PROCEEDINGS

Open Architecture Control for the Robotics Industry

February 9-10, 2000
Walt Disney World Swan & Dolphin Hotel
Orlando, Florida

A Workshop Sponsored by

Robotic Industries Association
900 Victors Way, P.O. Box 3724
Ann Arbor, MI 48106
www.robotics.org

National Institute of Standards and Technology
100 Bureau Drive, Stop 8230
Gaithersburg, MD 20899-8230
www.isd.mel.nist.gov

PROCEEDINGS

Open Architecture Control for the Robotics Industry

February 9-10, 2000
Walt Disney World Swan & Dolphin Hotel
Orlando, Florida

A Workshop Sponsored by

Robotic Industries Association
900 Victors Way, P.O. Box 3724
Ann Arbor, MI 48106
www.robotics.org

National Institute of Standards and Technology
100 Bureau Drive, Stop 8230
Gaithersburg, MD 20899-8230
www.isd.mel.nist.gov

Table of Contents

Executive Summary

At the 1999 Robotic Industries Association (RIA) Annual Forum in Orlando, Florida, General Motors emphasized the importance of reducing system integration costs, and open architecture controls were proposed as one important means of achieving that objective. Other presentations and discussions highlighted this as an important, timely, and controversial topic. As a result of this interest, RIA and the National Institute of Standards and Technology (NIST) organized a workshop to explore this topic further.

The Open Architecture Control for the Robotics Industry Workshop attracted over 50 participants who shared perspectives on open architecture control for the robotics industry and heard reports on related work in the machine tool and programmable logic controller areas. The one-day workshop was divided into two parts. In the morning, short presentations highlighted the viewpoints of three key sectors of the robotics market: end users, vendors, and systems integrators. Following these presentations were three reports on related standards: the Open Modular Architecture Controller (OMAC) application programming interface standard for machine tools; the proposed IEC 61499 standard for programmable logic controllers; and the Open Robotic Interface Network (ORiN) standard from Japan.

In the afternoon, participants were divided randomly into three breakout sessions. Each group was given the task to discuss topics that arose during the presentations, note the important areas that could form the basis for future work, and make recommendations. At the conclusion of the breakout sessions, each group presented its results, resulting in the following recommendations for short-term actions:

1. Determine the structure of a group that can address the issues on a continuing basis, state its mission, and provide a roadmap for its work.
2. Set up a web presence, with a glossary, references, and related links.
3. Review and comment on the OMAC API specification from the perspective of the robotics industry.
4. Establish initial guidelines for interfacing to factory networks, including media and protocols, information presentation, time synchronization, and network management.

The participants proposed meeting again in conjunction with two upcoming industry events, the Robots 2000 Conference in June, and the RIA Industry Forum in November.

Open Architecture Workshop
Registration List

Mr. Joseph Aleman
Software Engineer
Deneb Robotics Inc.
5500 New King Street
Troy, MI 48098
Phone: (248) 205-5126
Fax: (248) 267-8585
Email: jaleman@deneb.com

Mr. Robert Ballard
General Sales Manager
Robotic Workspace Technologies, Inc. (RWT)
17105 San Carlos Boulevard, Suite A6151
Fort Myers Beach, FL 33931-5336
Phone: (941) 466-0488
Fax: (941) 466-7270
Email: rballard@rwt.com

Mr. Sushil Birla
Engineering Group Manager
General Motors
30300 Mound Road
MC 480-109-164
Warren, MI 48090-9040
Phone: (810) 602-9834
Fax: (810) 947-0910
Email: sushil.birla@gm.com

Mr. Michael Calardo
Director, Automotive Operations
ABB Flexible Automation Inc.
1250 Brown Road
Auburn Hills, MI 48326
Phone: (248) 391-8478
Fax: (248) 391-6114
Email:

Mr. Joe Campbell
Vice President, Marketing
Adept Technology, Inc.
150 Rose Orchard Way
San Jose, CA 95134
Phone: (408) 432-0888
Fax: (408) 434-5119
Email: joe.campbell@adept.com

Mr. Bruce Casner
Sr. Staff Engineer
Miller Electric Mfg. Co.
1635 West Spencer Street
P.O. Box 206
Appleton, WI 54912
Phone: (920) 735-4191
Fax: (920) 735-4003
Email: bcasne@millerwelds.com

Mr. Fabrice Ciccarelli
Software Engineer
Nachi Robotics Advanced Technologies
23370 Commerce Drive
Farmington Hills, MI 48335
Phone: (248) 473-7537
Fax: (248) 473-7597
Email: fciccarelli@nrata.com

Mr. Patrick Crilly
Program Manager
Caterpillar, Inc.
P.O. Box 1875
Technical Center K
Mossville, IL 61656-1875
Phone: (309) 578-4331
Fax: (309) 578-4484
Email: crilly_patrick_j@cat.com

Mr. Doug Dalgliesh
General Manager
Yamaha Robotics
5123 West Chester Pike
P.O. Box 937
Edgemont, PA 19028
Phone: (610) 325-9940
Fax: (610) 325-9946
Email: doug@yamaharobotics.com

Mr. William DeCamp
Director of Marketing
Motoman, Inc.
805 Liberty Lane
West Carrollton, OH 45459
Phone: (937) 847-3214
Fax: (937) 847-3288
Email: bill_decamp@motoman.com

Mr. Jim Degen
President
KUKA Robotics Corporation
6600 Center Drive
Sterling Heights, MI 48312
Phone: (810) 795-2000
Fax: (810) 795-4871
Email: jdegen@kukausa.com

Mr. John Dunlop
Manager, Plant Material Handling
US Postal Service
8403 Lee Highway, 2nd Floor
Merrifield, VA 22082-8155
Phone: (703) 280-7282
Fax: (703) 280-8408
Email: jdunlop@email.usps.gov

Mr. Roger Erdely
Senior Application Engineer
Wago Corporation
244 Barneys Road
Perryopolis, PA 15473
Phone: (724) 736-0202
Fax: (724) 736-0202
Email: roger.erdely@wago.com

Mr. Jerry Eshbaugh
Director
Forward Vision Services, Inc.
12055 Hubbard
Livonia, MI 48150
Phone: (734) 458-7300
Fax: (734) 458-7913
Email: jme@tir.com

Mr. John Evans
Chief, Intelligent Systems Division
NIST
100 Bureau Drive, Mail Stop 8230
Gaithersburg, MD 20899
Phone: (301) 975-3418
Fax: (301) 990-9688
Email: j.evans@nist.gov

Mr. David Faulkner
Executive Vice President of Marketing
Cimetrix
6979 South High Tech Drive
Salt Lake City, UT 84047
Phone: (801) 256-6500
Fax: (801) 256-6510
Email: faulkner@cimetrix.com

Dr. Phillip Fiedler
Development Manager
Genesis Systems Group
8900 Harrison Street
Davenport, IA 52806
Phone: (319) 445-5670
Fax: (319) 445-5699
Email: pfiedler@gensysgrp.com

Mr. Joseph Fryman
Manager, Standards Development
Robotic Industries Association
P.O. Box 3724
900 Victors Way, Suite 140
Ann Arbor, MI 48106
Phone: (734) 994-6088
Fax: (734) 994-3338
Email: jfryman@robotics.org

Mr. Tom Fuhlbrigge
Software Engineering Manager
ABB Flexible Automation Inc.
1250 Brown Road
Auburn Hills, MI 48326
Phone: (248) 391-8787
Fax: (248) 391-8789
Email: thomas.a.fuhlbrigge@us.abb.com

Mr. Tim Garner
Staff Development Engineer
Delphi Automotive Systems
P.O. Box 9005
MS9159
Kokomo, IN 46904-9005
Phone: (765) 451-9055
Fax: (765) 451-7151
Email: timothy.d.garner@delphiauto.com

Mr. Steve Glor
Director & National Sales Manager
Sankyo Robotics
1001-D Broken Sound Parkway, NW
Boca Raton, FL 33487-3532
Phone: (561) 998-9775
Fax: (561) 998-9778
Email: robots@sankyo.com

Mr. David Gravel
Sr. Technical Specialist
Ford Motor Company, AMTD
24500 Glendale Ave.
Redford, MI 48239
Phone: (313) 592-2743
Fax: (313) 592-2212
Email: dgravel@ford.com

Mr. James Heaton
President
KVQuest Ltd.
P.O. Box 550
Chelsea, MI 48118
Phone: (734) 475-9400
Fax: (734) 475-5752
Email: jheaton@kvquest.com

Mr. Steven Holland
Director of Controls, Robotics & Welding
General Motors Corporation
M/C 480-109-200
30300 Mound Road
Warren, MI 48090-9040
Phone: (810) 947-1145
Fax: (810) 947-0971
Email: holland@gmr.com

Mr. Paul Horvat
Marketing and Sales Manager
Parker Hannifin
1140 Sandy Hill Road
Irwin, PA 15642
Phone: (724) 861-3217
Fax: (724) 861-3330
Email: phorvat@parker.com

Mr. Al Hufstetler
Deneb Robotics Inc.
5500 New King Street
Troy, MI 48098
Phone: (248) 267-9696
Fax: (248) 267-8585
Email: al_hufstetler@deneb.com

Mr. Rajive Joshi
Senior Research Engineer
Real-Time Innovations Inc.
155A Moffett Park Drive
Sunnyvale, CA 94089
Phone: (408) 734-4200
Fax: (408) 734-5009
Email: rajive@rti.com

Mr. Greg Kangiser
Sales Manager
Mek-A-Nize Robotics, Inc.
975 Elkton Drive
Colorado Springs, CO 80907
Phone: (719) 598-3555
Fax: (719) 548-9227
Email: greg.kangiser@mekanize.com

Mr. William Kneifel
Senior Engineer
Trellis Software & Controls
2619 Product Drive, Suite 106
Rochester Hills, MI 48309
Phone: (248) 844-0560
Fax: (248) 853-0707
Email: billkneifel@trellissoftware..com

Mr. John Lapham
Engineering Manager
Robotic Workspace Technologies, Inc. (RWT)
17105 San Carlos Boulevard, Suite A6151
Fort Myers Beach, FL 33931-5336
Phone: (941) 466-0488
Fax: (941) 466-7270
Email: lapham@rwt.com

Mr. Thomas Luther
Director of Sales & Marketing
Forward Vision Services, Inc.
12055 Hubbard
Livonia, MI 48150
Phone: (734) 458-7300
Fax: (734) 458-7913
Email: tluther@forwardvision.com

Mr. Richard Mathias
Technical Fellow
Boeing Commercial Airplane
MS 5H-88
P.O. Box 3707
Seattle, WA 98124
Phone: (253) 931-4484
Fax: (253) 931-4119
Email: richard.mathias@pss.boeing.com

Mr. Scott McCrary
President
Advanced Automation, Inc.
17 Haywood Road
Greenville, SC 29607-3421
Phone: (864) 627-0900
Fax: (864) 627-1604
Email: smccrary@aautomation.com

John Miller
Systems Integration Manager
Parker Hannifin
6035 Parkland Boulevard
Cleveland, OH 44124
Phone: (216) 896-2532
Fax: (216) 896-4031
Email: johnmiller@parker.com

Mr. Kevin Nelson
R&D
Staubli Unimation, Inc.
201 Parkway West
P.O. Box 189
Duncan, SC 29334
Phone: (864) 486-5480
Fax: (864) 486-5497
Email: k.nelson@staubli.com

Dr. Brent Nowak
Group Lead, Machine Perception and Controls
Southwest Research Institute
Automation Engineering Department
6220 Culebra Road
San Antonio, TX 78228-0510
Phone: (210) 522-2838
Fax: (210) 522-4644
Email: bnowak@swri.org

Mr. James Olejniczak
Electrical Engineer
Miller Electric Manufacturing Co.
1635 West Spender Street
Appleton, WI 54912-1079
Phone: (920) 735-4498
Fax: (920) 735-4041
Email: jolejn@millerwelds.com

Mr. Frank Pagano
Sales Manager
Advance Research & Robotics, Inc.
341 Christian Street
Oxford, CT 06478-1023
Phone: (203) 264-3333
Fax: (203) 264-4693
Email: Sales@ar2.com

Mr. Everette Phillips
General Manager
Seiko Factory Automation & Robotics
2990 West Lomita Boulevard
Torrance, CA 90505
Phone: (310) 517-7856
Fax: (310) 517-8158
Email: everette.phillips@seiko-la.com

Mr. Thomas Pilz
CEO
Pilz Automation Safety L.P.
24850 Drake Road
Farmington Hills, MI 48335
Phone: (248) 473-1133
Fax: (248) 473-3997
Email: tpilz@pilzusa.com

Mr. Fred Proctor
Group Leader, Control Systems Group
NIST
100 Bureau Drive
Mail Stop 8230
Gaithersburg, MD 20899
Phone: (301) 975-3425
Fax: (301) 990-9688
Email: frederick.proctor@nist.gov

Mr. Ross Rawlings
President & CEO
Radix Controls Inc.
2105 Fasan Drive
Oldcastle, ON N0R 1L0
Canada
Phone: (877) 467-2349
Fax: (519) 737-1810
Email: sales@radixcontrols.com

Mr. Ronald Reeve
Chairman
IRobotics
3036 Madan Park Drive
Indianapolis, IN 46241-5460
Phone: (317) 244-7626
Fax: (317) 244-8650
Email: ron_reeve@irobotics.com

Mr. Fred Robinson
Engineering Manager
Trellis Software & Controls
2619 Product Drive, Suite 106
Rochester Hills, MI 48309
Phone: (248) 844-0596
Fax: (248) 853-0707
Email: fredrobinson@trellissoftware.com

Mr. Helmut Schreiberhuber
Vice President
KEBA Corporation
100 West Big Beaver Road, Suite 200
Troy, MI 48084
Phone: (248) 526-0561
Fax: (248) 526-0562
Email: schr@us.keba.com

Mr. Donald Stephanic
Vice President
Applied Manufacturing Technologies, Inc.
1200 Harmon Rd.
Auburn Hills, MI 48326-1550
Phone: (248) 391-9560
Fax: (248) 391-9534
Email: dons@appliedmfg.com

Dr. Harry Stephanou
Director
Rensselaer Polytechnic Institute
Center for Automation Technologies
110 Eighth St., CII Building, Ste. 8015
Troy, NY 12180-3590
Phone: (518) 276-6156
Fax: (518) 276-4897
Email: hes@cat.rpi.edu

Mr. Dave Sytkowski
Tower Automotive
3533 North 27th Street
Milwaukee, WI 53216
Phone: (414) 447-4351
Fax: (414) 447-4882
Email: sytkowski.david@towerautomotive.com

Mr. George Tecos
Manager, Engineering & Development
KUKA Robotics Corporation
6600 Center Drive
Sterling Heights, MI 48312
Phone: (810) 795-4595
Fax: (810) 795-4871
Email: gtecos@kukausa.com

Prof. Delbert Tesar
Director, Robotics Research Group
The University of Texas at Austin
PRC/MERB 1.206 R9925
Austin, TX 78712-1100
Phone: (512) 471-3039
Fax: (512) 471-3987
Email: tesar@mail.utexas.edu

Mr. Clifton Triplett
Information Officer - Global Produce Product
General Motors Corporation
1155 Brewery Park Blvd., MC 482-BP1-502
P.O. Box 07960
Detroit, MI 48207-7960
Phone: (313) 667-4905
Fax: (313) 667-4678
Email: clif.triplett@gm.com

Mr. Donald Vincent
Executive Vice President
Robotic Industries Association
900 Victors Way, Ste. 140
P.O. Box 3724
Ann Arbor, MI 48106
Phone: (734) 994-6088
Fax: (734) 994-3338
Email: dvincent@robotics.org

Mr. Gregory Webb
Manager Software R&D
Motoman Inc.
2150 South Dorset Road
Troy, OH 45373-4708
Phone: 937-440-2621
Fax: 937-440-2626
Email: greg_webb@motoman.com

Mr. James Wells
Engineering Group Manager
General Motors Corporation
Controls, Robotics & Welding
30300 Mound Road/480-106-163
Warren, MI 48090-9040
Phone: (810) 602-9879
Fax: (810) 947-1039
Email: jwells@gmr.com

Open Architecture Control for the Robotics Industry Workshop
Walt Disney World Swan & Dolphin Hotel _ Orlando, Florida
February 9-10, 2000

Sponsored by:
Robotic Industries Association
National Institute of Standards and Technology

Agenda

Wednesday, February 9

6:00 pm–8:00 pm (Swan 5A-B)	Networking Reception and Early Bird Registration

Thursday, February 10

7:00 am–8:00 am (Dolphin Salon A4)	Registration and Continental Breakfast
8:00 am	Welcome and Introductions Don Vincent, RIA John Evans, NIST
8:15 am	User Perspective Clif Triplett, General Motors Dick Mathias, Boeing
9:00 am	Vendor Perspective Dave Faulkner, Cimetrix Jim Degen and George Tecos, KUKA Robotics
9:45 am	Break
10:00 am	Third Party Perspective Tim Garner, Delphi Automotive Scott McCrary, Advanced Automation
10:45 am	Related Efforts OMAC: Dick Mathias, Boeing IEC 61499: Sushil Birla, GM
11:30 am (Swan 5)	Group Luncheon Featured Speaker: Mara Liasson, White House Correspondent, National Public Radio
1:30 pm (Dolphin Salon A4)	Open Robotic Interface Network (ORIN): Bill De Camp, Motoman
1:45 pm 2:00 pm	Group Discussion Objectives and Priorities Group Discussions, Parallel Sessions
3:45 pm	Break
4:00 pm	Presentation of Group Discussion Results and Open Forum
5:00 pm	Adjourn

Section One

Introduction

John Evans, Chief
Intelligent Systems Division

NIST

RIA/NIST
Open Architecture Workshop

RIA

Don Vincent, Executive Vice President, RIA
Jeff Burnstein, Director, M&PR

NIST

John Evans, Chief, Intelligent Systems Division, NIST
Fred Proctor, Chief, Control Systems Group

RIA 1999 Robotics Industry Forum

Open Architectures came up several times

Contentious issue

No agreement

No opportunity to explore

Related programs in OMAC/OSACA/JOP
and IEC 61131/61499

RIA/NIST
Open Architecture Workshop
Objectives

- Understanding of user and vendor and third party perspectives

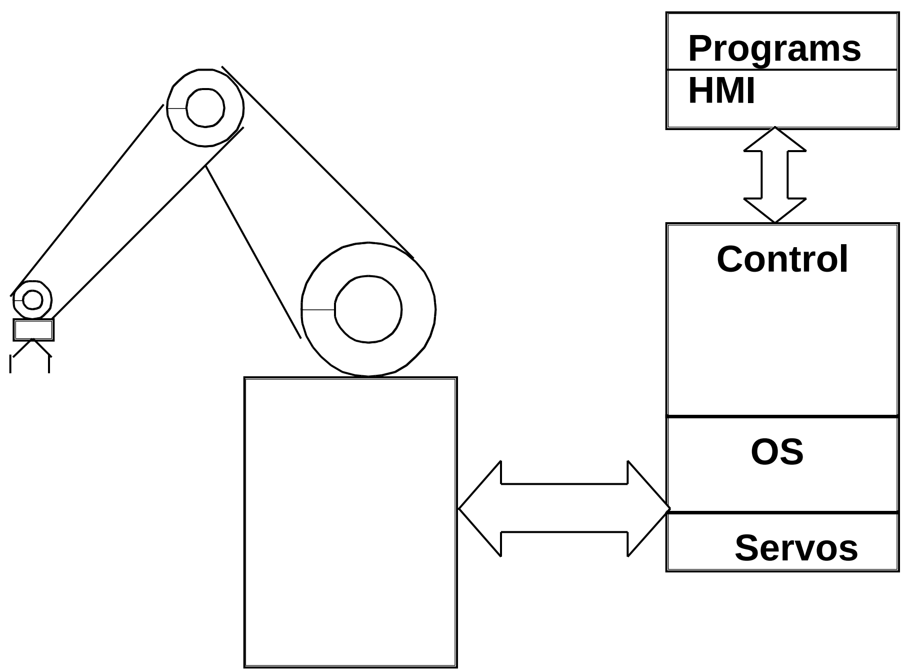
- Understanding of related efforts

- Consideration and prioritization of possible future RIA programs

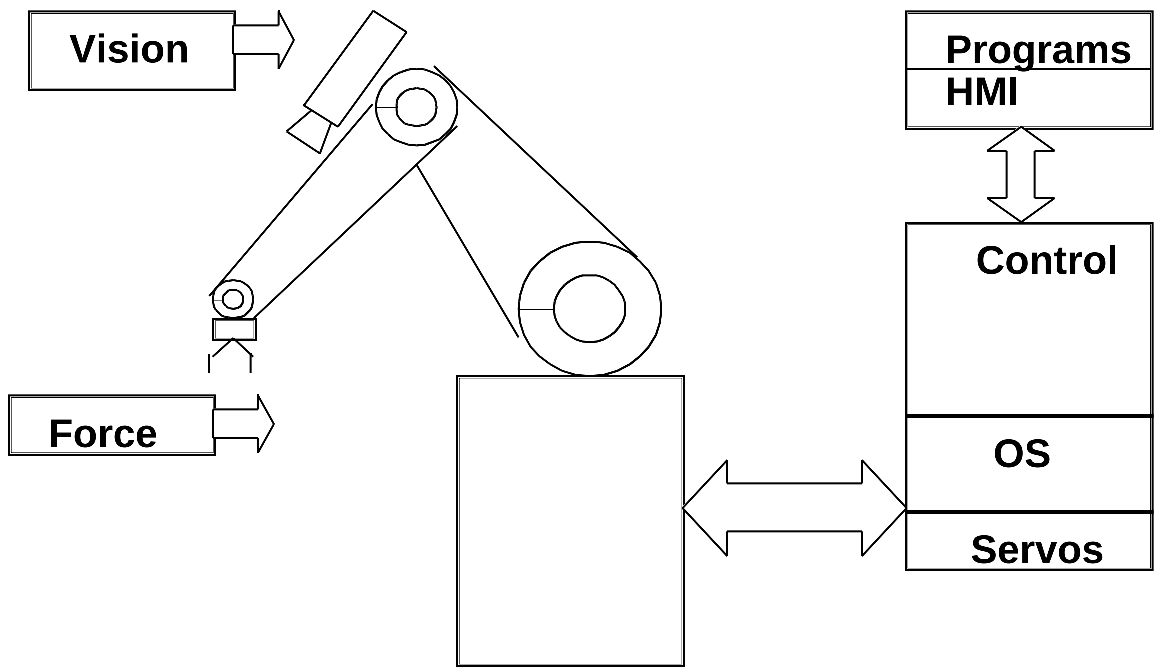
What is an Open Architecture?

- Defined and user accessible interfaces
- Run third Party Software
- Uses standard platform for component plug and play

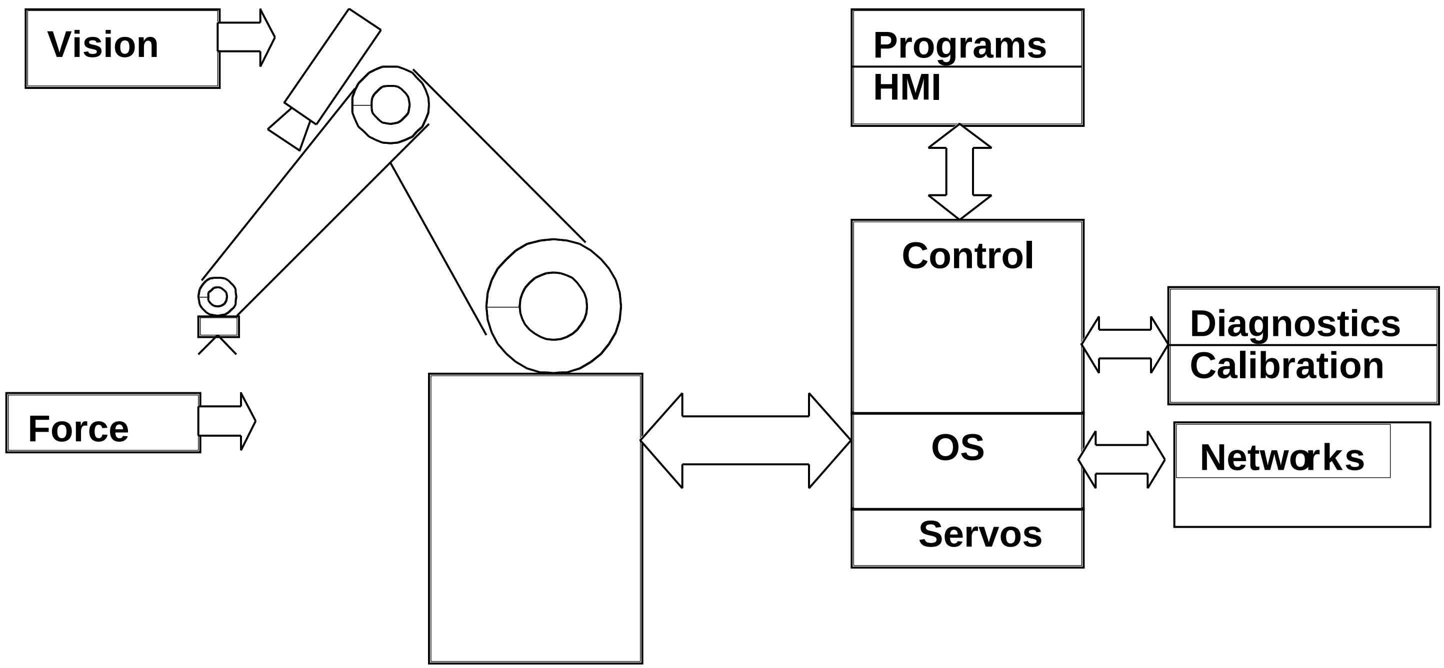
Open Architectures for Robot Controls



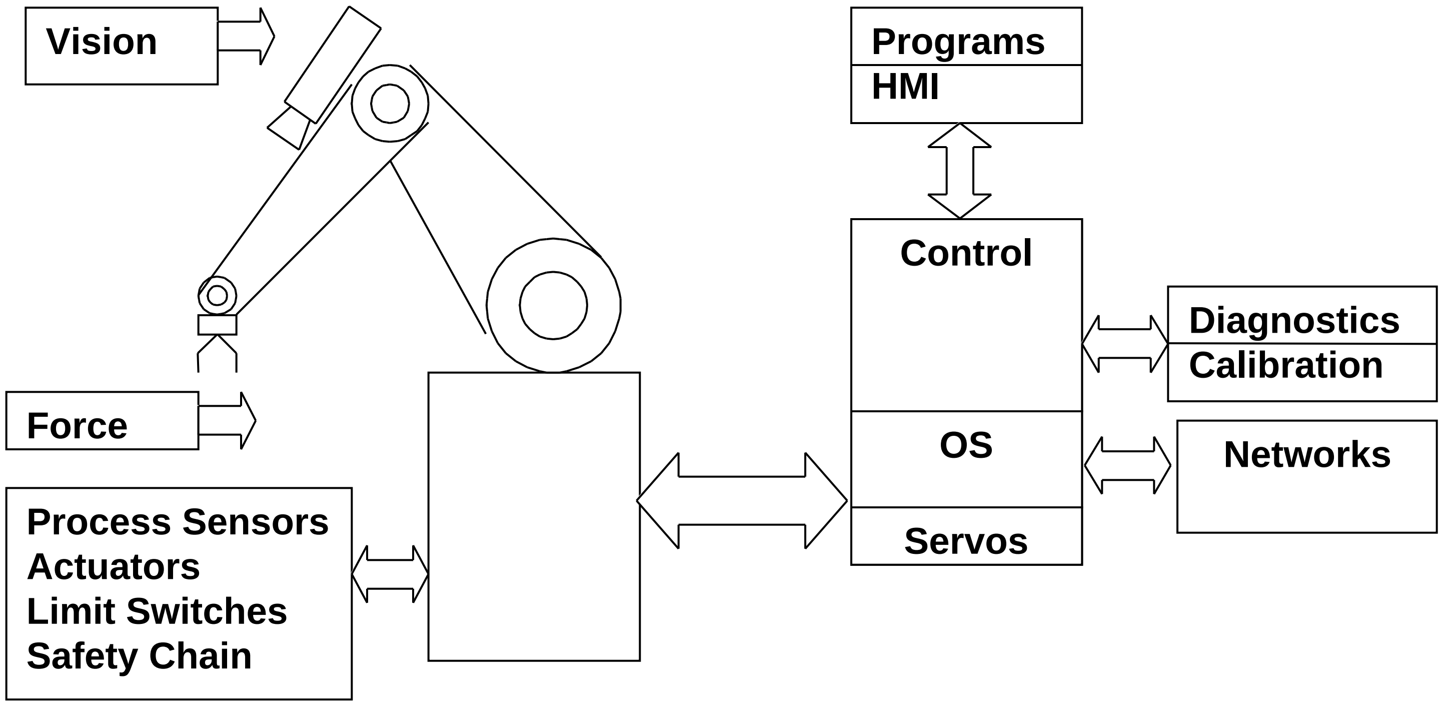
Open Architectures for Robot Controls



Open Architectures for Robot Controls



Open Architectures for Robot Controls



Fieldbus and Networking Standards

Fieldbus and Networking Standards

- ARCNET
- AS-I
- CANOpen
- ControlNet
- DeviceNet
- FoundationFieldBus
- INTERBUS-S
- SP50 Fieldbus
- Seriplex
- WorldFIP
- LonWorks
- SDS
- PROFIBUS DP/PA

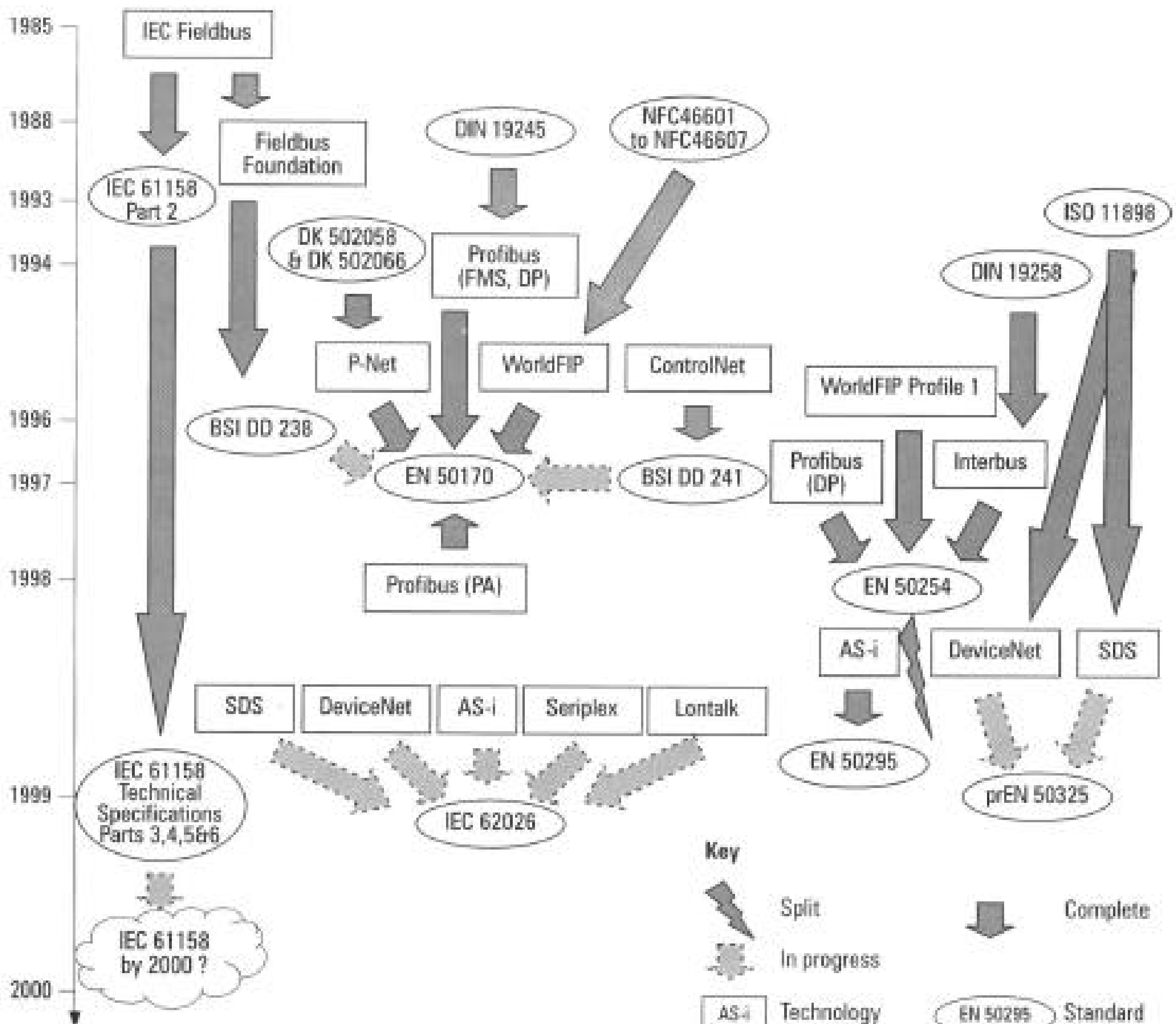
Computer Interfaces

- ISA
- PCI
- PCMCIA
- VME
- RS232/422
- Ethernet
- Industrial Ethernet
- Firewire (IEEE 1394)
- USB
- SCSI

IEEE 1451 Smart Transducer Interface

Messaging Standards: ISO/IEC 9506-1 (MMS), COM

European Fieldbus Standards Development



Section Two

Robotics Simulation

Clifton Triplett, Information Officer
Global Produce Product Process

General Motors Corporation

Robotics Simulation

Information Systems & Services
Produce Product

February 10, 2000

Clif Triplett
Global Produce Product Process Information Officer

Problem Statement

We are challenged to:

- Dramatically reduce the non-value added cost of technical integration ***and*** the total lifecycle service.
- Realize the benefits of volume price curves seen in the PC industry for replaceable components
- Realize the benefits of service levels seen in the IT industry for mission critical systems

Problem Statement-continued

Today, we must:

- Attack the cost of integration
- Match the availability of technical features with the PC industry
- Select standards, establish a focus and gain momentum

Missed Opportunity

PRODUCE PRODUCT

◆ Start simple and build on success

◆ Three wave strategy:

1. Leverage the Existence and Volumes of Marketplace Technology Standards
2. Define the Baseline of Standard Business Capabilities
3. Automate Selected Business Capabilities

Leverage the Existence and Volumes of Marketplace Technology Standards

Several unique robotic technologies duplicate capabilities available in other higher volume technology markets (unique should differentiate, not complicate).

