§ 1 What is Industrial Automation?

1.1 Definition of Several Basic Terms

1.2 Degree of Automation and Computer Deployment

1.3 Automation of Technical Products and Technical Plants

1.4 Components of an Industrial Automation System

1.5 Levels of Process Management and Automation Functions

1.6 Technical Systems

1.7 Graphical representation of Technical Processes

1.8 Effects of Industrial Automation on People, Society and Environment

Chapter 1 - Learning targets

- to know what Industrial Automation is
- to understand what a real-time system is
- to know what is meant by the „degree of automation“
- to recognize the different kinds of computer deployment
- to be able to differ between product automation and plant automation
- to know the components of an industrial automation system
- to know the different levels of an industrial automation system and their requirements
- to be able to classify processes in technical systems
- to know the different kinds of graphical representation of technical processes
- to become aware of the responsibility of an automation engineer

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Definition 1:

A **technical process** is a process during which material, energy or information is altered in its state. This modification of state can imply the transition from an initial state to a final state.

process, procedure, event

transformation

transport **storage**

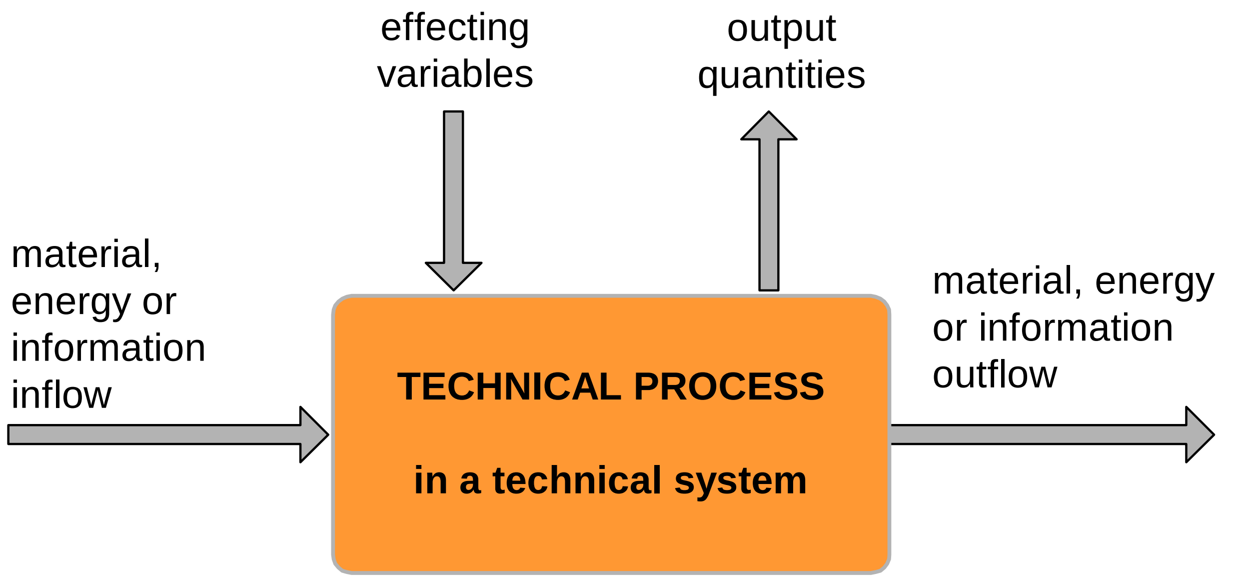
Technical process means flow of material, energy or information

Examples

Initial State	Technical Process	Technical System	Final State
Low ambient temperature	Heating of a house	Oil-fueled heating system	Higher ambient temperature
Dirty laundry	Washing process	Washing machine	Fresh laundry
Unsorted parcels	Transportation and distribution processes	Parcel distribution system	Parcels sorted by destinations
Energy of fossil or nuclear fuels	Energy transformation and energy generation processes	Power plant	Electric energy
Parts to be stored	Storage process	High bay warehouse	Parts compiled for commissions
Train at location A	Traffic process	Train	Train at location B
Monomere substance	Chemical reaction	Chemical reactor	Polymeric substance
Untested device	Test process	Test laboratory	Tested device
Parts without a drill-hole	Drilling process	Drilling machine	Parts with drill-hole
Pollutants	Pollution monitoring	System for air pollution monitoring	Information on pollution concentrations are indicated in monitoring center

Definition 2: DIN 66201

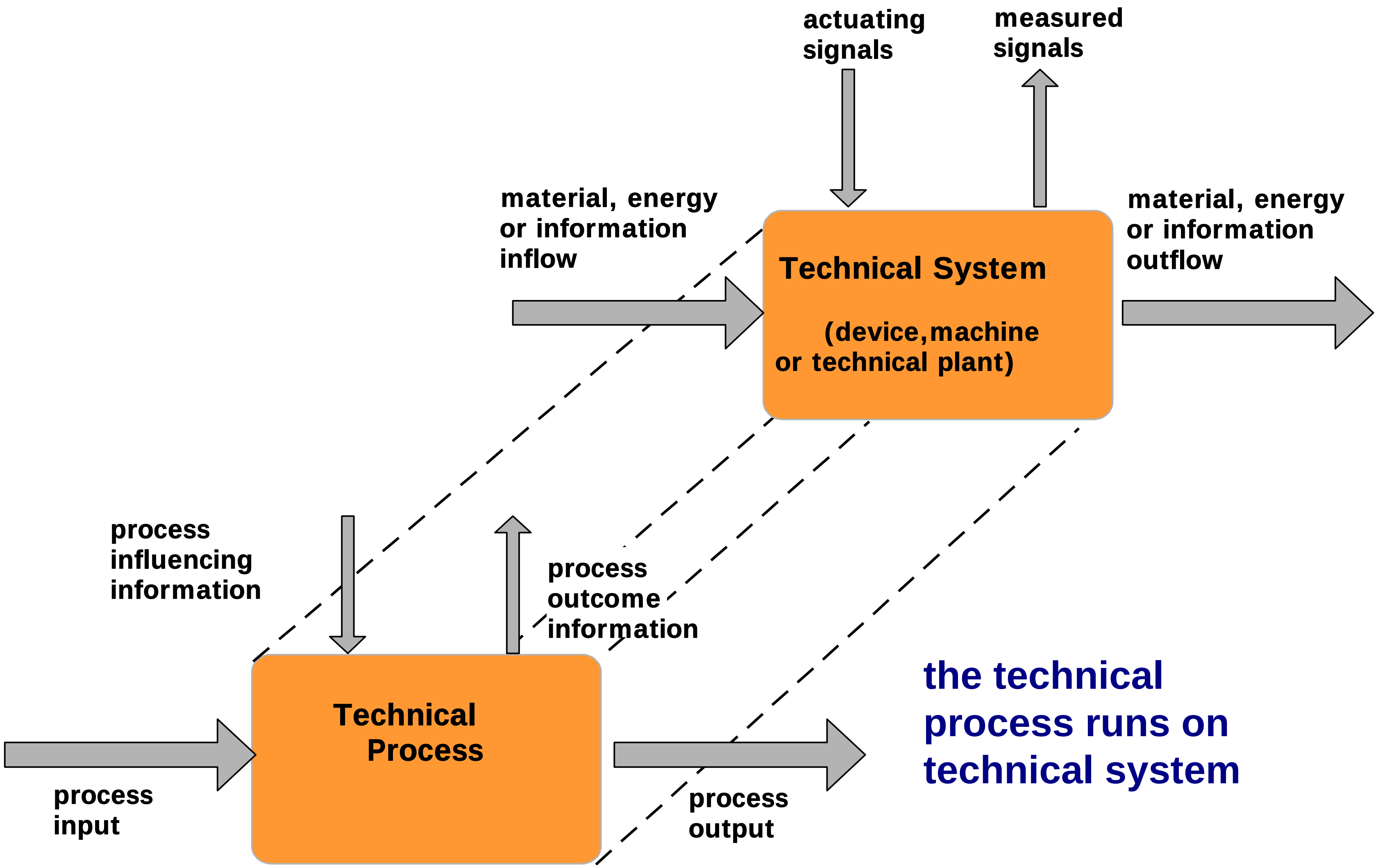
A process is the entirety of all interacting processes within a system that transforms and stores material, energy or information.
A **technical process** is a process in which its physical parameters are recorded and influenced by **technical means**.



– from simple to highly complex **washing machine, power plant**

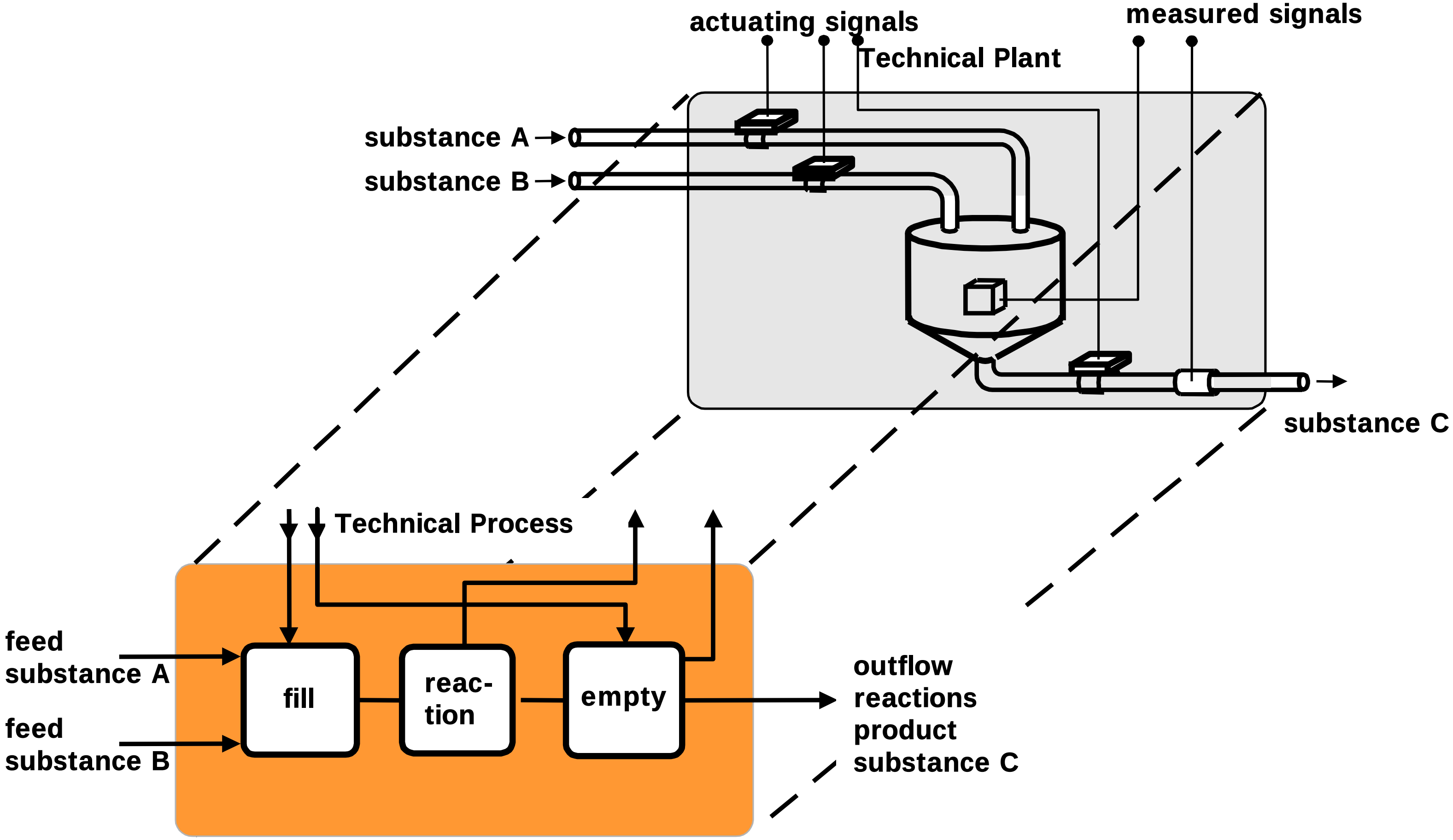
– different partial processes are combined to an overall process **car with automotive electronics**

Technical system with technical process



the technical process runs on technical system

Example



- technical plant: chemical reactor
- technical process: 3 sub-processes (fill, reaction, empty)

