INDUSTRIAL AUTOMATION
- PAST, PRESENT, FUTURE

Professor Günther Schmidt

Institute of Automatic Control Engineering
Technische Universität München

INDUSTRIAL AUTOMATION
- PAST, PRESENT, FUTURE

TOPICS

- MILESTONES AND ACHIEVEMENTS OF IA
- INDUSTRIAL INFORMATION TECHNOLOGY AND AUTOMATION
- NEXT-GENERATION CHALLENGES
- CONCLUDING REMARKS

INDUSTRIAL AUTOMATION - PAST, PRESENT, FUTURE

- **MILESTONES AND ACHIEVEMENTS OF IA**

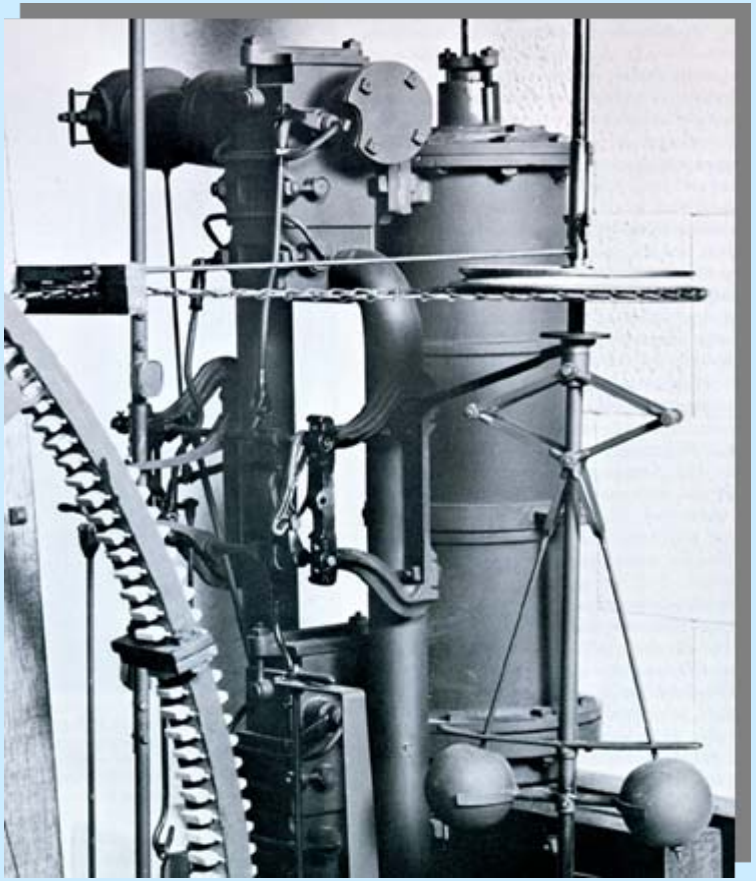
  "We can't understand the future without knowing the past"

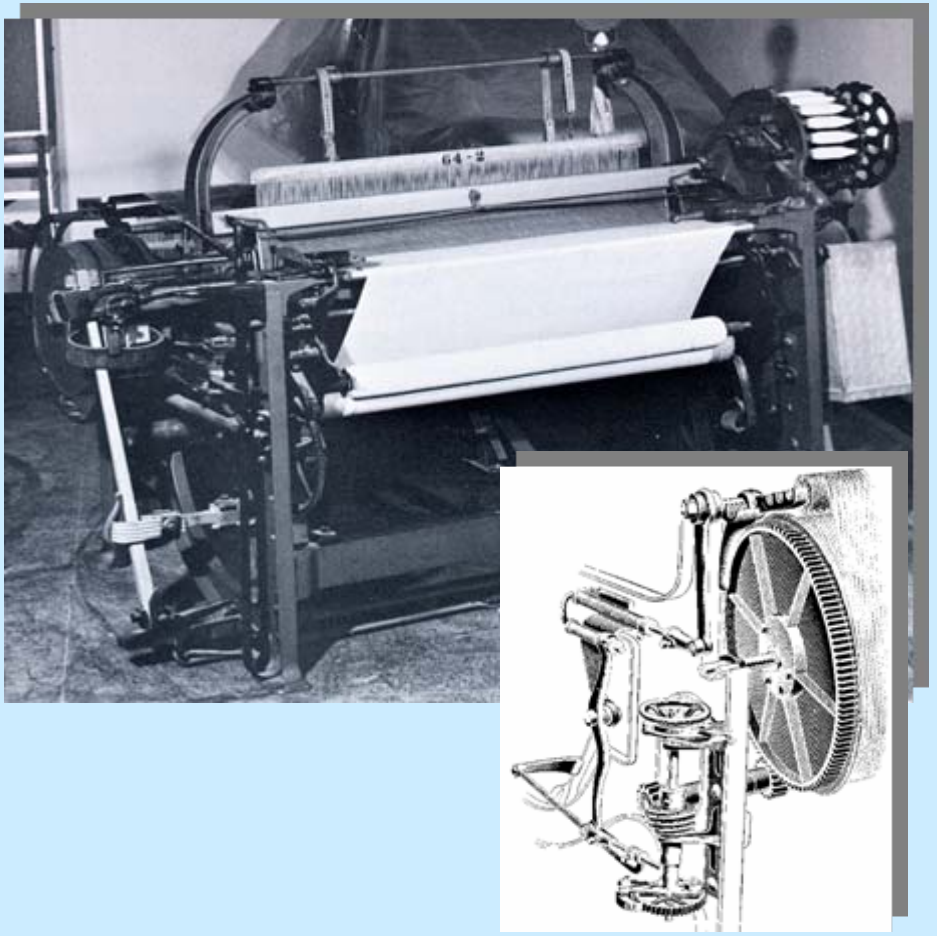
- INDUSTRIAL INFORMATION TECHNOLOGY AND AUTOMATION

- NEXT-GENERATION CHALLENGES

- CONCLUDING REMARKS

19th Century: First Automatic Machines





“Lap“ (Steam) Engine,
James Watt , 1788:
continuous control operation

Power Loom
with Bartlett Let-off Mechanism:
discontinuous control operation

…. 1950: Era of Instrumentation

Instrumentation Designs
- Electromechanical
- Pneumatic, Hydraulic
- DC-Amplifier

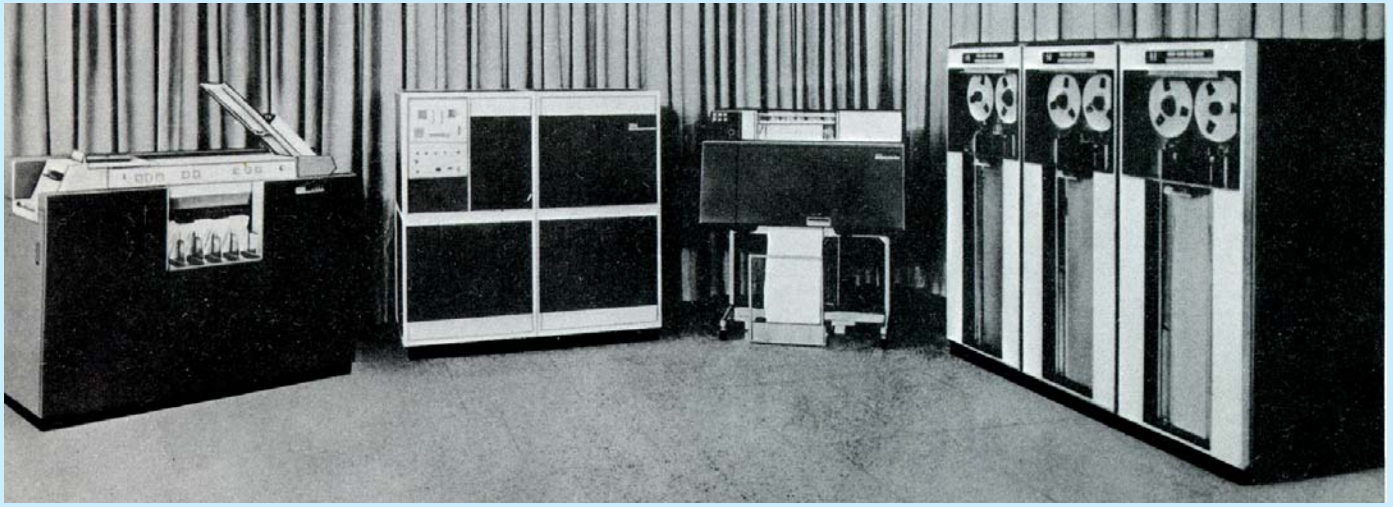
Automation Tasks
- Single Control Loops
- Monitoring and Recording
- Simple Signal Processing

Hardwired Control Functions
- Analog Signal
- Relay Logic

Automated Processes
- Steel und Automobile Industry
- Chemical Processing
- Power Generation

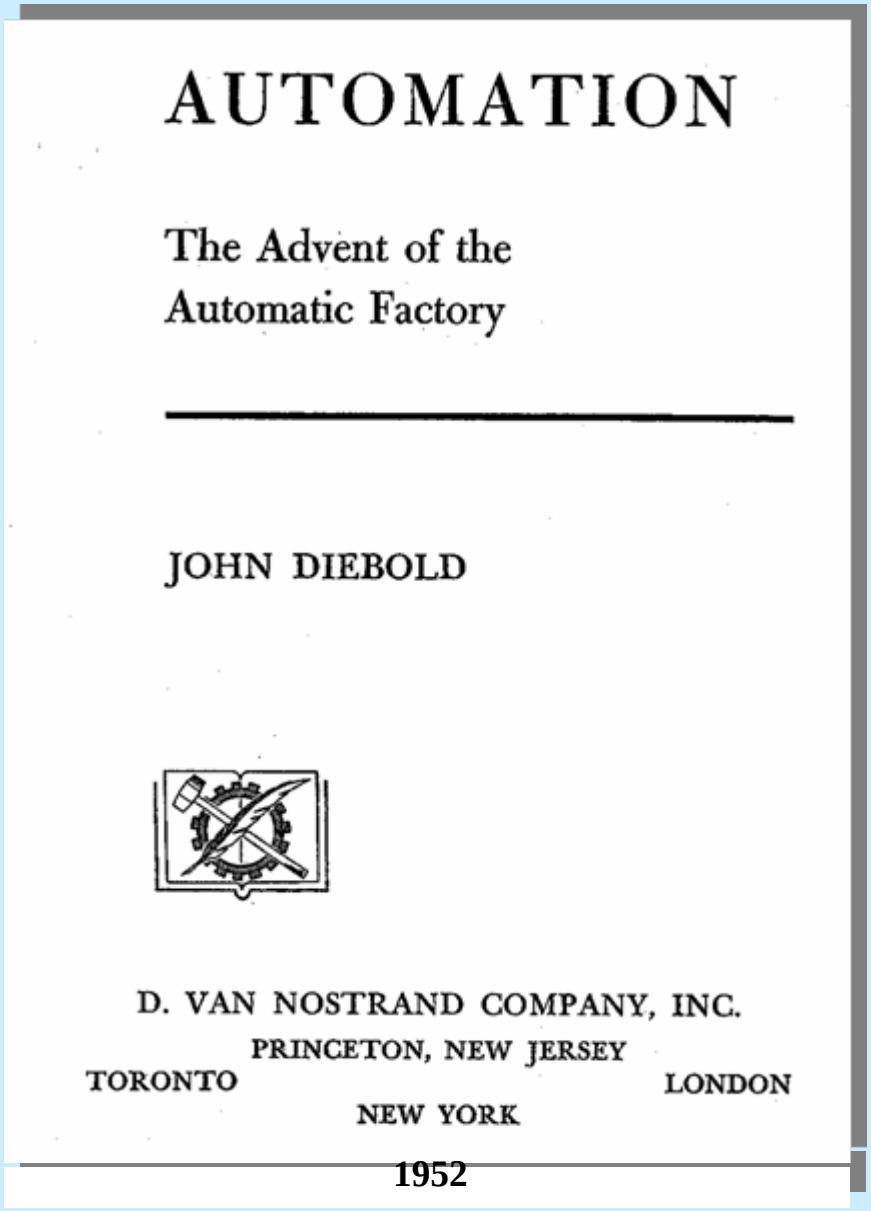
1960: Beginning of Modern Industrial Automation

First Digital **Computers** for
Real-Time Industrial Applications (IBM)



First Industrial **Robots**
(Unimate, GM)

A Remarkable Milestone



AUTOMATION

The Advent of the
Automatic Factory

JOHN DIEBOLD

D. VAN NOSTRAND COMPANY, INC.
PRINCETON, NEW JERSEY
TORONTO LONDON
NEW YORK

1952

Automation:
"Key Enabling Factor"

- Comprehensive View of IA, Discussing Technological as well as Related Business and Social Issues
- Objectives and Directions still Remain Major Driving Forces and Challenges of Current Developments

A Remarkable Milestone

AUTOMATION

The Advent of the Automatic Factory

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Contents

1980: Multi-Microcomputer Based DCS, PLC, SCADA, ...