		Current	Emerging
Communications	Media	Copper - CAT 5 / CAT 6	CAT6
		Fiber Single & Multi Mode	Fiber Single & Multi Mode
	Communications Protocol	TCP - RFC 793	TCP - RFC 1122
		IPv4 - RFC 791,1122,1812	IPV6, IPSEC RCF 1825-7
	Event Management	SNMP - RFC 1901-10	SNMP w/ MIB II - RFC 1213,1157
Operator Presentation	Graphics	Browser (IE, Netscape)	Browser (IE, Netscape)
	Character	Browser	Browser
Network Services	Setting Common Time	NTP - RFC 997	NTP - RFC 1119
	Network Management.	SNMP	SNMP w/ MIB II
	Data Representation	XML	XML/XSL ISO 8879 & W3C XML v1
	Development	JAVA / C++ / GNU	JAVA / GNU

Define the Baseline of Standard Business Capabilities

- SDX simulation data exchange models for robots
- Standard state and error status communications content

Automate Selected Business Capabilities

- Self aligning / leveling robots
  (match reality to simulation models)
- Self defining tooling
  - Weight
  - Spatial Dimensions
  - Function
  - Serial Number

Proposal

- Create Industry Momentum to Deliver "Win - Win" Standards
- Leverage:
  - Robotic Industry Association (RIA)
  - National Institute of Standards and Technology (NIST)
  - Automotive Industry Action Group (AIAG)
- Go After Wave 1
  - May 2000 Adoption or Key Issues Identified

Section Three

Open Architecture Controls for Robots

Richard Mathias, Technical Fellow

Boeing Commercial Airplane Group

Open Architecture Controls for Robots

Dick Mathias/Craig Battles
Boeing Commercial Airplane Group
richard.a.mathias@boeing.com
craig.f.battles@boeing.com

Agenda

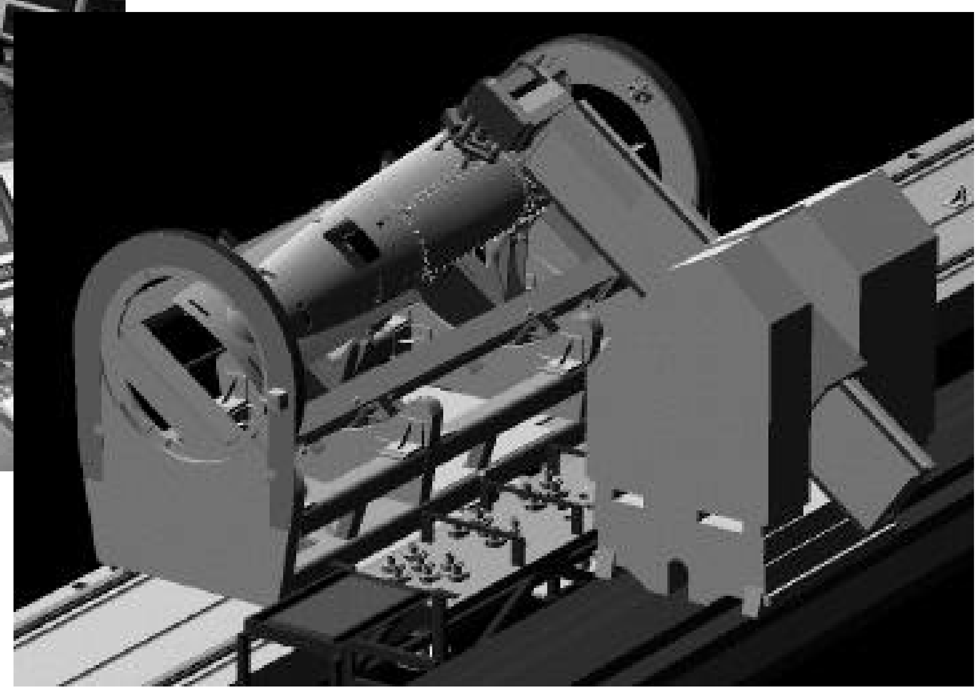
- **Boeing at a Glance**
- **Robot Use at Boeing**
- **Why Should You Care about Aerospace?**
- **What Boeing Wants in Open Architecture for Robots**
- **Open Architecture and Standards**
- **Summary and Questions**

Boeing at a Glance

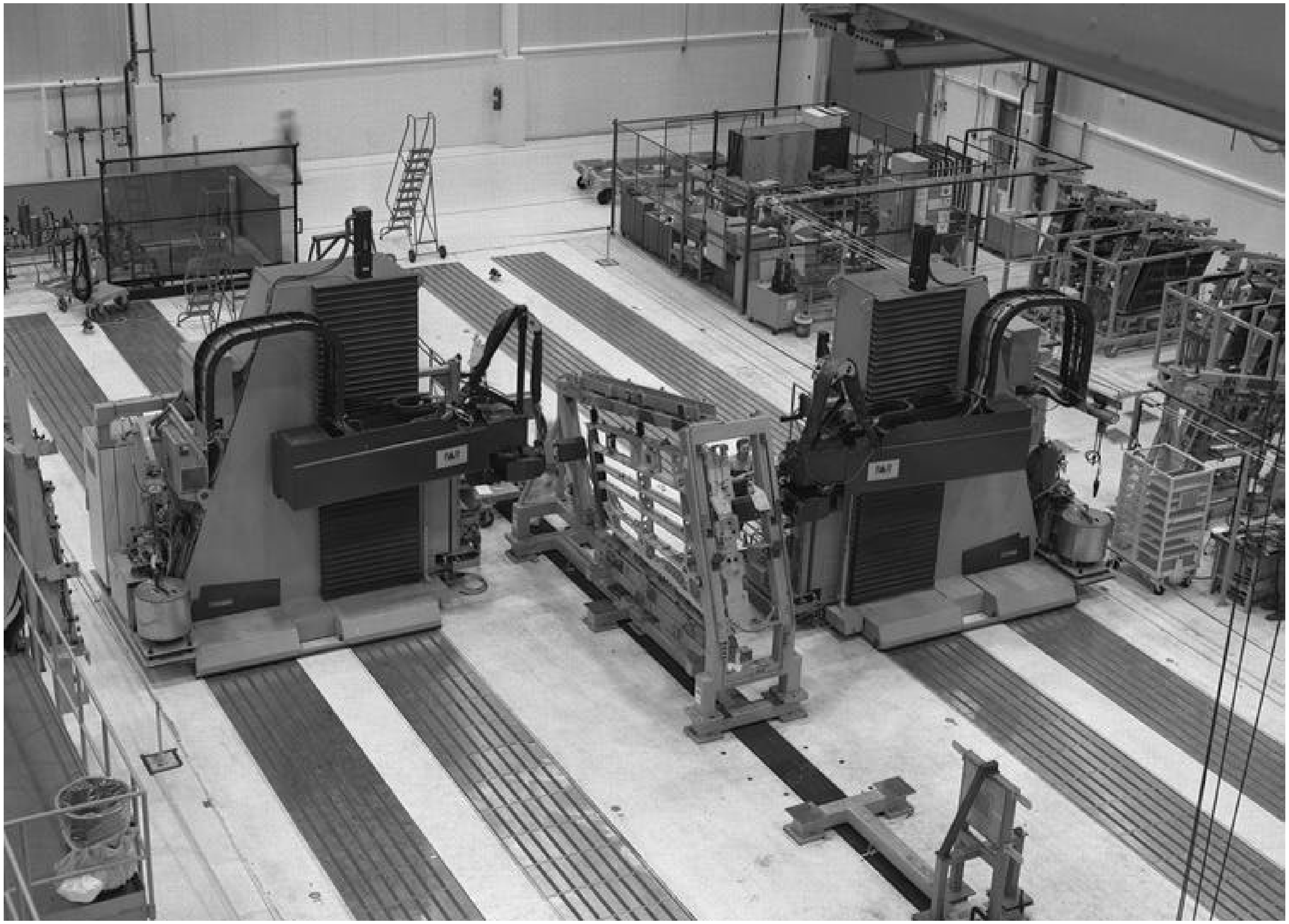
- **Largest Aerospace Company in the World**
- **Active in:**
  - Commercial Aircraft
  - Military Aircraft
  - Missiles
  - Space
- **Global Employer of 195,000**
  - 27 States
  - 60 Countries

- **Revenues of $57.99 B in 1999 ($2.309 B Net)**
- **Currently Use Fewer than 150 Robots Worldwide**

Robot Use at Boeing

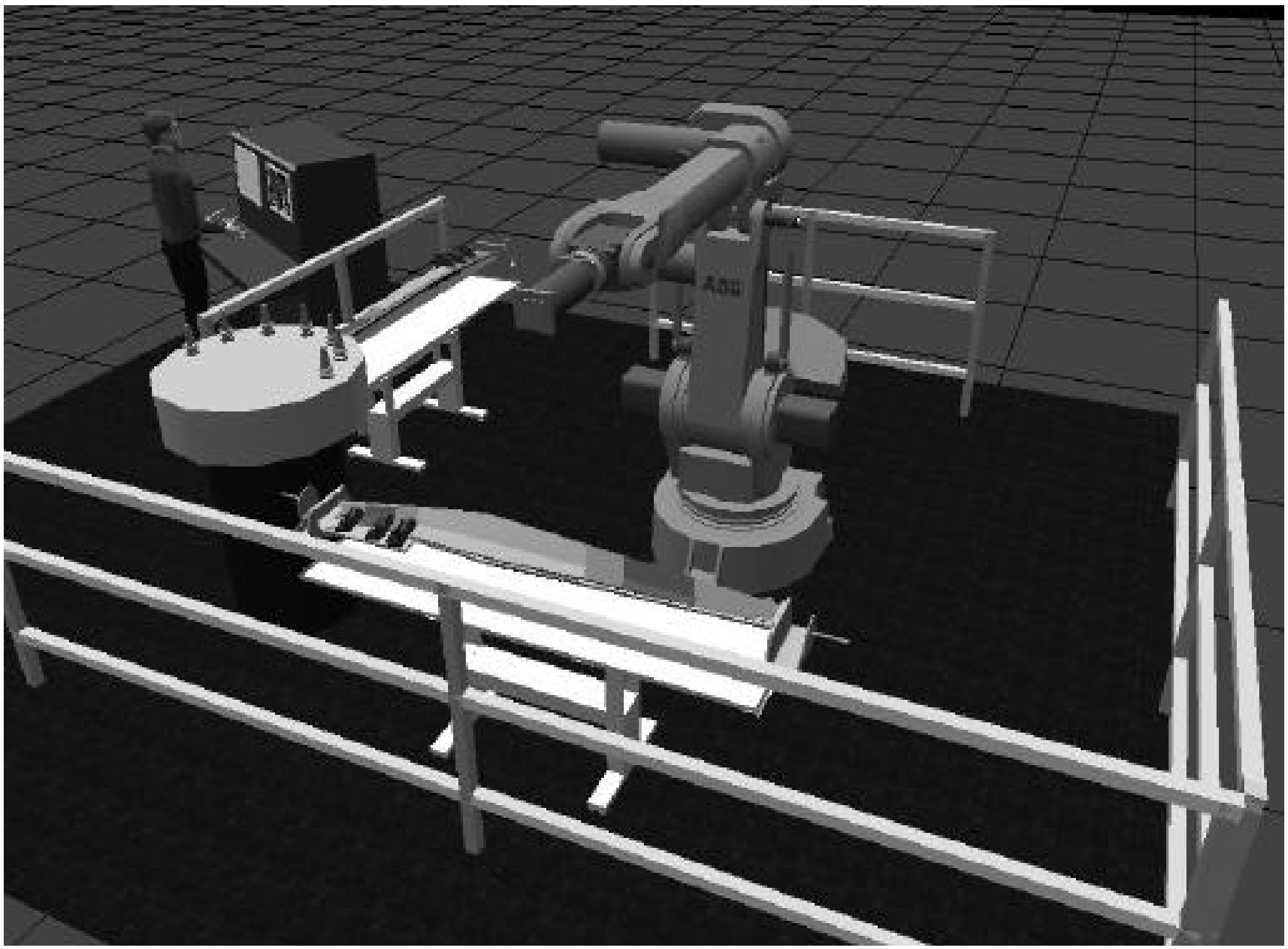


Robot Use at Boeing



Robot Use at Boeing

Robot Use at Boeing



Robot Use at Boeing

Robot Use at Boeing

- **High End Applications**
  - High Value Parts
  - Few Robots
  - Many Sensors
- **Complex Programs**
  - Run Times Measured in Hours
  - Off-line Programming
  - Calibration/Accuracy Enhancement
- **Simulation Used to Optimize Equipment Choice**
  - Heterogeneous Mix of Robot/Equipment Manufacturers

Aerospace Requirements

- **Reduce Cost/Time of Integration**
  - Adaptable to Custom Machines
  - Sensor Integration down to the Servo Level
  - Language Neutral
  - Multi-Network Capable (Device Net, Firewire, Profibus, Sercos, Interbus-S ...)
- **Reduce Cost of Use**
  - Data Creation and Transfer
  - Operator Training
- **Reduce Cost of Maintenance**
  - Remote Diagnosis
  - Common Spares

Why Should You Care?

Because we know where you live….

But Seriously….

Why Should You Care?

- **Your Largest Customers Are or Will Be Asking for the Same Things**
  - OMAC, OSACA and others
  - Industry Move to Reduce “Transaction Costs”
  - Reference “GM’s Needs in Robotics Simulation” by Clif Triplett at 1999 Robotics Industry Forum
- **Aerospace Represents a Large Untapped Market**
  - Boeing Alone Spends Hundreds of Millions for Facilities Each Year - How Much of That Did Robotics Companies Get?
  - Controls
  - Robots
  - Systems (VARs)

What Boeing Wants in OAC

- **Standard Hardware and Software**

- **The Ability to Alter/Replace/Enhance**
  - Hardware
  - Software

- **A Controller that Supports Modular Programs and Code Re-Use**

- **A Controller that Allows Us to Choose <u>Our</u> Standard Programming Language**

Open Architecture and Standards

- **Software Should Be Modular and Support a Variety of Standards**
  - Communications
    - Serial RS-232
    - Network (TCP/IP, Firewire, Profibus, DeviceNet, Interbus-S)
    - Protocols (Telnet, FTP, RPC, ORBIX,COM, DCOM, SOAP)
  - Languages
    - C, C++, Java, Basic
    - Karel, V+, RAPID
- **Standards Should Still be Here in 2007**
- **Don’t Tie Us to A Single Vendor (Even Microsoft)**

Open Architecture and Standards

- **Hardware Should be:**
  - Standard
  - Modular
  - Widely Available
  - Reliable
  - Inexpensive
- **Hardware (or Compatible Replacement Should be Available in 2007**
- **Don’t Tie Us to A Single Vendor**

Summary

- **Boeing is a Small, High End Robotics User**
  - Offline Programming
  - Heavy Requirements
    - Sensors
    - Data Communications
    - Simulation

- **What we Really Need is What Most Users Need**
  - Reduce Our Costs to Buy, Use and Maintain Equipment
  - Make Equipment Differences “Transparent” to the Operator
  - Enable Sophisticated Users and VARs to Build in Transparency by Giving them Access to Hardware and Software

Section Four

Open Architecture Control at Cimetrix

David Faulkner,
Executive Vice President
of Marketing

Cimetrix, Inc.

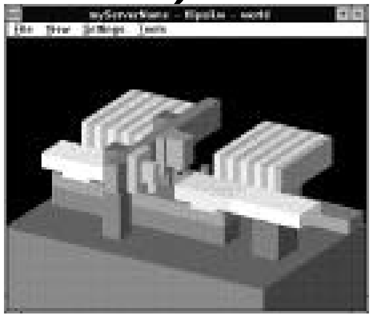
Cimetrix INCORPORATED

Cimetrix INCORPORATED

"Bringing the Power of the PC to the Factory Floor."

Cimetrix Products

- **CODE (Cimetrix Open Development Environment)**
  - Open architecture motion control software
    - NEMI/IEEE supported
    - Suitable for high volume OEM installations
  - Our Vision
    - Mass market general purpose software motion controller fully supporting OMAC specifications



- **GEM (Generic Equipment Model)/SECS**
  - Communications software for the SMT and Semiconductor industries
    - Plans driven by Motorola
  - Our Vision
    - Web enabling factory communications interface

Acquisitions

- **Systematic Designs International, Inc. (SDI)**
  - Semiconductor integrator in Vancouver, WA
  - New GEM/SECS products targeting semiconductor

- **Object Factory**
  - Software company in Greenville, SC
  - Spin-off from robot systems integrator
  - Excellent product fit - AART

Industry Experience

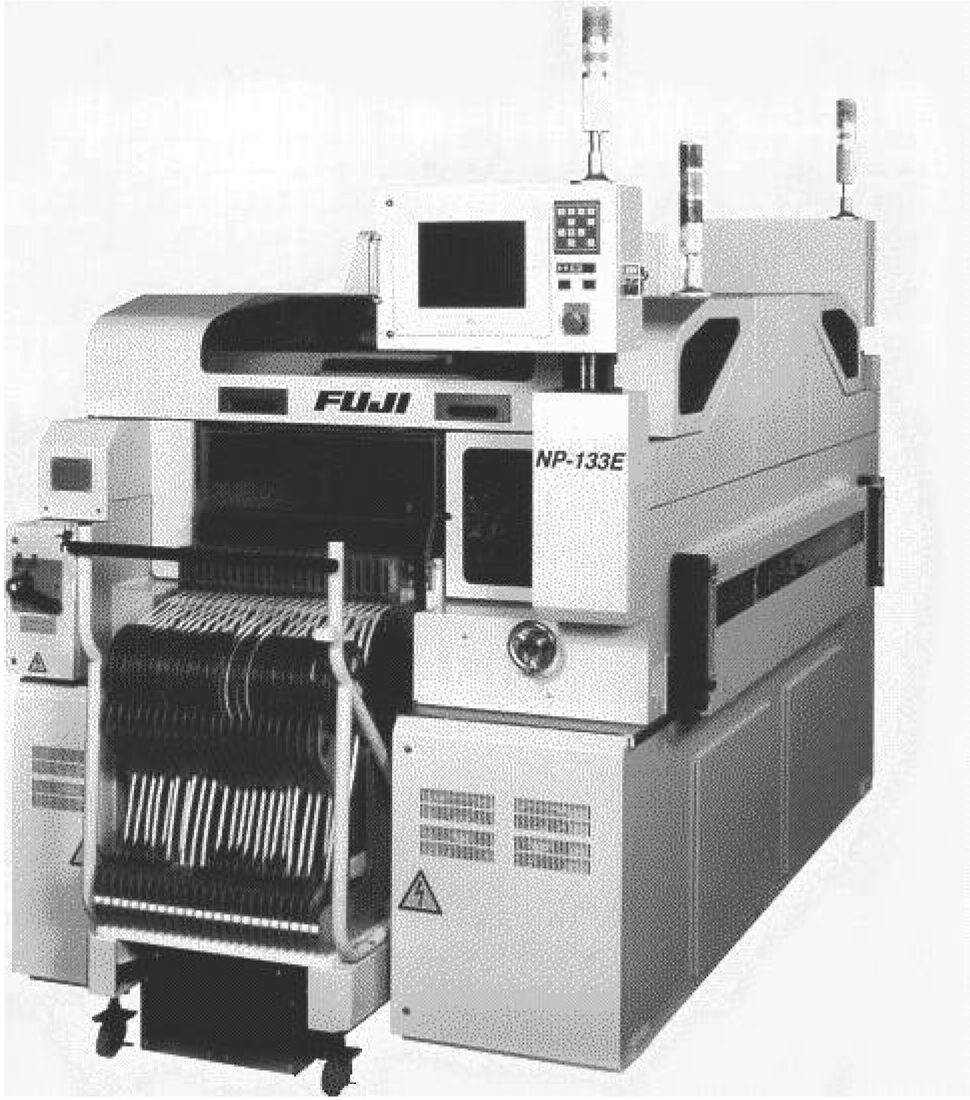
Cimetrix Incorporated

- ***Is the robot industry ready for open architecture?***

GENERAL MANUFACTURING				ELECTRONICS				
MACHINE TOOLS		ROBOTS		SEMICONDUCTOR		OTHER ELECTRONICS		
Metal Forming	Metal Cutting	General Robots	Niche Robots	Wafer Fab	Semi Back End	SMT	Small Part Assembly	Disk Drive
✓	✓	✓	✓	✓	✓	✓	✓	✓
		↑				↑	↑	↑

FUJI NP133E

- **Twin Station High-Speed SMD Mounter**
- **20,000 Parts/hour**
- **12 axes with 2 Rotating Heads**



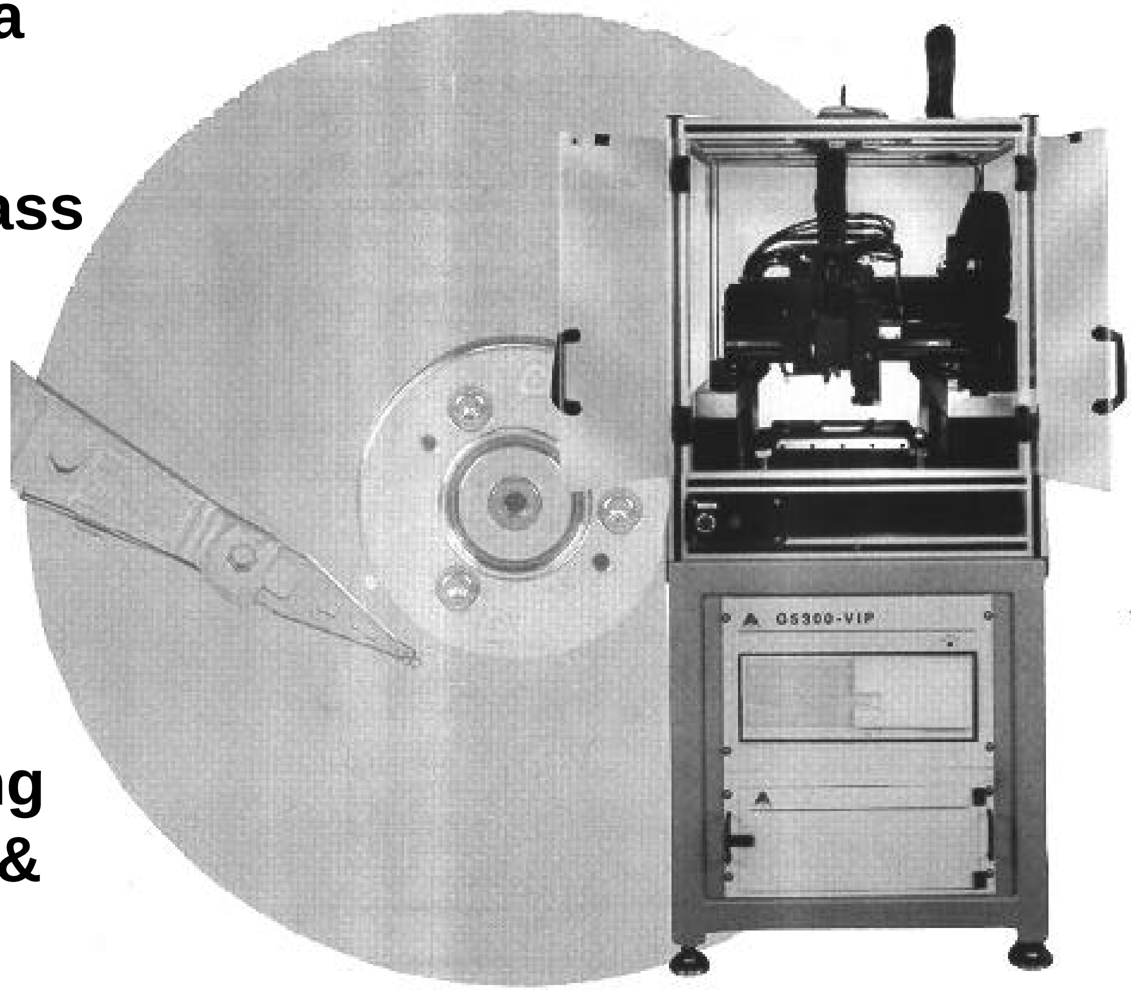
Motorola Manufacturing Systems (MMS) High Density CSP Singulation

- **Integrated Handling and Dicing Solution**
- **2-3X Cost of Ownership Improvement**
- **Standalone or Integrated**

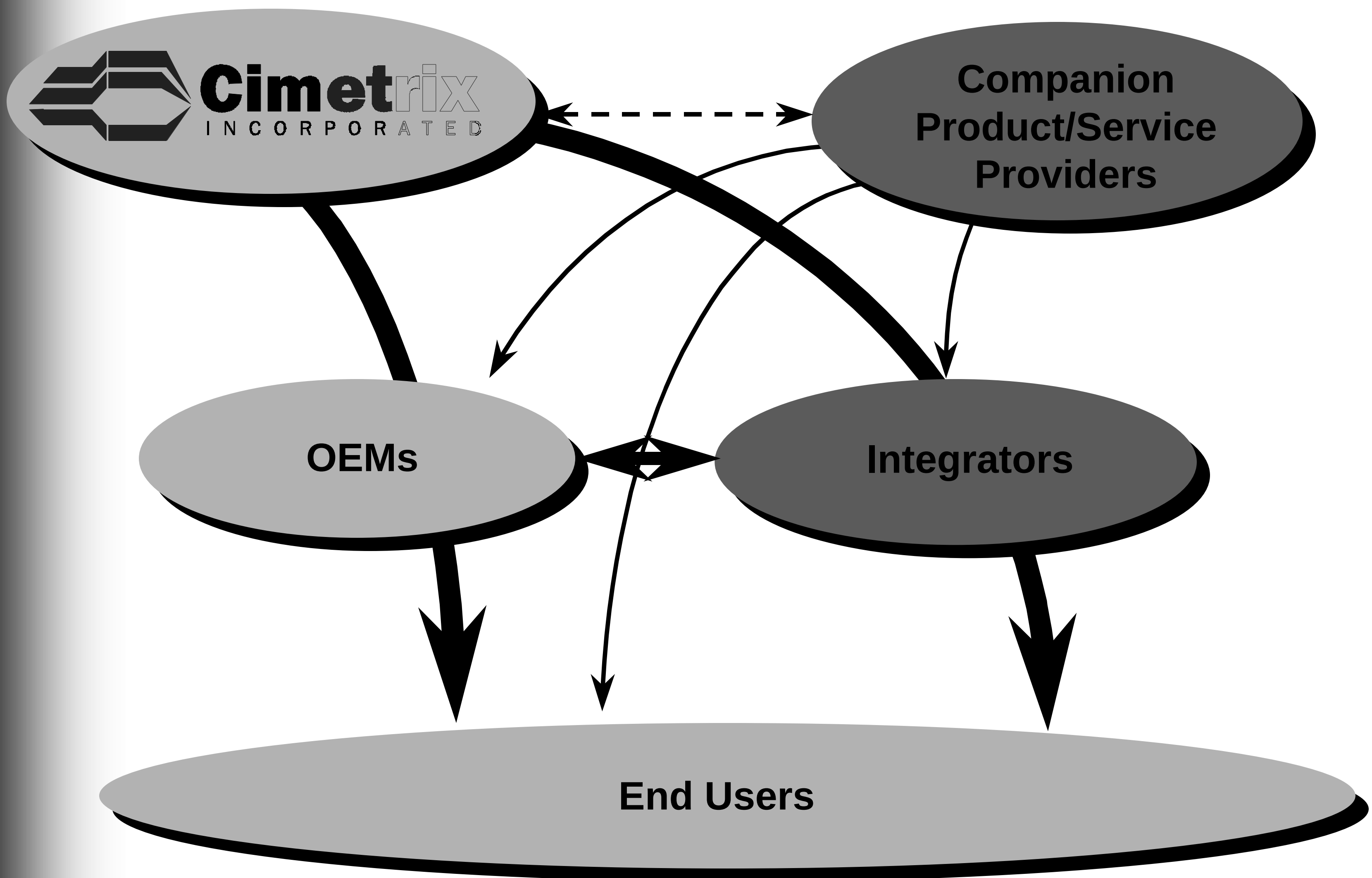
Cimetrix® INCORPORATED

Anorad Slider Sorter System

- **X, Y, Z, Theta Gantry**
- **1 m/s, 1g Class Machine**
- **10 Micron Accuracy**
- **Sorts 1,800 die per hour**
- **Down-looking die location & side looking OCR cameras**



Business Channels



The Cimetrix Open Development Environment (CODE™ 99)

Windows NT

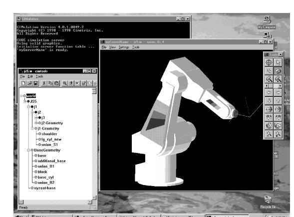
Machine Specific Application Software

NT Infrastructure and Domain Specific Objects

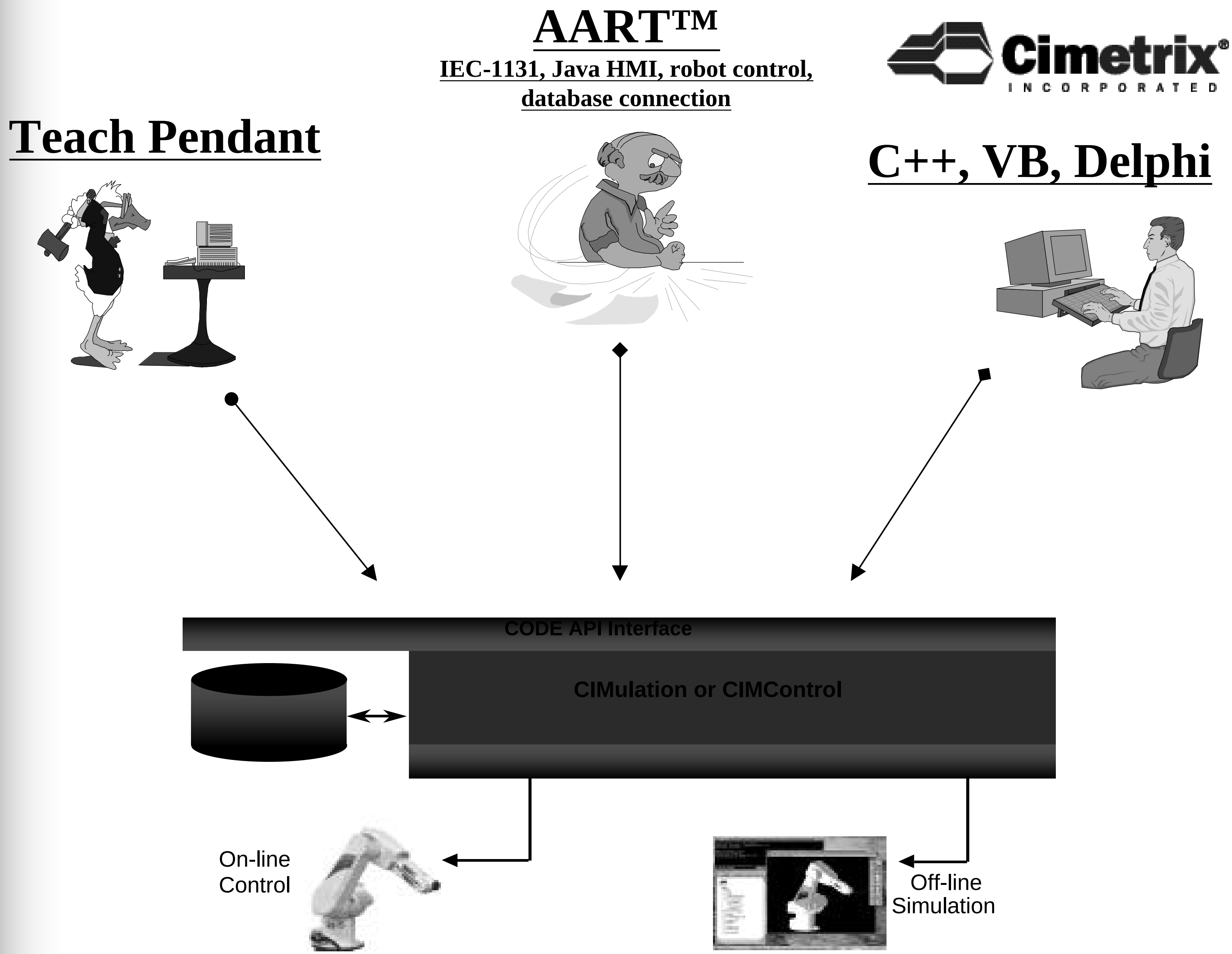
CODE

CODE Motion and I/O Control and Simulation Software

On-line Control

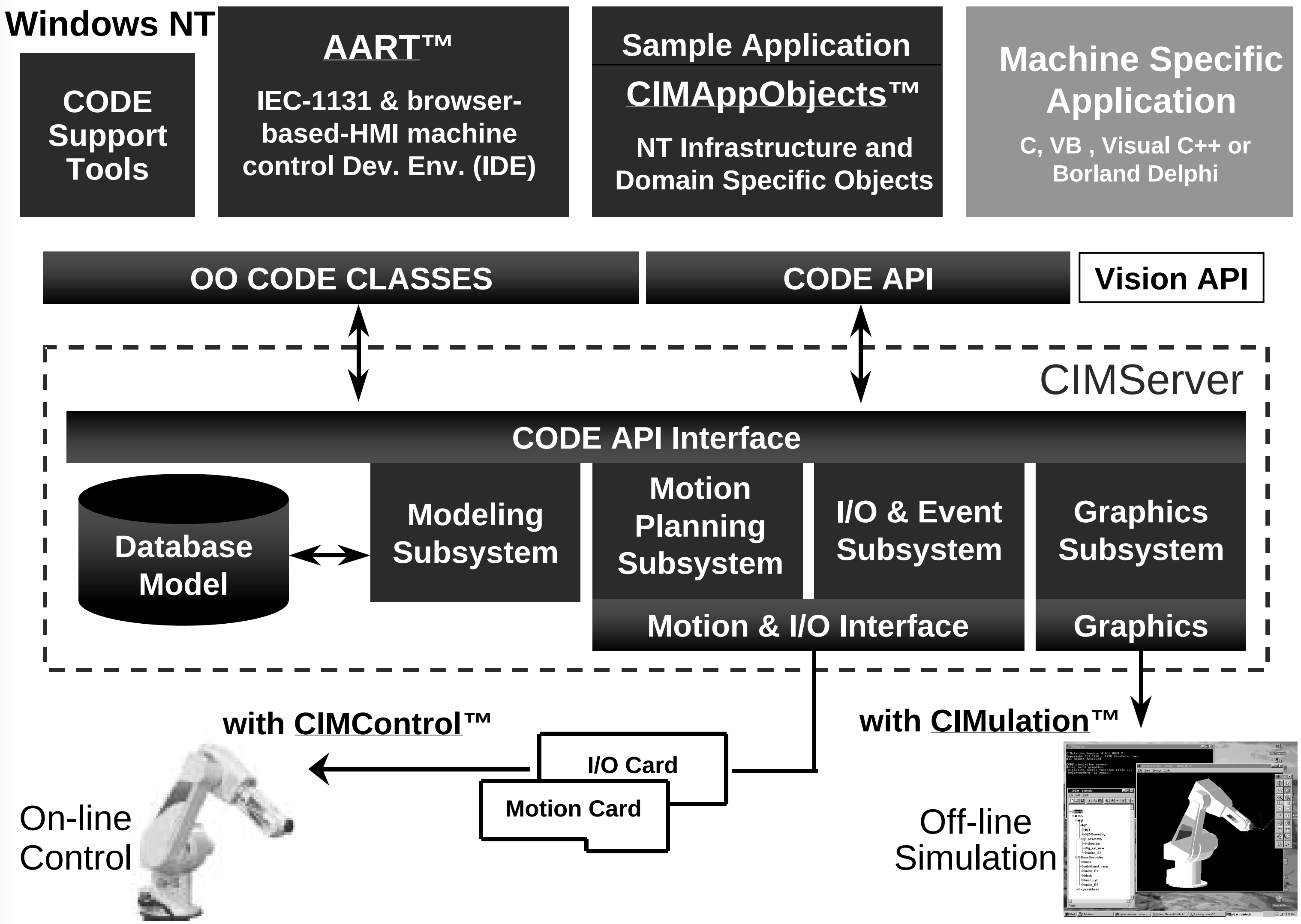


Off-line Simulation

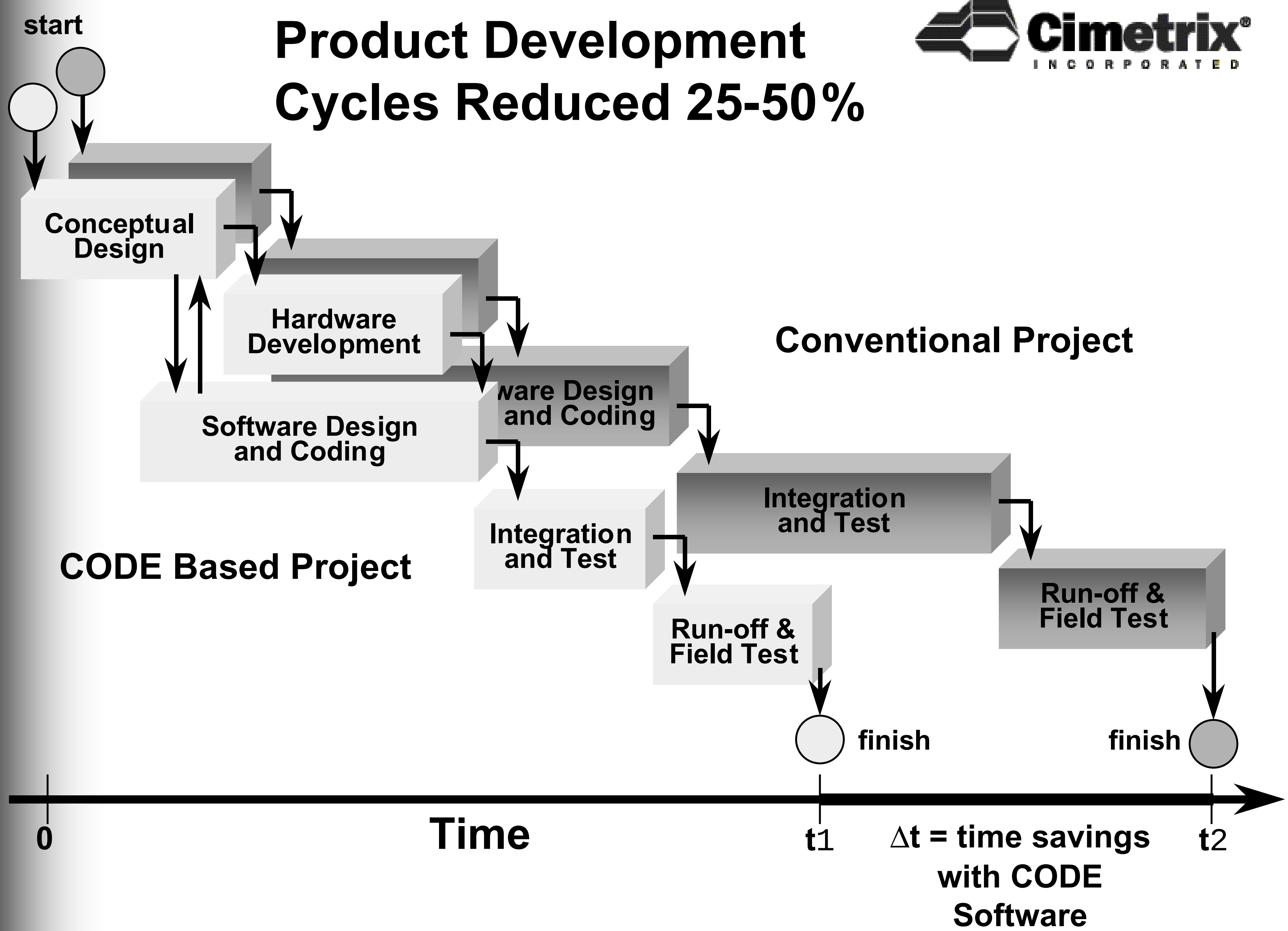

AART™
IEC-1131, Java HMI, robot control, database connection
Cimetrix
INCORPORATED
Teach Pendant
C++, VB, Delphi
CODE API Interface
CIMulation or CIMControl
On-line Control
Off-line Simulation

Cimetrix INCORPORATED

The Cimetrix Open Development Environment (CODE™ 99)

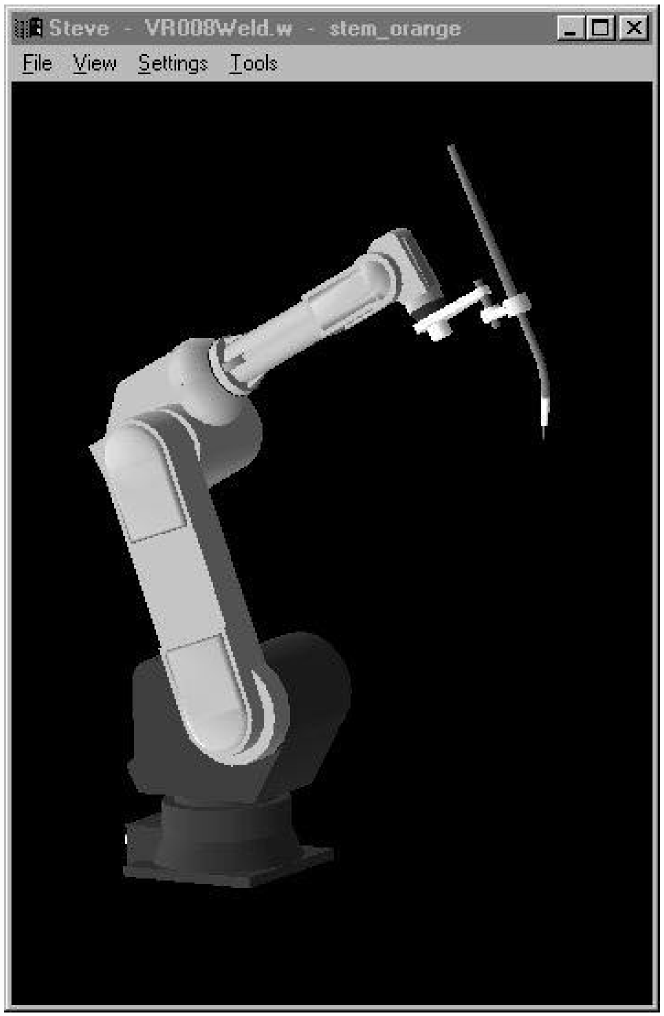


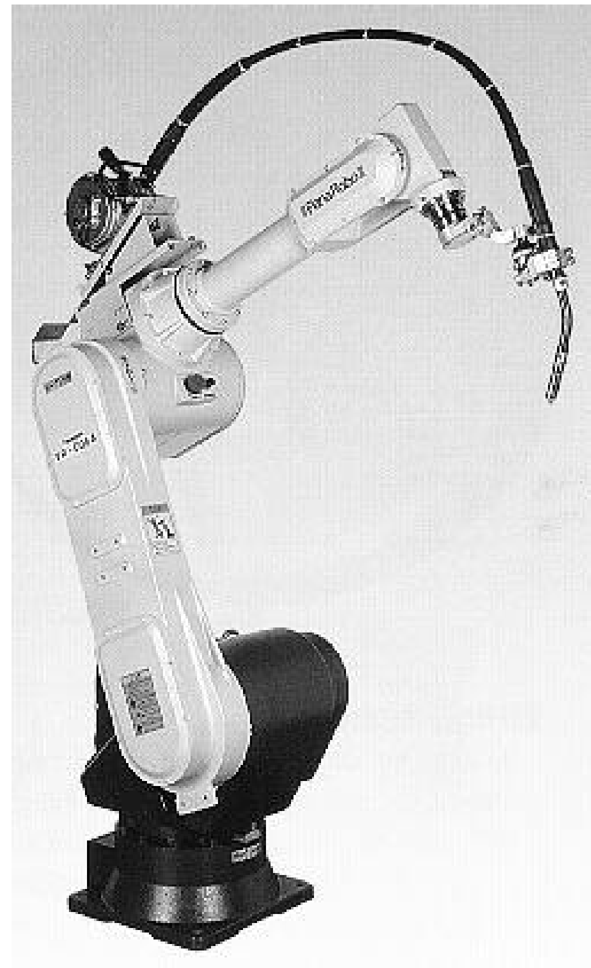
Product Development Cycles Reduced 25-50%



Cimetrix®
INCORPORATED

Simulation and control - same software!