Industrial automation

= process + automation

automat

= independently operating technical systems

cigarette vending machine

ticket vending machine

automation

= to enable machines, installations and facilities to operate independently

office automation,

traffic automation,

railway automation,

industrial automation

Industrial automation

= the automation of a technical process

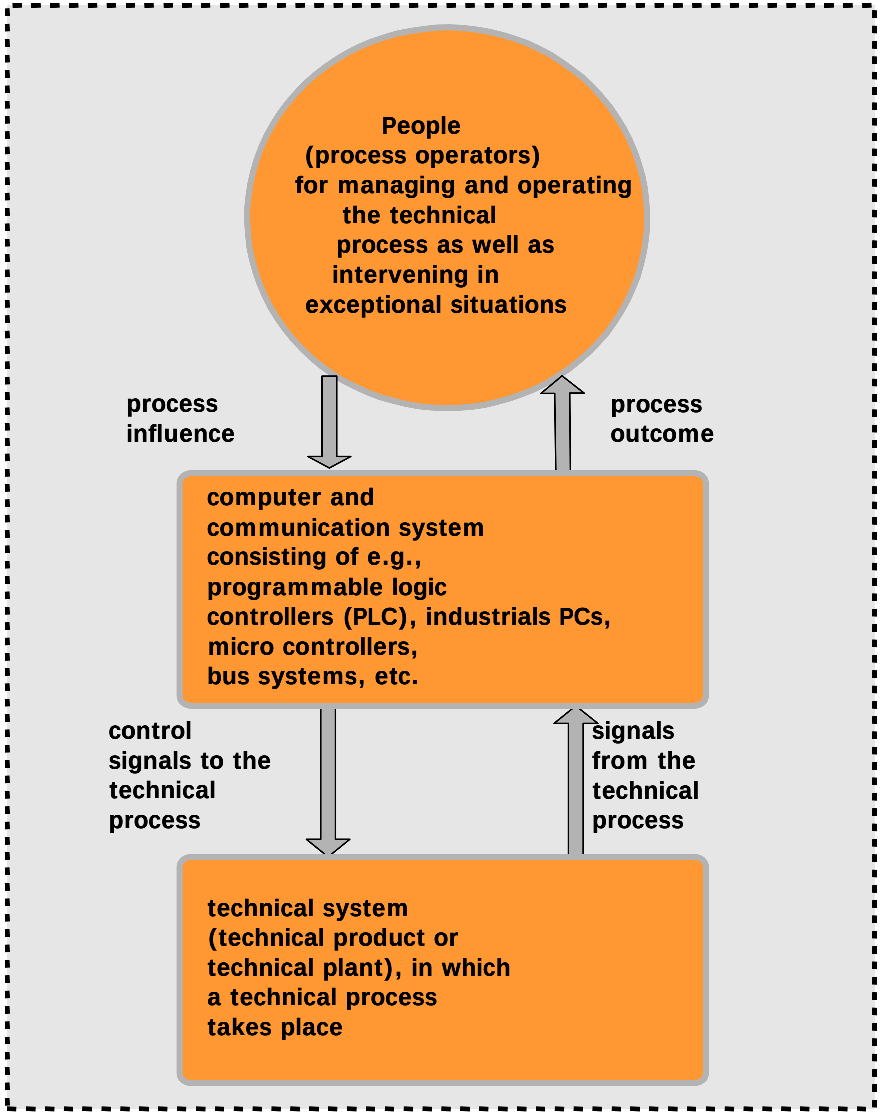
Industrial automation system

= technical system with technical process

+ computer and communication system

+ process operators

Structure of an industrial automation system



Industrial automation system

– Goal is the automation of operations in the technical process with the help of appropriate information processing units

– Human operators only place requests on the operating results

automation of the technical process in the foreground

Process control system

– Goal is the management of the procedure of the technical process by human operators, supported by the automation of individual operations

– Managing refers to controlling and regulating

operation in the foreground

Process computer sciences

– Goal is an automation software system

– Real-time system

computer and communication system in the foreground

Definition: Real-time operation (DIN 44300)

Real-time operation is the operation of a computer system, in which programs required for the handling of incoming data are **in constant operation** so that the **processing results** are available within a **given period of time**.
This data may appear according to a random time distribution or at regular intervals.

Features of a real-time system

- Hardware/software system
- Data reception, data processing, data delivery to the process within a given time interval
- External events
- Processing priority

Real-time system allows real-time operation

Requirements on real-time systems

- **Timeliness**
  reaction right on time

not too soon, not too late

- **Simultaneousness**
  simultaneous reaction to various events

parallel processes

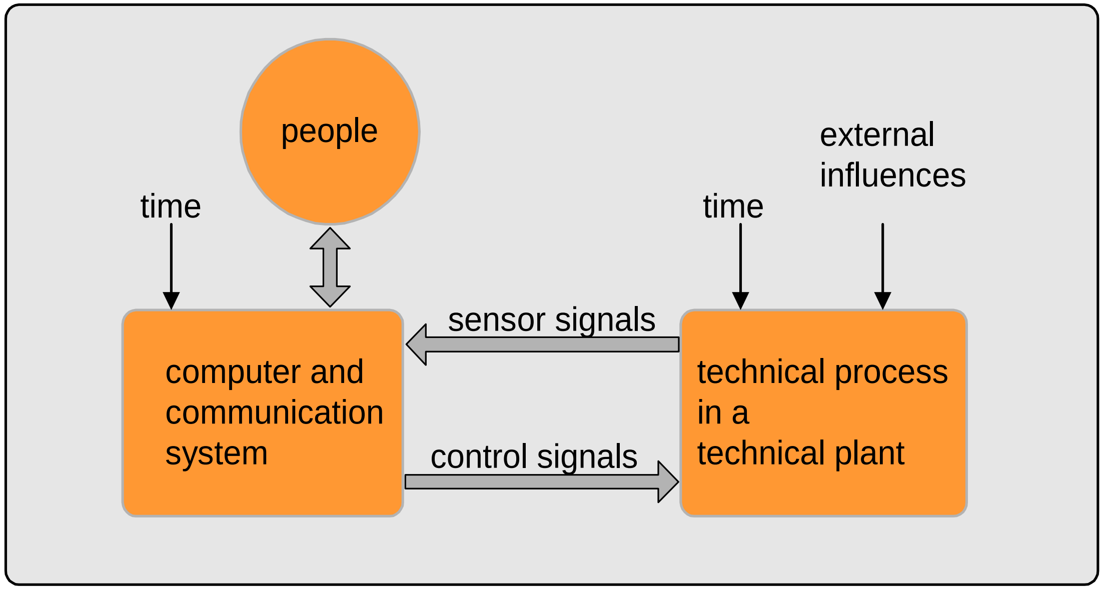
- **Dependability**
  reliable, safe, available

important reason for purchase

- **Predictability**
  all reactions must be predictable and deterministic

comprehensible in case errors occur

Industrial automation system as real-time systems



Features

Processors applicable in a process automation system are freely programmable digital processors (computers) that have to show mainly 3 features:

- Compliance of real-time operation requirements, that are: recording, processing and output of process data in a timely manner
- Possibilities for input/output of process signals (directly or via a communication system) for process connection
- Processing of numbers, characters and bits

In 60th and 70th years specific „process computers“
- Antiquated term, because differences have disappeared

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Degree of automation

The sense and benefit of an automation depends on the technical process (accessible / inaccessible) and the general conditions (economically reasonable / senseless). The degree of automation describes the extend of the processes included in the automation.

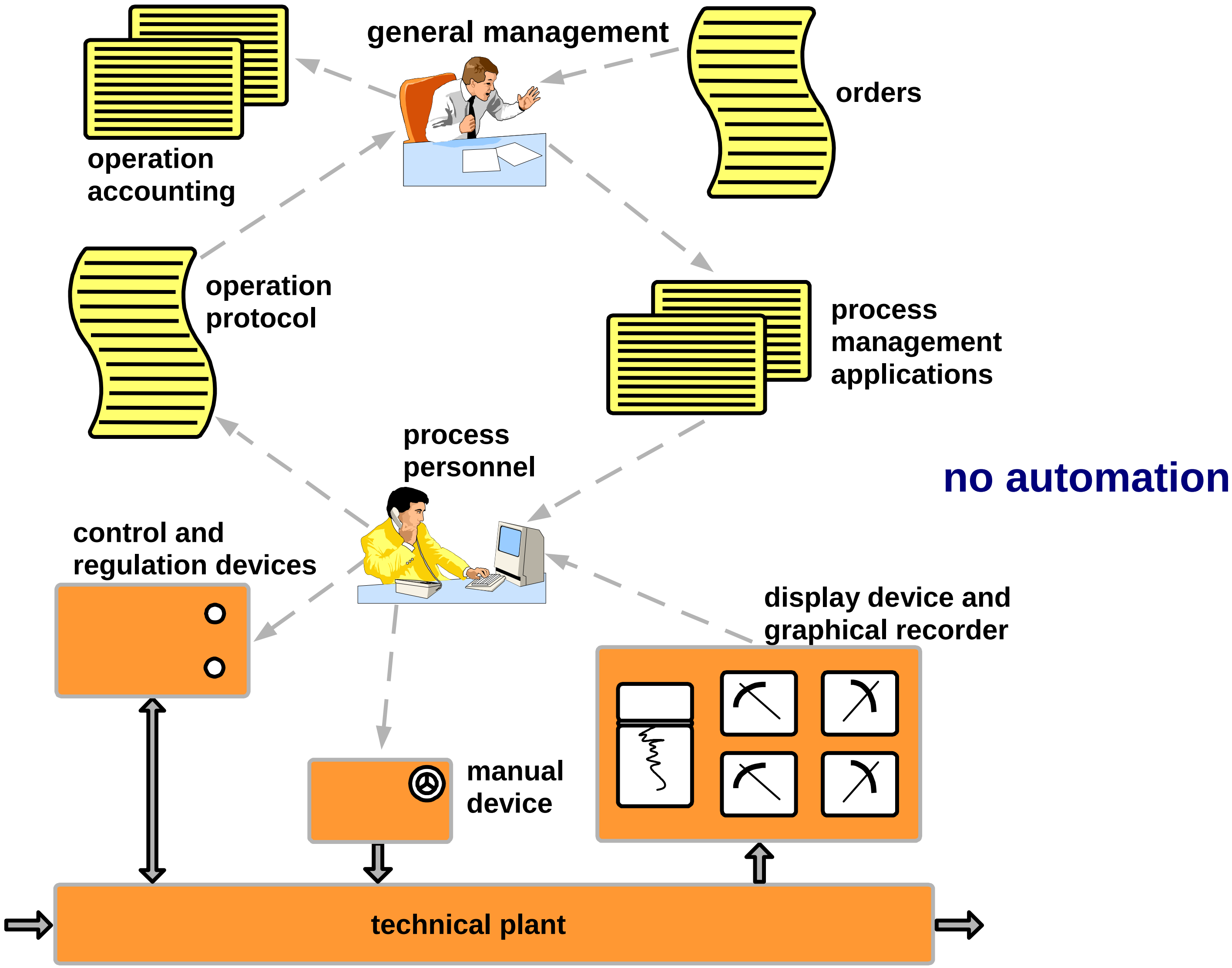
bandwidth: from zero up to fully automated operation

Caution! - Also with fully automated operation the human being can make interventions (set point default or malfunction)!