Systems
- Decentralized Architecture
- Standard and Customized Integrated Electronic HW
- Industrial Robots

Automation Tasks
- Multivariable Control
- Sequential Control
- Coordination, Optimization
- Fault Detection

Flexible Control Software
- CFC and SFC Algorithms
- Configurable HMI
- Serial Bus Communication

Automated Factories
- Large-Scale Industrial Plants
- Manufacturing, Production
- Transportation, Distribution

List of Abbreviations

DCS	Distributed Control System
PLC	Programmable Logic Control
HMI	Human Machine Interface
SCADA	Supervisory Control and Data Acquisition
SFC	Sequential Function Chart Control
CFC	Connectionist Fuzzy Classifier
CNC	Computer Numerical Control Machine
EDI	Electronic Data Interchange
OPC	Open Interface over PC-based Software by means of
OLE	Object Linking and Embedding
PCR	Polymerase Chain Reaction
CE	Cost Effectiveness Analysis
CACSD	Computer Aided Control System Design
RFID	Radio Frequency IDentification

1990: Beginning of Information Age in IA

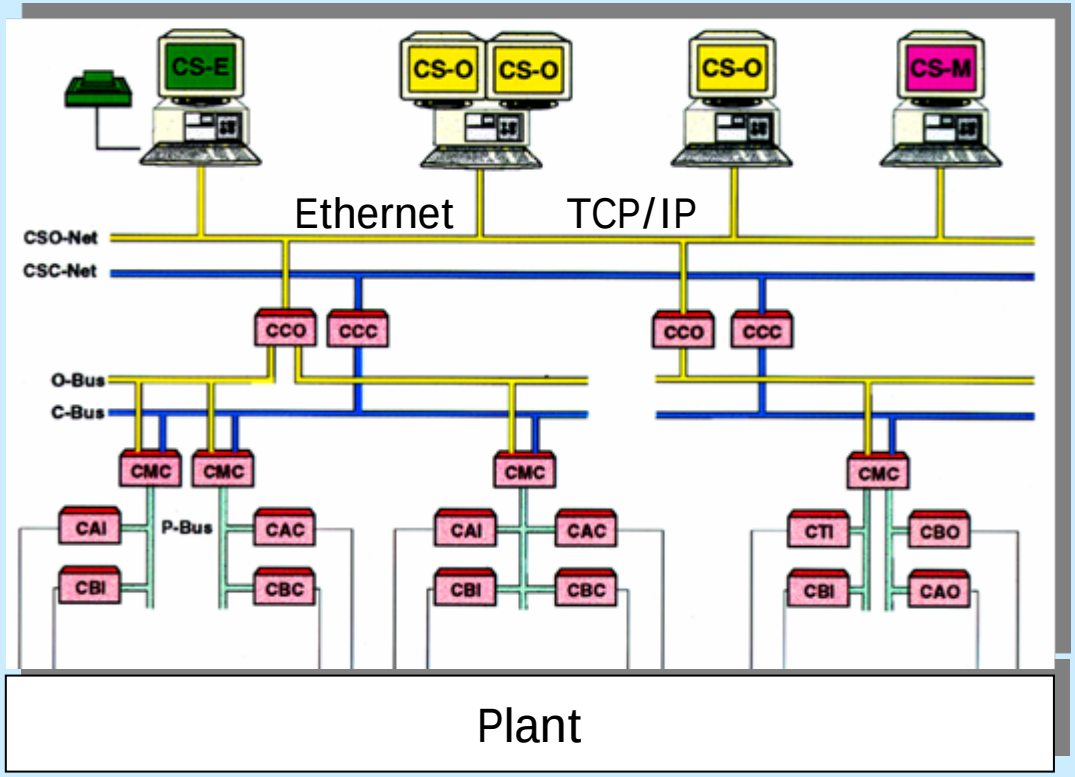
"From *Signal*-orientation to *Information*-orientation"

Industrial Automation Technology
establishes a
Plant-wide, Real-time Digital Nervous System

Operator, HMI

Data Communication

Automation, Control



Industrial Efficiency, Productivity and Safety Closely Linked to Advances in IA

Processing Industries
(Continuous)

DCS,
Motion Control

Hybrid Industries
(Continuous/Batch) + Discrete)

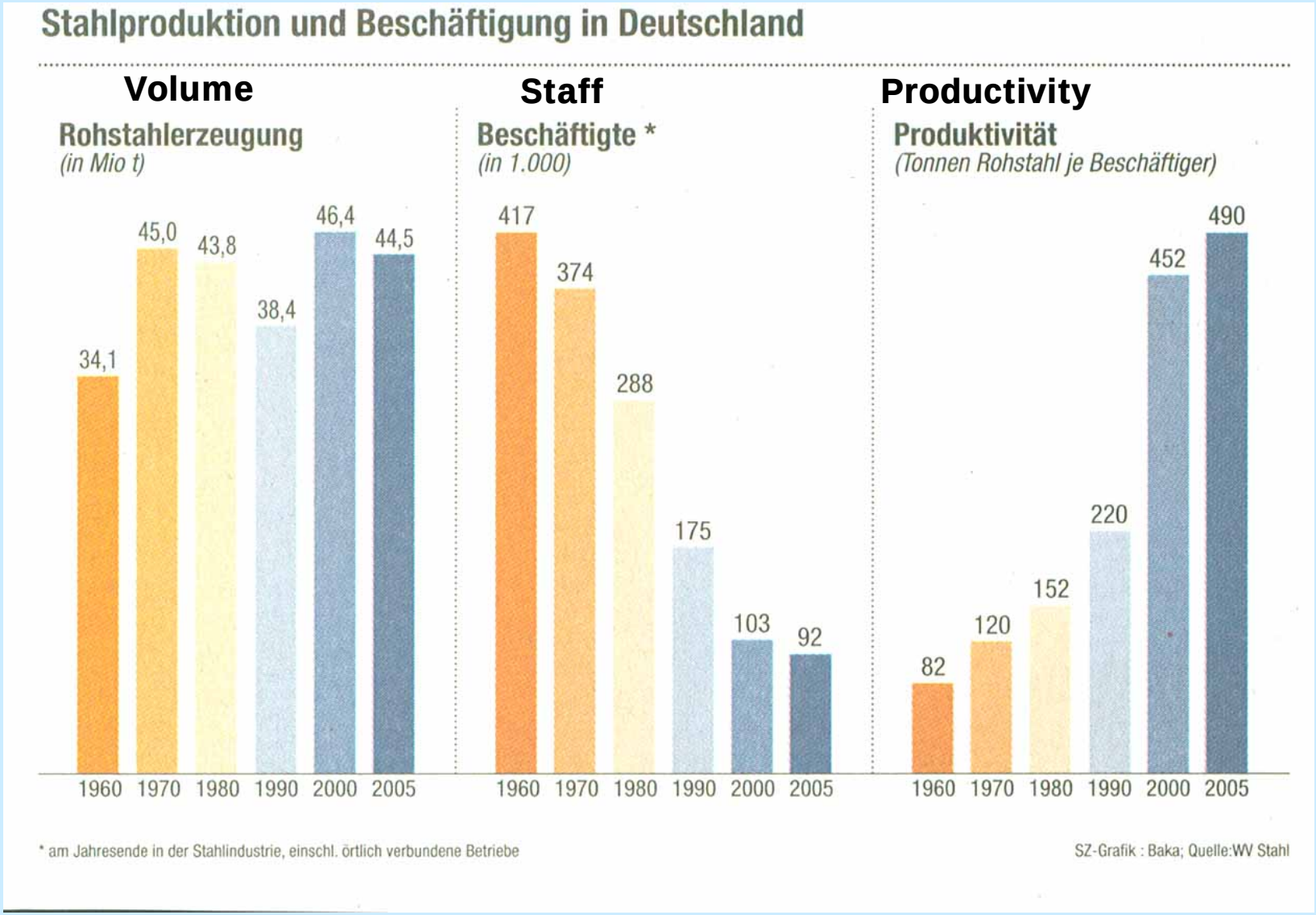
DCS + PLC,
Motion Control

Manufacturing Industries
(Discrete)

PLC, CNC,
Motion Control

IA Solutions Developed by System Integrators

Growth of Productivity in Steel Production



Major Contributions of IA in the Recent Past

- Computers, Interfaces and Related Components for Safe, Real-Time, Closed-Loop Operations in a geat Variety of Harsh Industrial Environments

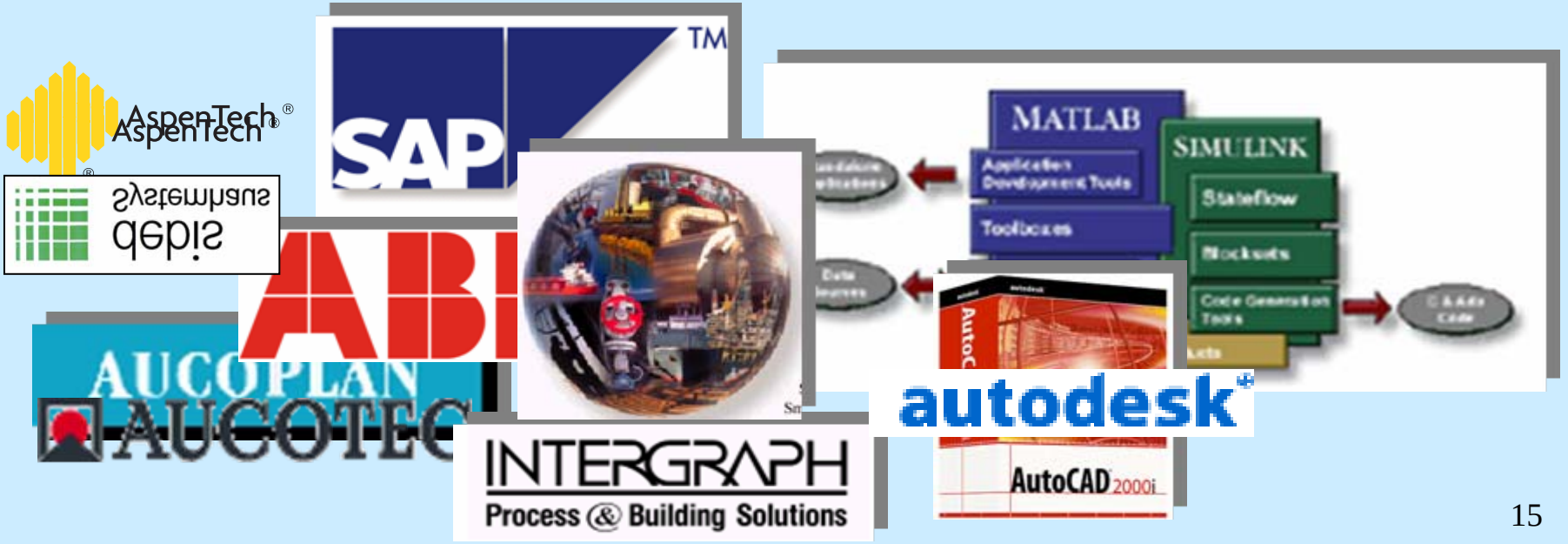
- Novel HW- and SW-Systems for Advanced Control and Color CRT-HMI Technology

- Robot Technology as Means of Flexible Automation

Major Contributions of IA (cont'd)

- Conceptual, Methodological, Theoretical Foundations for Analysis and Design of Sophisticated Automation Functions

- Modelling and Simulation Techniques and SW-Tools for CAD/CAE-Approaches in Automation



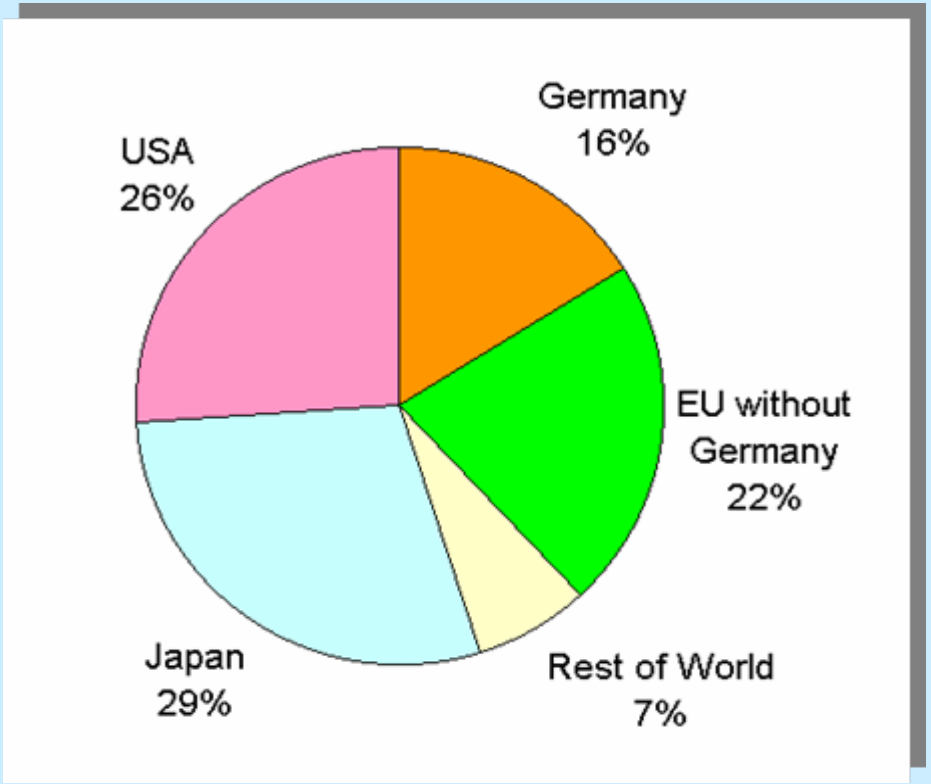
INDUSTRIAL AUTOMATION - PAST, PRESENT. FUTURE

- MILESTONES AND ACHIEVEMENTS OF IA
- **INDUSTRIAL INFORMATION TECHNOLOGY AND AUTOMATION**
- NEXT-GENERATION CHALLENGES
- CONCLUDING REMARKS

Industrial
Information Technology and Automation

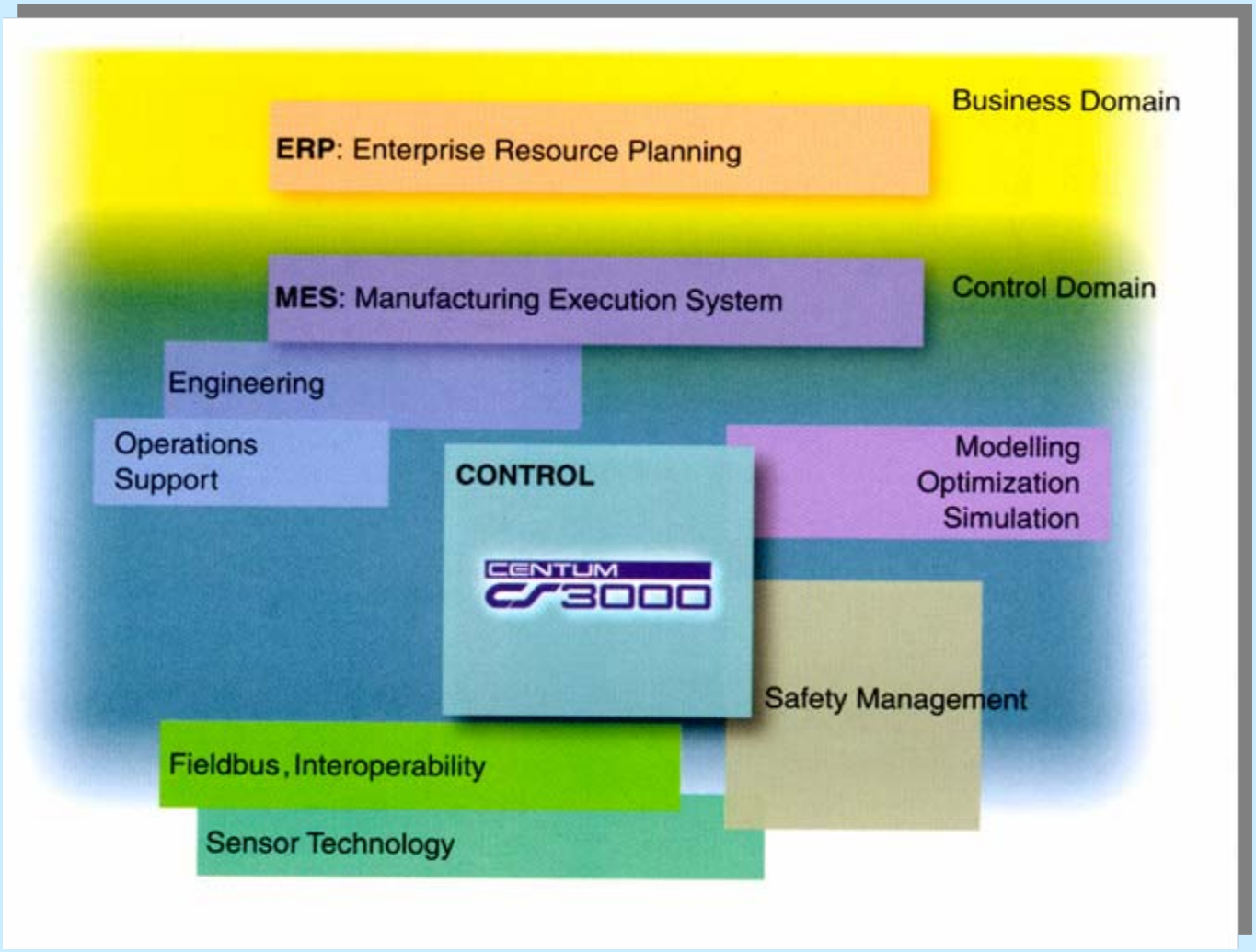
- **General Trends and Driving Forces**
- Vertical and Horizontal Integration by IT
- Open Automation System Platforms
- Impact of Innovative Technology
- New Requirements to IA from Plant-floor

