to the implementation of CIM systems. The traditional heirarchical structure firmly in place in most plants has these inherent problems:

a) Policies, systems and procedures are outdated.

b) Work tasks are often polarized.

c) Top-down chain of command allows little feedback from bottom up.

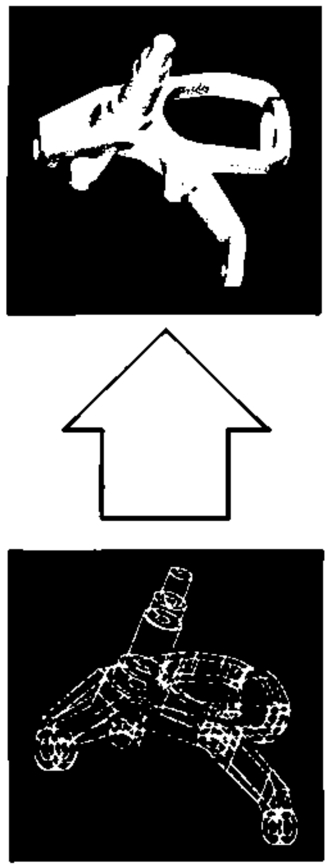
d) Fixed logic management decision systems are not equipped to handle the variable decisions needed to justify and maintain CIM systems.

Some experts are calling for a complete revamping of the manufacturing organization from a heirachical structure to more of a matrix structure where information is easily accessed by individuals at every level. The fixed logic so prevalent in the industrial era is giving way to a more variable logic made possible by the information revolution. When individuals at all levels can quickly and easily access information, communication is vastly improved and more intelligent decisions can be made.

The lack of properly trained personnel also contributes to the problem. CIM technologies are complex and changing rapidly. Many have only been developed in the last five to ten years, so it can often be difficult to find people with the necessary background and experience. With the trend toward more and more specialization, it can also be difficult to find people that understand how all the various technologies integrate into one centralized system.

This problem is only temporary, however, because as more and more systems are put into place, a larger pool of experienced people will be available who understand the wide-ranging implications of CIM systems.

Another problem is that, with CIM technologies evolving so quickly, it becomes very difficult to keep up with new developments. (Figure 5) Trade magazines and industrial trade shows and seminars can help, but the technology is changing so rapidly that manufacturers still have a general lack of understanding of CIM systems and their implications on the manufacturing process. CIM has a significant impact on the structure, competitive positioning, financial performance, employment patterns and labor relations of a company, so in some respects it is understandable why managers have been reluctant to enbrace CIM. Computer-integrated manufacturing technology is still



Technology Changing Quickly

in the somewhat early stages of development, and there are some gaps in the technology. Users must still bear the burden of identifying and developing many specific applications. They must also choose among a wide range of potential systems, and are still largely on their own in integrating the entire CIM structure in their manufacturing operations. But their failure to at least learn more about the advantages of CIM will have serious long-term implications.

THE TECHNOLOGICAL IMPERATIVE

Computer-integrated manufacturing provides engineers and manufacturers with a powerful new set of tools. But these individuals must educate themselves if they are to successfully capitalize on CIM's advantages. Because CIM drastically changes the traditional way a new product is designed and manufactured, massive revamping of current design and manufacturing techniques must take place. Change of this magnitude can only come from one place: top management.

But this goes against the grain of the typical manner in which a company with a hierarchical structure purchases capital manufacturing equipment. Change in this type of company typically starts at the bottom and works its way up. When purchasing a machine tool, for example, the bottom up approach is fine because the person or group actually using the system knows their needs best. But because CIM integrates and automates every phase of the manufacturing process, it must be the responsibility of top management to insure effective implementation in the face of almost certain reactionary resistance at all lower levels.

If CIM is to be successfully implemented, the old philosophy of designing the system to meet user requirements must be abandoned. Instead, manufacturers must carefully evaluate and understand user requirements relative to the total manufacturing picture rather than for individual elements of it.

Manufacturers face a dramatic change in the methods and operations as fundamental as the changes that set the stage for the Industrial Revolution. Until now, relatively few companies have risen to the challenge, and many are not even aware that it exists. But most are starting to see the effects.

The free market system, with all of its pluses and minuses, does insure one thing: only the strongest competitors survive. CIM truly is a technological imperative that can help to insure economic survival in an increasingly competitive marketplace.

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COMPUTER COMPANIES AND INTEGRATION

Richard L. Gimbel
Manager, End-User Marketing
Apollo Computer, Inc.

Mr. Gimbel is Manager of End-User Marketing for Apollo Computer, Inc. He is responsible for developing and implementing marketing support programs for established markets and customers, as well as identifying, developing, and implementing business plans for new end-user markets. Prior to joining Apollo, Mr. Gimbel worked for Digital Equipment Corporation, where he held a number of positions within Digital's Engineering Systems Group, most recently as Manager of Marketing Programs. Before joining Digital, Mr. Gimbel was a Software Engineer for Control Data Corporation. Mr. Gimbel holds a B.S. degree from the University of Oregon and an M.S. degree in Computer Science from Purdue University.

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COMPUTER COMPANIES AND INTEGRATION

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COMPUTER COMPANIES AND INTEGRATION

- INTEGRATION: DEFINITION AND REQUIREMENTS
- ROLE OF COMPUTER VENDOR
- "THE INDUSTRY"

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COMPUTER INTEGRATED MANUFACTURING

- TASK AUTOMATION
- UNITE INTERRELATED TASKS
- VIEWED AS AUTOMATING THE PROCESS

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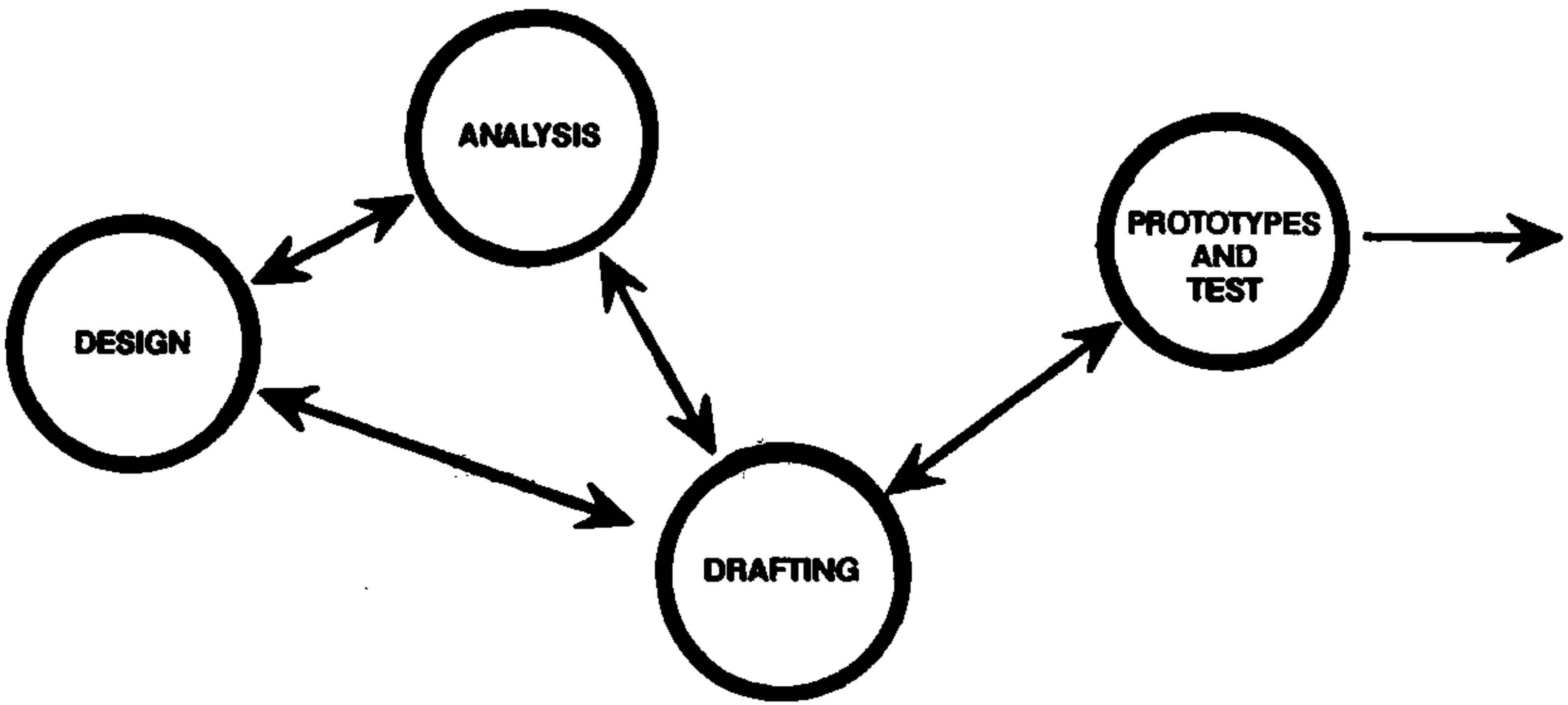
PROCESS MODEL



- TECHNICAL TASKS AUTOMATED
- INFORMATION SHARED/COMMUNICATED

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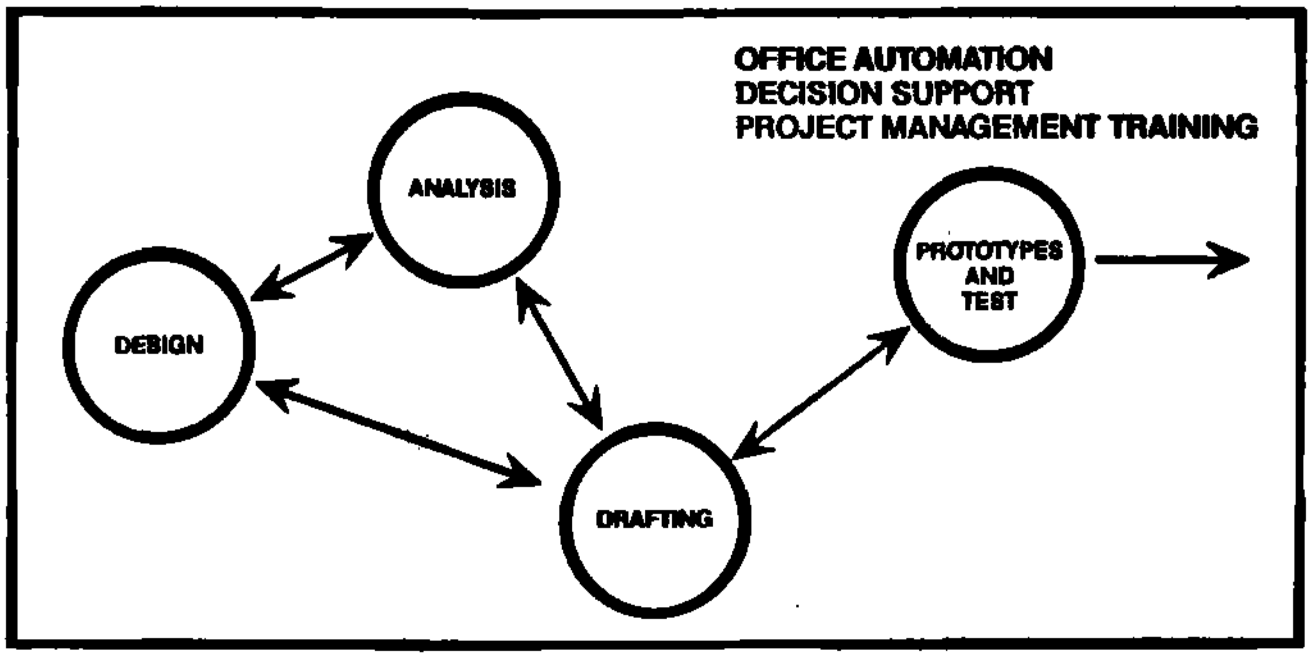
EXTENDED PROCESS MODEL



- PROCESS IS MANAGED
- EXISTS WITHIN AN ORGANIZATION

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INTEGRATION

- UNITE TASKS INTO MORE EFFICIENT PROCESS
- CONSIDER ALL ASPECTS OF WORK PROCESS

BENEFITS

- ELIMINATES INFORMATION TRANSFER STEPS/ERRORS
- MORE PREDICTABLE/MANAGEABLE ACTIVITY

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CIM IMPLEMENTATION CONSIDERATIONS

- WIDE RANGE OF APPLICATIONS
- RANGE OF COMPUTING ENGINES
- NETWORK AND DATA MANAGEMENT
- HUMAN INTERFACE
- SUPPORT

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ROLE OF A COMPUTER VENDOR

CONSIDERATIONS

- MANY MARKET SEGMENTS
- PRODUCT LIFE CYCLES
- INTERLOCKING TECHNOLOGIES
- INERTIA OF INSTALLED SOLUTIONS

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ROLE OF A COMPUTER VENDOR

APPLICATIONS

- SOFTWARE DEVELOPMENT TOOLS
- 3RD PARTY PROGRAM
- "GENERIC" OFFERINGS

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ROLE OF A COMPUTER VENDOR

COMPUTING ENGINES

- MANAGE TECHNOLOGY
  - A. Architecture
  - B. Standards
  - C. Alternatives
- GENERAL PURPOSE WITH MARKET SPECIFIC OPTIONS
- PROTECT SOFT INVESTMENTS

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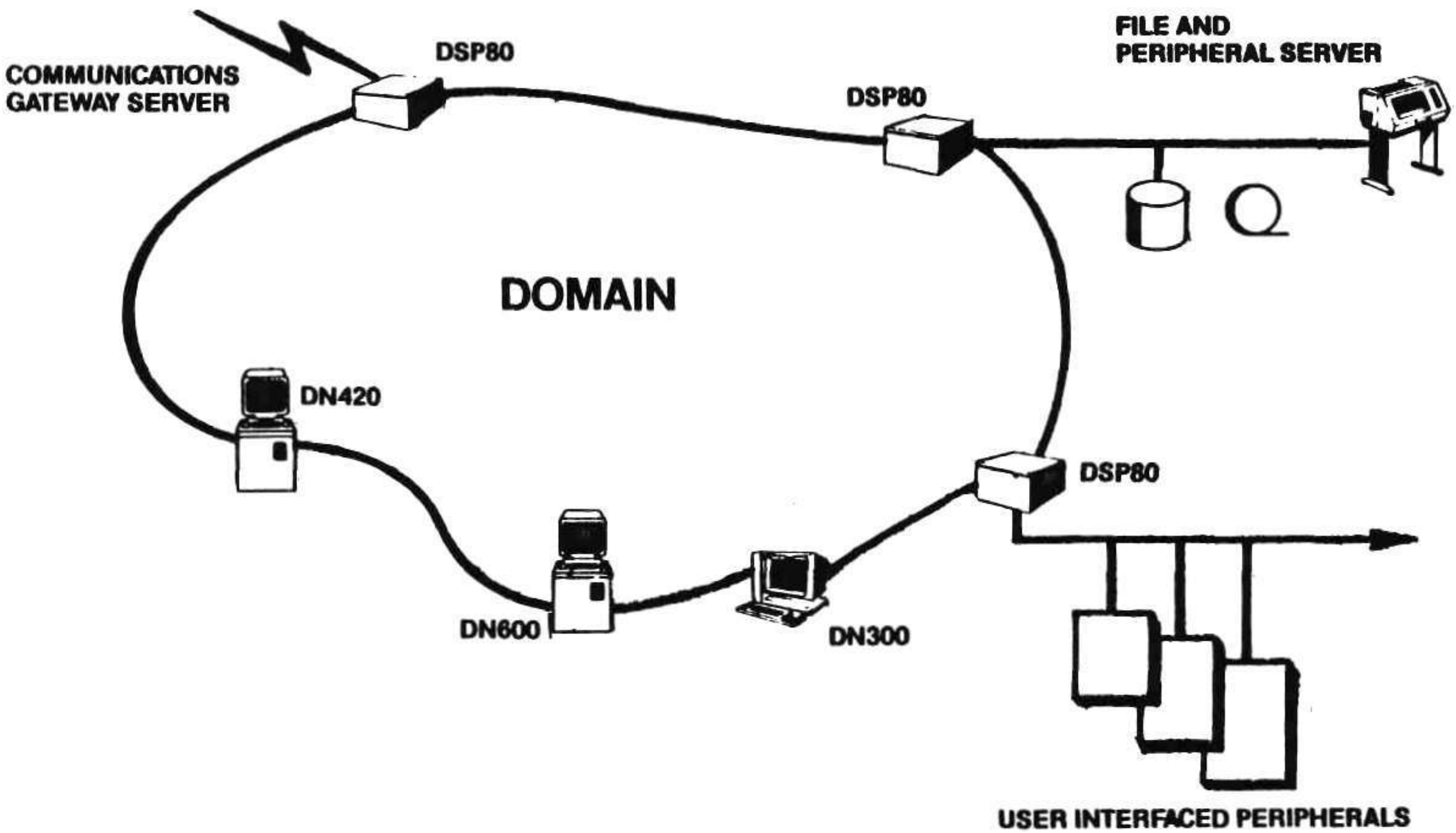

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ROLE OF A COMPUTER VENDOR

NETWORK/DATA MANAGEMENT

- BASIC FILE TRANSFER
- DATA BASE & TRANSLATOR TECHNIQUES
- DOMAIN NETWORK DATA MANAGEMENT

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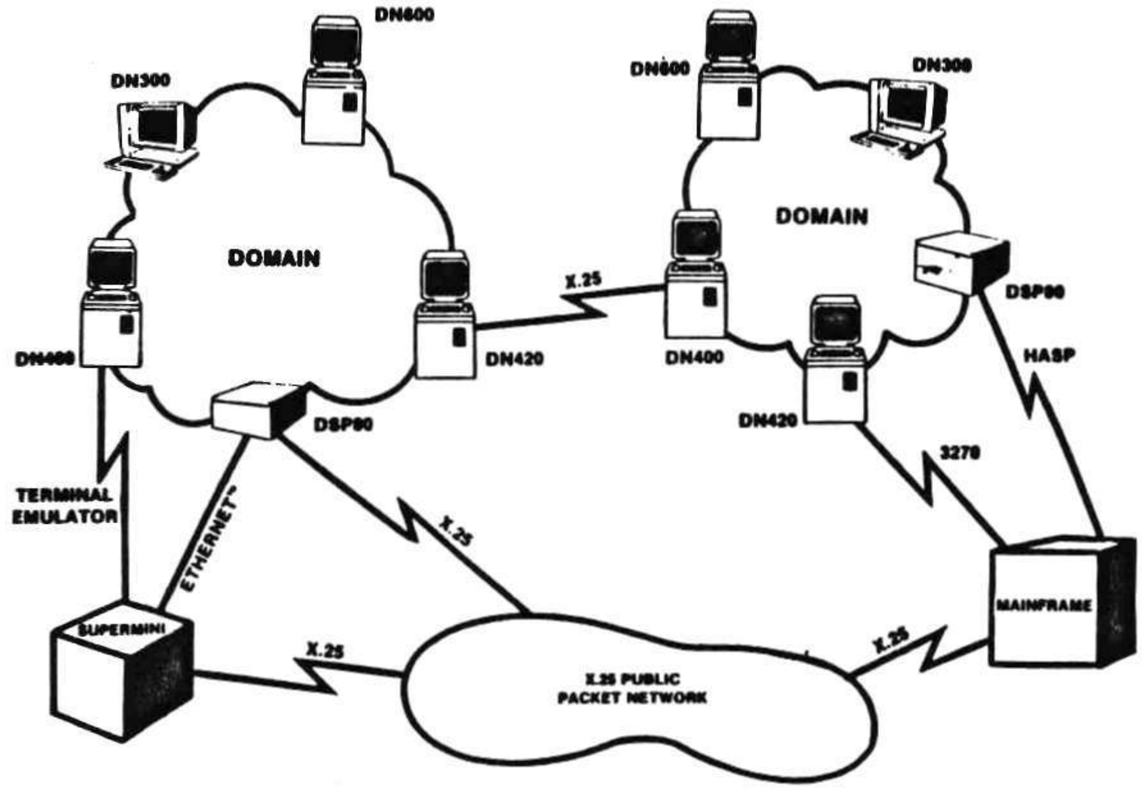
DOMAIN CAPABILITIES



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ROLE OF A COMPUTER VENDOR

CONSISTENT HUMAN INTERFACE

- MULTI-TASKED WINDOWS AS 'FRONT END INTEGRATOR'
- EASE OF USE FEATURES

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ROLE OF A COMPUTER VENDOR

- MANAGED TECHNOLOGY
- INDUSTRY RELATIONSHIPS

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THE INDUSTRY

- MULTI VENDOR
- RAPID ADVANCES

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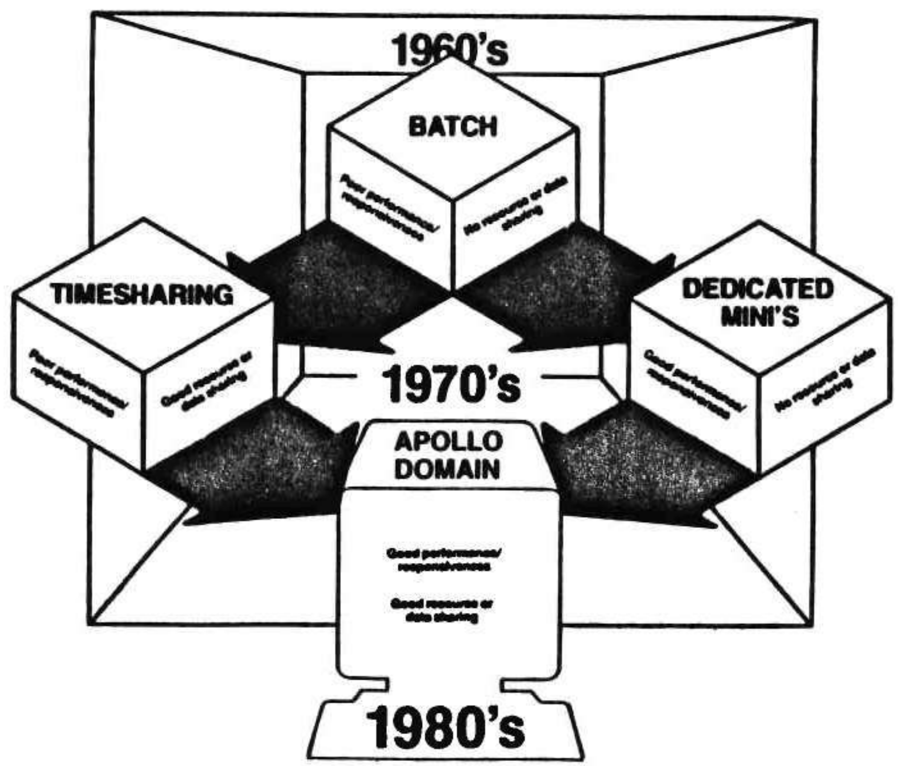
THE INDUSTRY

ARCHITECTURAL EVOLUTION



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THE INDUSTRY

"HIGH PERFORMANCE PERSONAL NETWORK-BASED COMPUTER SYSTEMS"

■ HIGH PERFORMANCE	SUPERMINI-CLASS WITH PREDICTABLE RESPONSE PER USER
■ PERSONAL	COMPUTER WITH INTERACTIVE GRAPHICS PER USER
■ NETWORK-BASED	INTEGRATED COMPUTING ENVIRONMENT WITH ECONOMICAL RESOURCE SHARING AND MODULAR GROWTH

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computer inc.

DOMAIN PROCESSING SYSTEM

- LARGE MACHINE PERFORMANCE AND FUNCTIONALITY DEDICATED TO COMPUTER PROFESSIONALS
  —32-BIT HIGH PERFORMANCE PROCESSOR
  —HIGH RESOLUTION, BIT-MAPPED GRAPHICS
- NETWORKED COMMUNITY OF USERS
  —HIGH-SPEED LOCAL AREA NETWORK
  —NETWORK-WIDE VIRTUAL MEMORY OPERATING SYSTEM
  —DISTRIBUTED DATA BASE MANAGEMENT SYSTEM

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THE INDUSTRY

- STANDARDS?!
- SOFTWARE
  - A. SUPPORT
  - B. LICENSING
  - C. TRAINING
  - D. CUSTOMIZATION

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COMPUTER COMPANIES AND INTEGRATION

"INTEGRATE OR PERISH"

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THE IMPACT OF ENGINEERING WORKSTATION NETWORKS ON CAD PRODUCTIVITY

David E. Weisberg
Manager, Market Analysis
Auto-trol Technology Corporation

Mr. Weisberg is Manager, Market Analysis, at Auto-trol Technology Corporation, where he is responsible for the evaluation of industry trends within the computer graphics and CAD/CAM industries. He has also worked in management positions involving Product Planning, Product Marketing, and Applications Software Development at Auto-trol. Previously, he was Field Marketing Manager for Tektronix's Mechanical Engineering Graphics activity. He has been engaged in the computer graphics field in both the development and marketing of software/hardware systems since 1961. His work has been in applications areas including cartography, process control, IC design, mechanical design, and architecture and engineering design. Mr. Weisberg received his B.S. and M.S, degrees in Civil Engineering from Massachusetts Institute of Technology.