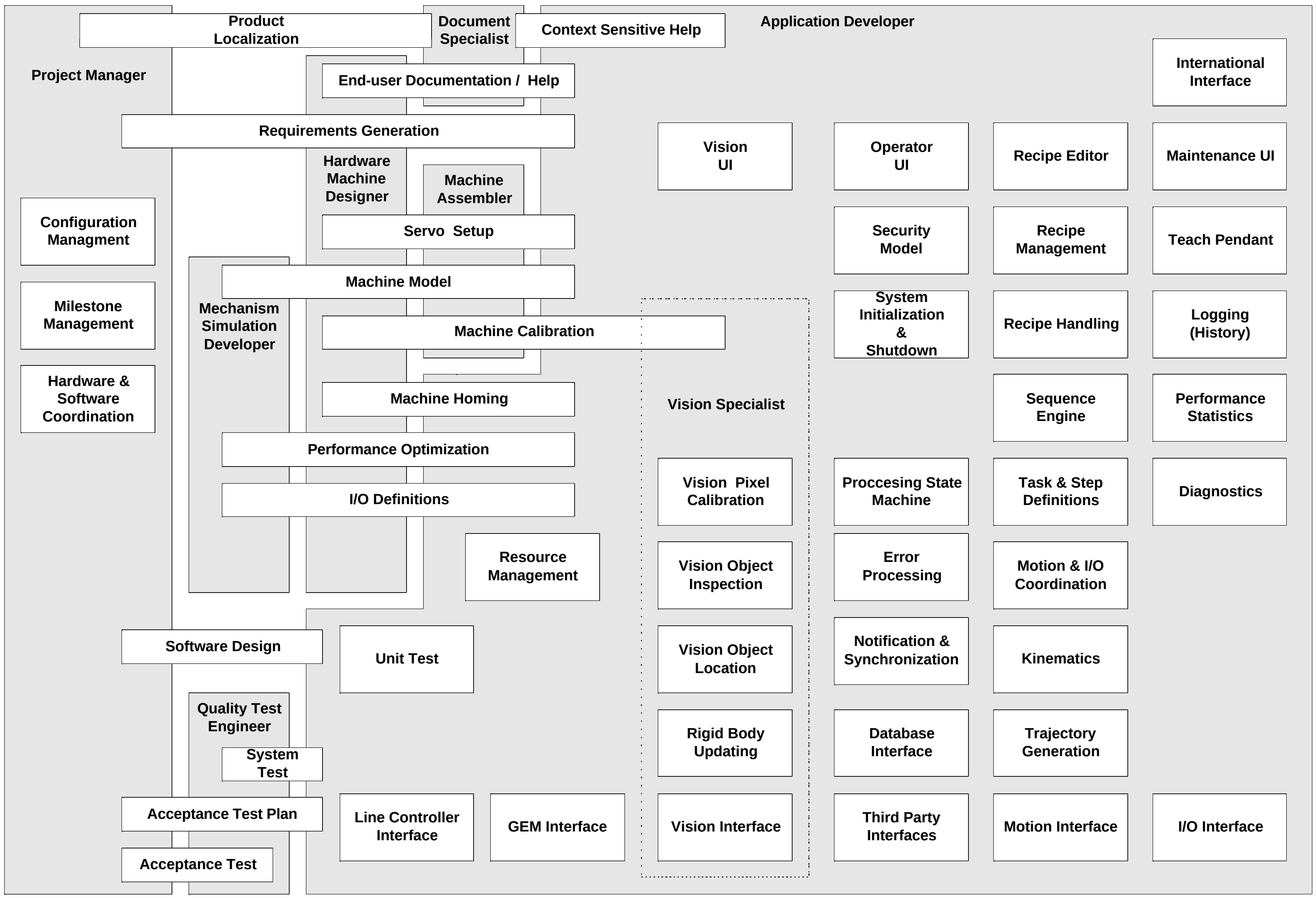


Robot Maker Tasks

- Teach Programming Environment
- Programming Language
- Hand Held teach pendent
- Select Published Interfaces (APIs)
- Application Packages
  - Arc Weld
  - Material handling
  - Spot Weld
  - Electronics Assembly
  - Paint
  - Palletize
- Robot Model & Parameters
- Jacobean solution
- Tuning Modification Package
- GEM Interface
- Operator Panel
  - Cycle start, hold
  - Resume, E-stop
  - Operator stop, prompt
- System Initialization, Shutdown & Recovery
- Diagnostics
- System Backup and Restore
- Version Control
- Device Interface
- GUI/Desktop
- Integrated Help
- Robot Safety Standards
- System Level Test Plan
- System Documentation

TITLE: EA Workcell - Software Development Tasks

Version: 1.3



Technology and Standards

- **Technology**
  - *Object Oriented*
  - *UML - Unified Modeling Language*
  - *100% Windows NT (and real-time extensions if needed)*
  - *COM/DCOM/ActiveX*

- **Standards Conformance**
  - *NEMI, OMAC API, JOP, OSACA, IEC-61131-3, IEC-61499, World Wide Web, Microsoft*

Cimetrix® INCORPORATED

Computer Industry Analogy

	1981 Vertical Structure		1999 Horizontal Structure
CPU's	IBM All Products	DEC All Products	Intel, AMD, Motorola, Etc.
Operating Systems			Microsoft, UNIX, Mac, ...
Database Mgt. Systems			Oracle, Informix, Microsoft, ...
Applications Software			SAP, CA, Microsoft, ...
Assembled Hardware			Dell, IBM, Compaq, Toshiba, ...

Source: MIT & Martin Piszczalski

Section Five

Open Architecture Controls for the Robotics Industry

Jim Degen, President
George Tecos, Manager,
Engineering and Development

KUKA Robotics Corporation

KUKA Robotics Corporation, 6600 Center Drive, Sterling Heights, MI 48312, Tel.: +810-795-2000, Fax: +810-795-4871

Open Architecture Controls for the Robotics Industry

Jim Degen
President
KUKA Robotics Corporation
Sterling Heights, MI

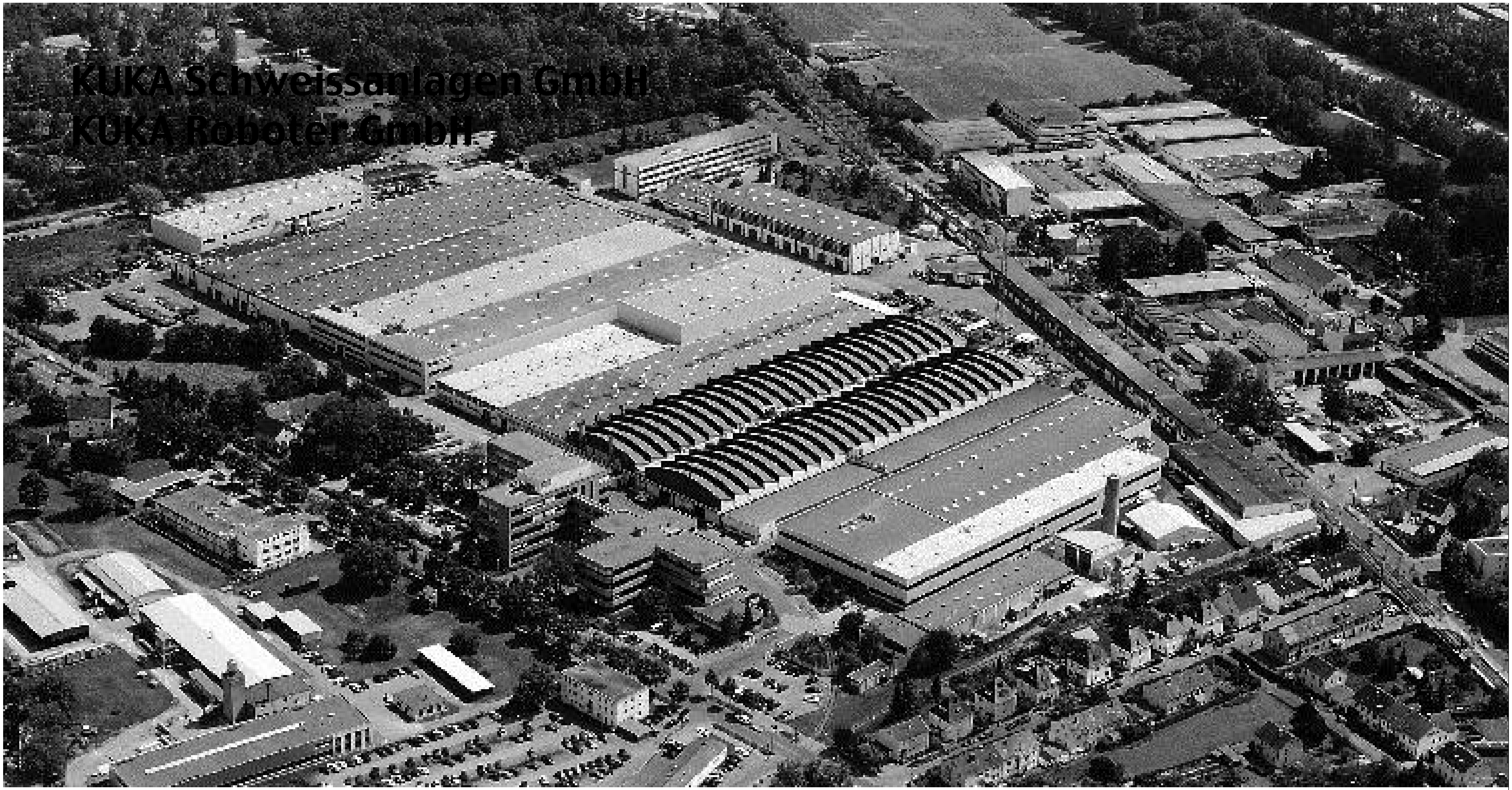
KUKA Robotics Corporation, 6600 Center Drive, Sterling Heights, MI 48312, Tel.: +810-795-2000, Fax: +810-795-4871

KUKA Robotics Corporation

KUKA Flexible Production Systems Corporation

Production, Assembly, Laboratories	**300,000**
Sales, Design, Development, Administration	**70,000**
Training	**5,000**
Total Area in Square Feet	**375,000**

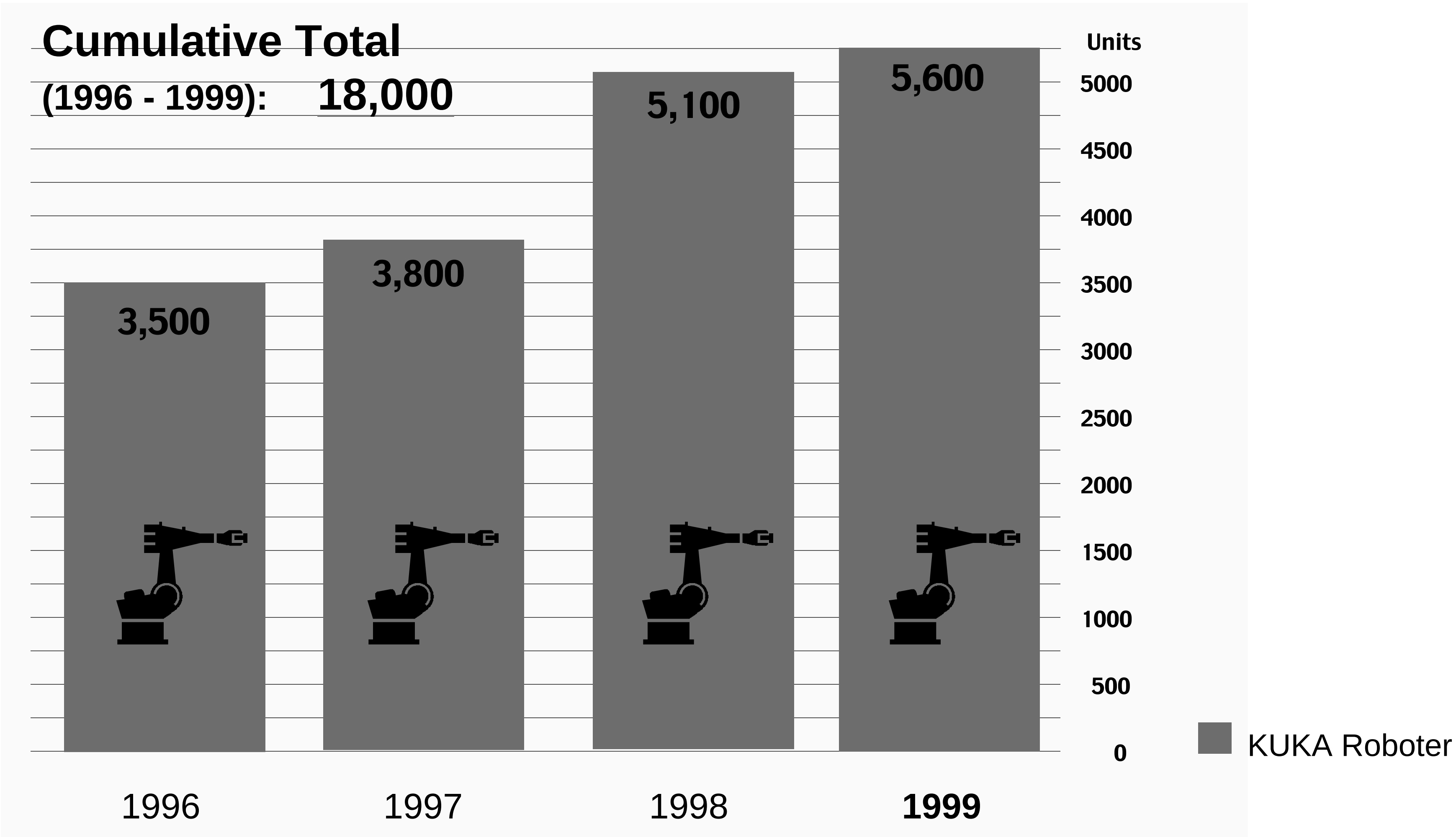
KUKA Robotics Corporation, 6600 Center Drive, Sterling Heights, MI 48312, Tel.: +810-795-2000, Fax: +810-795-4871



Production, Assembly, Laboratories, Stores	375,000	137,500
Sales, Design, Development, Administration	161,700	38,500
Training	3,300	11,000
Total Area in Square Feet	540,000	187,000

The Number of Robots Built Per Year Is Also on the Rise

KUKA Roboter Production Trend



KUKA Robotics Corporation, 6600 Center Drive, Sterling Heights, MI 48312, Tel.: +810-795-2000, Fax: +810-795-4871

We Are a Global Market Leader

No. 1

in Germany

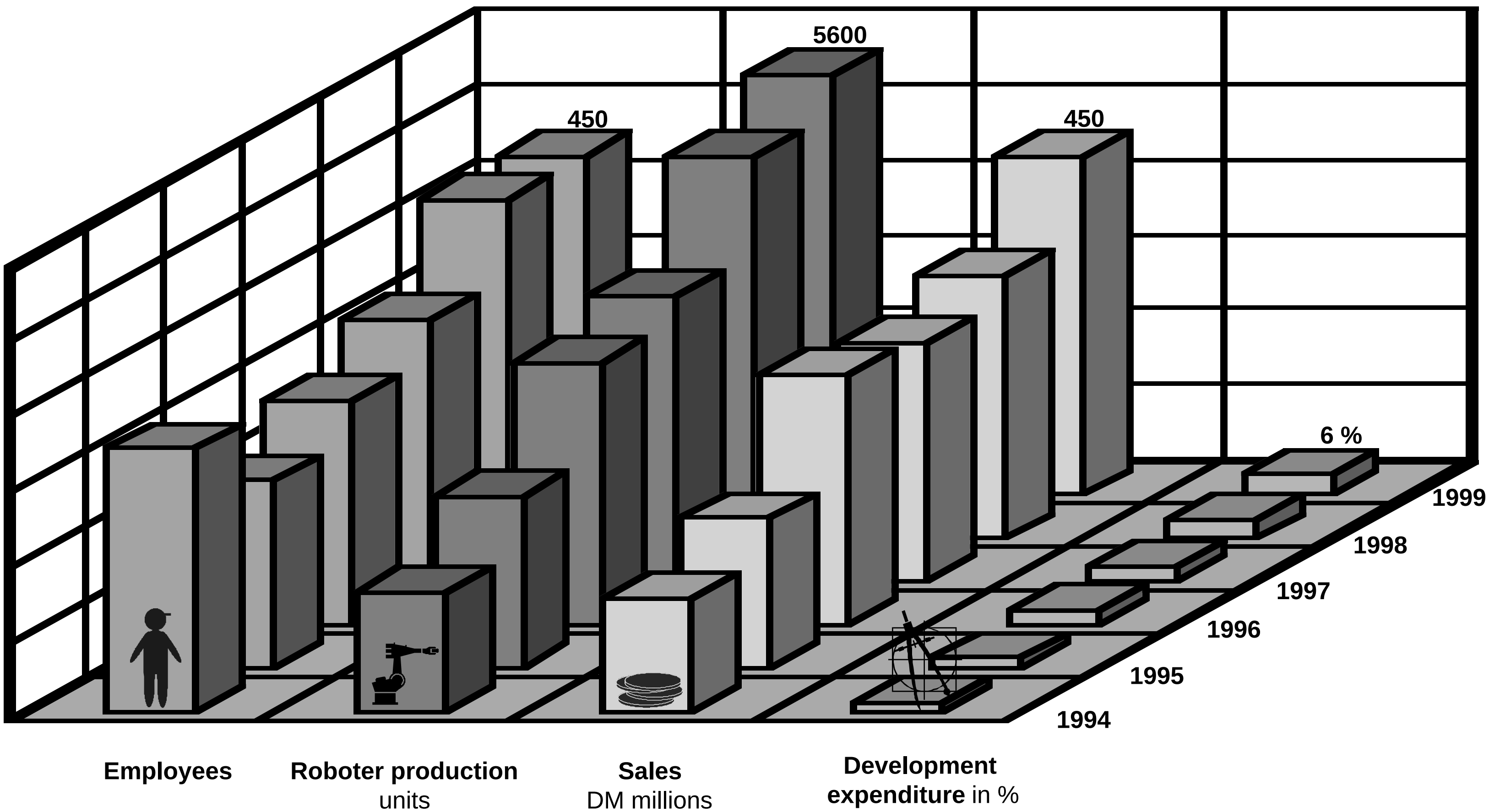
No. 2

in Europe

No. 3

in the world

KUKA Roboter GmbH key data (1994 – 1999)



KUKA Robotics Corporation, 6600 Center Drive, Sterling Heights, MI 48312, Tel.: +810-795-2000, Fax: +810-795-4871

Open Architecture Controls for the Robotics Industry

George Tecos
Manager, Engineering & Development
KUKA Robotics Corporation
Sterling Heights, MI

What the Customer Expects From the New Robot Technology

KUKA

Very good price-performance ratio

Windows 95

Open PC architecture

Reliable, powerful, future-oriented

Standard PC hardware components

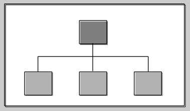
Compact, low space requirements

Easy integration into systems

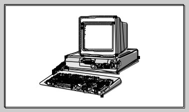
Make it fun to use

Is what the customer expects from the new robot technology. A system which introduces a fast integration of customized path planners, real time sensing devices, and improved robot performance.

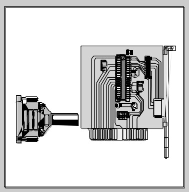
Advantages of PC-based control technologies



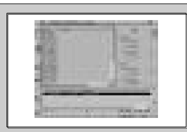
Openness and networking (Ethernet, bus connections)
-> simplified system integration



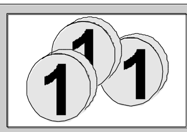
Use of de-facto-standards (hard- and software)



Use of developments in PC technology: Performance increase by new processor generations, internal bus systems (e.g. PCI), standard storage and input devices (hard disk, CD-ROM, Floppy, MF2-keyboard, mouse etc.), advanced operating systems



Graphical user interface based on Windows (95, 98, CE, NT)



Cost reduction in comparison with custom solutions

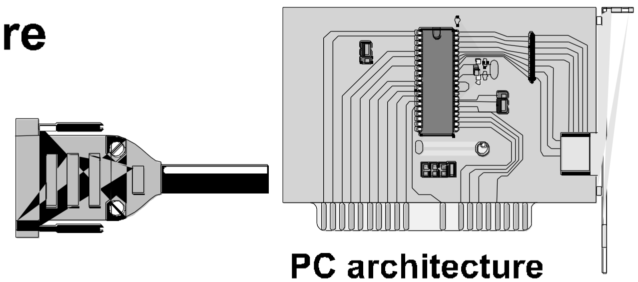
Trends in control technology with standardized hardware and software basis

from closed control systems (special solutions)

to openness and modularity in hard- and software using industry standards

Hardware

communication interface (Ethernet, fieldbus connection etc. e.g. for sensor integration)



PC architecture (Intel Pentium processor)

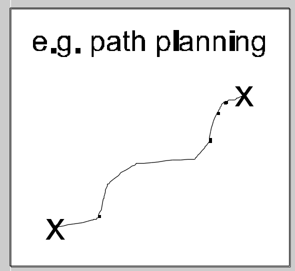
independent of users and applications!

Software

operation system Windows (95, 98, CE, NT)

real time extension possible

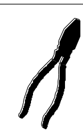
control



user interface

specific for users and applications

example of development tools



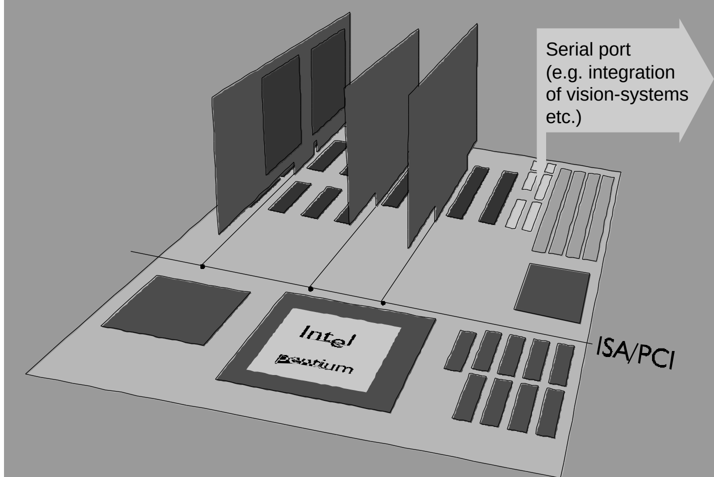
Tornado

C, C++ and Visual Basic

KUKA Robotics Corporation, 6600 Center Drive, Sterling Heights, MI 48312, Tel.: +810-795-2000, Fax: +810-795-4871

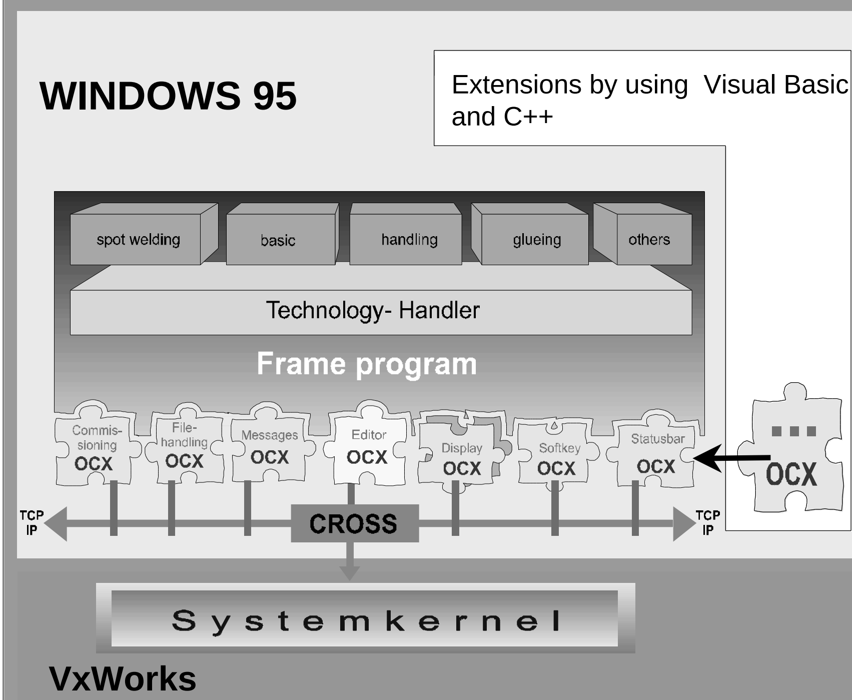
Base of KR C1: Open Architecture

PC-Technology in Hard- and Software

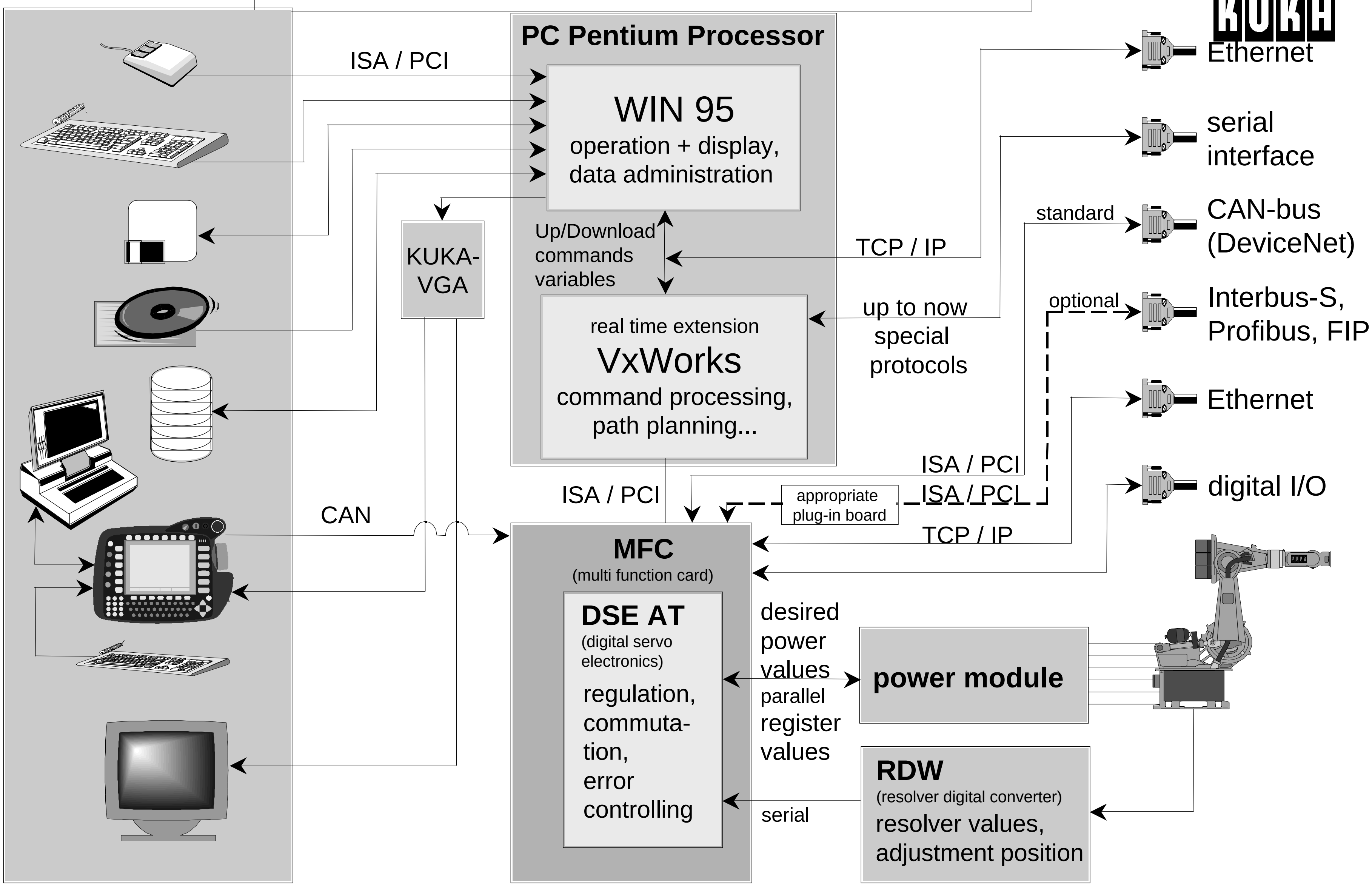


- PC-typical modular extendable
- Integration of PCI cards
  (e.g. for vision systems)
- PC-typical networking

WINDOWS 95 as operating system



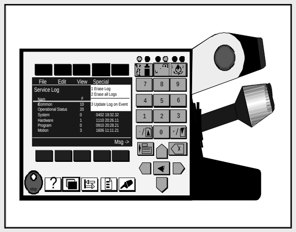
Structure of the KR C1 Robot Controller



KUKA Robotics Corporation, 6600 Center Drive, Sterling Heights, MI 48312, Tel.: +810-795-2000, Fax: +810-795-4871

System Architectures in Robot Controlling

Custom-made hard- and operation systemsoftware

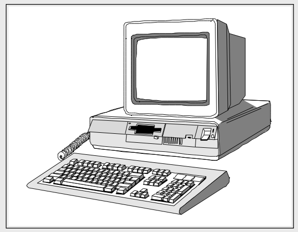


line-oriented display without graphic-capability

PC - hardware and custom-made operation system

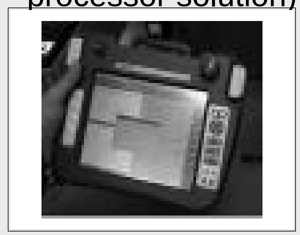
display with graphic capability, not used due to limited graphic capability of operation system

PC- hardware with operation system WIN-DOWS 95 and VxWorks (double processor solution)



no teach-pendant available only library for user interface elements

Custom-made and PC-hardware with custom-made operation system and additional WIN-DOWS 95 (double processor solution)



graphic - capability
use of the graphic - capability only special electronic cards for integration

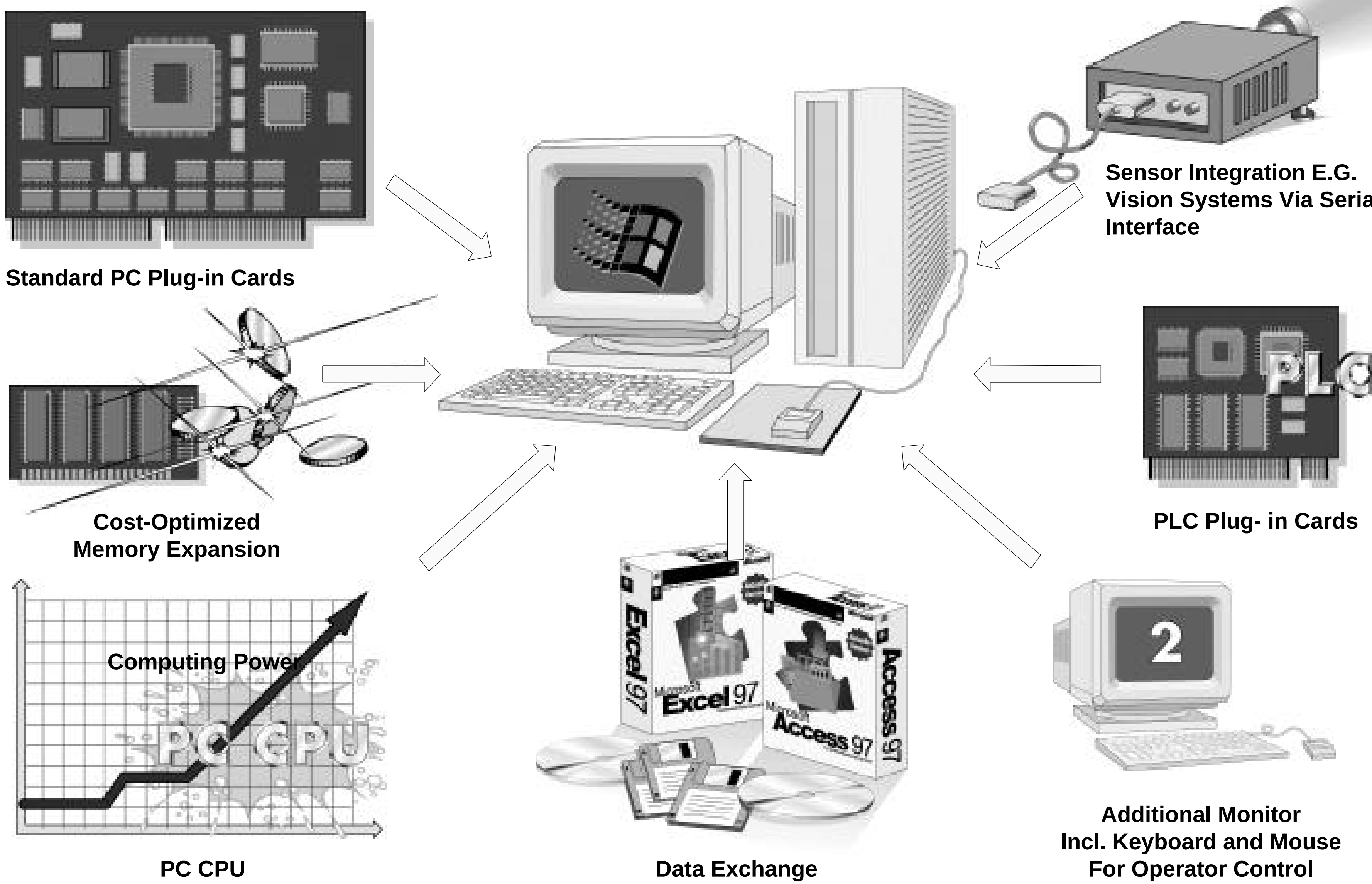
PC-hardware with operation system WINDOWS 95 and VX Works (single processor solution)

graphic - capability,
use of graphic - capability,
use of ISA/ PCI for integration of additional Hardware
only KUKA

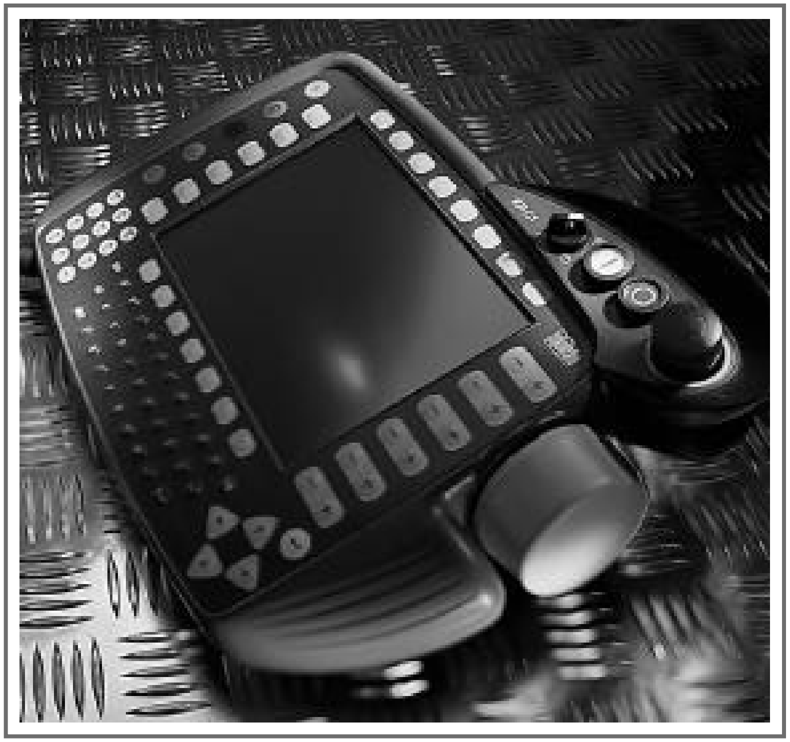
progress

KUKA Robotics Corporation, 6600 Center Drive, Sterling Heights, MI 48312, Tel.: +810-795-2000, Fax: +810-795-4871

Implementation of PC Technology With Standard Concepts

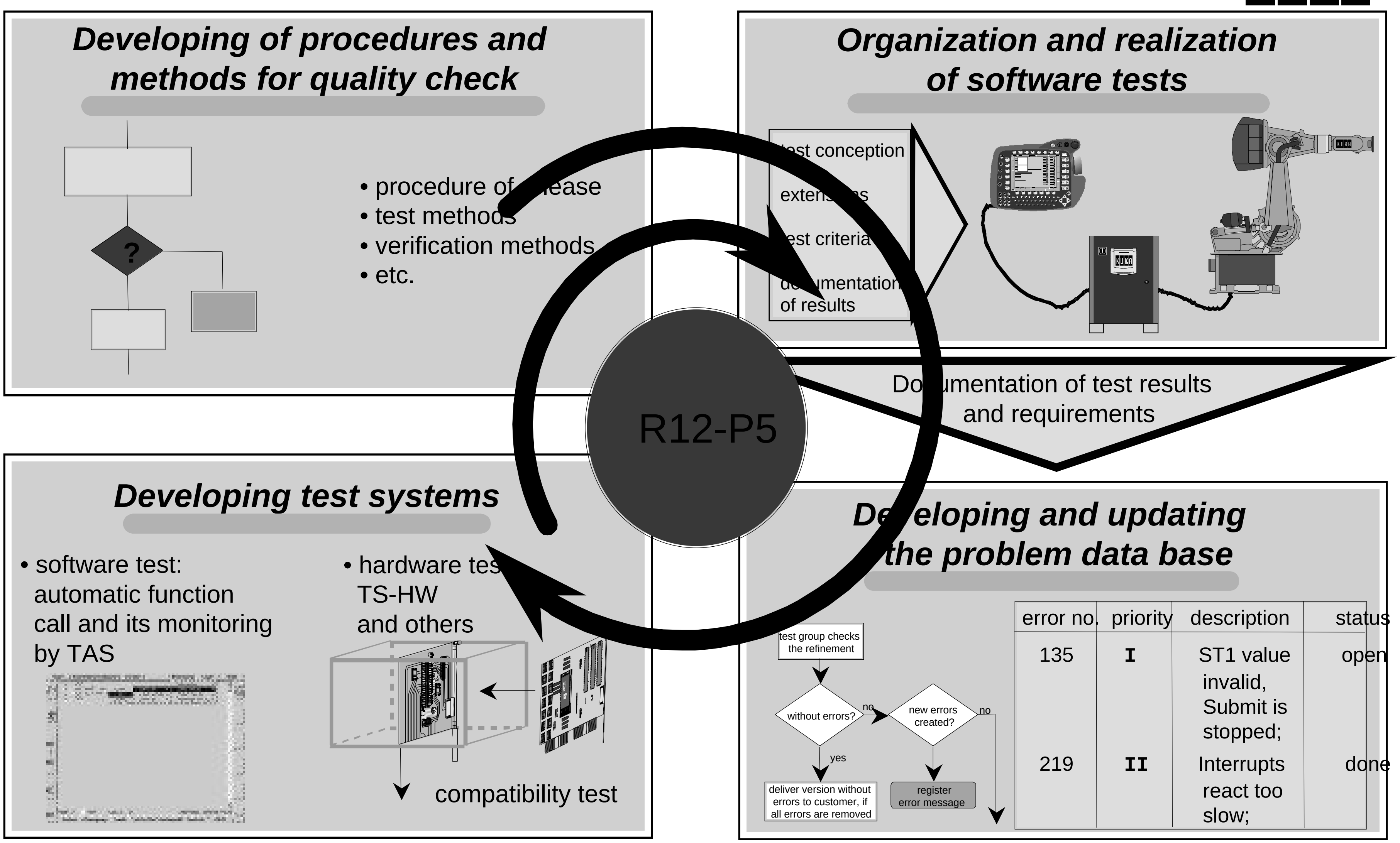


Open to Faster Programming: KUKA Control Panel (KCP)



- **Real-time PC with Windows user interface**
- **Quick operation using windows**
- **Predefined input boxes**
- **6D mouse for rapid teaching**
- **Block functions for faster programming**
- **Recognized standards for experts**
- **Special user interfaces for operators**

Quality Check



error no.	priority	description	status
135	I	ST1 value invalid, Submit is stopped;	open
219	II	Interrupts react too slow;	done

Safety / Reliability Approach for PC Based Control

KUKA

Safety:
- Hardware based safety board
- Proved real time O/S

Reliability:
- Proven availability of product greater than 99%
- Industry proven hardware

NSF International Strategic Registrations, Ltd.