Global Market Volume for IA Equipment



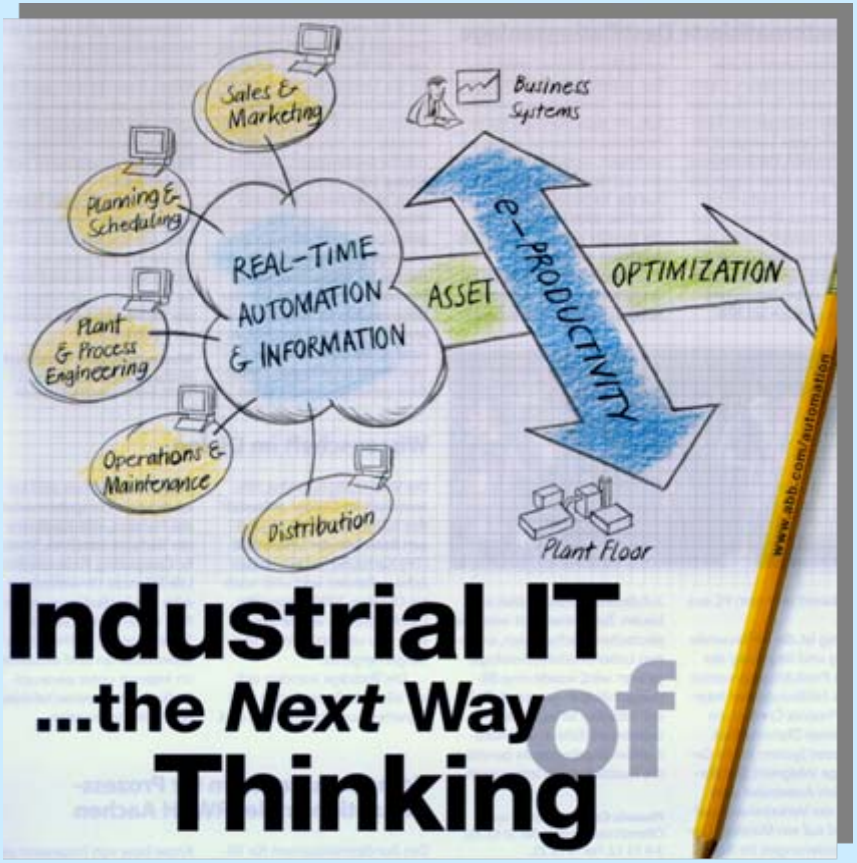
Total: 200 Billion Euro
(excluding mechanics)

Changes in IA Scope, Examples

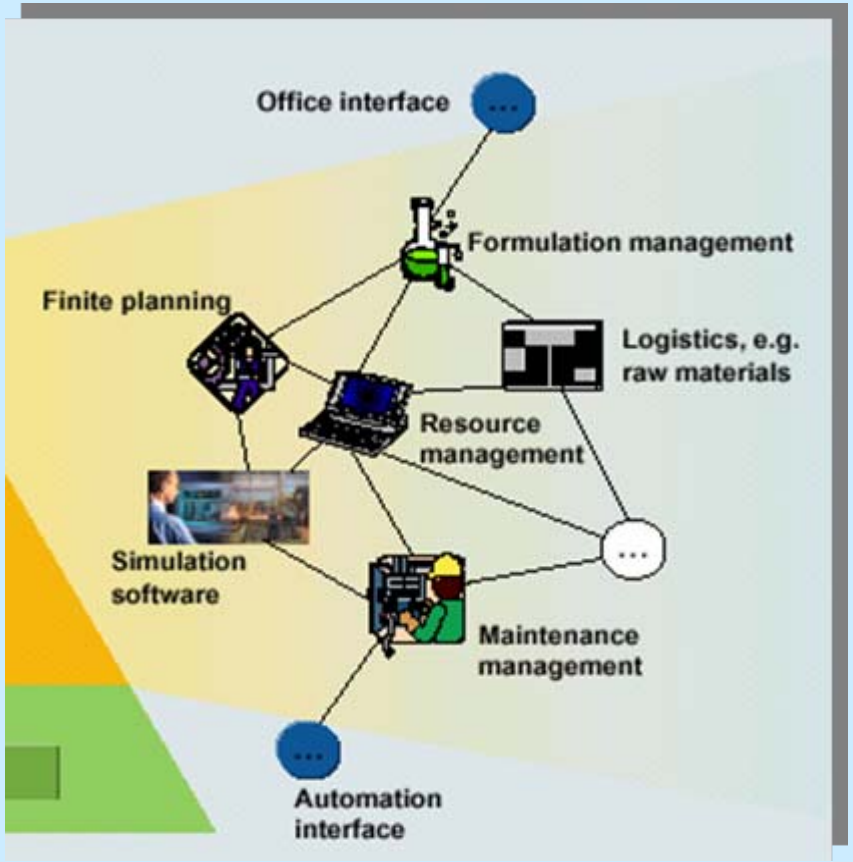


Enterprise Technology Solution, Yokogawa

Changes in IA Scope (cont'd)



Industrial IT,
ABB



Totally Integrated Automation, Siemens

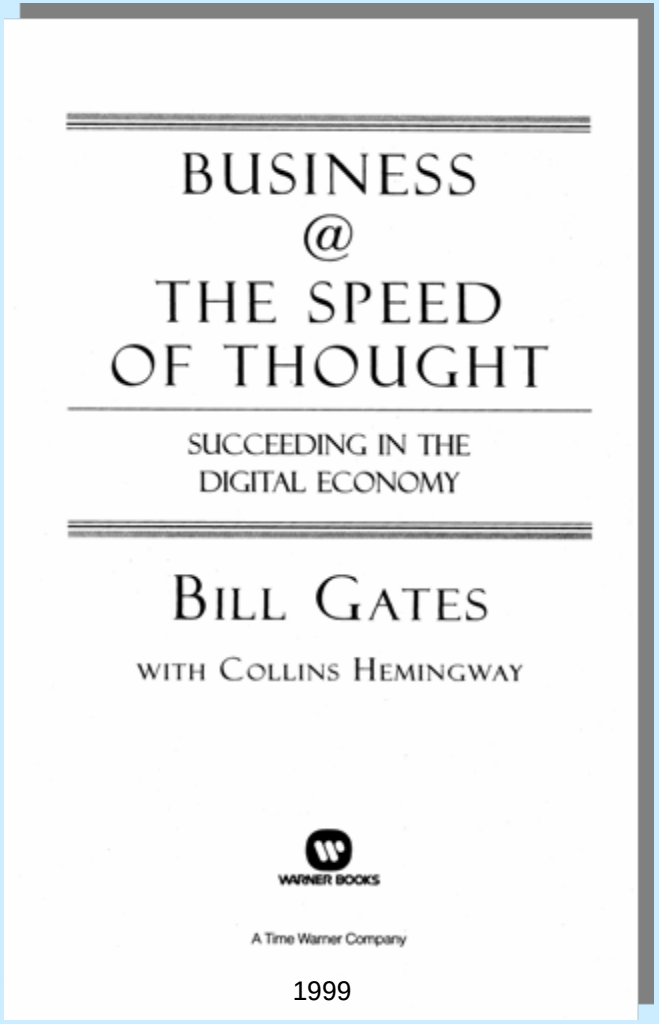
FROM *IA* TO ***INDUSTRIAL IT AND AUTOMATION***

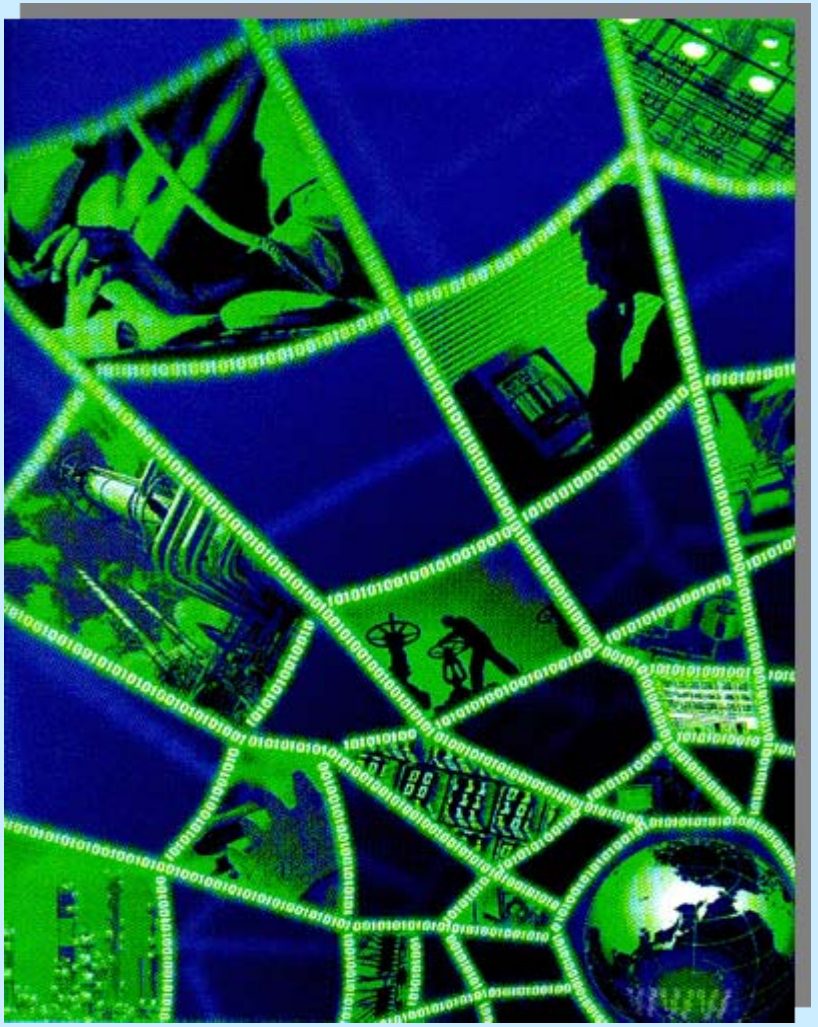
- **Familiar Topics**: Automation, Control, Sensors, …

- **New Buzzwords and Topics:**
  - ERP: Enterprise Resource Planning
  - MES: Manufacturing Execution
  - PAM: Plant Asset Management
  - LCM: Life Cycle Management
  - Supply Chain Management
  - Logistics & Services
  - E-Commerce
  - …….

PC and Web-Based Operations

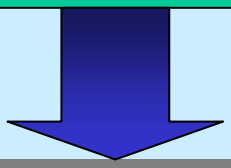
Enterprise-Wide Digital Nervous System





FROM **IA** TO
INDUSTRIAL IT AND AUTOMATION

Enterprise-Wide Information Flow
Enterprise-Wide Information Logistics



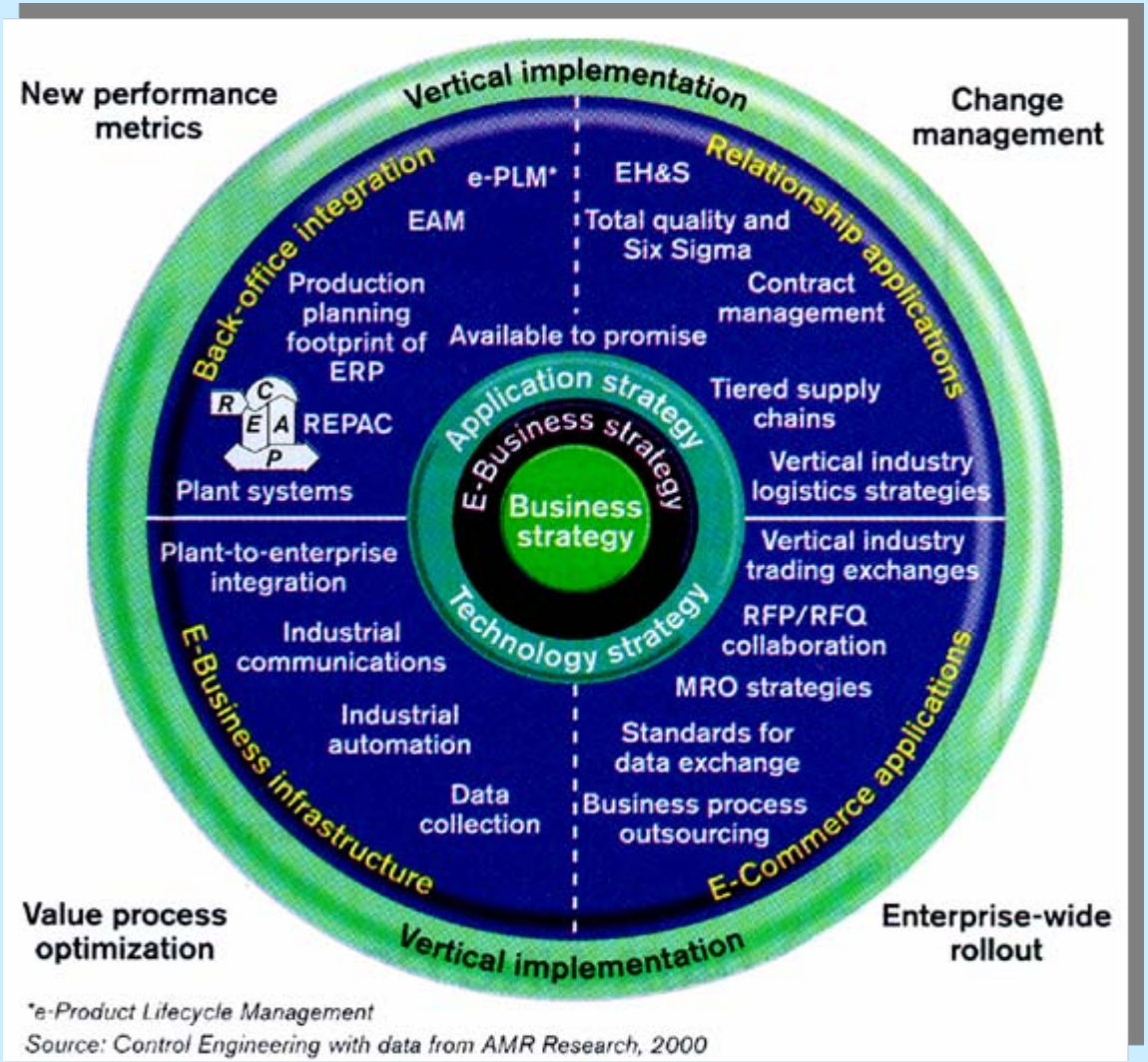
Industrial Information Technology and Automation