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PERFORMANCE AND PRODUCTIVITY IN

COMPUTER AIDED DESIGN SYSTEMS

With Computer Aided Design (CAD) systems becoming a common engineering tool, it is necessary that there be a solid understanding of the importance of overall system performance and its impact on productivity. This paper presents reasons why a predictable level of performance can enhance the productivity of system users and an analysis of the factors that can impact performance. Perhaps this will also explain why systems can look very good under certain circumstances and fail to live up to expectations when installed in a real world environment.

We are now entering the fourth decade of the serious use of computers in engineering design. During this period almost unbelievable changes have taken place in the tools that are available to the user. With these changes in technology have come changes in the level of expectations. The computer mystique is gone when you go home from a hard day at the office and find your preteen son or daughter hunched over the family APPLE II or TRS-80.

Technical management today will not accept the tools of yesterday. One good example of this is in the area of structural design using FINITE ELEMENT ANALYSIS (FEA). In the early 1960's, the first programs using this technique appeared on the scene. In order to use these analysis programs, the engineer had to manually create his node and element model, convert the model to input on a coding form, have it keypunched, take it to the computer site, run it, and then receive back a huge stack of numerical listings. The entire process for a moderate size problem could take 4 to 6 weeks.

Because of the lack of graphic capabilities, errors were common. This resulted in frequent reruns and large amounts of engineering effort spent reviewing coding forms and listings. Today, this sounds like an agonizing process. We must remember, however, that without the FEA programs, these analyses just could not be done. Effort then began to address speeding up the process.

In the last 20 years we have seen many developments that have improved the productivity of using FEA techniques. Remote batch entry of problems eliminated the need to physically take card decks to the computer. Plotters were used to reduce the huge volume of printed output to a few easy to understand plots. With the advent of interactive graphics in the early 1970's a huge step forward was made. It was possible to create a model and submit it for analysis from a graphics workstation. Unfortunately, time-sharing graphics were slow and costly. But it did reduce the turnaround time to a few days or less for fairly large problems. The next step was to use stand-alone modeling systems or extensions of CAD systems to build the model and then transmit the model in a batch mode to the computer doing the analysis. This was a more efficient use of the engineer's time. The turnaround time was still measured in many hours, if not days.

Recently, CAD systems have been implemented on "superminis" that are also capable of performing the actual analysis as well. Now it is possible to design a part, convert it to a finite element model, add the necessary loading data, perform the analysis, view the results and decide what changes need to be made to the model; all in one continuous operation For a moderately complex part, an entire iteration may only take a few hours.

As the above described process has gone from taking many weeks to only a few hours, the use of the technology has skyrocketed. Engineers today will use the technique because the cost to do so is acceptable, the process is effective, and it is a satisfying way to accomplish the work.

Other examples of design time compression can easily be found in areas such as Integrated Circuit design, Printed Circuit Board layout, Numerical Control, Architecture, and Process Plant design. The key point is that designers and engineers today require and need systems that can support the expected compression of the design and development time cycle. CAD systems performance is very important to meeting these objectives.

As a basic principle let us take as our thesis that " An engineer or designer is most effective when his thought process is not delayed by artificial constraints". A second principle is that " An engineer or designer works more effectively with a computer system that has predictable performance than with one where the performance is unpredictable moment to moment". A third factor to be considered is that a level of system performance that was acceptable several years ago is no longer felt to be acceptable by many users.

What we are dealing with is the subject of the emotional needs of a technically oriented systems user. We are not digging ditches or unloading boxcars. The designer is working with the system to create something meaningful. The thought processes are often complex and extensive. If the system is slow to respond to an operator action, it is very easy to lose one's train of thought. Perhaps this is one reason why engineers with similiar intellectual capabilities turn out such dramatically different volumes of completed work. The high performer is the one who can best keep himself focused on the task at hand. What we want to do with a well designed CAD system is not create any artificial barriers to this concentration. We want the system and the user to work together as one in solving the problem. The easiest way to destroy this relationship is to frustrate the user to the point that he loses his concentration.

A very key point is that we are not talking just about blazing speed. In fact a system that can perform extremely fast on occasion and on other occasions is very slow because of contention from other users may actually be counterproductive. What the user needs is a reasonably high level of performance that he can count on. When the response of a system is smooth, the user gets into a rhythm. He knows how long an action is going to take to execute and is prepared for the next step. A system that demonstrates widely varying performance leads to frustration because the user does not know why a step that took a few seconds a while ago is now taking 20 seconds. One reaction is that he did something wrong. So he will try to do the operation again only to find that the first attempt was successful. Then he has to backtrack the redundant operation out of the system.

Another reason why predictable performance is important is to avoid the frustration of delays happening that are outside of the user's control. If a designer requests the system to calculate the intersection between two very complex surfaces, he knows that this involves a substantial amount of calculations but the system is doing these calculations for him. When someone in another room or even another department, requests a complex analysis be performed it is going to degrade the performance of the total system. Our user does not know why performance has just gone through the floor, he just knows that it has. "If that is the case, why not just go down to the company coffee shop and get a cup and maybe the system will be cooking when I get back". Where did his train of thought and concentration on the problem go?

Until recently, the primary means of implementing for a CAD system was to use a medium to large minicomputer with a capacity of 4 to 16 workstations. The architecture of these systems is very consistent and it is not difficult to understand how performance can significantly degrade under many circumstances. One way to appreciate this is to look at a system as a series of gates with all the users trying to get through at once. Some of these gates as shown in Figure 1 are:

1. Access to disk files.

Most CAD tasks are very disk file intensive. This involves the retrieval of both program modules and data files. The typical system has a single disk channel with one or more disk drives connected through a single controller to that channel. The channel speed in most systems is about 1.2M bytes per second. Data frequently can not be transferred over this channel while the read/write head is being positioned so the effective throughput is often a lot lower. It is not hard to see that with more users actively using the system, the more likely that access to the disk will become a controlling factor on performance.

There are hardware and software techniques that can be used to reduce the negative impact of this problem. From a hardware point of view, we can add multiple data channels, controllers, and disk drives so that there can be several data transfers being performed at the same time. These devices can add substantially to the cost of a system and are not necessarily available on all minicomputers.

The structure of data files is also a characteristic of data transfer performance. The more selective the access process is and the amount of data required to describe a geometric element also have an impact on performance.

2. Central processor performance

There are a large number of factors that impact processor performance in a multi-user system. Some of these are hardware related such as the basic speed of the unit in executing instructions, the memory speed, and extent to which operations can be overlapped. The size of memory and how it is organized can be very important. Large CAD systems can involve literally millions of bytes of program. If only a small portion of memory is available to each user, the computer will frequently be going back to the disk to retrieve additional program modules. The bottom line is that if a computer can execute 1 million instructions per second and there are 10 users on the system, then each user has in effect a 100,000 instruction per second computer at his disposal. Granted, when the system is lightly loaded, he has a lot more power available, but what happens when two or three users decide to do complex analysis tasks. Off to the coffee shop!

3. Operating systems

Since there are many users doing a variety of tasks on the system, it is necessary to use a complex operating system to allocate resources. The science of developing these operating systems has reached a very advanced state. The major problem is they have been optimized to handle a wide range of needs and are not necessarily the best for multiple CAD users. Ease of use and flexibility have been emphasized over performance. This generalization allows the user to have access to a wide range of capabilities, but at a significant cost of machine resources.

Some CAD systems attempt to solve this problem by utilizing special purpose operating systems. This approach trades off increased performance against generalized support. It also makes it very hard to support software from a variety of sources.

4. Output to workstation

The next step in the process is to output information to the user workstation. The most important factors here are the speed of the transfer and the amount of data that has to be transferred. A large drawing may require the output of 20,000 vectors. At 32 bits per vector (a fairly common situation), this means transferring 640,000 bits of data. If a terminal is operating at 9600 bits per second this transfer would take 67 seconds. This is typical of many non-turnkey systems. Specialized systems currently on the market tend to use a lot higher transfer rates.

Another measure of output capacity is how many workstations are linked to each output channel. A system may have a 500,000 bits per second channel, but it is shared by 16 workstations. When only one or two workstations are active, this will not degrade performance. If everyone is busy, however, each user is reduced to a 31,250 bps channel. In actual practice, the effective throughput will be a lot lower because of the system overhead in managing the channel. Some communication protocols can reduce throughput to 60% or less of the theoretical data link capacity.

The volume of data that must be sent to the workstation also has a big impact on responsiveness. Some workstations have very limited local computational capability and a very large volume of data must be transferred. Other systems allow data to be sent in a very compact form.

5. Display generation

Most of the workstations being used in CAD systems today use raster technology. This requires that vectors be converted to individual points or pixels on the display. There are many different software and hardware techniques for doing this that can result in varying levels of performance. Some systems use fairly fast hardware, but the hardware is shared by several workstations. Other display functions such as fitting a portion of the drawing onto a section of the screen can either be done by the host computer or by a processor in the workstation. In systems where this hardware is shared by several workstations, performance is adversely affected.

6. User interface

How the system handles the interface between the user and the workstation can have a major impact on performance. If these tasks are handled by logic in the workstation, one user will have minimal impact on other users when he is entering commands, picking elements on the screen, or entering textual information. If the central processor is used, each activity will have an impact on other users.

The above discussion is actually a fairly brief discussion of what goes on in typical multi-user environments. It is easy to see that an effecient system requires the very careful balance of a large number of conflicting factors. Some people have done this well, while many others have ended up with systems that did not live up to expectations or where performance could degrade badly under certain circumstances.

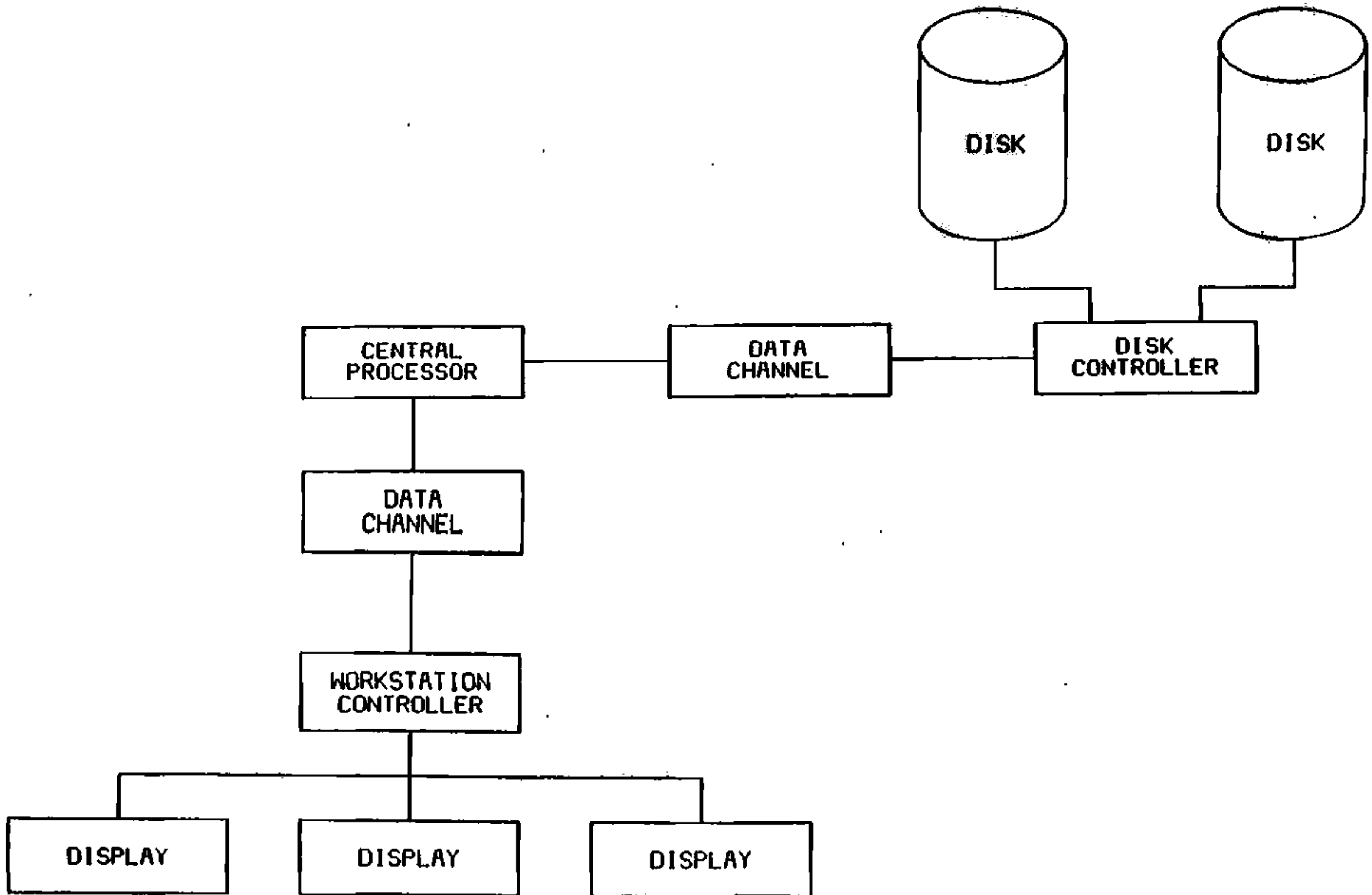
There are two primary ways in which our desired level of predictable performance can be achieved, One is to use a very large or super-computer that may be in the range of 10 to 30 mips (million of instructions per second). These computers are expensive with price tags in the millions of dollars. Even a very large system can suffer noticeable degradation when a complex analysis task is executed unless the number of workstations is kept very low. Unfortunately, this is a solution that few can afford. It also suffers from the problem that when it goes down, your whole engineering design activity is out of business. Everyone to the coffee shop!

A second alternative is to eliminate the central host computer and provide each workstation with a complete set of computer, file storage, and graphics capabilities. The contention for access to a community disk file is eliminated because each workstation can have its own disk. A similiar situation exists with display output since the workstations display processor is integrated into the workstation's computer. This computer needs to have sufficient power to provide a high level of performance with a wide range of engineering design, analysis, and drafting software. Since no system vendor can provide all the specific applications that everyone needs, the user must be able to create his own application software. These computation requirements can be met by providing each user with a state-of-art 32-bit computer ,a 1 to 16 M Byte virtual memory, and an industry standard operating system that supports programming languages such as FORTRAN, PASCAL,and C. See Figure 2 and Figure 3.

On first impression, it seems that this will result in a collection of powerful, standalone systems. For some applications, that might be acceptable. Most users, however, need to have a substantial amount of interaction between users or wish to have a higher degree of control over the situation than can be achieved with independent workstations. The solution is to tie the workstations together via a Local Area communication Network (LAN) and provide an operating system that permits transparent sharing of programs, data, and drawings as well as centralized control over common peripheral devices such as plotters. This means that a user at one workstation can, with appropriate access codes, obtain a drawing or symbol file from another workstation as easily as from his own.

The best of both worlds; a very high level of predictable performance as well as a tightly linked network of users sharing data and resources. Such a system is available today from Auto-trol. It consists of the Advanced Graphics Workstation and the associated Auto-net communication network. Performance of a single workstation is comparable to any available in the industry. The key fact is that this performance is available whether there is 1 workstation or 100 in the network! See Figure 4.

The AGW overcomes the performance limiting gates described above by 1) providing a separate disk for each workstation, 2) containing a high performance 32-bit virtual memory oriented processor in each workstation, with 1 M bytes or more of physical memory, 3) an industry standard operating system, 4) an integrated computational and graphics system with no transfer of data to an external display, 5) high performance graphic display capabilities integrated into the system, 6) and very efficient user interface techniques. Overall, a well balanced system designed for a high level of predictable performance.



TRADITIONAL CAD SYSTEM
FIGURE 1

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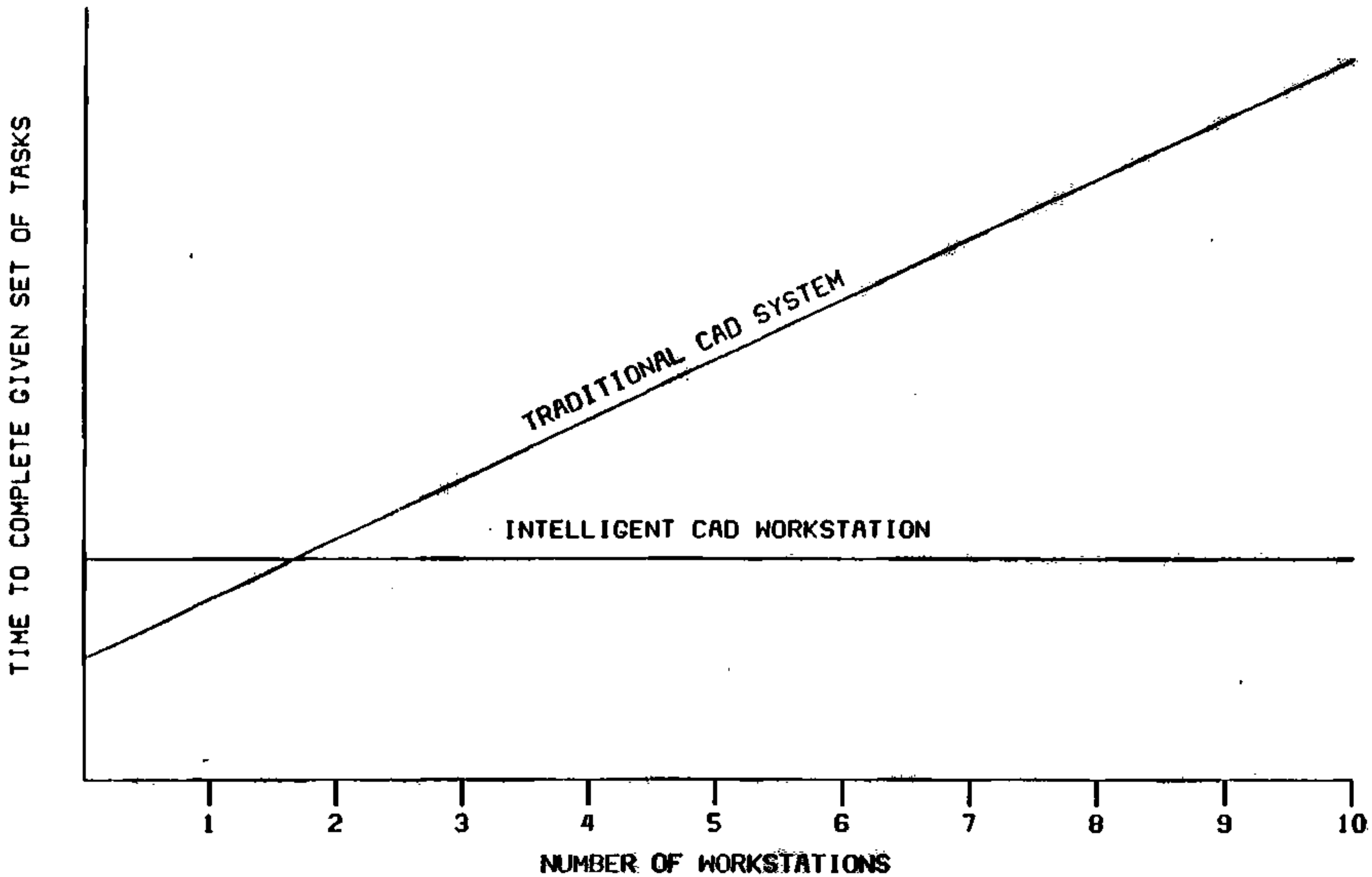
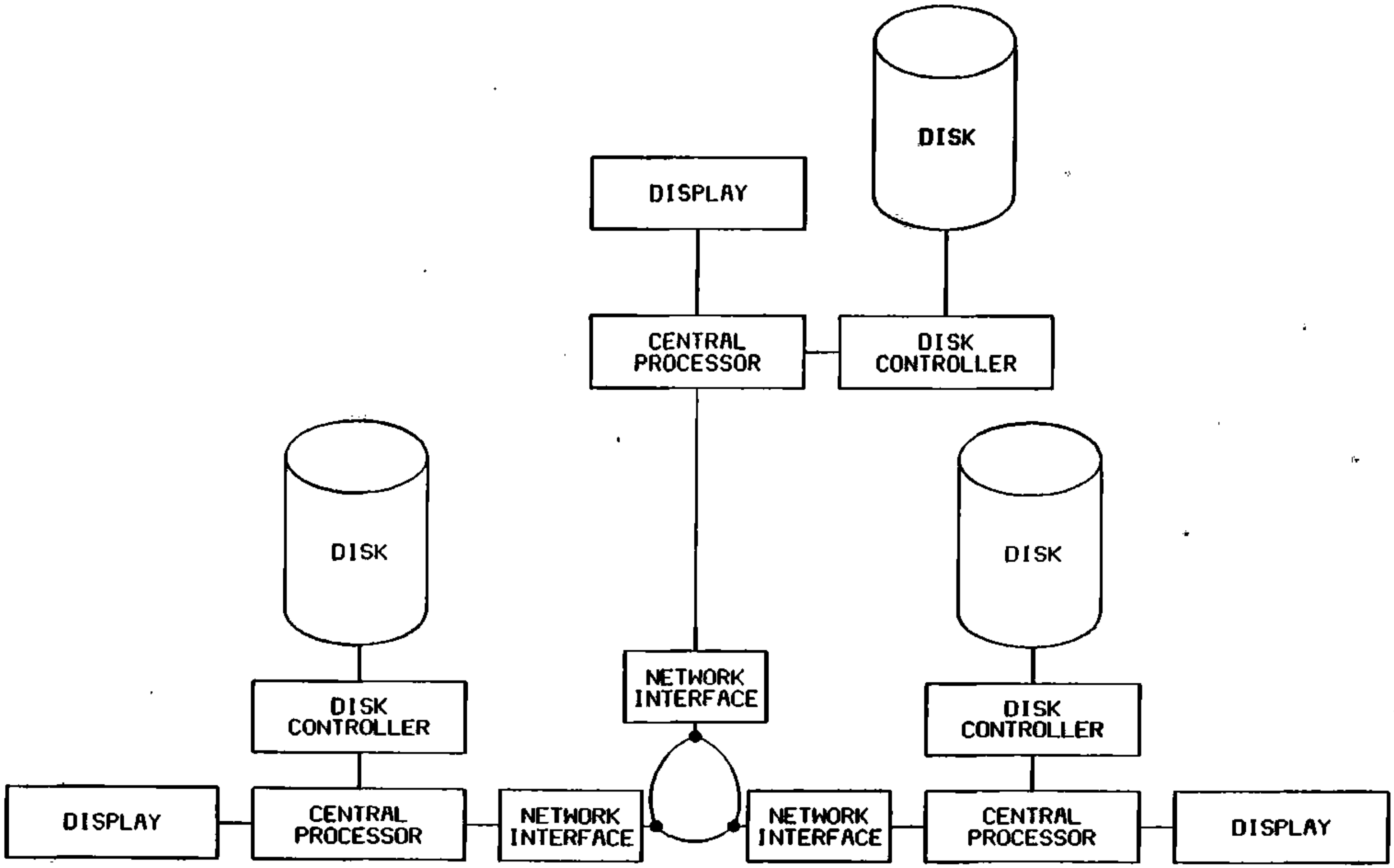


PERFORMANCE DEGRADATION
FIGURE 2



INTELLIGENT WORKSTATION NETWORK
FIGURE 3

AUTO-TROL ADVANCED GRAPHICS WORKSTATION
FIGURE 4

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IMPACT OF COMPUTER-INTEGRATED MANUFACTURING ON A COMPANY

Wilfred J. Corrigan
President
LSI Logic Corporation

Mr. Corrigan is President, Chairman, and Chief Executive Officer of LSI Logic Corporation. Formerly President, Chairman, and Chief Executive Officer of Fairchild Camera and Instrument Corporation in Mt. View, California, Mr. Corrigan also held a series of management positions at Fairchild. Before joining Fairchild, Mr. Corrigan was Director of Transistor Operations at Motorola, Inc.'s, Semiconductor Products Division in Phoenix, Arizona. He graduated from the Imperial College of Science in London, England, with a B.Sc. degree in Chemical Engineering.

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SLIDE 1

1. WORLD SEMICONDUCTOR MARKET

Chip sales will swing to non-standard devices as we approach end of this decade. We will have a 50 billion dollar per year market for semiconductors; 50 percent of this market will consist of devices which are customized to the applications:

Custom Circuits
Semi Custom
EPROMS
ROMS
E^2 Devices
Pals
etc.

Customization of these products may be done by the semiconductor manufacturer.....or by the user. Many of these products will be reprogrammable in situ. This is a major change.

Largely, this was inevitable as we move to large scale integration.

As we trend towards the whole system being on a chip, either we must move to all chips being different, or all systems being the same.

