Trends in Manufacturing Research: DIGITAL MANUFACTURING Perspectives and Outlook

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OUTLINE

- Introduction
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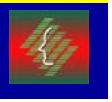
- MANUFUTURE Approach
- Digital Factory: Academic and Industrial Perspectives
  - CAD, CAE, CAPP and CAM
  - Manufacturing Control
  - Simulation of Manufacturing Systems
  - Enterprise Resource Planning and Manufacturing Optimization
- Recent Developments
- Outlook – Digital Manufacturing



INTRODUCTION

They said …

"I think there's a world market for maybe five computers."

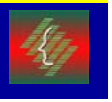
*(Thomas Watson, the Chairman of IBM, in **1940**)*

"I have traveled the length and breadth of this country and talked with the best people, and I can assure you that data processing is a fad that won't last out the year."

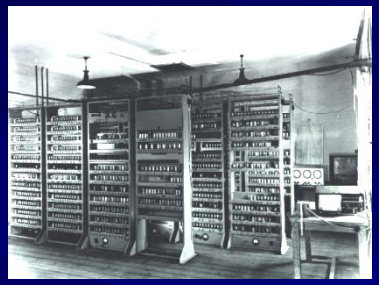
*(The Editor in Charge of business books for Prentice Hall, in **1957**)*

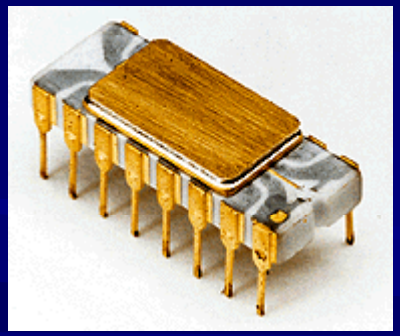
"There is no reason why anyone would want to have a computer in their home."

*(President of Digital Equipment Corporation, in **1977**)*



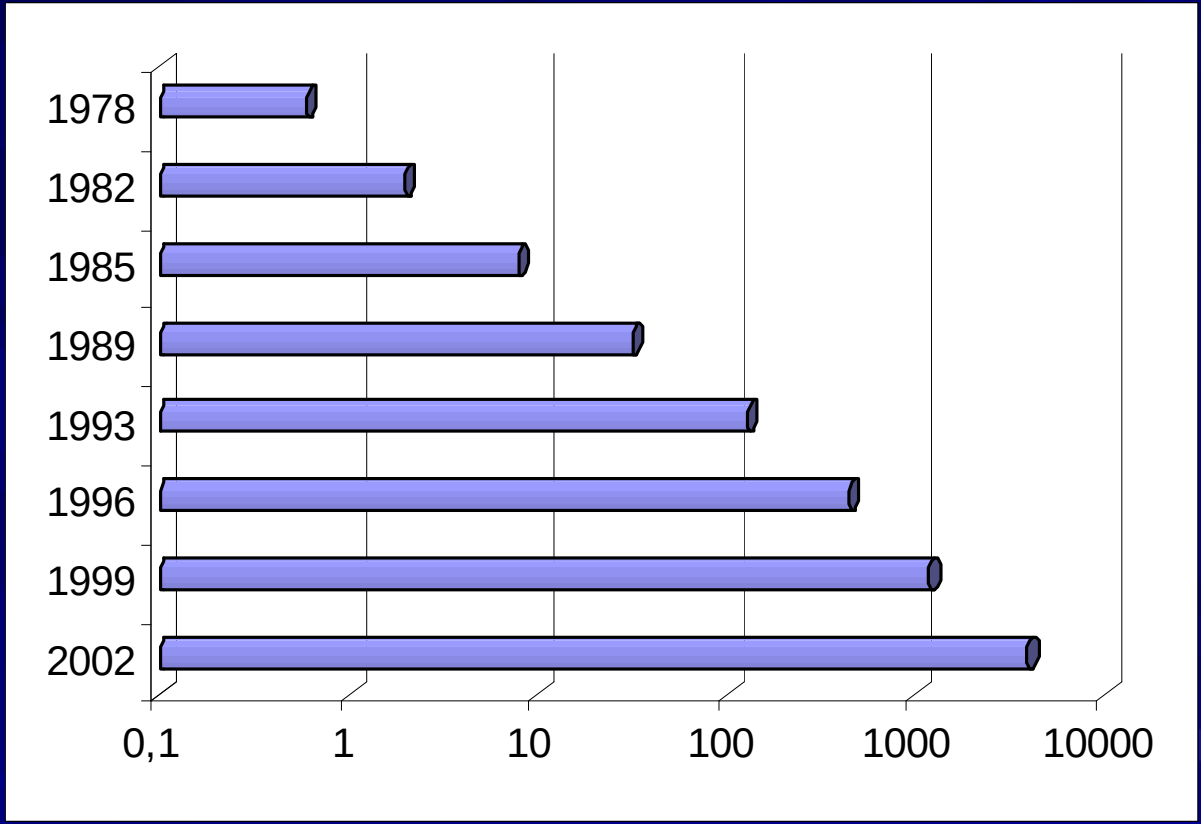
INTRODUCTION





Years	IT evolution
1940	Machine Accounting
1950	Data Processing
1960	Mainframe Data Centers
	Information Services
1970	Minicomputers
1980	Microcomputers
1990	Client / Server Technology
2000	Internet / Intranet

INTRODUCTION



CPU Million Instructions Per Second (MIPS)

INTRODUCTION

The **Product Development** & **Product Lifecycle** include the following stages:

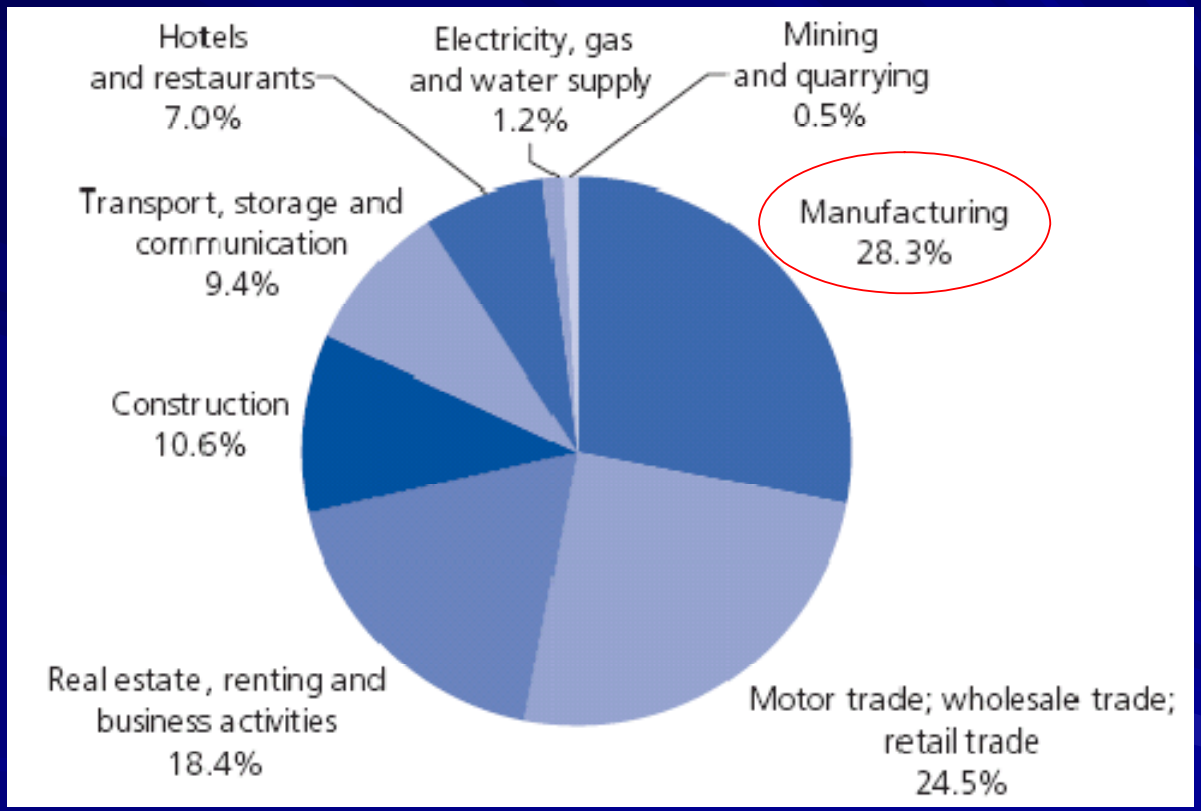
- ✓Product Conceptualization
- ✓Product Design
- ✓Process Planning
- ✓Production Network Optimization
- ✓Manufacturing
- ✓Maintenance and End of Product Lifecycle

During product development **CAD tools** have been extensively used over the last years in order to **speed-up the development process** and to **eliminate the need for early physical prototypes**

The logical continuation of the **Digital Product Development** process is the **Digital Factory** towards to the **Digital Manufacturing**

The Importance of Manufacturing

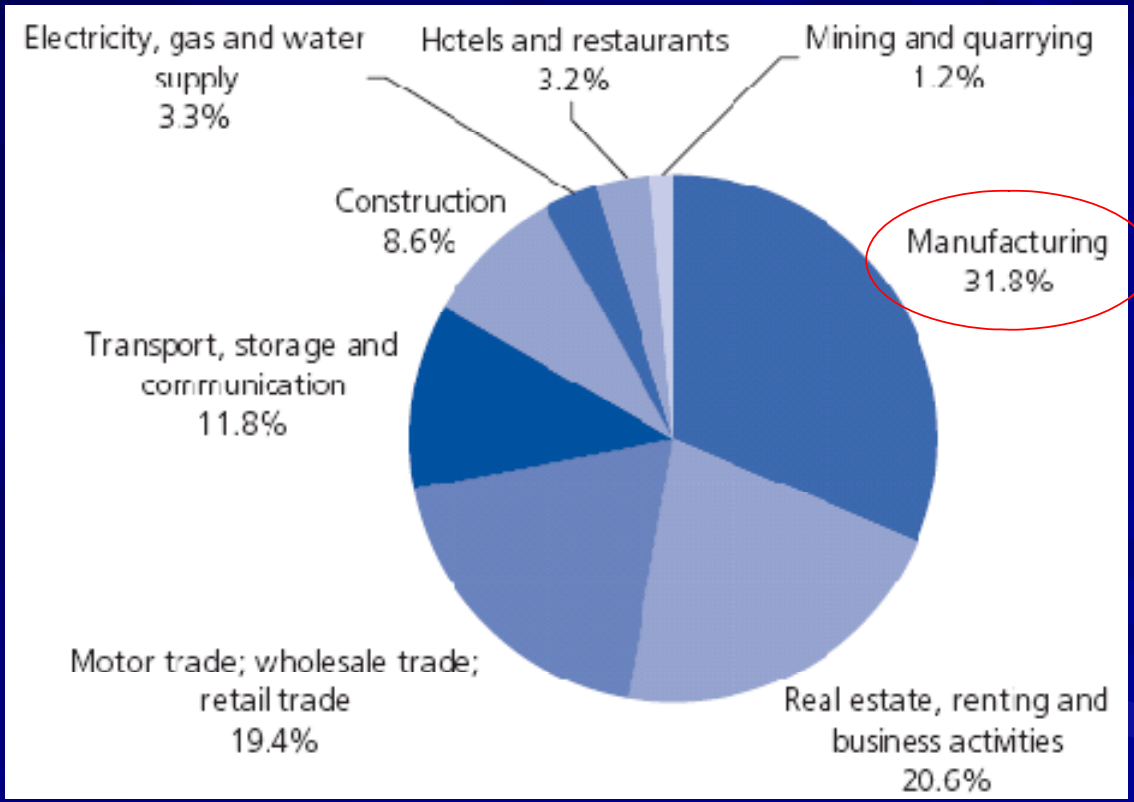
Manufacturing = Jobs + *Value*



Breakdown of number of persons employed in the non-financial business economy, EU-25, 2003 (Source: Eurostat yearbook 2006-07)