„… with the Goal to Integrate Automation Systems in Real-time from Pursuit of Orders via Traditional or E-Commerce Methods right through Production and Delivery of Finished Products“

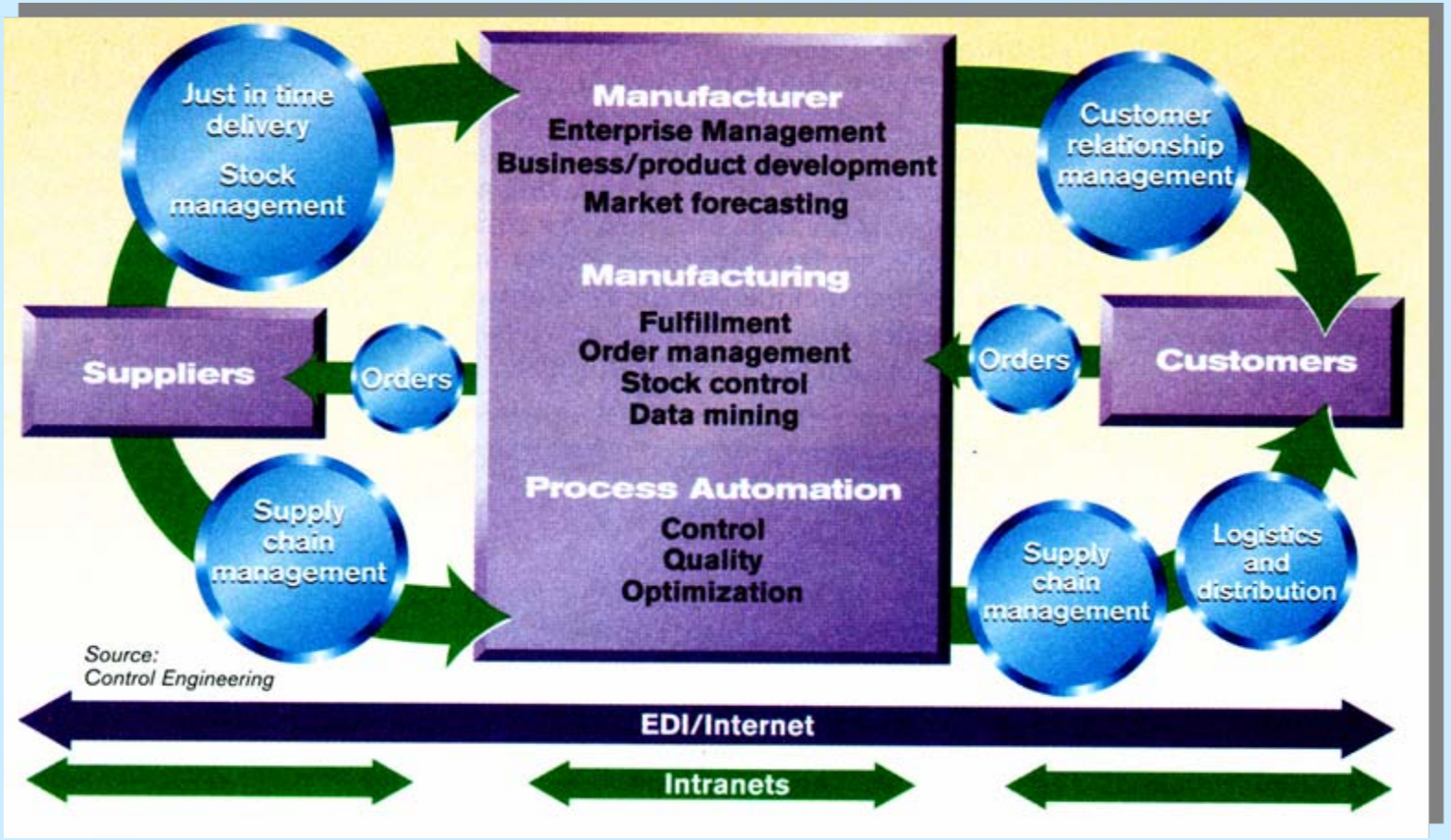
Industrial Information Technology and Automation

- General Trends and Driving Forces
- **Vertical and Horizontal Integration by IT**
- Open Automation System Platforms
- Impact of Innovative Technology
- New Requirements to IA from Plant-floor

Manufacturing Layer of an E-Business Model

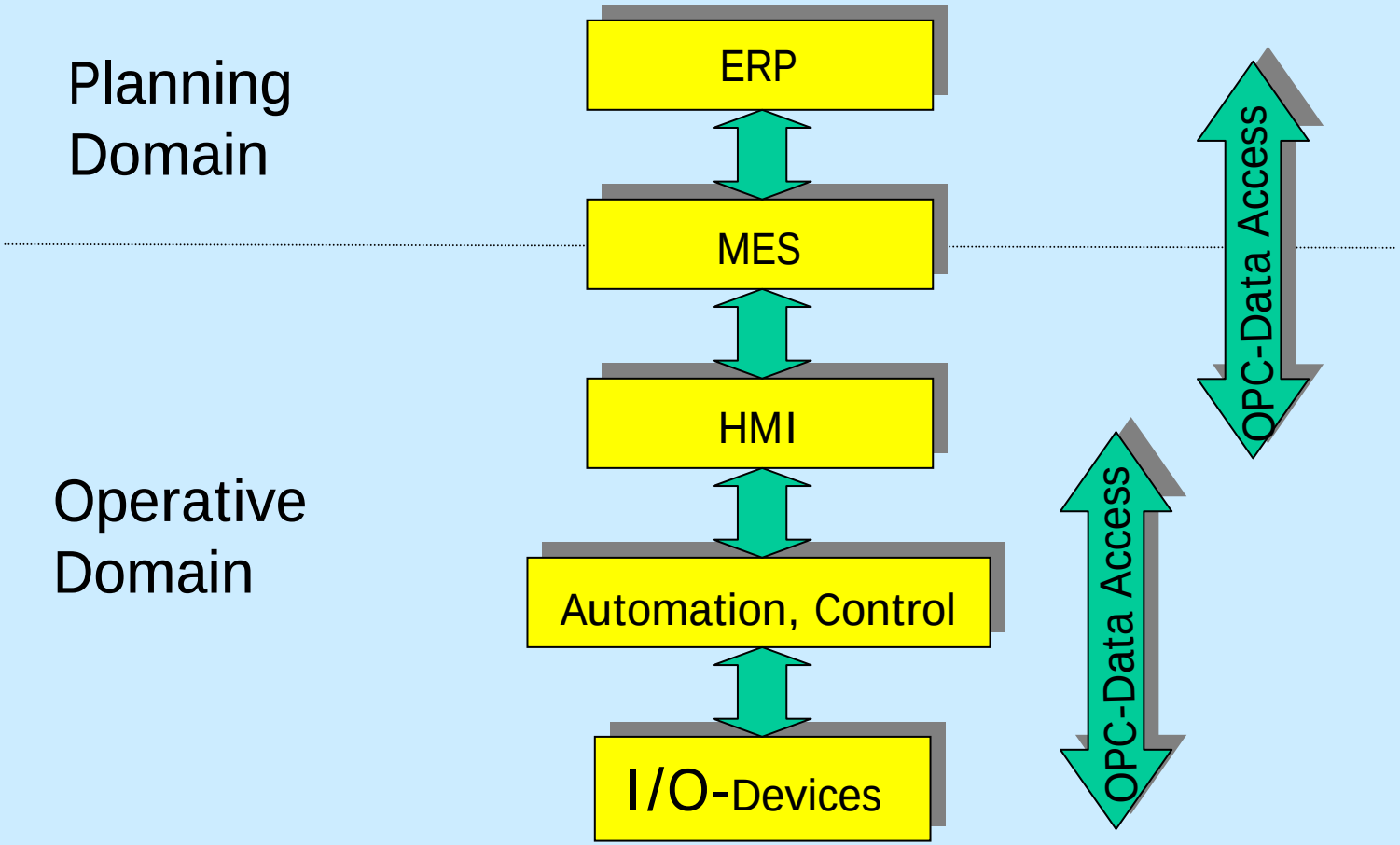


Information Management links Automation, Enterprise, Suppliers and Customers

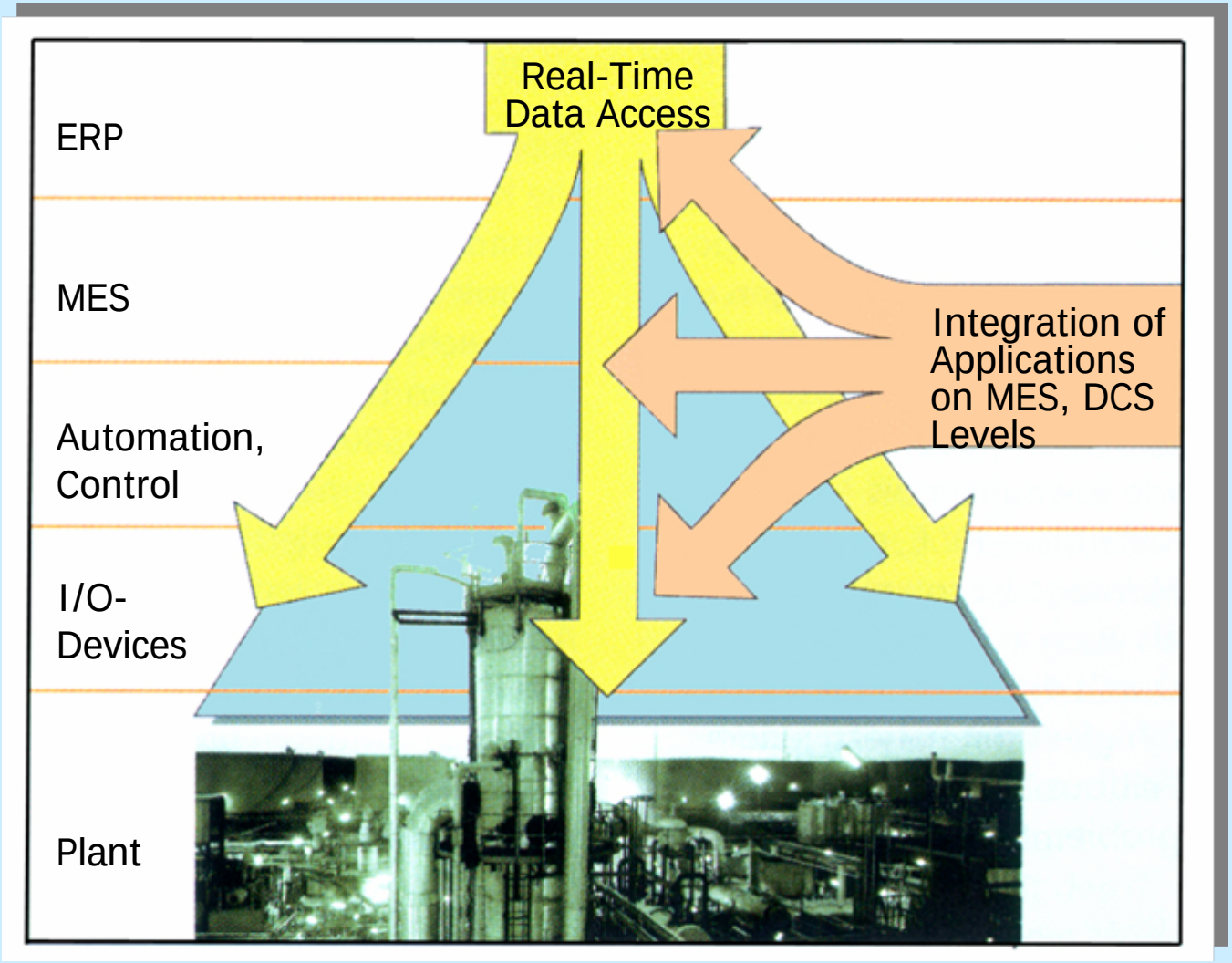


Vertical Integration of Enterprise by IT

Transparency of all Business Processes,
e. g. by Means of Open Standardized Communication



Vertical and Horizontal Integration by IT



Interconnection of the Various Digital Nervous Systems

Industrial Information Technology and Automation

- General Trends and Driving Forces
- Vertical and Horizontal Integration by IT
- **Open Automation System Platforms**
- Impact of Innovative Technology
- New Requirements to IA from Plant-floor

From Proprietary Systems to Open Automation System Platforms

Cost Reduction in DCS by Use of **Standards**

- Official Standards, e.g.
  - Ø IEC 1131-3 PLC Programming Language
  - Ø IEEE 802.3 Ethernet

- Consortium-Developed Standards, e.g.
  - Ø Profibus PA
  - Ø Foundation Fieldbus

- De Facto Standards, e.g.
  - Ø Microsoft Windows CE
  - Ø Java Sun Microsystems

Open Platform Automation Systems

Cost Reduction by **Commercial-off-the-Shelf HW and SW**

COTS-Hardware

- PC, Laptop, Notebook
- Mobile Phone
- Internet
- Ethernet
- ....

COTS-Software

- Microsoft Windows
- Web Browsers
- ....