The area that we focus on at LSI Logic is very Dense Logic Arrays which is the best way at the present time to address this need for customized random logic in both small and large electronic systems. What I will do today is quantify the extent of the need, describe what a Logic Array is, and show how the only way to address this market opportunity was to use advanced CAD/CAE. In the process, we have found that we had to organize into two (2) "Factories" - a) "Design Factory" with the charter to manufacture designs, and b) "Silicon Factory" is virtually 100 percent computer controlled, both in terms of technical aspects, and scheduling.

SLIDE 2

World Wide Logic Array Market. This is Strategic, Inc. data and being a new field any data should be only viewed as approximate, but the projection of growth from the $200 Millon+ range to $7 Billion+ between '82 and '92 gives a flavor for the size of the opportunity. Of course, the Semicustom Products of 1992 will be much more complex and probably use different technology than we currently conceive. Also note the rapid predominance of HCMOS in the general purpose area.

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SLIDE 3

What is a Logic Array?

Basically, it is a semi finished product that is customizeable at the metal layers to implement a user defined function. It is very close to being a printed circuit board executed in Silicon.

SLIDE 4*

This is what a High Density CMOS Array looks like.

SLIDE 5*

The dual layer metal which is the key to high performance arrays shows a strong similarity to the ubiquitous printed circuit board - this is several hundred times magnification.

SLIDE 6*

This shows metalization at 2,000 times magnification. Metal widths are about 3 microns, centre to centre on metal lines about 10 microns.

SLIDE 7*

The finished, packaged array. This happens to be 6,000 gates in 144 pin package.

SLIDE 8

Array Application

A)	SSI Integration	300 - 1,000 Gate CMOS
B)	User Defined LSI	700 - 2,000 Gate CMOS
C)	Subsystem on a Chip	2,000 - 6,000 Gate CMOS

SLIDE 9

Example Conversion of 27 T^2L

I.C.'s to a Single Array.

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SLIDE 10

ECONOMICS OF LOGIC ARRAYS

- Implementing a system in LSI usually creates a dramatically lower cost system. In most cases the part costs are less also. Particularly as T^2L is rapidly increasing in price.

- Design cost is usually lower and more predictable, the forced use of the computer necessitates a discipline which improves the "Right the First Time" attitude. It also, creates a more measureable and controllable design cycle.

- Field service costs with LSI are much lower. Reliability improves as the interconnects move on the chip. As the chips become more complex, the system becomes simpler and more reliable.

  e.g. Calculator 1 chip Very Reliable

  For example: To illustrate the HCMOS impact on a traditional T^2L design, we analyzed a popular mini computer implemented in T^2L MSI and DID a hypothetical redesign in HCMOS 3 Micron Arrays.

  The printed circuit boards in the system dropped from 35 to 4!!
  Relative cost dropped by 60 percent!!

SLIDE 11

So, in addressing this large and rapidly growing market the challenge basically was that with:

- System and chip complexity increasing
- Development times stretching when they need to compress
- Increased competion .... and an
- Engineer shortage,

How to meet these needs in a cost effective fashion:

SLIDE 12

THE SOLUTION
COMPUTER AIDED ENGINEERING

As we were postulating a design factory, we needed computer driven manufacturing. This required a heavy duty approach, and to address the issue on an appropriate scale -- not "How do we use the Computer to do a Design?" But....."How do we use the Computer to Produce:"

a Design per day
10 Designs per day
100 Designs per day

i.e. A Design Factory -- Not an Engineering Department.

SLIDE 13

WORLD DESIGN RESOURCES

There are several thousand Silicon Designers feeding a user base of several hundred thousand system designers. With appropriate computer resources, and software tools we can convert some percentage of these designers into Silicon Designers. Thus the bottleneck disappears and the LSI revolution can continue.

The main software system we use at LSI Logic is the LDS-II.

SLIDE 14

This gives us the ability to train a customer's system designer in about two (2) days. Typically, most of the work is done on a large Amdahl, either V6 or V8, but we are able to interface with smaller machines where all or portions of a simulation have been performed on a workstation.

SLIDE 15*

Milpitas Computer Center

SLIDE 16

Customer Design Support--System Designer orientation rather than Semiconductor Designer orientation. We provide local design centers with applications support, and direct 9600 baud access to our main computer facility.

SLIDE 17

More detail of our current LDS-II System

Using this approach we can handle a large number of designs flowing through our design factory with a surprisingly small number of applications engineers. Obviously, every customer design is different, but we have been able to sell the concept of a standard methodology, with a flexible interface to the outside world. We expect by the end of this year to have working interfaces with all the major workstations vendors. We already are able to interface with the more popular software simulators.

SLIDE 18

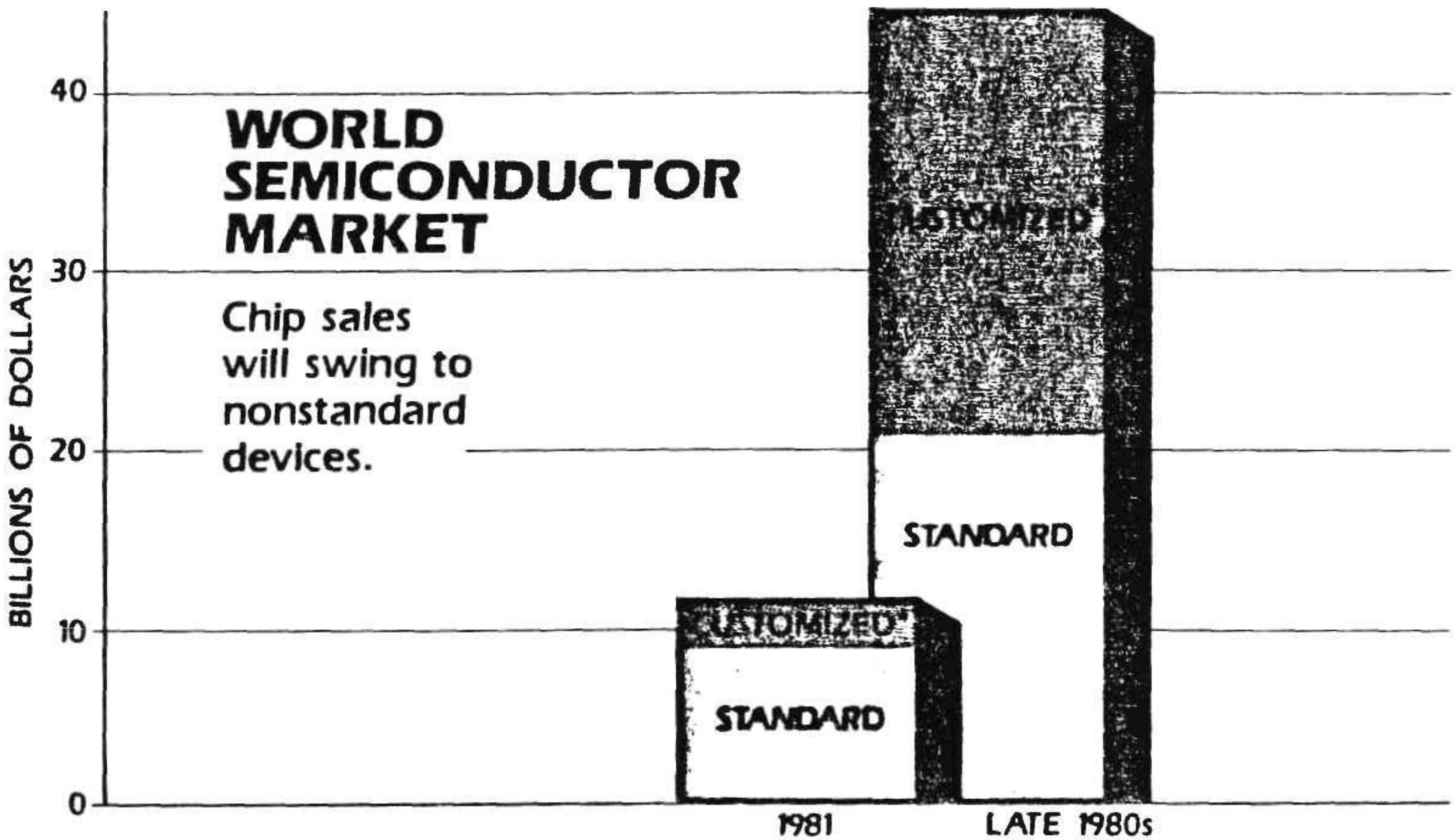
Our future thrust will be to move this capability up to the system level to assure that major LSI subsystems work together prior to implementing the Silicon. This will further compress system design time and improve design accuracy. We will be describing this system later this year.

SLIDE 19

Close. LSI Logic

*Hardcopy of these slides unavailable.

LSI LOGIC CORPORATION

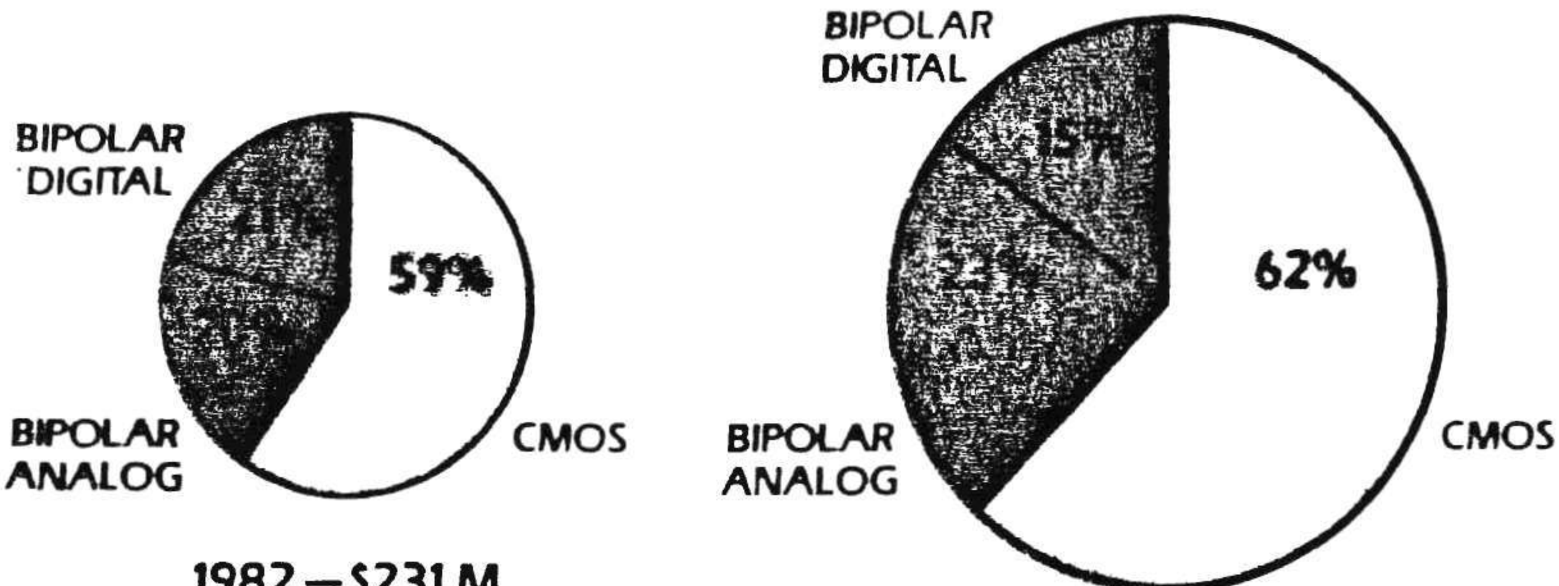


*Includes custom, semicustom, and programmable logic and memory chips.
Data: Texas Instruments Inc., BW estimates.

SOURCE: BUSINESS WEEK

LSI LOGIC CORPORATION

WORLDWIDE LOGIC ARRAY MARKET
BY MAJOR PROCESS TECHNOLOGY



1982 — $231 M

1992 — $7.3 B

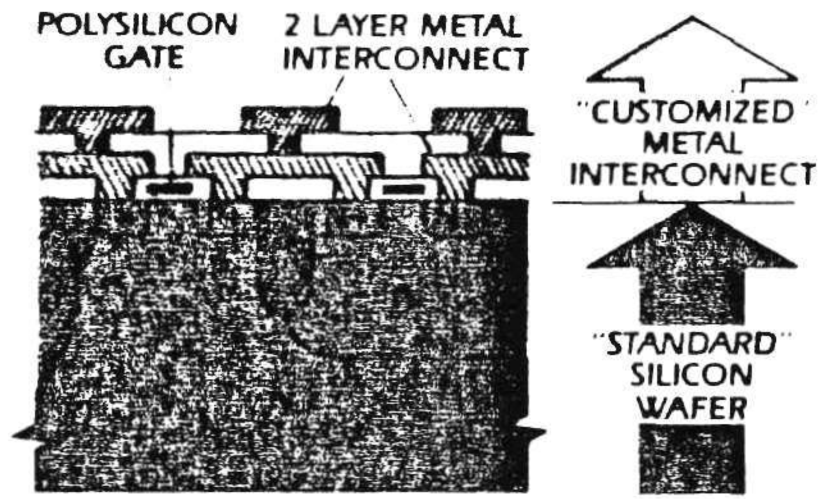
COMPOUND ANNUAL GROWTH RATE: 41%

SOURCE: STRATEGIC, INC.

LSI LOGIC
CORPORATION

WHAT IS A LOGIC ARRAY?

- An uncommitted array of logic functions that are interconnected at the metal level to implement a user defined function.
- The silicon wafer is preprocessed to the standard array cell design.
- The metal interconnect is subsequently processed to implement the user defined logic function.



HCMOS STRUCTURE

ARRAY APPLICATIONS

- SSI INTEGRATION
  TYPICALLY 300-1000 GATE CMOS.
  28-40 PIN DIP.
- USER DEFINED LSI ELEMENTS
  TYPICALLY 700-2000 GATE CMOS OR HCMOS.
  600-1200 GATE ECL. 40-68 PINS.
- SUBSYSTEM ON A CHIP
  2000-6000 GATE HCMOS.
  68-120 PINS.

LSI LOGIC
CORPORATION

EXAMPLE OF A CONVERSION FROM 27 TTL ICs TO A SINGLE ARRAY

EXISTING SYSTEM	EQUIV. GATES PER IC	TOTAL EQUIV. GATES
2 ea. 74LS91	43	86
2 ea. 74LS100	18	36
4 ea. 74155	21	84
2 ea. 74174	37	74
10 ea. 7402	4	40
2 ea. 74LS10	6	12
5 ea. 7430	6	30
1 ea. 74163	68	68
10 ea. Non-Inverting Output Buffers; 2X Drive (for array)	4	40
2 ea. Non-Inverting Tri-State Output Buffers (for array)	6	12
TOTAL EQUIVALENT GATES		482

ECONOMICS OF LOGIC ARRAYS

- Silicon vs. System Costs
- Design Costs
- Market Window Costs
  - —Speed of Design
  - —Rapid Manufacturing Ramp
  - —Ease of Technology Insertion
- Qualification Costs
- Field Service Costs

CHALLENGE

- SYSTEM AND CHIP COMPLEXITY INCREASING
- DEVELOPMENT TIMES STRETCHING OUT
- INCREASED U.S. AND JAPANESE COMPETITION
- ENGINEER SHORTAGE

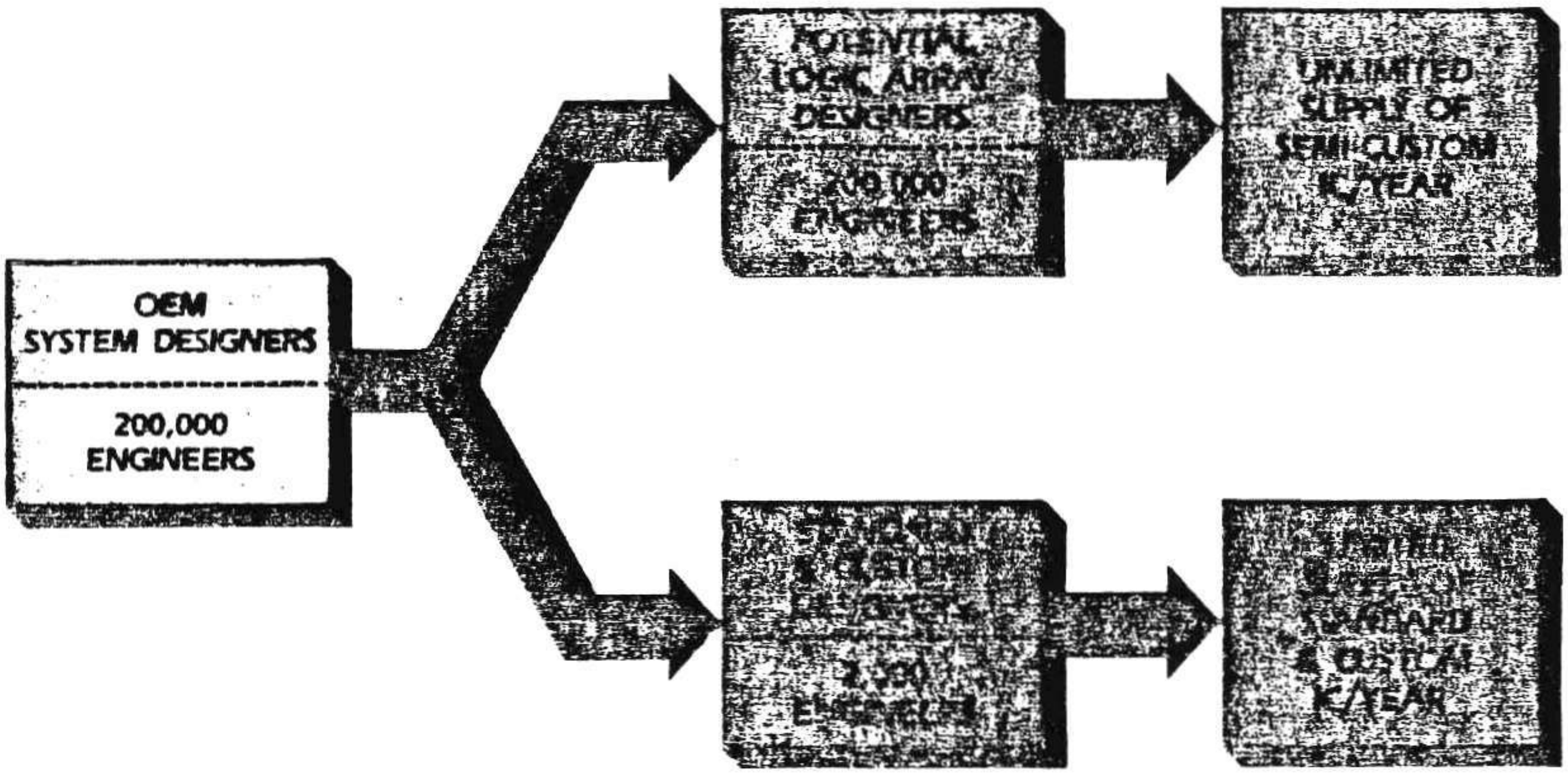
SOLUTION:
COMPUTER-AIDED ENGINEERING

FOR EXAMPLE,
OUR LDS-II LSI DESIGN SYSTEM

- MULTIPLIES ENGINEERING PRODUCTIVITY
- ALLOWS SYSTEM ENGINEERS TO DESIGN ICs
- GENERATES PRODUCTION TOOLING AND TESTS
- REDUCES DEVELOPMENT TIME

