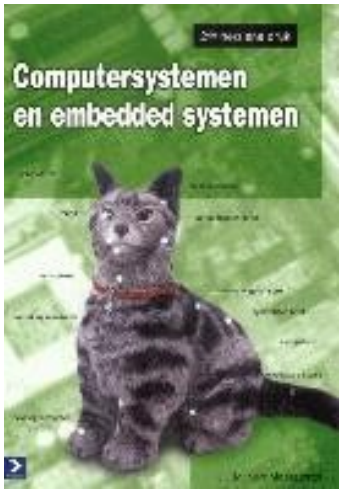
Intelligent Manufacturing in the Past, Present and Future

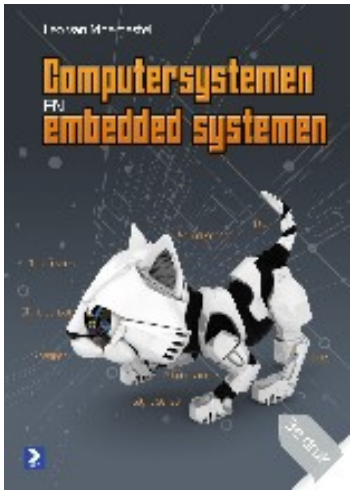
Leo van Moergestel
HU Utrecht University of Applied Sciences
Utrecht University
Utrecht, the Netherlands

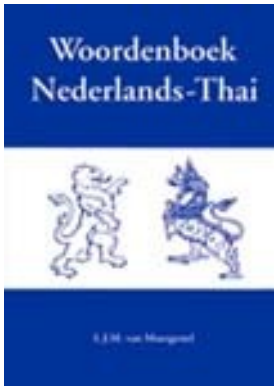
Let me introduce myself

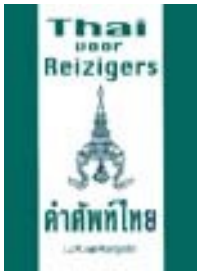
- Utrecht University of Applied sciences
  - Reseach team Micro Systems Technology (prof. Erik Puik)
- Utrecht University
  - Member of the Intelligent Systems group (prof. John-Jules Meyer)