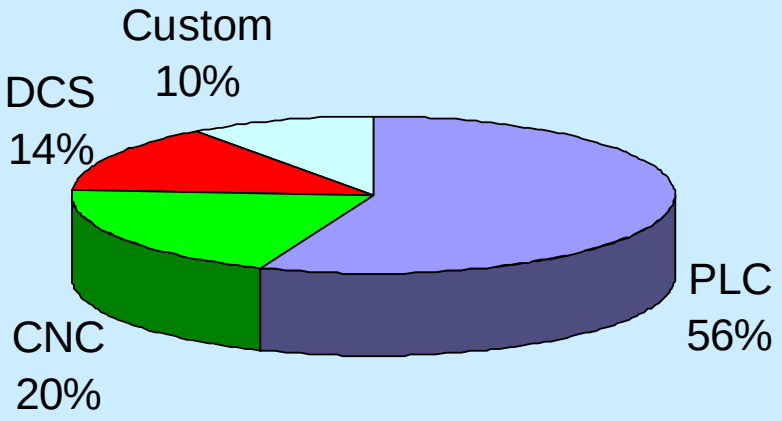
Open Systems Approach in IA

Essential Industrial Requirements

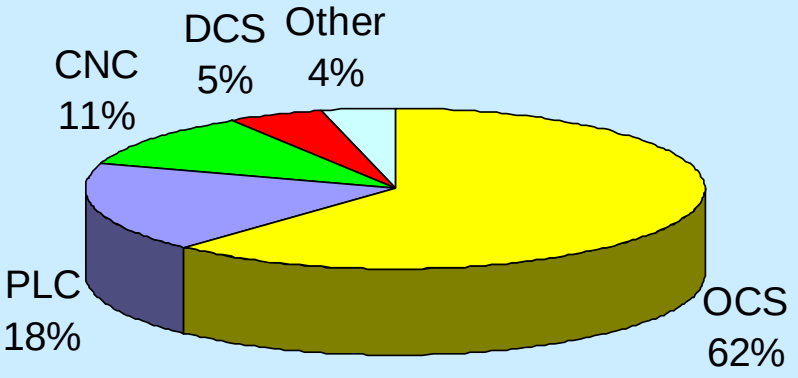
- Real-time Capability
- 24 hrs Availability
- Robustness
- Safety, Security
- EMC
- .....

Open Platform Control Systems (OCS)

- **Present** Controls Market



- **Future** Controls Market



OCS Approach in IA

Benefits for Users

- Reducing Initial and Maintenance Cost
- Increased Performance by Advances in Technology
- Ability to Integrate Special Purpose Products
- ....

Drawbacks for Users

- Develop Systems Specifications
- Select and Evaluate Products
- Responsibility for Integration and Trouble-shooting
- ....

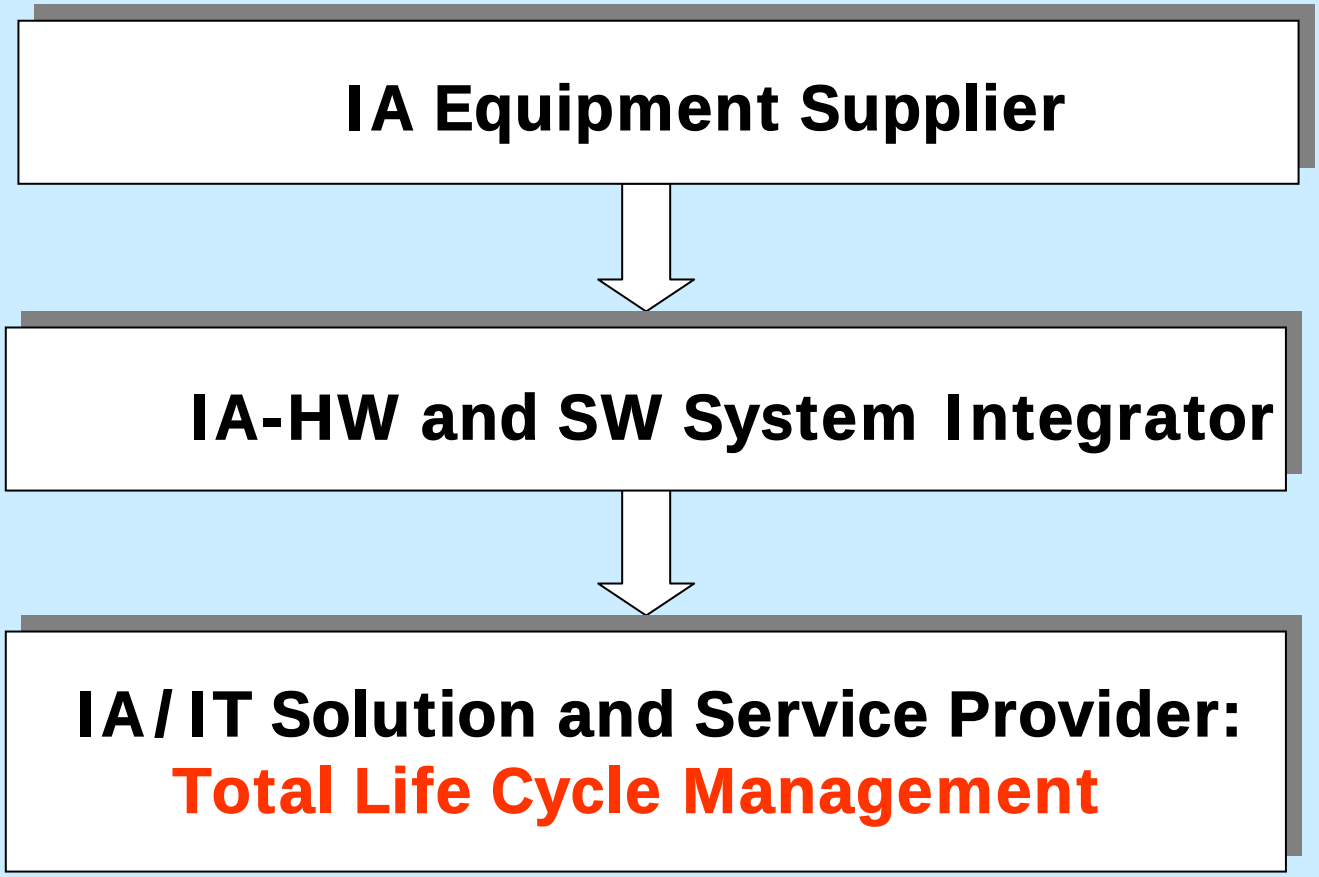
Unsolved Problems for Users and Suppliers

- Incompatibility of Technology Cycles in IA and IT Investments: 10 years to 1 year

Mid-term and Long-term Trends

- From Proprietary to Interoperable and Interchangable Systems, Sensors and Actuators
- DCS, PLC, ... may become a “Throw-Away-Item“ ?
- DCS, MES, ... Automation Services via Internet from Remote Service Provider ?
- ...

Future Role of IA Companies



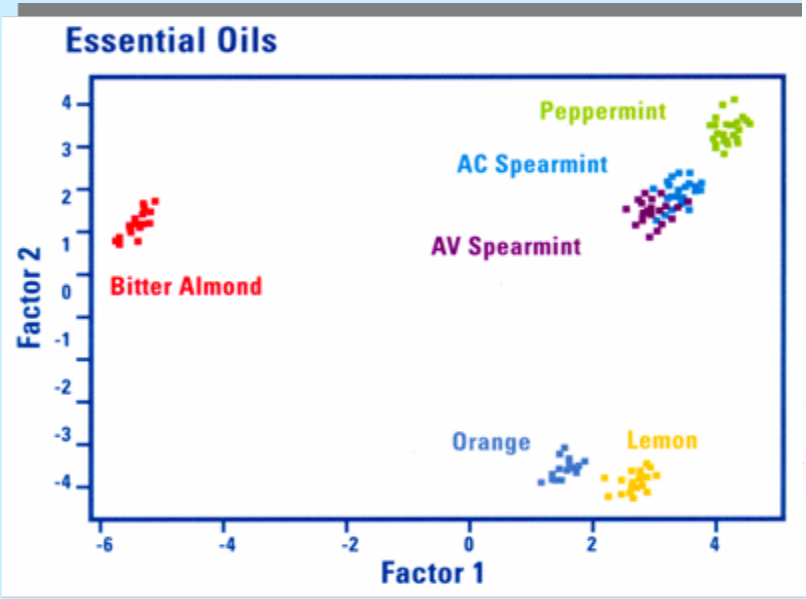
Industrial Information Technology and Automation

- General Trends and Driving Forces
- Vertical and Horizontal Integration by IT
- Open Automation System Platforms
- **Impact of Other Innovative Technology**
- New Requirements to IA from Plant-floor

Sensors for Complex Physical and Chemical Quantities

Monitoring and Control in Process Industries:
Foods, Pharmaceuticals, ...

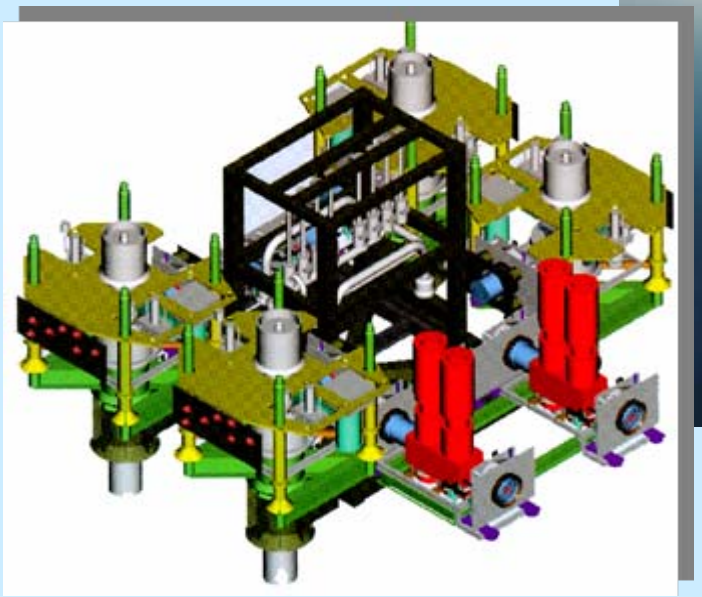
E-nose CYRANOSE
- 32 Polymer Composite Sensor Elements
- PCA Analysis



Embedded Sensors / Actuator Systems

"Intelligent" Components Through Embedded Sensors and Sensor Data Fusion

- Fault Detection
- Predictive Maintenance
- Asset Management



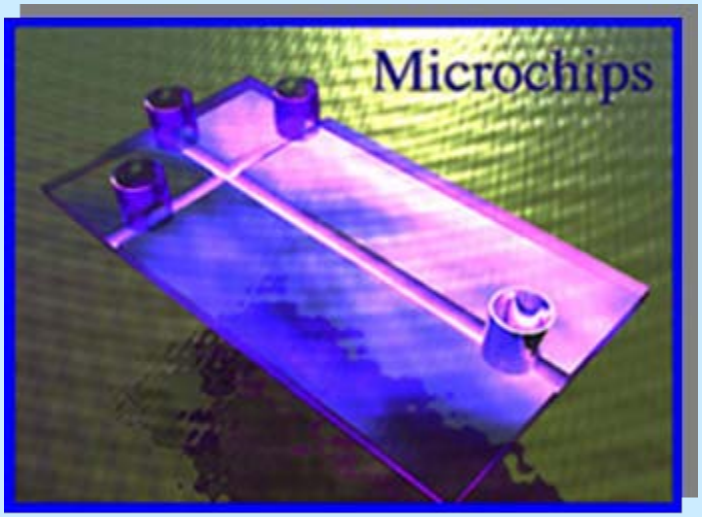
Subsea Equipment

Remote Robotics

MEMS Technology, e.g. Laboratory on Chip (LOC)

Real-time Multiplex Product Analysis on a Micro Chip

Multiplex PCR and
CE Analysis on a Chip;



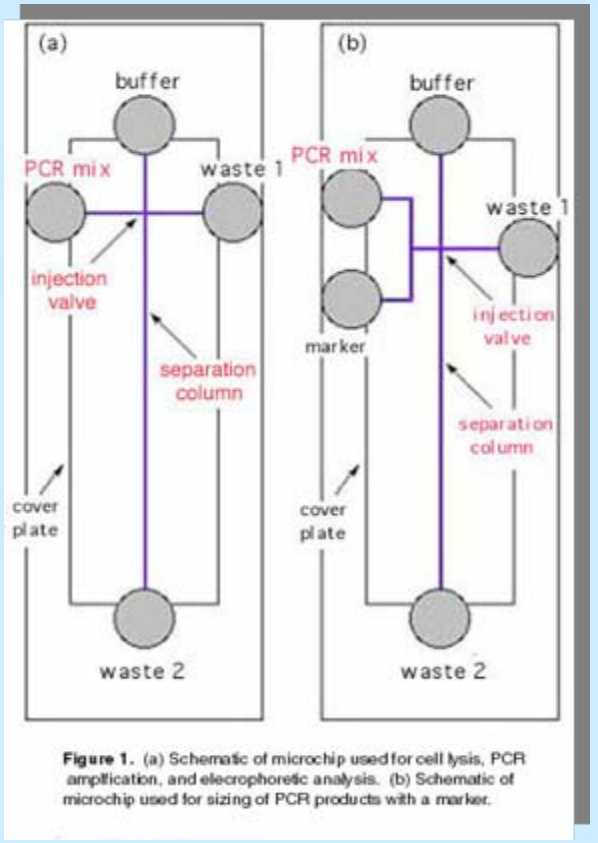


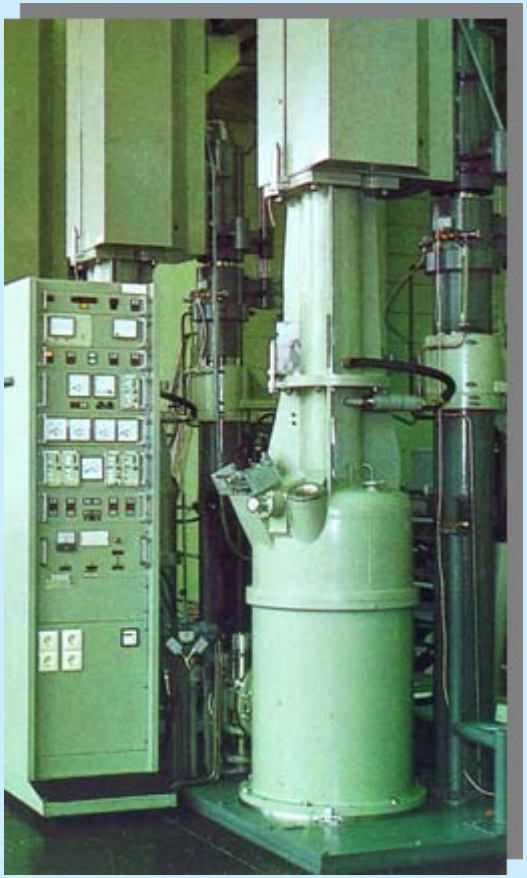
Figure 1. (a) Schematic of microchip used for cell lysis, PCR amplification, and elecrophoretic analysis. (b) Schematic of microchip used for sizing of PCR products with a marker.