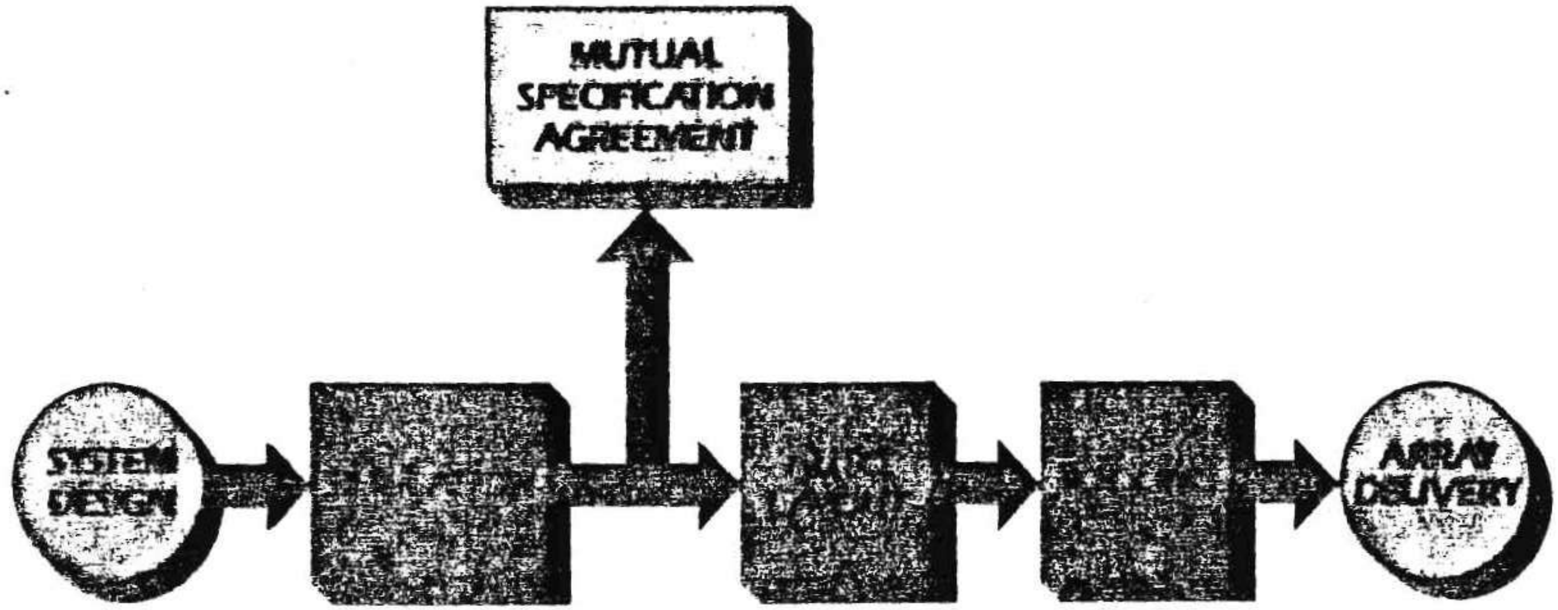
LSI LOGIC CORPORATION

WORLD IC DESIGN RESOURCES



LSI LOGIC
CORPORATION

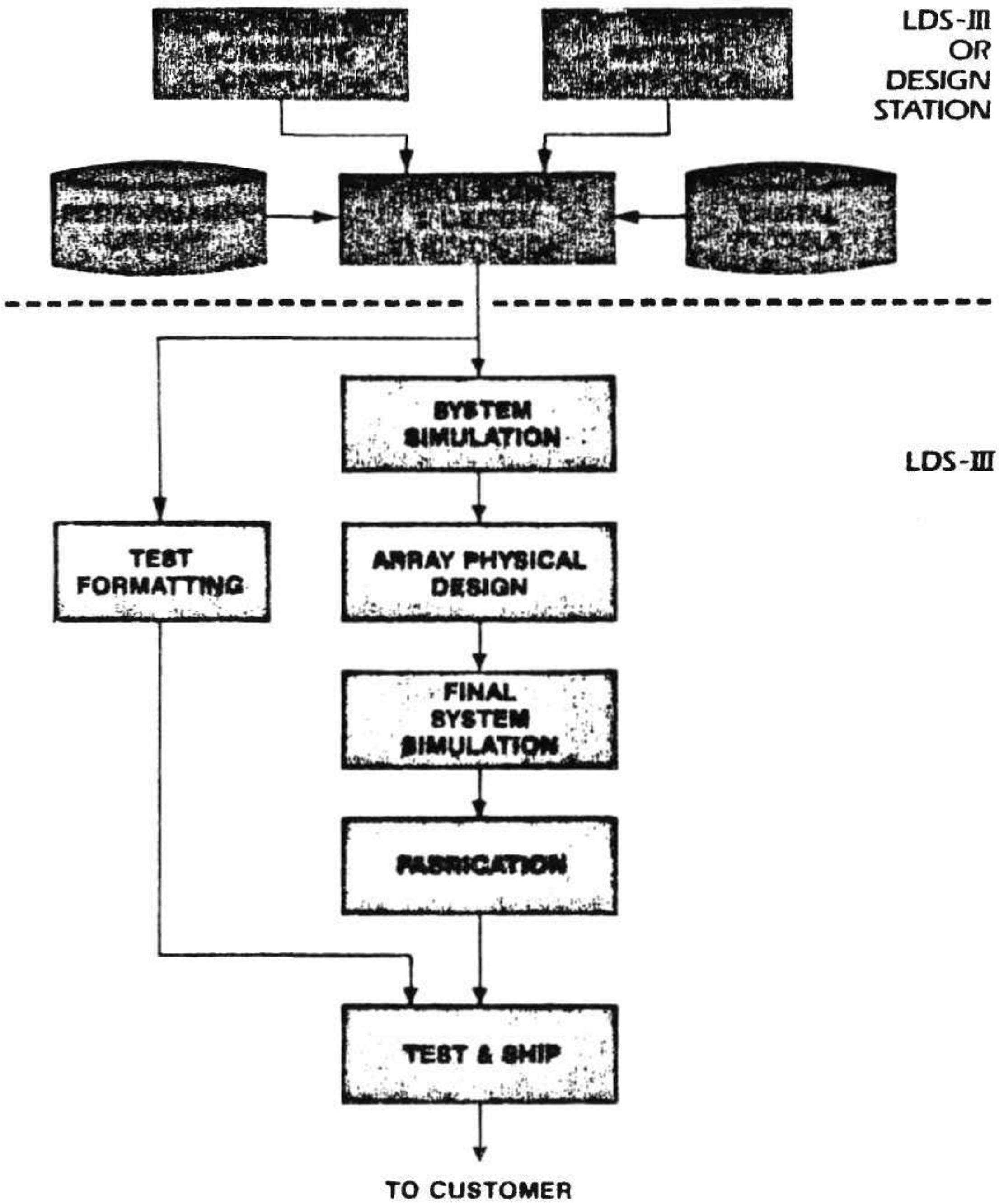
DESIGN AUTOMATION USING LDS™



CUSTOMER DESIGN SUPPORT

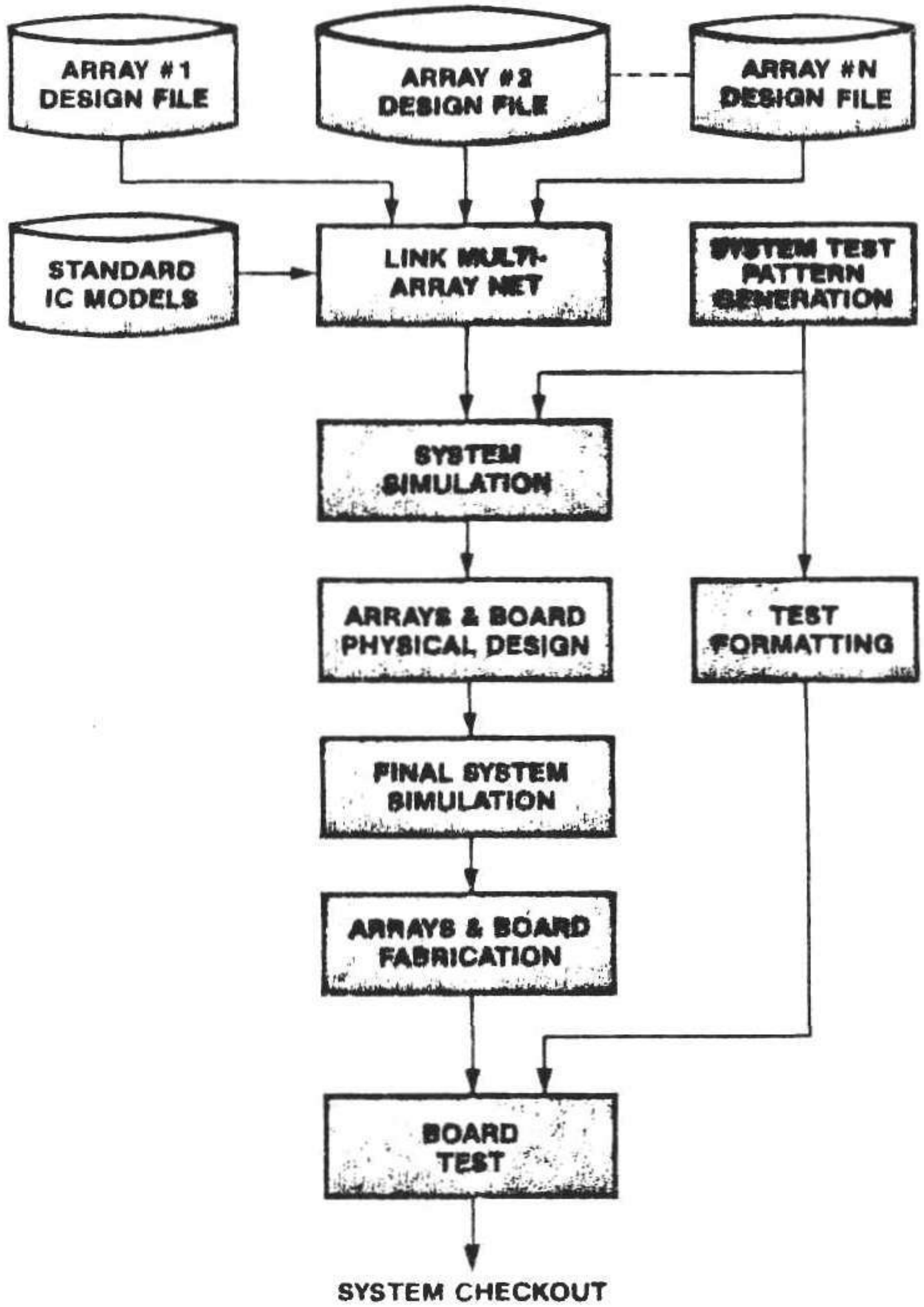
- System designer rather than semiconductor designer oriented interface
- Training centers and courses
- Applications support on hand
- Multi Design centers
- Documentation

INDIVIDUAL ARRAY DESIGN FLOW



LSI LOGIC CORPORATION

SYSTEM SIMULATION



Nielsen Dataquest

apollo
computer inc.

COMPUTER COMPANIES AND INTEGRATION

apollo computer inc.

COMPUTER COMPANIES AND INTEGRATION

- INTEGRATION: DEFINITION AND REQUIREMENTS
- ROLE OF COMPUTER VENDOR
- "THE INDUSTRY"

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Nielsen Dataquest

**THE ROLE OF A MODERN CUSTOM SUPPLIER
IN THE FIELD OF VLSI DESIGN**

Graham Shenton
Vice President Marketing
International Microelectronic Products

Mr. Shenton is a Vice President of IMP and is responsible for Marketing and Engineering Design Systems. Prior to assuming this responsibility, he was a founder and Vice President of Engineering at IMP. Previously, he was Director of International Engineering for AMI, Inc., based in the United Kingdom. His earlier experience includes positions at Plessey and Amalgamated Wireless Value Company, involving product design, engineering management, marketing, quality assurance, test engineering, and applications. Mr. Shenton studied Electrical and Electronic Engineering at the Universities of Sydney and NSW and holds B.S. and M.S. degrees in Engineering.

Dataquest Incorporated
CAD/CAM INDUSTRY CONFERENCE
September 26-28, 1983
Newport Beach, California

THE ROLE OF A MODERN CUSTOM INTEGRATED CIRCUIT SEMICONDUCTOR MANUFACTURER

by

Graham Shenton
Vice President, Marketing
International Microelectronic Products
San Jose, California

What I plan to do today is look at the role of a modern custom--and the emphasis is on custom--semiconductor manufacturer from the user's point of view. I want to explore how the prospective user of a custom IC should select a vendor, when he should use the resources and specialized knowledge of the vendor, and when the decision is his alone. A corollary to this is the use of a custom IC manufacturer to help determine if a custom IC is even the best solution. In fact, that should be the starting point.

By now you have probably heard all the reasons for choosing a custom circuit: Increased confidentiality so the competition will have a harder time copying your design. A unique application for which no standard products exist.

Lower production cost traded off against higher development cost and maybe, but not always, a longer development cycle.

What you haven't heard from custom manufacturers (and we may be doing you a disservice), is why and when you don't need a custom IC to do your job. Sometimes we don't tell you because of ego--yours. A system designer comes to us and wants his latest system cast in silicon because it is sexy, or because everybody else is doing it, and "who do you think you are, Mr. Semiconductor Manufacturer, to tell me whether or not I need a custom circuit. Just build what I tell you to build."

With markets changing so rapidly, some designers want their systems in a custom IC to prevent easy reverse engineering, before they have had a chance to recover their engineering costs and meet their business plan's ROI. However, that rapidly changing marketplace happens for two reasons and the designer must decide which reason causes the change before he can decide whether or not to use a custom IC.

If the market is changing because the manufacturer has hit upon a gold mine and it is easy for his competitors to copy his system and enter the market with little or no development cost, then there are few alternatives. You could encase your product in a metal box, weld the box shut and have it self-destruct when forcibly opened--messy. Mislabel the parts--expensive. Or switch to custom circuits, which also saves you costs and increases your reliability while giving you the confidentiality you sought.

The personal computer market is a textbook case. Apple II computers are easy to copy and have been copied by many manufacturers. It's simple: just pop the cover, read the labels on the ICs, and bingo! The fact that Apple is using more and more custom ICs in their machines, and that the IBM PC started with six semi-custom gate arrays (as has been reported in the media), supports the use of custom ICs in this market environment as the right move.

However, if the market is changing because products have a very short lifecycle, then it may not be appropriate to put your system in a custom IC. Some markets, particularly in the consumer fad area, have such a short market window, that to lose any of it to development time would be a disaster. A product built of off-the-shelf components still takes some time to copy, and by the time your competitors are to market, there is no market left.

I hedged my bet on that last item because there are times that a custom IC can be advantageous in markets with a short time span. One is when TTL lead times get so long it is faster to design and build a custom circuit. In fact, that is the case today if your design is dependent on certain TTL parts that have lead times of 20 weeks or more.

A second case is when you know your market and you know what some of the changes are going to be, or you are confident of the new bells and whistles your product is going to need in six months. Then go ahead and build your custom IC, but include on it all the features that you can release over a reasonable market timeframe in order to continuously upgrade your product. The features are then on all products, but you're not releasing them for general use until you are ready. Having a feature on a chip is useless unless someone tells you it is there and how to access it.

Some watch manufacturers used that strategy and they still do. First, they designed one chip with all the bells and whistles. Then they introduced a plain vanilla watch with time and date. Their next version added day-of-the-week. This was followed by a timepiece with a stopwatch built in. And if they thought far enough ahead, they included a calculator function with memory. They did this partly because of the economy of scale--it was cheaper to build one chip and not use all its functions in one product than to keep redesigning the chip--and partly because the chip was one of the least expensive items in the watch.

Now that you have decided that a custom IC is the only way to produce your product, your design problem starts--how do you pick a vendor? If a custom manufacturer has helped you get to this point, then the question is probably answered already. If not, then we start to get into the role of the modern custom IC manufacturer. I will assume that you compile your vendor list from industry lists, advertisements word-of-mouth, etc. And that you have whittled down the list by eliminating those vendors whose minimum requirements in terms of volume and/or money are beyond your needs. Now, how do you select from the dozens that are left?

First, you need to realize some things about the custom business. You have all heard how custom vendors are looking for close, long-term relationships with their customers. But I'm not sure you really understand what that means and how profoundly it can affect your business. Most of you look at this relationship in terms of "can I trust the custom manufacturer to keep my confidence and not reveal any of my secrets, even inadvertently, to my competitors? And, can he deliver a reasonably reliable product on time?"

That's not enough. Let's start at the beginning. You decide you need a custom chip and have heard, for example, that IMP can give you a full custom circuit, using a standard-cell design methodology, in 14 weeks from approved logic diagram to packaged, tested working parts. What a shock when you discover that before you can even get to the actual design phase, you still have to negotiate for price, NRE, delivery, etc., go through the traditional credit checks, and then finally get to the definition phase!

This is where you have to carefully evaluate the custom supplier from a long-term point of view. In the short-term, you are going to have to endure the same routine with every supplier on the first circuit. And some can do it faster than others. This is where the experience of the custom vendor can make a tremendous difference.

The learning overhead is so high, that an experienced custom supplier with a good reputation can minimize this phase of the project by preventing the customer from reinventing the wheel. The right custom supplier knows the customer interface well, he knows what will and won't work, and he knows how to help the customer define his own needs.

Furthermore, buying a custom circuit is so different from buying a standard product that top management (as well as engineering management) must get involved. In fact, Purchasing may be the last to get involved.

Remember, we're still just talking about the first circuit you are going with a particular custom supplier. However, it is rare that a company does a single custom circuit unless they have been burned. If the circuit works, the benefits are so great that they often look at any other designs they have that can be reduced to a single silicon chip.

This is where that long-term relationship really pays off. By working well with the customer, the negotiations on each succeeding circuit can be minimized. Passing on to the systems designer as many design skills as possible, either through teaching or CAD, minimizes the definition and maybe the whole design phase. Additionally, intimate knowledge of the custom design process allows the systems designer to incorporate superior cost/performance in his next design.

It is extremely important that you establish that the vendor will continue to be as responsive after the initial contacts. It does you no good to have the president and chief design engineer put a full-court press on you for the initial circuit and then never see them again on succeeding circuits. What you are buying with this long-term relationship is a commitment from the vendor to always give you the best possible design and manufacturing available. That he will help you decide what should and should not be put in silicon and not just try for every circuit he can get. But most of all, that the vendor will grow with you; that he will continuously upgrade his processing and design capabilities to keep you on the leading edge of technology.

Ask where the vendor is positioned in terms of process capabilities. He must be on the leading edge if he is to give you the best processing there is. This is where you are going to get your cost/performance edge in the marketplace. You have to be given the ability to build your products in processes comparable to those used on standard products, but you also have to balance aggressive technology advances against production requirements.

And, even if you can't make use of that state-of-the-art technology, you need to know that it will be available when you can. It also shows you a commitment by the custom IC vendor to continually hone his skills and not simply rest on past performance.

The custom IC vendor who is not aware of where the market is going and who is not reasonably close to it is going to be left behind. This can prove especially deadly to a customer because the security that builds up with the credibility of a custom vendor over time can lull a customer into not keeping tabs on the custom market. The customer is caught unaware and, before he knows it, he is scrambling to find another vendor on a rush basis.

Keeping up on process technology is only one aspect of the custom business today. The other is design. In particular, computer-aided design.

The high cost of custom ICs can be directly attributed to the labor intensive aspects of design. This also accounted for the long design cycles. The newer CAD equipment and the methodology for using it has significantly decreased both the cost and design cycle time, as you have previously heard at this conference.

The task of selecting among vendors based on their design tools, then, becomes increasingly difficult if you start focusing on minor variations in these factors. The difference between an 11- and 14-week design cycle or $30,000 or $40,000 design cost are minuscule against the 36-week and $200.000 cost of a fully hand-drawn design. The focus should be on design methodology first and then CAD tools; the trick is not to get hung up on details.

Don't get me wrong. I'm not trying to say that $10,000 is insignificant, but other factors may be more important and may offset that cost difference. One of those factors is vendor reliability; i.e., does he deliver on time? Does he do what he says he is going to do? Another is credibility; i.e., what is the probability that the circuit will work the first time?

Of increasing importance are customer-usable CAD tools that are touted as "user-friendly". Be careful of this buzz word. Find out if it means easy-to-use or easy-to-learn. Ideally it means both but, if not, be sure that you get the one you need. If a few people or a single group are going to be responsible for designing all custom chips in your company, then an easy-to-use system is more important. It becomes worthwhile to learn a great number of sophisticated and complicated commands once because constant use will ingrain them in the chip designer's mind.

If, on the other hand, chip design is just one aspect of the engineer's job, then an easy-to-learn system is more desirable. There is going to be a certain amount of time wasted going up the learning curve each time the systems designer returns to the CAD system to design his next chip. An easy-to-learn system minimizes this time.

Regardless of how the system is used, the ideal design methodology should encompass the following:

- o Minimize the time needed to implement a system design in a working chip in production. The emphasis should be placed on design accuracy and on achieving "first-time correct" performance.

- o Allow for designer controlled flexibility in the trade-off between development time and silicon area, i.e., the trade-off between development cost and production cost.

- o Hierarchical system to allow the user to enter at the level of his expertise or need. For example, system designer should be able to work at a functional block level and to produce good designs without becoming a semiconductor circuit design and layout expert.

- Capable of designing the most complex circuits possible with advanced technology. This also means the ability to easily assimilate technology improvements into the design system.

- Provide techniques to ensure that the chips produced are testable. The best time to think about the testing problem is during the system and logic design phase.

To implement the above methodology in a system expressly designed for the systems designer would require the following features:

- Design capture via schematic entry on a color graphics terminal or via a direct textual description of the logic design on a video display unit. In either case, the design must be captured once and automatically translated to the same hierarchical network description from which the design proceeds and to which the design is continually compared.

- o Design consistency implemented by having a single integrated data base that contains all the various levels of abstraction of the design, system description, logic diagrams, transistor representation and final physical layout in mask and wafer form.

- o Library of functional blocks that exist at various levels, e.g., logic, transistor, layout, but to the designer represent the fundamental design components of the system. The system designer should be able to call on a range of commonly used TTL elements or their CMOS equivalents from which to construct a system.

- o Construction of the functional blocks should be as process independent as possible to avoid a major limitation inherent in most libraries. In attempting to work with the most advanced technologies, there is a limited amount of time to characterize new design elements before the process advances and you have to go back and recharacterize all elements. Process independence allows the custom IC vendor to concentrate on adding new cells and features to the CAD system rather than on updating an older library.

Process independence allows the whole library to "instantly" take advantage of process advances.

- The designer must be allowed to the make the complex design decisions. The system should give him rapid answers from which to proceed with the design process. For example, if the requirement is to implement a TTL design with minimal design time and cost, he may decide to make maximum use of existing library components. If more engineering effort is justified in the form of developing new functional elements or in the planning of the layout because of high production volume, then more interactive design time can be spent with subsequent reduction in silicon area and production cost savings.

Features such as these make a complete design system and not just another development aid.

One further point: the purpose of all custom IC CAD systems is to help more engineers design better circuits more easily. And all CAD systems on the market do this to a greater or lesser extent. However, if the system is not universally available, then you are being locked in to a sole source design and lose a lot of flexibility.

Design flexibility comes from having a company's functional library resident on many different workstations, CAD systems houses, to customer mainframes to the specific IC manufacturer's design system. Each offers a different level of versatility for the user.

To make maximum use of a custom IC manufacturer's capabilities requires using the manufacturer's own design system. It was built with their manufacturing facility in mind and there is almost an implied guarantee that what is designed can be built. The system will be even more powerful if the manufacturer uses the same system as his in house design system. This will insure that it will be constantly upgraded and include all the latest features. It also means the manufacturer has an intimate knowledge of what the design system can and can't do and how to get the user out of the jams he will inevitably find himself.

Purchasing just the design software and running it on your own mainframe will accomplish almost the same thing. The possible glitch here is that no two mainframe systems are identical and care must be taken in bringing up the software. And then you have the problem of maintaining the system and incorporating updates as they are issued.

The most flexible position for the user is the standalone workstation that can access any number of different libraries ranging from gate arrays to full custom standard cells, to PC board layout, etc. Here, you must be very careful to ensure that the design methodology is not missing. CAD systems houses don't design ICs. Only the custom IC manufacturer is the source of that knowledge. So it is important when selecting an independent CAD system to make sure that this training is available to you either from the owner of the library directly or through the CAD manufacturer.

In fact, that last point is so important, I want to repeat it. In order for the relationship between the custom manufacturer and the custom user to work smoothly over the long haul, the IC manufacturer must be willing to help the user acquire a design capability regardless of the design system or manufacturer chosen. The custom IC vendor must help in the selection of hardware. The custom IC vendor must recognize the need for and help select a second source. And, the IC manufacturer must, above all, remember that the design belongs to the customer and all he can expect is a reasonable production return.

Another point which is often overlooked because it was not a problem during the recent recession, is the availability of manufacturing capacity to build the parts designed. Many custom IC manufacturers do not have their own wafer fabrication facilities; they contract actual production out to silicon foundries. This worked fine during the recession when there was a lot of excess capacity available, even though it did require them to juggle the various process differences of different foundries. But if a foundry loses a process or decides to change or even cancel it, they have no recourse but to find another foundry. Their customer doesn't want to hear about another once-removed vendor's problem. A more likely scenario is unavailability of capacity as the business starts to boom again. Those vendors without the ability to control their own manufacturing, those without a factory, could well be squeezed out of the market.

A custom IC vendor with manufacturing capability must perform on both the design and manufacturing phases to be credible. This ensures customers that the right attention will be paid to producing their parts with the best possible yields. In the final analysis, a custom IC manufacturer is selected based on the company's reputation more than any other factor. This is an easy thing for a new customer to check via references and industry sources.

In this discussion I have tried to emphasize the roles of a modern custom IC semiconductor manufacturer, how to select a custom solution (and how this choice is directly influenced by the market), how to select a vendor and when to use his knowledge and resources, and how to implement design methodologies for a flexible, all-custom IC CAD system. A company that satisfies these roles is an extremely valuable partner in system development. The conclusion I hope you have drawn is that you need a well-balanced custom IC manufacturer if your designs are to be consistently successful.

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CAM ON THE MANUFACTURING FLOOR:
PRODUCTS THERE TODAY

Albert H. Libbey
Vice President New Business Development
Programmable Controller Division
Gould Inc.

Mr. Libbey is Vice President of New Business Development at Gould Inc.'s, Programmable Controller Division in Andover, Massachusetts. Prior to that position, he was Vice President of Engineering at Gould. His experience includes management and design roles associated with programmable controllers and their I/O products, applications of programmable controllers, communication systems, and instrument systems. Previously, he was Scientific Executive at E.G.&.G., Inc., Bedford, Massachusetts, where he worked in the Bedford Division for twelve years. He received his B.S.E.E. degree and his M.S. degree in Electrical Engineering from the Massachusetts Institute of Technology. He is a member of the Instruments Society of America and the Institute of Electrical and Electronic Engineers. He also holds memberships in Etta Kappa Nu and Sigma XI.

Dataquest Incorporated
CAD/CAM INDUSTRY CONFERENCE
September 26-28, 1983
Newport Beach, California

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CAM ON THE MANUFACTURING FLOOR: PRODUCTS THERE TODAY

ABOUT

- DISCRETE MANUFACTURING
- MAKING ENGINES
- CANNING SOUP
- ASSEMBLING TV'S

NOT ABOUT

- CONTINUOUS PROCESS MANUFACTURING
- MAKING PLASTIC
- DISTILLING GASOLINE
- GENERATING ELECTRIC POWER

NOTE THAT

O SO CALLED PROCESS INDUSTRIES HAVE DISCRETE MANUFACTURING AND VICE VERSA.

NOTE THAT (CONT'D)

- O CONTINUOUS PROCESS ALREADY AUTOMATED.
- O DISCRETE MANUFACTURING IS STRUGGLING TO INCREASE PRODUCTIVITY THROUGH CAD AND CAM.