Some of my books

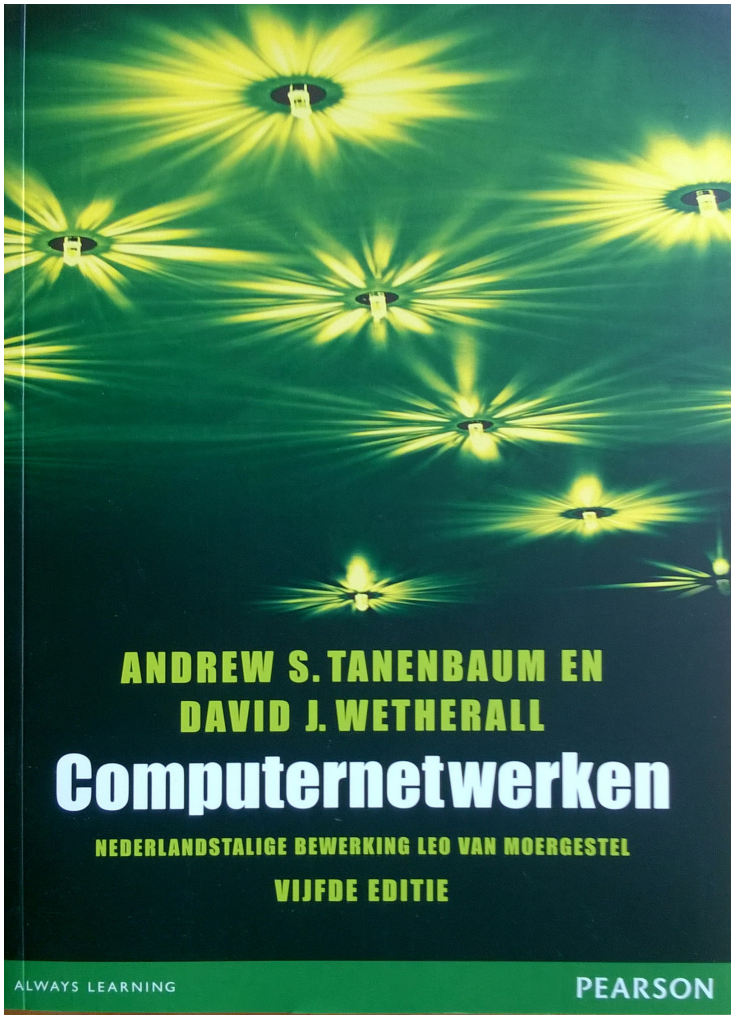


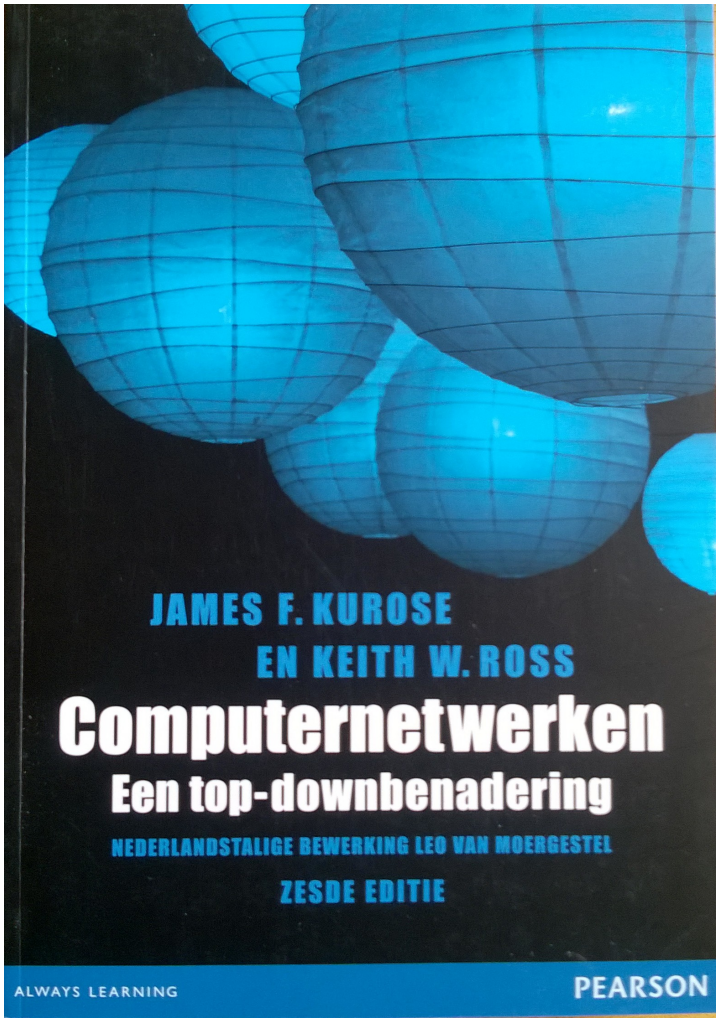






Translations to Dutch





Overview

- Part 1: Manufacturing overview from past to current state
- Part 2: My research (is this the future?):
  - Agent-based manufacturing
  - Agent-based product support

Overview Part 1

- Industrial revolutions
- Standard manufacturing
- Modern technologies
- Concepts and hot topics
- Point of concern