A Subsidiary of NSF International
789 North Dixboro Road, Ann Arbor, Michigan 48105
(888) NSF-9000

NSF-ISR

Certificate of Registration

This certifies that the Quality Management System of

KUKA FLEXIBLE PRODUCTION SYSTEMS CORPORATION AND KUKA ROBOTICS CORPORATION

Corporate Address:
6600 Center Drive
Sterling Heights, MI 48312
Phone: (810) 826-8270
Fax: (810) 978-0429
Contact: Mr. Robert Seecoomar

Site Address:
KUKA Flexible Production Systems Corporation
and KUKA Robotics Corporation
6600 Center Drive
Sterling Heights, MI 48312

has been assessed by NSF-ISR and found to be compliant to the following standard(s):

ISO 9001:1994 (with QS-9000 TE Supplement: 1998)*

**having been audited in accordance with the requirements of TE Supplement Appendix B, Code of Practice.*

Scope of Registration:
Design and manufacture of flexible automation welding and robot equipment.
[Supplier Code(s): Ford- K171A / GM-018651778 / Chrysler-15812]

Industrial Classification:
SIC Code: 3500
NACE Code: DK 29

NSF

Quality System Registered to ISO 9001:1994 (with QS-9000 TE Supplement: 1998)

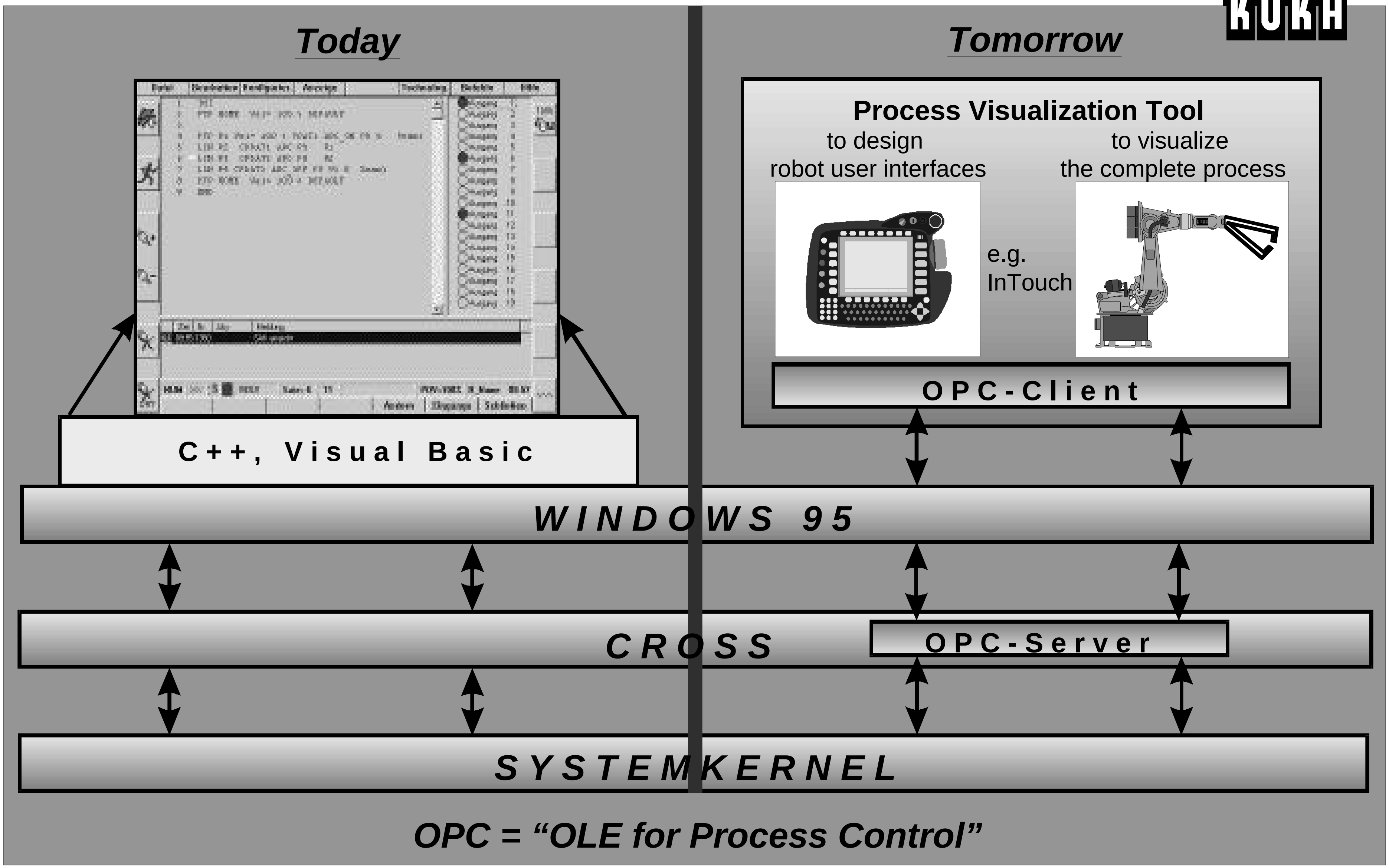
Randy A. Dougherty, President, NSF - ISR

Certificate Number: 66051-TE3
Certificate Issue Date: 09/23/99
Date of Initial Registration: 06/03/99

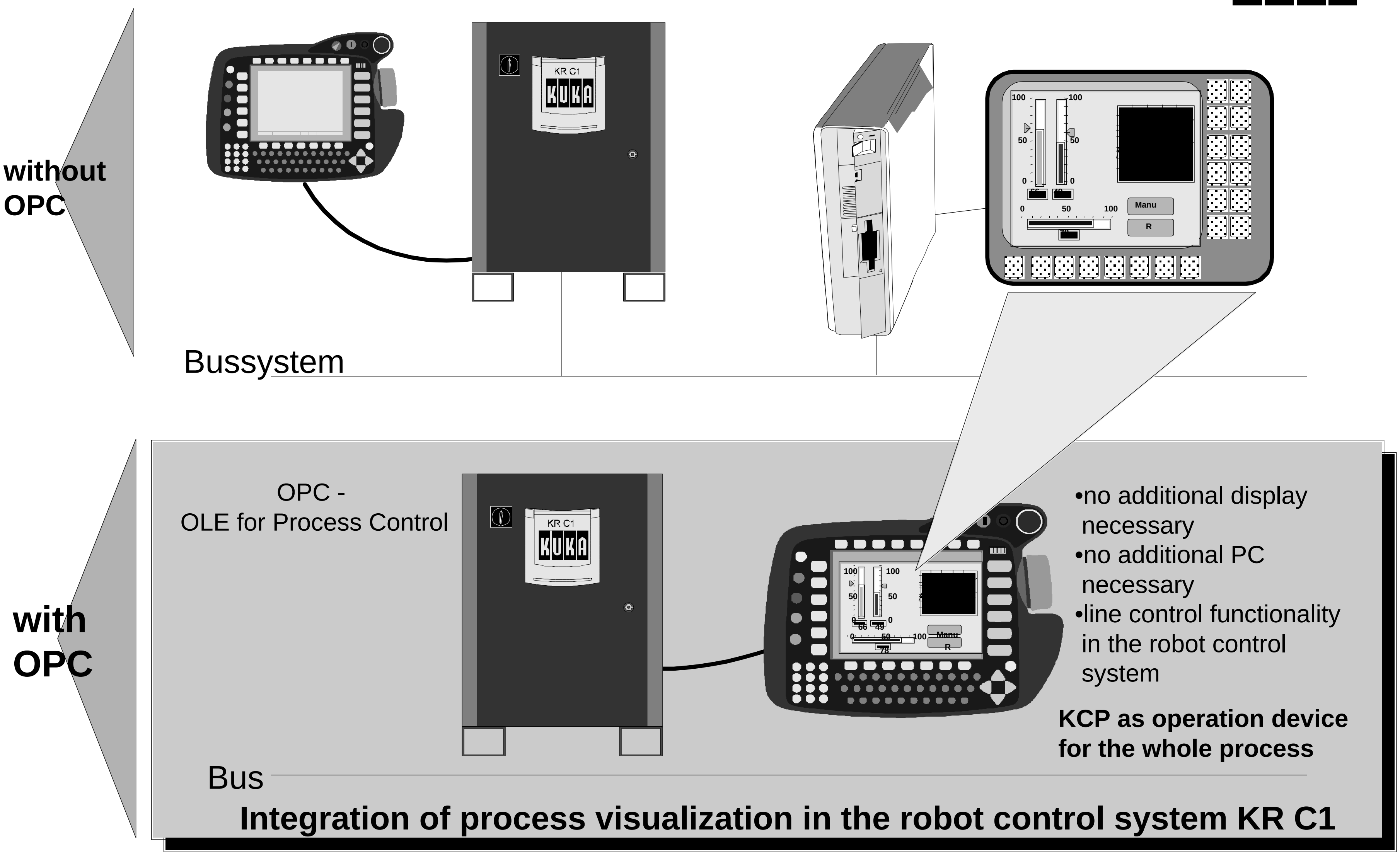
ANSI-RAB QMS ACCREDITED

Authorized Registration and Accreditation Marks

OPC-Server-Technology



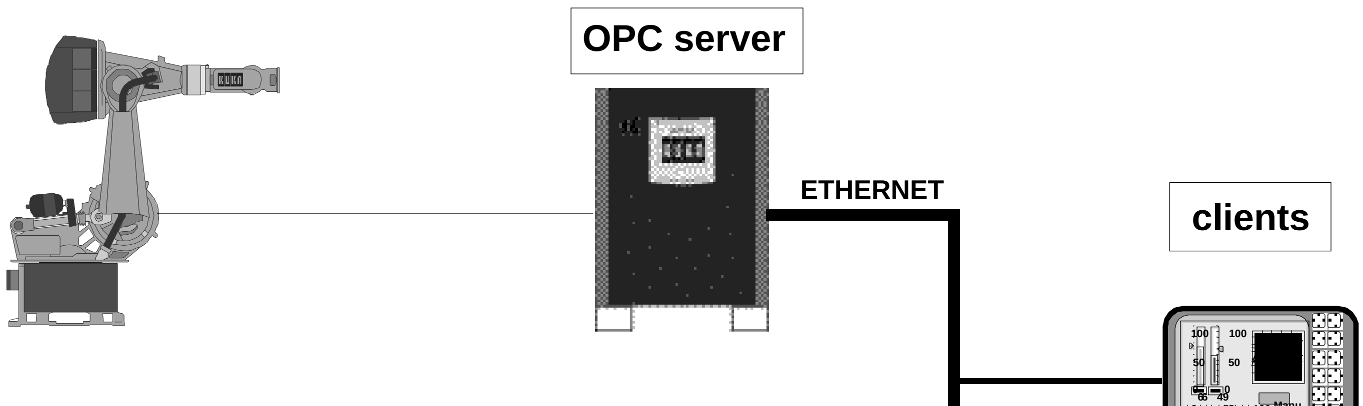
Integrated Process Visualization by using OPC

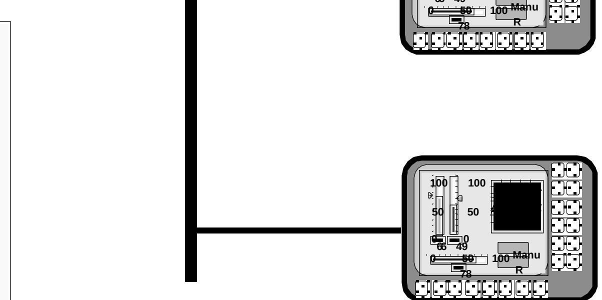


KUKA OPC Server

OPC: the open interface for factory automation

OPC:
OLE for **P**rocess
Control



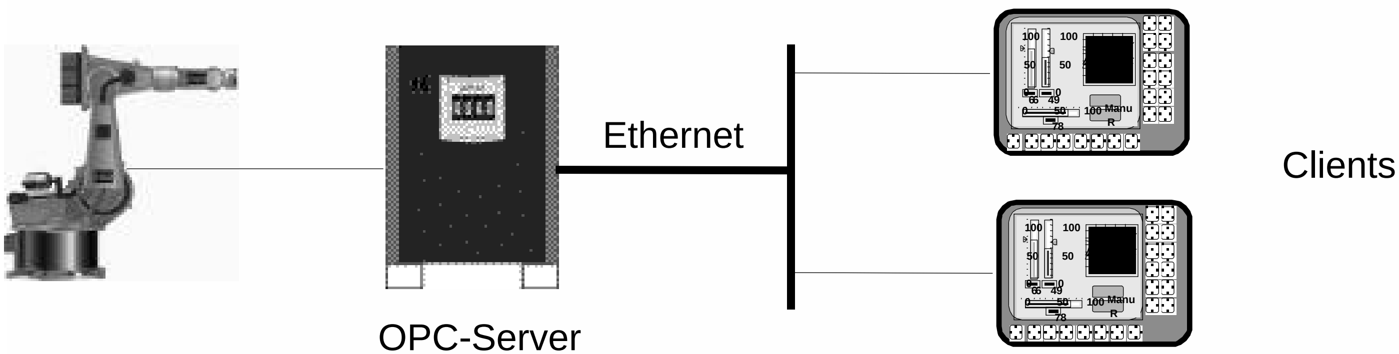


- network access
- production data entry
- visualization of positioning data, messages (emergency stop), modes of operation, program parameter
- read and write of system and user variables (e.g. current robot position, trace velocity...)
- connection between OPC server and system PC (client) with Windows 95, Windows 98, Windows NT
- course of a complete robot work space can be visualized and controlled (also by KCP)

KUKA OPC-Server

OPC = Open Interface for Factory Automation

OPC = **O**LE for **P**rocess **C**ontrol



KUKA OPC-Server

visualization of KR C
system and user variables

↕

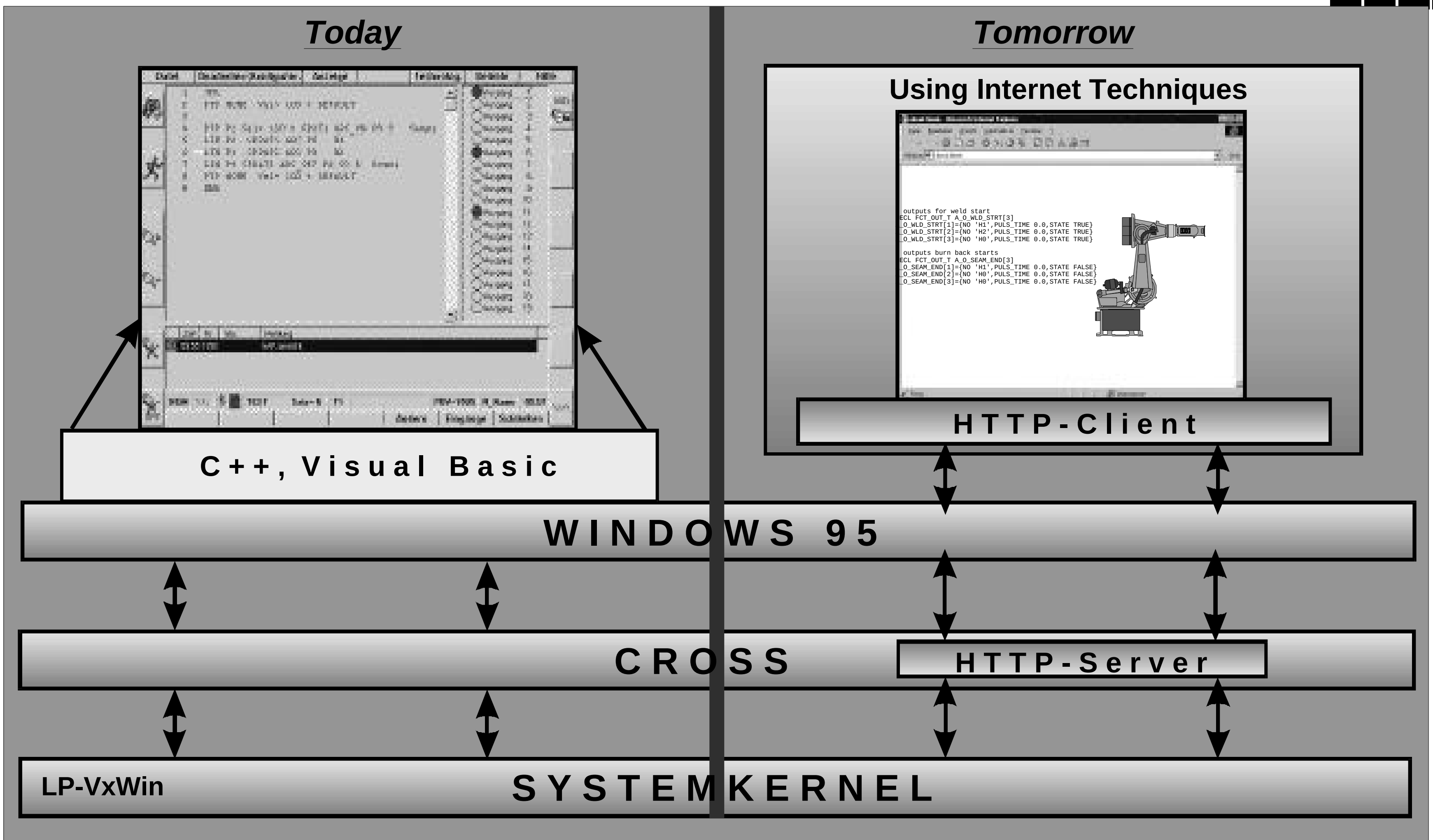
- the OPC server is a **software addition**
- OPC specifies the data exchange between OPC server (control system) and OPC client (visualization component, e.g. VisualBasic-/ C^{++}-applications)

↕

Features OPC Servers

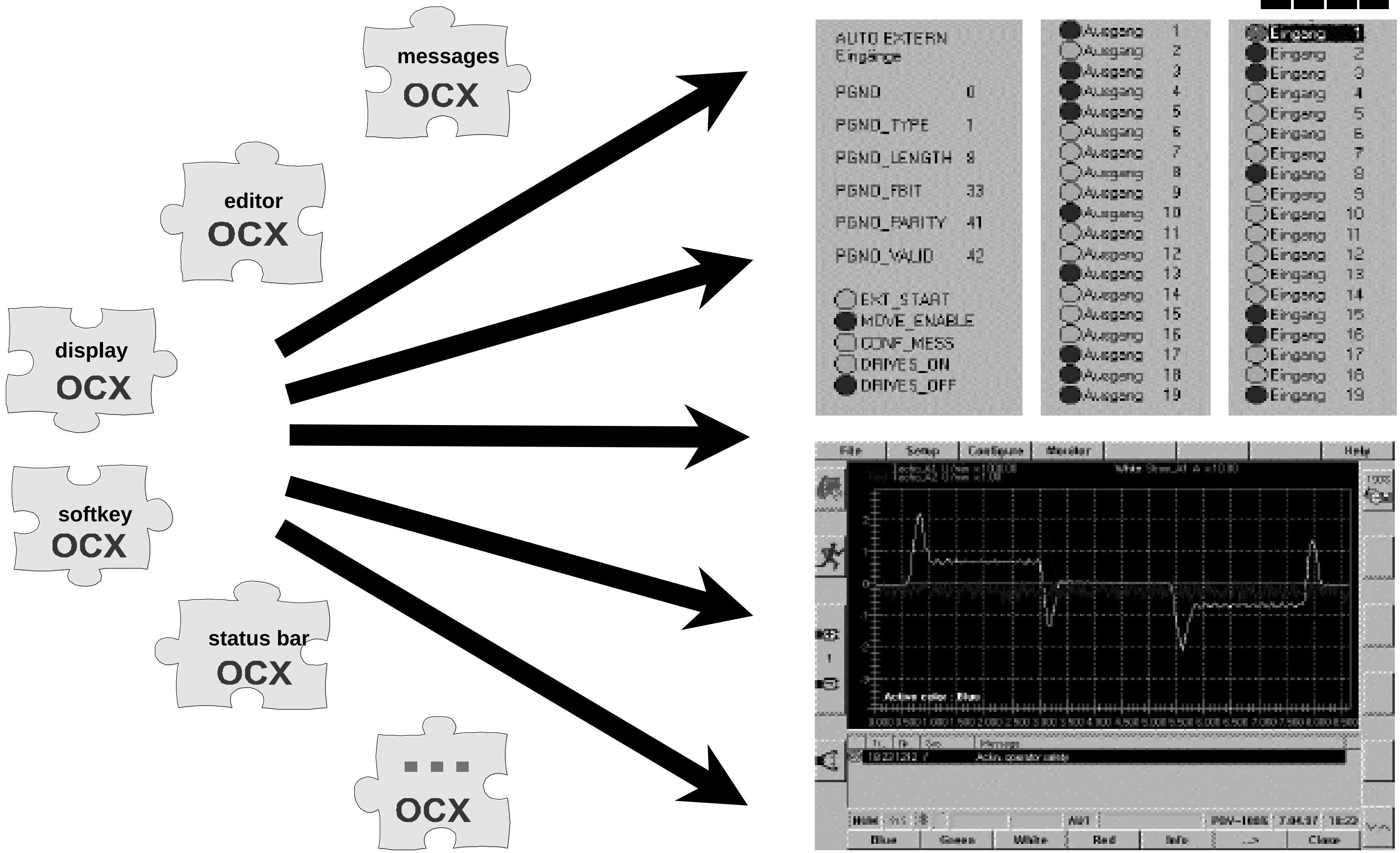
- connection of 10 clients at the same time
- 200ms refresh rate for updating variables
- no access for non-authorized persons
- determine user rights: is the user allowed to write, to read or to write and read?
- synchronous or asynchronous reading and writing of KR C system variables
  synchronous: on demand client immediately receives the current value of the variable
  asynchronous: client receives updated values on condition that values within the KR C have actually changed
- OPC server is **not** real time relevant

HTTP Server Technology

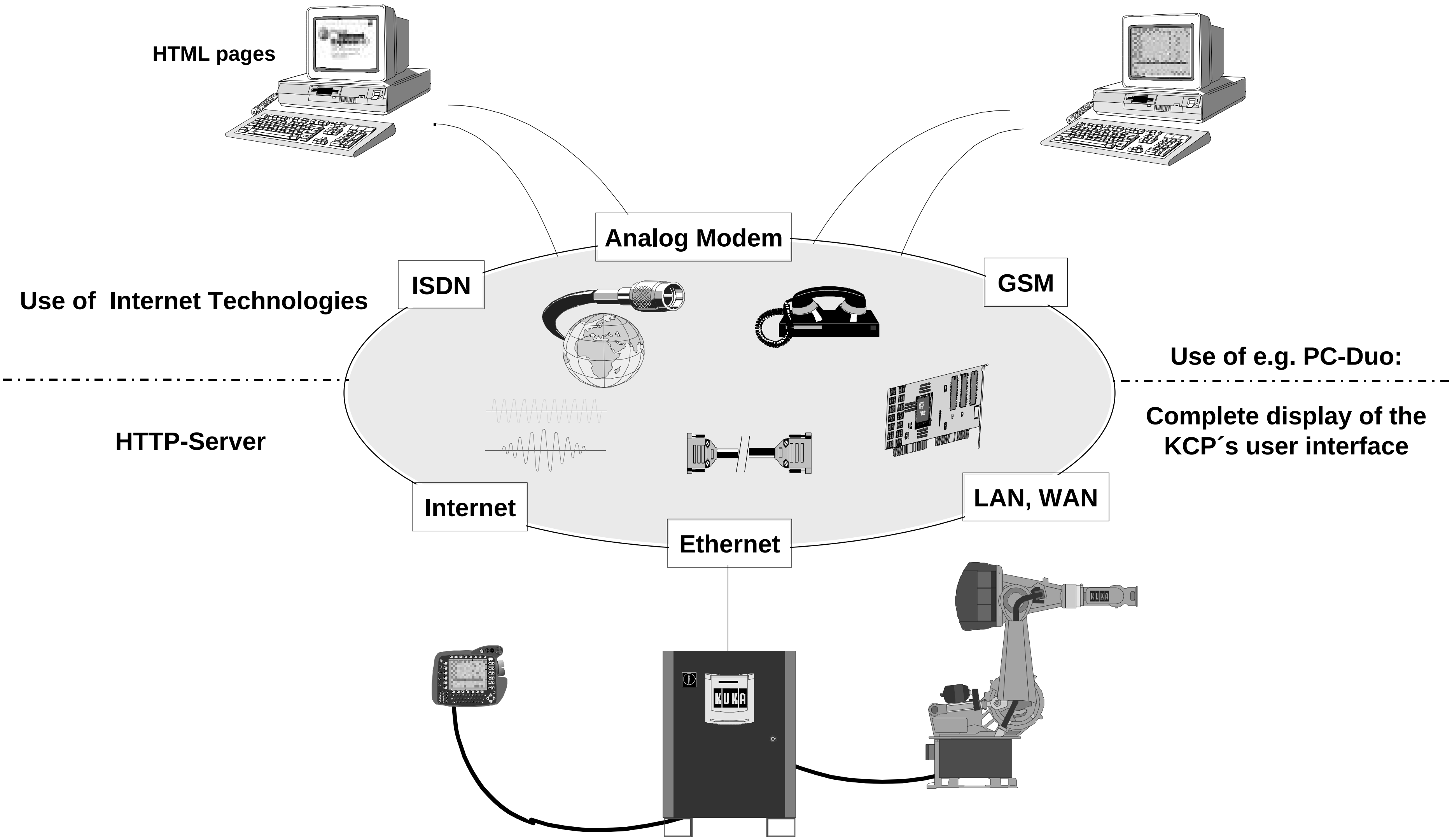


HTTP = "Hypertext Transfer Protocol"

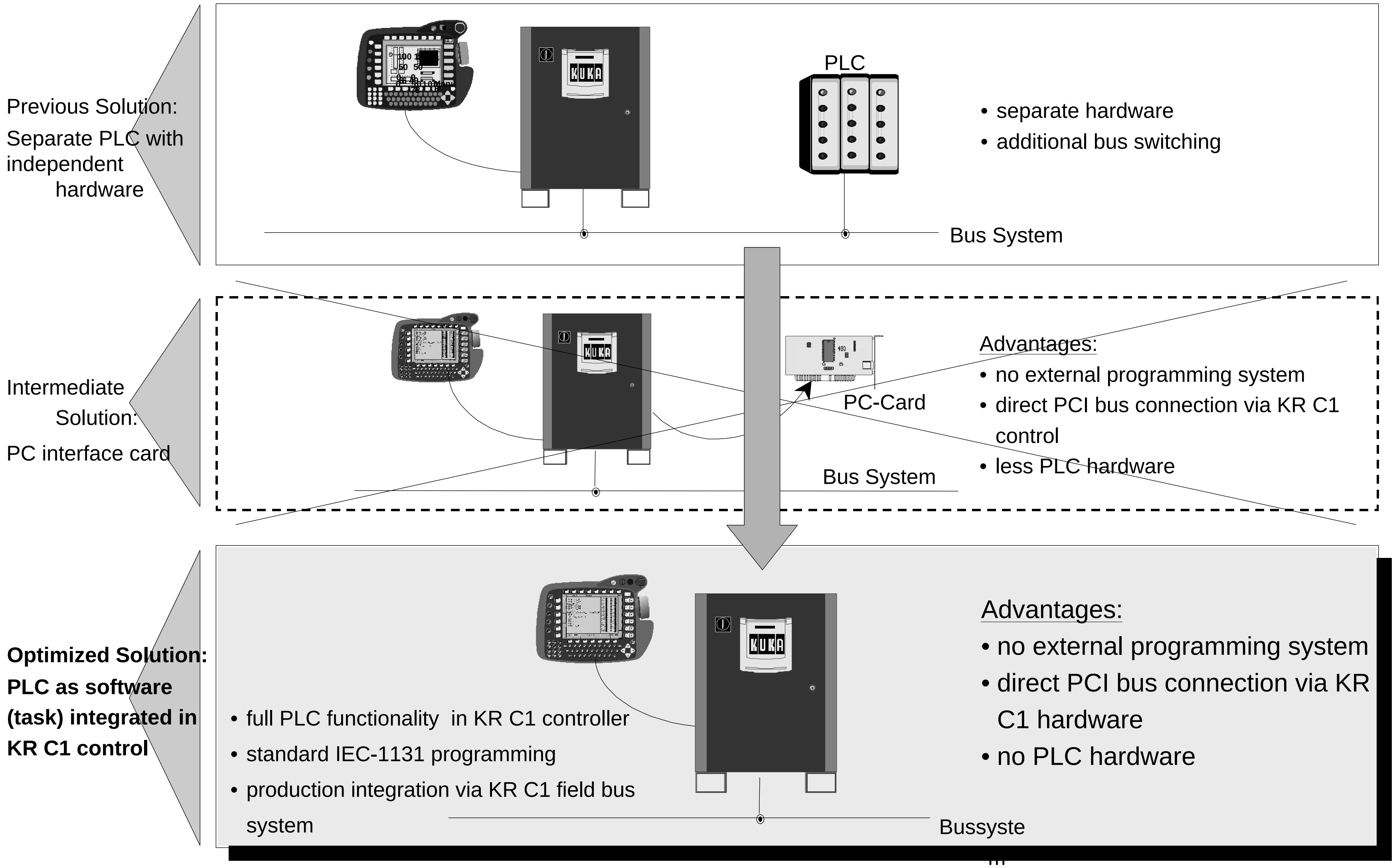
Modularized Process Visualization



Remote Diagnostics – KR C1



Soft-PLC Integrated in KR C1 Control

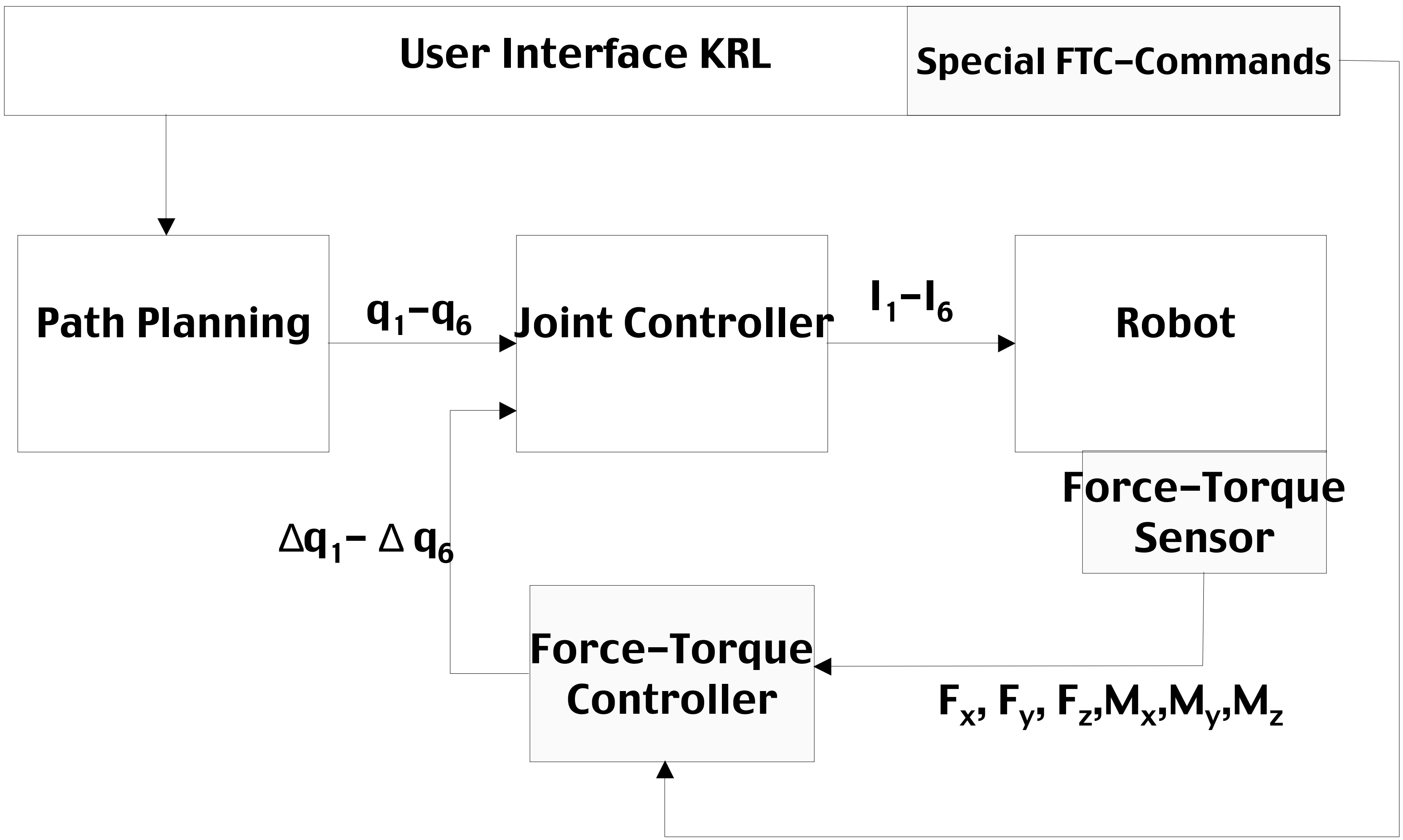


Why Soft-PLC in KR C1 ?

- Lower costs for additional hardware
- Shared processor usage
- Relief of the robot control system (Submit Interpreter)
- Fast command execution - 1 kByte in approx. 20µs
- Programming according to International Standard IEC 1131-3
- Simple interfacing to existing hardware via fieldbusses
- Open interfaces to other systems (OPC)

- Soft-PLC is limited to being the master of Profibus, Interbus, DeviceNet, and FIPIO bus-systems. (ControlNet available Spring 2000)
- Typical learning curve of a new technology.