The importance of Manufacturing

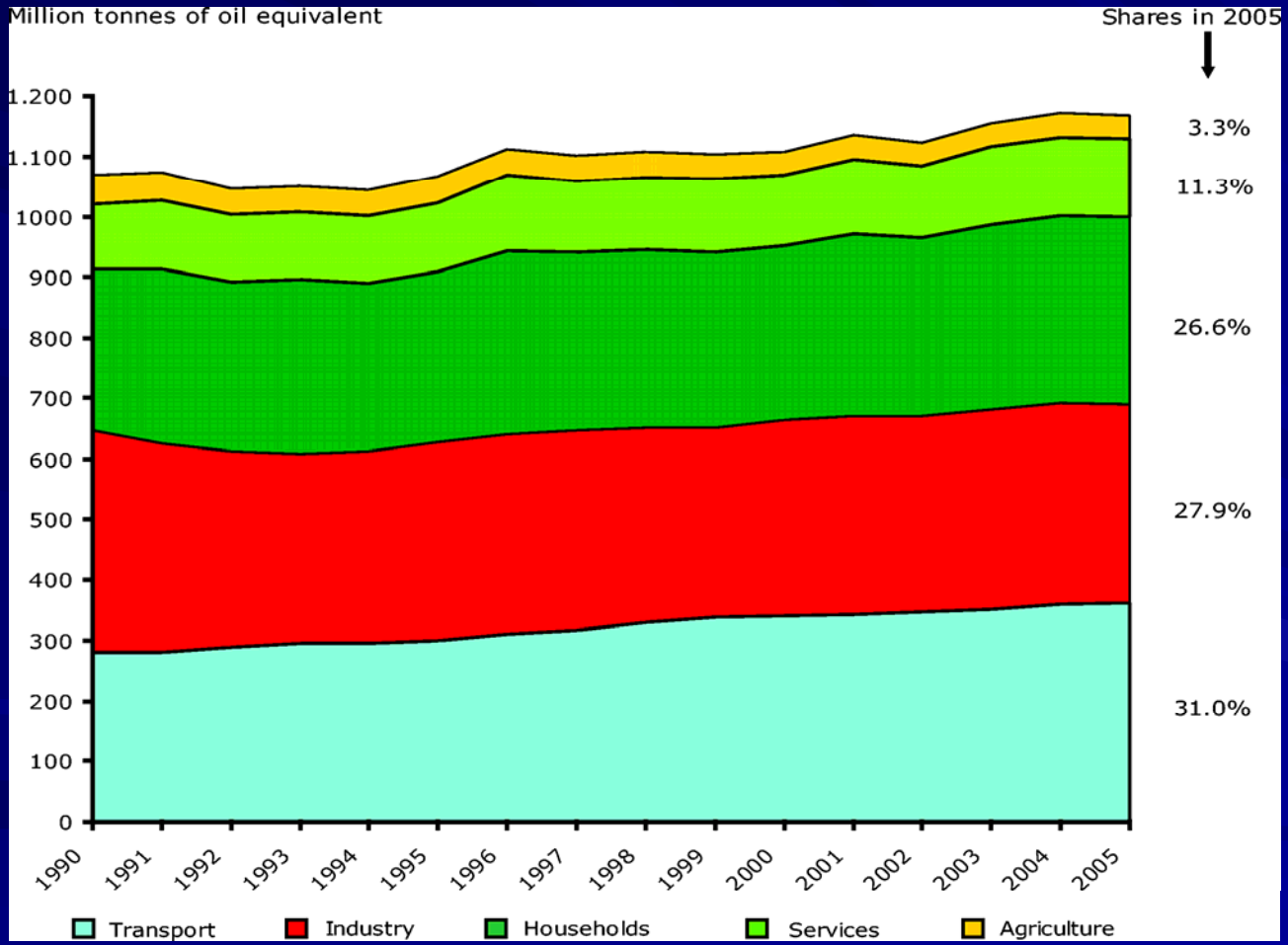
Manufacturing = *Jobs + Value*



Breakdown of value added at factor cost in the non-financial business economy, EU-25, 2003 (Source: Eurostat yearbook 2006-07)

The importance of Manufacturing

Manufacturing has a substantial environmental impact



Final energy consumption by sector, EU-27 (Source: European Environment Agency, Energy & Environment Report 2008)

The importance of Manufacturing

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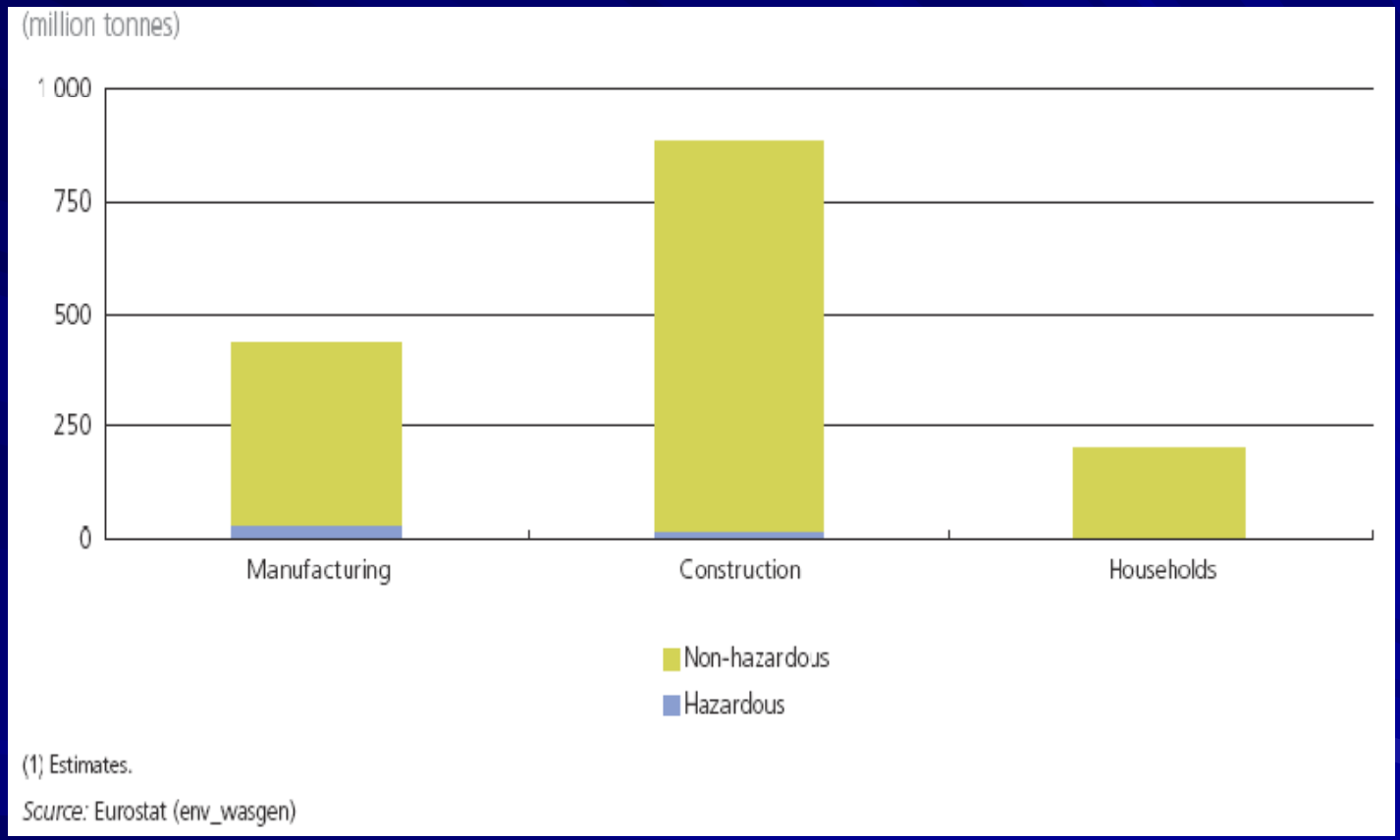
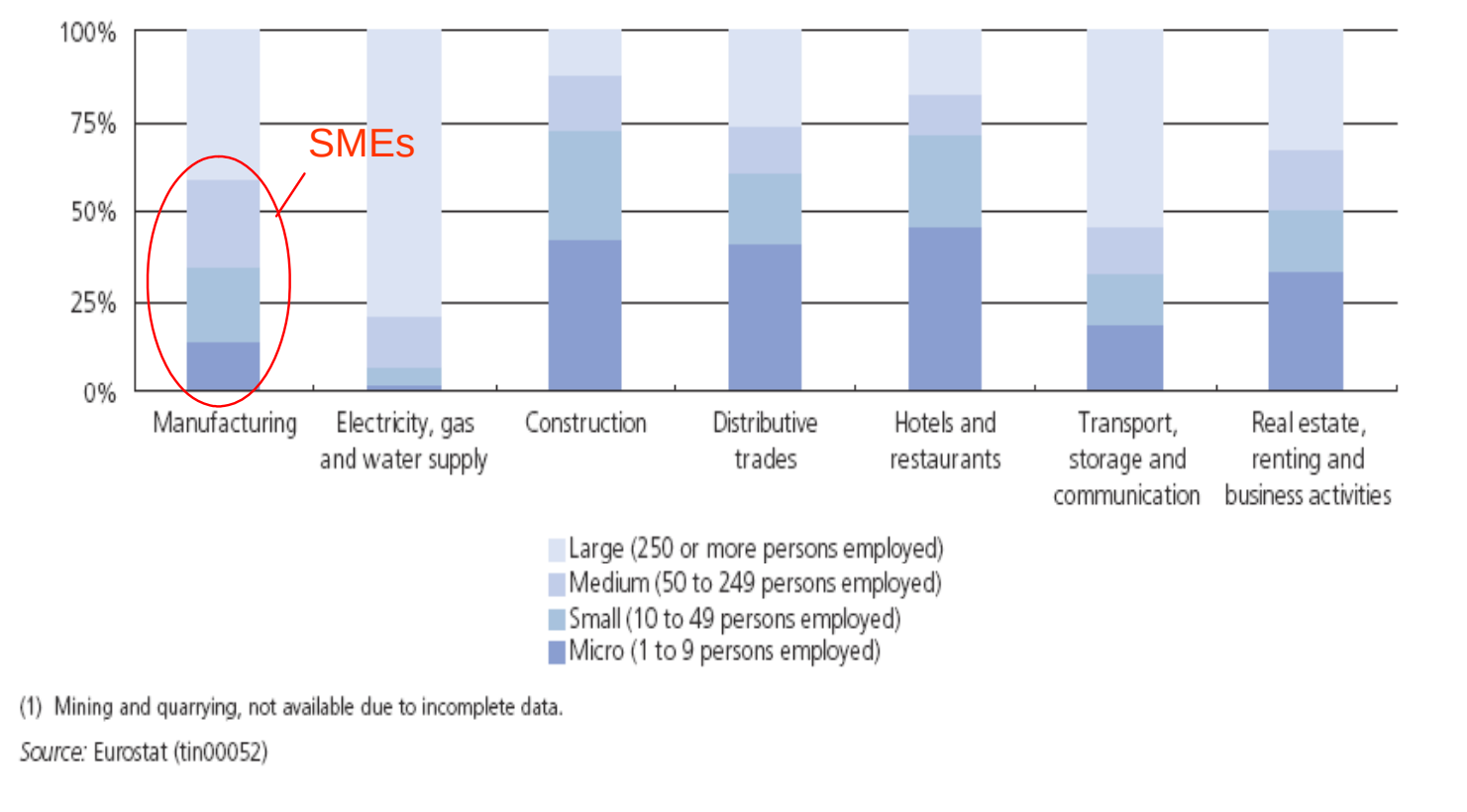


Generation of waste by origin, EU27, 2004
(Source: EUROSTAT Statistical Books, Europe in Figures, Year Book 2008)