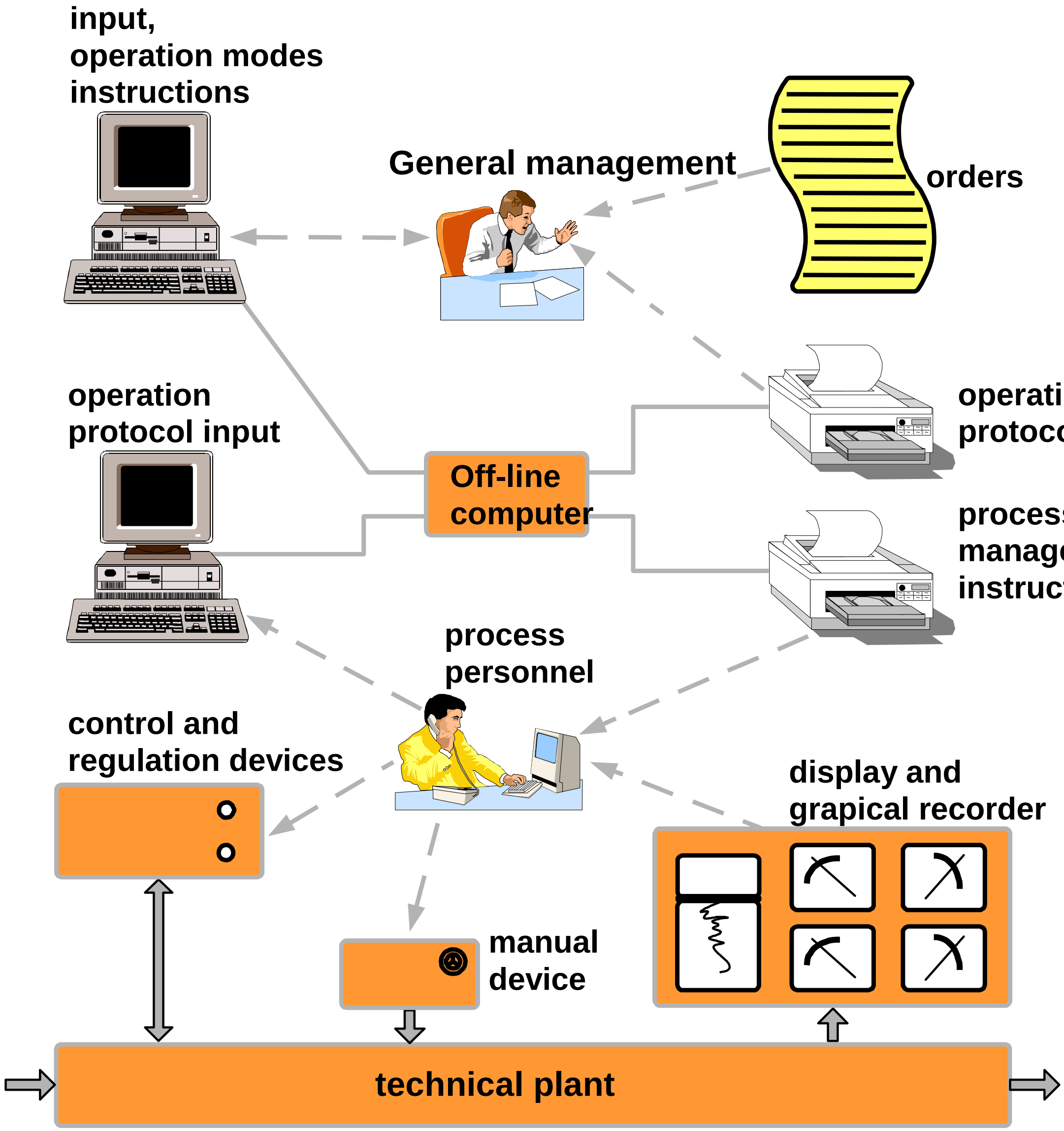
Types of operation

- Off-line operation (operation with indirect process connection) with the lowest degree of automation
- On-line / open-loop operation (open on-line operation) for a medium degree of automation
- On-line / closed-loop operation (closed on-line operation) for a high degree of automation

Operation without computer use

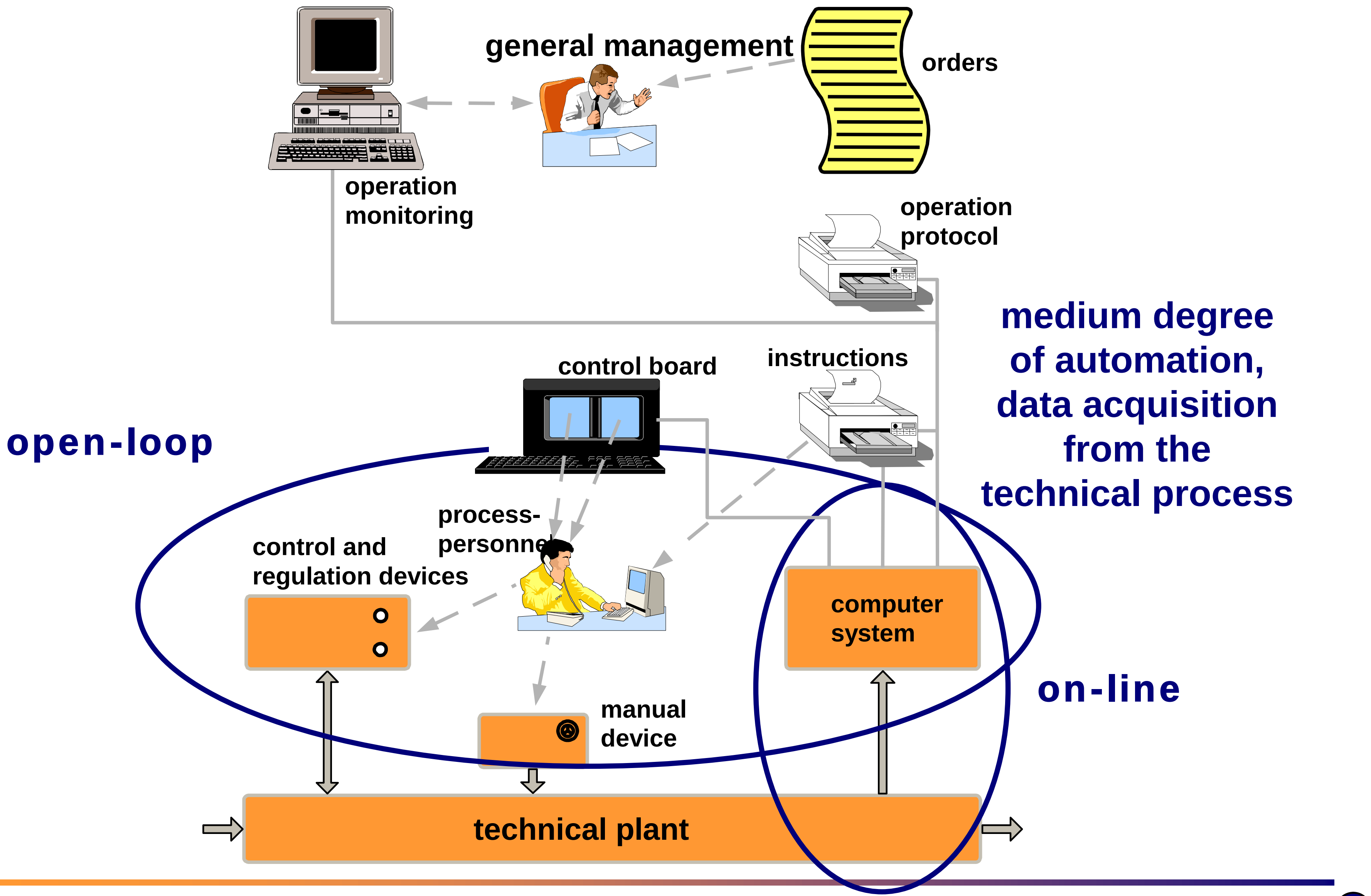


Off-line operation (indirectly connected operation)

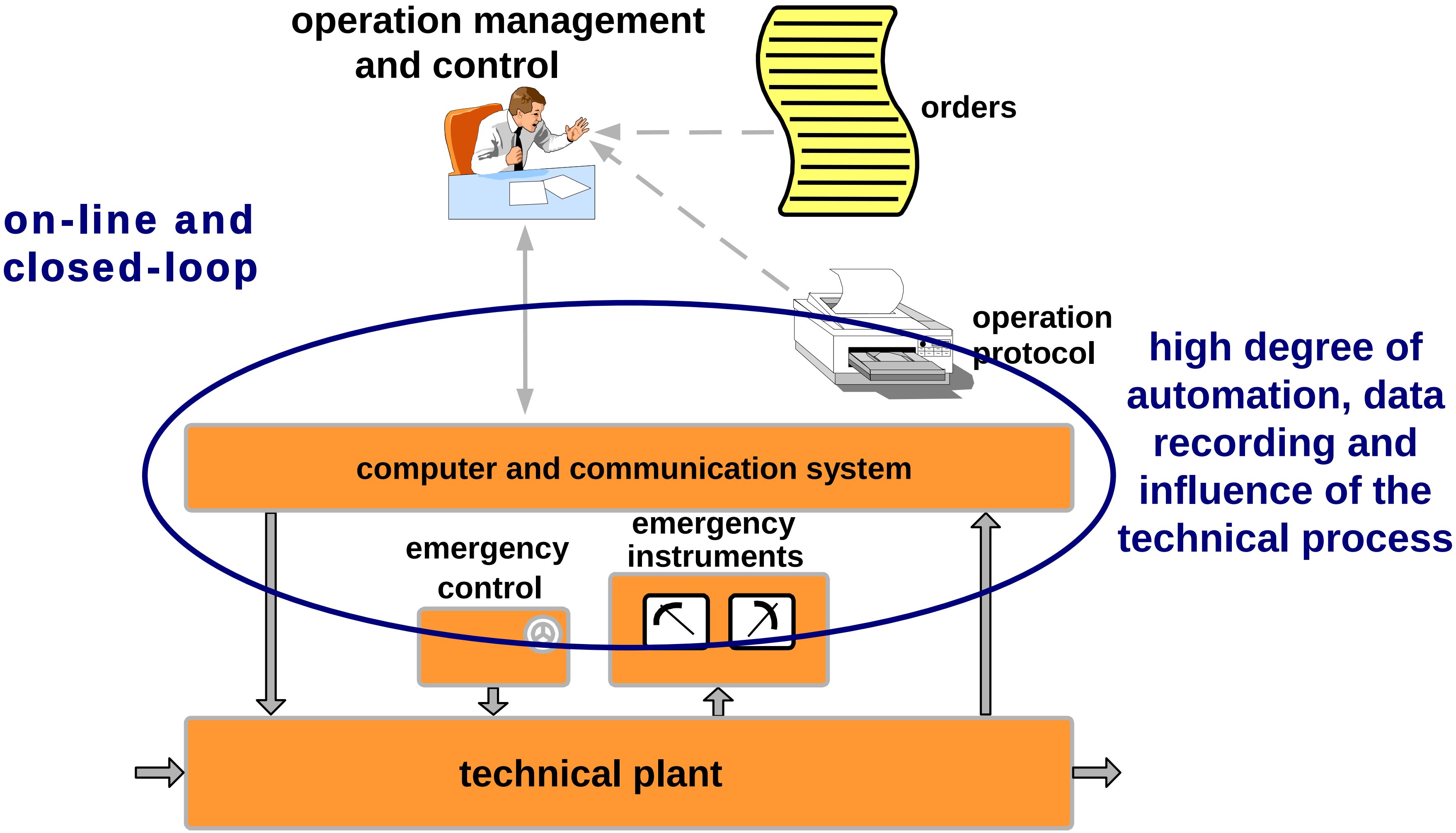


low degree of automation, no connection to the technical process

On-line / open-loop operation of a computer system



On-line- / closed-loop operation of a computer system



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Product automation

industrial automation systems, in which the technical process takes place within a device or within a single machine

large quantities

Plant automation

industrial automation systems, in which the technical process is composed of single partial processes that take place on greater, often geographically wide spread plants