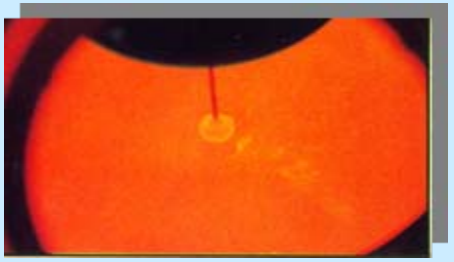
ornl, Laser Spectroscopy and Microinstrumentation Group

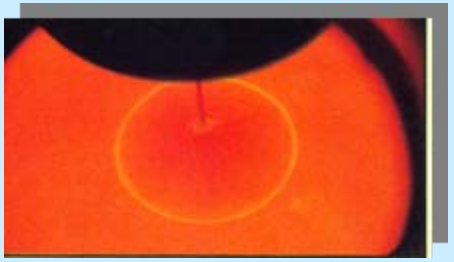
Digital Imaging and Advanced Image Analysis

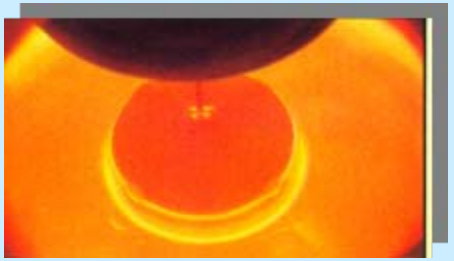
Advanced Process Control and Optimization

- Ø Polymer Reaction
- Ø Steel Continuous Casters
- Ø Semiconductor Material Production
- Ø Recycling
- Ø .....



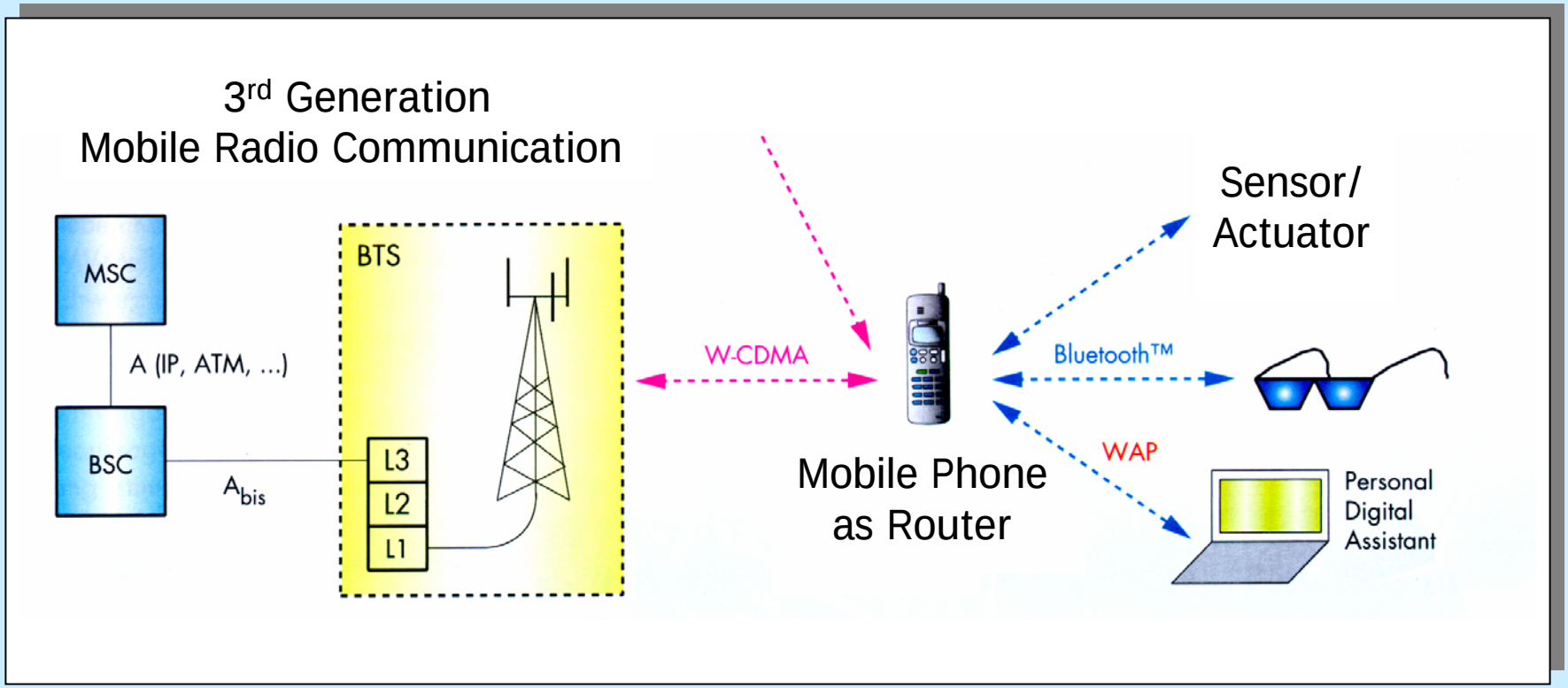






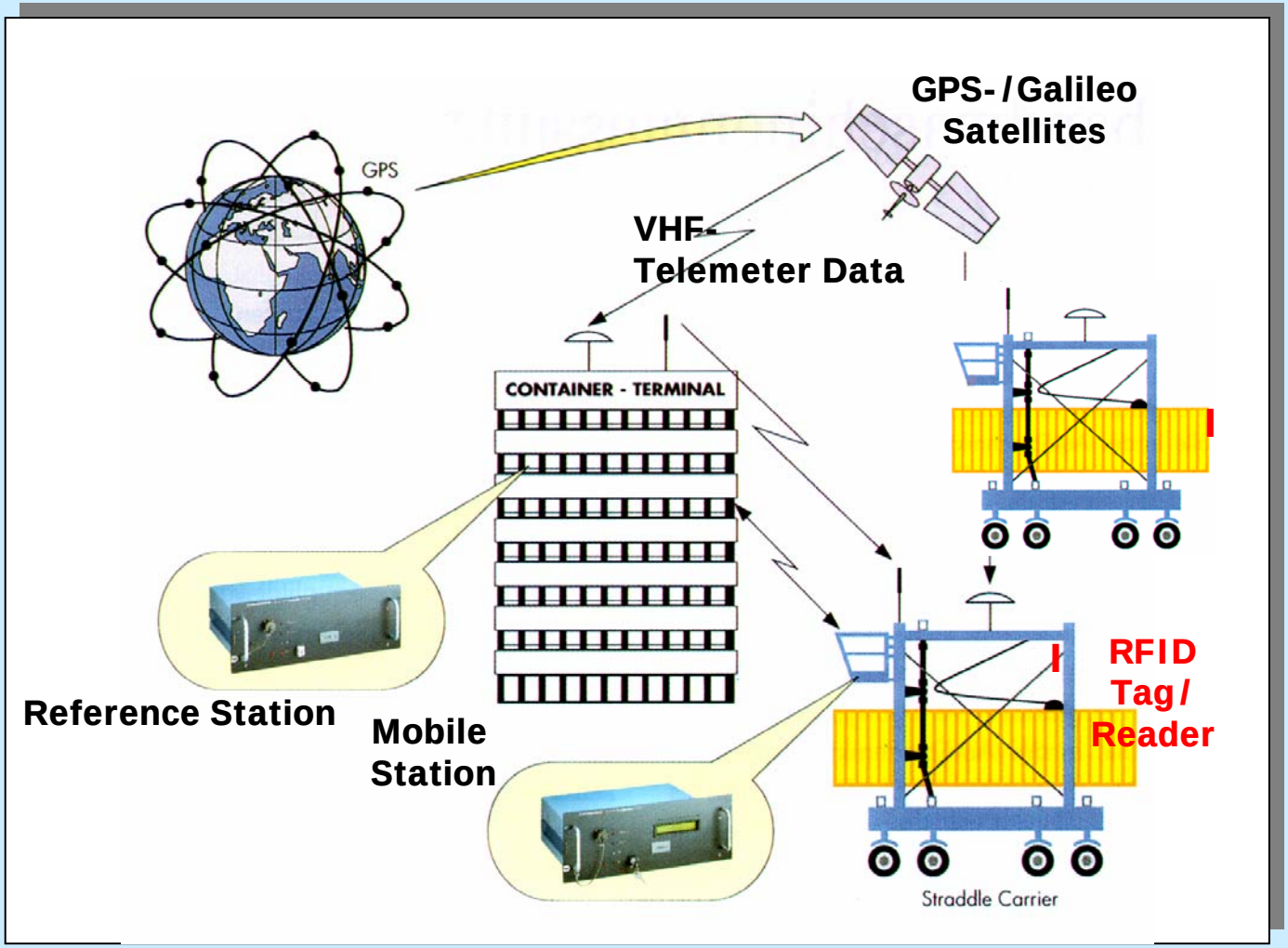
Short-haul Wireless Communication Technologies

- Ø Reconfiguration of Production Line without Extensive Rewiring
- Ø Communication from and to Sensors / Actuators



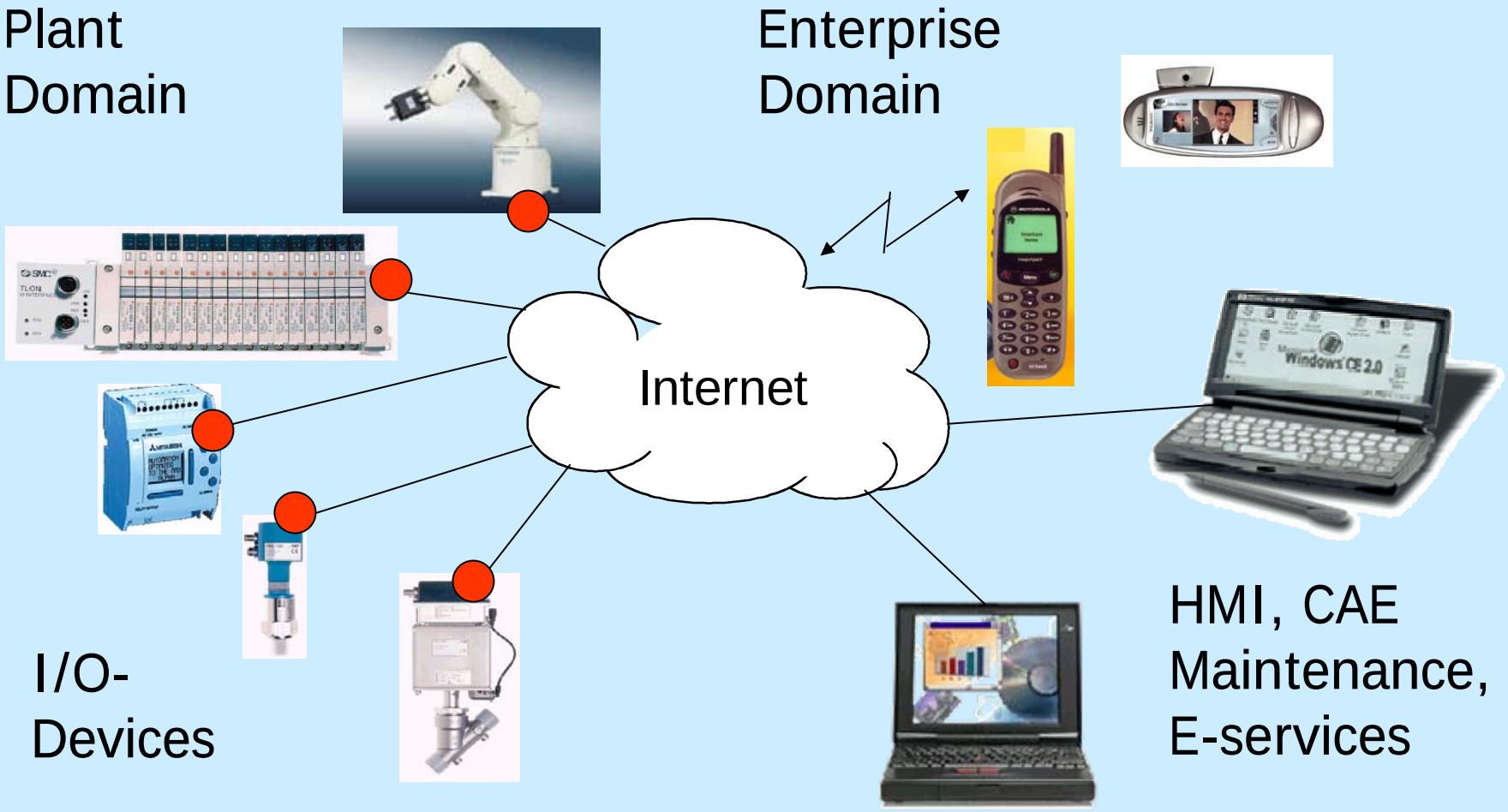
Location-based Services and Supply Chain Control

In/OutdoorTracking and Tracing of Location of Objects and Persons



Intelligent Appliance Silicon Chip Technology

Totally Distributed Architectures Through Networking



Built-for-Purpose IT Devices

Control / Automation Systems Assembled out of BFPs

Scalable Supercomputer Technology

- Distributed Parallel Processing
- Terabytes of High-speed Memory
- Penta/Tera-flops of Performance

Potential applications in IA, e.g.