Force Torque Control (FTC) Design



Motivation

Many applications require a sense of touch of the robot:

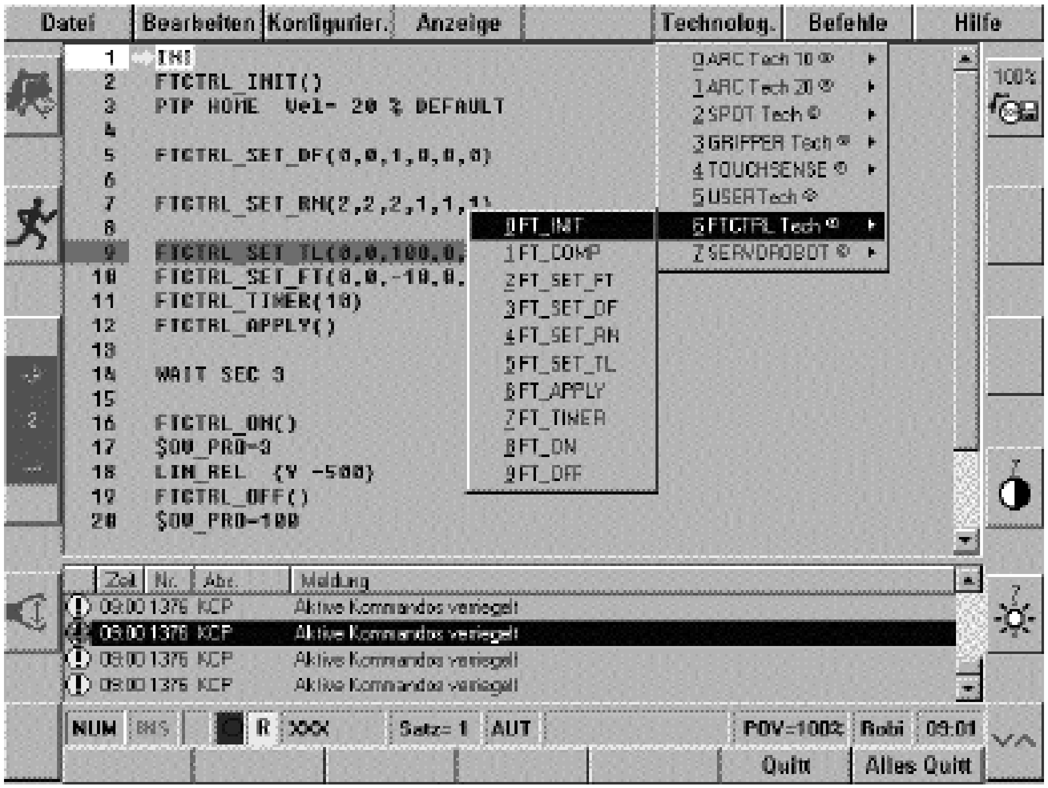
- Polishing
- Grinding
- Assembly
- Collision detection & Crash protection

The Solution:

- Force-Torque-Sensor on the flange of the robot to measure contact forces and torques
- Control algorithms and strategies to realize a force-torque control instead of a position control
- Fully integrated soft- and hardware with an easy-to-handle user-interface

FTC Abilities

Complete functionality of the FTC is accessable via KRL



FT_INIT	Initializes FTC
FT_COM	Compensates FT-Sensor
FT_SET_FT	Sets desired FT values
FT_SET_DF	Specifies which DoF is force controlled and which is position-controlled
FT_SET_RN	Sets tolerance range for The FTC. A range of
FT_SET_TL	Transformation from sensor Measurement plane to TCP (Tool Contact Point)
FT_APPLY	Moves the robot according to the specified desired FT-values until the measured FT values are within the Tolerance range
FT_TIMER	Applies and holds the Specified FT values for a certain time
FT_ON FT_OFF	Embraces a cartesian robot movement to superpose position-controlled and FT-controlled movements

Force Torque Control (FTC) Features

- Controller is independent from FT-Sensor (JR3, ATI, ...)
- Many different sensors available (payload range:

  12N/0.12Nm - 4500N/1500Nm)
- Controller is adaptible to the required payload capacity

Section Six

Open Architecture Robotic Platform

Timothy D. Garner,
Staff Development Engineer

Delphi Automotive Systems

Open Architecture Robotic Platform

Timothy D. Garner
Staff Development Engineer
Advanced Equipment Development
Delphi Delco Electronics Systems
Delphi Automotive Systems

Where We Have Been

- Ideacell developed with Automatic Assembly MTT
- Influenced by NCMS LFMA Project and NEMI Final Assembly TIG
- Developed to meet Delco's manufacturing strategies
  - Robotic cell for agile, flexible platform for critical processes
  - Common, global solutions supporting multiple product lines
  - Use standard processes with off-the-shelf equipment where possible
- Designed to take advantage of key enabling technologies
  - Open architecture PC computing power and software
  - Object-oriented RAD software development tools
  - Client-server simulation and control architecture

Final Assembly Strategy

- Develop common flexible robotic assembly platform
- Use globally available of-the-shelf components where possible
- Own the design and license the build where it makes sense
- Use third-party process modules on common platform
- Make platform versatile enough to handle a wide range of processes and applications
- Make platform fit existing lines, as well as new installations
- Use low cost machine vision to replace hard tooling where possible
- Use network communications to link cells, lines, and plants
- Software is the key enabling technology to make flexible platform strategy work

- **Inexpensive Delco Electronics Assembly Cell**
- **Utilizes Seiko 4-axis cartesian robot manipulator**
  - two sizes (600 x 400 mm, or 1000 x 600 mm)
  - high speed of 2000 mm/sec, 2g acceleration
  - good repeatability of +/-15 microns
- **Small, but sturdy base**
  - 820 x 820 mm top with tapped hole grid
  - extruded legs for attachments
  - 19 inch rack mount controls on four sides
  - casters for easy reconfiguration
  - multiple spacer heights for flexibility
- **Arm mounts in 7 positions in 80 mm steps**
- **Work area can overhang base up to 500 mm**
- **Arm can be reversed for total overhang**
  - tooled carts can be interchanged
  - reach over conveyors, boxes, testers, etc.

Mechanical Design

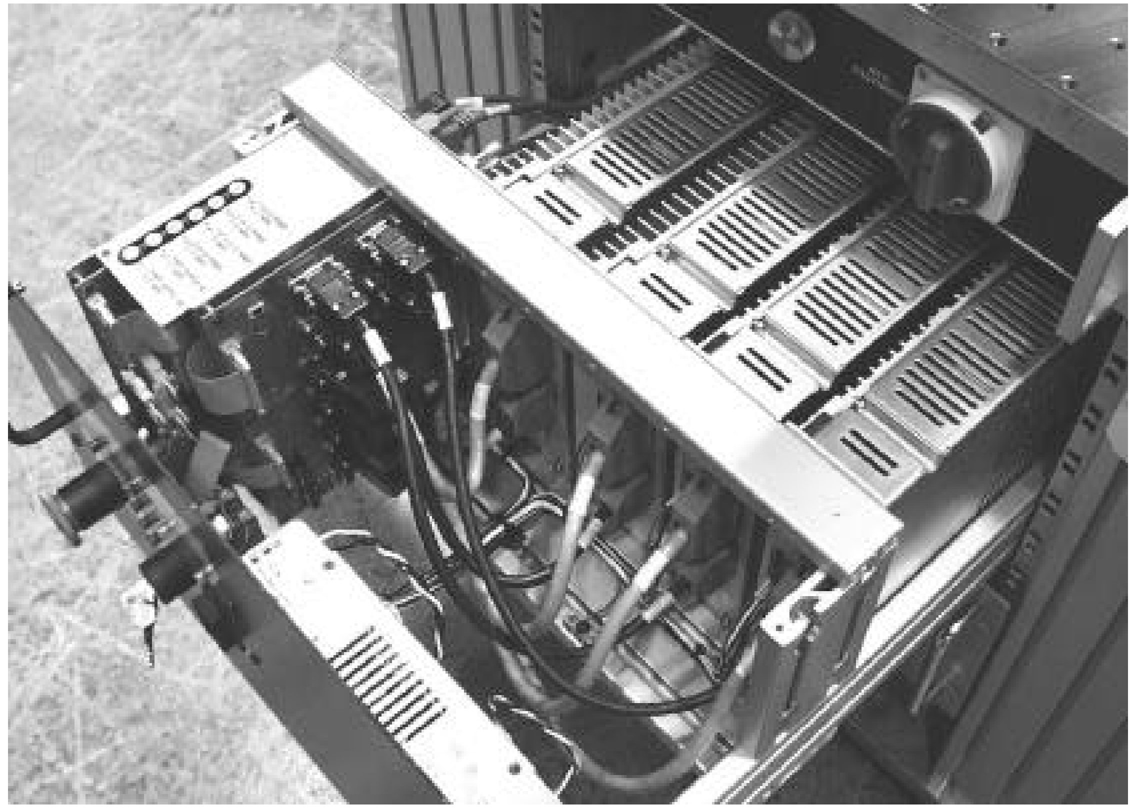
- Cartesian robot selected over SCARA arm
  - Generally more space efficient for large rectangular workspaces
  - Better suited for multiple tools, including screwdrivers and dispensers
  - Sturdy, high load and torque capacity, high acceleration
- Small, sturdy base allows overhanging reach
  - Most cells use an enclosed base with all functions enclosed within
  - Small cell with large reach fits the most applications
  - 820 mm x 820 mm rectangular base
  - Leads to an exposed look, making guarding difficult
- Use extruded framing components where possible
  - Helps define mechanical architecture using 40 mm grid pitch
  - Design tooling, mounts, etc. to fit the grid for maximum reuse
  - Item extrusions are close to being a defacto standard (4 compatible vendors)

Software and Controls History

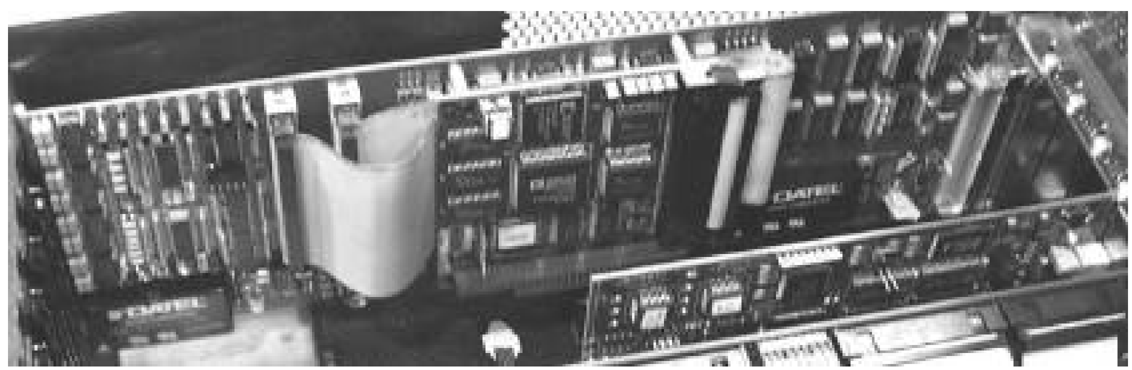
- Control strategy derived from Flip Chip Placement
  - Simulation-based development reduces design cycle time
  - Hardware and mechanism independent programming enables code reuse
  - Open architecture controller is adaptable and scalable to other applications
- Seiko controller did not have adequate connection to PC
  - Designed amp box and controller interface to be maintainable and reliable
- We did not want to invent a programming language
  - Off-the-shelf development environments are very powerful and efficient
- Evolved from Pascal to object-oriented to components
  - Delphi RAD make graphical interface easy
  - Object-oriented software started formation of an architecture
  - Components enabled easier code reuse and fast application development
- First component architecture was Run Dialog
  - Simple to use, but couldn’t handle complex cells with multiple parts

Amp Box and Controller

- Off-the-shelf Yaskawa Amps
- PCB-mounted fuses, E-stop relays, safety fence circuit, high-power enable
- Uses standard Seiko cables



- PC-104 MEI DSP
- E-stop monitoring
- I/O buffering



Enabling Technologies for Control

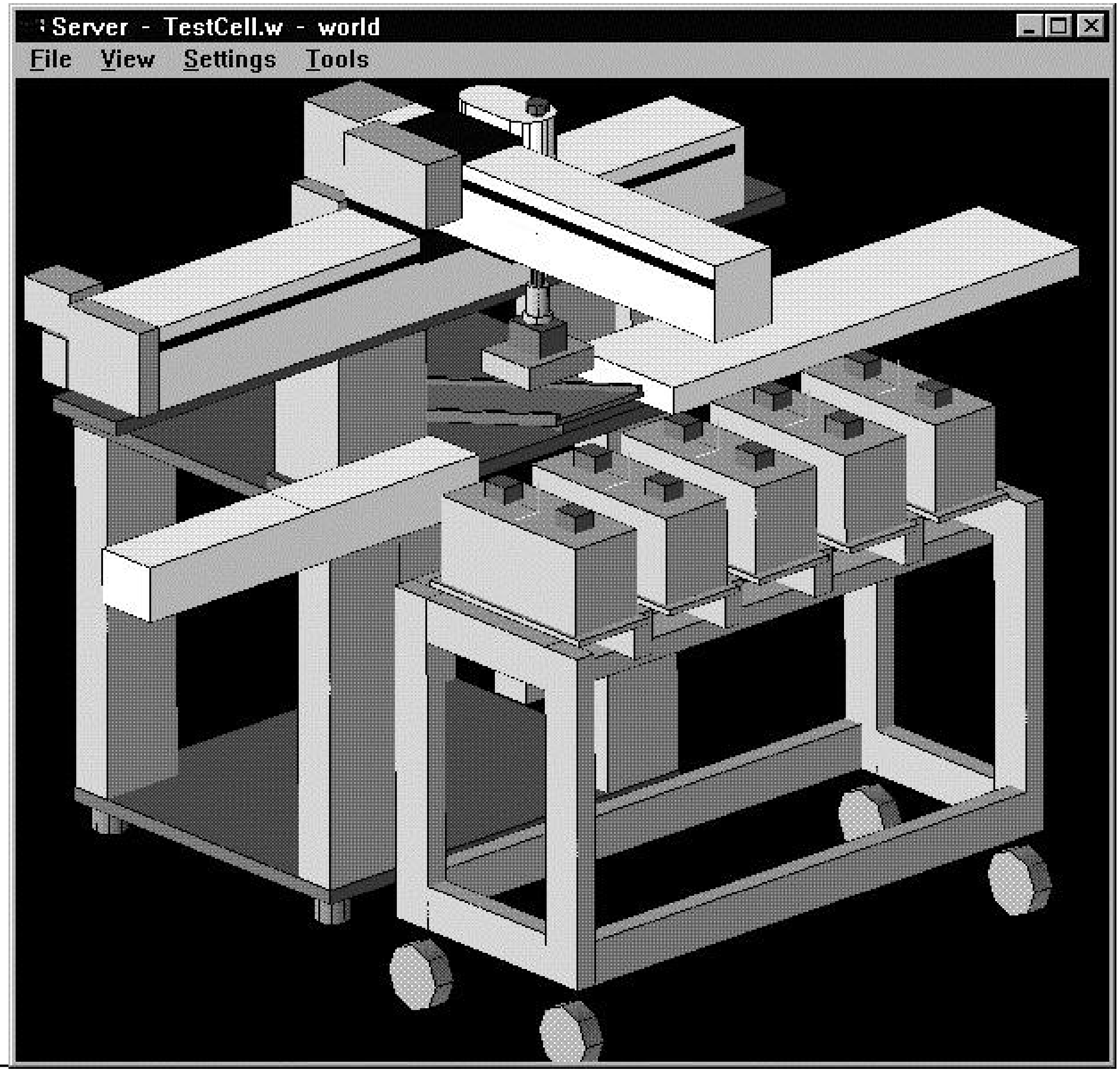
- Open-Architecture hardware and Software
  - Standard PC computing architectures
  - Standard operating systems
  - Programmable using standard languages
  - Extensible to allow for growth and expansion
- Client-Server control architecture
  - Hardware independent API for motion and control
  - Simulation-based software development environment
- Modern, high-productivity programming techniques
  - Rapid Application Development programming tools are highly efficient
  - Object-oriented, component-based programming maximize code reuse
  - Structured exception handling lends structure to error handling
  - Multi-threaded programs balance sequential and parallel activity

Controls Selection

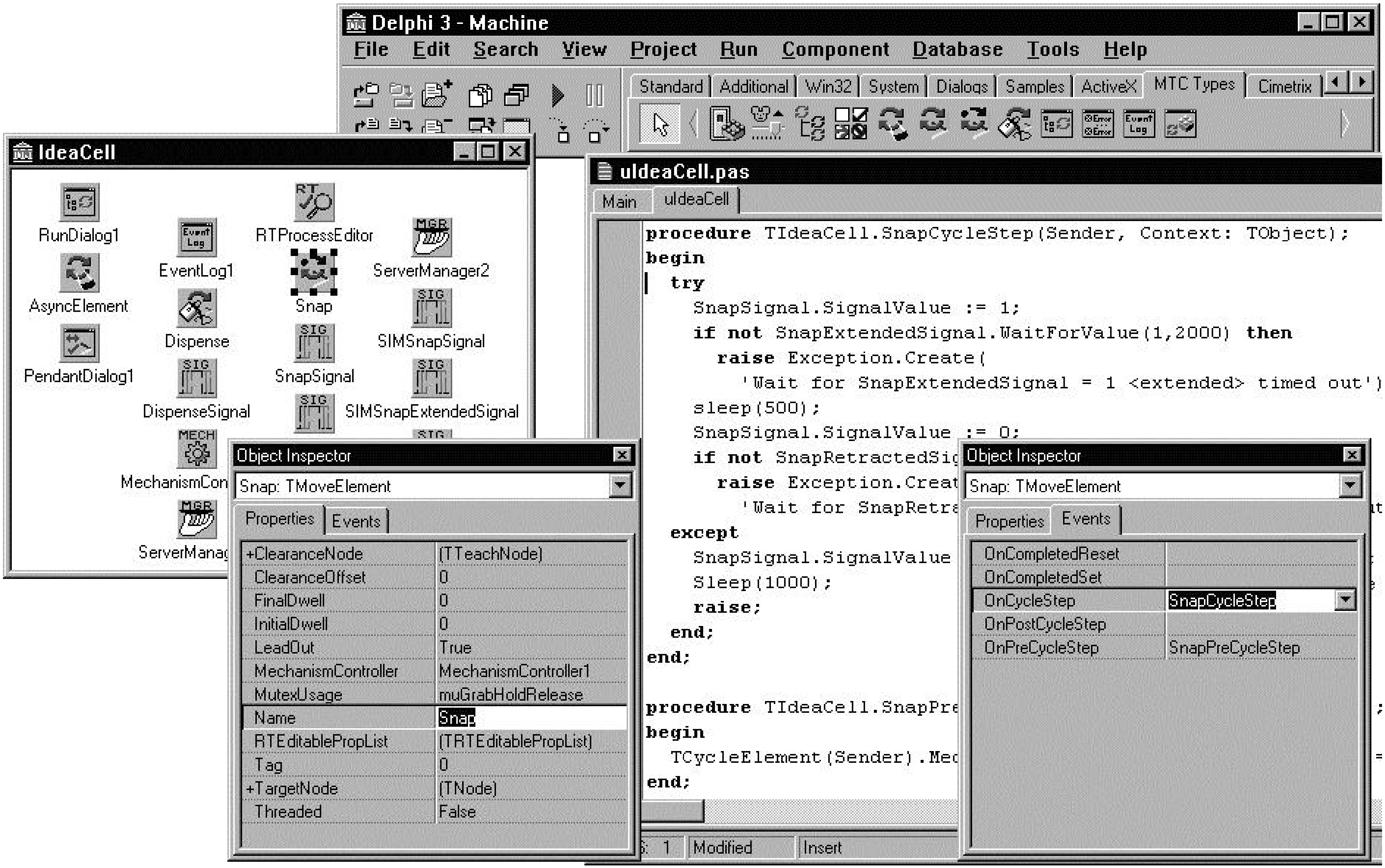
- Windows NT operating system on standard PC hardware
  - industrial passive backplane, PC/104, CompactPCI, desktop computers
  - provides powerful platform to add intelligent functions
- Borland Delphi programming environment
  - component-based, object-oriented Pascal
  - fully compiled
  - supports multi-threading, structured exception handling, custom components
  - VCL components easier to develop than ActiveX
  - provides integrated SQL database support
- Cimetrix CODE motion and control API
  - hardware and mechanism independent programming
  - simulation server and control server use identical API

Cimetrix Client-Server Model

- 3D model database helps visualize application
- Database stores actual positions of machine
- Node-based motion enables code re-use
- Inverse kinematics solution derived from the model
- Simulation server has common API with Control server
- Hardware independent API
- Enables controls development in parallel with build
- Enables multiple people working on one machine
- Better long term support

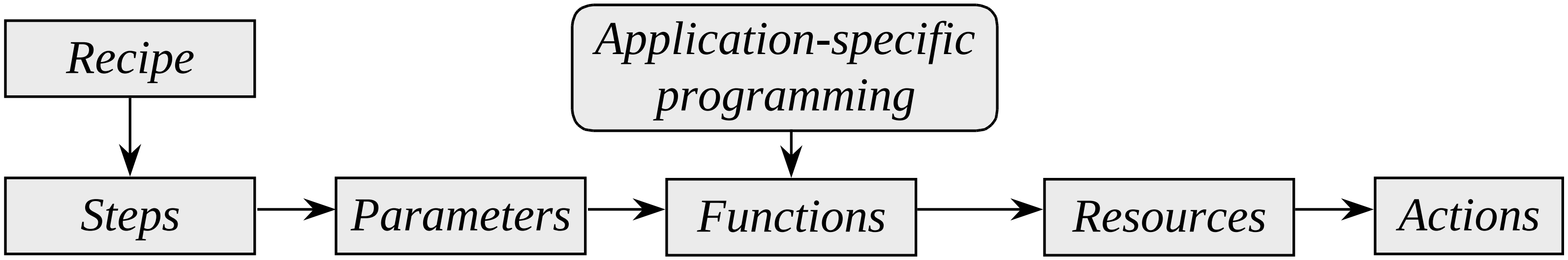


Borland Delphi Environment



Control Architecture

- Machines have functions, which are programmed in
- Machines have resources, which have properties and methods
- Parts have a recipe
- Recipes have steps, corresponding to machine functions
- Steps have parameters for the functions and resources
- Sequencer initiates actions, associating steps to machine functions and resource methods using step parameters
  - Sequence dependencies
  - Resource dependencies
  - Parallel steps are possible



Issues

- Safety must not be compromised
  - Robot controller hardware needs safety circuits and hardware interlocks
- Real-time performance
  - Performance could be enhanced with better real-time integration of controller.
  - Real-time coprocessor might be useful, as long as cost and integration are seamless.
- Open systems need standards and support
  - Driver availability for various hardware is limited
  - Need to protect the investment in software
- Mechanical elements can benefit from open standards
  - Difficult to interchange robots and tooling
- Machine vision needs better integration and ease of use
  - High level vision functions (glue path inspection, etc.)
- Mechanical, electrical, and control hardware integration

Future Trends

- Work with robot vendors to enable use of robot controllers
  - PC-based Seiko controller (need Cimetrix driver)
  - Panasonic PC-based controller
  - Adept to use Firewire-linked integrated controllers (need Cimetrix driver)
  - Robot controllers should move to client-server architectures
- Industry is moving toward component-based software
  - Evolve software to more language-independent implementation (ActiveX)
  - Comotion, Object Automation, Object Factory, etc.
  - Industry-standard component-based API
- High speed standard serial busses will play major role
  - USB, Ethernet, Firewire, USB-2
- Hardware modules with integrated controllers
  - Smart conveyor modules with component interface for flexible integration

Section Seven

Open Architecture Control for the Robotics Industry: Third Party Perspective

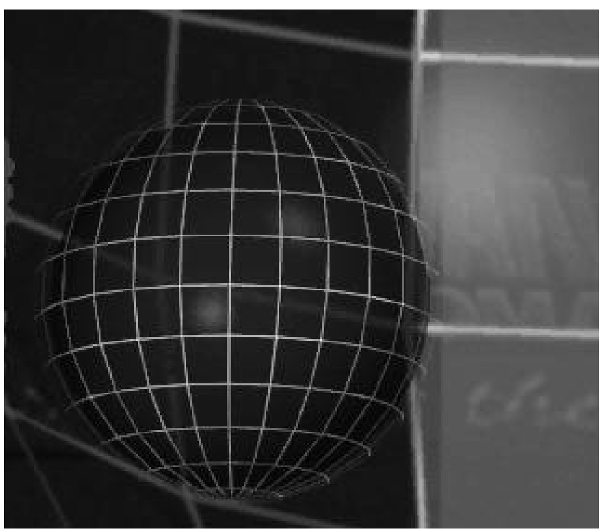
Scott McCrary, President

Advanced Automation, Inc.

Robotics Industry
Workshop

Open Architecture Control for the Robotics Industry

Third Party Perspective



Scott McCrary, President
Advanced Automation

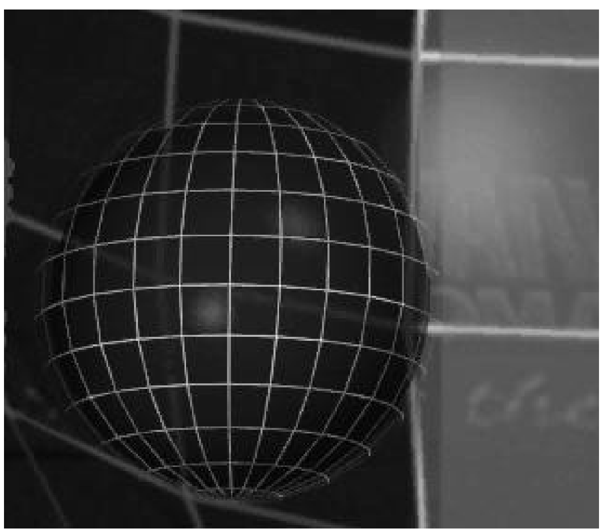
Advanced Automation Capabilities and Experience

- 21 Years of System Integration Experience
  - Flexible Systems, and PC Controls Leader
    - Modular Systems Expertise

- Full Range Controls Integration - Levels 1, 2, & 3

Robot Experience

Our experience with robots includes: Seiko, Adept, C&D, Fanuc, Panasonic, Yamaha, Nachi, Staubli, and others



End Users

Our experience with end users includes: IBM, Black & Decker, TRW, Siemens, Bosch, Northern Telecom, Norton, and others

Robocentric

Robocentric (r_·b_·c_n´·trÌk)

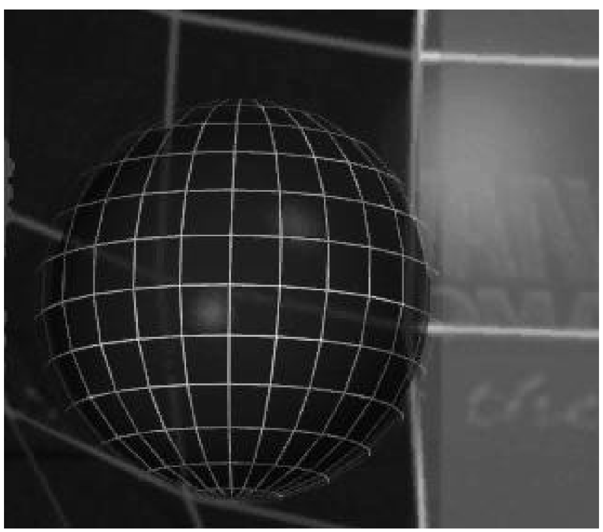
- The tendency among manufacturers of “nameplate robots”, and the users of same, to consider the robot as the center of the universe

Robot

The robot as an intelligent peripheral

… is like a printer in an office automation solution (vis-à-vis the PC, the network, the software)

End Users Want



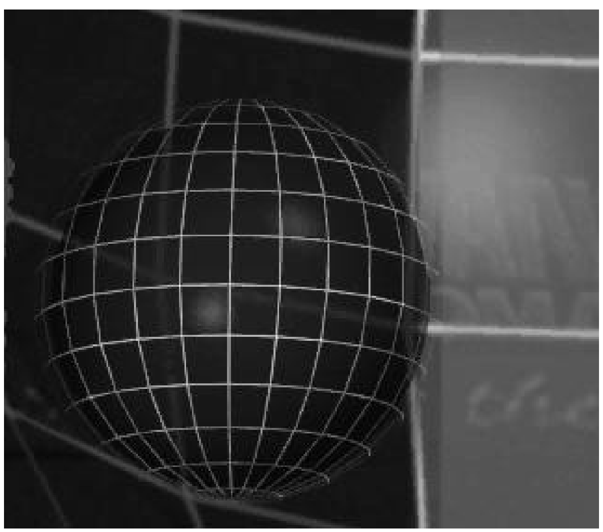
1 Price… best expressed as cost of ownership; unfortunately collapsed sometimes to first cost

2 Schedule… time to receive an effective solution to the posed problem

3 Quality… of concept and all other aspects of the solution, not just hardware quality

Presentation

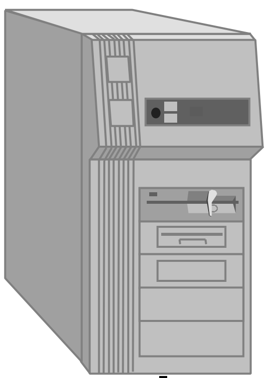
Following is a modified company presentation of ways to meet price / schedule / quality needs of the End User

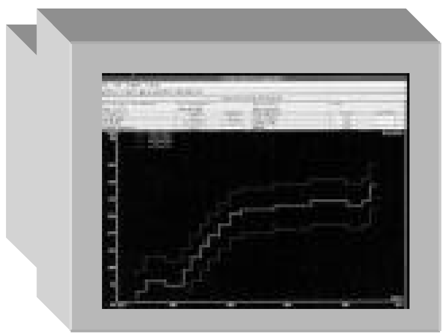


Advanced Automation's Answer to "The Solution End Users Need"

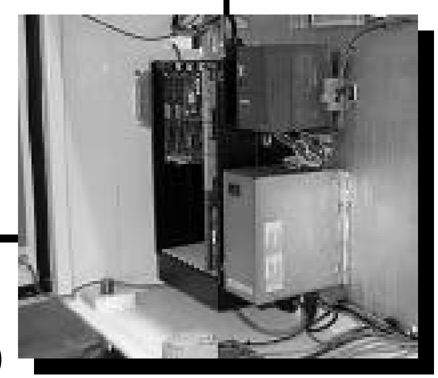
Concept Specification

- Common Station Platform
  - Integral Real-time PC Based Controls
  - Interbus-S Distributed I/O
  - Thin Client Pier-to-Pier Network
    - TCP/IP Protocol





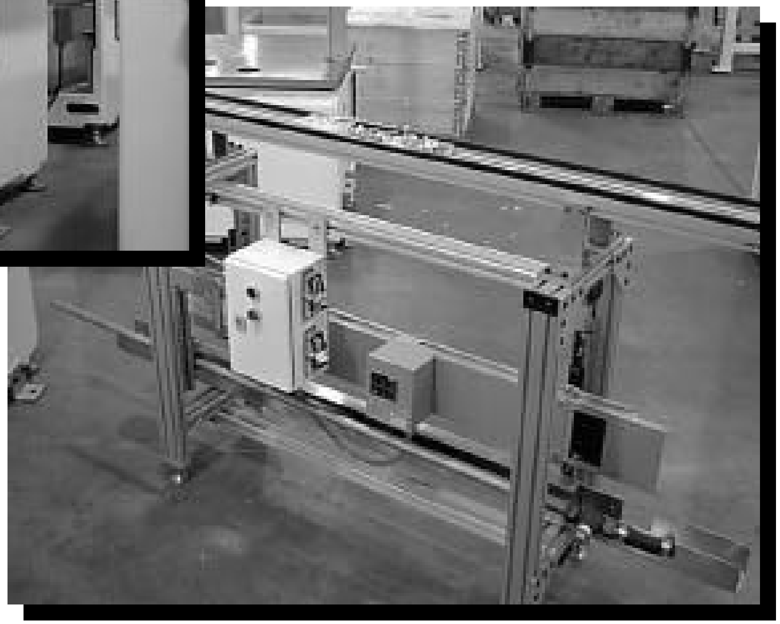
- Built-In System Statistics
- Robots and Motion Control as Needed



Advanced Automation’s Answer to “The solution End Users Need”

Concept Specification:

- Plug-and-Play Modularity
- Motion Control and Robotics are a subset of the solution

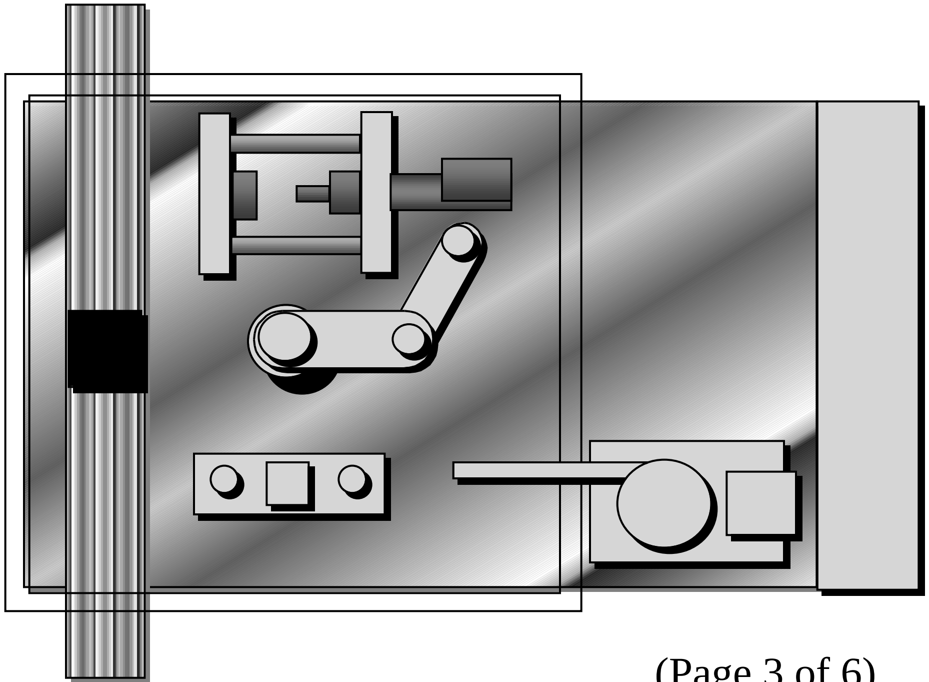


Advanced Automation's Answer to "The Solution End Users Need"

Concept Specification

- Modular Tooling Components

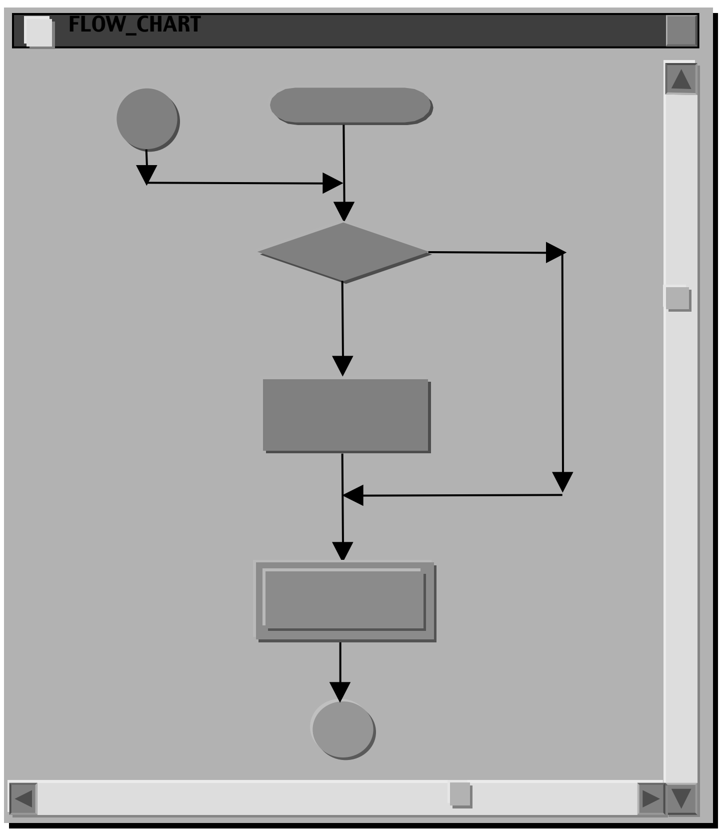
(Including Robots, Software)



Advanced Automation's Answer to "The Solution End Users Need"

Concept Specification

- Simplified Controls and interface
  - Windows NT Network Environment
  - IEC 1131 Standard Function Chart/Flowchart Programming

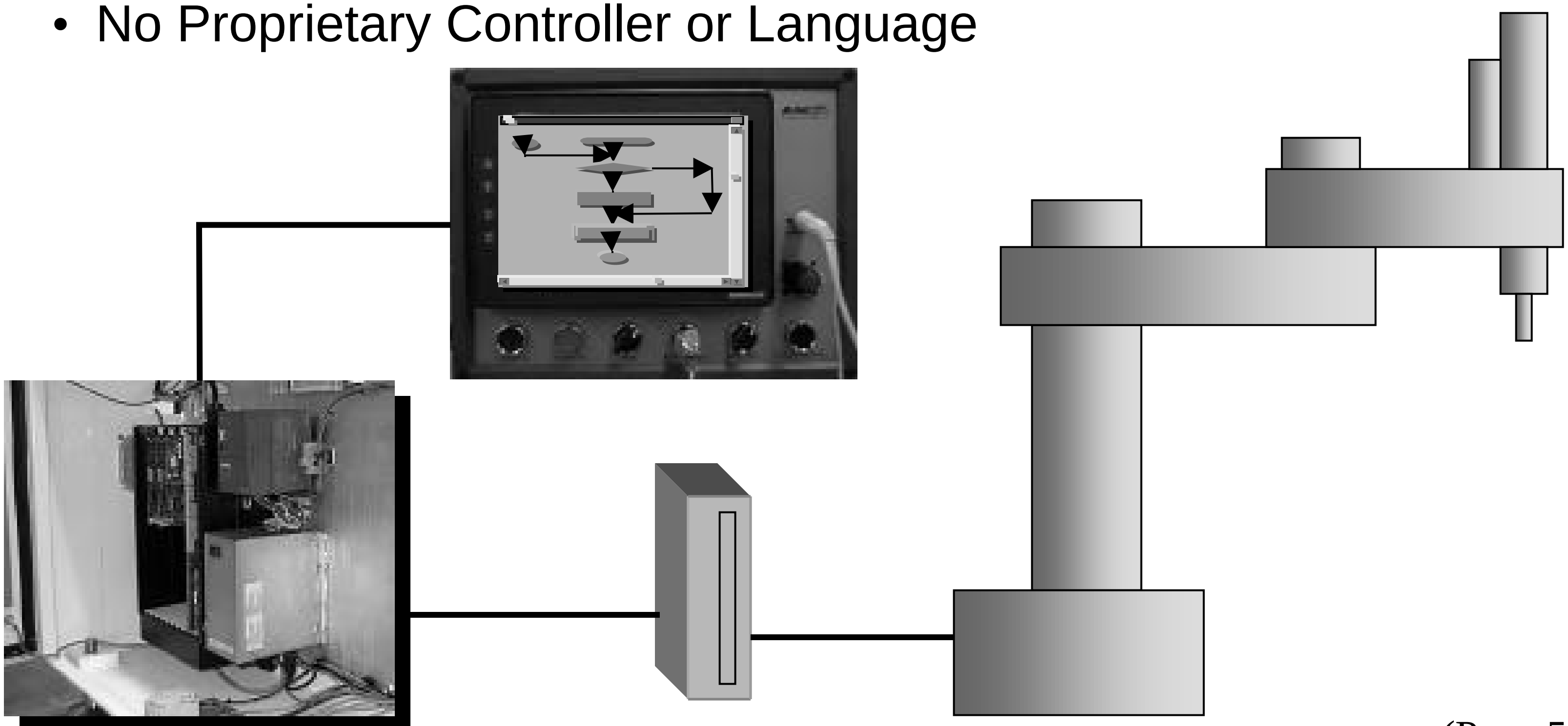


No Robocentric Solutions

Advanced Automation's Answer to "The Solution End Users Need"

Concept Specification (robot example):