unique systems

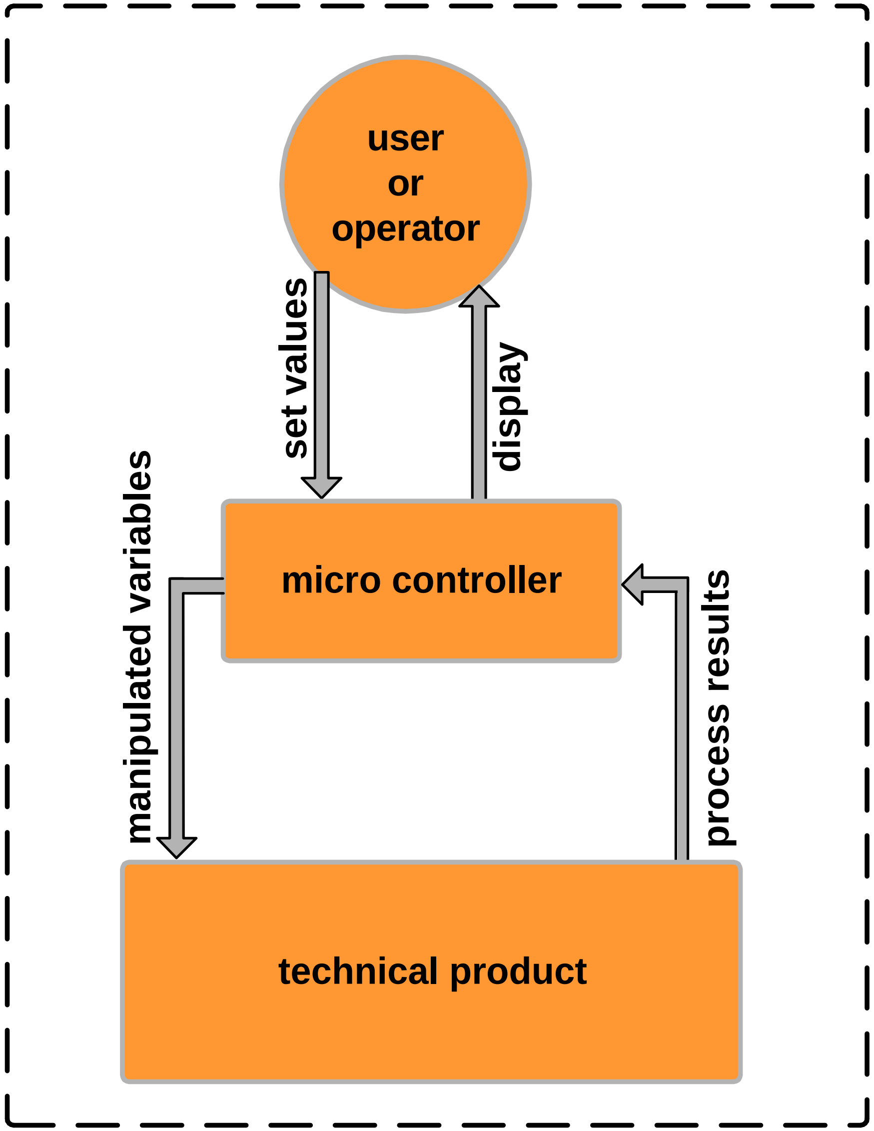
Examples

Examples of products in product automation	Examples of technical plants in plant automation
heating systems washing machines sewing machines kitchen appliances (e.g., dish washer, microwave, etc.) TVs, radios cameras alarm systems toys navigation systems answering machines musical instruments machine tools measuring devices automobiles with sub-systems: motor control, ABS, distance warning system, route planning, etc.	power plants (steam generators, turbines, generators) energy grid high bay warehouse parcel distribution installations chemical reactors process engineering installations steel production plants milling installations railway traffic system (long distance trains, commuter railways, metros) traffic light installations gas supply installations purification and water plants building system installations laboratories and test fields environmental measurement installations etc.

Characteristic criteria regarding product automation

- Technical process in a device or machine (embedded systems)
- Dedicated automation functions **simple**
- Automation computer in the form of a micro controller or PLC
- Few sensors and actuators
- Degree of automation 100%, on-line/closed-loop operation
- High quantities (serial or mass products)
- Engineering and software costs of inferior importance since they are distributed among large unit numbers

Structure with simple product automation

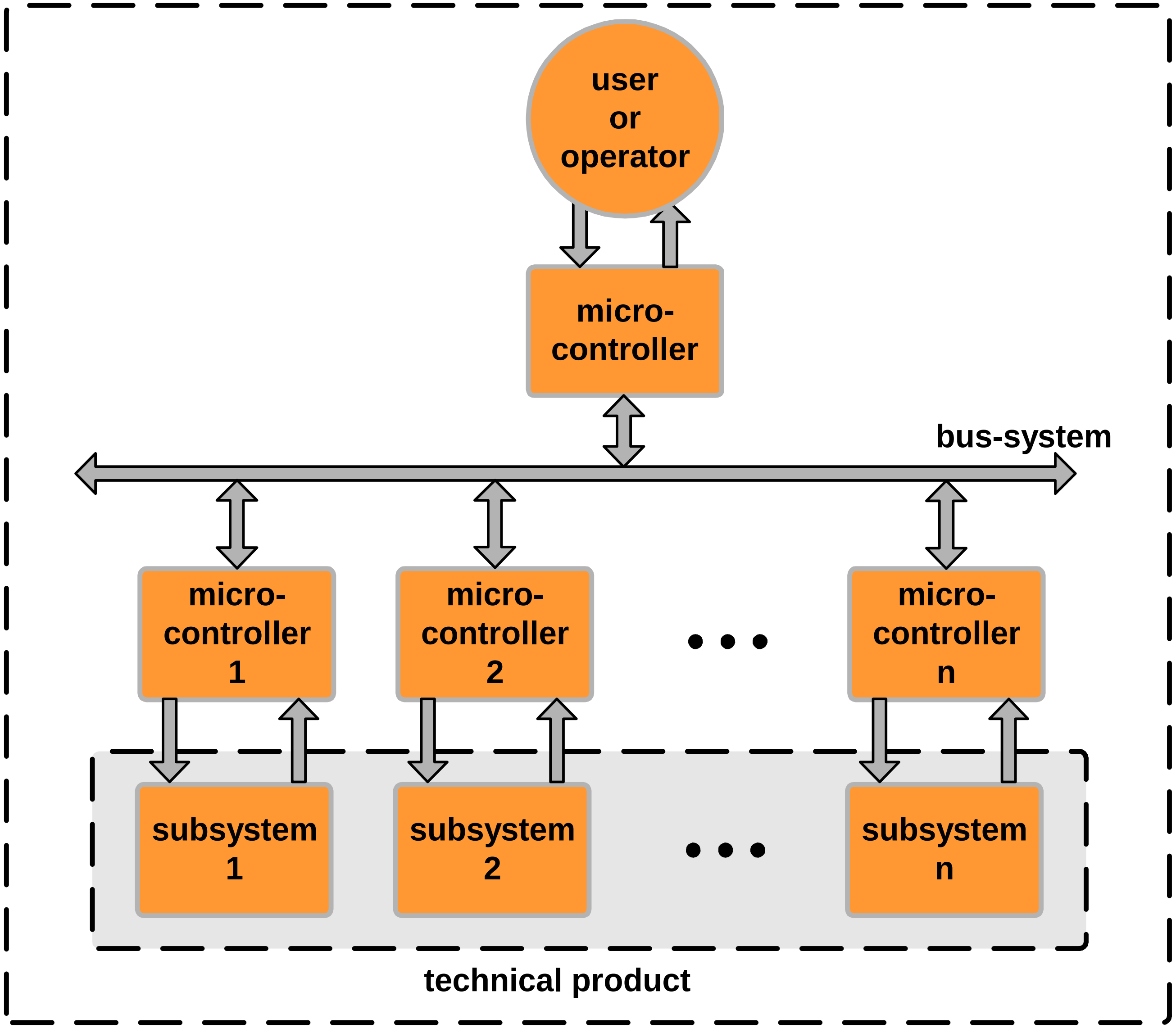


example:

kitchen appliance

Example of a simple product automation (chalkboard writing)

Structure with complex product automation



example:
automotive
electronics

Characteristic criteria regarding plant automation

Technical process in an industrial plant, often geographically wide spread

Extensive and complex automation functions

PLCs, PCs and process control systems are used as automation computer systems

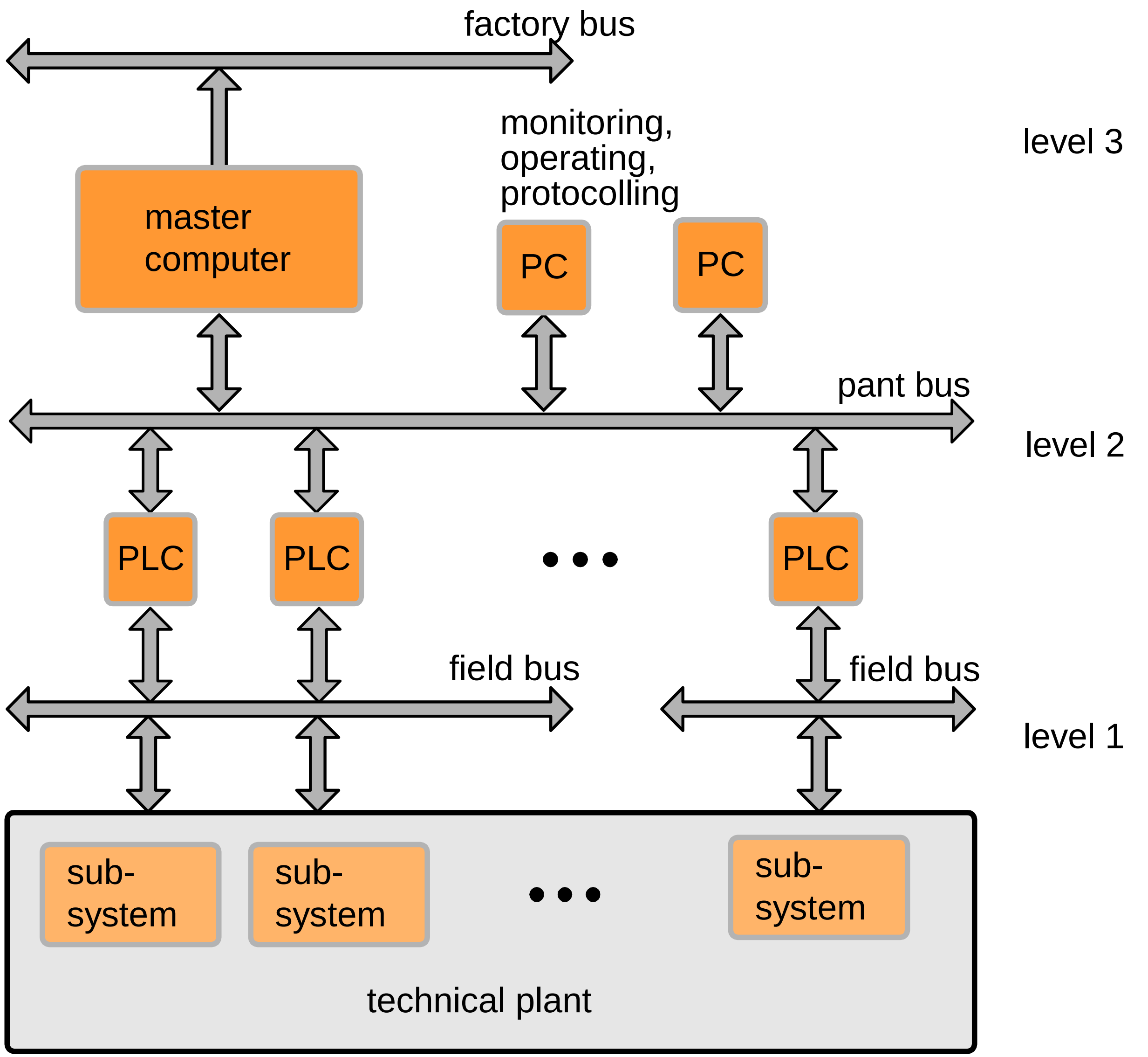
Large number of sensors and actuators

Medium to high degree of automation

Unique system

Engineering and software costs are critical for overall costs

Structure for a larger technical plant



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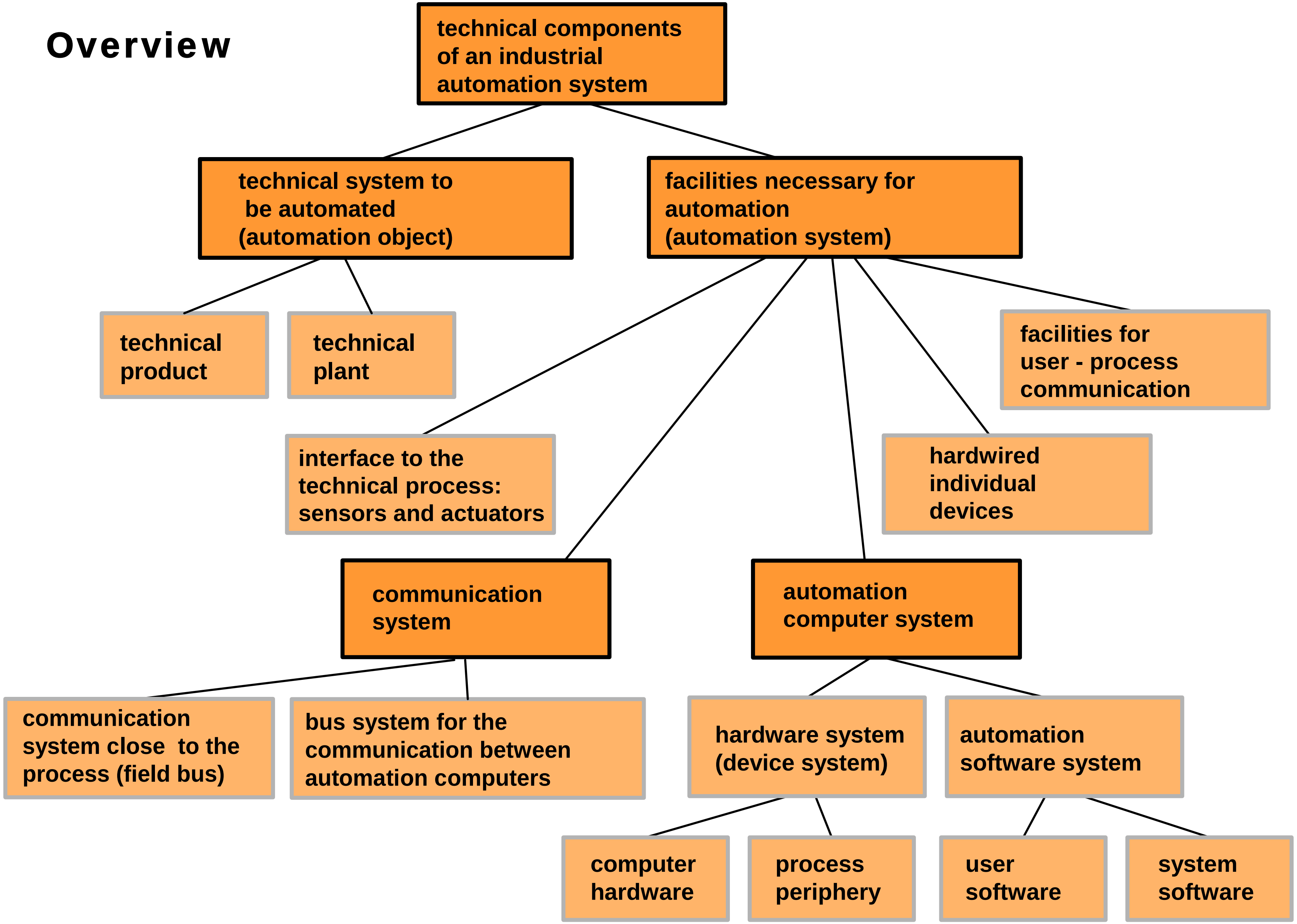
Overview