The importance of manufacturing

Manufacturing activity is important for SMEs



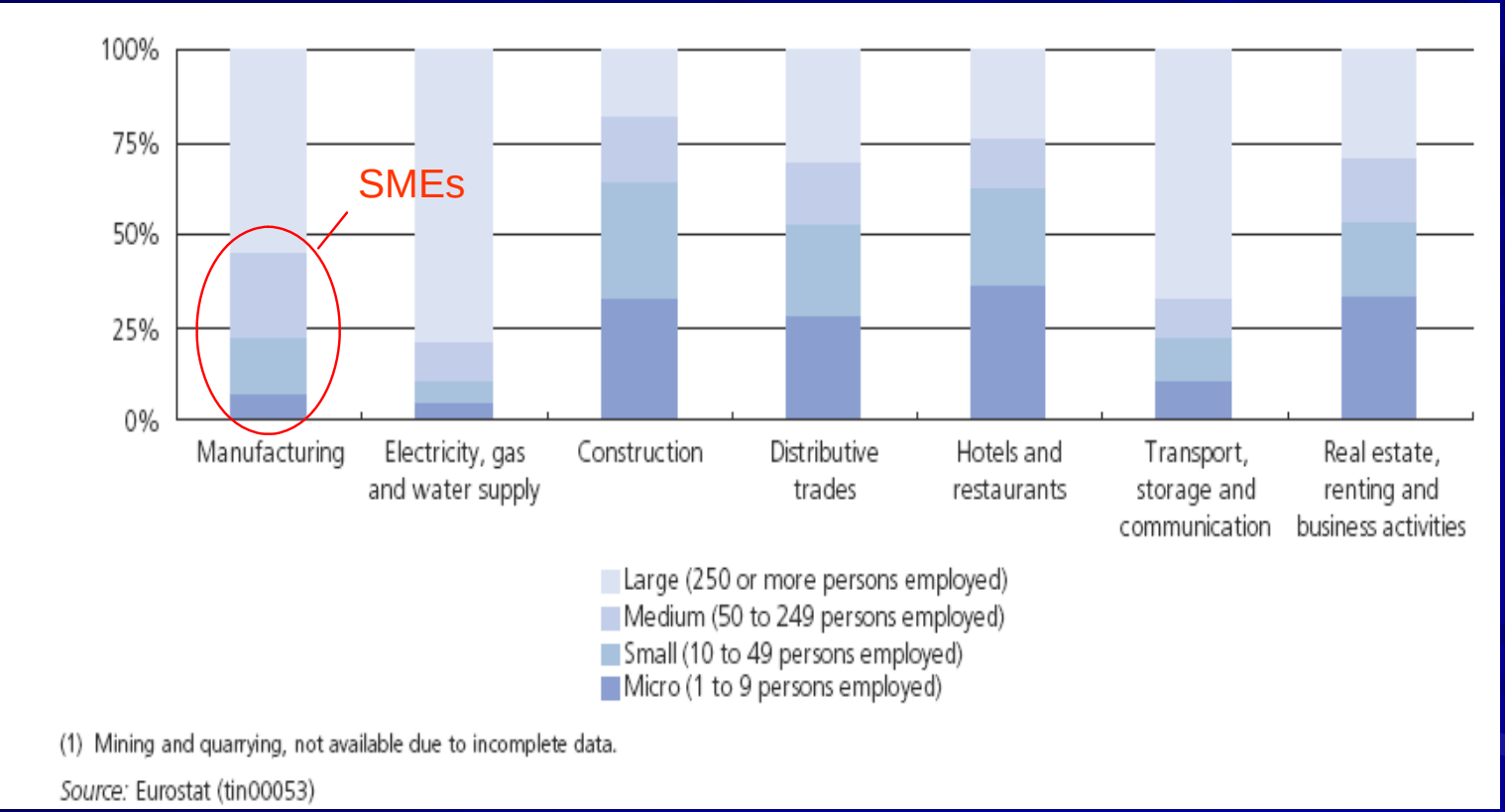
(1) Mining and quarrying, not available due to incomplete data.

Source: Eurostat (tin00052)

Employment by enterprise size class, EU 27, 2004 (%) of Sectorial Total (Source: EUROSTAT Statistical Books, Europe in Figures, Year Book 2008)

The importance of manufacturing

Manufacturing *activity is important for SMEs*



(1) Mining and quarrying, not available due to incomplete data.

Source: Eurostat (tin00053)

Value added by enterprise size class, EU 27, 2004 (%) of Sectorial Total (Source: EUROSTAT Statistical Books, Europe in Figures, Year Book 2008)

CHALLENGES for European Manufacturing

- European Manufacturing has been addressing **major challenges** like:
  - productivity growth
  - competitive pressure
  - environmental impact
  - innovation risks etc
- A number of underlying **socio-economic and technological drivers** have affected the developments
  - globalization
  - S&T advances
  - sustainability requirements
  - regulatory environment etc.
- The current **economic crisis** has made the situation even more challenging, since output in many manufacturing sectors has been especially **hard hit** by the financial crisis and has experienced the **sharpest decline in decades**

MANUFUTURE Mission

The mission of MANUFUTURE is to propose a strategy based on research and innovation, capable of speeding up the rate of industrial transformation in Europe, securing high added value employment and winning a major share of world manufacturing output in the future knowledge driven economy

MANUFUTURE Approach

… from resource-based to knowledge-based manufacturing

MANUFUTURE

Compete by

REDUCING COSTS

Cheap labour, Automation

MANUFACTURING
Research-Innovation based

European industrial sectors

Compete by

HIGH VALUE ADDED

High performance
Customisation
New business models
New human capital

DIGITAL FACTORY

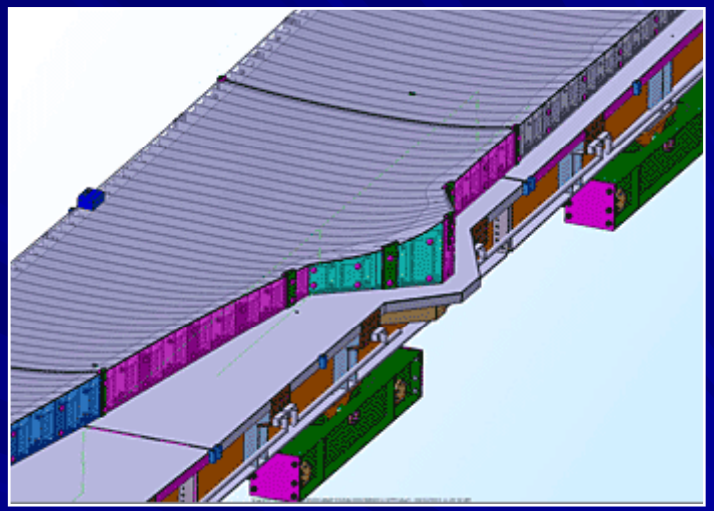
The Digital Factory comprises **digital planning and optimization** of the real-life plant as well as of its production processes on the basis of an **integrated data model and geometry-based planning**

Product Design, Process and Production Planning procedures are supported by:

- Advanced **simulation** tools and models
- Computer Aided Design / Manufacturing - **CAD / CAM** - SW packages
- Enterprise Resource Planning – **ERP** - systems
- Supply Chain Management – **SCM** - systems based on Computer-Integrated Manufacturing – **CIM** - concepts
- Product Lifecycle Planning and Management – **PLM** - methods

Computer Aided Design (CAD) Systems

- 3D Virtual Product **Functional** Modelling
- **Collaborative** Environment (Groups / Suppliers)
- Parts Libraries
- FEA / Simulation Integration
- Product Engineering Optimization
- Styling Capabilities
- Integrated NC programming
- Product Lifecycle Modelling Features
- **Rapid Prototyping** Technology



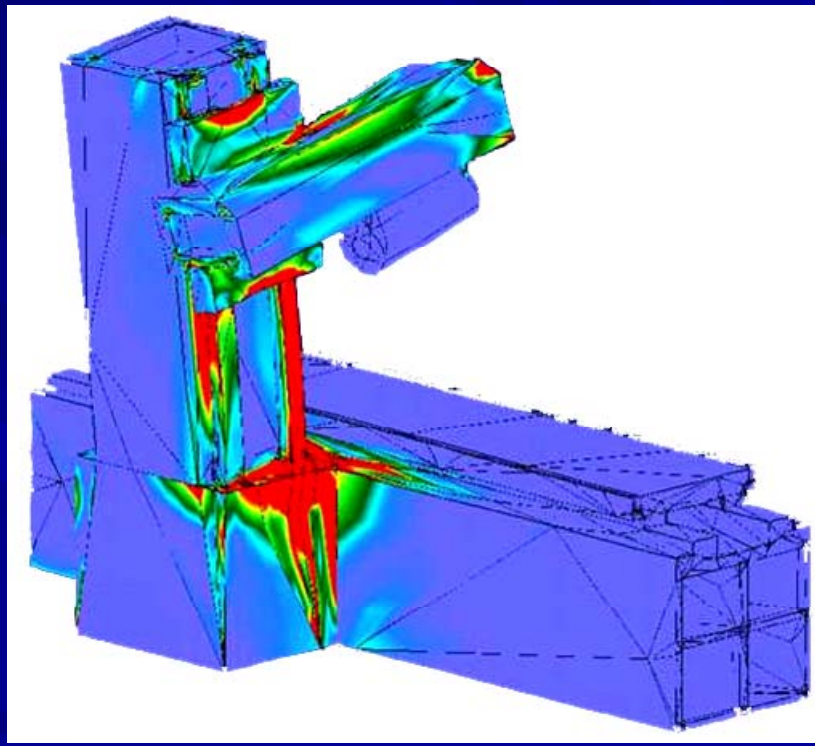
CAD image (CATIA v5) of the creep forming tool for panel 1 of the Airbus A380 wing skins, showing the aluminium skin (dark grey) resting on the forming surface, which is supported by laser-cut steel ribs. The forming tool stands on a steel deck (pale grey), and the whole assembly is moved on bogie units (green)

http://www.bennettmg.co.uk/News/news_airbus_catia.html

Computer Aided Engineering (CAE) Systems

CAE systems are used for ***reducing the level of hardware prototyping*** during product development and for ***improving understanding*** of the system:

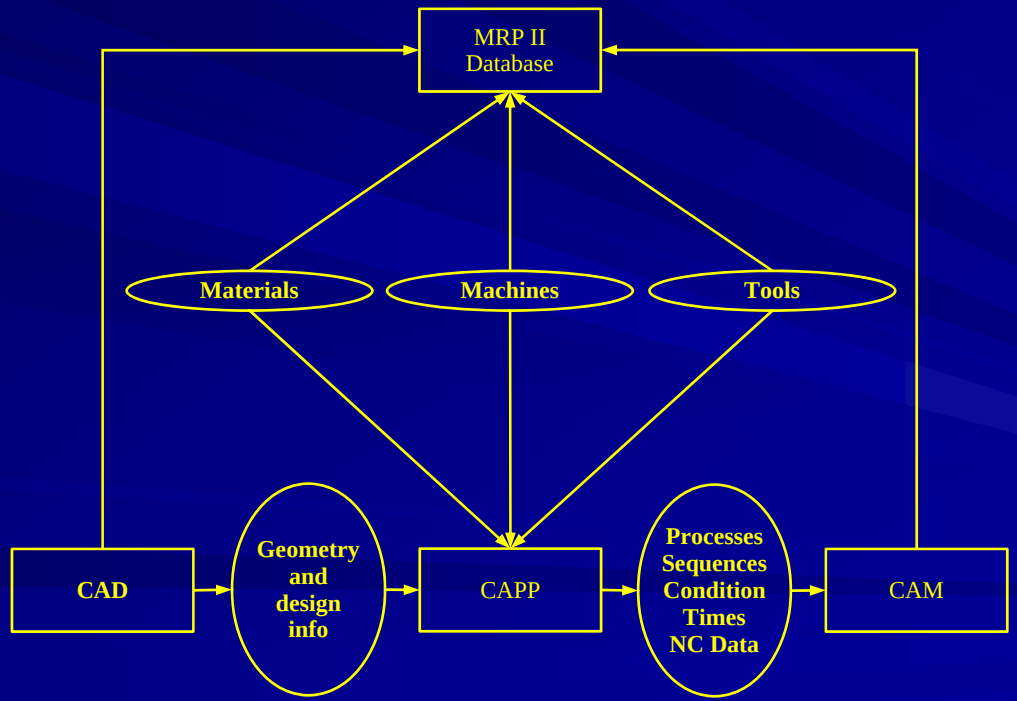
- ***Computational Fluid Dynamics*** using 3D mesh and simplified Navier-Stokes equations to predict fluid flow
- ***Finite Element Analysis*** for analysing materials for structural characteristics, thermal performance and electromagnetic fields
- ***One-dimensional fluid analysis*** for predicting the flow of a fluid around circuits, e.g. pipes
- Often ***integrated in advanced CAD*** **systems**



Computer Aided Process Planning (CAPP) Systems

Process Planning activities determine the necessary ***manufacturing processes and their sequence*** in order to produce a given part **economically** and **competitively**

CAPP ***aim at automating process planning tasks*** so that the process plans are generated consistently