Intelligence in manufacturing

Mass production

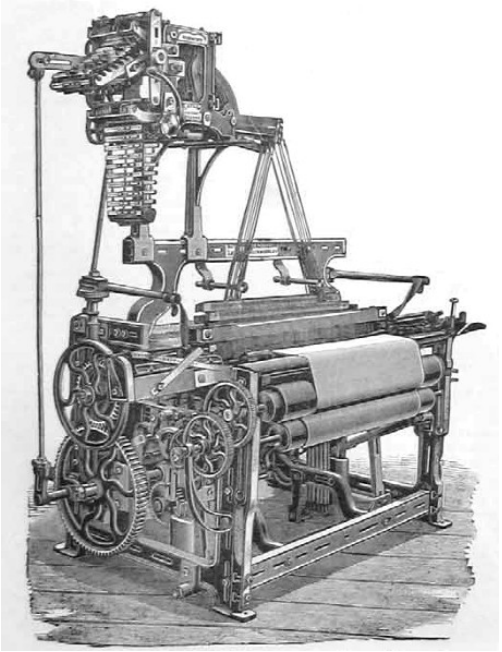
In time more advanced machinery

Industrial revolutions

- Power driven systems (steam, waterpower)
- Electrical driven systems, production lines
- Automation with electronics and IT
- Cyber connected systems

Revolution 1

- Introduction of mechanical production facilities with the help of water and steam power
- The first power loom was designed in 1784 by Edmund Cartwright and first built in 1785.



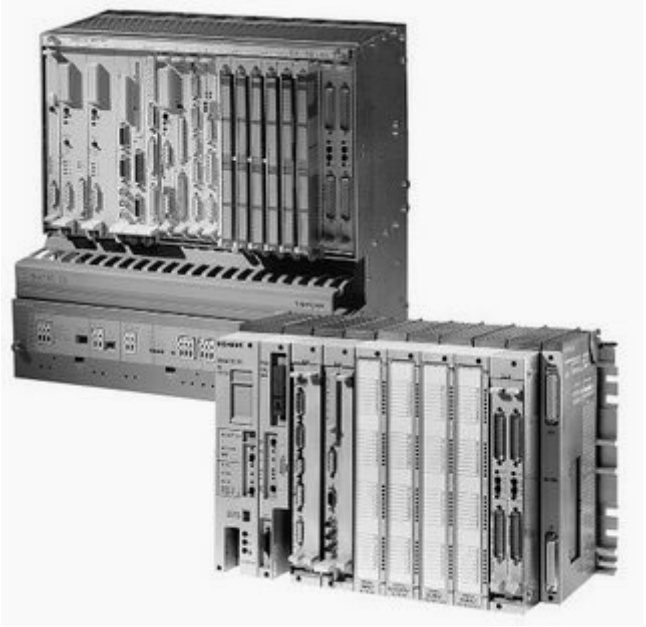
Revolution 2

- Division of labor, mass production, production lines
- Use of electric power
- First assembly line Cincinnaty slaughter houses (1870)
- Remember 'Modern Times' (Chaplin)

Assembly line

Revolution 3

- Automation by electronics, IT and advanced electro-mechanical systems like industrial robots
- First Programmable Logic Controler (PLC) Modicon 084



Revolution 4

- Cyber-physical systems
- Smart interconnected systems communicating, sharing information, negotiating and making decisions

How things are made

- Single product (unique, tailor made)
- Continuous production (chemical industry)
- Batch production (food, consumer products, industrial products)