technical components of an industrial automation system
technical system to be automated (automation object)
facilities necessary for automation (automation system)
technical product
technical plant
facilities for user - process communication
interface to the technical process: sensors and actuators
hardwired individual devices
communication system
automation computer system
communication system close to the process (field bus)
bus system for the communication between automation computers
hardware system (device system)
automation software system
computer hardware
process periphery
user software
system software

Sensors

- Acquisition of information on the progression of process variables
- Sensors, detection devices, measuring devices
- Conversion into electrical or optical signals

examples: temperature,
pressure ,
velocity

Actuators

- Conversion of control information in order to influence process variables
- Actuators (correcting element)

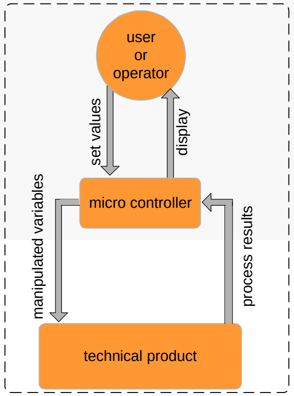
examples : relays,
magnets,
servomotors

Communication system in product automation

Simple products

– few sensors and actuators

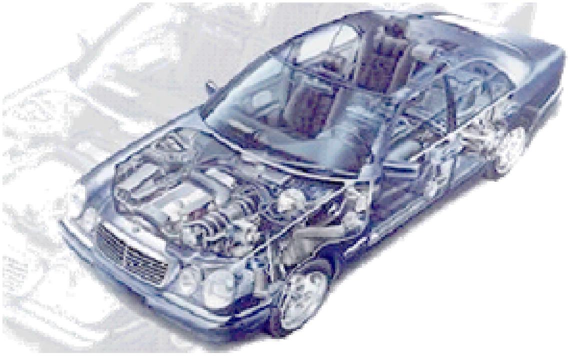
– short line distances

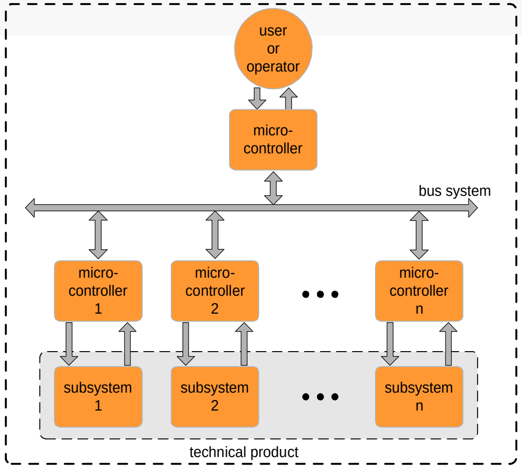


Complex products

– communication between subsystems via bus system

– examples: CAN bus, Interbus-S



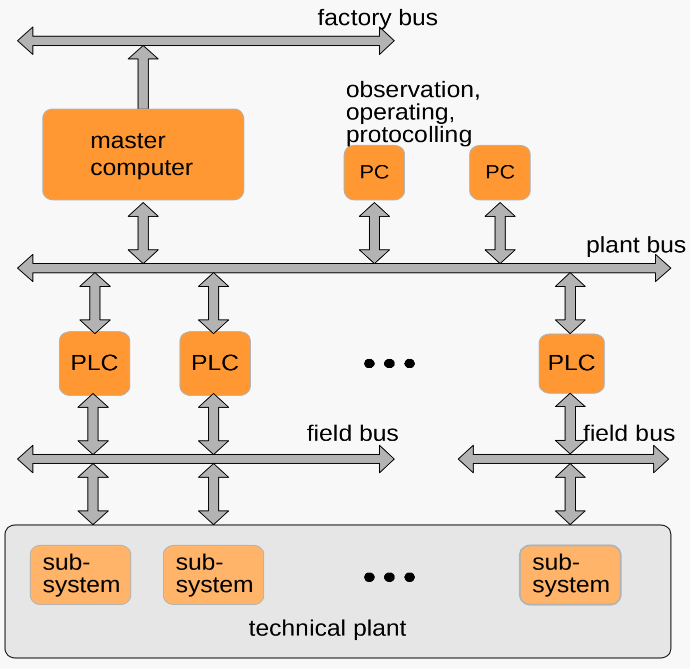


Communication system in plant automation

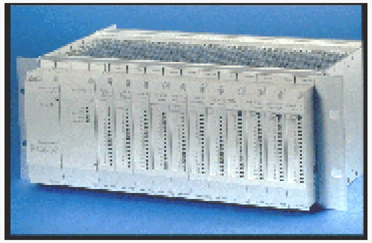
- Many sensors and actuators, geographically distributed
- Many automation computers, geographically distributed

Communication tasks on several levels

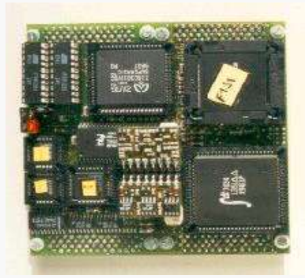
- Factory bus
- Plant bus (process bus)
- Field bus



Different forms of automation computers



– Programmable logic controller (PLC)



– Micro controller

– Personal computer (PC)

– Process control system

Automation software system

– Set of all programs necessary for the execution of automation tasks, including their documentation

– Differentiation between executive and organizational/administrational tasks

Executive programs (application software)

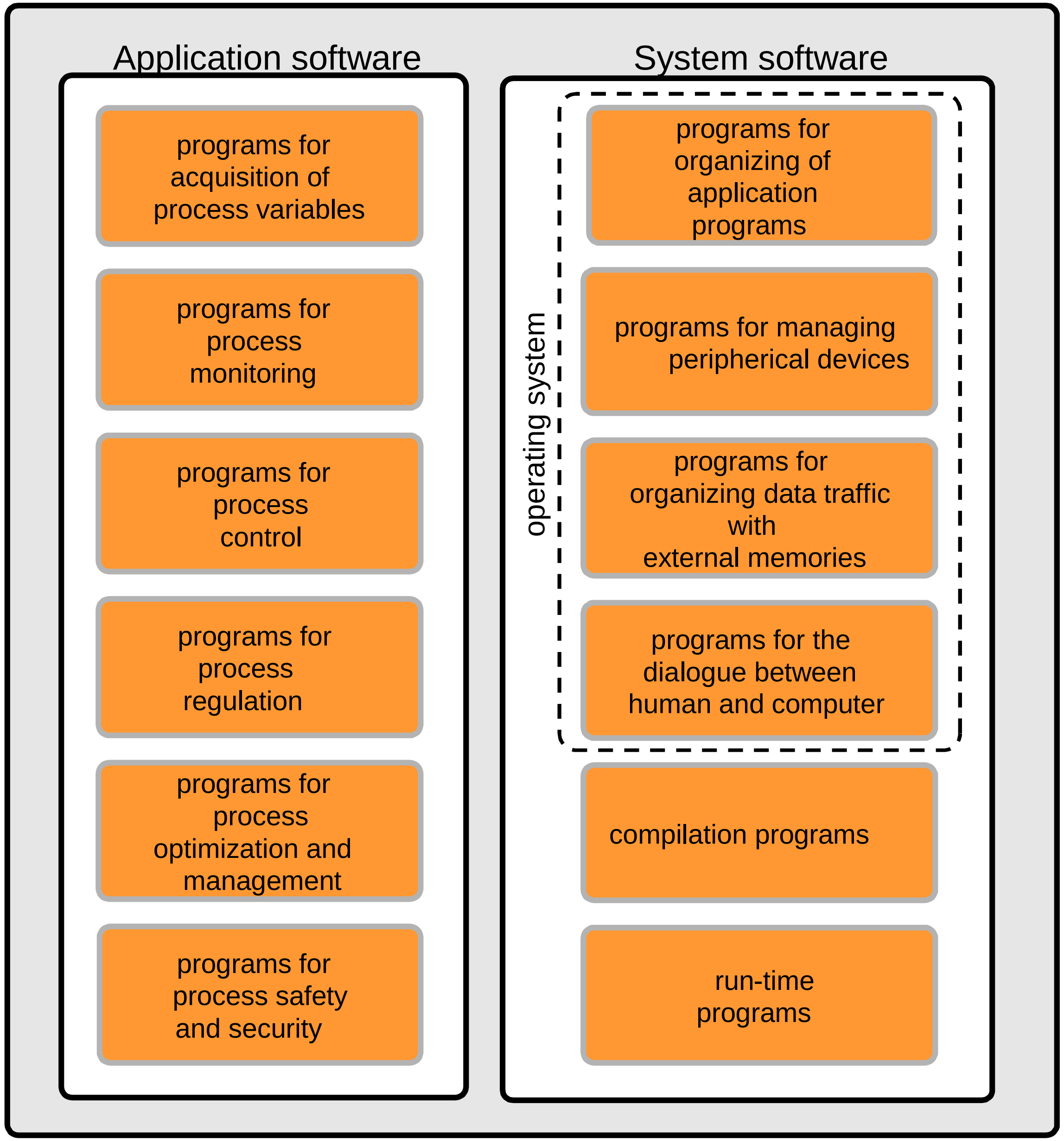
Organizing and administrating programs (operating software or system software)

input measured values

calculation of control variables

software device drivers

operating system


Application software
programs for acquisition of process variables
programs for process monitoring
programs for process control
programs for process regulation
programs for process optimization and management
programs for process safety and security
System software
operating system
programs for organizing of application programs
programs for managing peripherical devices
programs for organizing data traffic with external memories
programs for the dialogue between human and computer
compilation programs
run-time programs