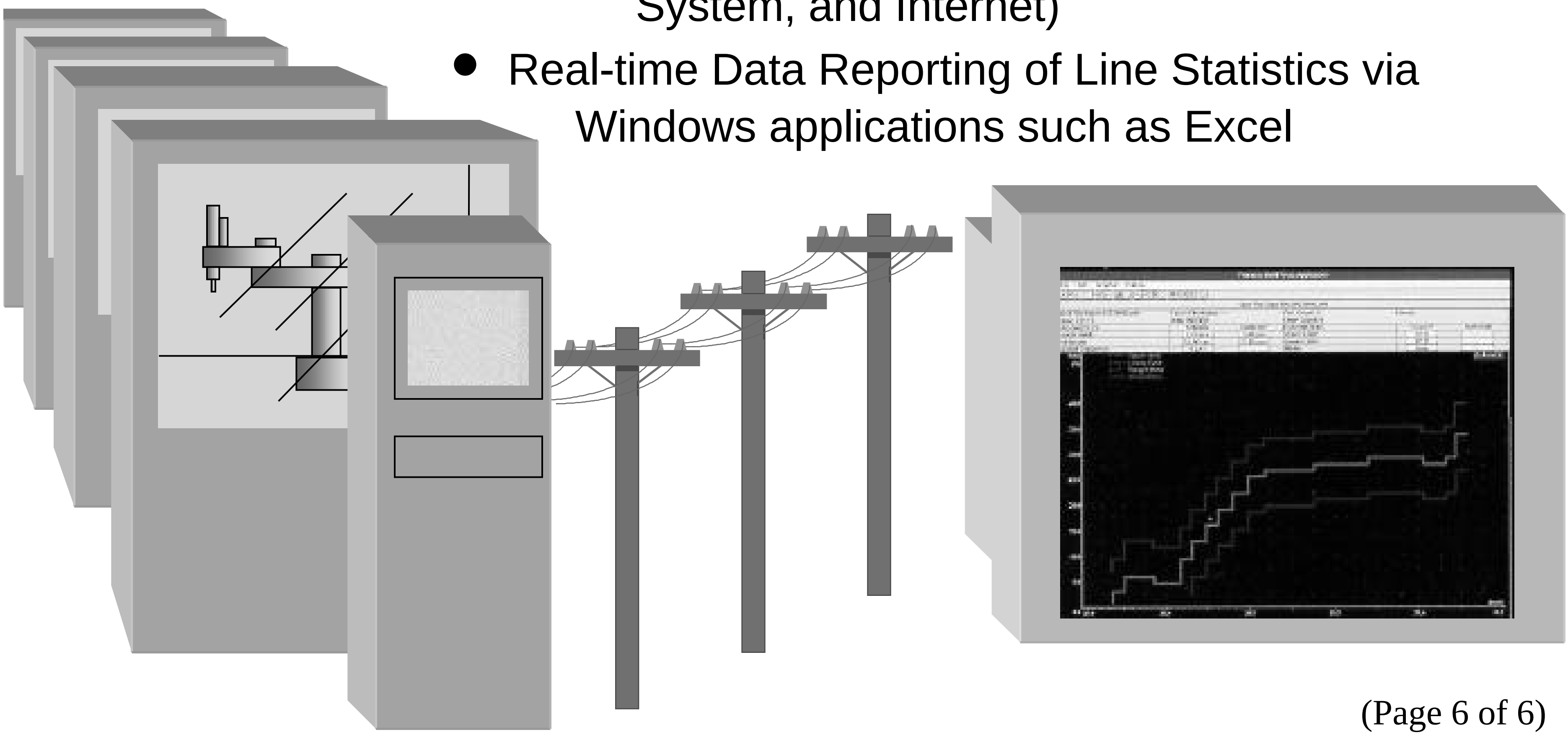
- Flexible cell Methodology
- Compliant SCARA Robot with Payload
  - Direct Real-time PC Control through Single GUI Interface
  - No Proprietary Controller or Language



Concept Specification:

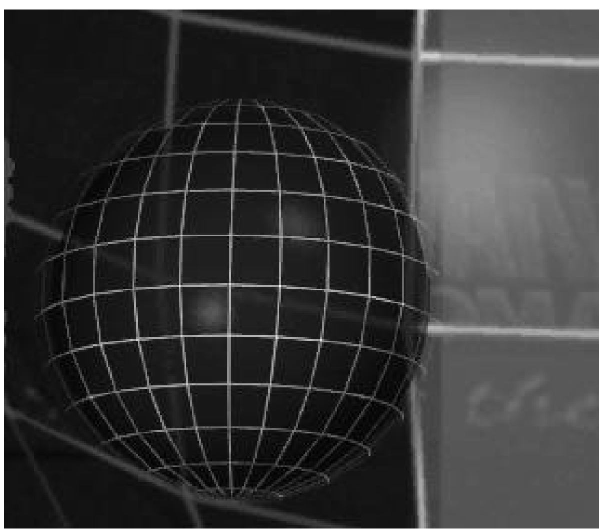
Advanced Automation's Answer to "The Solution End Users Need"

- Networked Station and System Statistics and Diagnostics
  - Windows NT Network Interface
  - Remote Data Access and Control (Office Network, MES System, and Internet)
  - Real-time Data Reporting of Line Statistics via Windows applications such as Excel



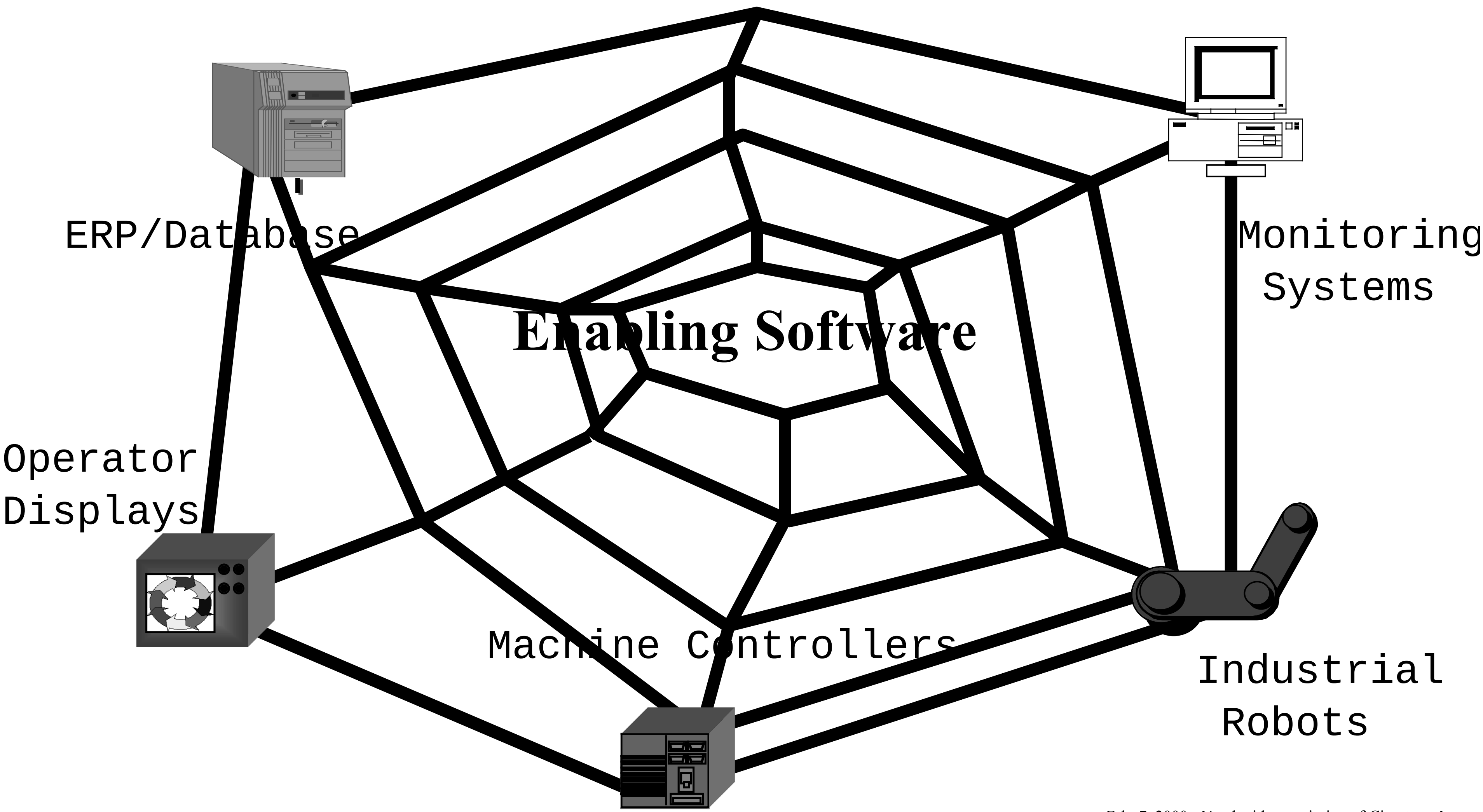
Controls

Following are modified slides from a presentation on how Advanced Automation uses a PC - controlled, open-architecture control approach to meet End User Needs



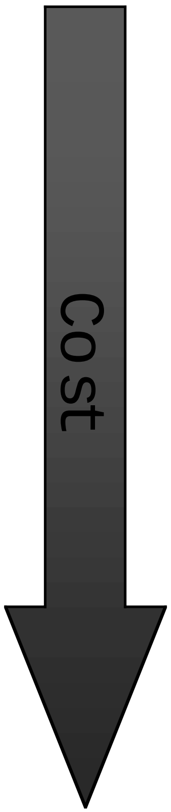
Open-Architecture, PC-Controlled, Systematic Approach

the software foundation of your WEB Factory



Feb. 7, 2000 - Used with permission of Cimetrex, Inc.

Manufacturing Needs



faster Development

50% reuse of software

Enterprise Connectivity

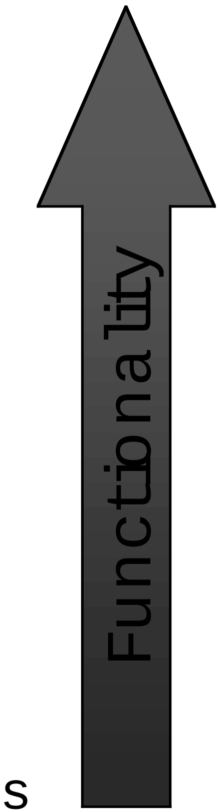
Oracle, Sybase, Access

less Training

hypertext point & click

lower Operating Costs

remote diagnostics & analysis



The Equipment - Product Lifecycle

Automation Design/Development Phase

software reuse, enterprise connectivity

Line Installation and Startup

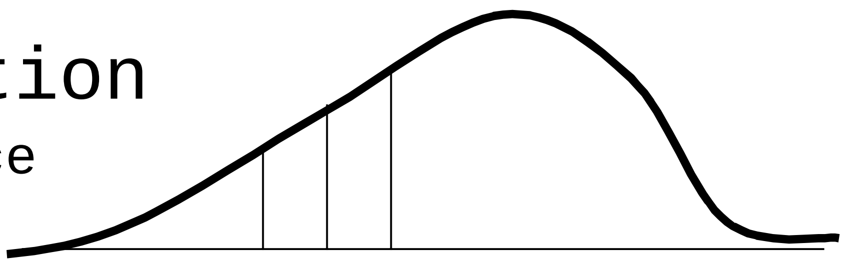
comprehensive diagnostics

Initial Production

graphical HMI, online JIT instruction

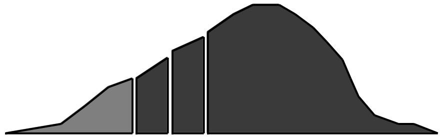
Sustained Production

predictive maintenance



Goal: Improve Productivity & Reduce Cost

Development



Customer Benefit

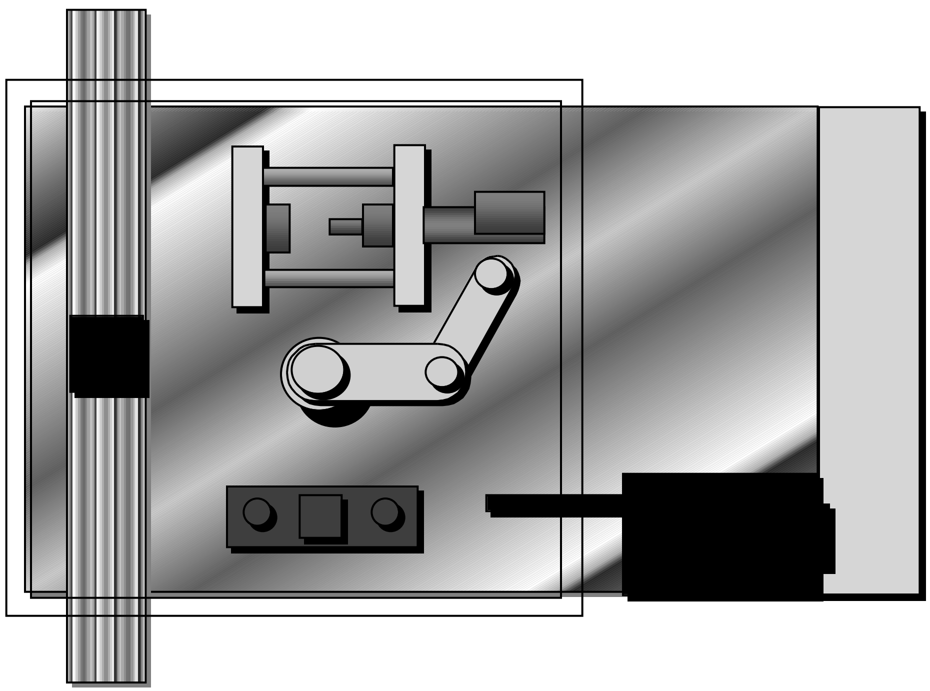
- Dramatic reduction in programming time ***(50% software reuse)***
- Higher code quality
- Manage complexity
- Standardization

Contemplated Approach

- Component-based software libraries
- Data-driven controls design
- Open control
- IEC-1131 standard
- Plug-n-Work

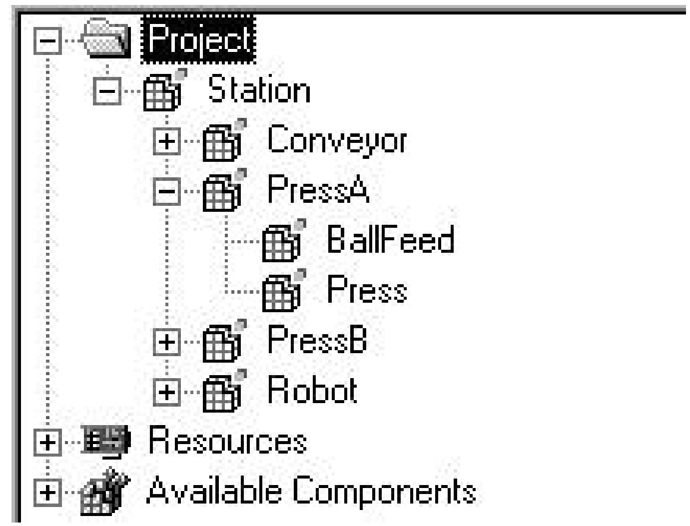
Modular Hardware Components Make Sense

- ➢The contemplated approach extends this idea to software



ERP
SCADA
HMI
ROBOT
TEST
MOTION
CONTROL
SENSORS I/O

Software Components (Objects)



Components = Data + Instructions

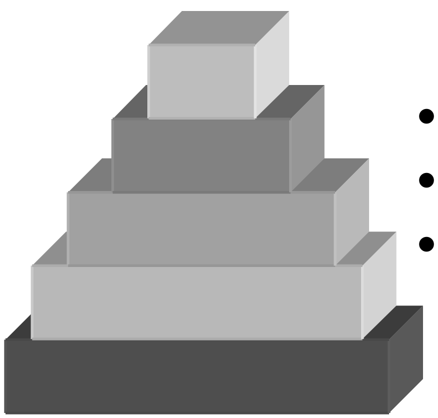
Properties (variables) & Resources (devices)

Methods (programs)
IEC-1131-3
- Structured Text (ST)
- Sequential Function Chart (SFC)

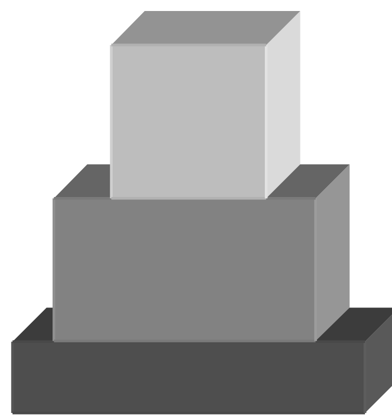
Connectivity

➢Information Access

Existing ... your choice ... with contemplated approach



- Complex
- High Cost
- High Maintenance



- Scalable
- Open Systems
- Low Cost
- Low Maintenance

Installation

Customer Benefit

- Faster Startup
- Improved training & ease of use
- Customer Confidence

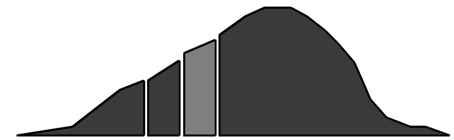
Contemplated Approach

- Fault tracking
- Many levels of diagnostics
  - **graphical logic flow**
  - **multiple message channels**
  - **watch windows, breakpoints, single step**
  - **trace buffer with replay**

Multi-Level Diagnostics

- **Descriptive Text Messages**
  - **Channels, IO Mapping**
- **Graphical Troubleshooting Tools**
  - **Power Flow**
  - **Watch Windows/Breakpoints**
  - **Internet Remote Diagnostics**
  - **Single Stepping**
- **Trace Buffer (with replay)**
  - **email notification**
  - **automatic paging**

Initial Production

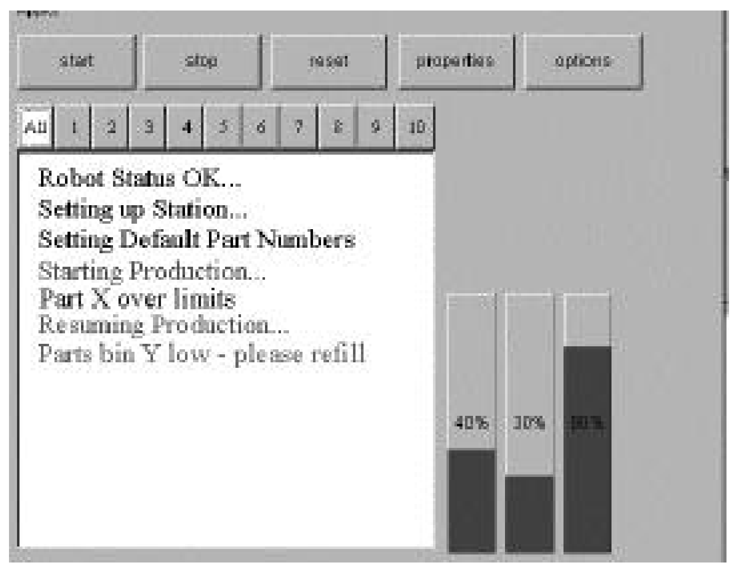


Customer Benefit	Contemplated Approach
➢ Achieve production targets & quickly	➢ Powerful HMI
➢ Faster training	➢ Shared production information
➢ Increased efficiencies	➢ Single software interface
➢ Higher yield	➢ Windows-based point-and-click environment

Visual HMI Components

- Buttons
- Message Windows
- Charts
- HTML Documentation
- Debug tools

- Java IDE
- stand-alone java apps
- Web-ready java applets



Sustained Production

Customer Benefit

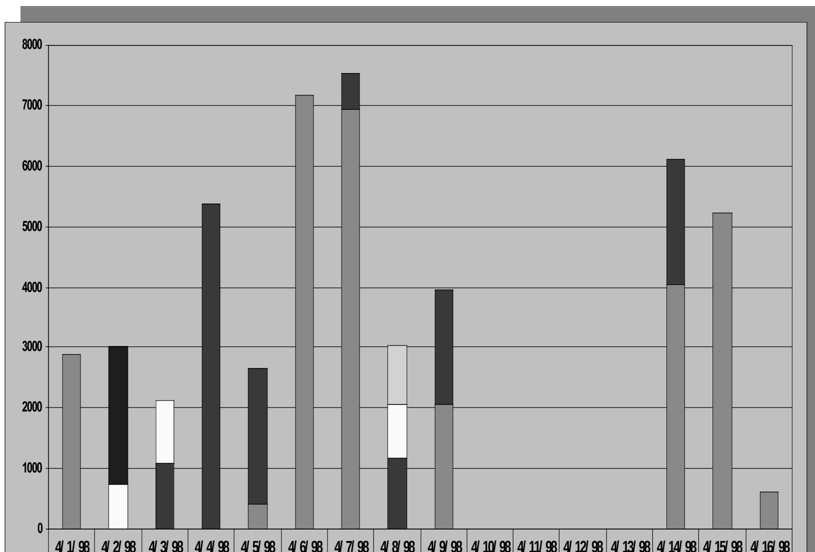
- Predictive maintenance
- Increased equipment uptime
- Faster training for new operators

Contemplated Approach

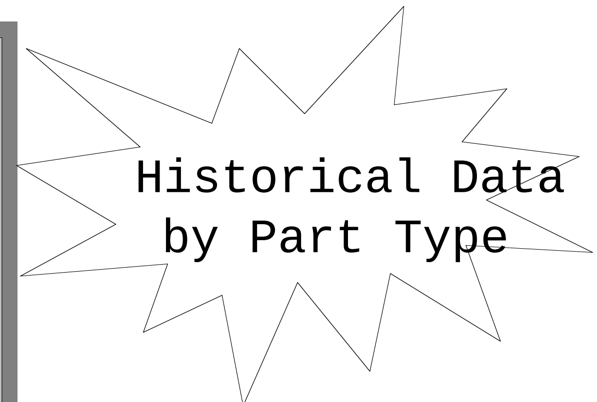
- Online documentation (HTML)
- Remote diagnostics
- Statistical tracking
- PM schedules

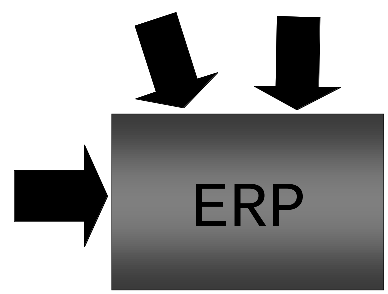
Database Reporting

Efficiency,yield
uptime,downtime
starved time,blocked time
fault time,bypassed time, stop time



	4/ 1/ 98	4/ 2/ 98	4/ 3/ 98	4/ 4/ 98	4/ 5/ 98	4/ 6/ 98	4/ 7/ 98	4/ 8/ 98	4/ 9/ 98	4/ 10/ 98	4/ 11/ 98	4/ 12/ 98	4/ 13/ 98	4/ 14/ 98	4/ 15/ 98	4/ 16/ 98
63		2273														
62								982	0							
61		734	1030					894								
22			1091	5361	2239		578	1172	1877					2069		
21	2907	0			419	7176	6935		2073	0	0	0	0	4032	5224	610

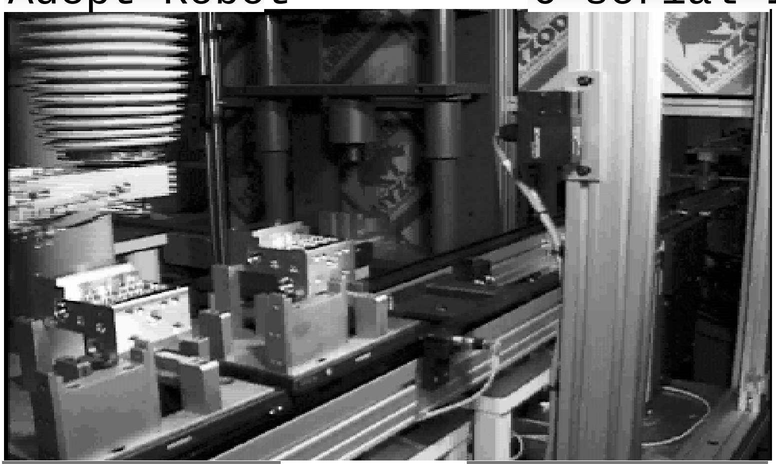




Successful Implementations

Adept Robot

6 serial I/F



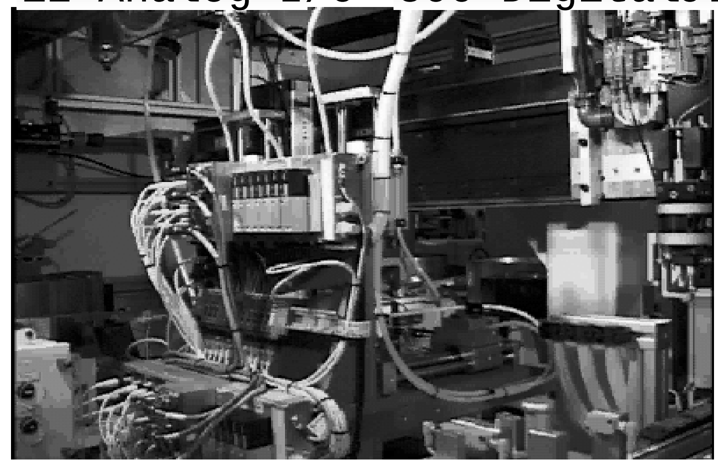
Pentium 233 MHz CPU

Database I/F

Graphical HMI

12 Analog I/O

500 Digital I/O



Real-time

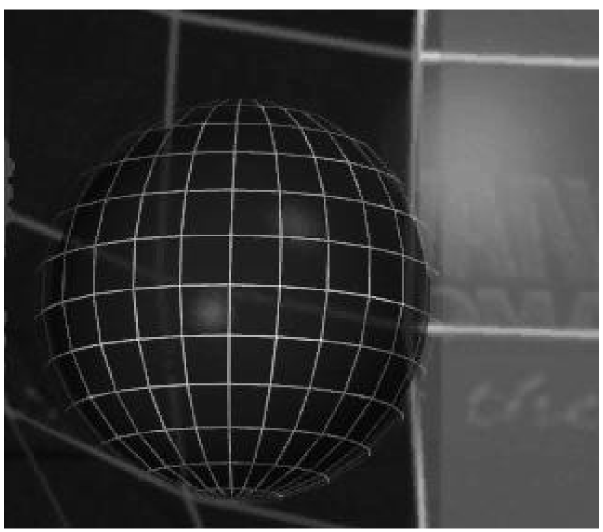
Factory tested

Embedded PC Control

First Component-based
Machine control software

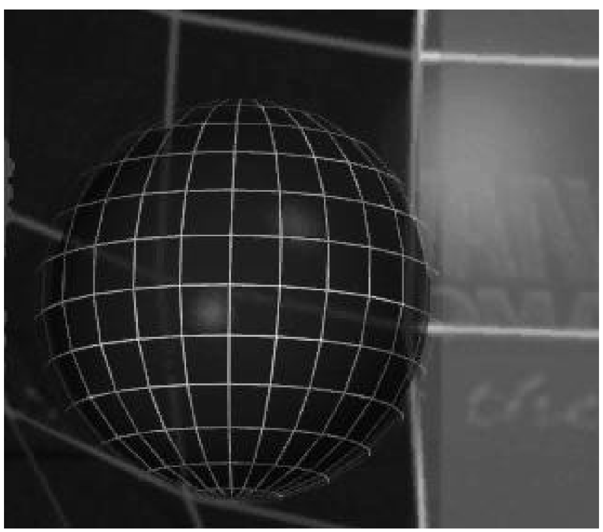
Suggested Directions

- Abandon robocentric mentality, adopt PC open architecture paradigm for the mass market



Suggested Directions

- Excel at
  - Manipulators with power amplifiers
  - Safety-related applications
  - Difficult Kinematics
  - Special applications



Suggested Directions

- Supply the following only if you have a world-class product:
  - Controller hardware (CPU, network cards, cage, etc.)
  - Vision hardware / software
  - I/O
  - Data handling / IT
  - HMI
  - Logic software

Section Eight

OMAC API Workgroup
Status Report

Richard Mathias, Technical Fellow

Boeing Commercial Airplane Group

OMAC API Workgroup Status Report

John Michaloski

Intelligent Systems Division

Manufacturing Engineering Laboratory

National Institute of Standards and Technology

February 2, 2000

Outline

- Objectives and Goals
- Methodology Overview
- OMAC API Technologies
- Status
- Future Work

OMAC API Objective

- Enable control vendors to supply standard components that machine suppliers configure into machine control systems. The integrated control system and machine are then delivered to the end-user.

OMAC API Goals

- Component based plug and play analogous to PC industry
- Integration of third party process modeling with control e.g., sensor feedback
- Controllers built from best value components
- Design and Component reuse to reduce cost

Benefits

- **Flexible**
  - handle many applications with similar solutions
- **Extensible**
  - modify system to accommodate new technology
- **Scalable**
  - can handle single axis or multi-axis applications
- **Modular**
  - encapsulation isolates changes
- **Reusable**

Example User Applications

- Replace PWM drives with SERCOS drives
- Add closed loop scanning probe;
- Add acoustic emission sensor for tool breakage
- Add real time image recognition of surface finish
- Add LAN communications functions to support part program upload part program download, remote status monitoring and remote data acquisition;
- Replace human interface module with industry de facto standard operator interface;
- Replace part program interpreter to support CL data generated from AutoCad or ProEngineer.
- Enable “art to part” such as feature-based or NURBS-based machining

OMAC API Methodology Overview

- Adopt component/framework Architecture
  - Offering encapsulation by using Object Oriented technology class definitions containing both data and methods
  - Adding specialization by leveraging OO notion of inheritance to use base and derived classes
- Use finite state machine for control and data flow
- Use proxy agents to hide distributed communication
  - Implying need for DCOM or CORBA
- Emphasize on embedding information into components
- Focus on component life cycle

Component Based Technology

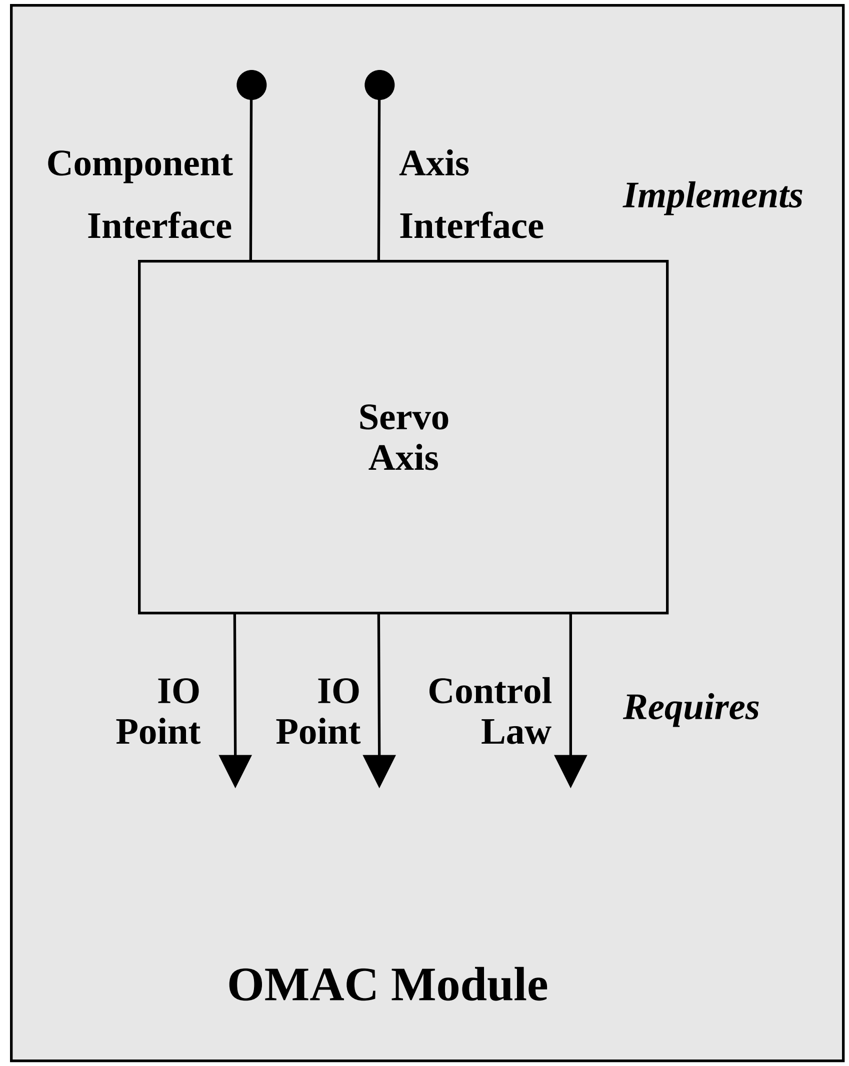
- Build software from parts, not from scratch
- A component is a reusable piece of software that serves as a building block within an application
- OMAC API is both a component API specification and a framework for using components
- Components are easier to integrate
  - Allow configuration tools to be built such that complete systems can be “wired” together graphically, no programming required
- Components are distributable

"Introspection"

- Introspection allows components to be manipulated in Integrated Developer Environment (IDE) builder tools.
  - Common elsewhere in the software industry (JavaBeans and Active/X), rare in controller industry
- Vision: IDE builder tool can query an OMAC component for the references it publishes, the types of OMAC interfaces it requires as references, and the events-in it requires and the events-out it generates. The designer can then connect the "wires" among the various OMAC components.
- Entity that is alive at design time, can aid , and can communicate with the development environment.

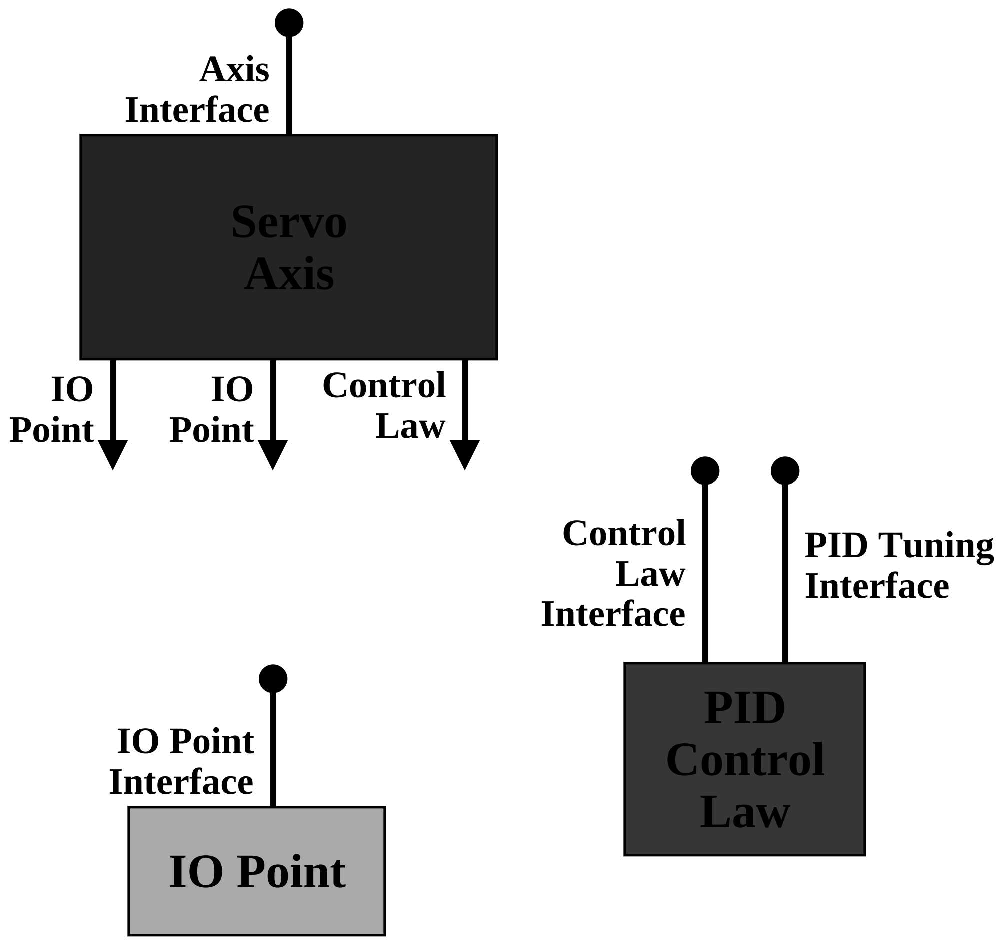
Component Interface

- A Module "advertises" which interfaces it requires another module to implement through its Component Interface
- The module specifies which type of interfaces it will need to connect to
- Each connection is identified by a name, and has a textual description associated with it



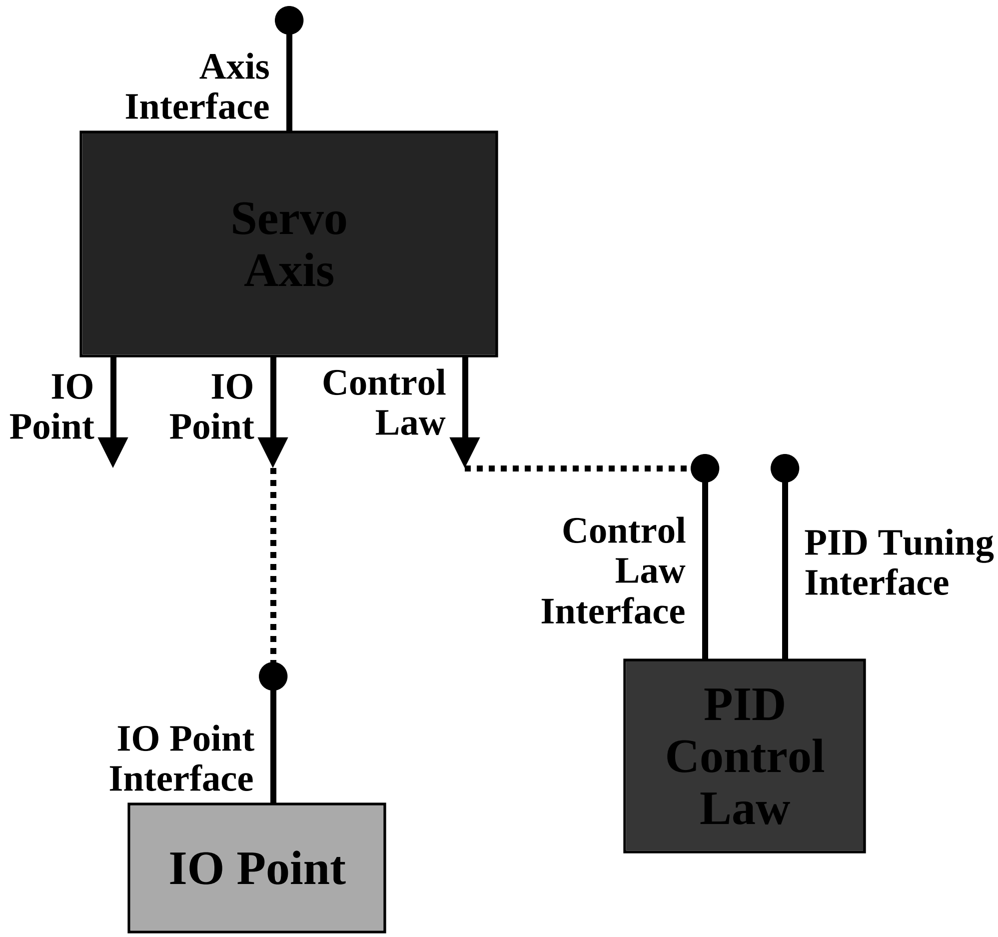
Step 1

An Integrator starts by choosing the modules required for an application:



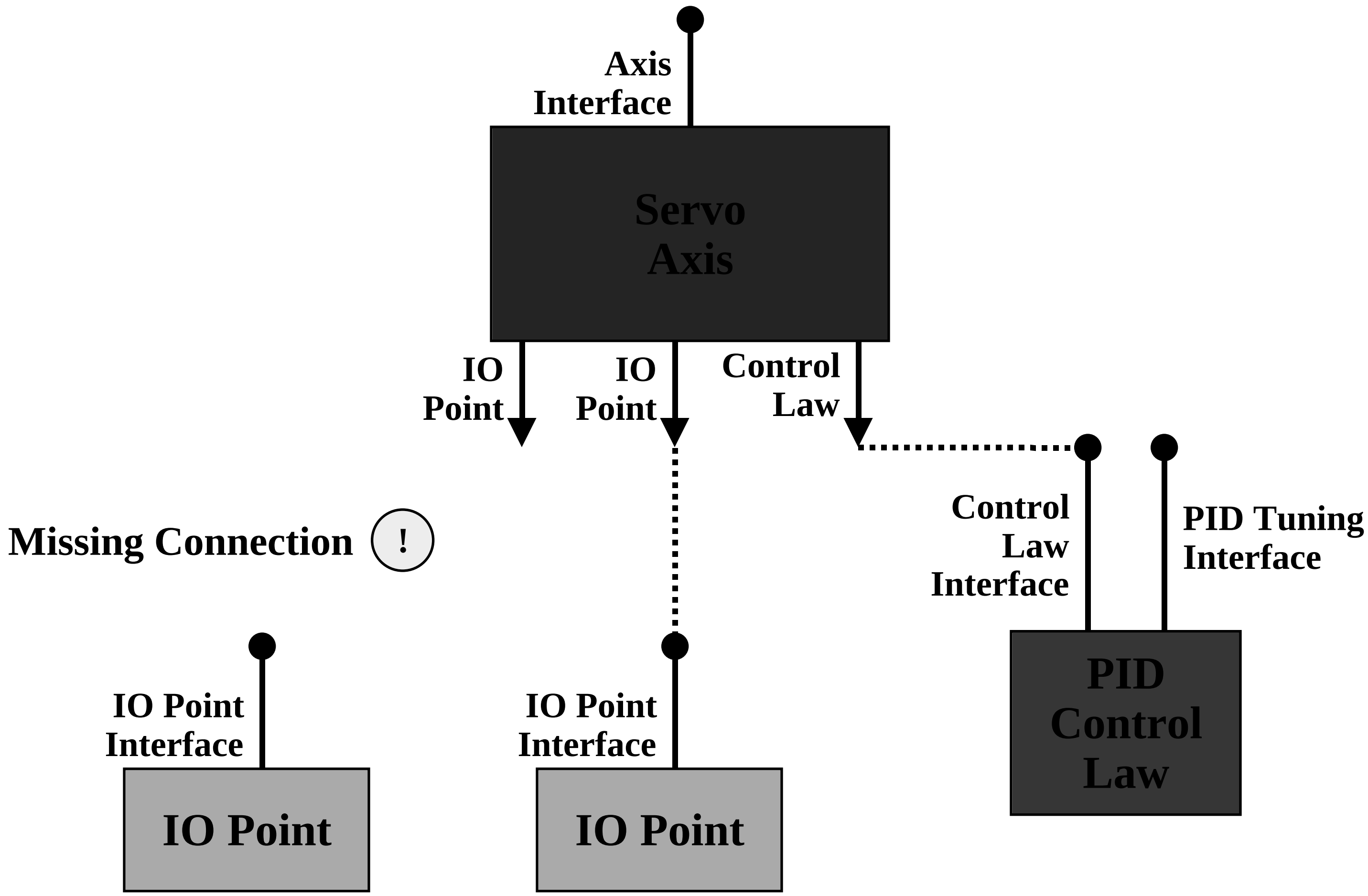
Step 2

Tools allow an Integrator to connect the components together:

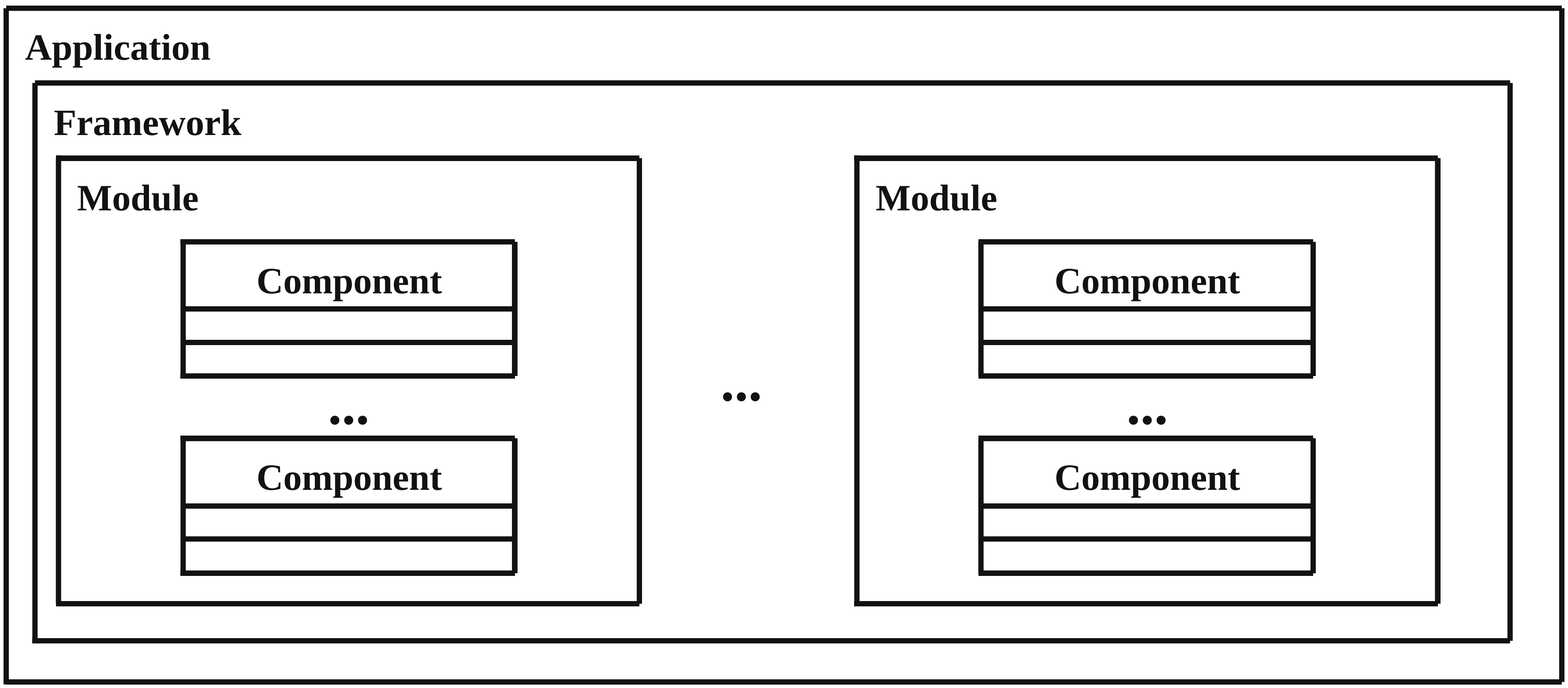


Step 3

Missing Connections and Modules May Be Identified:



Methodology Hierarchy



Application

- Application domain ranges from discrete logic applications with or without motion to complex multi-axis coordinated machines.
- Unified model for CNC, PLCs, robotics, CMM inspection machines, etc. (economies of scale)

Framework Solution

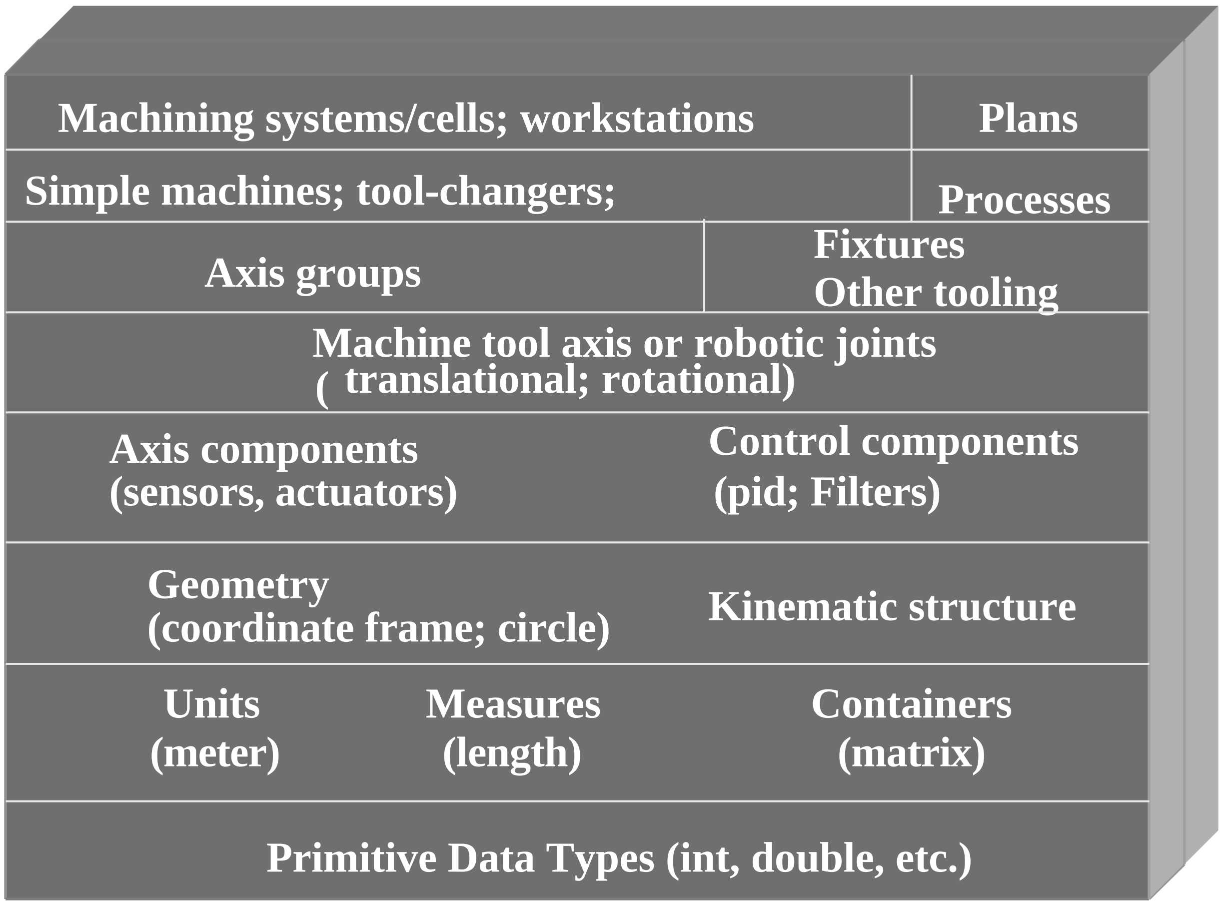
- A framework is an infrastructure for integrating software components.
- Components are tied to framework
- Examples
  - Microsoft COM - Windows NT/CE, VxDCOM
  - Real Time CORBA - HARDPack from LMCO, ORBExpress, Vertl/Expersoft Orb e*ORB, Highlander port of VisiBroker to RTOSs
  - Java with Real-Time Extensions

Frameworks go beyond run-time!

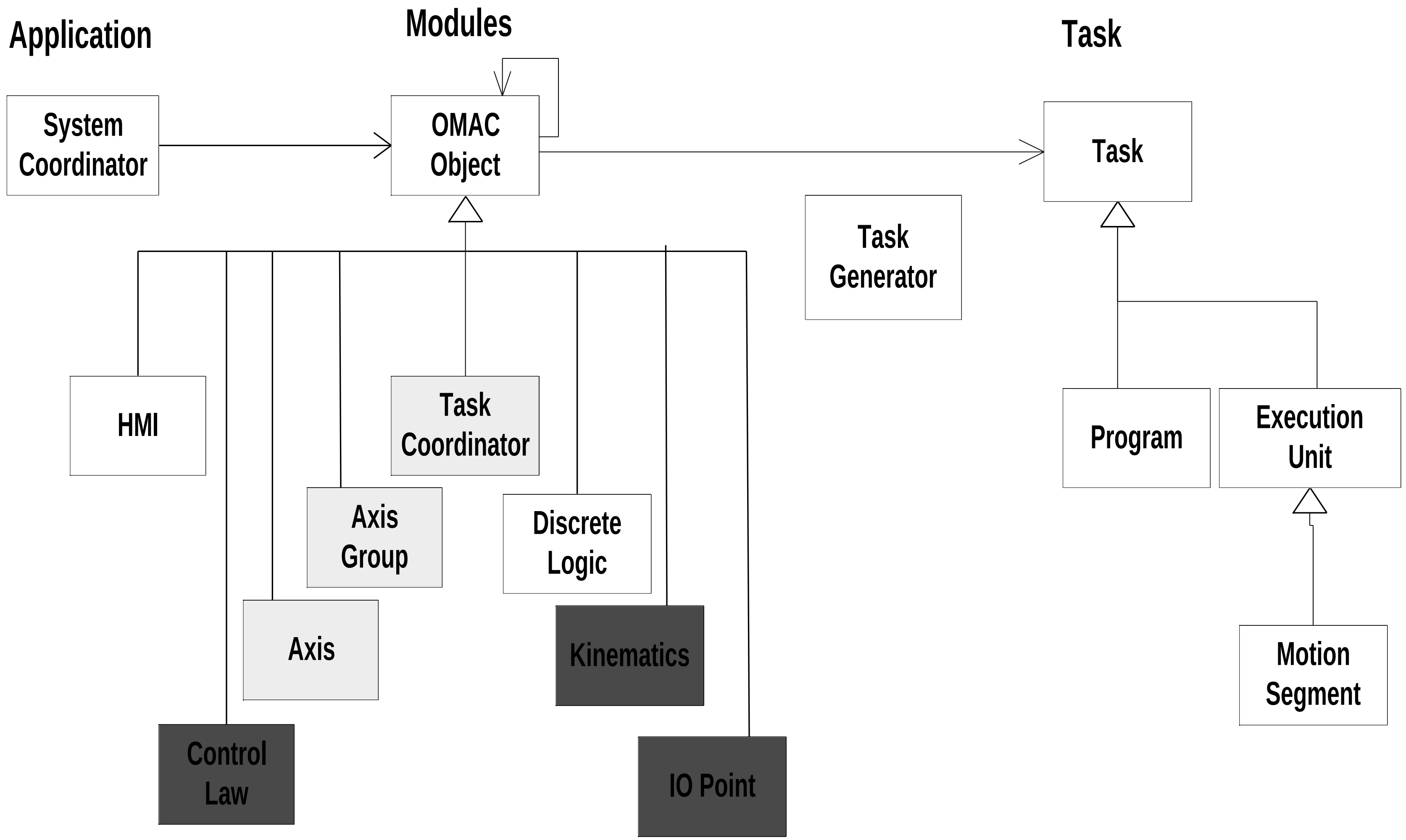
- Activation
- Binding
- Discovery
- Introspection
- Licensing
- Local/Remote Transparency
- Naming
- Registration
- Security
- Versioning
- Wiring

Framework Class Hierarchy

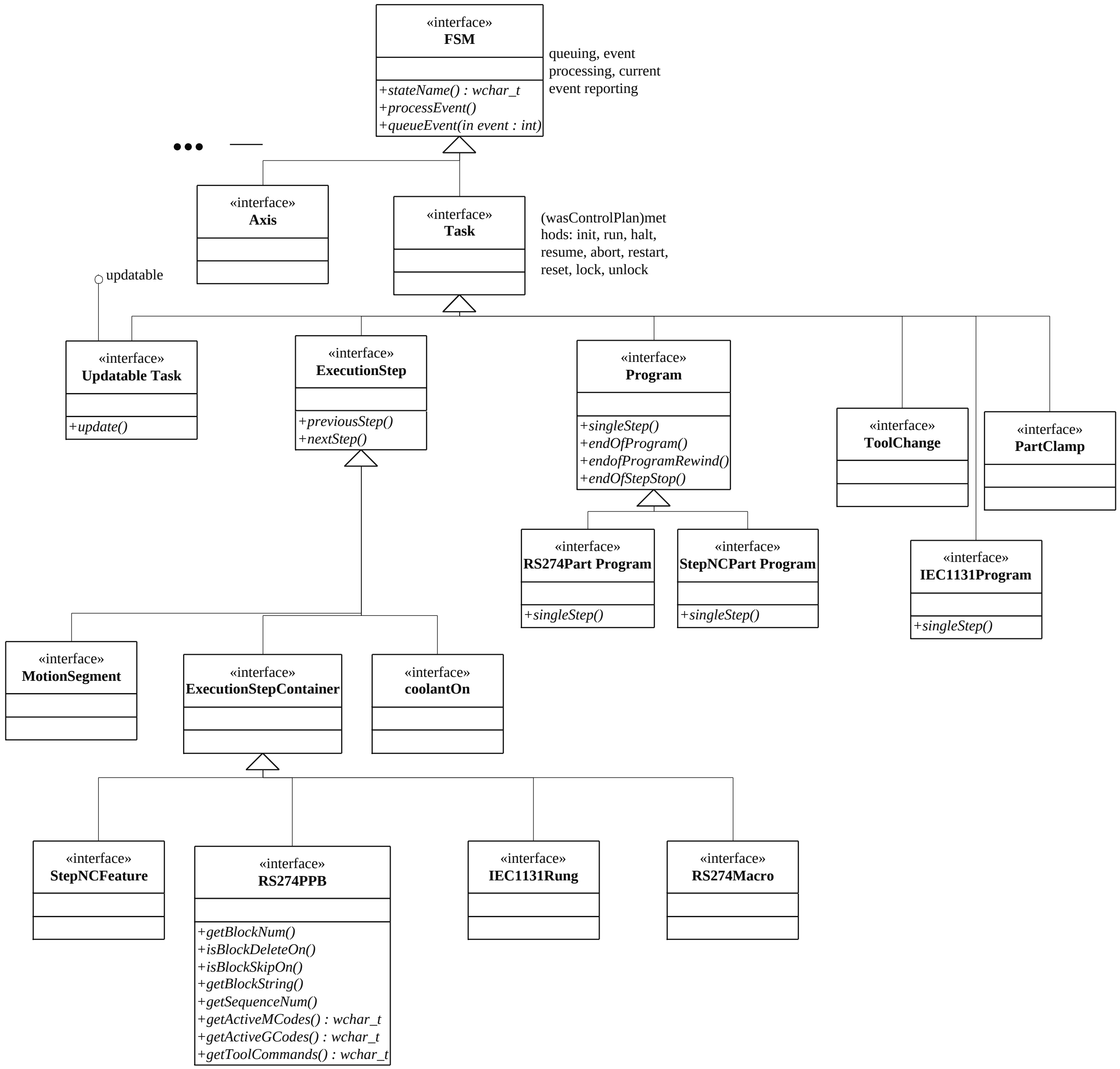
- First step in defining modules is to start with the domain classes



OMAC Interfaces

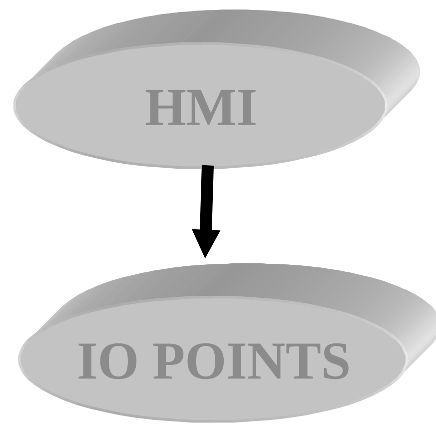


FSM and Task Interface Hierarchy



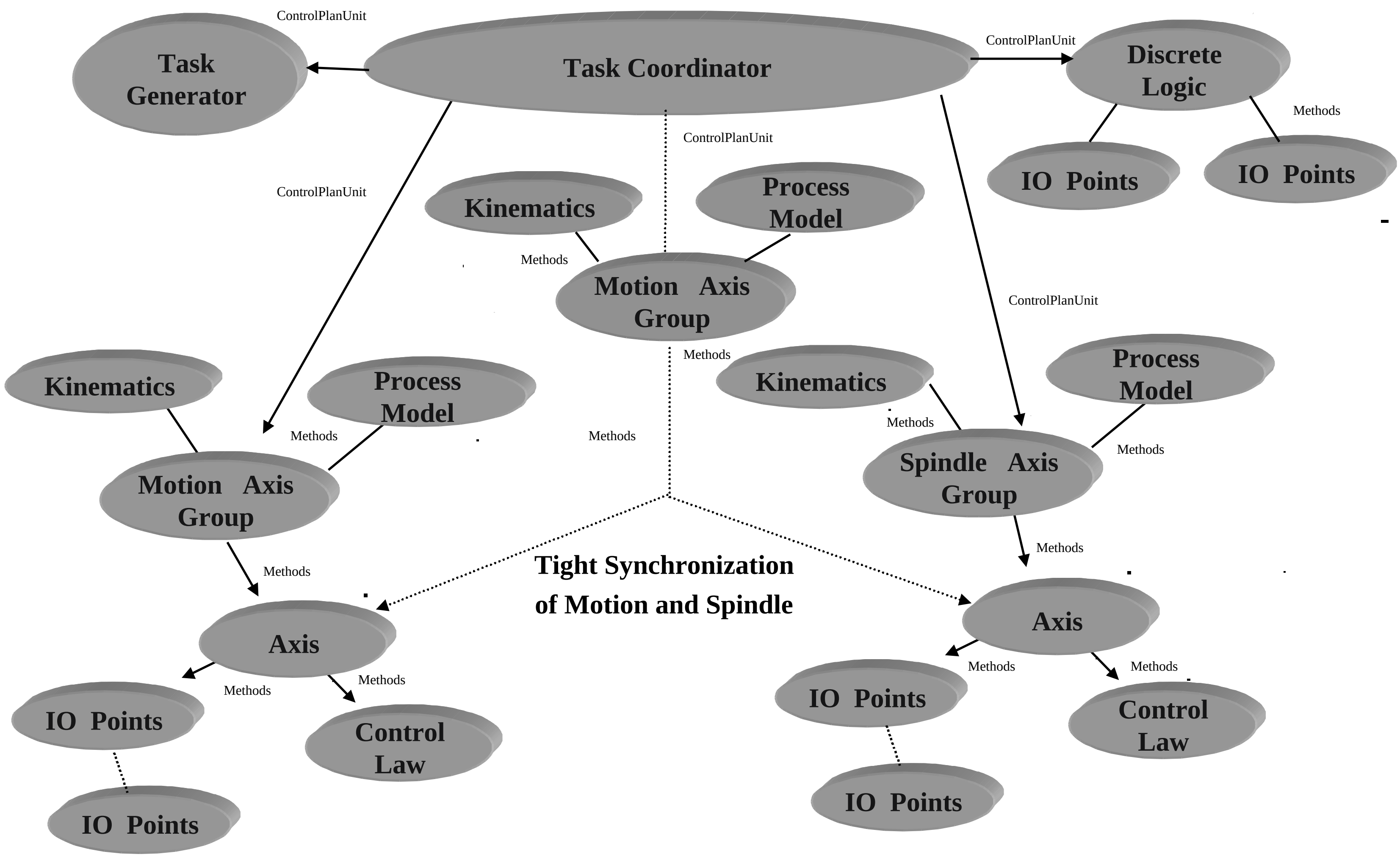
Application Example

- OMAC API is not monolithic, systems can start small and be pieced together



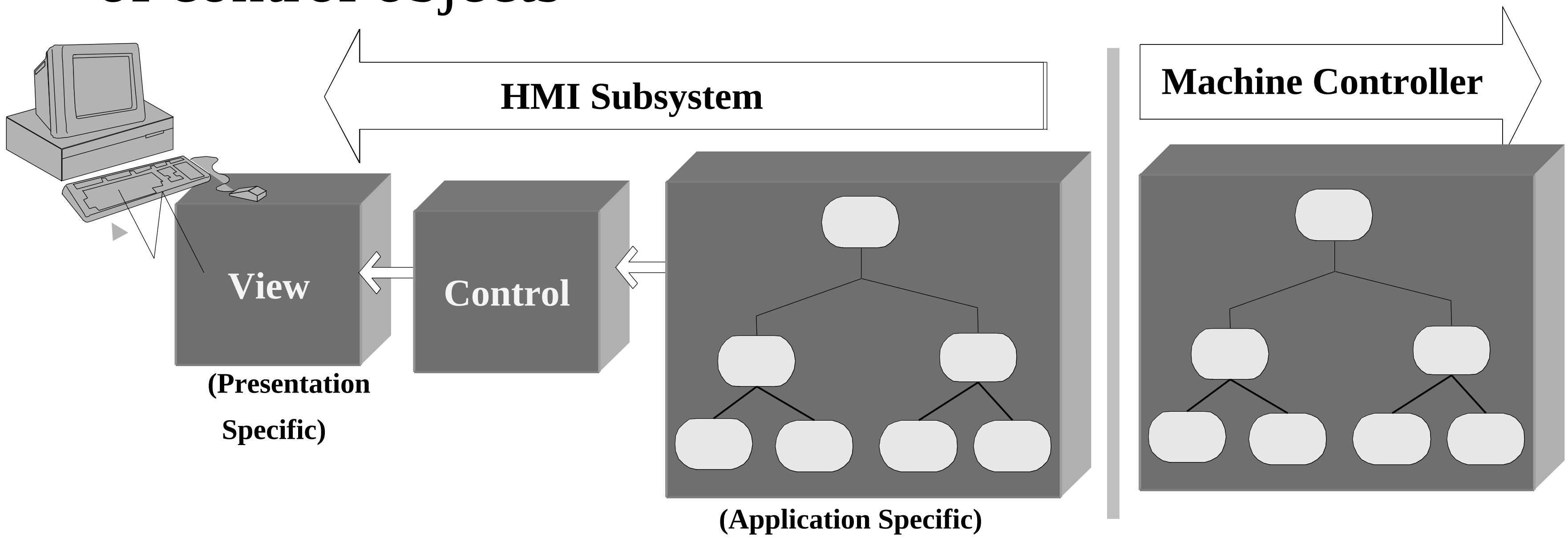
Operator controlling several IO points

Putting it all together

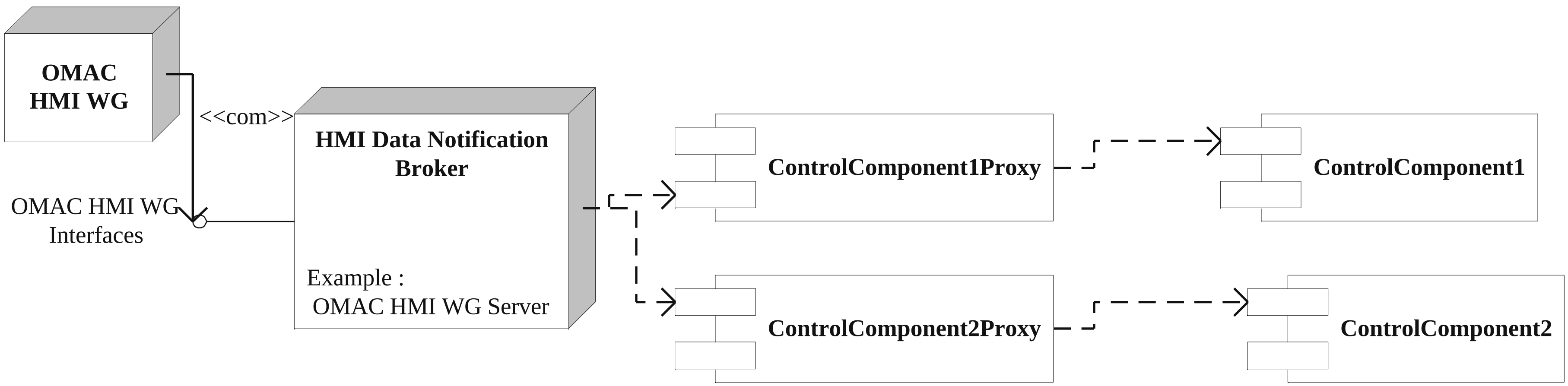


HMI

- Bundling of control software and human machine interface
- Model/View/Control - HMI objects mirror control objects in the system
- Model or data base is sum of HMI object snapshots of control objects

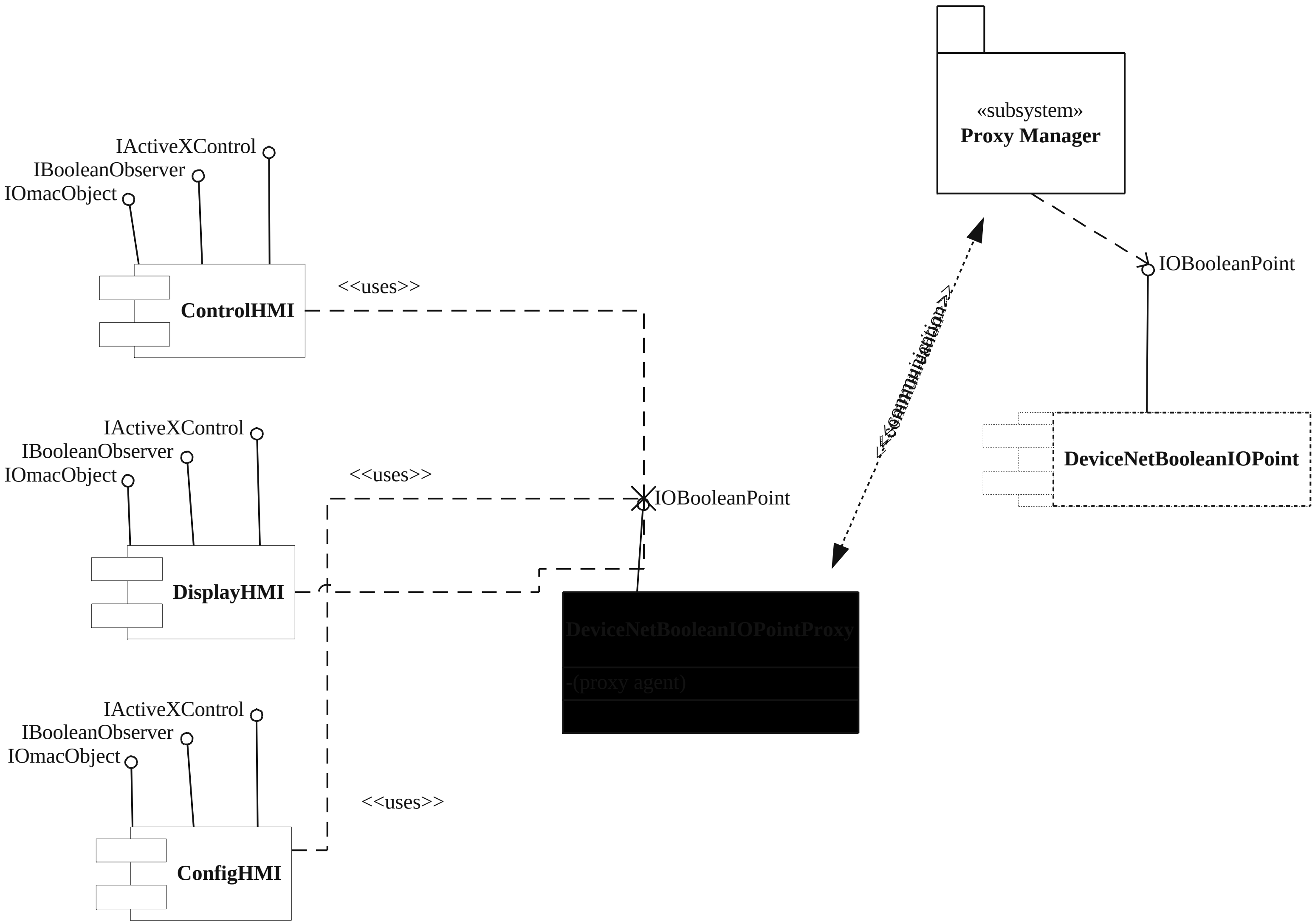


Relationship to OMAC HMI Workgroup



Centralized object interaction and notification through a broker, in a three tier model.

HMI UML Structure



Where are we?

- Agreement to basic model
  - Component-based technology
  - UML as API specification, FSM as behavior specification
  - COM as first Reference API
- Prototype set for public review - February 29, 2000
  - Axis, IO, Task Coordinator, Control Law, Task
  - Includes API and Reference Documentation

Future Work

- Work with Relative Standard Bodies, for example,
  - IEC 61499
  - OPC
- Work with other OMAC WGs
  - HMI
  - Lifecycle economics - link with the model
- Prototype implementation to validate the specification for Axis, IO, Task Coordinator, Control Law, Task
- Incorporate review feedback
- Finish remaining work and publish Complete Specification
- URL: http://www.isd.mel.nist.gov/info/omacapi

Questions?

Section Nine

IEC Project 61499

Sushil Birla,
Engineering Group Manager

General Motors Corporation

IEC Project 61499
RIA Workshop

Orlando, U.S.A.
2000-2-10

prepared by:
Dr. Sushil Birla, General Motors
Dipl.-Eng. H.-P. OTTO, Siemens AG
Dr. J. CHRISTENSEN, Rockwell Automation

ftp://ftp.cle.ab.com/stds/iec/sc65bwg7tf3/html/news.htm

IEC 61499 - Potential Benefits

- **Reduced engineering costs**
  - Component-based software encapsulation and reuse
  - Framework independent of hardware, operating system, programming language, communication protocol
  - Integrated tools for configuration, programming, data management
  - Simple yet complete model of distributed systems
- **Reduced system implementation time**
  - Common concepts and skill sets for multiple tasks
  - Elimination of patch-ware and glue-ware
- **Higher system reliability and maintainability**
- **Ease of future improvements in applications:**
  - Earlier technologies ==> common framework
  - Technology upgrades within framework

Scope & Extent

- **Applications in manufacturing automation**
  - Measurement & control of discrete processes & devices
  - Measurement & control of continuous processes
  - Information & control system integration
- **Main participants in IEC 61499 WG:**
  - England
  - Germany
  - Italy
  - Japan
  - France
  - USA
  - Sweden

Needs & Trends in Industrial Automation

- **Users are demanding systems engineering for integration and seamless communication**
- **Heterogeneous solutions with components from different hardware and software manufacturers are often required**
- **Smart field devices and distributed controllers will replace a considerable number of centralized controllers**
  - **Decentralized systems** (Maybe 30% in 5 years)
- **Need for a widely accepted Industrial Standard to facilitate system integration**

Intelligent components in open and distributed automation

- **The "mechatronic" concept:**
  - Electromechanical components combined with the associated control modules (hardware & software)
  - "Lego set" of smart and reusable mechatronic components
  - Mutual synchronization and coordination by messages + methods
- **Examples of mechatronic components:**
  - Manufacturing Cell + controller,
  - Robot + smart end-effector + controller, ...
  - Servo-driven axis + controller, ...
  - Two-solenoid two-switch Device + controller

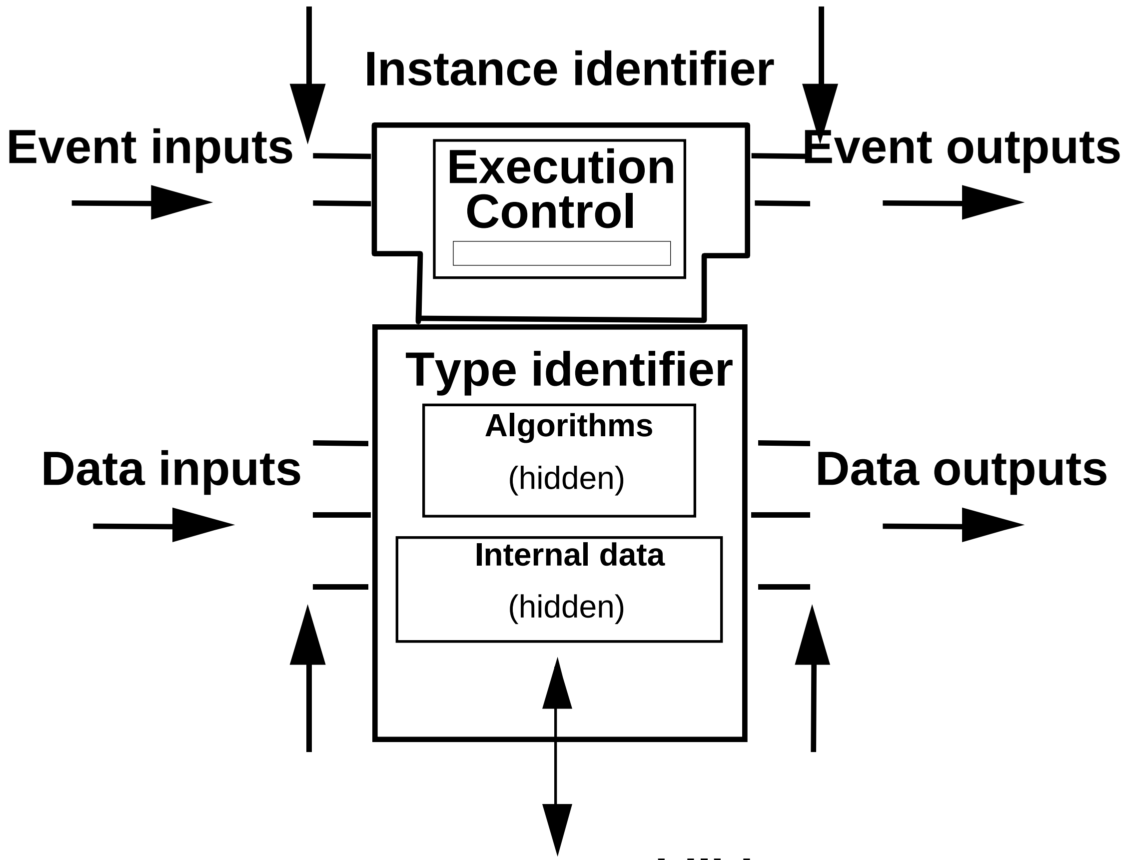
What should be standardized in an open distributed system ?