- Both continuous and batch are considered industrial production

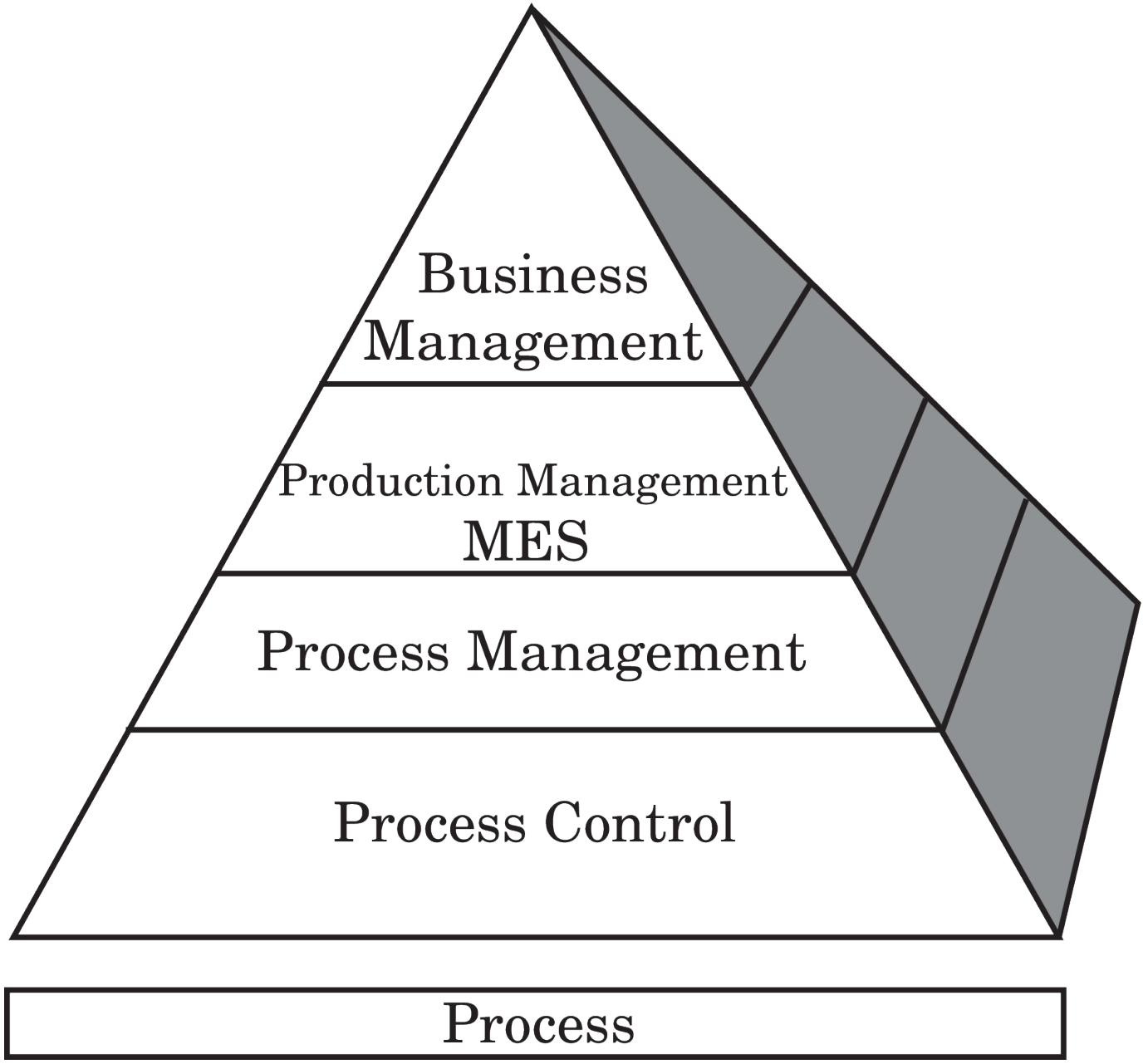
Example: single product

Example: continuous production

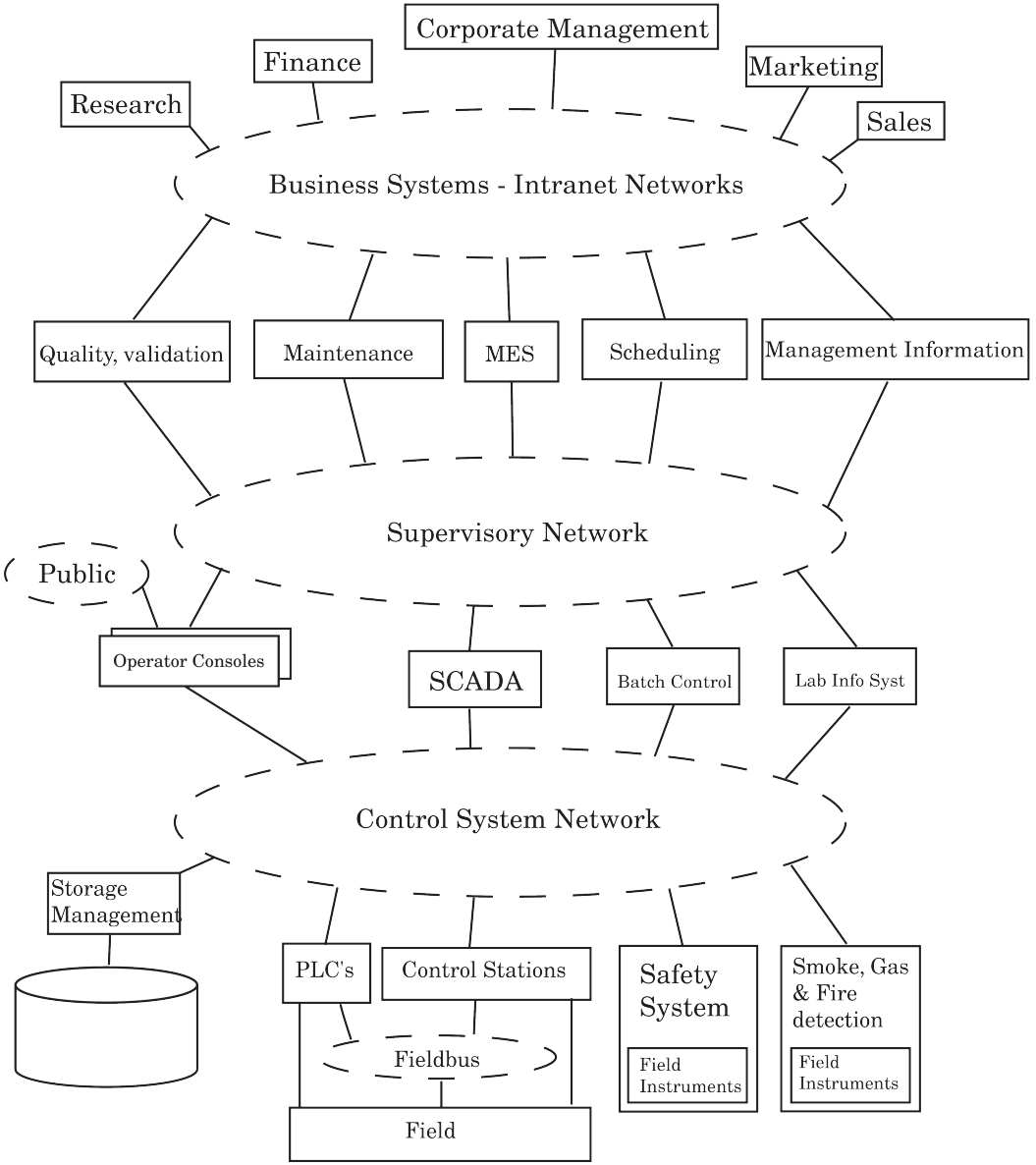
Example: batch production

Batch results

Automation piramid



Control layers

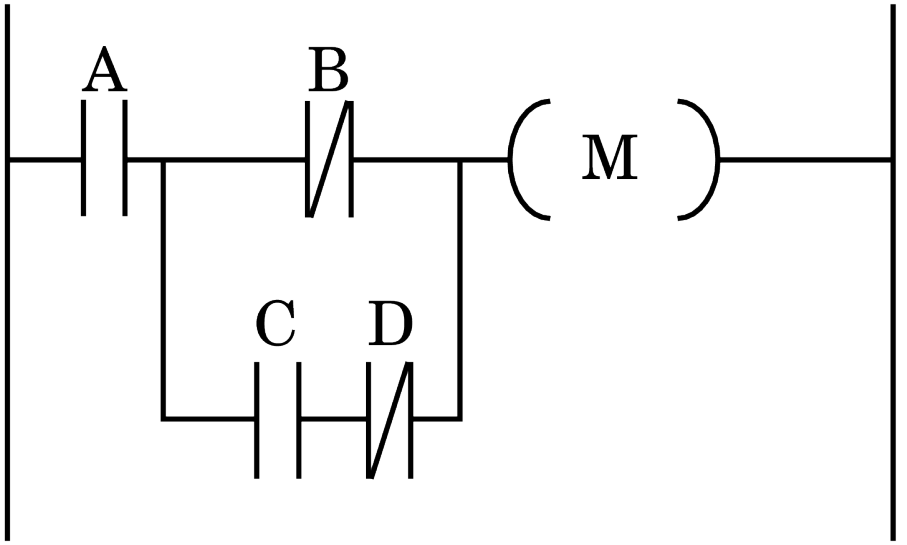


Intermezzo PLC

- Programmable Logic Controller
- Programming standards IEC 61131-3 (1993, third edition: 2013)
  - LD (graphical, relay logic)
  - IL (Textual, low level commands like assembler)
  - ST (Textual, Pascal-like procedural language)
  - FBD (graphical, logic diagrams)
  - SFC (graphical, state machine, GRAFCET)