Ssemakula, M.E. (1990). Process planning system in the CIM environment, Computers and Industrial Engineering, 19/1-4, 452-456

Computer Aided Manufacturing (CAM) and NC

CNC Machining was one of the most important developments for manufacturing technologies in the 20th century, allowing for **Mass Production** of consumer products and **Flexibility** **in** cases of specialized parts

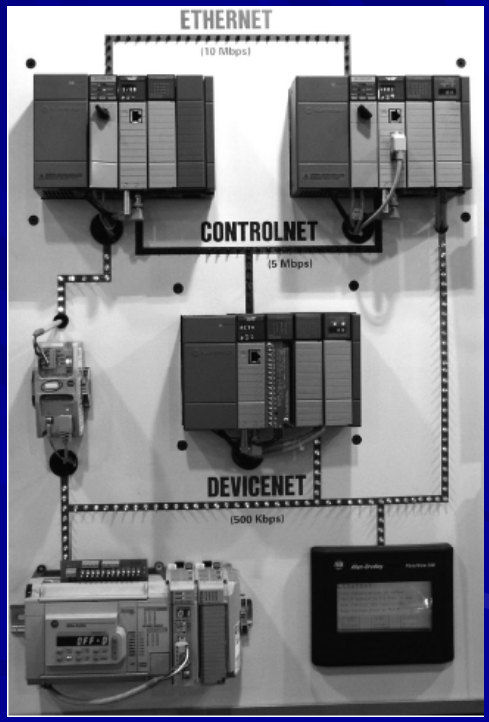
- Most CAD/CAM systems are capable of generating CNC tool paths, providing interactive graphic animations to verify the NC part program
- The planning of the machining process, including decisions regarding roughing and finishing, number of passes and sequence of paths, relies on the programmer's knowledge
- CAM systems of the future will be able to use downloaded tooling geometry, and to make use of vendor-approved manufacturing processes for the tooling

Manufacturing Control

Automation in production systems is considered as a way to improve flexibility

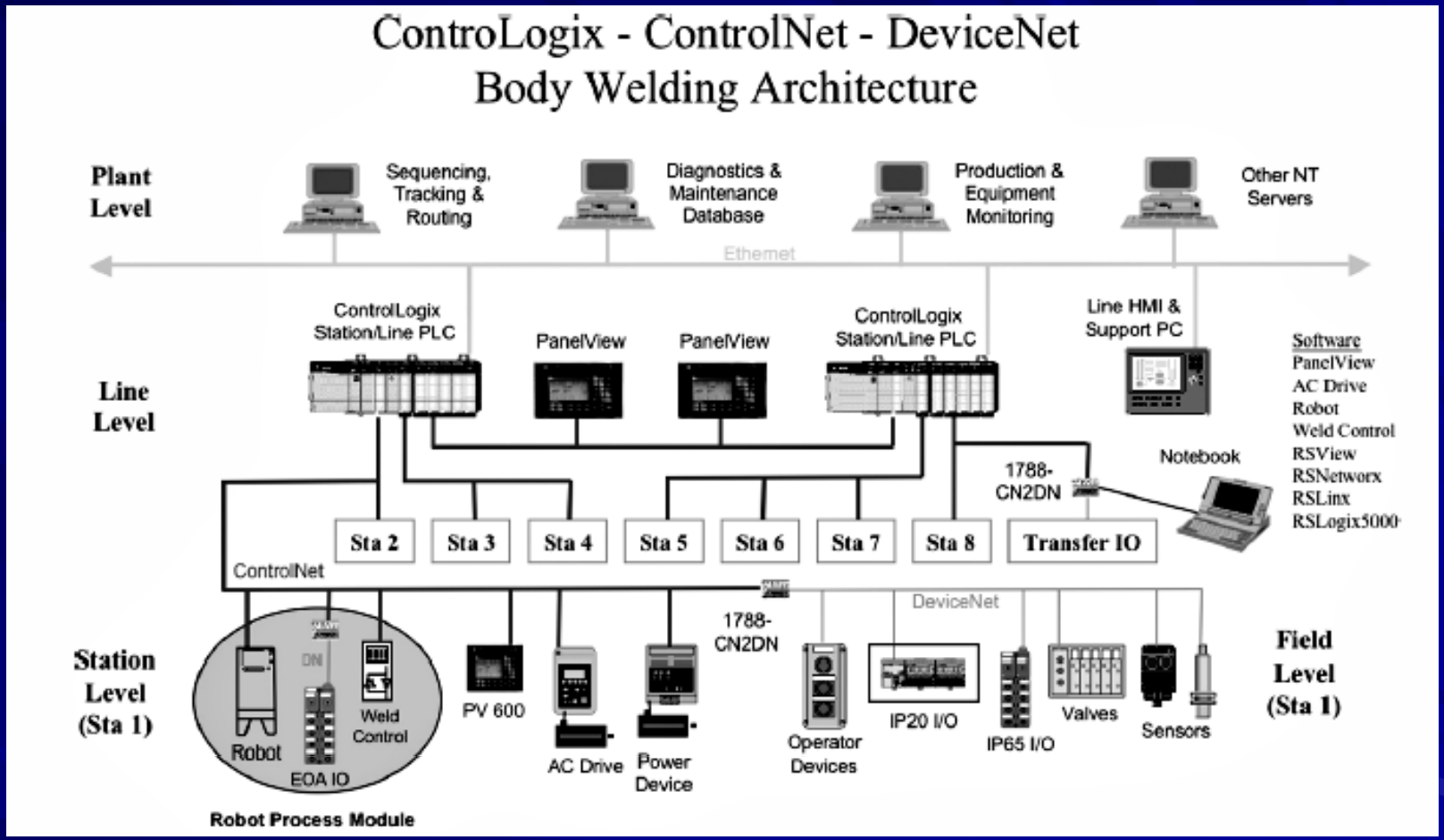
Huge steps have been made from the pneumatic transmission of process data and pneumatic controllers to PLCs of the **70's**, the multi-variable model-based predictive controllers of the **80's**, and the large – handling over 400 variables – controllers of the **90's**

- ***Smart sensors and actuators*** able to process information related to calibration, fault detection, diagnosis and others, appeared during the **1990's** and allowed the control of complex functions or processes
- ***New technologies (802.11, RFID)*** enable the wireless transmission of data even in noisy industrial environments
- ***Integration of Control Systems with CAD / CAM and Scheduling Systems*** as well as real-time control based on the distributed networking between sensors and control devices are key research topics



(Courtesy of Rockwell Automation, USA)

Manufacturing Control



*An example of a Rockwell Automation, Allen-Bradley developed **automotive body welding architecture**, with real-time distributed networking between sensors and management monitoring and control systems (Courtesy of Rockwell Automation, USA)*

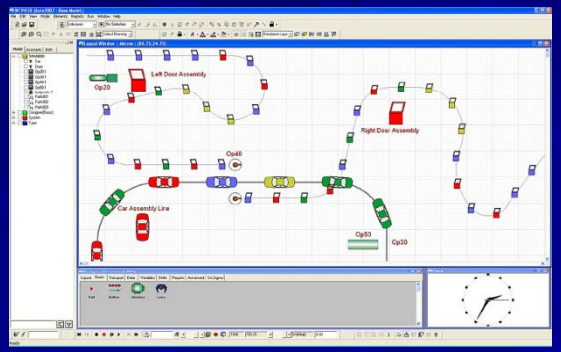
Simulation of Manufacturing Systems

Computer simulation is widely used technique in MFGs design, enabling ***decision makers and engineers to investigate the complexity of the systems*** and **how changes in the system configuration or in the operational policies** may affect the performance of the system / organization

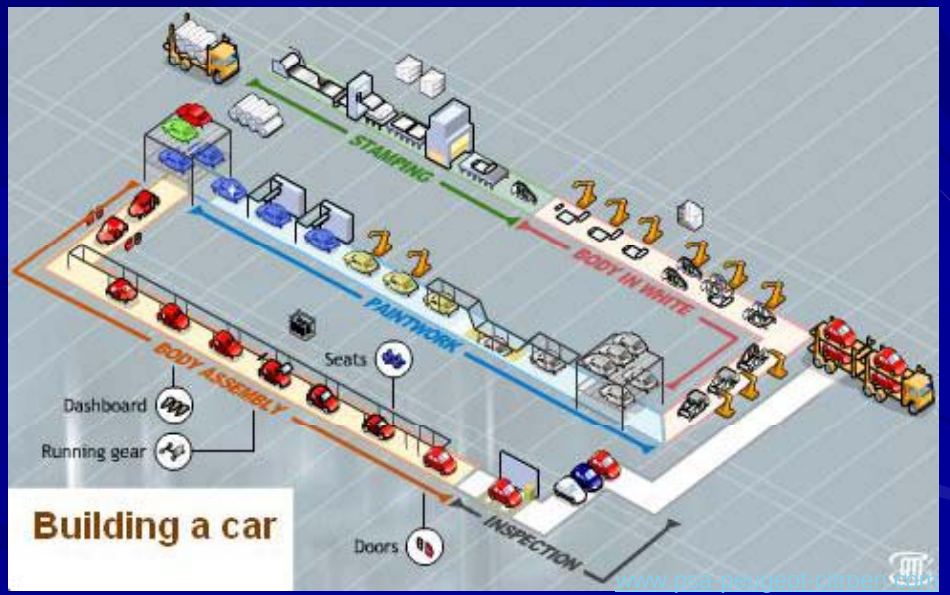
- Simulation Systems offer ***advanced visualization capabilities***
- ***Integration and interfaces*** **with other IT systems**
- ***Virtual Reality Applications*** for process simulation and verification
- ***Digital Human Simulation***, including motion capturing / modeling techniques
- ***Virtual Collaborative Environments***
- ***Ergonomics and safety***, employing prognostic and diagnostic tools (fault tree analysis, decision tools, risk assessment, discomfort evaluation)

Discrete Event Simulation

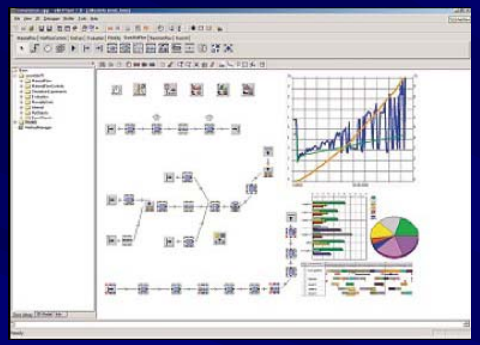
- **Main Research Areas**
  - Flexibility Assessment - Quantification
  - Change management and adaptability
  - Automotive assembly simulation
  - Cost modelling of assembly operations
  - Supply chain network flexibility

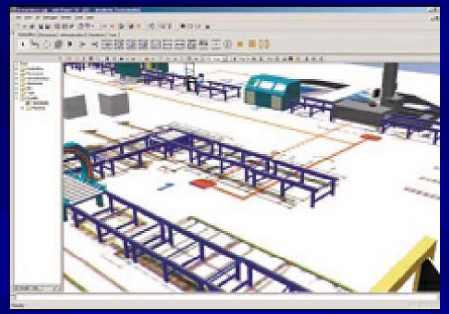


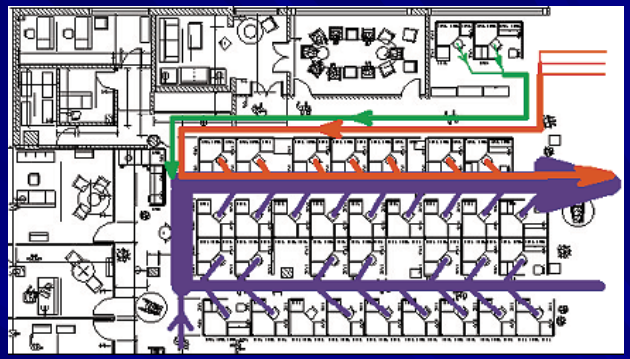
- **Tools**
  - ❑ Witness
  - ❑ Tecnomatix eM-Plant
  - ❑ iThink etc



Automotive Assembly Line Modelling





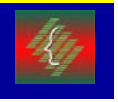


Discrete-event Simulation and 3d Modelling

- Final Assembly
- BodyInWhite (BIW)
- Production departments (Punching department, etc)