- Decision-making in Closed-Loop Automated, High-Quality Demand-Based Production
- Advanced SPC/SPQ including Data-Mining Techniques

Industrial
Information Technology and Automation

- General Trends and Driving Forces
- Vertical and Horizontal Integration by IT
- Open Automation System Platforms
- Impact of Innovative Technology
- **New Requirements to IA from Plant-floor**

Requirements from the Plant-floor

- Deregulation, Regulatory or Economical Constraints
- Trimming of Primary Buffers
  - Ø Operate Process Closer to Capacity and Stability Limits
  - Ø Operation Closer to Constraints, without Violation

- Novel Manufacturing and Processing Techniques, e.g. in
  - Ø Biotechnological Operations
  - Ø Discrete Parts Manufacturing
  - Ø Microelectronics Manufacturing

Biotechnology Plant

Flexible Automation: Management of Equipment, Product Recipes; Integral Control of Production and Cleaning of Equipment

Reactor Line in a Multi-Product, Multi-Stream Batch Process

Demand-based Pull-type Discrete Manufacturing

From Scheduled to Demand-based Flow Techniques

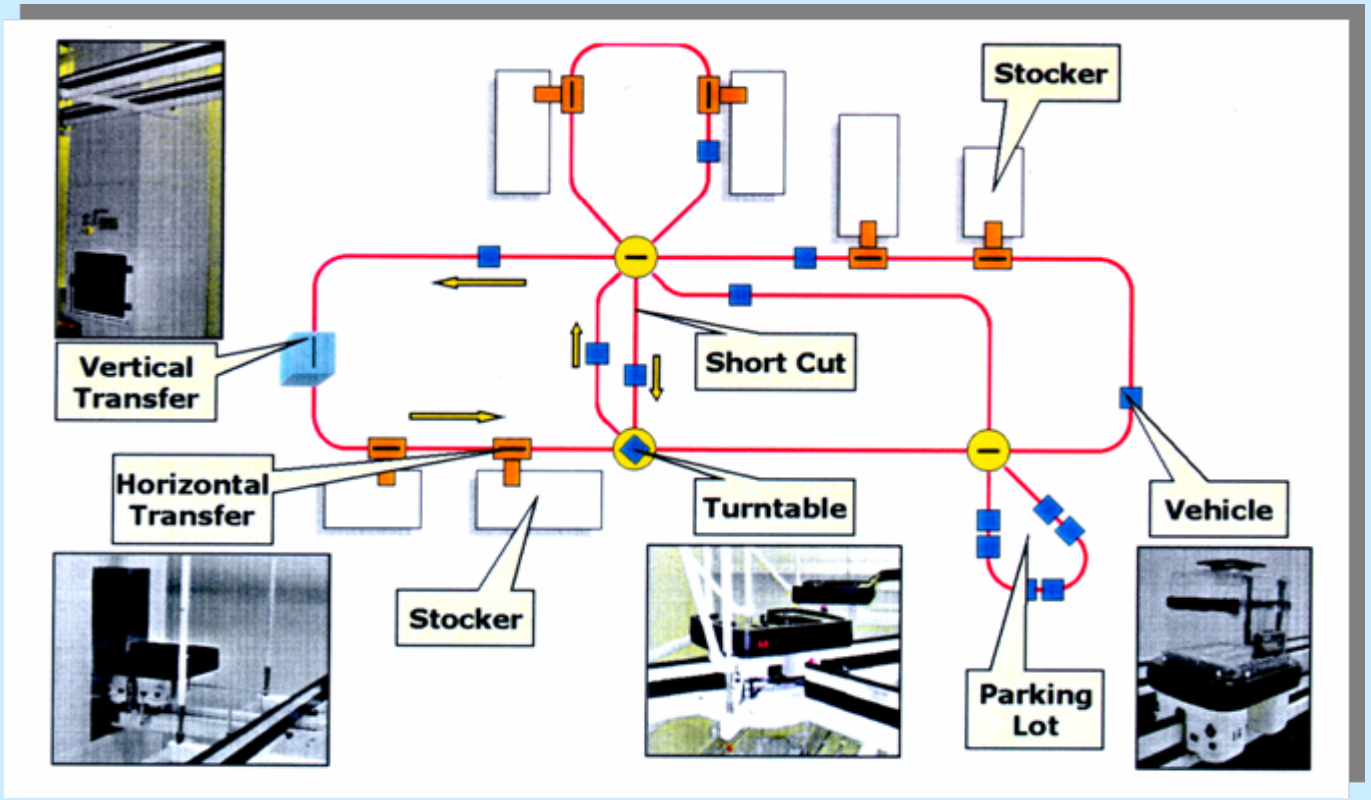
- Close Coupling between MES and IA System
- Short Cycle Production Feedback
- Flexible Material Handling and Assembly by Intelligent Robots

- Improvements in Quality and Deliverability
- Reduced Lead Time
- Reduced Inventory
- Customized Products
- ....

Assembly of Model Mix with Thousands of Options on a Single Production Line

Electronic Chip Manufacturing in Mega Fabs

Reduce Contamination by Minimizing Retention Time of Operators in Facility through Higher Degree of Automation



- Sophisticated Automated Waver and Material Handling Systems
- Real-time Equipment and Run-to-run Supervisory Control

INDUSTRIAL AUTOMATION - PAST, PRESENT, FUTURE

- MILESTONES AND ACHIEVEMENTS OF IA
- INDUSTRIAL INFORMATION TECHNOLOGY AND AUTOMATION
- **NEXT-GENERATION CHALLENGES**
- CONCLUDING REMARKS

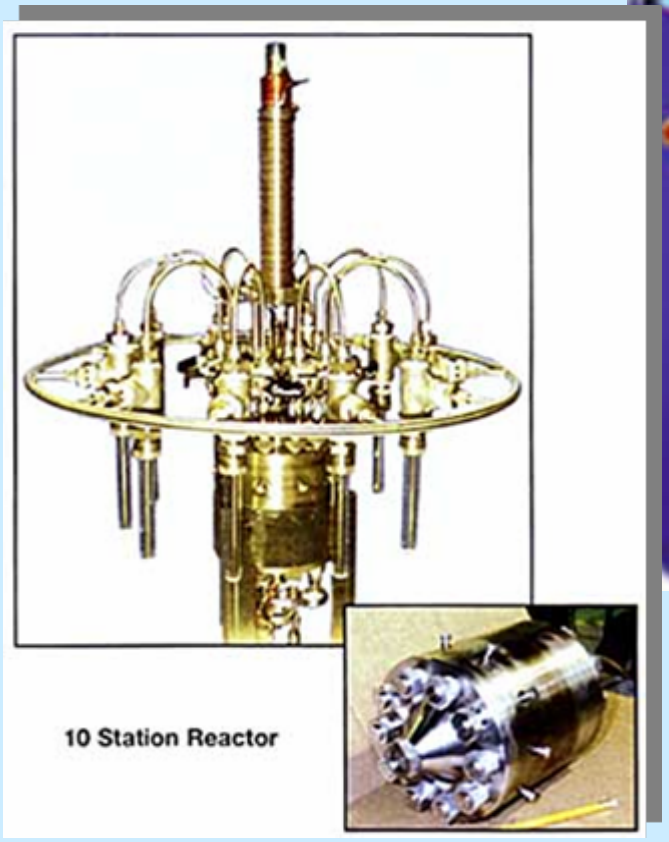
Selected Examples of Emerging Processing and Manufacturing Technologies

- **Microreactors in Chemical Process Engineering**

- Genomics: Systems for High-Throughput Screening, Synthesis and Sequencing

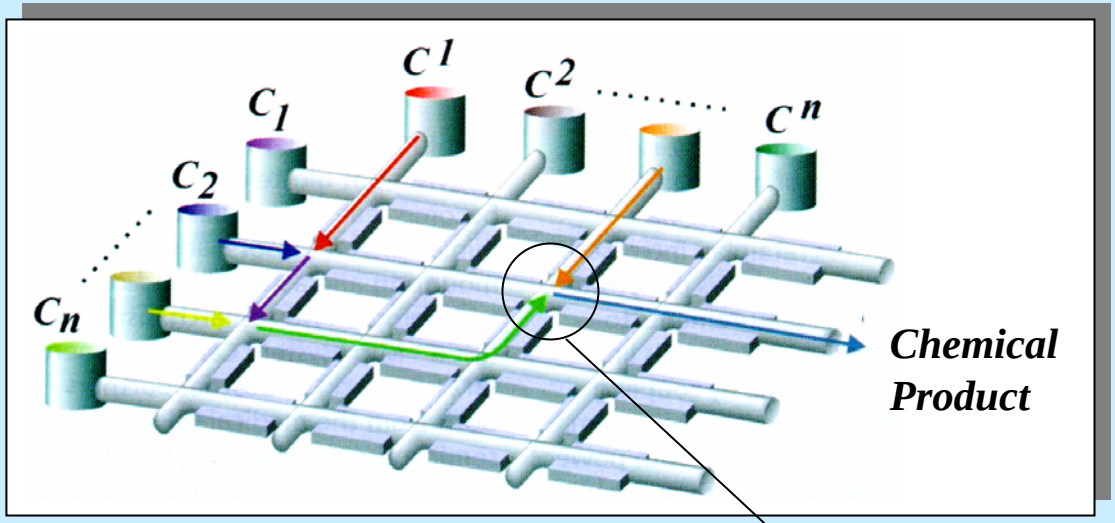
- Automatic Design and Manufacturing of Robotic Lifeforms

Scalable and Just-in-Time Production with Desk-top Microreactor Systems



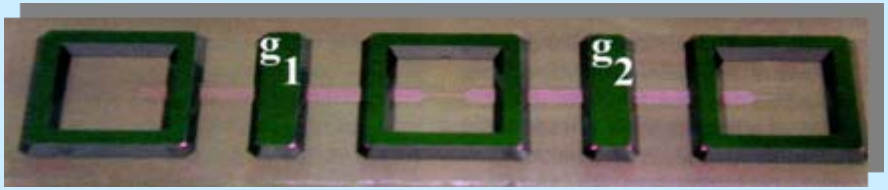
Automated Production Line

Microreactor Chips and Networks



CombiChem
Microreaction Network
Based on FlowFETs

FlowFET Structure
incl. Sensors / Actuators



Controlled
Operation

NEXT-GENERATION CHALLENGES

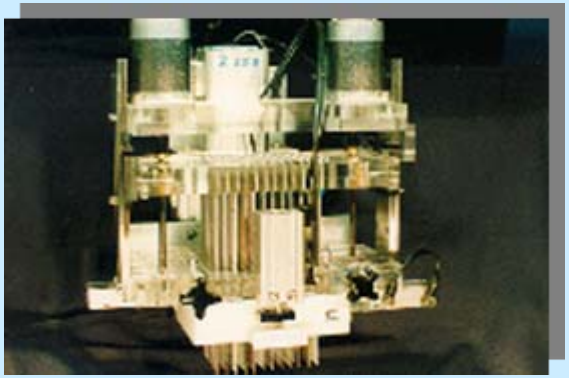
- Microreactors in Chemical Process Engineering

- **Genomics: Systems for High-Throughput Screening, Snythesis and Sequencing**

- Automatic Design and Manufacturing of Robotic Lifeforms

High-throughput Screening and Synthesis

Cope with Combinatorial Complexity through
Parallel Operations and Sophisticated IA Approaches
Including Data Mining Techniques



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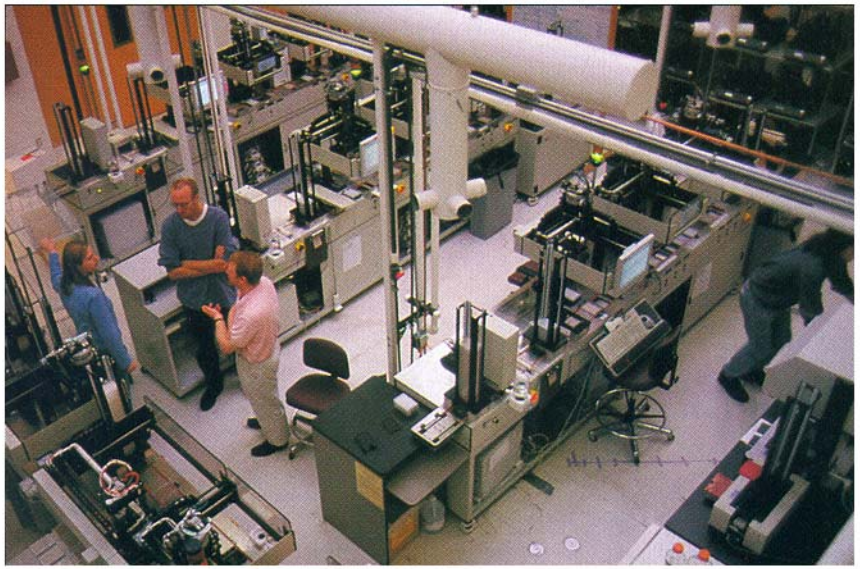
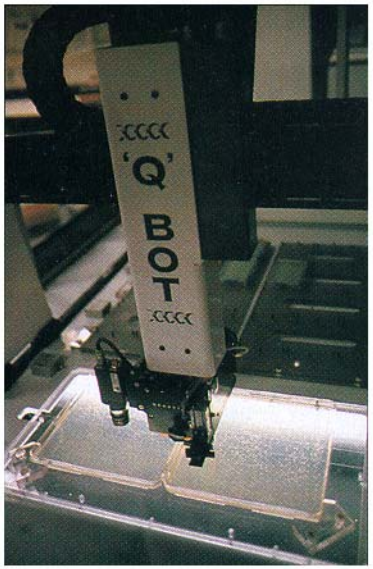
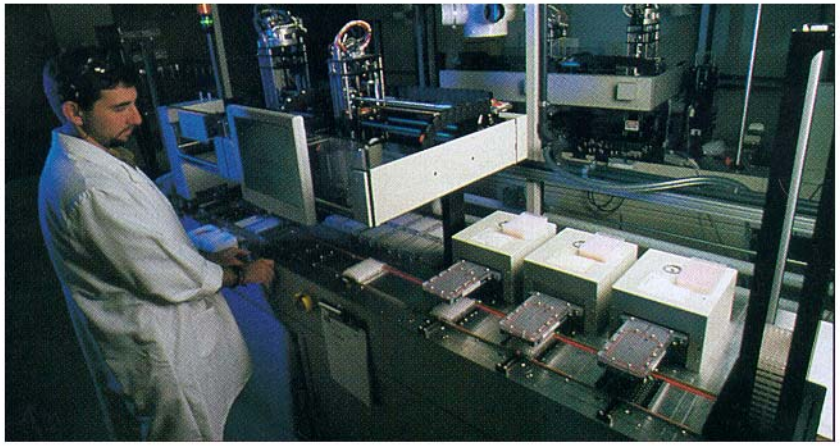
Automation Robots for Preparation of Screening

Compound Retrieval and Weighing
VIDEO

How Automation Made Decyphering the Human Genome Possible







[3] The sequencing laboratory at the Whitehead Institute [above] in Cambridge, Mass., uses a number of automation advances. For instance, the Q-bot [above, right] picks thousands of bacteria colonies from agar-coated plates and places them in wells filled with liquid growth media. DNA purification [right] has also been automated by a process invented at Whitehead.

PHOTOGRAPHS: STEPHEN ROSE/LIAISON AGENCY INC.