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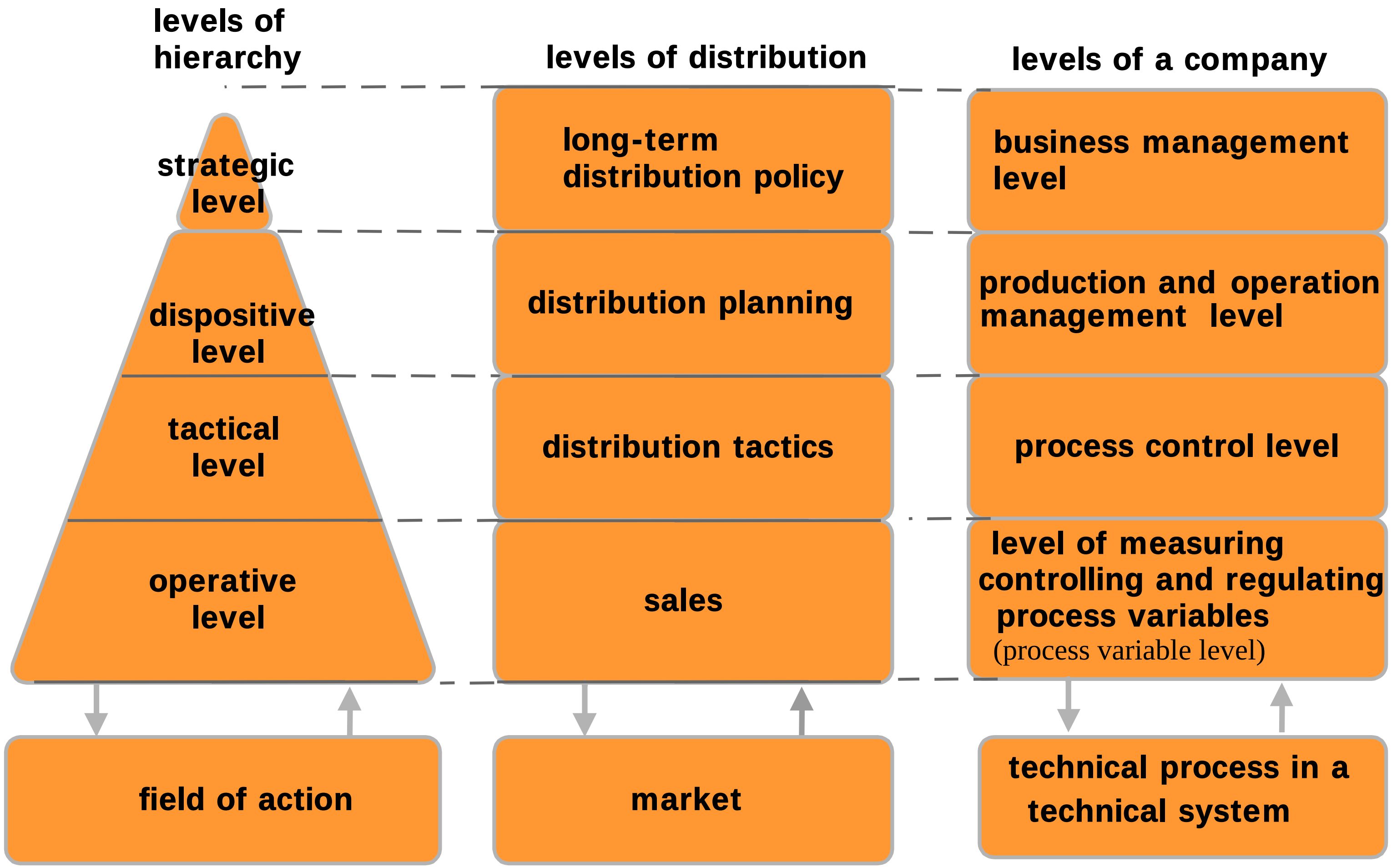
Model of levels in the management of a technical process



Time requirements on the different levels

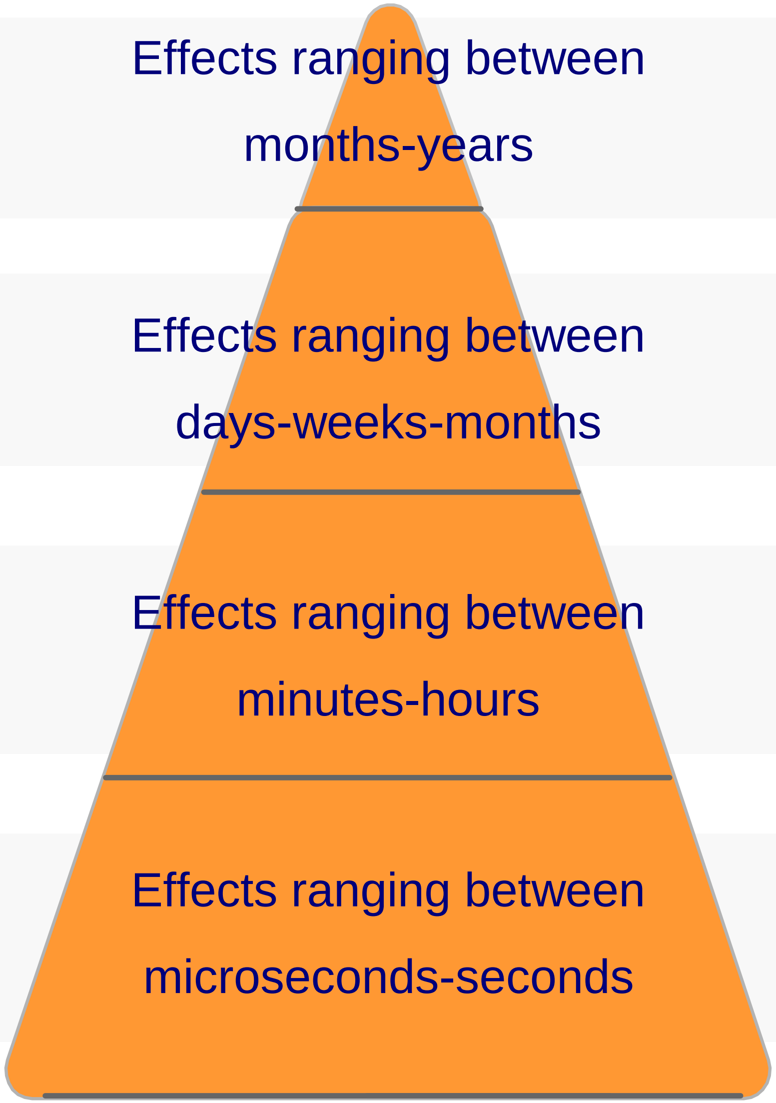
business management level:

production and operation

management level:

process control level:

process variable level:



Automation functions

Levels of a company	Automation functions
business management level	cost analysis, statistical evaluations
production and operation management level	work sequence planning, capacity optimization, evaluation of process results
process control level	process monitoring, start-up and shut-down, malfunction handling, process guidance, process security
process variable level	measuring, controlling, manipulating, regulating interlocking, emergency handling of process variables, shut-down, protection
field level	recording and influencing process variables with sensors and actuators

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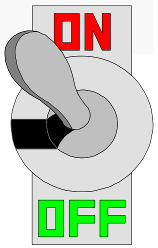
Types of occurring process variables (1)

– Process variables, that are allocated to the course of physical state-variables with a continuous or piecewise continuous range of values

example: temperatures in a heating system

– Process variables, that are allocated to certain discrete process states
  - physical variables with a continuous range of values that characterize the process states
  - binary process variables that are allocated to state transitions i.e., to events that cause the change of state

example: switch setting: 0/off - 1/on



Types of occurring process variables (2)

- Process variables that are allocated to individually identifiable objects
  - physical variables with a continuous range of values

    example: temperature of a slab in a clogging mill,
    size of a part in a store
  - non-physical variables

    example: type, design, application, depot number

Definition of three process types in technical systems

– continuous processes

– sequential processes, discrete event type processes

– object-oriented processes

Caution! - a clear distinction is not always possible !

example: transportation as a continuous and object-oriented process

Continuous processes in technical systems

Characteristics	**processes containing time-dependent continuous process variables**
Process variables	physical variables with a (at least piecewise) continuous range of values
Examples	generation processes, transformation processes, movements, etc.
Mathematic models	differential equations (time as an independent variable), transfer functions

Sequential processes in technical systems

Characteristics	**processes containing sequences of different, distinguishable process states**
Process variables	binary signals that cause or indicate discrete process states as well as continuous physical variables allocated to process states
Examples	sequences of process states during start-up or shut-down of a turbine, sequence of states during the operation of an elevator, sequence of states during production using a machine tool
Models	flow charts, function plans according to DIN 40719, state models, Petri nets

Object-oriented processes in technical systems

Characteristics	processes during which individually identifiable objects are transformed, transported or stored
Process variables	physical variables with a continuous range of values or non-physical variables (e.g., type, design, application, bay number) that are allocated to the objects, as well as binary variables, that cause or indicate state changes of objects
Examples	processes during the manufacturing of parts, traffic processes, storage processes, information processes in computers
Models	simulation models, queue-models, state models, Petri nets, OO-models

Classification methods

Classification according to the kind of...

- transformed or transported medium

  material related processes, energy related processes, information related processes

- effect

  generation processes, distribution processes, storage processes

- material-related transformation

  chemical processes, production processes

- dominating process type

  flow processes (continuous), successive processes (sequential), piece-related processes (object-related)

Assignment of technical production processes to process types

Technical processes	Process types
Energy-related processes	continuous processes, sequential processes
chemical processes	continuous processes, sequential processes
production processes	continuous processes, sequential processes, object-related processes
material-handling processes	continuous processes, sequential processes, object-related processes

Technical processes can contain processes of different types, on the other hand a process in turn can be a technical process.

Examples:

– Generation of electric energy in a turbo generator
  - continuous process
  - sequential process (start-up sequence of plant)

Energy-related processes

– Batch processes
  - single process steps are continuous processes
  - sequence of steps is a sequential process

Chemical processes

– Manufacturing a swivel
  - transportation of the machine' parts is an object-related process
  - manufacturing process consists of a sequence of steps ("mount part", "drive machine to position " etc.), thus it is a sequential process
  - cutting process is a continuous process

Production process

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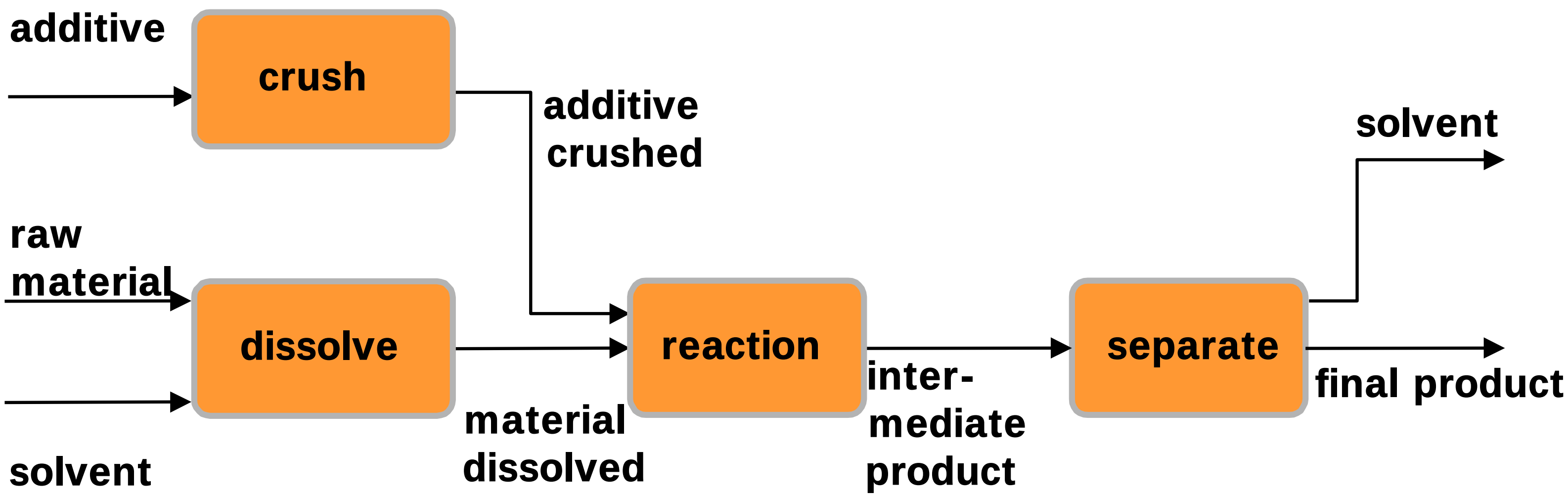
Flowchart

- Similar to block diagrams used in control engineering
- Processes and process steps are represented as rectangles
- Arrows represent the information or material flow
- Bundles of connections are shown as double lines with arrow