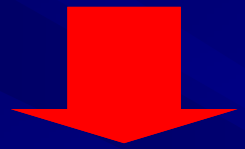
ERP and Manufacturing Optimization

- The **Material Requirements Planning (MRP)** systems in the **1970's**, were complemented with additional capabilities, leading to closed-loop MRP SW Systems
- The ***Manufacturing Resources Planning (MRP II)*** systems of the **1980's** incorporated the financial accounting and management systems
- The **MRP II** concept was expanded to incorporate all resource planning and business processes of the entire enterprise (e.g. human resources, project management, product design, materials and capacity planning)
- The **ERP** **concept** was devised to integrate smaller, otherwise isolated, systems so that real-time resource accountability across all business units and facilities of a corporation could be maintained
- **Real-time** manufacturing scheduling and production planning
- **E-business** and **E-work** applications
- **Supply Chain Management (SCM)**



ERP Implementations

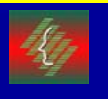
ERP implementations usually prove to be huge and complex projects, often resulting in cost and schedule overruns - Statistics show that (Standish Group, 1998)



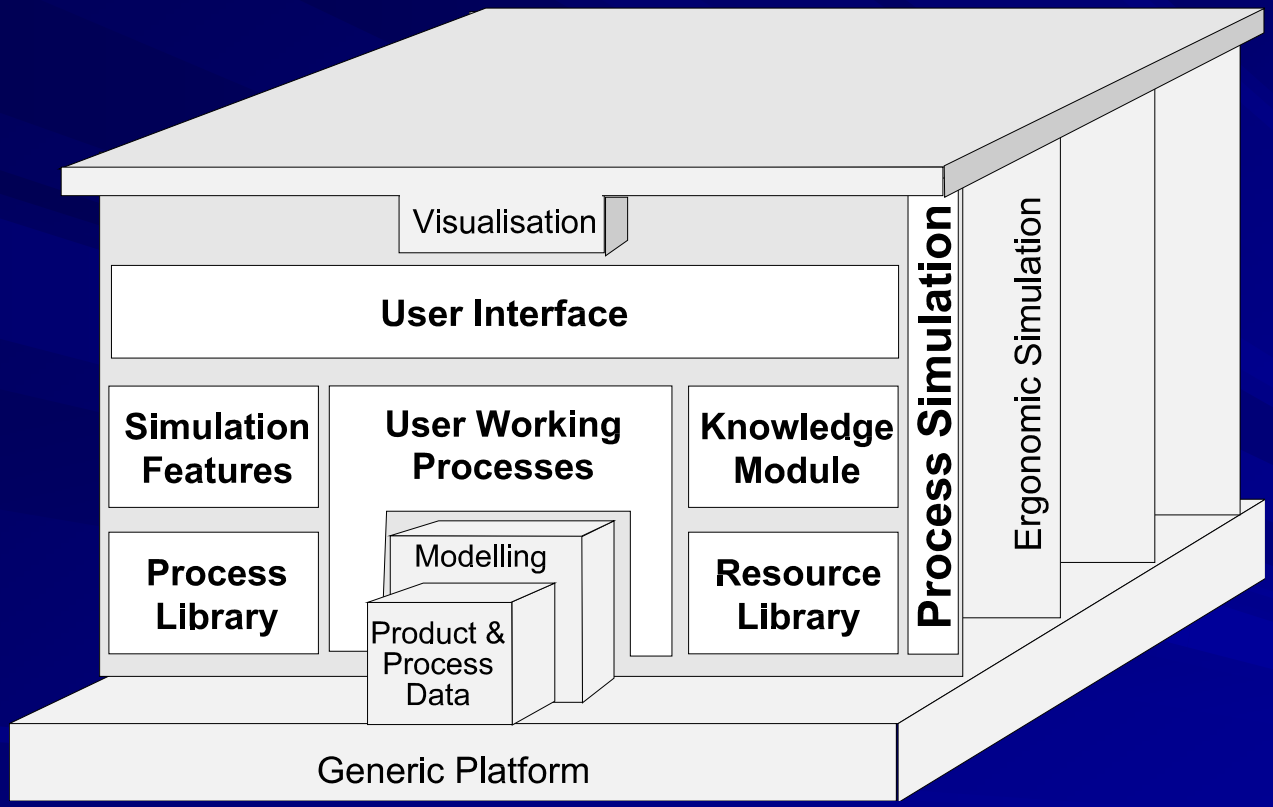
- Only ***10% of ERP*** implementations **are considered fully successful** in terms of functionality, estimated costs and time frames
- The **average** ***cost overruns reach a 178%***
- The **average** ***schedule overruns reach a 230%***
- The **average** ***implemented functionality reaches a 41%*** of what originally designed / desired

RECENT DEVELOPMENTS

- Academic research
- Industrial practices
- Software systems



Digital Mock-up Process Simulation



An **integrated framework** applied to the automotive & aerospace industry

Mavrikios, D., and G. Chryssolouris, "Digital Mock-up Process Simulation", Proceedings of the 3rd Aero days Post-Conference, Nouvelle Revue d' Aeronautique et d' Astronautique, Toulouse, France, (No 2, 1998), pp. 29-33.

Digital Mock-up Process Simulation

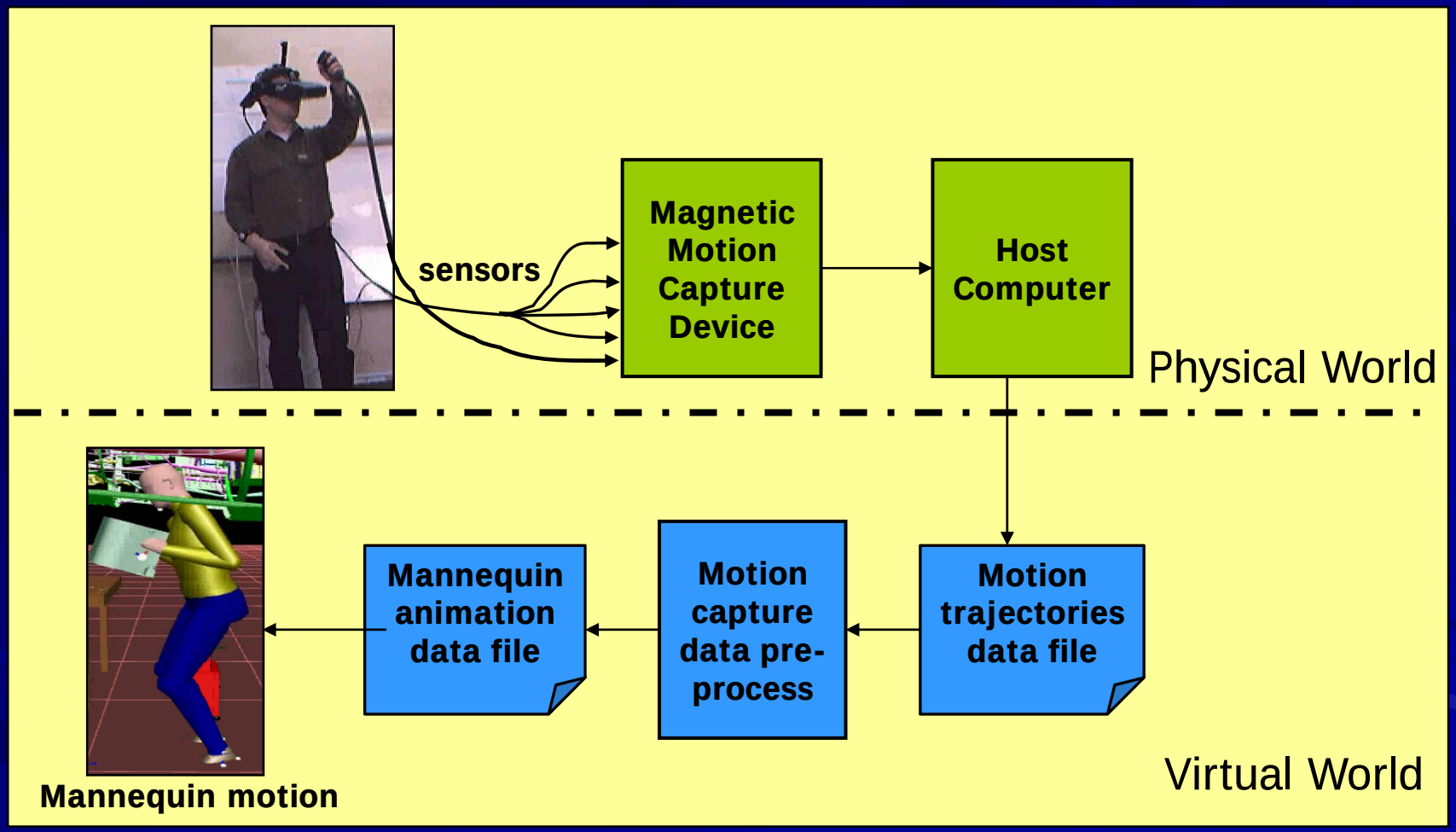
A Human Centric
DMU model

Human Model

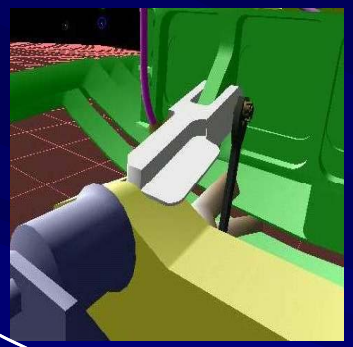
Product Model

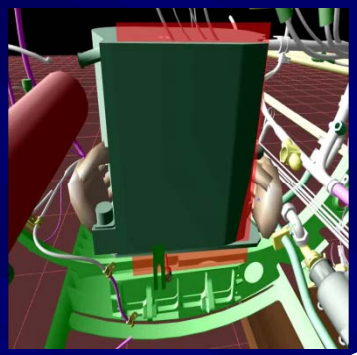
Process Model

Maintainability Analysis and Human Simulation



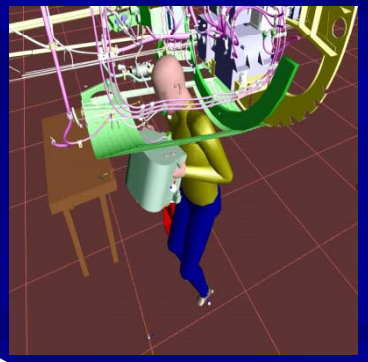
Maintainability Analysis and Human Simulation

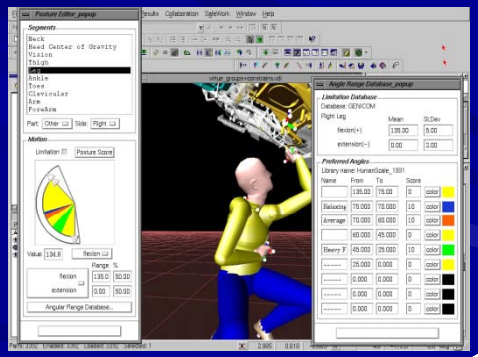




… from *immersive* planning using a **Real Human**

… to *desktop* analysis for a range of human populations using **Digital Mannequins**





Chryssolouris, G., D. Mavrikios, D. Fragos, V. Karabatsou and K. Alexopoulos, "A hybrid approach to the verification and analysis of assembly and maintenance processes using Virtual Reality and Digital Mannequin technologies", In Virtual Reality and Augmented Reality Applications in Manufacturing (ISBN 1-85233-796-6), Nee A.Y.C. and Ong S.K. (eds), Springer-Verlag, London (2004).