NEXT-GENERATION CHALLENGES

- Microreactors in Chemical Process Engineering

- Genomics: Systems for High-Throughput Screening, Snythesis and Sequencing

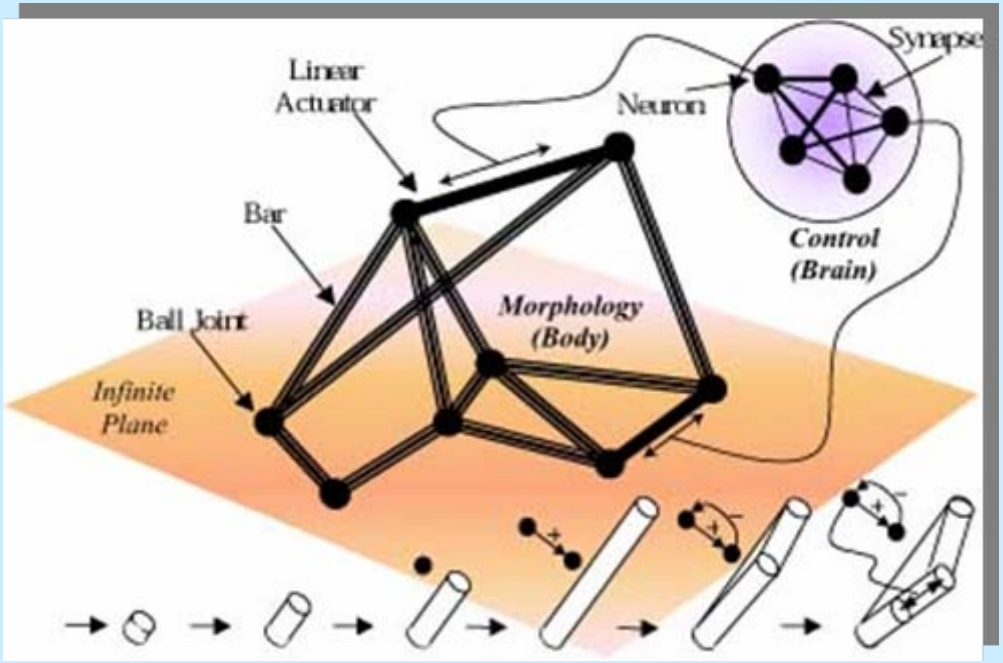
- **Automatic Design and Manufacturing of Robotic Lifeforms**

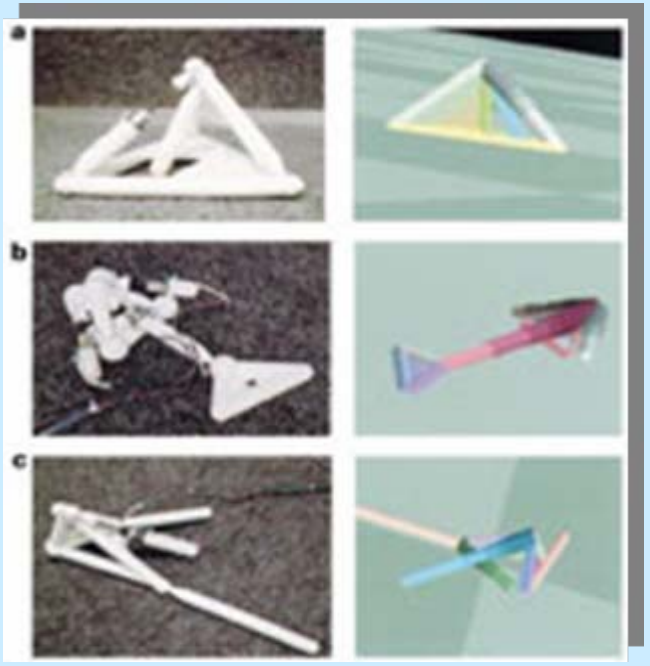
Artificial Evolutionary Design Process with Connection to Rapid Prototyping Machine

Example: Automation of Cognitive Mental Processes

The Golem Project: "Create a walking creature out of ....."

http://golem03.cs-i.brandeis.edu/index.html

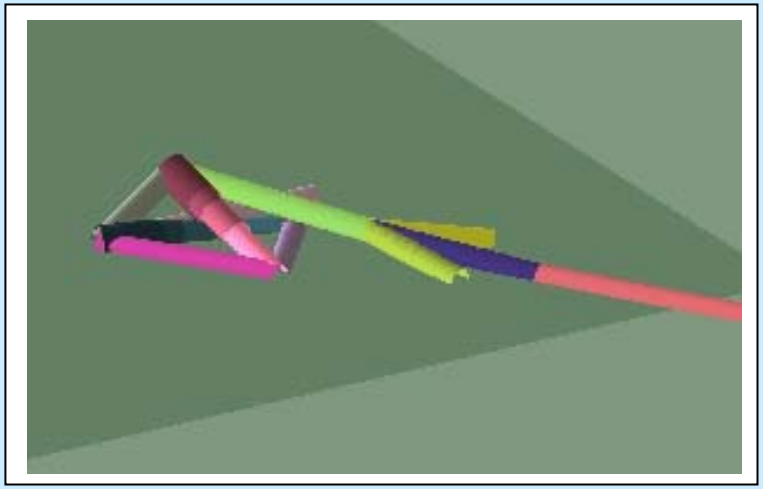


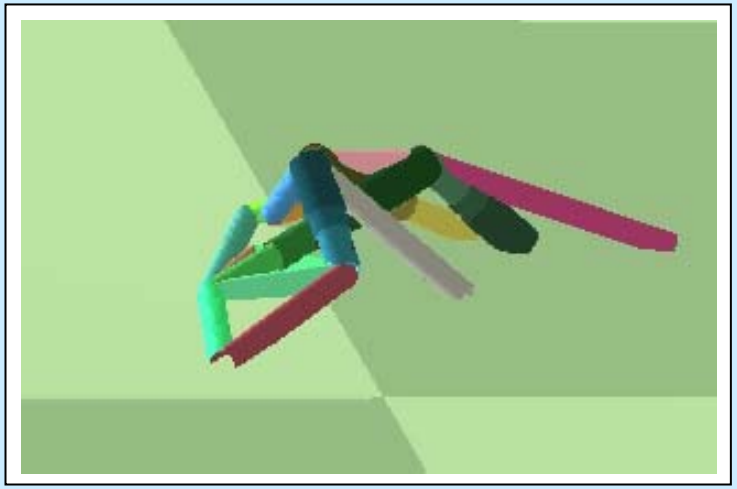


Real Virtual

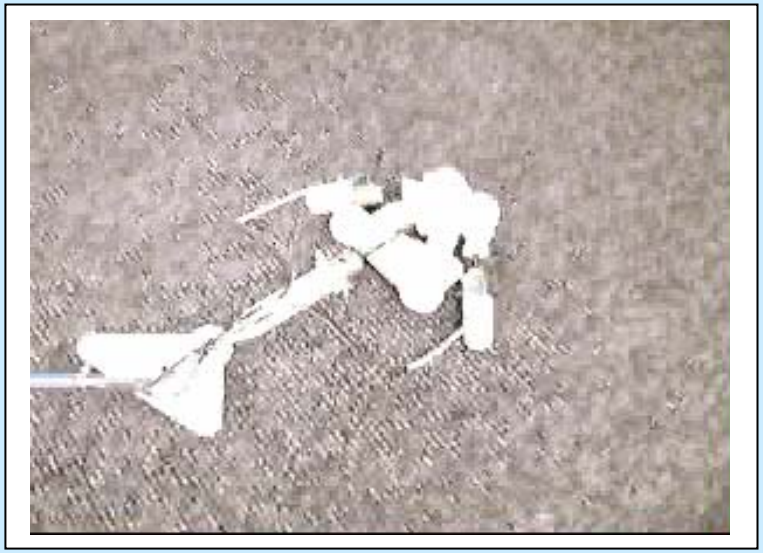
Design and Manufacturing Results and Performance

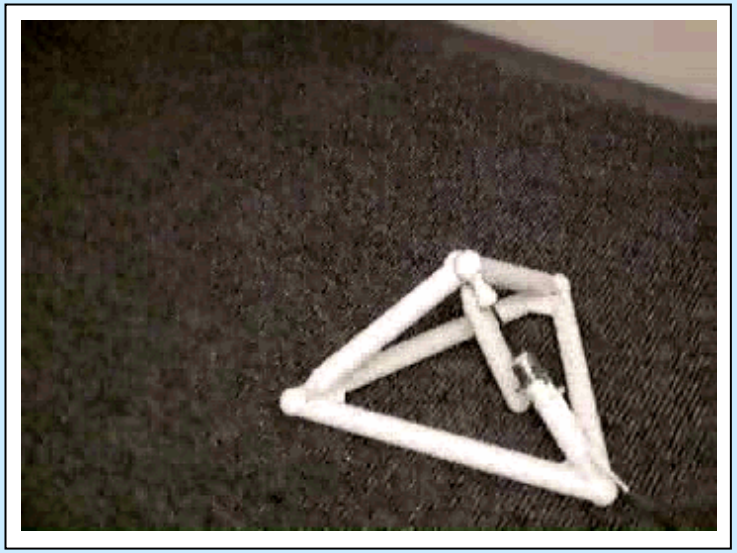
Virtual





Real





Notable Aspects of this Idea

- Evolutionary Design in Virtual World:
  - Ø Dynamic Process Based on Feedback Control
  - Ø Simultaneous Information and Physical Processing
- Integration of Virtual Design and Rapid Prototyping Shows Features of Autonomy, Self-Organization and Artificial Life

- Possible Expansions of Approach
  - Ø Coupling of Performance Evaluation in Real World with Evolutionary Design Process
  - Ø Behaviour Optimization via Performance Feedback Loop

Prototype Model for a Novel Paradigm of Automated Design and Manufacturing ?

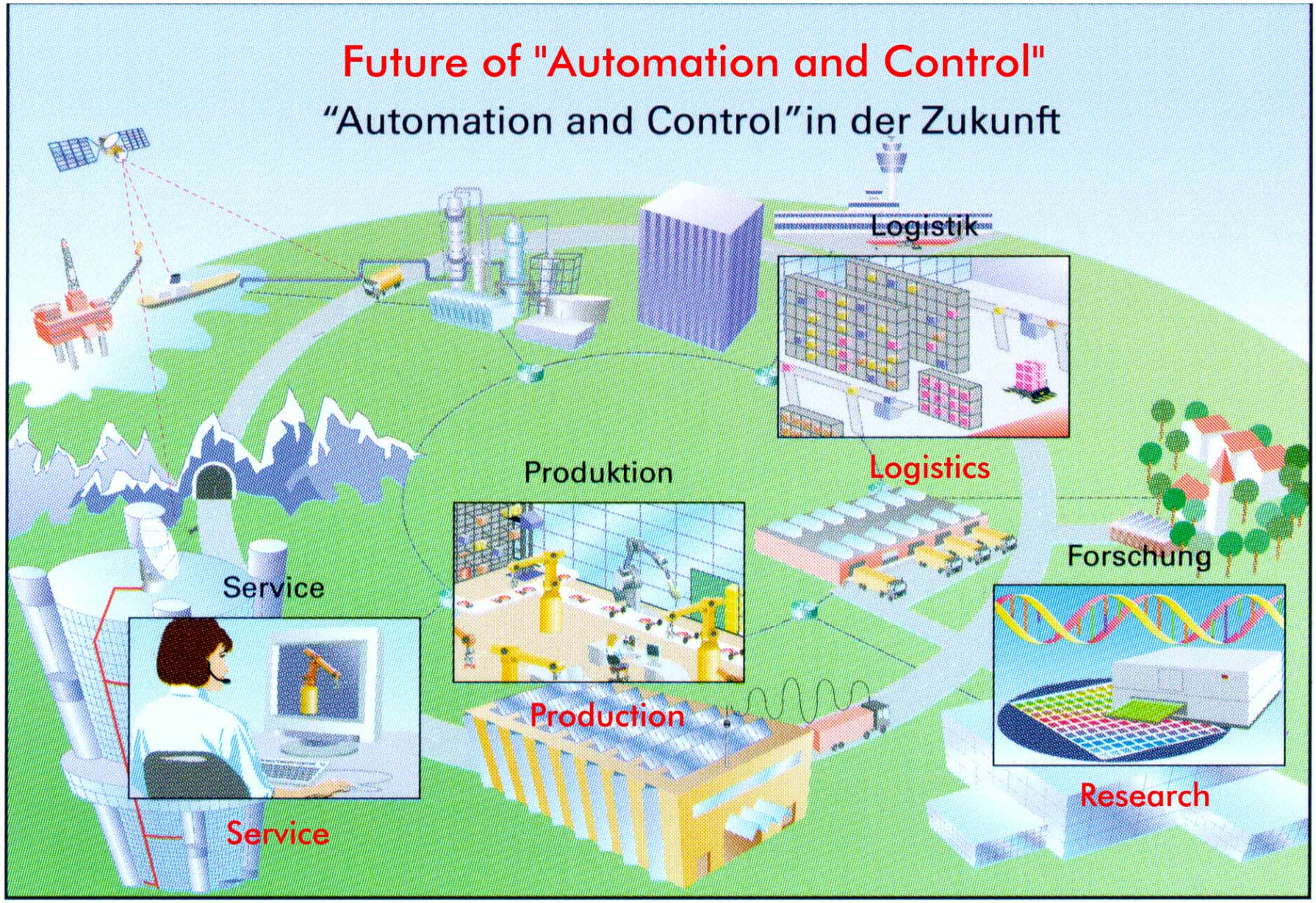
Concluding Remarks

Overall Challenges of IA at the Beginning of 21st Century

- Optimization of Technological Operations on Plant-floor
- Optimization of Entire Business Performance by Streng-thening of the Enterprise-wide Digital Nervous System

Incorporation of Technologies from IT & Telecommunications and Innovations in Industrial Electronics, Robotics etc.

- open wide Avenues for Novel IA Solutions & Applications
- define a New Role of IA as IA / IT Solution and Service Provider for Complex Industrial Activities and Operations



The Siemens View

Concluding Remarks, cont'd

This presentation did not focus ***novel theoretical and methodological aspects*** going along with the sketched technological evolution from

IA to IIT&A.

Those prove to be manifold, e.g. control *and* communication, or reconfigurable, cognitive, agent-based controls, etc

Discussion underscores trend at major universities to creation of a novel academic discipline

Services Science, Management, and Engineering - SSME

INDUSTRIAL AUTOMATION
- PAST, PRESENT, FUTURE

Résumé

"Industries, Economies and Societies of the 21st Century will Heavily Depend on Continuous Progress in Industrial IT and Automation"