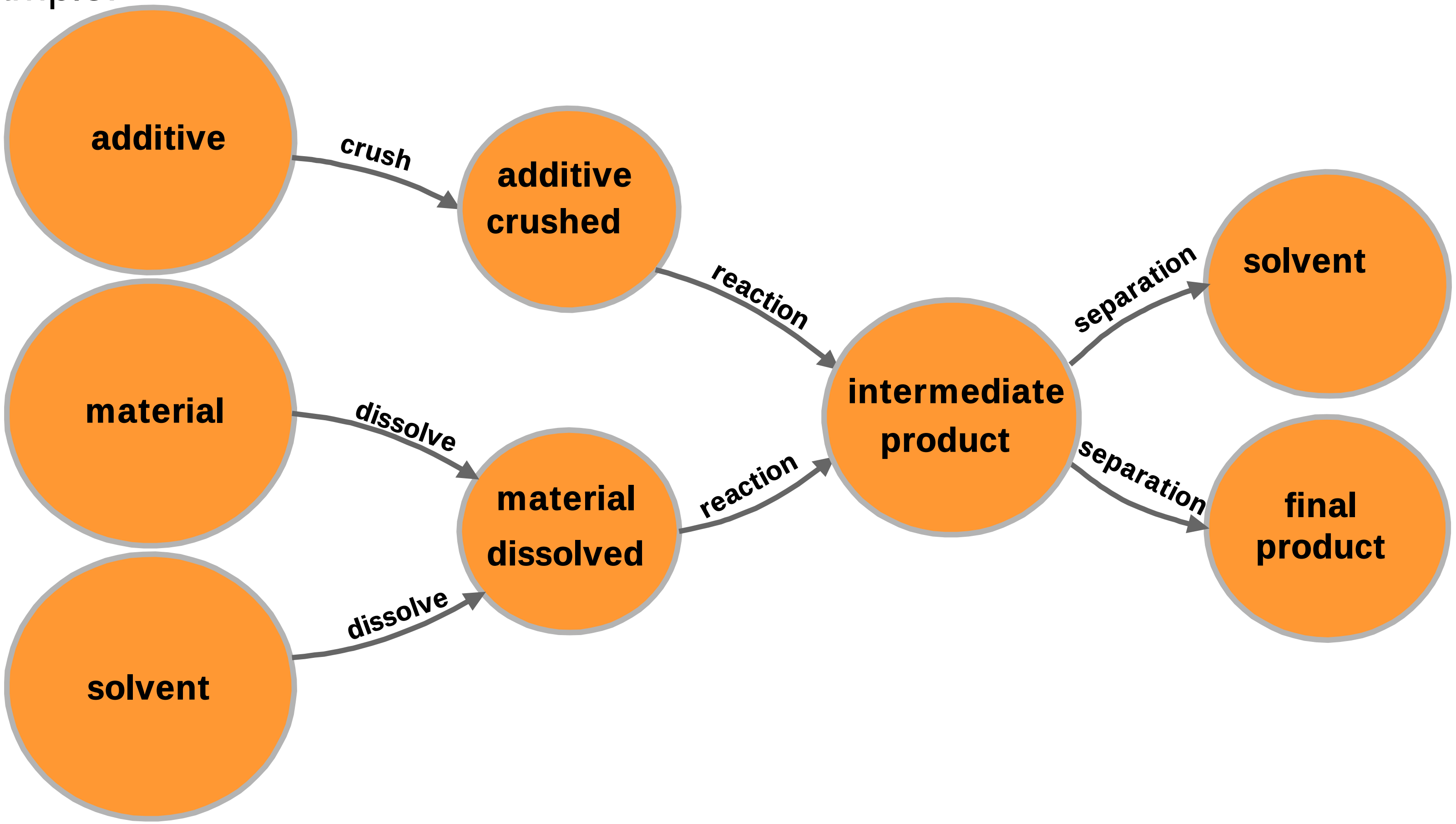
Example:



Information / material-oriented representation

- Information/materials as circles
- Processes/functions as linking arrows

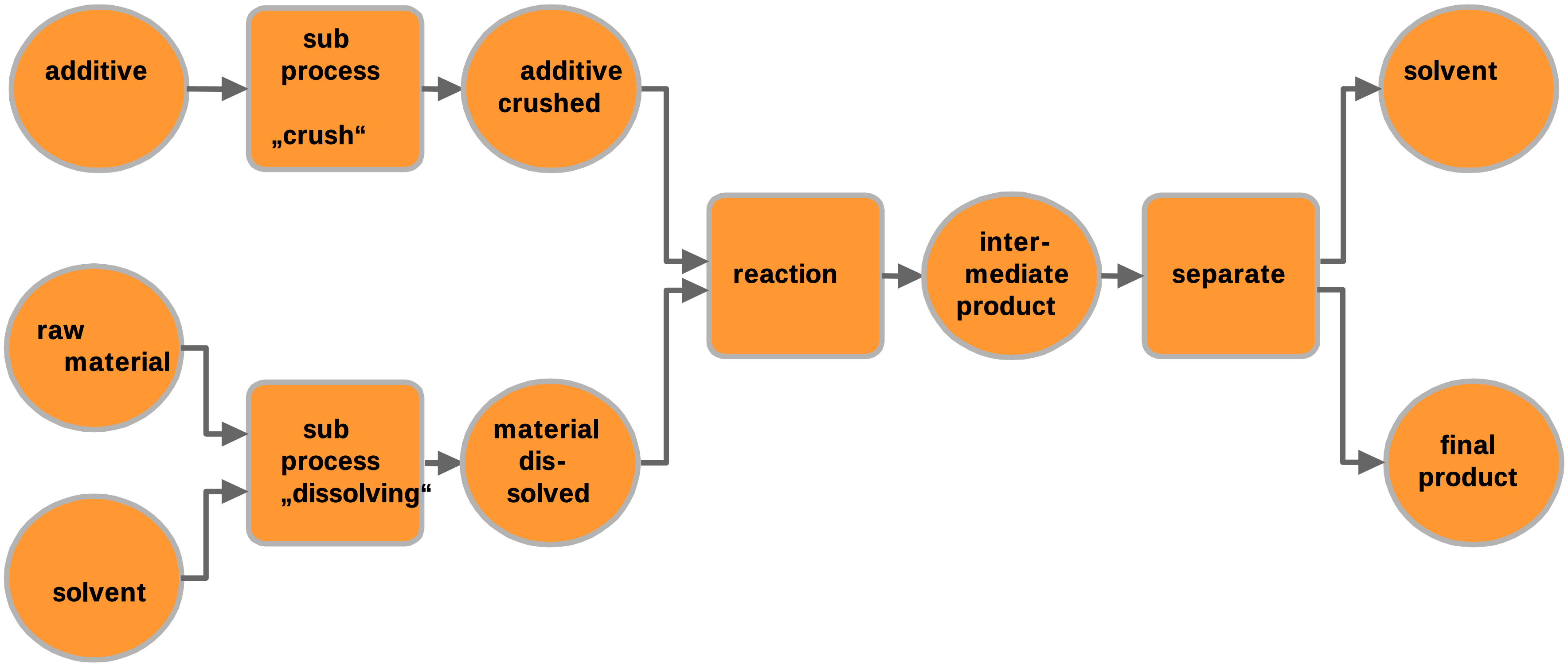
Example:



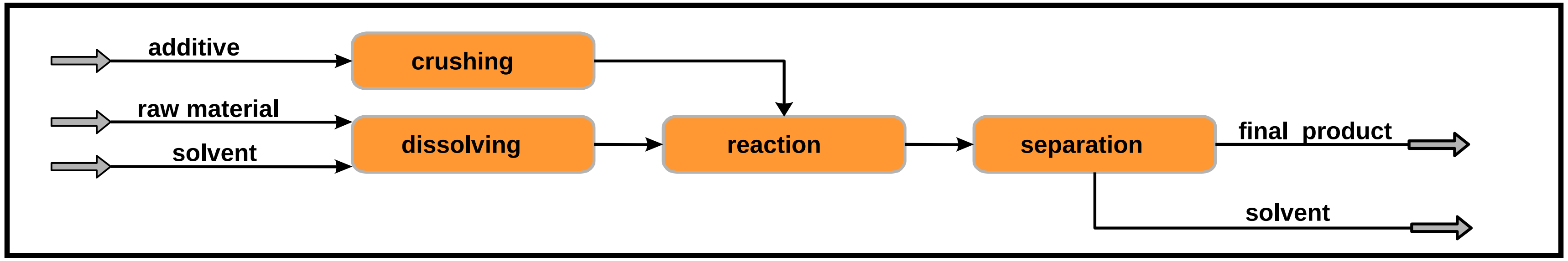
Phase model representation

– Mixture of flowchart and information/material-oriented representation

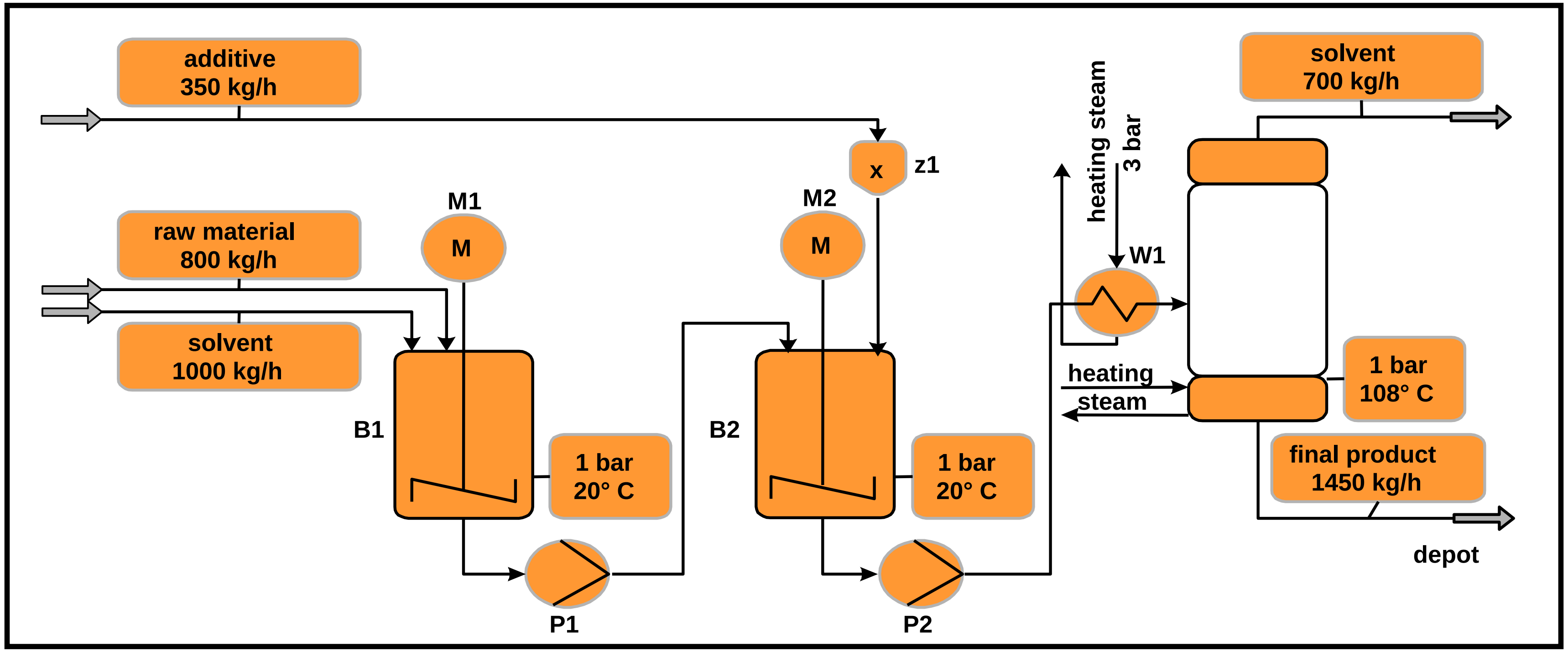
Example:



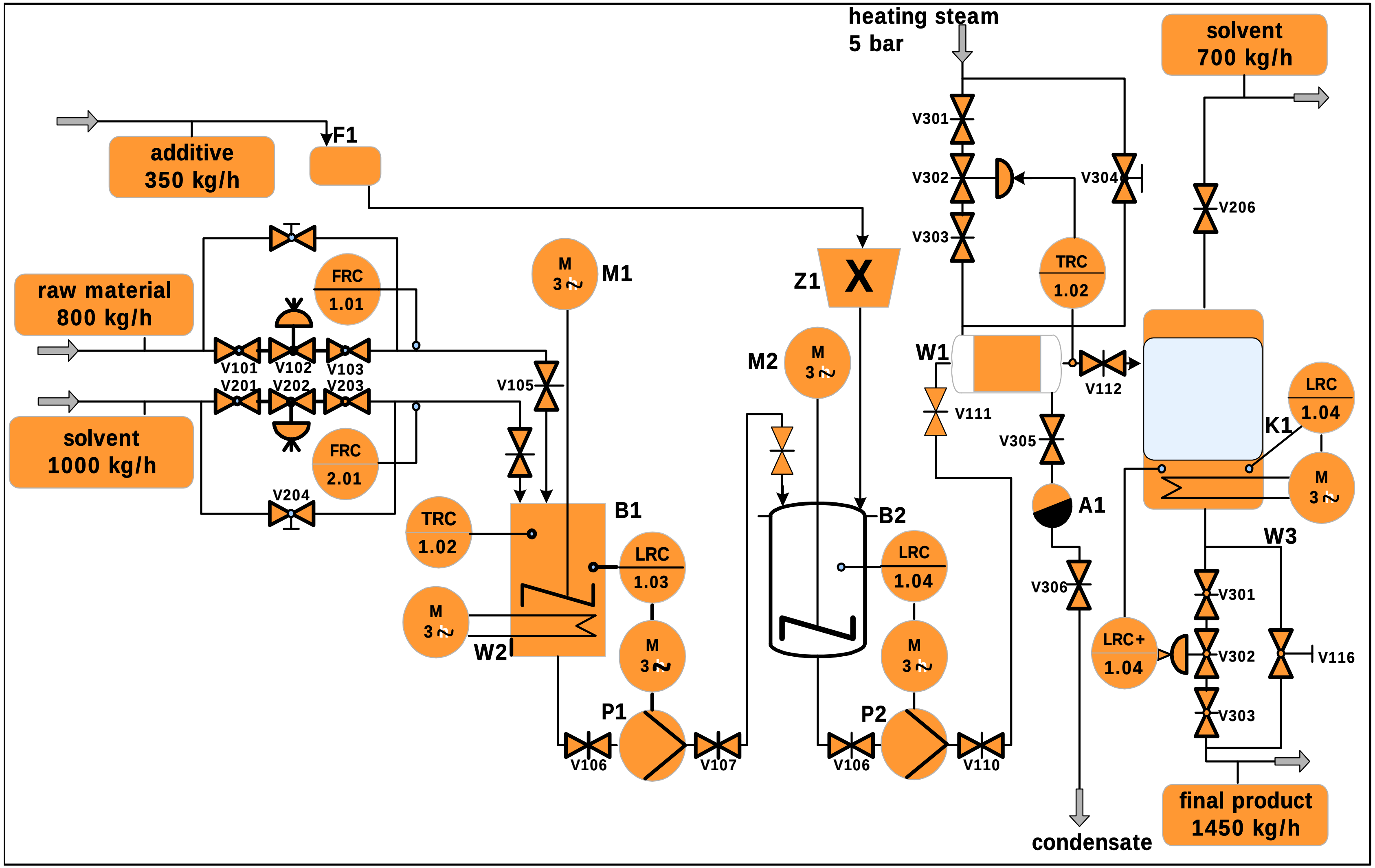
Examples for the flowchart representation



simple flow chart



process flow chart



Pipes and instrumentation flow diagram

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Intentional (positive) effects

- Simplified and more convenient operation
  - automation of a washing machine
  - automation of a heating system
- Production of better, cheaper products of equal quality with lowered production costs
  - automation of chemical production processes
- Reduction of hazards to people
  - ABS system
  - traffic system automation (like inductive train security, automatic barrier close)
- Better, more humane working conditions
  - automation of painting or foundry work
- Securing jobs through higher competitiveness
  - use of robots in automobile manufacturing

Unintentional (negative) effects

- Redundancy of workers may lead to unemployment
  - use of robots in manufacturing
- Restructuring of jobs due to changes in work flow and fields of work
  - lower/ higher qualified jobs
  - drop of ancillary tasks
  - increase of jobs in the service sector
- Reduction of human relationships
  - introduction of ticket vending machines and information systems
- Increase of stress and reduction of relaxing tasks
  - automation of testing systems
- Overtaxing in difficult situations
  - safety-critical decision in a nuclear power plant

– **Industrial automation has effects on:**
  - **people**
  - **society**
  - **environment**
  - **energy and resources**

The automation engineer is responsible for the effects of industrial automation!

Direct, immediate responsibility

- damages in industrial automation systems designed by him
- violations of generally accepted guidelines and regulations (regulations of the VDE, etc.)
- safety of automation systems

Indirect, collateral responsibility

- unintentional side effects

Dilemma: **trade-off between benefits and damage**

Question referring to Chapter 1.1

In addition to the correctness of the data the timeliness of data is of high relevance in industrial automation. Which of the following statements do you agree?

Answer

ü Early data is bad data

ü Late data is bad data

f ¨ As fast as possible data is correct data

f ¨ Precise data is bad data

ü No data is bad data

Question referring to Chapter 1.3

A company wants to automate the production of refrigerators. For this purpose, a new production line shall be constructed. In this production line, the coolant will be filled in and the rear will be screwed to the case.

Which kind of automation system is this ?

Answer

The given system is a plant automation system. The production process (assembly line) shall be automated and not the product itself.

Question referring to Chapter 1.4

For the control computer of a production line of refrigerators (described in the last question) the company received two offers:

- „ordinary“ PC 3000,- €
- industrial PC with the same performance 5000,- €

Which computer would you choose ?
Give reasons for your choice and explain the difference in price.

Answer

There is no difference in the performance range of the two computers. The main difference between an „ordinary“ PC and an industrial PC is that the industrial PC is especially built to endure the higher stress in industrial environments (temperature variations, EMI, vibrations, etc.)

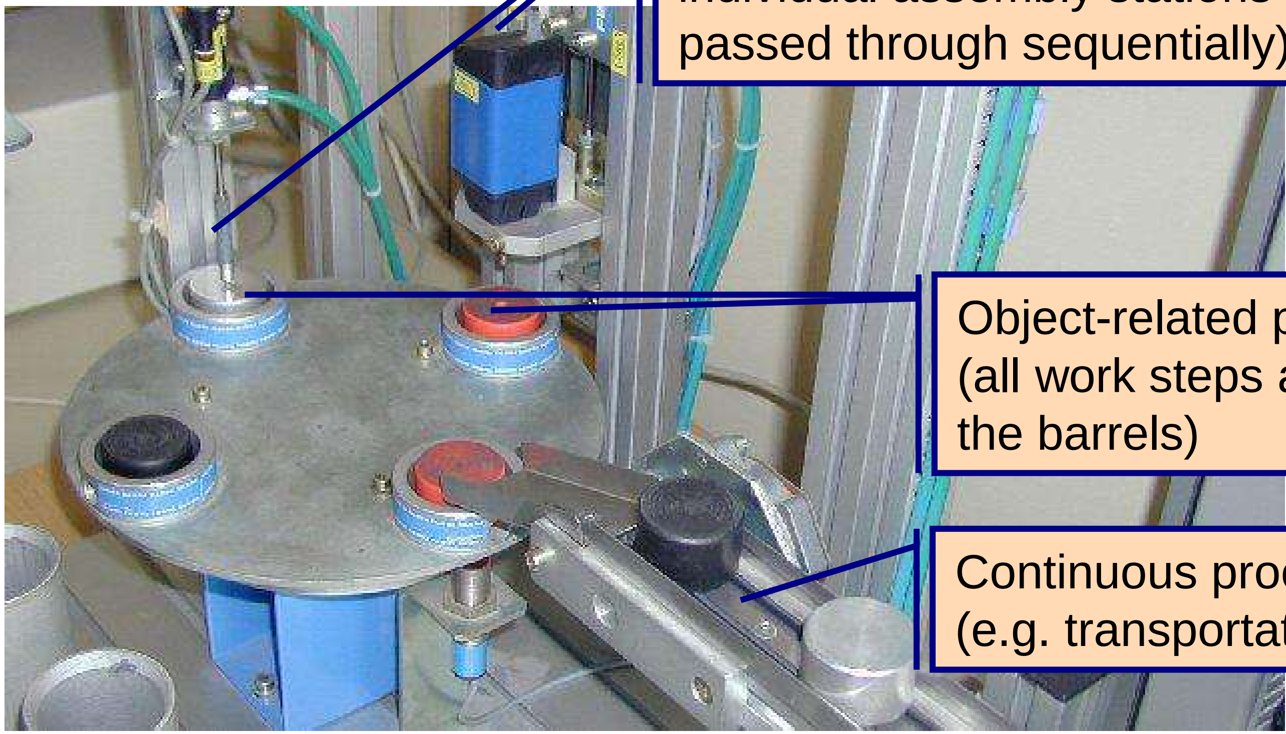
In this case, therefore, the choice would be an industrial PC.

Question referring to Chapter 1.6

The IAS modular production system is shown below.

Which kind of processes do you identify in this system?

Answer

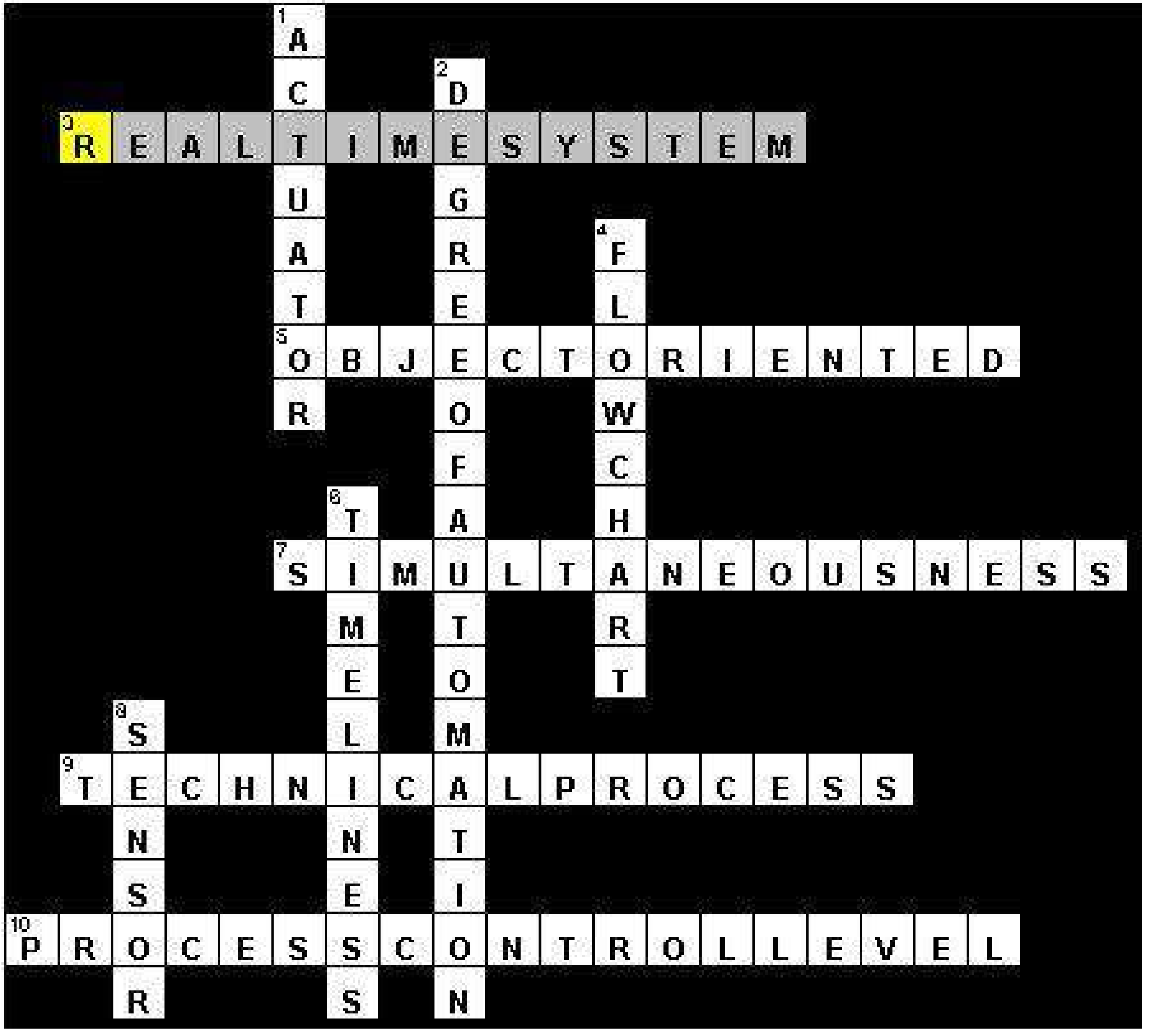


sequential processes (all individual assembly stations are passed through sequentially)

Object-related processes (all work steps are done at the barrels)

Continuous processes (e.g. transportation)

Crosswords to Chapter 1



Crosswords to Chapter 1

Across

3	Denomination of systems which have to be in synchrony with activities happening in an external system. (4,4,6)
5	Process type of manufacturing of parts. (6,8)
7	Simultaneous reaction to various events (16)
9	Process in which the physical parameters are recorded and influenced by technical means. (9,7)
10	Automation technical analog to "tactical level". (7,7,5)

Down

1	Device used to influence process variables. (8)
2	Term describing the extent in which a process is automated. (6,2,10)
4	Graphical representation of technical processes, similar to block diagram. (9)
6	Reaction to an event right on time (10)
8	Device used to measure process variables. (6)