- **Software objects <==> Function Blocks:**
  - **Interface** (declaration of data and event interconnections)
  - **Invocation and Execution** (cyclic, method or event driven, ...)
  - **Management** (upload/download, delete, insert, ...)
  - **Communication** (fieldbus protocols, process data access, ...)
- **Mechatronic component models ==> Devices:** (load-able, exchange-able, ...)
  - **Device properties/description**
  - **Dynamic behavior of device**
  - **etc.**

The claim of the IEC 61499 standard

***"The future standard
for the system model
of open distributed automation systems
with intelligent control components."***

IEC 61499 FUNCTION BLOCK MODEL



Resource capabilities

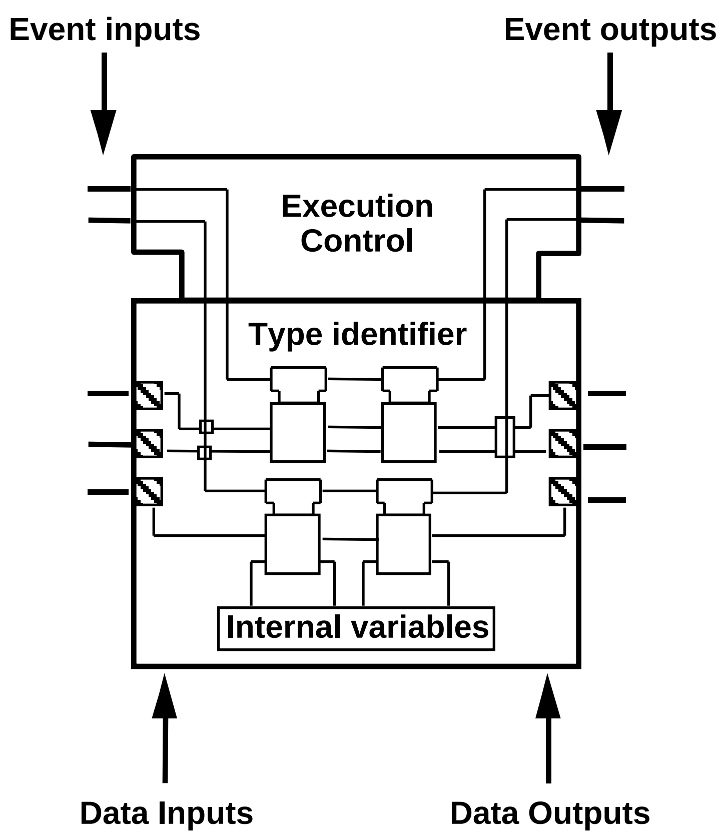
(Scheduling, communication mapping, process mapping)

FB Model of IEC 61499 contrasted with IEC 61131-3

- **State-transition control in each Function Block**
  - **using *events* as action and state transition triggers**
- ***Distributable***
  - **Load-able or embedded firmware FBs in smart field devices**
  - **Identical behavior of FBs in both local and distributed applications**
  - **Event-driven and/or cyclic transmission of data flow + events**
  - **Event-driven and/or cyclic FB execution**
  - **Explicit (user defined) and/or implicit (system defined) communication**

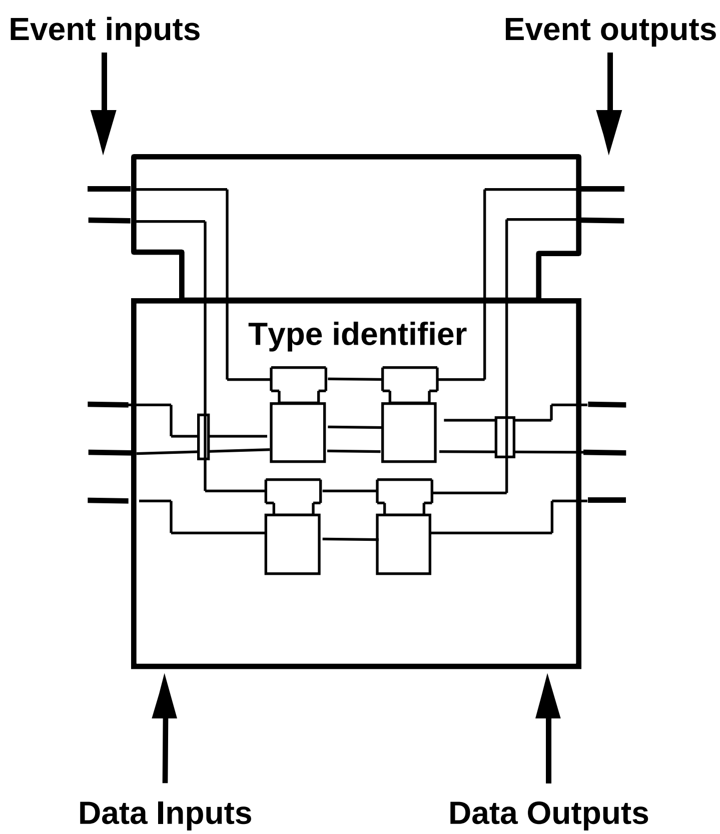
A Composite Function Block

- Functional composition
- Reusable
- Atomic (not distributable)



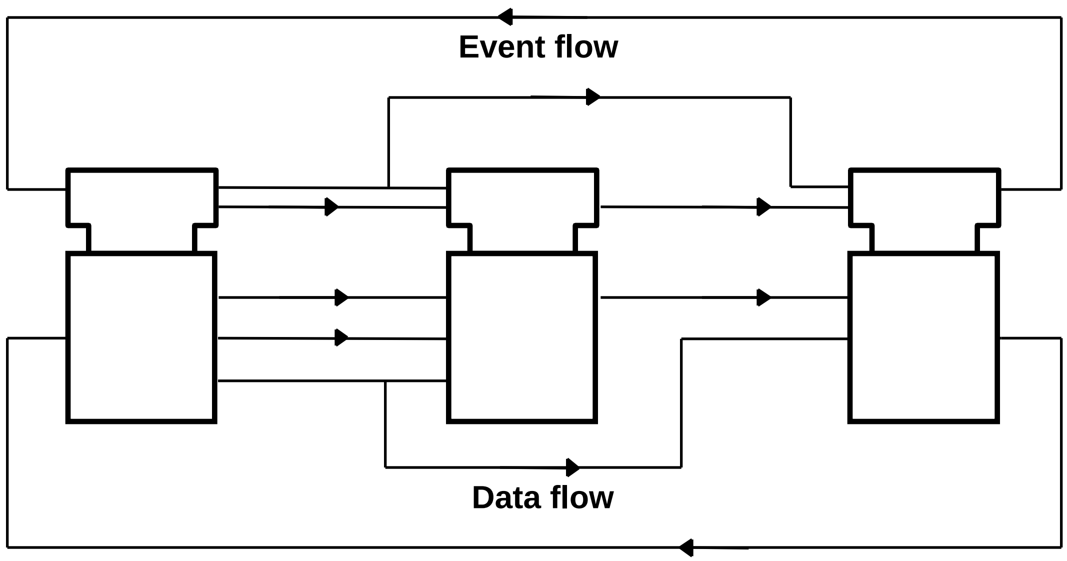
A Sub-application

- **Reusable**
- **Distribute-able**
- **Composed of Composite FBs and Basic FBs**

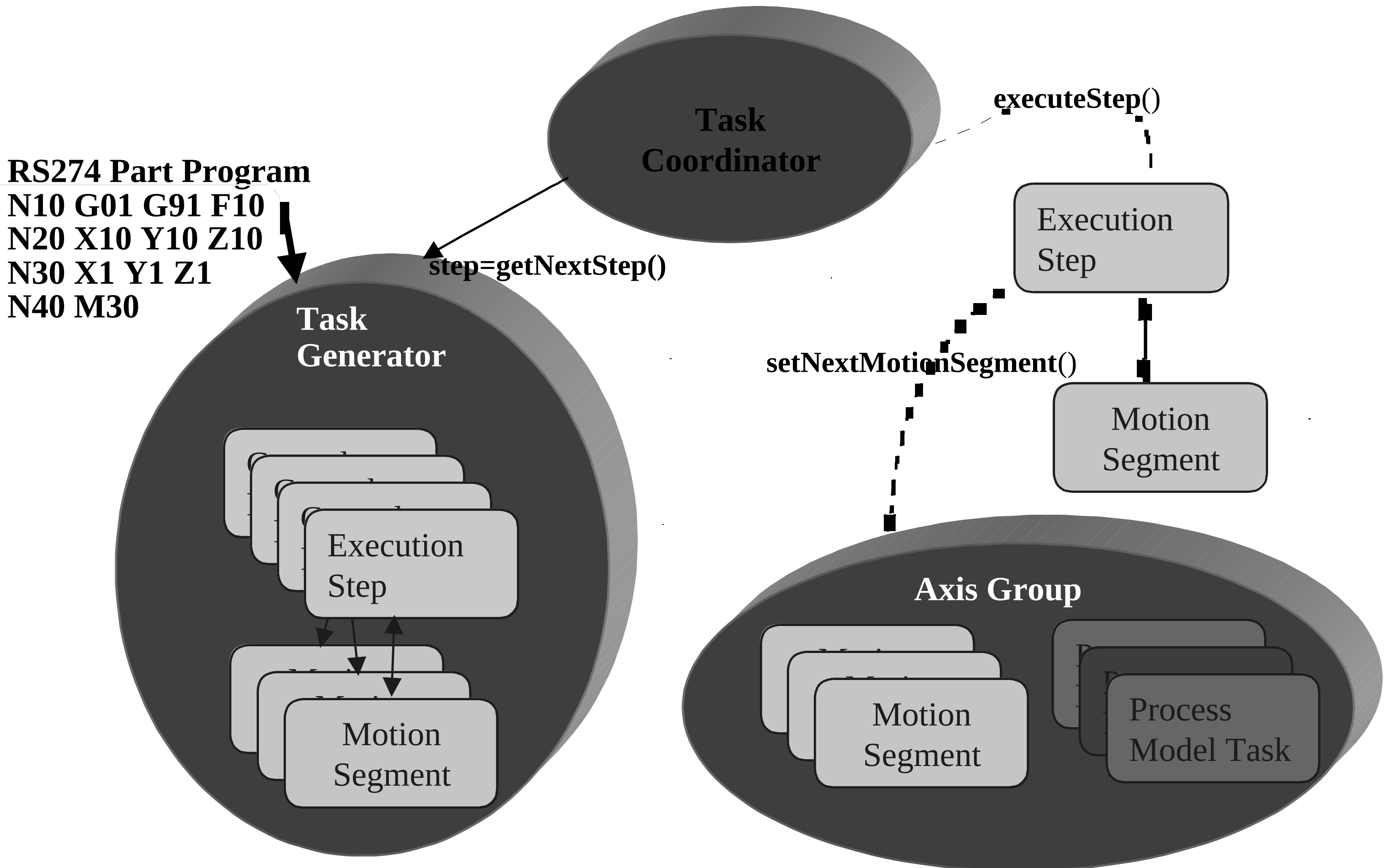


IEC 61499 Application

- Distribute-able among multiple devices
- Data and event flows
- Composed of sub-applications, composite FBs, basic FBs



Overview of System Control Flow



FSM

FSM

TASK

Program

RS274

StepNC

IEC1131

......

Routines

Execution Step

Device

2Position Device

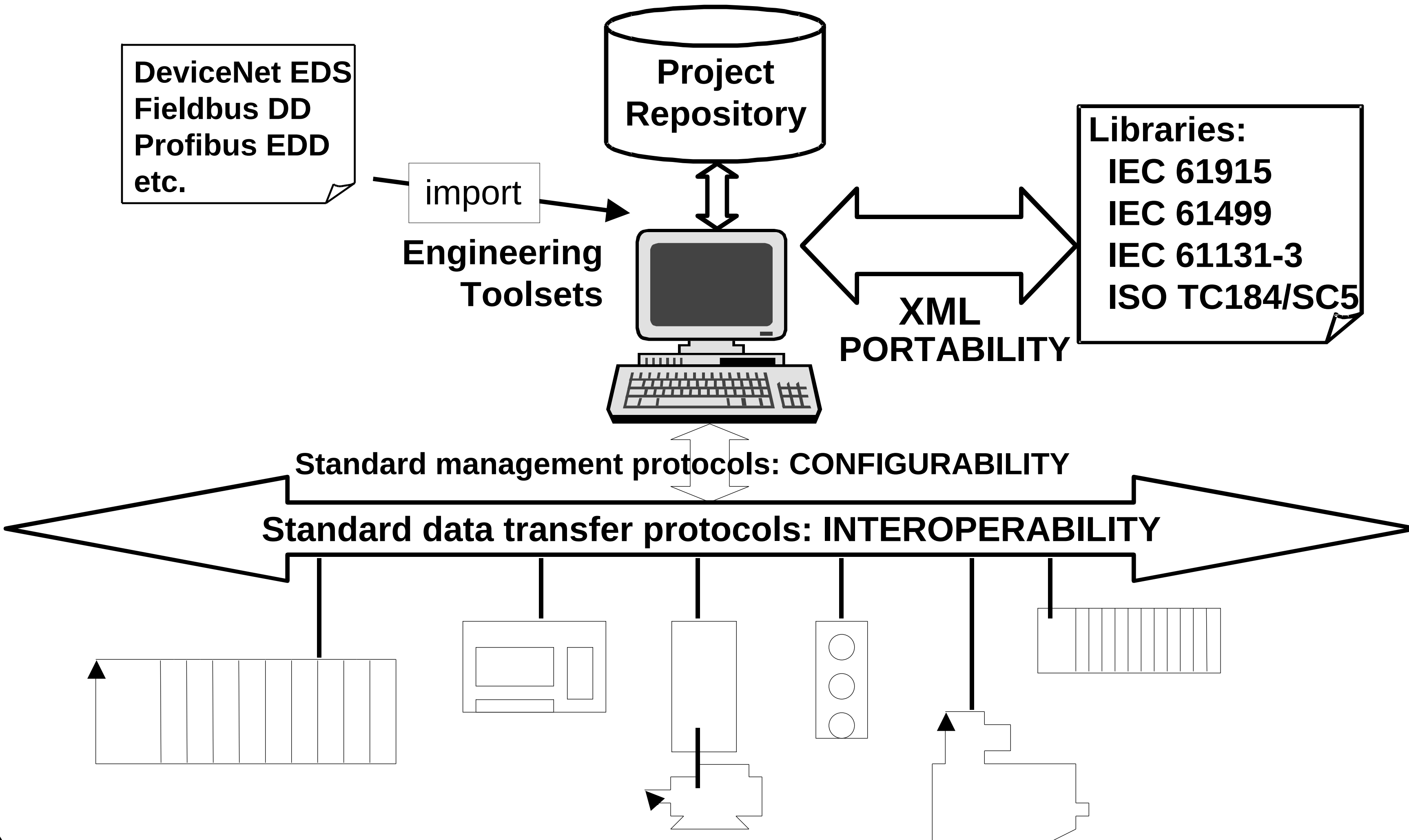
.....

Outline of IEC 61499- Part 1: Architecture

1. **General Requirements**
2. **Function Blocks & Sub-applications**
3. **Service Interface Function Blocks**
4. **Configuration**
5. **Compliance**

- **Annexes**
  - **A. Event Function Blocks** (normative)
  - **B. Textual Syntax** (normative)
  - **C. Object Models**
  - **D. Relationship to IEC 61131-3**
  - **E. Common Elements** (normative)
    - » **Identifiers, Literals, Data Types, Variables**
  - **F. Information Exchange**
  - **G. Device and Resource Management**
  - **H. Textual Specifications**
  - **I. Implementation Considerations**
  - **J. Attributes**

The IEC 61499 Vision: Open Distributed IPMCSs



Distributed intelligent devices & controllers

Current status

- Part 1 "Architecture" - FDIS 2000
- Part 2 "Engineering support" (Tool requirements) - CD 2000
- New Part 3, Technical Report: Application Guidelines - under development
- Technology maturation needs trial applications
- ITAs (Industry Technical Agreements) needed for software PORTABILITY, device CONFIGURABILITY & INTEROPERABILITY

Portability using XML

Java/XML prototype demonstration → System

DTD	LibraryElement
DataType	DataTypeDeclaration
FBType	FBTypeDeclaration
SubapplicationType	SubapplicationTypeDeclaration
AdapterType	AdapterTypeDeclaration
ResourceType	ResourceTypeDeclaration
DeviceType	DeviceTypeDeclaration
System	SystemConfiguration

XML = eXtensible Markup Language - see http://www.ibm.com/xml/
DTD - XML Document Type Definition

IEC Project 61499
Key URLS

- **Home Page**
  - **ftp://ftp.cle.ab.com/stds/iec/sc65bwg7tf3/html/news.htm**
- **IEC TC65/WG6 Roster**
  - **ftp://ftp.cle.ab.com/stds/iec/sc65bwg7tf3/html/wg6.htm**

Section Ten

Open Network Standard for Robotics (OriN)

William DeCamp,
Directory of Marketing

Motoman, Inc.

Open Network Standard for Robots

Open Architecture Control Workshop

Orlando, Florida

February 10, 2000

Benefits of Open Robot Network

- User Perspective
  - Enables networked multi-vendor robot environment
  - Reduces implementation cost
  - Improves accessibility to robot data
  - Simplifies training and operation w/ common HMI
- Vendor Perspective
  - Provides unified specification for communication
  - Enables vendors to maintain technical differentiation

Open Robot Interface Network (ORiN)

- Objective: To develop a proposed standard for a common Application Program Interface (API) for robots.
- Formed: April 1997
- Industrial Robot Standardization Committee in JARA.
- Working Group: WG4

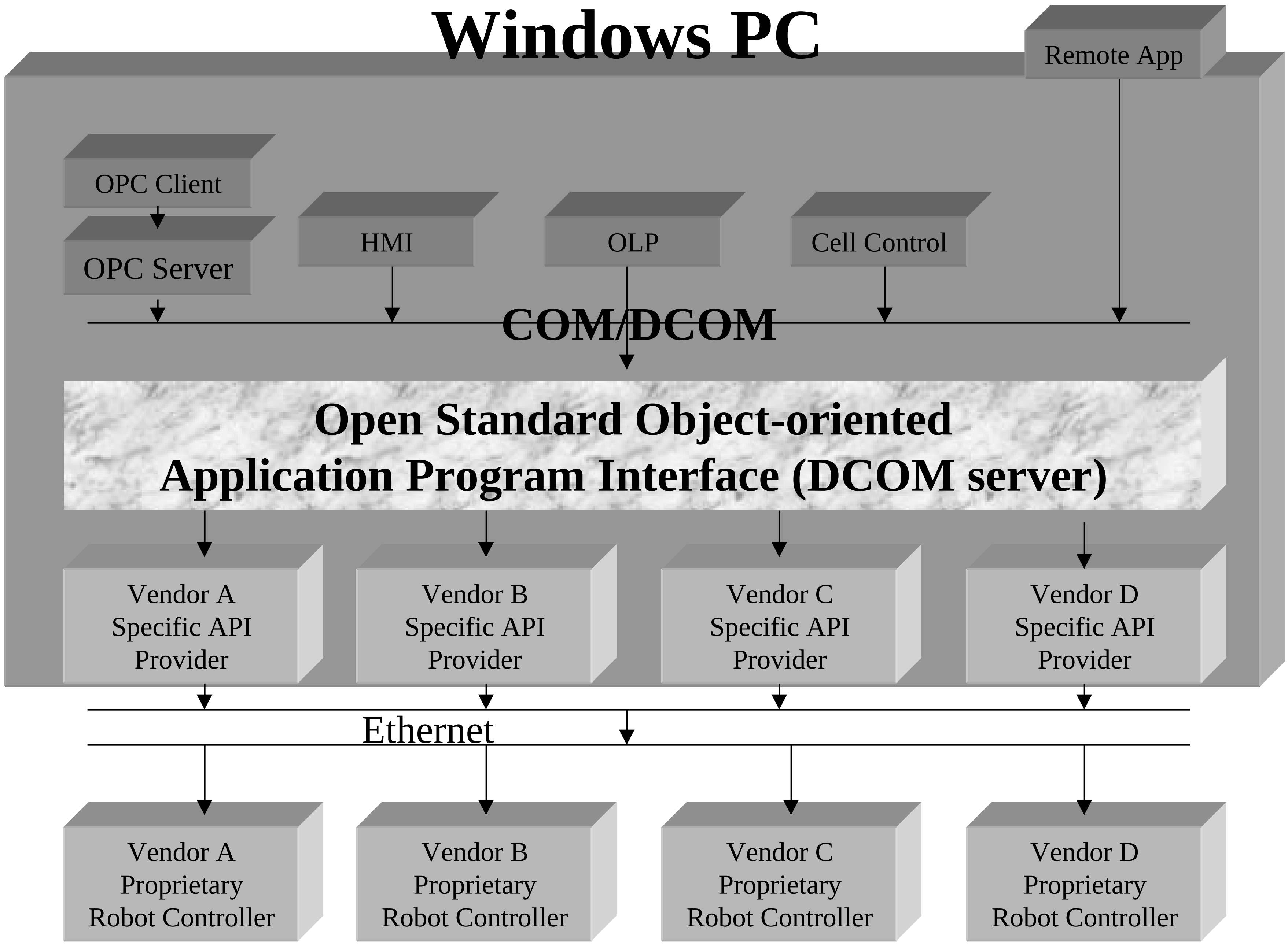
Working Group: WG4

- Yaskawa/Motoman
- Fanuc
- Kawasaki
- Denso
- Mitsubishi
- Matsushita
- Kobe
- Seiko
- Toshiba
- Toyoda
- Nachi

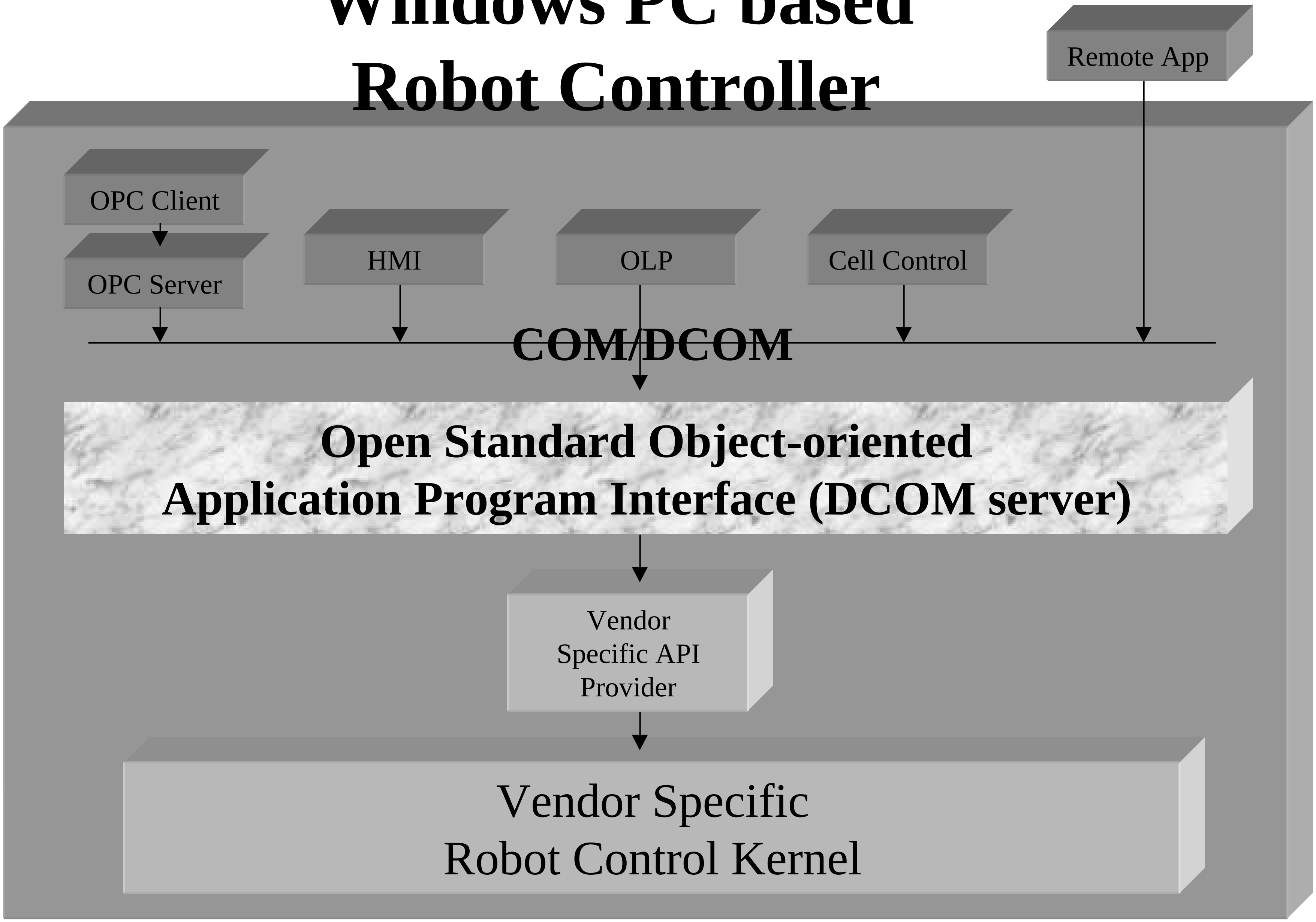
Participating in 1999 International Robot Exhibition Only

API Design Goals

- Adoption of de-facto standards-use existing standard technology.
- Object oriented design-distributed object robot model for network transparency.
- Flexible/Expandable-allows for manufacturer dependant options.
- Network independent- allows for varying networks including RS232 and Ethernet.
- Language independence-multiple language support (XML, Java, VB, C++, etc)


Windows PC
Remote App
OPC Client
OPC Server
HMI
OLP
Cell Control
COM/DCOM
Open Standard Object-oriented
Application Program Interface (DCOM server)
Vendor A Specific API Provider
Vendor B Specific API Provider
Vendor C Specific API Provider
Vendor D Specific API Provider
Ethernet
Vendor A Proprietary Robot Controller
Vendor B Proprietary Robot Controller
Vendor C Proprietary Robot Controller
Vendor D Proprietary Robot Controller

Windows PC based Robot Controller



Applications

- Production Monitoring/Control
- Robot Motion Monitor
- Robot Maintenance/Troubleshooting
- User File/Program Management
- Robot System Program Management

Recommendations

- Organize RIA/NIST sponsored open network robot work group.
- Develop RIA/ANSI industry standard robot API.
- Work with other open standardization groups to promote standard.
- It’s a logical place to start.

Charter for Breakout Groups

The breakout groups have been set up to facilitate more detailed and interactive discussions of topics of interest. At the conclusion of the breakout group, each group will present a summary of their discussions and requests for future actions.

A guideline for breakout discussions follows. Each group can follow this guideline or their own, whichever will lead to the most worthwhile output.

1. Viewpoints and Topics:
   - Are there any other groups whose viewpoints we should consider?
   - Did any topic get left out?

2. Contentious issues:
   - Were any resolved in the breakout group?
   - Which fall within the scope of the membership and should be addressed in the future?
   - What is the priority of their resolution?

3. Making sense of the standards landscape:
   - What can we do about profusion of standards?
   - Which types (e.g., software, device networks, languages, HMI) are the most important?
   - Have any already emerged as the dominant standards for this group?

4. Future activities, including: workshops, standards, guidelines, surveys and evaluations, publications, coordination with other groups, sponsoring research.

5. Specific action items not covered previously.

Breakout Session A

February 10, 2000 afternoon
Summary of discussion, following the checklist given by Fred Proctor

Are there any other groups whose viewpoints we should consider?[1]

1. **OPC**:
   - WG for Data Access level 3; (interface to exchange nested data structures; roadmap to extend it to handle I/O, commands, and objects such as IEC 61499 function blocks). Example: Program upload, download, compare
   - WG for XML as the language for data exchange.
2. Microsoft **DNA** group: Expect radical redesign of COM using XML later this year. Track it. Participate in it.
3. Microsoft **CE** group
4. **I2O**: next generation high performance I/O architecture
5. **RRS**: realistic robot simulation (Europe); intended to expand their work to PLCs, but no current activity.
6. PLCs should be part of the discussion
7. **Java**: industrial applications, JCP? (John Evans, NIST: Please track it down and connect RIA to it to the extent you find it relevant).
8. **Linux** world. Can inter-operate with all W2K standards
9. Track **real-time Java**; NIST is coordinating it. MS is reinforcing it now!
10. **IAONA**: Industrial Automation Network Architecture (European) www.iaona.org
11. **OSACA**: They have a style guide for HMIs that should be useful for robots too.
12. **ISO TC 184**:
    - 12.1. SC5 is addressing standardization of application integration frameworks.
    - 12.2. SC4 has done extensive work (STEP) in modeling space, geometry, shapes and paths that robots must follow. Follow their STE_ML initiative, which explores XML as the language for data exchange.
    - 12.3. There are other SCs (subcommittees) chartered to standardize languages for robots, numerical control machines, coordinate measurement machines, and other manufacturing devices (PLCs). The robotic industry open architecture effort is an opportunity to unify, harmonize, and facilitate efficient integration of various types of manufacturing automation and reduce effort and training costs to create and maintain various types of programs.
13. Under **IEC 65, IEC 17B** has defined device models/descriptions.

Did any topic get left out?

1. Human understandable/readable user/process application **programming languages** for robots. Whereas a collection of interfaces for modules in a cell or robotic machine serve as a language of discourse between computerized systems, subsystems or

[1] Does not list activities already presented in this workshop, e.g., ORIN, OMAC, IEC 61499. However, RIA should also track these activities and leverage and coordinated with them.

modules, how do they relate to the command language used by the human operator or similar user performing manual programming?

- Pertinent remarks from Rutledge: In the 80's, everyone thought the solution was to come up with a computer type programming language. And so were born KAREL, RAIL, VAL, and ARLA; derivatives of various computer languages with adaptations for robot control. While this was interesting to the engineers who designed robot cells, the people on the floor who actually made the robots work hated it. The real issue is that the general robot user does not want to program at all…. Process knowledge from databases containing the relationship of materials and process variables hold the potential of making the average operator perform at a significantly higher level.

2. Standardize **terminology/nomenclature** for robots and their components/modules, e.g., axis nomenclature.
3. Standardize **teach pendants**: Make them configurable. Use same color scheme? (Red vs yellow E-Stop). Refer to OSACA HMI Style Guide.
4. Survey the state of the art in **motion control cards for PC**.

Business aspects – controversies and uncertainties

Lower the cost of automation through reduction of duplicated efforts and use of common environments. Categorize software areas, so businesses can thrive. Standardization of interfaces made people creative in the electronics industry and expanded the market and opportunities to profit. Market grows when the cost drops. Concerns:

1.1. If it goes too far, businesses can lose opportunity to innovate, differentiate and profit.
1.2. How would this approach satisfy differing needs in different industries? Example: Menu driven programming vs. teach-pendant programming.
1.3. Would emerging public standards put companies out of business?
1.4. Three suppliers felt that opportunities will be created.

2. Perhaps, standardization (of interfaces) could get a head start with suppliers contributing their internally developed ideas.
3. Why are PCs considered open when they use proprietary technology? Answer: "Open" does not mean "non-proprietary". Standardization of interfaces still leaves opportunities for innovation, differentiation, and competition in the implementation of conforming modules.
   3.1. Issue: MS/COM is a proprietary standard - COM is published, but not stable. Answers:
      3.1.1. OMAC API is COM independent Defined in IDL and UML models. Language independent.
      3.1.2. Keeping these discussions MS independent will make them too theoretical. Practical choice.

4. Myth: PC based does not mean that it will be cheaper in the first cost. Savings are realized only later. However, many companies just look at initial purchase cost, not lifecycle costs.
5. How long will this standardization take?
6. Business case for robot companies needs to be made.

ORIN (Motoman) Proposal review comments

Group A agreements on the following principles and objectives:

- Adoption of existing and emerging technology, including leveraging de-facto standards.
- Object oriented (OO) specification for various distribute-able objects, e.g., robots and other resources, recipes, etc. An OO spec is extensible, allowing need-specific and supplier-specific specialization.
- Network independence
- Language independence.

Issue: If the "blue box" (front-end serving HMIs, etc) is a PC, there would be real-time issues!! How would these be addressed?

Conclusion of ORIN review: Evaluate OMAC APIs (to be released 2/29/00)

Review approach:

- Is the foundation sound?
- Can we build on it?
- Does it meet the needs?
- If not, give specific feedback!
- Is this addressing the needs of the semiconductor industry?
- Goal:
- Evolve OMAC API to be useful to RIA. Not hung up on a specific proposal.
- Build consensus
- Commonality across different types of manufacturing devices would reduce learning curve in the user plants.

Clifton Triplett's proposal

1. RIA should give a response by May 2000 to the proposal for Wave 1 (Why duplicate? Leverage mainstream technologies)
    - Network architecture
    - Protocols
    - Languages

    Clarify at what level and for what info interchange these are intended.
2. To create the proposed win/win momentum, RIA members have to put in effort.
3. Comments on XML for data representation: Good direction to track
4. Development: Java/GNU (www.gnu.org): ran out of time.

    Issue: Retraining people.

Priorities

(Sushil Birla added these items sent to Steve Holland by Gary J. Rutledge, Vice President Advanced Product Development, FANUC Robotics NA Inc., Rochester Hills, Michigan 48309)

Standards for Robot Peripheral Equipment communication on Internet protocols
The expanding use of Ethernet and Internet protocols by factory floor process equipment would be well served by the development of **standards for the interchange of setup and configuration information**.
(Addition by Sushil: See OMAC APIs pertaining to setup and configuration).

Standards for the interchange of path data
Interchangeable path data would simplify benchmarking among robot vendors and simplify transfer of information from simulation systems.
(Addition by Sushil: See OMAC APIs pertaining to path data aligned with STEP models).

Standards for graphical user interface (style guide)
The Europeans have been working on a style guide (ISO/DIS 15187) for icons and presentation to commonize industrial GUI without restricting the manufacturer from implementing new functionality. Perhaps such an initiative would help us.
(Addition by Sushil: See OSACA style guide).

Other comments from Rutledge communique to Holland

- A missing element for broader opening of the environment is the lack of provably safe and bug-free software. Robot manufacturers are keenly aware of the requirement for safe operation. Unless some mechanism exists to prove that software will perform reliably and not impact other running programs, integration of third party software at the real-time level will be limited. **Provably robust software that is contained in a structure for re-usability** would significantly open the robot environment to grow utilizing a wider spectrum of software sources.

- The connection of devices from different manufacturers can consume up to 30 - 40% of the engineering necessary to build an integrated system. This is usually for the real-time coordination of the process such as the robot's communication with a welding power supply.

Breakout Session B

We discussed a wide range of topics. Comments and recommendations from the group:

1. It was recommended that we harmonize with Europe and Japan.
2. Standards tend to stifle innovation.
3. Regarding interfaces: to simplify integration, put differences in software, not hardware.
4. Standards are moving targets. It would be useful for someone (NIST) to have a web site with pointers.
5. We need a forum for prioritizing and setting de facto solutions.
6. The move from sequential procedural languages to the distributed object-oriented paradigm implies that maintenance is a problem (new skill set).
7. Simulation is huge problem.
8. Standards should be adopted for a larger domain than robotics.
9. Regarding the process:
   - should RIA be involved? Who else?
   - robotics is a multi-segment market (e.g., safety issues are different for small robots and large robots)
   - need room for growth
   - workshops are OK, standards are not
   - education is needed
   - systems viewpoint needed
10. Different Fieldbuses have different niches.
11. Systems integration is a problem. There are many layers, like the onion; which layers should be agreed upon?
12. Trying to get global agreement compounds the systems integration problem.
13. What levels of openness are we after?
    - total? phased? single layer?
    - communication
    - HMI
    - high-level
14. Security is very important.
15. Reliability is very important, e.g., MTBF. Systems should withstand the “fork lift test.”
16. There needs to be an HMI for non-technical operators.
17. An API is needed at some point.
18. Component/system providers will take business from “name plate” vendors if they are more open.
19. The needs of users are not all the same, e.g., HP ≠ GM.
20. Simplicity of all aspects of an open system is important.
21. Manufacturing equipment has a long lifetime. Standards must last as long.
22. Compatibility (forward/backward) is important.
23. Different markets ⇔ different requirements ⇔ different ideas of openness

24. There are several different standards worlds. For example, heavy arms aren't used in assembly markets.
25. What should be done, and by when? Too soon may mean pain for many participants.
26. The place to start: LAN/WAN media & protocols, e.g., XML, TCP/IP, etc.
27. What is needed are resources describing current standards, pointers to more information, and how to find out more. Could be a web site.

From Clif Triplett's presentation, we discussed Wave 1:
Networking: media, e.g., single/multimode fiber, CAT5/6 wiring, TCP/IP protocol (Ethernet 10 Base T/100 Base T)
Information presentation: access via standard Internet browser, using XML
Time synchronization, using NTP
Network management, using SNMP and MIB II

We need goals/missions/the big picture!

Recommendations:

1. Determine Goals, Mission, and Where are we going.

2. Gather and disseminate information:
   LAN standards (media & protocols)
   Open Architecture Survey

3. Establish web site. This can be used for information dissemination and to enable dialog.

4. Get Started: We need some initial guidelines:
   Networking media, e.g., CAT-6, fiber
   Networking protocol, e.g., Ethernet, TCP/IP
   Presentation, e.g., Internet browser, XML
   Time synchronization, e.g., NTP
   Network management, e.g., SNMP
   Consider meeting in conjunction with Robots 2000 Conference (6/13-14/00)

5. Participate in November 2000 RIA Forum.

Breakout Session C

First, we grouped topics into 3 areas: simple things that can be dealt with quickly; difficult things that should be done but will take time; and things outside our purview, or already done. This division served to prioritize the following discussion.

We discussed openness, and vendors voiced the opinion that what users should do is state what they need, and vendors should decide how to achieve it. Vendors are concerned about safety and reliability.

If the interface to the robot controller was comprehensive enough, it would allow third parties and users to accomplish all they want, yet leave internals up to vendors so they could qualify and ship reliable systems.

Users stated that integration costs are too high but uptime is of paramount importance. We noted that it may be the case that poor integration is the source of downtime, so improving integration could serve two purposes: reducing integration costs and increasing reliability.

COTS leveraging was agreed to be already underway, and this is something we should leave up to vendor/user market relationship.

We discussed what the “low-lying fruit” is. Some tempting picks:

OLP: eliminate teach programming. This requires calibration and metrology that could be subject of standardization.

API: a higher-hanging but bigger fruit. This gives vendors the freedom to build reliable products, since APIs don’t specify implementation details, while giving users and integrators the ability to do what they want as long at the API supports it.

Programming Language. ISO standard may have come too early. The ideal is simple point and click interface that shop floor electricians and technicians could use.

An interesting suggestion was a survey of user needs and vendor solutions. This can serve two purposes: point out possible areas for standardization or unification, and serve to better direct university proposals for NSF funding.

Action Items

At the conclusion of the breakout sessions, a representative from each group presented a summary of their discussion. The following action items were agreed to by the entire group:

1. Determine the structure of a group that can address the issues on a continuing basis, state its mission, and provide a roadmap for its work [RIA/NIST].

2. Set up a web presence, with a glossary, references, and related links [RIA/NIST].

3. Review and comment on the OMAC API specification from the perspective of the robotics industry [Everyone]. This can be found at:
   http://www.isd.mel.nist.gov/projects/omacapi/

4. Establish initial guidelines for interfacing to factory networks, including media and protocols, information presentation, time synchronization, and network management. Discussion should be part of the June Robots 2000 conference.