Virtual Manufacturing

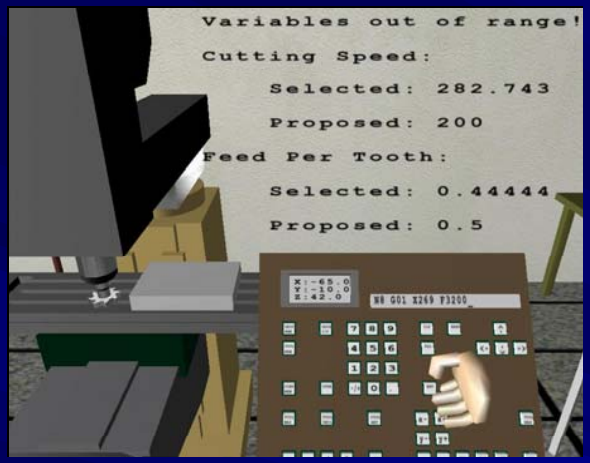
Immersive VR environments for *Process Analysis*

Machining

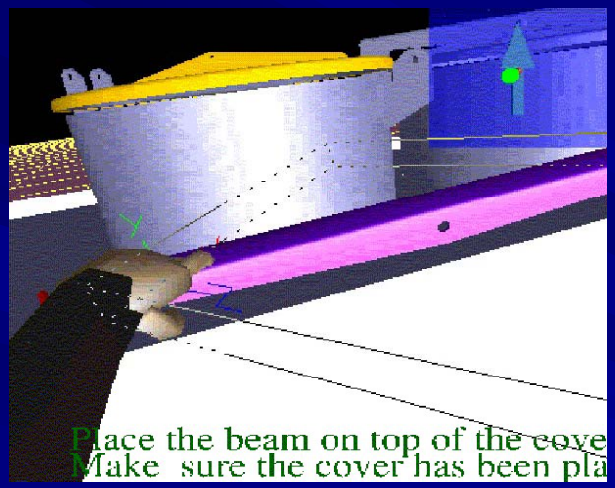
Assembly

Chryssolouris, G., D. Mavrikios, D. Fragos, V. Karabatsou and K. Pistiolis, "A Novel Virtual Experimentation Approach to Planning and Training for Manufacturing Processes-The Virtual Machine Shop", International Journal of Computer Integrated Manufacturing, (Vol.15, No.3, 2002), pp. 214-221.

Virtual Manufacturing

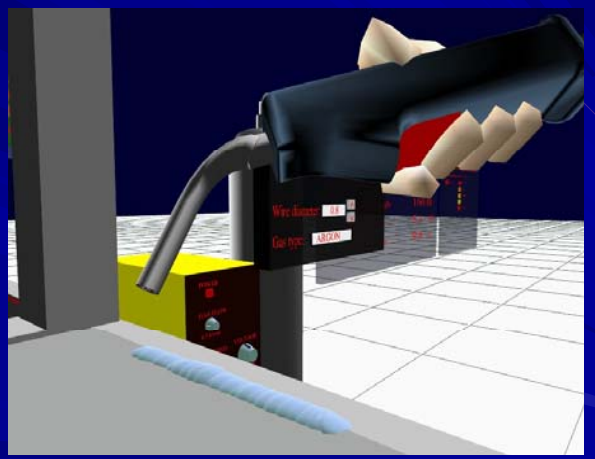


Machining



Assembly

Immersive VR environments for *Process Training*

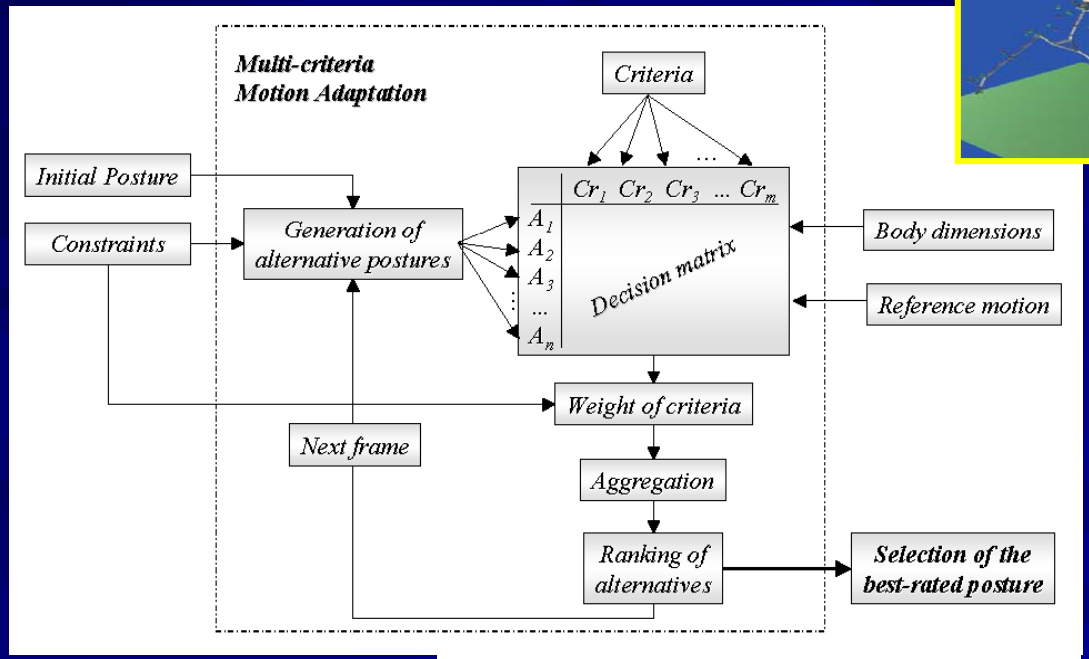


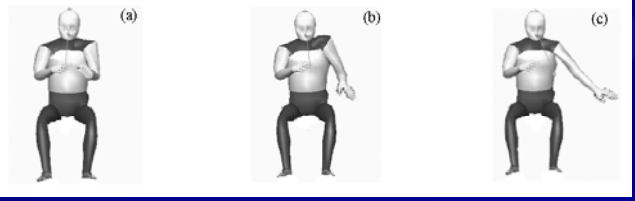
Welding

Mavrikios, D., V. Karabatsou, D. Fragos and G. Chryssolouris, "A Prototype Virtual Reality Based Demonstrator for Immersive and Interactive Simulation of Welding Processes", International Journal of Computer Integrated Manufacturing, (Vol.19, No.3, 2006), pp. 294-300.

Human Motion Modelling

Reference motion



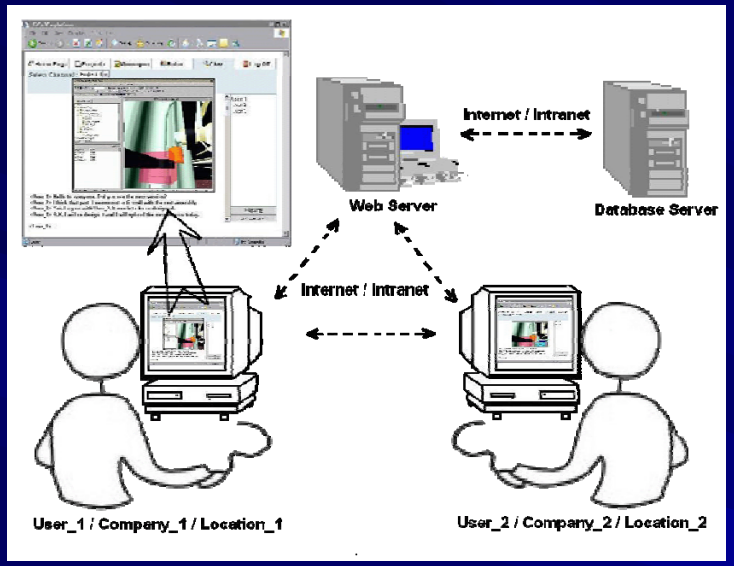


Adapted motion

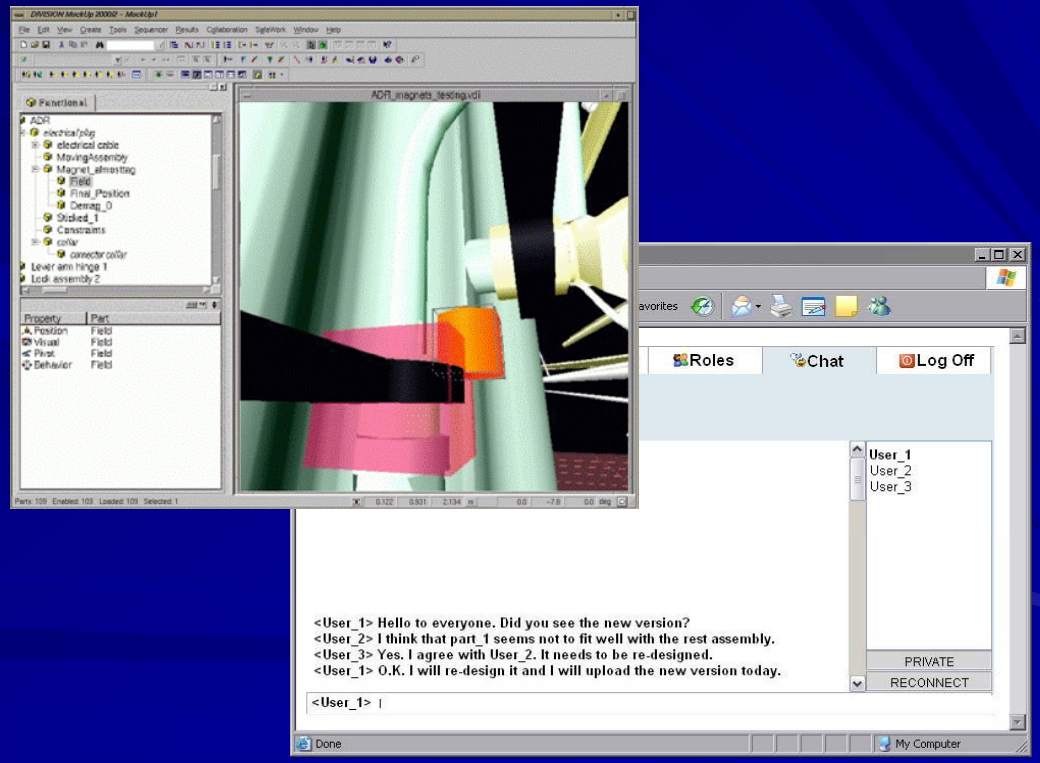
Alexopoulos, K., D. Mavrikios, M. Pappas, E. Ntelis, and G. Chryssolouris, "Multi-Criteria Upper Body Human Motion Adaptation", International Journal of Computer Integrated Manufacturing, (Vol.20, No.1, 2007), pp. 57-70

Multi-criteria upper body human motion adaptation

Collaborative Design and Manufacturing



Web-based
interaction & collaborative
product / process assessment



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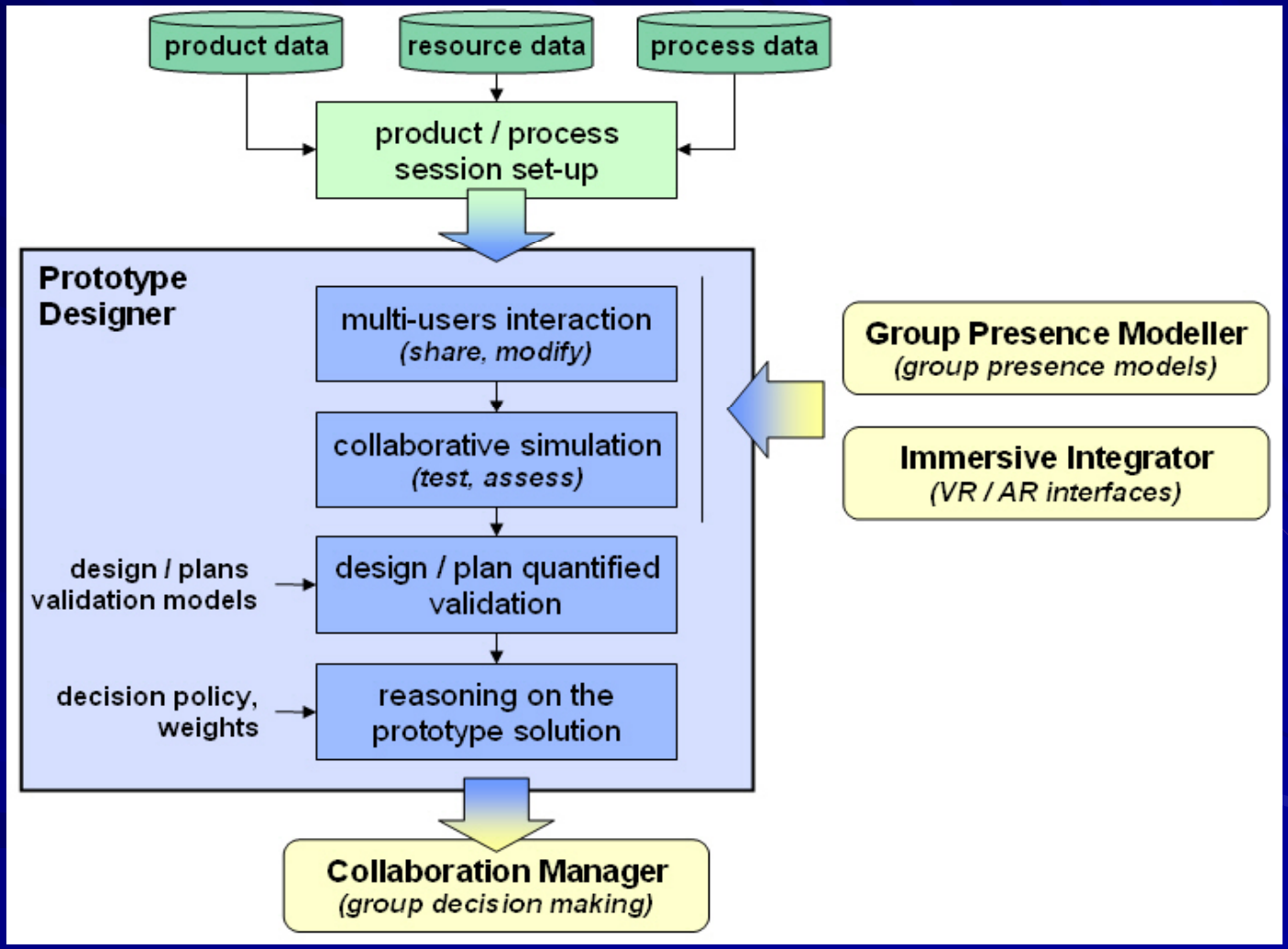
Collaborative Design and Manufacturing

Integrating VR & Decision Making in CME



Mavrikios, D., M. Pappas, V. Karabatsou and G. Chryssolouris, "A new concept for collaborative product & process design within a human-oriented Collaborative Manufacturing Environment", The Future of Product Development: Proceedings of the 17th CIRP Design Conference (ISBN 978-3-540-69819-7), Krause F.-L. (ed), Springer-Verlag, London (2007), pp. 301-310.