NO STANDARD SOLUTIONS

EXAMPLE: METAL REMOVAL OPTIONS

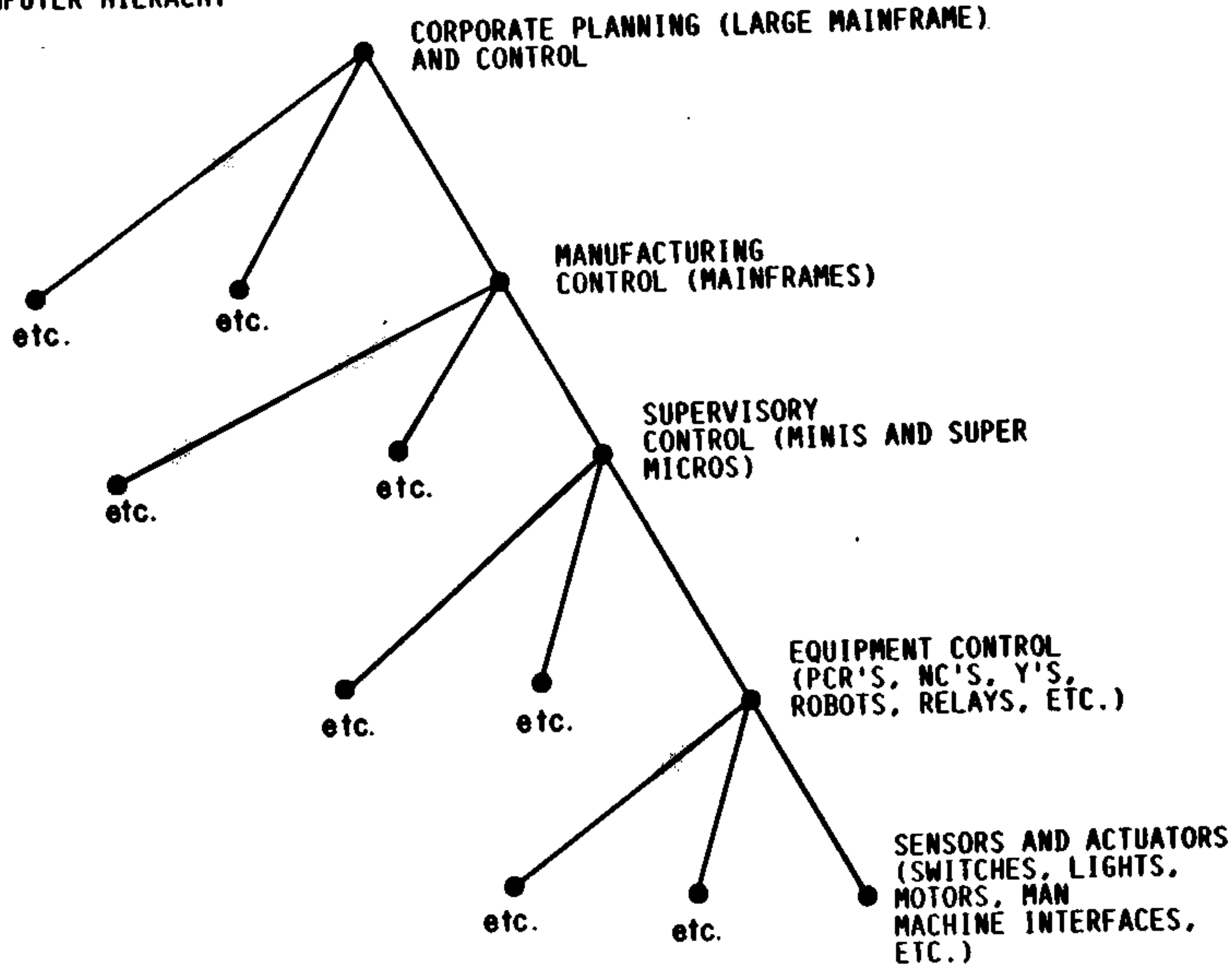
CHOOSE A SET AND SEQUENCE

FIXTURES	TAPPING
MILLING	DRILLING
REAMING	LAPPING
DEBURRING	ETCHING
CLEANING	FACING
THREADING	GRINDING
TURNING	TUMBLING
BORING	BURNING
PLANING	

COMMON THEMES

- O MANUFACTURING COMPUTER HIERARCHY
- O MANUFACTURING FLOW

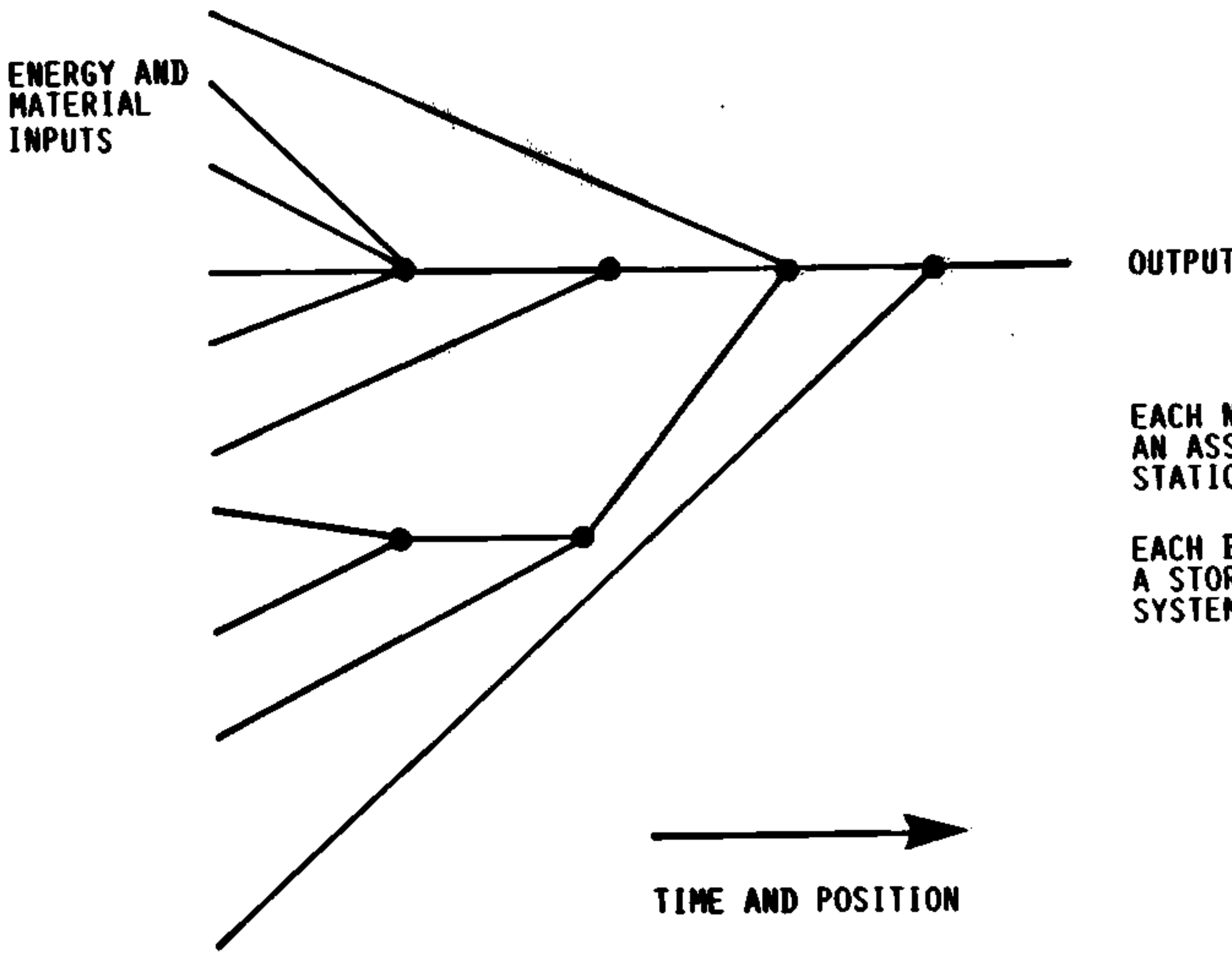
TODAY'S
MANUFACTURING
COMPUTER HIERACHY



CHARACTERISTICS OF THE MANUFACTURING COMPUTER HIERARCHY

- O THE MONEY IS SPENT AT THE BOTTOM.
- O THE NUMBER OF UNITS GOES DOWN BY A FACTOR OF 10 TO 100 FOR EACH STEP UP THE HIERARCHY.
- O THE RESPONSE TIME REQUIREMENT GOES DOWN BY A FACTOR OF 10 TO 100 FOR EACH STEP UP THE HIERARCHY.
- O THE LEVEL OF ABSTRACTION GOES UP WITH EACH STEP UP.
- O THE NUMBER OF PEOPLE WHO CAN UNDERSTAND EACH LEVEL GOES DOWN FOR EACH STEP UP THE HIERARCHY.
- O THE COMMUNICATION SYSTEM ARCHITECTURE OFTEN FOLLOWS THE HIERARCHY ARCHITECTURE.
- O THE BOXES AT THE BOTTOM OF THE HIERARCHY ARE ON THE FLOOR NEAR THE EQUIPMENT BEING CONTROLLED.

MANUFACTURING FLOW



EACH NODE, ●, REPRESENTS AN ASSEMBLY OR PROCESS STATION.

EACH BRANCH, —, REPRESENTS A STORAGE OR TRANSPORT SYSTEM.

CHARACTERISTICS OF THE MANUFACTURING FLOW

- EACH NODE AND BRANCH IS DIRECTLY CONTROLLED BY THE BOTTOM LAYER OF THE MANUFACTURING COMPUTER HIERARCHY.
- THE FLOW DIAGRAM HAS A ONE - ONE RELATIONSHIP WITH THE PHYSICAL FLOW OF WORK IN PROCESS.
- MANUFACTURING MARGINS GO UP AS THE INVENTORY IN PROCESS GOES DOWN.
- MANUFACTURING MARGINS GO UP AS THE PRODUCT QUALITY GOES UP.
- MANUFACTURING MARGINS GO UP AS POOR QUALITY IS DETECTED AND CORRECTED AT ITS INCEPTION.
- THE PRODUCT DEFINITION IS CHARACTERIZED BY THE MATERIAL INPUTS AND ASSEMBLY OR PROCESS STATION DEFINITION.

REQUIREMENTS FOR THE MANUFACTURING HIERARCHY

O REDUCE THE INVENTORY IN PROCESS

THROUGH ABILITY TO HANDLE SMALL BATCHES.

THROUGH ABILITY PROCESS BATCHES QUICKER.

THROUGH ABILITY TO MANUFACTURE IN RESPONSE TO ACTUAL SALES RATHER THAN SALES FORECASTS.

THROUGH HIGH AVAILABILITY.

O INCREASE THE PRODUCT QUALITY.

THROUGH INSPECTION AT ASSEMBLY OR PROCESS STATIONS OR AT THE NEXT STATION WITH IMMEDIATE FEEDBACK.

O RESPOND QUICKLY WITH LOW COST TO PRODUCT CHANGES.

O TOYOTA EXAMPLE.

FLOOR CONTROL FEATURES RESPONSIVE TO MANUFACTURING NEEDS

FEATURE	HOW PROVIDED
EASILY UPDATED WITH NEW PROGRAM NEW PRODUCT	O PROGRAMMABILITY O PROGRAMMABILITY BY MANUFACTURING PERSONNEL O COMMUNICATION TO SUPERVISORY COMPUTER
RAPID CONTROL RESPONSE FOR RAPID THROUGHPUT	O SHORT RESPONSE TIME O PROGRAM EASILY TUNED BY MANUFACTURING PERSONNEL O PEER - PEER COMMUNCIATION

FLOOR CONTROL FEATURES RESPONSIVE TO MANUFACTURING NEEDS (CONT'D)

FEATURE	HOW PROVIDED
HIGH, CONTROL AND CONTROLLED, AVAILABILITY	O RUGGED CONTROL O EASILY MAINTAINED BY MANUFACTURING PERSONNEL O CONTROL HAS ABILITY TO DIAGNOSE OUR FAULT O CONTROL HAS ABILITY TO DIAGNOSE CONTROLLED EQUIPMENT FAULT
PROVISION OF WORK IN PROCESS AND PROCESS FLOW DATA FOR PLANT PERSONNEL FOR PROCESS TUNING	O COMMUNICATION TO MANUFACTURING FLOOR MAN/MACHINE INTERFACE O QUALITY MEASUREMENT DATA GATHERING CAPABILITY O COMMUNICATE TO SUPERVISORY COMPUTER O GLOBAL COMMUNICATION

FLOOR CONTROL FEATURES RESPONSIVE TO MANUFACTURING NEEDS (CONT'D)

IMMEDIATE FEEDBACK OF OUT OF SPECIFICATION PERFORMANCE TO ALL CONTROL AND PERSONNEL

- O GLOBAL COMMUNICATION
- O COMMUNICATION TO SUPERVISORY COMPUTER
- O COMMUNICATION TO MANUFACTURING
- O FLOOR MAN/MACHINE INTERFACE
- O INTERFACE TO INSPECTION EQUIPMENT

MANUFACTURING FLOOR COMPUTATION DEVICES

- O RELAYS
- O NUMERICAL CONTROLS
- O PROGRAMMABLE CONTROLS
- O MINIS AND MICROCOMPUTERS
- O ROBOT CONTROLS

RELAYS

- O BOOLEAN LOGIC, HANDWIRED
- O SOFTWARE AND HARDWARE MAINTAINED BY ELECTRICIANS
- O MULTITASKING DONE BY SEPARATE LOGIC
- O COST EFFECTIVE FOR $<$ 20 RELAYS
- O RUGGED
- O 10 MS RESPONSE TIME
- O NO COMMUNICATIONS CAPABILITY
- O VERY LIMITED DIAGNOSTICS
- O MAJOR MANUFACTURERS

  ALLEN BRADLEY

  SQUARE D

PROGRAMMABLE CONTROLLERS

- LADDER DIAGRAM (BOOLEAN LOGIC).
- ALSO: TIMERS, COUNTERS, ARITHMETIC AND ASSEMBLY LANGUAGE LIKE INSTRUCTIONS.
- PROGRAMS SELF DOCUMENTING, EASILY CHANGED.
- PROGRAMS MAINTAINED BY ELECTRICIANS AND TECHNICIANS.
- HARDWARE MAINTAINED BY ELECTRICIANS AND TECHNICIANS.

PROGRAMMABLE CONTROLLERS (CONT'D)

- O DIAGNOSTIC CAPABILITY BUILT IN
- O MULTITASKING EASILY DONE
- O CAM INTERFACE TO INSPECTION EQUIPMENT
- O TYPICAL COST $5000.
- O RUGGED
- O DISCRETE AND ANALOG I/O
- O 10 - 100 MS RESPONSE
- O COMMUNCIATIONS VIA RS232 ASCII, AND PROPRIETARY BUS COMMUNICATIONS PROTOCOLS
- O MAJOR MANUFACTURERS
  - GOULD
  - ALLEN BRADLEY

ROBOT CONTROL

- O WALK THROUGH PROGRAMMING
- O SUPERVISORY PROGRAMMING VIA: VAL, RAIL, AML, ETC.
- O PROGRAMS CAN BE DOCUMENTED
- O PROGRAMS EASILY CHANGED
- O PROGRAMS MAINTAINED BY ROBOT CONTROL TECHNICIAN
- O HARDWARE MAINTAINED BY COMPUTER TECHNICIAN
- O SOME DIAGNOSTICS
- O SINGLE TASK
- O CAN INTERFACE TO INSPECTION EQUIPMENT
- O TYPICAL COST $15,000.
- O RUGGED
- O SERVO AND SOME DISCRETE I/O
- O TO MILLISECOND RESPONSE TIME
- O RS232 ASCII COMMUNICATIONS
- O MAJOR MANUFACTURERS

  G.E.

  GENERAL NUMERIC

MINI-MICRO COMPUTER

- ASSEMBLY AND HIGH LEVEL PROGRAMMING LANGUAGE (NAME YOUR FAVORITE).
- PROGRAMS CAN BE DOCUMENTED.
- PROGRAMS MAINTAINED BY SOFTWARE/SYSTEM PERSONNEL.
- HARDWARE MAINTAINED BY COMPUTER TECHNICIAN.
- DIAGNOSTICS MAY BE PROGRAMMED.
- MULTITASKING SUPPORTED BY VARIOUS OPERATING SYSTEMS.
- CAN INTERFACE TO INSPECTION EQUIPMENT.
- TYPICAL COST $5000. (WITHOUT PROGRAM).

MINI MICRO COMPUTER (CONT'D)

O NOT RUGGED.

O FULL RANGE OF I/O.

O TO 10 MICRO-SECOND RESPONSE TIME.

O RS232 ASCII COMMUNICATIONS

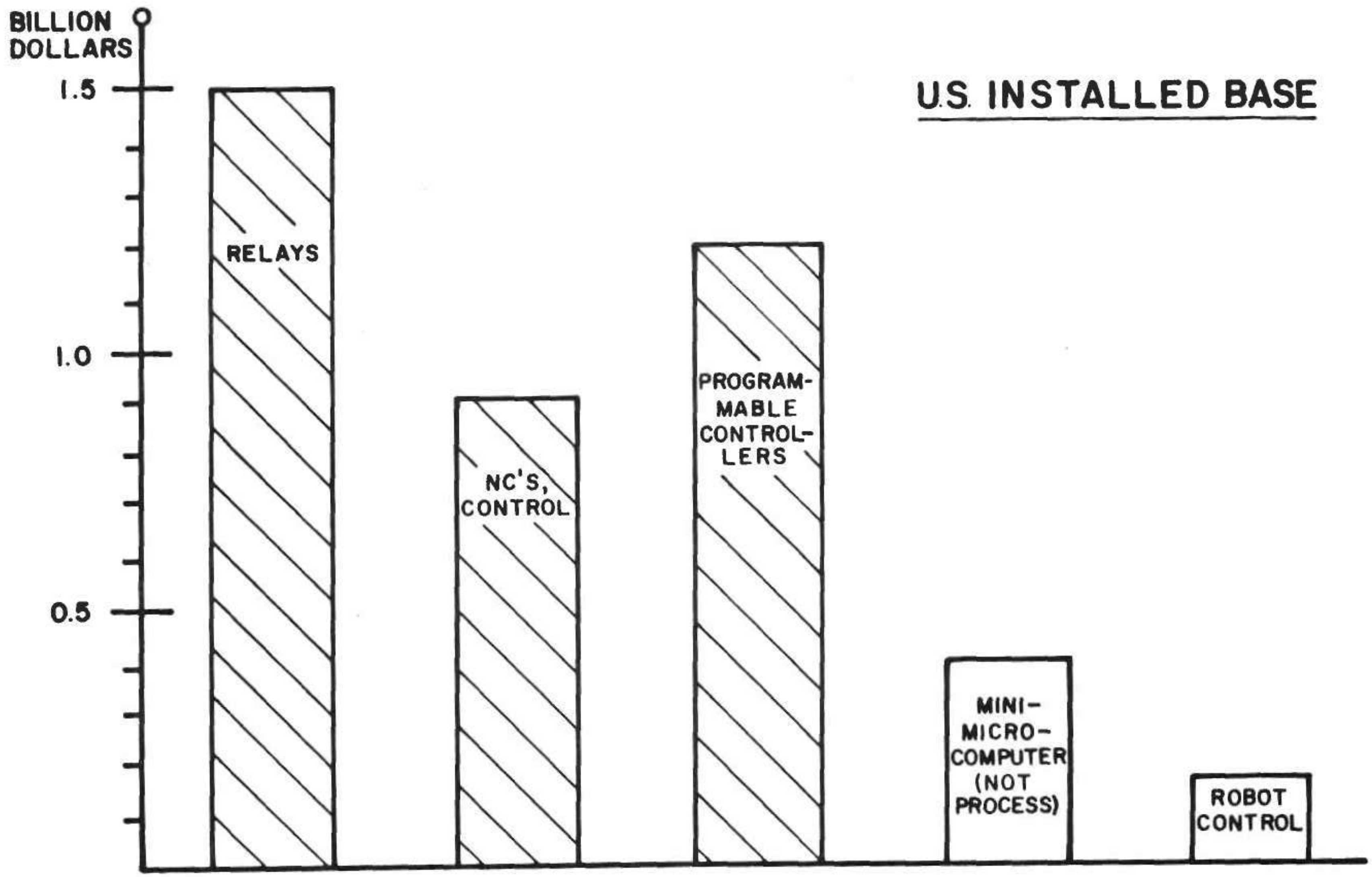
O MAJOR MANUFACTURERS

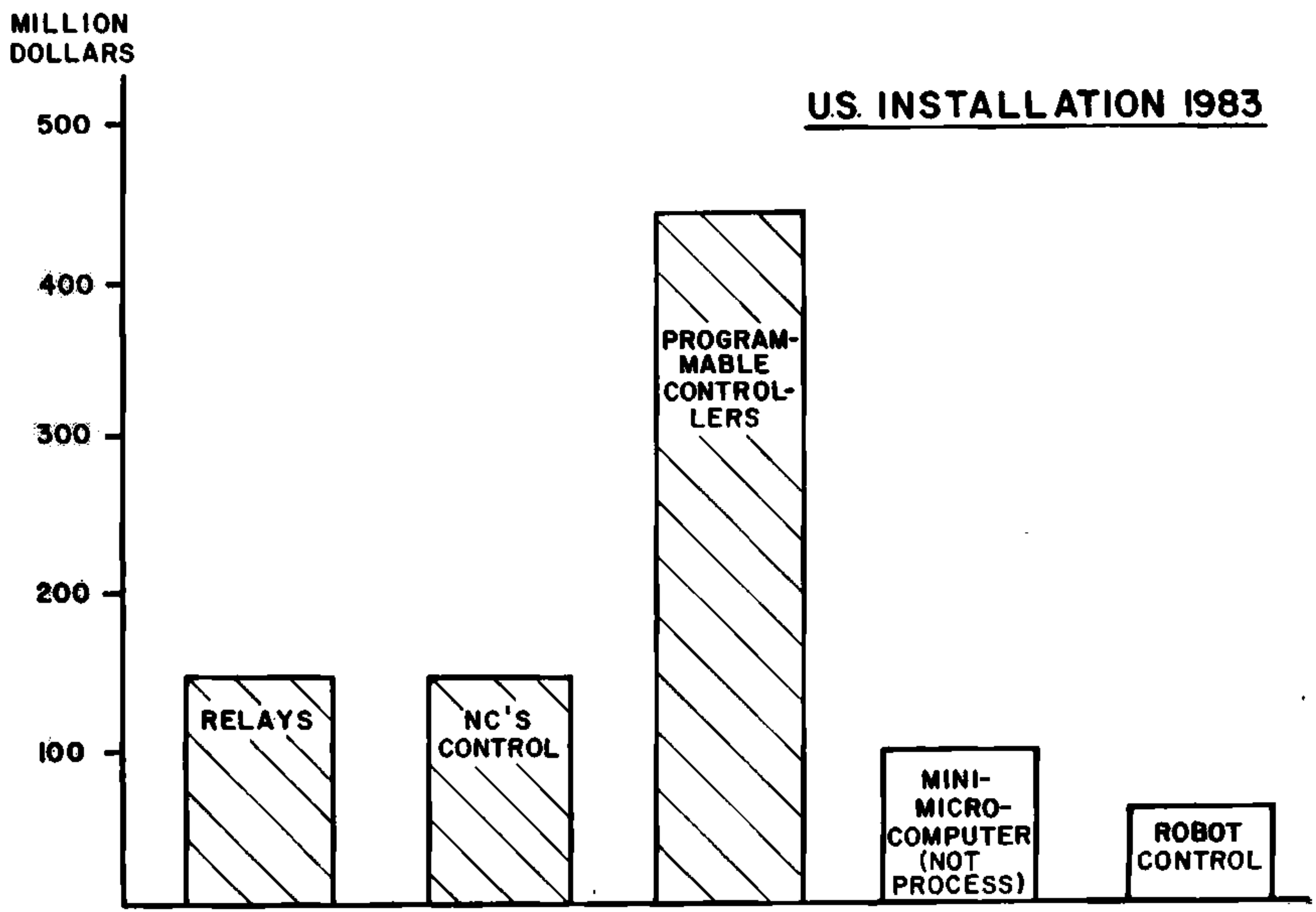
MOTOROLA

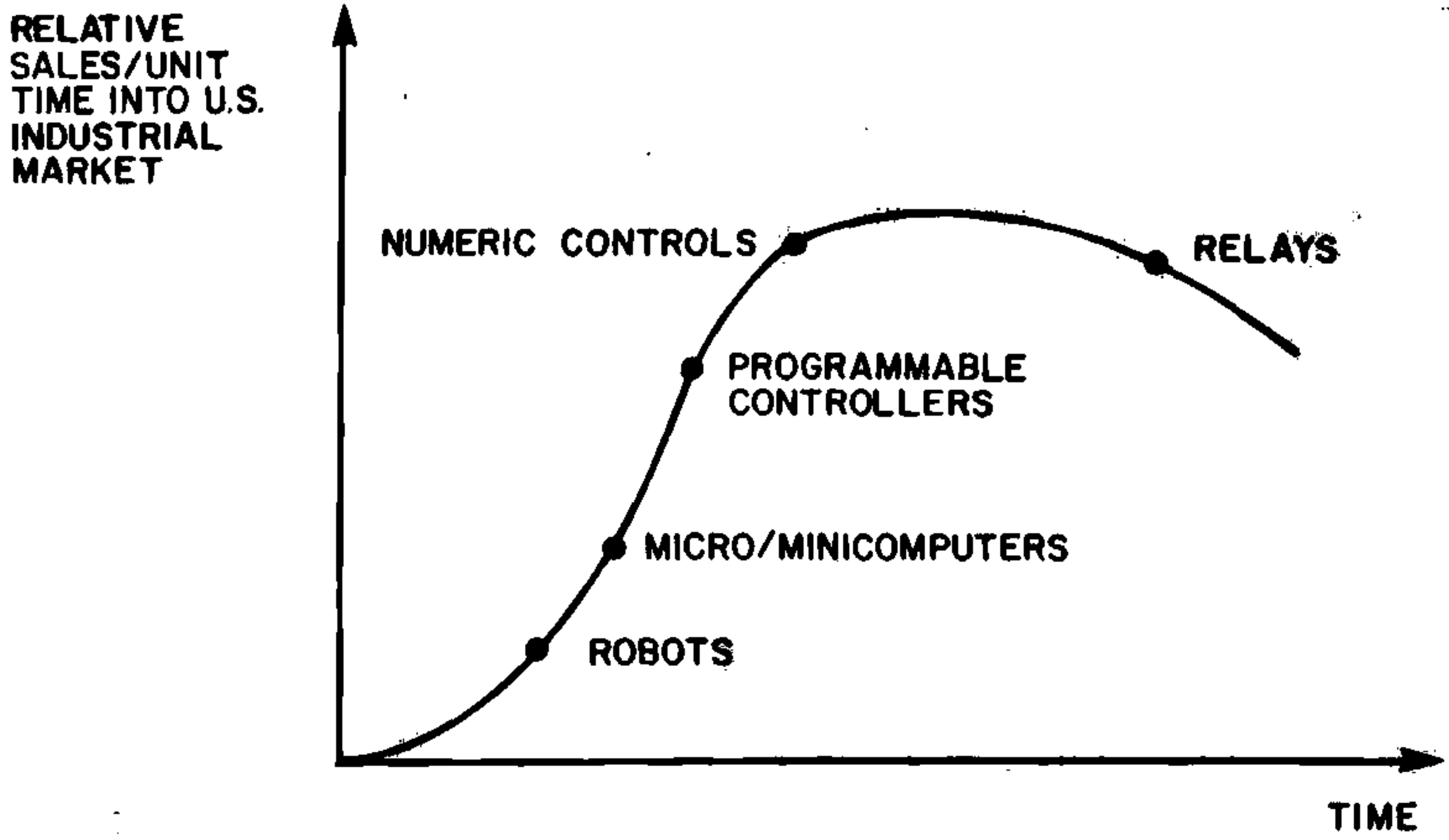
INTEL

DEC

U.S. INSTALLED BASE




U.S. INSTALLATION 1983
MILLION DOLLARS
500
400
300
200
100
RELAYS
NC'S CONTROL
PROGRAM-MABLE CONTROL-LERS
MINI-MICRO-COMPUTER (NOT PROCESS)
ROBOT CONTROL



PRODUCT POSITION ON LIFE CYCLE CURVE

Dataquest Incorporated, A Subsidiary of A.C. Nielsen Company / 1290 Ridder Park Drive / San Jose, CA 95131 / (408) 971-9000 / Telex 171973

COMMUNCATION ZOO

RELAYS DO NOT COMMUNICATE

OF THE COMMUNICATORS LESS THAN 20% ARE CONNECTED TO SUPERVISION

OF THE COMMUNICATORS 50% ARE CONNECTED TO AT LEAST ONE PEER

VENDORS ARE OFFERING:

- TI WAY
- AB DATA HIGHWAY
- MODBUS
- MODWAY
- GM MAP
- DEC NET
- ETHERNET
- 802
- NAME YOUR FAVORITE

LESS FAT

LESS HAPPY

LESS DUMB

Nielsen Dataquest

Nielsen Dataquest

INTEGRATED CAD/CAM: AN ACHIEVABLE GOAL

Richard L. Justice
Director
Engineering Computer Coordination
Advanced Product and Manufacturing Engineering Staff
General Motors Corporation

Mr. Justice is Director of Engineering Computer Coordination and is one of the principals involved in establishing the integrated CAD/CAM system for General Motors. He has served his entire professional career with General Motors. Prior to his current assignment, he was Manager of Research Development for the Personnel Administration and Development staff. Previously, he was Executive Engineer at the Chevrolet Engineering Center and was responsible for developing the On-Line Engineering Releasing System. Before that he served with the General Motors Proving Grounds and with the General Motors Research Laboratories. Mr. Justice received his bachelor's and master's degrees in Mathematics from Purdue University.

Dataquest Incorporated
CAD/CAM INDUSTRY CONFERENCE
September 26-28, 1983
Newport Beach, California

INTEGRATED CAD/CAM - AN ACHIEVABLE GOAL

Almost everything seems to be Computer Aided today. We now place CA in front of all of our industrial processes--design, engineering, test, manufacturing, instruction, scheduling--the list goes on and on. What is important to industry leaders today is achieving the full potential of that computer aiding. It has been remarkably profitable to use these aids even though, in most cases, they were strictly used for automating a formerly manual task--or only represented a productivity gain. What the industry now desires is a path that will lead to integration of these entire systems.

General Motors is a company that is certainly able to exhibit all of the issues that have spawned this current set of non-integrated computer-aided technologies. With over 500,000 employes engaged in 162 separate manufacturing and assembly facilities producing over 6,000,000 cars and trucks each year, and distributing them to more than 10,000 dealerships around the world--we do have an opportunity to severely test the extent to which our systems are integrated.

It is my contention, however, that any industrial concern can demonstrate most of these same problems, be it another General Motors or a cottage industry. The objective of this presentation is to outline for you just what are the obstacles or roadblocks to integrated CAD/CAM. Even though some would suggest that it is foolhardy to undertake such a listing, I believe it to be limited to ten broad categories.

Product Configuration Control

Data Representative and Proliferation

Data Exchange

Enterprise Data Management

2-D to 3-D Conversion

Surface/Solid Modeling

Math/Wood/Metal Models

Tool Design/Construction

Technology Transfer

Management Discipline

The format of this presentation will be to discuss each of these areas, or roadblocks, in a manner that illustrates not only how they delay the achievement of integration, but also to indicate how and when they may be overcome. Others will enumerate the cost/savings of integrated CAD/CAM, a subject to which our project could also make contributions, however, what is important at this point along the road to such a system is the recognition of and agreement concerning solutions to the major roadblocks. Consider each of them in turn:

PRODUCT CONFIGURATION CONTROL

In order to produce an end product, it is essential to describe in detail every aspect of that product--from conception through to fional assembly and distribution. Hence, product configuration information will encompass physical properties, geometric data, usage data, manufacturing concepts, assembly fixtures and a lot more. Control of these data in a manual world has been less than optimum. Unfortunately, many of us to date have only attempted to automate that cumbersome manual procedure--and not taken advantage of electronic methods to bring it into full operation.

From the point of view of producing a product, CAD/CAM has not yet achieved a significant level of integration. CAD/CAM has been applied separately to many aspects of design and manufacturing, and has resulted in significant local improvements in productivity. This first level of return from CAD/CAM has fueled rapid growth, but why has integration been so elusive? Major efforts have been going on for years in IPAD (Integrated Program for Aerospace Design), ICAM (Integrated Computer-Aided Manufacturing), and all other commercial systems tout their integrated functions. It is obviously easier to recognize the need for integration than it is to achieve it.

The key ingredient to the successful CAD/CAM applications to date has been the graphic console and the ability to use human understanding along with computer tools. Very little of CAD/CAM has become completely automated to the point where man is no longer valuable. The problem with integration is that it has been looked upon as a computer-automation process that did not require an extensive human component. All the data would be stored in the computer in a totally neutral form and drawn off as needed by downstream activities. More and more this simplistic view is proving to be unrealistic.

The successful data bank at GM's Fisher Body Division and the CIIN data management system at Boeing are largely manual processes that use limited computer aids. Every GM design activity has a defacto data administrator who has developed a mostly manual system for keeping track of design files. The PDDI program (Product Data Definition Interface), which is a subprogram to ICAM, is beginning to discover that product data bases are totally inadequate to drive manufacturing systems. The whole concept of a computer-driven CAD/CAM process is currently being overstated.

Industry needs to recognize the data administration function for design in the same way as it recognizes specifications people. (There is even the possibility that these two functions could be combined.) In any event, data administration processes need to be formalized rather than continue on an ad hoc basis.

There is technology becoming available that will greatly aid the data administration function. Relational data base managers, such as IBM's DB2, show promise of being flexible enough to evolve along with the data administration function and provide any degree of relationships.

Integration is inherently the management of relations. The combination of people and these new tools could result in a long-term breakthrough in data administration.

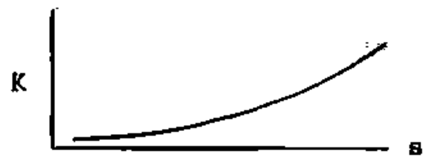
A general conclusion is that product configuration control is not attainable until this data administration function is put in place with a relational data base manager. I will return to this point later in my presentation.

DATA REPRESENTATION AND DATA PROLIFERATION

There are many ways to represent product design in a computer. The most simple schemes use the old concept of "Do it like we've always done it." The result is a computer-aided drawing system. Two dimensional representations of sections of the product are designed and plotted. Transfer of the 2-D data to other 3-D systems is difficult. There are many of these systems and CADAM is one example.

More complex computer systems allow the design of 3-D "wire frame" models. Wire frames are blended with equations to create surface "math models." Points and vectors are connected by other vectors or by polynomials, arcs, spirals, etc. The most suitable technique depends upon the product being designed. For example, sheet metal designs lend themselves to wire frame approach. Traditionally, parts are designed without metal thickness shown, and hidden lines are not shown as they are in the design of castings. Individual point locations are connected by Euler spirals.

Somewhat more important, than specific techniques used to design and define the product, is the compatibility with downstream users. Sheet metal product design is based on aesthetic and aerodynamic requirements. Basically, the mathematical implementation is the control of curvature along the arc length of individual lines. Ex:



Used for aesthetic design

K	= Increasing
dK/ds	= Increasing
d^2K/ds^2	= Increasing

Requirements for tooling and manufacturing are different from those in product design. Design of sheet metal parts in each stage of manufacture includes draw binders, draw walls, trim ledges, beads, prongs, and other metal control devices. Usually the design criteria involves length of line analysis and minimum energy curve design, or- $\int K^2 ds$ = minimum along arc length.

Obviously, computer systems need to be different to accomplish different design goals.

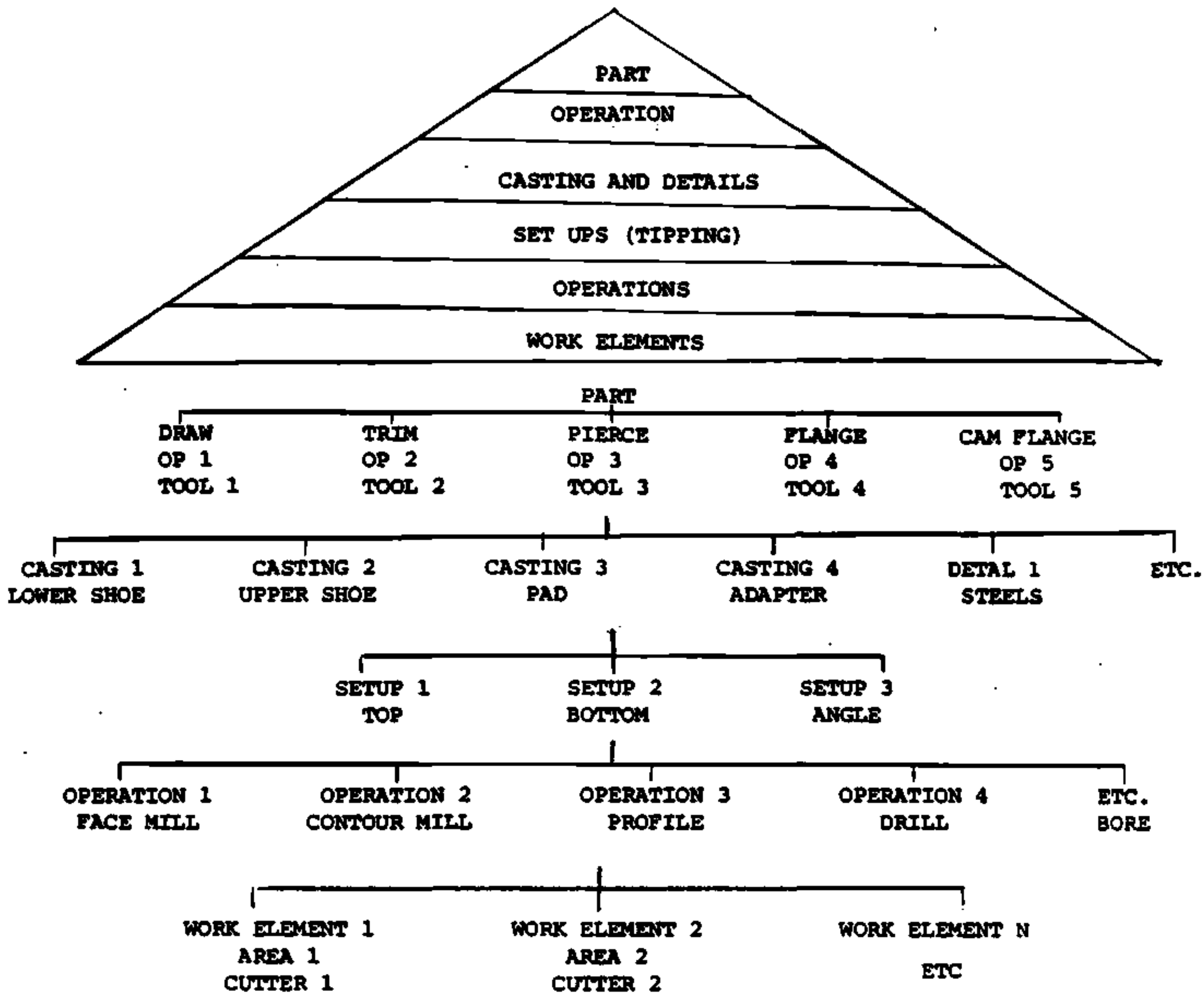
Transfer of data from one computer to another always involves some loss of precision and definition. Retaining data in one computer so that successive operations can be performed on it is a desirable goal. Even so, the problem remains that down stream users have little control over the format of the design given them. Curves designed by spirals in one system do not always map properly into a linear or vector environment. Two dimensional overlays or drawing type output can be almost useless in a 3-D machining mold.

Thus, we have the problem of:

1. <u>Data Compatibility</u>

   Integrated CAD/CAM systems must produce data in formats "usable" by all users.

The "explosion" of data that naturally emerges from the processing, tool engineering, machining, assembly and tryout activities must be managed. A single sheet metal part may contain 100 lines or a total of 5,000 discreet point locations. By the time this part data is received at the tool room machining area, it would look something like this: (See next page)


PART
OPERATION
CASTING AND DETAILS
SET UPS (TIPPING)
OPERATIONS
WORK ELEMENTS
PART
DRAW OP 1 TOOL 1
TRIM OP 2 TOOL 2
PIERCE OP 3 TOOL 3
FLANGE OP 4 TOOL 4
CAM FLANGE OP 5 TOOL 5
CASTING 1 LOWER SHOE
CASTING 2 UPPER SHOE
CASTING 3 PAD
CASTING 4 ADAPTER
DETAL 1 STEELS
ETC.
SETUP 1 TOP
SETUP 2 BOTTOM
SETUP 3 ANGLE
OPERATION 1 FACE MILL
OPERATION 2 CONTOUR MILL
OPERATION 3 PROFILE
OPERATION 4 DRILL
ETC. BORE
WORK ELEMENT 1 AREA 1 CUTTER 1
WORK ELEMENT 2 AREA 2 CUTTER 2
WORK ELEMENT N
ETC

Thus, we have problem number two:

2. <u>Data Proliferation</u>

In order to produce the parts for the dies which stamp one panel, we may be looking at several thousand operations. Some of these operations require enormous data storage and retrieval capabilities.

For example: Complete N/C machining of a draw die for a hood panel requires approximately 100,000 tool centers. Each tool center is an x, y, z coordinate (18 scalars). The 18 scalars plus relational information require 40 bytes or 20 words for a total of 2 million words. At the rate of one-tenth inch per character, over five miles of punched mylar tape are required to drive the N/C mill. This is approximately 40 rolls of tape--for just one die! Punched tape will not be the medium of the future.

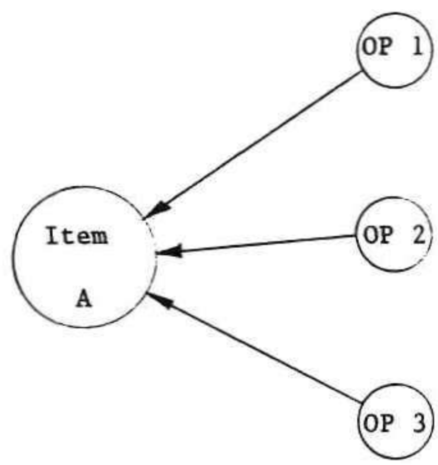
Astronomical numbers of tool centers are not the only concerns in data proliferation. As part surfaces are duplicated in tree structure processing/manufacturing operations, it becomes increasingly difficult to quantify the effects of engineering changes. Which element of which operation on which detail of which die is affected--and to what extent? Is a new stock list required? Are new setups required? And so on...

Modularized CAD/CAM systems cannot deal with the above problem. It doesn't matter whether B. Splines (Computer Vision), Polysurf (Prime) or Gordon Surface (GM CGS) were used to define the element if you cannot readily find every occurence on the structure.

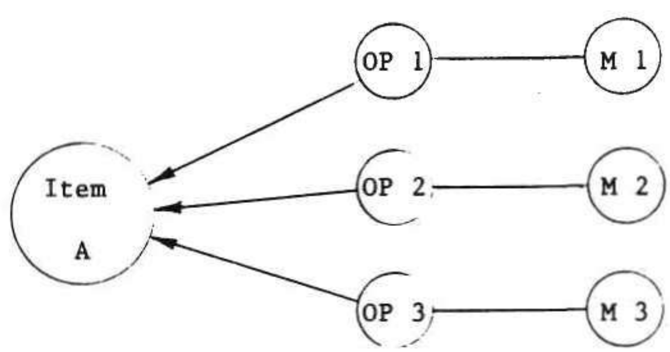
Perhaps the most important single change we could make is to completely sever the dependence on drawings. Their past importance still pervades current thinking. Design systems should create computer math models with downstream compatibility. Drawings are generally incomplete, inaccurate and out-of-date. The math model itself could be kept up to date and, if properly connected to a relational data base, all the downstream operations could be kept up to date as well.

What is needed is to have one item known to several operations.

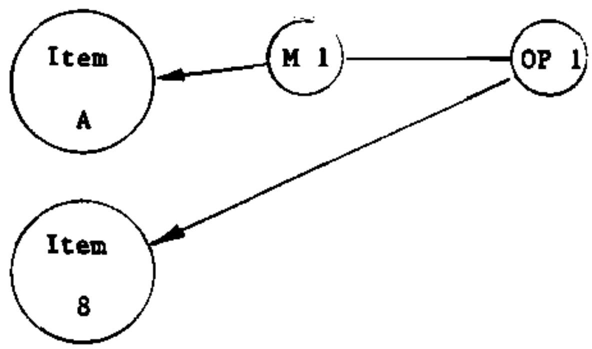
Example:



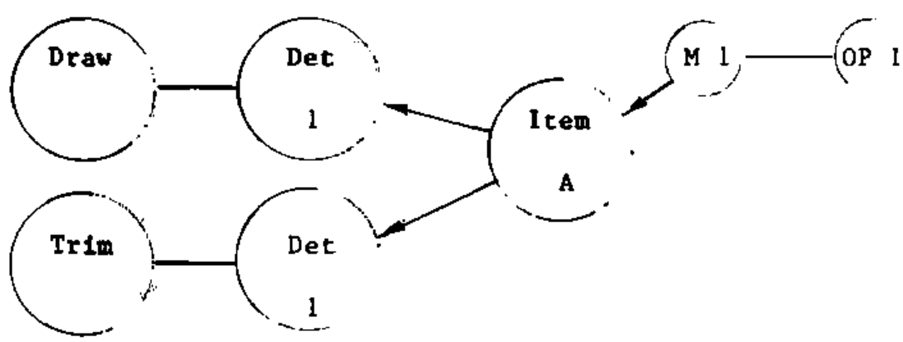
A more sophisticated system includes not only the associated part data to an operation, but the attitude (spatial position) of the item by use of a transformation matrix. This further reduces data proliferation.



In addition to the above structure, each operation would relate to items not transformed (generated directly in the attitude used in that operation). Item B could be transformed for some other operation.



Also needed is an associative mechanism whereby a surface (Item) would be known to the tooling members which contain it.



If Item A is changed, it should be possible to easily determine all the tooling members affected and all the operations affected.

In order to achieve effective integrated CAD/CAM, the Computer Aided Design must be formatted so that Computer Aided Manufacturing systems can properly utilize it. This includes compatible data structures and mechanisms for implementing change. Critical information, dimensions, etc. must be packaged according to the operations which will be performed at a later date.

DATA EXCHANGE

Since the early 70's, when CAD/CAM began to be used for production activities by non-computer related engineering practioners, there has been a serious problem in communicating between systems. In a large multi-product manufacturing organization there are not only the usual problems of communicating between product and manufacturing engineering departments, but also between the many, varied product engineering departments themselves. A system that would satisfy the needs of a department responsible for designing steering components might not be the same as for a department responsible for designing heating and air conditioning components. The facts are that many companies do not have a central controlling area for any one discipline, and the result is many different systems that cannot exchange data. The problem is so acute in a multi-divisional, multi- product organization that attempts to quantify the value of data exchange capability often fail. The lost opportunity of not using the computer-generated CAD/CAM layout background information alone, costs millions of dollars. The lost opportunity to use the design data for other dis- ciplines in product engineering has not been thoroughly investigated. Such straight forward applications as documentation, technical publications, mass calculations and engineering analysis, would amount to additional millions of dollars.

This brief statement has not even dealt with the use of the product engineering CAD data being used by the downstream departments in manufacturing engineering. Such activities as process planning, tool engineering, material handling, packaging, numerical control machining, robotics programming and numerical control inspection would all benefit immensely if the CAD and CAM data from various systems could be exchanged easily and with a substantial level of richness.

Many companies faced with the frustrations of not being able to exchange CAD/CAM data among their own units have developed very specific one-to-one converters. Some have met with fairly cost effective results. The GMDES (General Motors Data Exchange Standard) facility has been extremely productive and easy to implement by both General Motors and the major CAD/CAM suppliers. However, the GMDES software deals with three-dimensional point set data only. No dimensions or text have been implemented. While many applications do not require exchange of dimensional data, there are many applications that do require close tolerance dimensional data to accompany the part geometry.

In 1979, GM's representatives attended the first IGES (Initial Graphics Exchange Specification) meeting at the National Academy of Sciences Auditorium in Washington, D.C. In early 1980, General Motors accepted IGES as the long-range direction of the corporation. In May, 1983, this direction was confirmed by the Executive Committee of the Corporation, when it was proposed that IGES be the major data exchange facility in the GM integrated CAD/CAM plan. However, the problem of priority continues to plague the vendors in fully implementing IGES. The majority of the user community, although recognizing the need for data exchange, have not enforced their desires with performance requirements on purchase orders. It is one thing to verbalize support and quite another to specify with resulting withholding of funds for lack of compliance. General Motors units will begin specifying IGES compliance on purchase orders and the appropriation request review process will assure this compliance requirement. This in itself will not cause the data exchange problem to be solved, but major purchasers like GM, working with the major CAD/CAM suppliers, will hasten the acceptance of IGES as a true international standard.

ENTERPRISE DATA MANAGEMENT

Amongst the many good results of current CAD/CAM efforts are some new problems. Specifically, many members of the industrial community find themselves with a multitude of good usable data bases. Unfortunately, they are generally not locatable, connectable or shareable. Various terms have been used to describe this problem. We refer to it as the need for an Enterprise Data Manager.

In the automobile industry we have the following examples of this problem. How do we collect all of the data for one given car product--it resides in multiple divisions, multiple suppliers, multiple computer systems, and multiple data base managers. Some of the data is geometric, some is material properties, some is in part usage terminology, and some is proprietary.

Today, we have enterprise wide managers--there are people and paper systems. Tomorrow, we will have relational data base managers that will automate today's manual system. The technology for developing these managers is not new or mysterious. Several vendors are in the marketplace now with such product offerings.

Why has industry not stepped forward and used these offerings? They are expensive by way of resource consumption. They use cycles, they use facilities, and they are demanding in their initialization, as well as subsequent care and feeding. They will, however, perform the tasks that we need and all of us will be implementing them soon. It is inevitable. The constantly decreasing cost of MIPS, currently at about 25% per year, will hasten the use of these new relational data base managers.

Current projections are that pilot operations with these systems will commence shortly, run for two to three years, and become operational in late 1985. It may well be another two years before the vendors have fine tuned them (along with the new hardware) so that they will be truly cost effective. They will be commonplace this decade.

2-D TO 3-D CONVERTERS

A goal of Integrated CAD/CAM is to create solid models of all 3-D solid parts so that design analysis and validation can be performed to improve quality and optimize the designs.

Some of the roadblocks to this goal are:

(1) Many draftsmen have a difficult time handling the spatial relationships of 3-D, but can quickly create 2-D computerized layouts in a natural and intuitive manner using sketch-like input methods.

(2) It takes too long, using current interactive methods, to merge 2-D orthographic views to generate 3-D solid models; and hence only those parts that absolutely must be analyzed are modeled.

(3) There are thousands of existing hardcopy 2-D engineering drawings that need to be added to the data base so that they can be more easily used, modified, and integrated into new designs. Existing digitizer methods are too time consuming.

(4) 2-D engineering drawings must continue to be generated (and cannot yet be eliminated) due to the fact that many suppliers still require them.

There are two approaches to removing these roadblocks. First, continue to improve the 3-D solid modelling design aids and integrate existing 3-D design packages for those designers who can handle the spatial relationships of 3-D. Second, automate the process of changing 2-D computer designs and manual drawings to 3-D solid models.

Scanner digitizers are becoming available to automatically scan and input the 2-D engineering drawing information into CAD/CAM data base as 2-D data (i.e., points, lines, text, etc.). Developments, in regards to converting 2-D data to 3-D solids have been conducted at GM, IBM, MIT, Philips Research Laboratory, and others. Also, algorithms have been developed to automatically convert 2-D drawings (consisting of straight lines) into 3-D solid volumetric representations of polyhedral objects (solids formed by plane faces). Further developments are being conducted to extend these algorithms to handle circular arcs.

Industry can and will continue its efforts to automate the engineering process by developing better solid modeling techniques, scanner digitizers, and 2-D to 3-D conversion algorithms. Indications are that this roadblock to Integrated CAD/CAM can thereby be overcome by 1985.

SURFACE/SOLID MODELING

Many of the problems with solid modeling are related to the fact that this is an emerging technology. Most of our current efforts lie in the CAD area of modeling a solid part. Solid models offer advantages over wireframe technology in the area of complete definition of the part. Wireframe data is often ambiguous and can often represent nonsensical objects. One of the advantages of the solid model is its complete, unambiguous definition of the part.