Human Simulation in Assembly

Methods
- Vision analysis
- Reachability tests
- Accessibility tests
- Posture analysis
- Carry analysis
- Push/pull analysis
- Lift analysis (NIOSH)
- …

Critical assembly tasks
- overhead-assembling
- operations to be done almost “blind“
- heavy and/or frequent lifting activities
- operations with high level of hand-flexibility
- operations which demand bending or torsion of the upper body
- operations including a longer period of continuous static work

Concept / rough designs of assembly process

Ergonomic evaluation of alternative designs for the assembly process

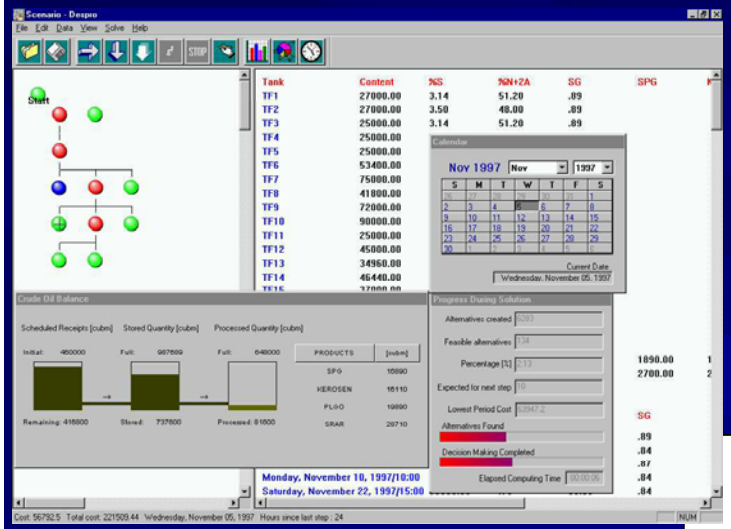
Detailed design of assembly process

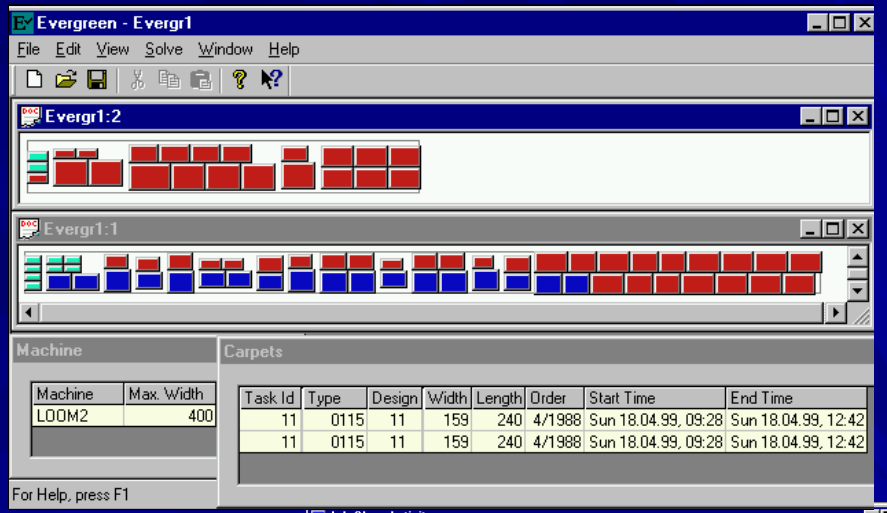
Re-design recommendations

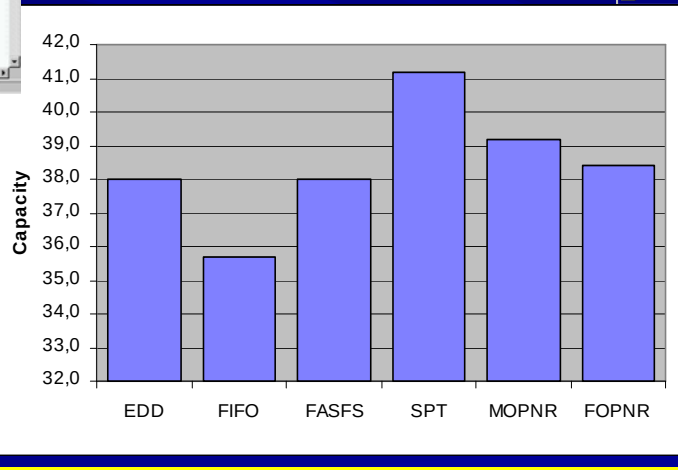
MY-CAR IP “*Flexible assembly processes for the car of the third millennium*” - FP6-026631-2

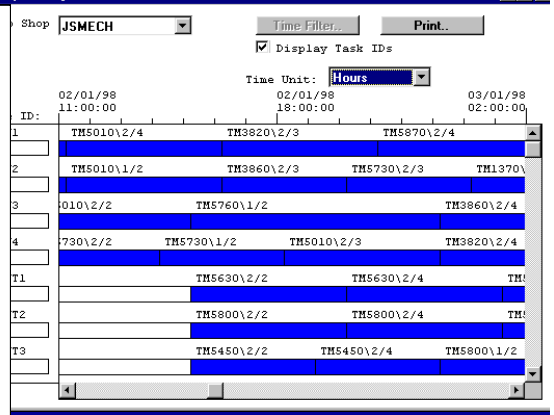
Real-time manufacturing scheduling and production planning

- Multi Criteria Decision Making
- Performance indicators
- Gantt Chart





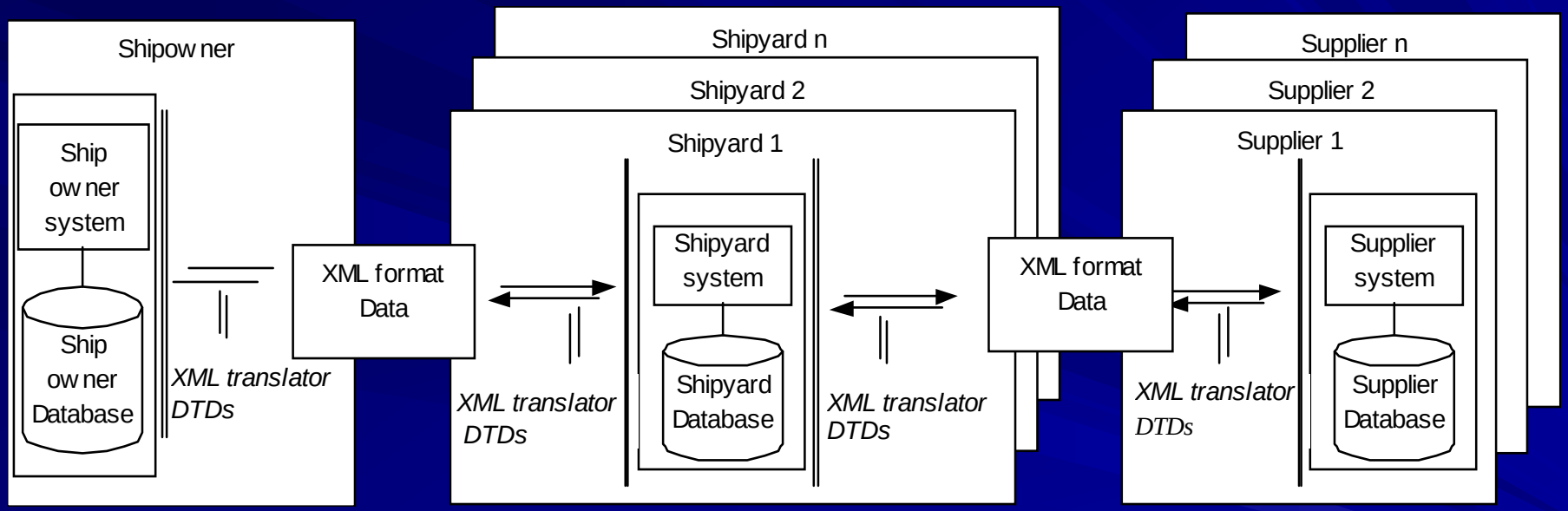




G. Chryssolouris, N. Papakostas and D. Mourtzis,
"Refinery Short-term scheduling with tank farm, inventory and distillation management: an integrated simulation-based approach",
European Journal of Operations Research, (Vol.166, 2005), pp. 812-827

Supply Chain Management XML DATA FLOW

-Communication in Production Network

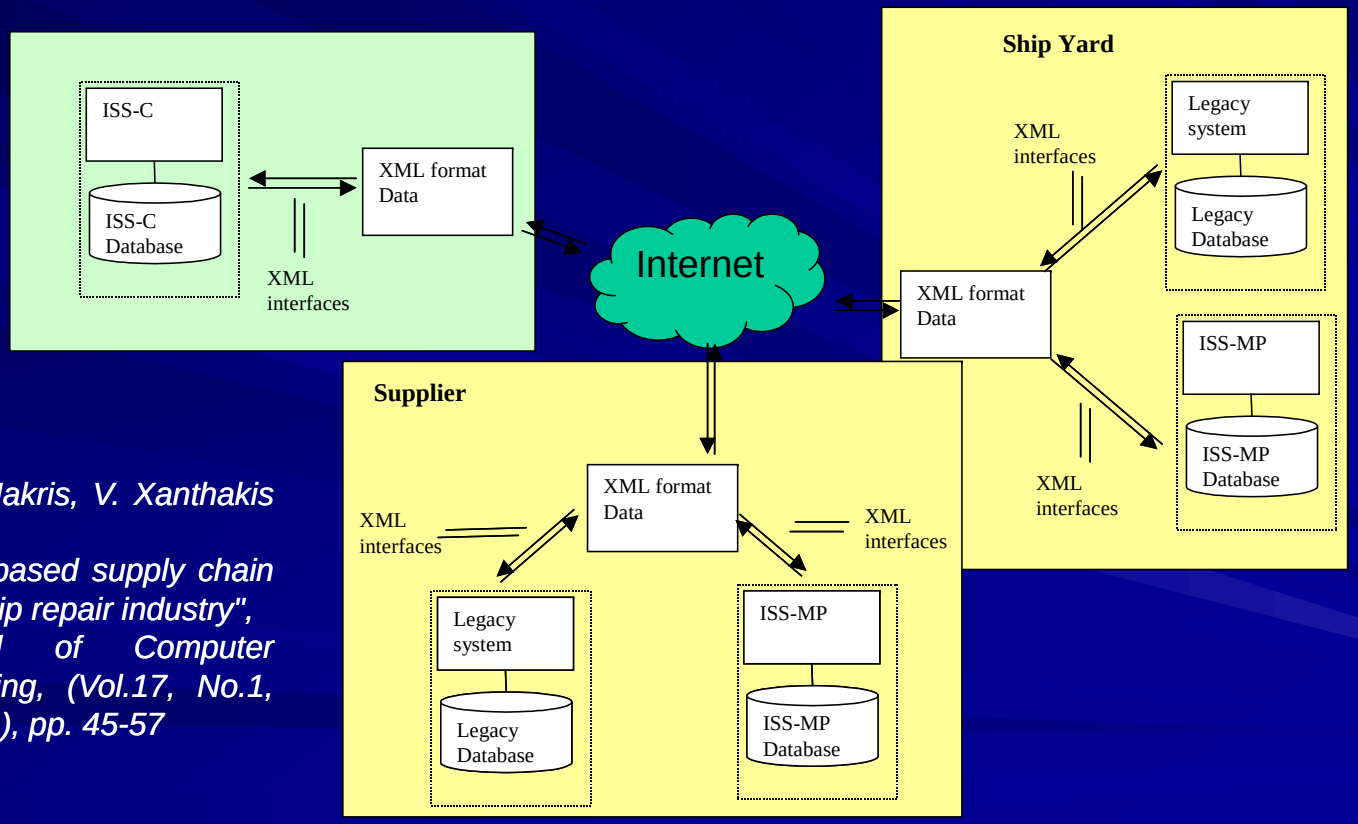


S. Makris, V. Xanthakis, D. Mourtzis and G. Chryssolouris,
"On the information modelling for the electronic operation of supply chains: A maritime case study",
Robotics and Computer-Integrated Manufacturing, (Vol.24, No.1, 2008), pp. 140-149