Because this technology is still being developed, certain computations cannot be performed reliably or automatically (collision detection). Solid modeling operations are computationally intense, which causes a large amount of the computer's resources to be used. This means that some operations are very slow, thereby preventing creative designers from achieving their full potential. As hardware speeds increase and algorithms improve, these speed problems will be minimized.

The ability to communicate data from other design or solid modeling systems is one other problem. There is research underway at a number of universities to produce solid models from 2-D and 3-D wireframe models. Solid modelers use different representation schemes:

* Boundary representation
* Constructive solid geometry
* Sweeps

* Spatial enumeration
* Cell decomposition
* Primary instancing

It is often impossible to communicate this information between different solid modeling systems.

Most solid modeling systems started with primitive solids (block, cone, sphere) but the world is composed of more than these primitive solids. Currently, most solid modelers are adding free form or sculptured surfaces that can represent blending or filleted areas. Many solid modeling systems provide the user with graphics (hidden line removal or color shading), mass properties (volume, moments of inertia, products of inertia, and surface area), and static interference detection.

As the CAD side of solid modeling becomes more stable, CAM applications are beginning to be developed. The areas that are under development by different solid modeling systems are:

* Automatic finite element mesh generation
* N/C programming and tool path verification
* Dynamic interference detection
* Kinematics using solids
* Robotics
    * Simulation
    * Off-line programming
    * Path and positioning of robot

It is through these applications that the power of a solid model can be realized. When automatic FEM generation becomes available, the designer will easily be able to design and then finite element analyze the part, determine areas of weakness and modify the design to eliminate potential problems. Currently, the fact that it often takes more time to create the finite element model than to design the part severely limits the use of finite element analysis. When the process of generating the finite element model is automatic, the designer can iterate through the design and analysis process for the optimum design.

If information is placed into the solid modeling data base while the part is designed, such as what size hole to drill or tap, then an N/C generation program could automatically interrogate the solid model to determine where to drill the holes. The verification of the tool path and the use of collision detection to detect when the tool interferes with the clamps or the machine tool is another application under development.

Robotics is another good CAM application under development on some solid modeling systems. The ability to simulate the movement and constraints of the robot is underway. Currently most robots are being programmed manually or in a teach mode. There are some systems that are investigating the off-line programming of robots. This would be much like the way N/C machine tools paths are now generated.

There are other very specialized applications such as combustion chamber analysis. This program uses the solid model to define the volume of the combustion chamber and calculate the flame front and flame travel as the gas is ignited. It is through these specialized applications of solid modeling that much of its potential application can be reached.

Clearly, the roadblocks of speed, resource requirements, data base and applications are all being addressed by the major solid modelers today. Before 1990, solid modelling will play a significant role in the integrated CAD/CAM system.

MATH, WOOD, AND METAL MODELS (DIES)

The tooling industry has, historically, depended on a conventional (manual) set of processes and procedures to construct dies and molds. The heart of this process is a master wood model which, until recently, was made by hand. Many wood model shops are now beginning to use numerical control. The model represents the actual full-scale male shape of the part.

Plaster/plastic male and female construction aids are duplicated off the master model and then traced (kellered) on milling machines to replicate the part surfaces in the dies. The current problems in this process include poor model/aid dimensional stability, manual errors, model construction costs, adverse impact of updated engineering changes and poor machining efficiency and quality resulting from the tracing operation. Final finishing is dependent on a hand-made checking model, called a spotting rack, which may also have dimensional errors due to the effects of temperature and humidity.

With the advent of computers and CAD/CAM/NC Systems, mathematics--under development for over 25 years--in conjunction with computer aided design systems have defined complex sculptured surfaces which are referred to as math models. The results of the design operation are stored in the computer's master data base.

Sculptured surface N/C programming systems are also being developed, particularly in the automotive and aerospace industries, to calculate accurate, error-free tool paths on complex shapes to N/C machine models, dies, molds, patterns, aircraft and missile surfaces, and a variety of other complex surfaces in various industries.

The major developments in this area have been spearheaded by automotive and aerospace companies. The original developments were proprietary for many years; however, companies like Renault and Dassault in France are marketing their systems, and Boeing's B-Surf has been in the public domain for many years. With the availability of more cost effective and faster computer hardware, commercial turnkey vendor companies specializing in CAD/CAM systems are also beginning to offer sculptured surface capability.

Sculptured surface design capability is becoming quite common. However, most N/C programming systems to machine complex shapes are still limited in their ability to control a tool over multiple surfaces with all interference problems solved correctly, particularly for flat end mill cutters. Intensive development effort is underway in the larger European, American, and Japanese automotive companies to solve this problem. While it is generally held that math models will not totally replace wood and metal models (i.e., achievement of clay-to-die design and build), huge savings will be produced by the reduction in requirements for such hard models. Much of this, however, will not be achieved during this decade.

TOOL DESIGN AND CONSTRUCTION

Tool design, like product design, has been a highly skilled labor intensive activity throughout the years since the Industrial Revolution. Manual drawings have been the interface and communications link between design and manufacturing. The purpose of tool design, generally speaking, is to develop any additional surfaces (addenda) required to make the actual part as in a stamping draw die, design all the details that must be machined and assembled into a complete tool assembly, establish correct dimensions, spacers, etc., for the die or mold to be installed in a press, and to design the interface equipment required to automate part handling between presses or molds. The tool design data serves as the primary input to tool construction, which at the present time, is also largely labor intensive with manual-based operations. Product and tool design information are used to make wood models which are then duplicated as construction aids for the actual die surface machining. The straight line miling, hole drilling and tapping has been done conventionally on manually-operated machines.

Commercial vendor turnkey systems are now becoming increasingly popular for geometric tool design. The sculptured surface design (die layout, e.g.) remains a major difficulty with turnkey systems and is being attempted mostly by in-house proprietary developments. CAD/CAM systems that have demonstrated good geometric mechanical design capability such as Computervision, Applicon, Calma, and CADAM are being utilized in tool design activities to an ever-increasing extent.

Much of the machining for tool construction is of a relatively simple geometric point-to-point nature. N/C point-to-point 2-D programming capability is becoming available on integrated graphic CAD/CAM systems. Some limited sculptured surface N/C machining capability is also available on these systems, but the more sophisticated systems primarily reside in the larger company proprietary operations.

The solution, again, calls for an acceleration of the technology transfer, since most of it exists but has not been produced for the ultimate user. Some of this will be accomplished during the eighties, but to become fully integrated will require another ten years.

TECHNOLOGY TRANSFER

Moving a manufacturing facility from a traditional manual environment to the high technology world of CAD/CAM has many problems associated with it. One of the most critical is the retraining of the workforce. Without a well-motivated and highly-trained workforce, the factory of the future with its sophisticated graphic systems and N/C machines will not function properly and will not provide the productivity gains that are being predicted. In addition, the employes will be confused and frustrated in their new environment, destroying any quality-of-work-life gains previously made.

The solution to this problem is a well-planned, multi-faceted training program. Simply providing a training class for a new graphics design system or N/C machining program will not be adequate. The problem must be attacked on several levels. The first level is an overview or introduction to the new technology for the entire workforce. The overview should explain what CAD/CAM is, what computer graphics is, what N/C machining is and how they work. At several plants today, this level of training is being handled by utilizing courses from local community colleges and schools. The second level of training involves making sure that the employes have the basic skills that will be required in the new environment. Personal skills such as blueprint reading and basic math abilities may be required, but not all employes possess them. This training can also be handled by local community colleges and adult education programs. The next level requires retraining machine operators to handle the new N/C equipment. This involves not only teaching them the new machine and controls, but also new work habits. Years of working with old equipment has ingrained many employes with practices and procedures that are no longer valid. Management and the union must work cohesively to establish new work standards.

The final level requires retraining employes to perform new functions. An example of this is training new N/C equipment. Because the function is new to the selected employes and the systems are so complex, the training will have to be handled in two steps. First training classes will be held to provide an understanding of the systems. Secondly, technical experts will work with them on a series of prototype jobs. These jobs will help strengthen their knowledge and build their confidence before they have to function independently.

Although training the workforce for the high technology environment is a critical problem, it should be obvious that with adequate planning, all the training components can be covered to provide a smooth transition.

MANAGEMENT DISCIPLINE

Finally, in addition to all of these technical roadblocks is the pervasive obvious problem of management discipline. It is one thing to enumerate the physical roadblocks, it is quite another to obtain the resources to overcome them. This is true whether you are buying or selling solutions. Because of the very breadth of the design-test-build process in industry, it is not easy for any vendor to excel in solutions to problems in mechanical-electrical, design-build, schedule-ship, etc. Consequently, it is most often recognized that if management feels they can solve the integration problem by specifying only one supplier, they are mistaken.

Indeed, all of the other nine roadblocks must be recognized and overcome, but there still remains a management resolve to be achieved. Whereas, we speak of user training and retraining, there also exists a need to carry that concept throughout all levels.

Effectively, there is little to be added here that is new, since we all have for years blamed "them" for any problems. We can always lay it at the feet of management. Fortunately, or unfortunately, there is a solution that stands four-square in front of us and will make this one easy. It is survival!

There is one way to gain full attention of everyone from the sweeper to the Chairman. That is profit! If American industry is to survive the great new off-shore competition, we must lead in the implementation of new technology. Let me assure you that the domestic auto industry fully recog- nizes this fact. We are well on the way to full implementation. Nothing will prevent us from being the leader in this process. We fully regard Integrated CAD/CAM as a cornerstone to this goal. No physical object or faint resolve can be permitted. We want to, we can and we will join hands with many partners to achieve this goal. We know what needs to be done, and we are setting out to do it.

Please join us.

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Nielsen Dataquest

ROLE OF START-UP COMPANIES IN COMPUTER-INTEGRATED MANUFACTURING

Laura Conigliaro
Vice President
Prudential-Bache Securities Inc.

As an analyst, Ms. Conigliaro covers the field of factory automation, including robotics, computer-based vision systems, advanced technology machine tools, and CAD/CAM, both from an industry and company perspective. Ms. Conigliaro's previous employment includes several years as an intelligence analyst at the National Security Agency. She was the contributing author to a book on investment and, more recently, has contributed numerous articles to various publications, including her own "CIM Newsletter." Ms. Conigliaro holds an M.B.A. degree in Finance. She is a member of RI/SME, CASA/SME, the EIC Robotics Advisory Board, and Phi Beta Kappa.

Dataquest Incorporated
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THE ROLE OF START-UP COMPANIES IN COMPUTER-INTEGRATED MANUFACTURING

THE WINNERS IN THE ROBOTICS AND/OR COMPUTER-INTEGRATED MANUFACTURING AREAS WILL BE -

ALLEGHENY INTERNATIONAL
BENDIX
CINCINNATI MILACRON
GENERAL ELECTRIC
GENERAL MOTORS
IBM
TEXTRON
UNITED TECHNOLOGIES
WESTINGHOUSE

OR WILL THEY? I CAN'T TELL YOU HOW MANY TIMES SINCE THESE COMPANIES ENTERED THE ROBOTICS INDUSTRY THAT I'VE HEARD IT SAID THAT THE GIANT COMPANIES WOULD STEP ON THE SMALLER ONES AND END UP OWNING THE INDUSTRY.

IT IS TRUE THAT THESE GIANTS HAVE SOME IMPORTANT ADVANTAGES - SUCH AS INSTANT NAME RECOGNITION AND MAJOR FINANCIAL STRENGTH. THEY ALSO HAVE VAST DISTRIBUTION NETWORKS AND MAJOR FINANCIAL STRENGTH. BUT IT'S ALSO TRUE THAT IF WE TURN THE COIN OVER, WE SEE THAT POWERFUL FINANCIAL STRENGTH FOR THE CORPORATION AS A WHOLE SHOULD NOT BE INTERPRETED AS BEING EQUIVALENT TO UNLIMITED FINANCIAL RESOURCES FOR THE ROBOT ENTITY WITHIN THE COMPANY. THE ROBOT GROUP - IT'S OFTEN NOT EVEN A DIVISION - IS JUST A TINY, TINY FISH IN A GREAT BIG POND. EVEN THE GREAT - THE TRULY GREAT - IBM IS, IN THE END, RESOURCE-LIMITED. IT'S HARD TO CONCEIVE OF A COMPANY THAT WANTS TO BE IN ROBOTICS, FOR EXAMPLE, SO BADLY THAT THEY WOULD CONTINUE TO WHOLEHEARTEDLY SUPPORT THEIR ROBOT GROUP IF IT TURNS OUT TO BE A LEADER PRIMARILY IN ONLY ONE AREA - THE ABILITY TO LOSE MONEY.

ONE THING THAT I AM FULLY CONVINCED OF IS THAT A NUMBER OF THESE GIANT COMPANIES WISH THAT THEY HAD NEVER GOTTEN INVOLVED IN THE ROBOTICS AREA OR, IF THEY HAD, THAT THEY HAD NOT PUBLICIZED IT QUITE AS MUCH. A QUIETER ENTRY INTO THE INDUSTRY WOULD HAVE ALLOWED THEM TO MOVE MORE SLOWLY, TO TEST THE WATERS BEFORE DIVING IN AND FINDING OUT THAT THIS WAS NO SWIMMING POOL - IT WAS A SHARK-INFESTED MUDHOLE. A LESS PUBLICIZED ENTRY WOULD ALSO HAVE MADE IT EASIER TO MAKE THE ULTIMATE DECISION MORE EASILY - PULLING OUT OF THE AREA ENTIRELY.

NOW THAT'S NOT TO SAY, IMPLY, OR MEAN - IN ANY WAY - THAT A FEW OF THESE GIANT COMPANIES WILL NOT BE SUCCESSFUL IN THIS AREA. I AM CONVINCED THAT THEY WILL - BUT IT'S NOT GOING TO BE EASY. AND SUCCESS FOR THEM IS GOING TO HAVE TO BE MEASURED ULTIMATELY THE SAME WAY IT IS FOR ANY BUSINESS - IS THIS A BUSINESS WHERE YOU CAN MAKE ENOUGH MONEY TO JUSTIFY BEING IN IT?

I'VE CHOSEN THE ROBOTICS AREA OF CIM AS MY EXAMPLE HERE BUT ALOT OF WHAT I'M SAYING WILL BE TRUE FOR OTHER AREAS OF THE OVERALL COMPUTER-INTEGRATED MANUFACTURING INDUSTRY. IT IS A BRUTAL AREA. ALOT OF THINGS THAT MAY HAVE HELD TRUE FOR OTHER INDUSTRIES DON'T NECESSARILY HOLD TRUE HERE.

FOR ONE THING, IT IS QUITE TRUE THAT MICROPROCESSORS ARE WORMING THEIR WAY INTO THE FACTORY FLOOR - WHETHER IN THE FORM OF PROGRAMMABLE CONTROLLERS, PERSONAL COMPUTERS, MINIS, PROCESS CONTROLLERS, CNC MACHINE TOOLS, COMPUTER AUTOMATED MATERIALS HANDLING DEVICES, ROBOTS, CAD/CAM, ARTIFICIAL VISION SYSTEMS, OR WHATEVER. BUT IT'S NOT THE SAME AS MICROPROCESSORS IN THE WORLD OF OFFICE AUTOMATION OR DATA PROCESSING OR TELECOMMUNICATIONS. ON THE FACTORY FLOOR,

THERE IS GENERALLY A BASIC DISCOMFORT WITH COMPUTERS AND SOFTWARE DESPITE THE GROWING REALIZATION THAT THIS IS ALL PRETTY MUCH INEVITABLE. WHAT THIS RESULTS IN IS THAT CUSTOMERS NEED AND WANT HANDS-ON APPLICATIONS ENGINEERING AND SUPPORT FROM THE VENDOR. MANY OF THE COMPANIES THAT HAD BEEN IN ROBOTICS FOR A NUMBER OF YEARS AS WELL AS MANY THAT ENTERED THE INDUSTRY ONLY WITHIN THE LAST FEW YEARS REALLY FELT - AND HOPED BECAUSE IT'S ALOT EASIER - THAT THE BEST WAY TO BE SUCCESSFUL IN THE INDUSTRY WAS GENERALLY STAY AWAY AS MUCH AS POSSIBLE FROM THE SYSTEMS END OF THE BUSINESS. IN FACT, AN OFFICER AT ONE OF THE GIANT COMPANIES THAT ENTERED THIS AREA A FEW YEARS AGO WAS THEN QUOTED AS SAYING THAT THEY WERE HOPING THAT THEY COULD SELL ROBOTS PRETTY MUCH LIKE COOKIES. THAT HAS HARDLY TURNED OUT TO BE THE CASE. AS AN ASIDE, IT'S KIND OF INTERESTING TO SEE THAT MANY OF THE VENDORS WHO HAD SWORN THAT THEY WERE GOING TO STEER CLEAR OF THE SYSTEMS END OF THE BUSINESS ARE NOW EMBRACING SYSTEMS INTEGRATION ALMOST AS A RELIGION.

OUR BOTTOM LINE RIGHT NOW ABOUT THE AREA OF COMPUTER-INTEGRATED MANUFACTURING IS GENERALLY THIS - WE DO NOT BELIEVE THAT ANY COMPANY IN THE AREA REALLY KNOWS YET EXACTLY WHERE AND HOW IT IS GOING TO BE POSITIONED OVER THE LONG TERM. THE MARKET IS STILL TOO DYNAMIC AND IN TOO MUCH FLUX - KIND OF A LEARNING PHASE - WITH VERY FEW BROAD-SCALE TRENDS EVIDENT.

THAT GENERALLY SUGGESTS THAT COMPANIES THAT ARE GOING TO BE RESPONSIVE TO THE MARKET HAD BETTER BE -

- DYNAMIC OR ADAPTABLE, BECAUSE THEY'RE PROBABLY GOING TO HAVE TO MAKE ALOT OF TACTICAL CHANGES AND PROBABLY A FEW STRATEGIC ONES AS WELL OVER THE NEXT FEW YEARS;

- QUICK, BECAUSE THEY HAD BETTER MAKE THOSE CHANGES FAST. IN THE ROBOT INDUSTRY ALONE THERE ARE ABOUT 98 U.S.-BASED COMPANIES, 250+ JAPANESE BASED COMPANIES AND SEVERAL DOZEN IN EUROPE. IN ARTIFICIAL VISION, THERE ARE ALREADY 50 OR SO U.S.-BASED VISION SYSTEMS COMPANIES.

- WELL-MANAGED, BECAUSE WITH ALL THESE CHANGES GOING ON AROUND THEM AND THE ONES THAT THEY'RE GOING TO HAVE TO MAKE IN THEIR OWN ORGANIZATIONS, YOU CAN BE SURE THAT THINGS CAN START TO GET OUT OF HAND PRETTY DAMN QUICK IF MANAGEMENT ISN'T REALLY ON TOP OF THEM.

- MARKETING-DRIVEN IN PART, AND HEADED BY ONE SUPER MARKETING PERSON WHO CAN READ THE DYNAMICS OF THE MARKET, MOTIVATE HIS FORCES, AND RESPOND.

- TECHNOLOGY-DRIVEN IN PART, BECAUSE THE INDUSTRY IS SO DAMNED COMPETITIVE THAT WHEN THEY RESPOND, THEY BETTER BE RESPONDING WITH MORE THAN JUST HOT AIR. THIS ALL SUGGESTS THAT WHILE A COMPANY MAY BE SELLING PRODUCTS THAT ARE STATE-OF-THE-MARKET, IT BETTER BE WORKING ON PRODUCTS THAT ARE STATE-OF-THE-ART NOW.

- WELL-BACKED FINANCIALLY - BUT WE'VE ALREADY DISCUSSED THE DILEMMA OF BEING AN ENORMOUSLY WELL-FINANCED GIANT COMPANY BUT STILL NOT HAVING INFINITE RESOURCES TO THROW OFF INTO EVERY DIRECTION. AND, IN ORDER TO GET THOSE RESOURCES, YOU OFTEN HAVE TO TAKE YOUR CASE UP THE LADDER FROM GROUP HEAD TO DIVISION HEAD TO CORPORATE AND SO ON - THROUGH COMMITTEES. KIND OF A CIRCULAR DILEMMA WHEN YOU'RE ALSO TRYING TO BE DYNAMIC AND QUICK.

THERE HAS NEVER BEEN AN IMPORTANT HIGH TECH-ORIENTED AREA YET WHICH HAS BEEN SO DOMINATED BY GIANT COMPANIES THAT ALL THE START-UPS HAVE ESSENTIALLY BEEN STIFLED, CUT OFF AT THE PASS, STEPPED ON, OR STRANGLED. AND IT'S NOT GOING TO HAPPEN THIS TIME EITHER. WE MAY END UP WITH A FEW GIANT COMPANIES THAT HAVE BECOME SUCCESSFUL BUT THAT WILL PROBABLY NOT BE THE NORM.

SO LET'S FLIP THE COIN OVER FOR A MINUTE AND LOOK AT SOME OF THE START-UPS - THE ONES FINANCED BY VENTURE CAPITALISTS TO THE TUNE OF OVER $100M IN THE ROBOT AND VISION INDUSTRIES ALONE SO FAR. ON THE PLUS SIDE, THEY CERTAINLY HAVE THE ABILITY TO ATTRACT AND HIRE SOME OF THE MOST AGGRESSIVE AND SMARTEST INDIVIDUALS. THE BEST OF THESE COMPANIES CAN BE VERY DYNAMIC, AGILE, AND QUICK. ON THE MINUS SIDE, THEY OFTEN HAVE VERY LITTLE NAME RECOGNITION IN AN INDUSTRY INHABITED BY NAMES LIKE IBM AND GE. ALSO, BECAUSE THE INDUSTRY IS SO COMPETITIVE, THERE'S VERY LITTLE ROOM FOR ERROR OR FOR LEARNING FROM MISTAKES.

LET ME DIGRESS FOR A MOMENT TO SHOW YOU SOMETHING ABOUT THESE START-UPS. YOU CAN JUDGE FOR YOURSELVES. PERHAPS IT POINTS UP JUST HOW AGGRESSIVE AND AMBITIOUS THEY CAN BE, HOW HUNGRY THEY ARE. BUT IT'S INTERESTING IN ANY CASE.

I READ ALOT OF BUSINESS PLANS FOR SMALL START-UP COMPANIES, ESPECIALLY THOSE ENTERING ROBOTICS. IT'S NO EASY MATTER TO WRITE AN 80-100 PAGE BUSINESS PLAN ESPECIALLY WHEN THE PURPOSE OF THE BUSINESS PLAN IS TO CONVINCE POTENTIAL BACKERS THAT YOU HAVE A SOUND STRATEGY FOR SUCCESS - TO GET MONEY, SOMETIMES SEVERAL MILLION DOLLARS, FROM FINANCIERS WHO HAVE SEEN IT AND HEARD IT BEFORE. EVERY BUSINESS PLAN INCLUDES FORECASTS MADE BY THE COMPANY - HOW WELL THEY THINK THEY CAN DO USING THE STRATEGY THEY'VE LAID OUT. ODDLY ENOUGH, NEARLY EVERY BUSINESS PLAN I'VE READ SHOWS THE COMPANY GAINING 10% OR BETTER OF THE MARKET. UNFORTUNATELY, I'VE READ OVER 50 BUSINESS PLANS - FOR A GRAND TOTAL FROM THESE COMPANIES ALONE OF 500% OF THE MARKET IN A GIVEN YEAR.

NOW I'VE GONE THROUGH THIS EXERCISE NOT TO DEMONSTRATE MERELY HOW OUTLANDISH BUSINESS PLANS CAN BE (ALTHOUGH SOME ARE OFTEN JUST THAT) BUT RATHER TO SHOW HOW EXTREMELY AMBITIOUS AND AGGRESSIVE SOME OF THESE SMALLER COMPANIES TEND TO BE. THEY HAVE TO BE - REMEMBER, THEIR SURVIVAL DEPENDS ON THEIR RAPID GROWTH.

SO THERE IS SOMETHING TO BE SAID FOR BEING A SMALL COMPANY, STARTING WITH FEW PRECONCEPTIONS, AND RUNNING LIKE HELL. LEST I EVEN HINT AT SUGGESTING THAT BEING SMALL MAKES THE INDUSTRY OBSTACLES DISAPPEAR AND MEANS THAT YOU'VE GOT IT MADE, LET'S TAKE AN IMAGINARY LOOK AT SOME OF THE OBSTACLES FROM THE POINT OF VIEW OF A START-UP COMPANY -

- EARLY 1980 - YOU ENTER THE INDUSTRY FILLED WITH GREAT IDEAS AND A CERTAINTY THAT YOU'RE GOING TO CONQUER THE WORLD OF CIM. YOU'RE GOING TO BECOME THE IBM OF THE CIM WORLD.

- YOU CALL UP A FEW VENTURE CAPITALISTS - FRED ADLER, KLEINER PERKINS, J.H. WHITNEY, OR WHOMEVER AND SOME ASSISTANT ASKS YOU FOR A BUSINESS PLAN.