D. Mourtzis, "An integrated system for managing ship repair operations",
International Journal of Computer Integrated Manufacturing, (Vol. 18, No 8, 2005), pp. 721-733

Supply Chain Management

HETEROGENEOUS APPLICATIONS INTEGRATION
- XML based integration
- Application in shipyards enterprise

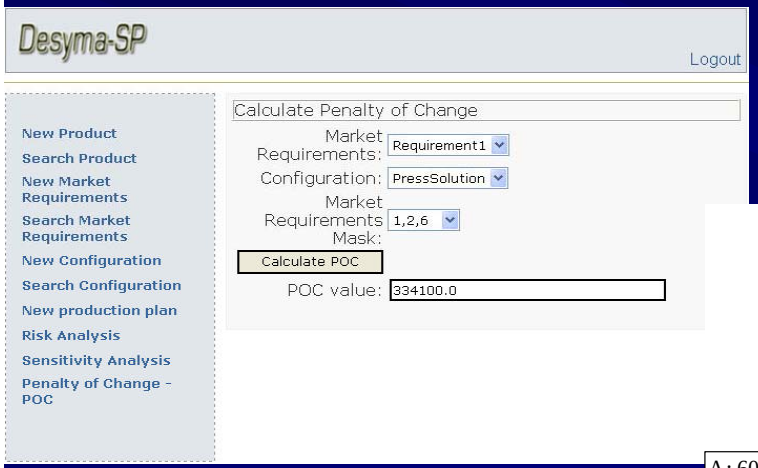


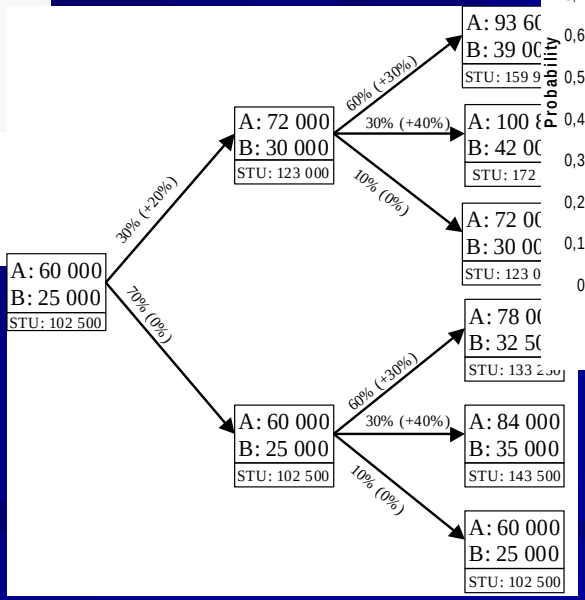
G. Chryssolouris, S. Makris, V. Xanthakis and D. Mourtzis
"Towards the internet based supply chain management for the ship repair industry", International Journal of Computer Integrated Manufacturing, (Vol.17, No.1, January-February 2004), pp. 45-57

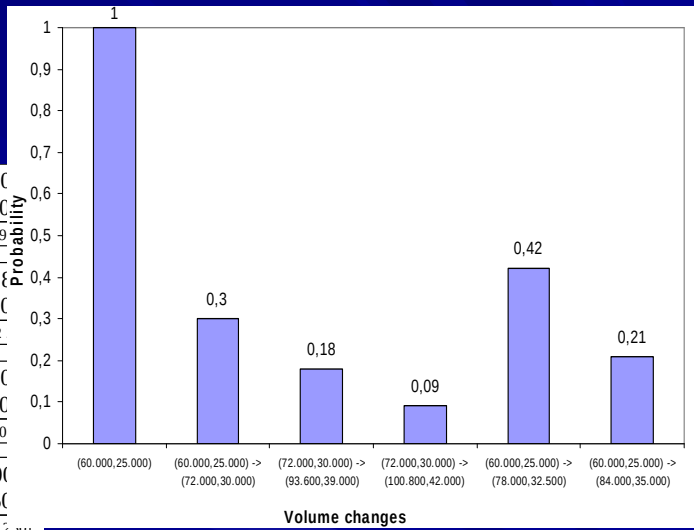
Flexibility in Manufacturing Systems

PENALTY OF CHANGE

- Flexibility measurement / quantification
- Inclusion of flexibility in decision making



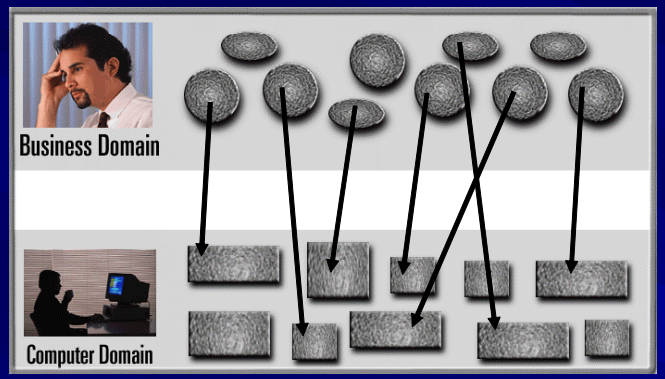


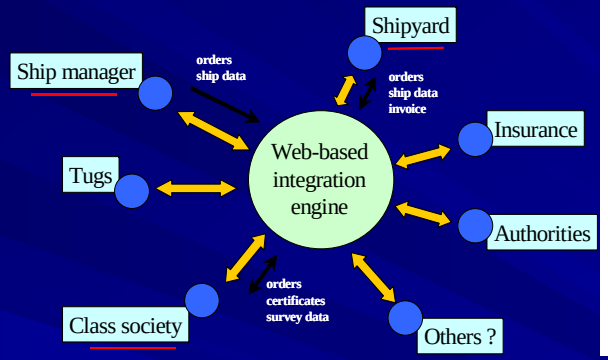


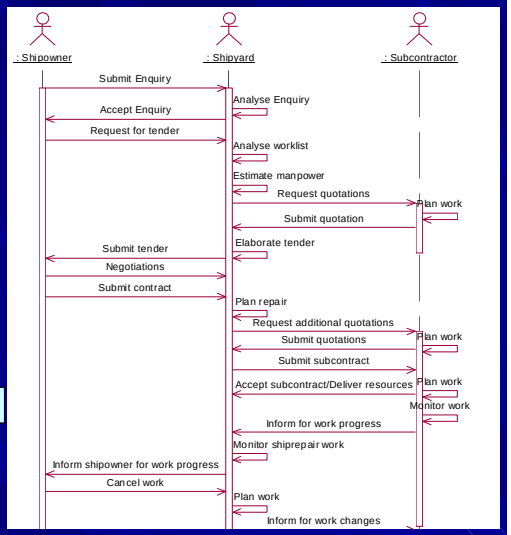
K. Alexopoulos, D. Mourtzis, N. Papakostas, and G. Chryssolouris,
"DESYMA - Assessing flexibility for the lifecycle of manufacturing systems",
International Journal of Production Research, (Vol. 45, No. 7, 2007), pp. 1683–1694

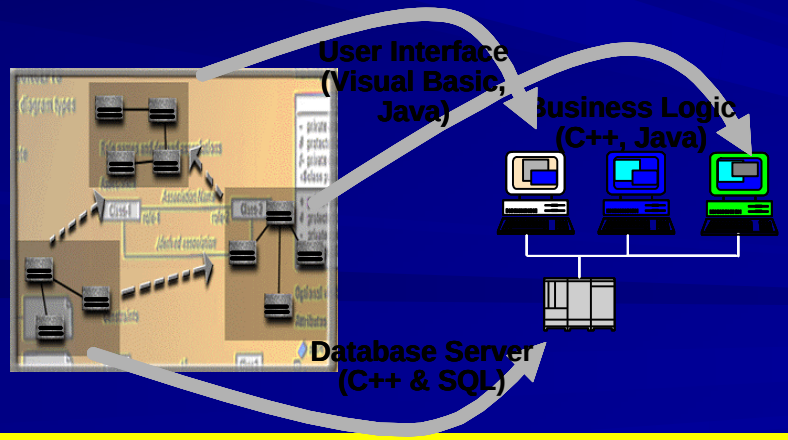
Visual modeling of business processes
SHIPYARDS VIRTUAL ENTERPRISE

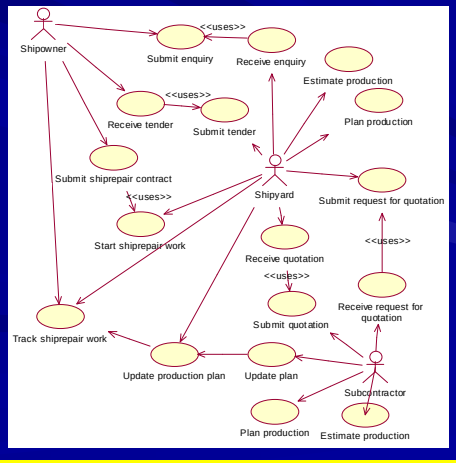
- *Business rules modeling*
- *Companies collaboration*











OUTLOOK: Digital Manufacturing

Definition:

- *Digital manufacturing is **the ability to describe every aspect of the design-to-manufacture process digitally** — using tools that include digital design, CAD, Office documents, PLM systems, analysis software, simulation, CAM software and so on*

Major benefit:

- Data created in any department are reusable in a different department

Interesting converging trends:

- Increased emphasis on innovation and successful, rapid, new product launches
- Shorter product lifecycles
- On-demand production driven by customer orders
- The need to accelerate time-to-value in line changeovers reducing costs

Digital Manufacturing

Data integration and availability is the key to success - Integrated and consistent data management is required through all stages of Digital Manufacturing sequence which involves:

- Product development
- Process planning
- Factory layout
- Ergonomics
- Robotics and machining
- Quality control
- Factory simulation

G. Chryssolouris, D. Mavrikios, N. Papakostas, D. Mourtzis, G. Michalos and K. Georgoulias,
"Digital Manufacturing: History, Perspectives and Outlook",
Journal of Engineering Manufacture, (Vol. 222, 2008), pp. 1-12

Digital Manufacturing

Benefits:

- ✓ Shortened product development
- ✓ Early validation of manufacturing processes
- ✓ Faster production ramp up and faster time-to-market
- ✓ Reduced manufacturing costs and improved product quality
- ✓ Enhanced product knowledge dissemination
- ✓ Reduction of errors
- ✓ Increase flexibility

Applications:

- ➢ Computer Aided Design (CAD) Systems
- ➢ Computer Aided Engineering (CAE) Systems
- ➢ Computer Aided Process Planning (CAPP) Systems
- ➢ Computer Aided Manufacturing (CAM) and NC Machining
- ➢ Virtual Reality Applications and Digital Human Simulation
- ➢ Enterprise Resource Planning (ERP)
- ➢ Discrete event simulation

Thank you for your attention !!!

For any more information:

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