- YOU SAY - "A BUSINESS PLAN? WHILE I'M SITTING AND WRITING THIS 100-PAGE DOCUMENT, EVERYONE ELSE WILL BE GAINING GROUND." BUT, STILL, THEY WANT A BUSINESS PLAN.

- SO YOU SIT DOWN AND WRITE A BUSINESS PLAN. THEN YOU SEND IT TO THE VENTURE CAPITALISTS WHO, AFTER ALL THAT FUSS, TREAT IT AS IF IT

WERE A PIECE OF FICTION AND RIP IT APART WHEN THEY COME TO VISIT YOU. ANYWAY, YOU FINALLY GET FINANCED.

- EARLY 1981 - HERE YOU ARE, GREAT IDEAS AND ALL, A DAMNED GOOD MANAGEMENT TEAM, BEGINNING TO MAKE CONTACT WITH THE MARKETPLACE AND THE WHOLE ECONOMY RUNS RIGHT INTO A BRICK WALL AND DIES. YOUR ENTIRE CUSTOMER BASE IS STILL TALKING ABOUT PRODUCTIVITY AND KANBAN AND ROI BUT THEIR CASH FLOW IS GOING DOWN THE TUBES. YOU REALIZE THAT THE CYCLE TIME FROM INITIAL CONTACT TO PURCHASE ORDER IS GOING TO BE ABOUT TWICE AS LONG AS YOU FORECAST IN YOUR BUSINESS PLAN.

- UNIMATION, THE LEADER IN THE INDUSTRY, FILES TO GO PUBLIC AT A $115M VALUATION. THAT SOUNDS ENCOURAGING UNTIL EVERYONE REALIZES HOW BAD UNIMATION'S MARGINS HAVE GOTTEN AND VENTURE CAPITALISTS START TO ASK - "THIS IS THE INDUSTRY THAT WE PUT ALL THIS MONEY INTO?" EVERYONE STARTS TO TALK ABOUT THE "PROFITLESS PROSPERITY" THAT WILL BE THE FATE OF THIS INDUSTRY.

- GENERAL ELECTRIC ENTERS THE CIM INDUSTRY. THEY ARE GOING TO OFFER FACTORIES OF THE FUTURE. THEY NOW HAVE CAD/CAM, MICROPROCESSORS, CNCs, PROGRAMMABLE CONTROLLERS, ROBOTS, VISION, NETWORKING AND SO ON. AS IF THIS WEREN'T FORMIDABLE ENOUGH, JACK WELSH - THEIR CHAIRMAN - DRIVES HOME THE POINT BY SAYING THAT THIS IS GOING TO BE A MAJOR AREA OF EMPHASIS FOR GE AND FOR HIM AS WELL.

- MORE AND MORE START-UPS ARE GETTING FINANCED. THE INDUSTRY NOW HAS FAR MORE COMPANIES IN IT THAN THERE ARE SALES TO GO AROUND.

- NATURALLY, YOUR FORECASTS HAVE VIRTUALLY FALLEN OUT OF BED WHAT WITH THE RECESSION, THE NUMBER OF COMPETITORS AND THE NORMAL RELUCTANCE OF ENDUSERS TO ADAPT TO NEW TECHNOLOGIES. STILL, IT'S TIME FOR MORE MONEY - TIME TO RAISE THE VALUATION, GIVE AWAY MORE OF THE COMPANY AND SPEND THE NEXT MONTH OR SO PRACTICALLY IGNORING THE BUSINESS SO YOU CAN MEET WITH VENTURE CAPITALISTS.

- RECESSION STILL HOT AND HEAVY. STILL, YOU'VE MADE INROADS AT GENERAL MOTORS, THE LARGEST BUYER OF ROBOTS AND VISION SYSTEMS PROBABLY THROUGHOUT THE DECADE.

- IBM ENTERS THE INDUSTRY. SO MUCH FOR YOUR WANTING TO BE THE IBM OF THE CIM WORLD.

- GENERAL MOTORS ENTERS THE INDUSTRY - IN A JOINT VENTURE WITH FANUC, A JAPANESE COMPANY VERY WELL KNOWN IN FACTORY AUTOMATION.

NOW I COULD CONTINUE THIS FOR QUITE SOME TIME BUT I'M SURE THAT YOU GET THE POINT. START-UPS NEVER HAVE AN EASY TIME AND, IN THIS INDUSTRY, IT'S PARTICULARLY TOUGH BECAUSE THE INDUSTRY ITSELF IS SO TOUGH. BUT THE BEST OF THEM - AND ONLY THE VERY BEST - CAN BE VERY SUCCESSFUL BECAUSE THEY ARE QUICK, DYNAMIC, AGGRESSIVE AND SOMEWHAT LIKE PERSISTENT, OBNOXIOUS INSECTS - YOU CAN SPRAY AT THEM (KIND OF LIKE THE PERVASIVE, GLOBAL, I'M BIG SO I'LL-BE-EVERYTHING-TO-EVERYONE APPROACH TAKEN BY GIANT COMPANIES) BUT UNLESS YOU ACTUALLY HIT THEM WITH THE SPRAY CAN (UNLESS LARGE COMPANIES ACTUALLY PICK A FOCUSED, NICHE TYPE OF APPROACH AND CONTINUALLY GO HEAD-TO-HEAD WITH THESE START-UPS), THE BEST OF THE START-UPS ARE HARD TO KILL.

NOW LET'S TAKE A LOOK AT TWO OF THE SUBSEGMENT INDUSTRIES WITHIN CIM AND SEE WHAT THIS MEANS AND WHERE THEY'RE GOING.

IN THE ROBOT OR ROBOT SYSTEMS SEGMENT, SALES IN 1982 DID NOT JUMP BY THE FORECAST 35% OR SO FOR THE INDUSTRY - THE RECESSION WAS JUST TOO BAD. BUT THEY DID GO TO $190M, UP 23% OVER 1981 - NOT BAD FOR A PRETTY TERRIBLE YEAR.

THIS YEAR WE'RE EXPECTING SALES FOR THE INDUSTRY TO BE UP AGAIN BY LESS THAN 35% - UP ONLY ABOUT 30% TO BETWEEN $235-265M WITH A BIG JUMP OF ABOUT 40% OR SO IN 1984. BUT LET'S LOOK UNDER THE INDUSTRY-WIDE NUMBERS.

WHEN WE DO, WE SEE THAT THE ORIGINAL COMPANIES - NAMES LIKE UNIMATION, CINCINNATI MILACRON,, PRAB ROBOTS, ASEA, DEVILBISS AND COPPERWELD - COMPANIES THAT ESSENTIALLY WERE THE INDUSTRY IN 1979, 1980 AND 1981 HAVE BEEN GIVING UP MARKET SHARE TO THE NEWER COMPANIES. BY THE END OF 1983, THESE NEW COMPANIES COLLECTIVELY WILL HAVE ABOUT 48% OF THE MARKET AND, IN 1984, ABOUT 55%.

IF WE LOOK EVEN FURTHER, IT IS CURIOUS TO SEE THAT THE START-UPS - COMPANIES THAT STARTED FROM NOTHING JUST A COUPLE OF YEARS AGO AND WERE CLEARLY IN A POSITION TO MAKE EVERY MISTAKE IN THE BOOK AND, EVEN IF THEY DIDN'T THEY WERE GOING TO GET STEPPED ON BY THE GIANTS WHO ENTERED THE INDUSTRY - START-UPS HAVE GONE FROM A MARKET SHARE OF ALMOST NOTHING - ABOUT 2.3% IN 1980 TO AN ESTIMATED 14.4% IN 1983 AND COULD WELL GO OVER 20% OF THE TOTAL U.S. MARKET IN 1984.

GIANTS HAVE GONE FROM ABOUT 5.4% IN 1982 TO AN ESTIMATED 21.3% IN 1983 AND WILL LIKELY BE OVER 30% BY 1984.

BUT IT'S BEEN THE START-UPS THAT HAVE SET THE TONE AND THE DIRECTION AND THE PACE. THE SAME HAS BEEN TRUE IN THE ARTIFICIAL VISION SYSTEMS INDUSTRY. IF WE LOOK AT ONLY THAT SEGMENT OF THE VISION INDUSTRY WHICH IS SELLING SYSTEMS THAT ARE RELATIVELY STANDARDIZED IN GIVEN APPLICATIONS, AND WHICH DOES NOT INCLUDE THOSE COMPANIES SELLING IMAGE PROCESSING SYSTEMS OR SYSTEMS SINGULARLY DEDICATED TO A PARTICULAR TASK OR PRETTY MUCH CUSTOM-BUILT AND ALSO DOESN'T INCLUDE SALES OF VISION-RELATED COMPONENTS, WE'VE STILL GOT MORE THAN 30 COMPANIES. BUT ONLY 2 OF THEM ARE LARGE COMPANIES. THE REST ARE TINY. THIS INDUSTRY WASN'T EVEN A SPECK IN 1981 WHEN EXTERNAL SALES FOR THE INDUSTRY WERE ESTIMATED TO BE ABOUT $8.5M. AND IT WASN'T MUCH MORE THAN A SPECK IN 1982, WITH $17.5M IN SALES. THIS YEAR, IT'S STILL JUST A DOT OF AN INDUSTRY AT ABOUT $35M AND NEXT YEAR NOT MUCH MORE AT ABOUT $75M. BUT THIS WAS ALL DONE BY START-UPS. ONE HUNDRED PERCENT GROWTH PER YEAR COMING FROM TINY COMPANIES IN AN INDUSTRY THAT'S NOT CONSIDERED EVEN LEGITIMATE ENOUGH TO CALL IT AN INDUSTRY. IT WAS THE LITTLE COMPANIES WHO RECOGNIZED THE POTENTIAL AND HAD TO ESSENTIALLY USE TRIAL-AND-ERROR IN THEIR MARKETING EFFORTS BECAUSE USERS COULDN'T UNDERSTAND WHAT IN THE WORLD THIS WAS ALL ABOUT. IT WAS THE TINY COMPANIES WHO WERE PREPARED TO HOLD HANDS WITH ENDUSERS, SUPPORT CUSTOMERS, AND SPEND THE TIME BECAUSE, TO THEM, THIS 100% REVENUE GROWTH COUNTED ALOT ALTHOUGH LARGER COMPANIES GENERALLY COULDN'T AFFORD TO DO THIS. TO THE GIANTS, IT WAS TOTALLY INSIGNIFICANT. IN 1983, THESE COMPANIES WILL COLLECTIVELY SELL ABOUT 1000 ARTIFICIAL VISION SYSTEMS FOR INSPECTION, ADAPTIVE CONTROL, DIMENSIONAL CHECKING AND GUIDANCE.

TO GIANTS, THIS MAY NOT MEAN MUCH - BUT SOMEWHERE OUT THERE, THERE ARE COMPANIES THAT ARE GAINING A TREMENDOUS AMOUNT OF VISIBILITY IN INDUSTRIES WHERE MANY OF THE GIANT COMPANIES - THOUGH CERTAINLY NOT ALL - ARE STILL SCRATCHING THEIR HEADS AND TRYING TO FIGURE OUT WHERE THE MARKET DISAPPEARED TO.

WHILE MANY OF THE LITTLE ONES ARE RUNNING AS FAST AS THEY CAN JUST TRYING TO STAY A STEP AHEAD OF THE SUPPOSED THUNDERING HERD OF GIANTS BEHIND THEM, MANY OF THE BIG ONES ARE STILL BUSY TRYING TO FORECAST THE INDUSTRY - AND WE ALL KNOW WHAT A THANKLESS AND HOPELESS TASK THAT IS. SO MUCH OF THE DATA WE GET TENDS TO BE RECYCLED DATA COMING FROM THE SAME SOURCES. IN FACT, TO DIGRESS A MOMENT, I REMEMBER NOT TOO LONG AGO, HAVING A CONVERSATION WITH THE VP OF ONE OF THE OPERATING GROUPS AT A VERY LARGE COMPANY IN THE FACTORY AUTOMATION INDUSTRY. HE ASKED ME WHAT MY FORECASTS WERE FOR THE INDUSTRY. SO I GAVE HIM MY NUMBERS FOR ROBOTS, VISION, CNC MACHINE TOOLS AND CAD/CAM AND THAT WAS THAT. A FEW WEEKS LATER, I WAS SPEAKING TO ONE OF THE CORPORATE VPs AT THE SAME COMPANY. WE WERE JUST CHATTING AND I HAPPENED TO MENTION TO HIM THAT I HAD HAD THIS OTHER CONVERSATION WITH THIS OPERATING VP, AT WHICH TIME HE SIMPLY STARTED TO LAUGH. I ASKED HIM WHAT WAS SO FUNNY AND HE SAID, "WELL, YOU'RE GOING TO BE OUT HERE IN A FEW WEEKS ON A NORMAL ANALYST'S VISIT AND, PROBABLY, AT THE END OF YOUR VISIT, YOU'LL ASK US, 'SO WHAT DO YOU THINK THE INDUSTRY'S GOING TO BE DOING OVER THE NEXT FEW YEARS?' WE'LL GIVE YOU OUR NUMBERS. AND YOU'LL WALK OUT SHAKING YOUR HEAD AND SAYING TO YOURSELF, 'I MUST BE REAL SMART. LOOK HOW CLOSE MY NUMBERS CAME TO THEIR NUMBERS.'" SO MUCH FOR RECYCLED INFORMATION!

I MENTIONED EARLIER THAT, IN MANY CASES, IT HAS BEEN THE START-UPS THAT HAVE SET THE TONE, THE NEW DIRECTION AND THE PACE AND I SUPPOSE THAT'S TRUE FOR MOST HIGH TECH AREAS. LET'S LOOK AT SOME OF THE TRENDS AND DIRECTIONS IN CIM THAT HAVE BEEN GENERATED BY THE START-UPS -

- IN COMPUTER PROCESSING FOR THE ENGINEERING MARKET, START-UPS HAVE SUCCESSFULLY INTRODUCED AND MADE IMPORTANT A WHOLE NEW GENERATION OF COMPUTERS - COMPUTER TECHNOLOGY BASED ON MODERN MICROPROCESSORS OR 32-BIT INTELLIGENT WORKSTATIONS. COMPANIES WITH NAMES LIKE APOLLO, SUN MICROSYSTEMS, THREE RIVERS AND, MASSCOMP, HAVE BEEN DEVELOPING AND COMMERCIALIZING THIS TECHNOLOGY FOR THE CAD/CAM AND CAE INDUSTRIES. THE RESULT, OF COURSE, HAS BEEN TO DISTRIBUTE COMPUTER POWER DOWN ONE MORE NOTCH AND MAKE REAL-TIME INTERACTIVE CAPABILITIES AVAILABLE, FOR EXAMPLE, TO MANUFACTURING AND PRODUCTION ENGINEERS.

- IN MECHANICAL CAD/CAM, COMPANIES LIKE CADLINC HAVE DEVELOPED SYSTEMS OUT OF THEIR OWN 32-BIT INTELLIGENT WORKSTATIONS.

- IN ELECTRONIC DESIGN AUTOMATION, SINGLE USER FUNCTIONALITY COMING FROM 32-BIT INTELLIGENT WORKSTATIONS HAS BEEN COMMERCIALIZED BY COMPANIES SUCH AS DAISY SYSTEMS, MENTOR GRAPHICS, VALID LOGIC, METHEUS, ETC.

- WATCHING THESE TRENDS, A FEW OF THE LARGER CAD/CAM COMPANIES, LIKE COMPUTERVISION, AUTO-TROL, AND CALMA ARE NOW DEVELOPING PRODUCTS IN THIS AREA.

- IN ROBOTICS, START-UPS WITH NAMES LIKE AUTOMATIX AND ADVANCED ROBOTICS RECOGNIZED RIGHT FROM THE START THAT THE CAM INDUSTRY WAS SIMILAR TO THE CAD INDUSTRY AT LEAST IN ONE RESPECT: CUSTOMERS NEED AND WANT SUPPORT FROM THE VENDOR. AS I MENTIONED EARLIER, OVER TIME, NEARLY ALL THE VENDORS - LARGE AND SMALL - BEGAN TO REALIZE THAT, WHETHER THEY LIKED IT OR NOT, THIS WAS PROBABLY TRUE, AND THEY ALSO BEGAN TO PROMOTE THEMSELVES AS BEING IN THE TURNKEY SYSTEMS BUSINESS AND OFFERING COMPLETE CUSTOMER SUPPORT.

- ARTIFICIAL VISION IS PERHAPS THE MOST AMAZING AND TELLING OF ALL. I TOUCHED ON IT BEFORE BUT, AGAIN, THERE SIMPLY WAS NO INDUSTRY. THERE WAS A TECHNOLOGY - THE TECHNOLOGY OF SENSING IMAGES, DIGITIZING THEM, PROCESSING AND ANALYZING THEM AND MAKING DECISIONS BASED ON THAT ANALYSIS - BUT THERE WERE NO SPECIFIC PRODUCTS AIMED AT DOING SPECIFIC INSPECTION, ADAPTIVE CONTROL, DIMENSIONAL CHECKING, OR GUIDANCE TASKS, EXCEPT IN VERY LIMITED AREAS. POTENTIAL ENDUSERS DIDN'T KNOW WHAT THEY WANTED AND WEREN'T PREPARED TO WASTE MONTHS AND MONTHS FIGURING IT OUT SINCE THERE WERE ALTERNATIVES. THE MARKET WAS ALSO EXTREMELY AMORPHOUS - KIND OF LIKE GETTING YOUR HANDS ON A LARGE JELLYFISH - BECAUSE IT WAS POTENTIALLY EVERYWHERE AND YET IT WAS, AT THE SAME TIME, REALLY NOWHERE. IT WAS THE START-UPS WHO WENT THROUGH THEIR OWN LEARNING CURVE TRYING TO FIGURE OUT HOW TO MARKET INTO THIS NON-INDUSTRY, WHAT COULD REALLY BE SOLD TO THIS NON-INDUSTRY, HOW IT SHOULD BE PACKAGED AND SOLD, AND THEN REALLY CREATED AN INDUSTRY. THUS, WE HAVE NAMES LIKE AUTOMATIX, COGNEX, CONTROL AUTOMATION, ITRAN, PERCEPTRON AND OTHERS THAT ARE MAKING A BUSINESS OUT OF THIS. THIS HASN'T GONE UNNOTICED BY THE BIG COMPANIES. GENERAL ELECTRIC, FOR ONE, HAS NOW PICKED UP IT'S OWN PACE IN THE INDUSTRY. OTHERS LIKE OWENS-ILLINOIS AND CHESEBROUGH PONDS, HAVE TAKEN INTERNALLY DEVELOPED AND USED TECHNOLOGIES, AND HAVE BEGUN TO COMMERCIALIZE THEM, WITH OTHER GIANTS DEVELOPING THEIR PRODUCTS IN THE WINGS.

DOES THIS MEAN THAT ALL OF THESE INDUSTRIES ARE REALLY DESTINED TO BELONG TO START-UP COMPANIES AND THAT WE CAN ESSENTIALLY IGNORE THE GIANTS? OBVIOUSLY, THE ANSWER IS NO. MOST OF THE START-UPS WILL NEVER MAKE IT IN ANY IMPORTANT WAY. MEANWHILE, THAT JOINT VENTURE THAT I MENTIONED EARLIER BETWEEN GENERAL MOTORS AND FANUC, THE COMPANY CALLED GMF, IS PROBABLY GOING TO DO ABOUT $22-25M WORTH OF ROBOTIC BUSINESS THIS YEAR AND OVER $60M NEXT YEAR. HARDLY A SNEEZE. A LITTLE COMPANY CALLED IBM - THE SAME ONE WHERE AN INDEPENDENT BUSINESS UNIT SPAWNED OFF A PERSONAL COMPUTER BUSINESS THAT'S SETTING THE PACE FOR AN ENTIRE INDUSTRY - HAS ANOTHER INDEPENDENT BUSINESS UNIT IN THE ADVANCED AUTOMATION SYSTEMS AREA THAT JUST BOOKED A $5M+ ORDER FOR A SOPHISTICATED ROBOTIC ASSEMBLY SYSTEM FOR AN ELECTRONICS COMPANY. AGAIN, HARDLY A SNEEZE SINCE THIS IS POTENTIALLY THE MOST EXCITING SEGMENT IN THE ROBOTICS AREA. AND THAT COMPANY THAT'S BRINGING GOOD THINGS TO LIFE, GE, THEY HAVE SO MANY PIECES - CAD/CAM, ROBOTICS, VISION, CNC, SOFTWARE, NETWORKING, A VERY AGGRESSIVE, COMMITTED CEO, AND AN UNBELIEVABLE DISTRIBUTION NETWORK IN THE INDUSTRIAL MARKET - THAT WE'D BE FOOLS TO IGNORE IT. STILL, I REALLY BELIEVE THAT MOST OF THE LARGE COMPANIES, LIKE MOST OF THE SMALL COMPANIES, WILL NEVER MAKE IT IN CIM IN ANY IMPORTANT WAY.

BUT THE ONES THAT DO MAKE IT - THE LARGE ONES AND THE SMALL ONES (AND IT'S NOT REALLY HARD TO FIGURE OUT WHICH START-UPS HAVE A GOOD SHOT AT BEING SUCCESS STORIES) WILL HAVE AN INCREDIBLY ATTRACTIVE INDUSTRY TO SELL IN AND GROW IN BECAUSE FACTORY AUTOMATION OR COMPUTER-INTEGRATED-MANUFACTURING IS ONE OF THE GIANT AND IMPORTANT INDUSTRIES OF THE 1980s.

FINALLY, A STORY TO DEMONSTRATE HOW PERVASIVE THE POWER OF A LITTLE START-UP CAN BE. ABOUT 2 1/2 YEARS AGO, I WAS TALKING TO SOMEONE AT A VERY LARGE AUTOMOTIVE COMPANY WHICH ALSO HAPPENS TO HAVE ALREADY OPENLY ADMITTED THAT THEY WILL BE AN ENORMOUS BUYER OF CIM TECHNOLOGY OVER THE DECADE. HE WAS ASKING ME ABOUT A PARTICULAR START-UP WHICH HAD THEN BEEN IN BUSINESS FOR ABOUT 6 MONTHS AND WHICH HAD RECEIVED ALOT OF PUBLICITY ALREADY BECAUSE OF THEIR HIGH-POWERED MANAGEMENT TEAM. WE'LL CALL IT COMPANY X. HE ASKED ME, "WHO IN THE WORLD IS THIS COMPANY

X? WHY IS IT THAT THEY'RE BEATING ON OUR DOOR CONSTANTLY THINKING THEY'RE GOING TO GET OUR BUSINESS? WE ALREADY HAVE A LIST OF VENDORS THAT WE'VE BEEN DOING BUSINESS WITH FOR YEARS AND WHO KNOW US WELL. THE PEOPLE AT COMPANY X PROBABLY KNOW A BIG, FAT ZERO ABOUT THE FACTORY FLOOR. WHILE I'LL ADMIT THAT THEY'RE PROBABLY BRILLIANT BASED ON THEIR BACKGROUNDS - IN FACT, I WOULDN'T MIND IF ONE OF THEM COULD SOMEHOW TAKE THE COLLEGE-ENTRANCE SATs FOR MY SON ON SATURDAY - THERE'S JUST NO WAY WE'RE GOING TO TURN THEM LOOSE HERE." ABOUT 6 MONTHS AFTER THAT CONVERSATION, WE TALKED AGAIN. BY THEN, ALOT OF THE GIANT COMPANIES HAD BEGUN TO ENTER THE INDUSTRY. I ASKED HIM WHICH OF THE GIANTS HE HAD ALREADY BEGUN TO DO BUSINESS WITH. HE MENTIONED ONE OR TWO OF THEM AND ADDED THAT THEY HAD ALSO BEGUN TO DO SOME BUSINESS WITH COMPANY X, THIS PEANUT START-UP. HE NOTED THAT COMPANY X MAY NOT HAVE KNOWN TONS ABOUT THE FACTORY FLOOR COMING IN BUT THEY WERE WILLING TO LISTEN HARDER THAN ANY OF THE COMPANIES HE HAD ALWAYS BEEN DEALING WITH. NOW, A COUPLE OF YEARS LATER, I SHOULD TELL YOU THAT COMPANY X IS ONE OF THE MAJOR SUPPLIERS IN ITS AREA OF BUSINESS TO THIS AUTO COMPANY. THE EXECUTIVE FROM THE AUTO COMPANY IS STILL SHAKING HIS HEAD IN AMAZEMENT AT THAT ONE.

AS FOR ME, I LOOK AT START-UPS ALL THE TIME. I TRY TO EVALUATE THEM BASED ON MANAGEMENT DEPTH, TECHNOLOGICAL STRENGTH, MARKETING, THE STRENGTH AND POTENTIAL OF THE INDUSTRY THEY'RE IN, FINANCIAL BACKING, AND SO ON. STILL, I THINK IT'S AN INTANGIBLE THAT SEPARATES OUT THE REAL WINNERS. I CALL IT "SOUL." I DON'T REALLY EVEN KNOW WHAT IT MEANS BUT I CAN TELL YOU THAT THOSE THAT HAVE IT ARE IN A POSITION TO POTENTIALLY, IN THEIR INDUSTRY, SHOOT FOR THE MOON.

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