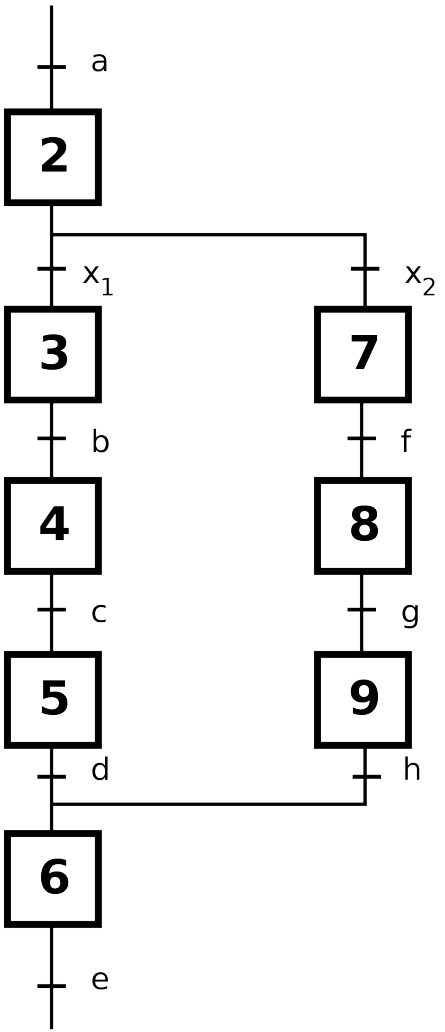
Intermezzo PLC

PLC programming 1(2)



PLC programming 2(2)

OR



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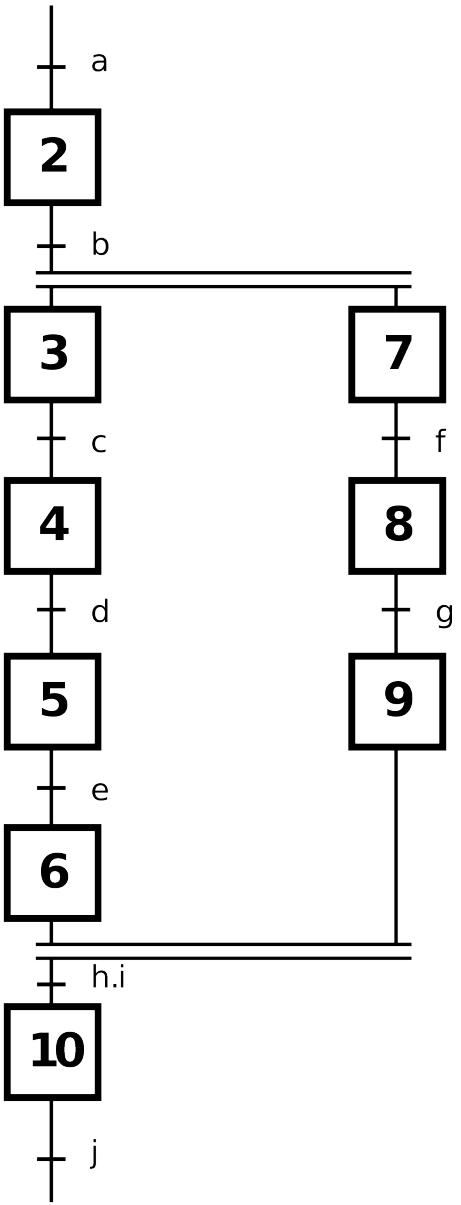
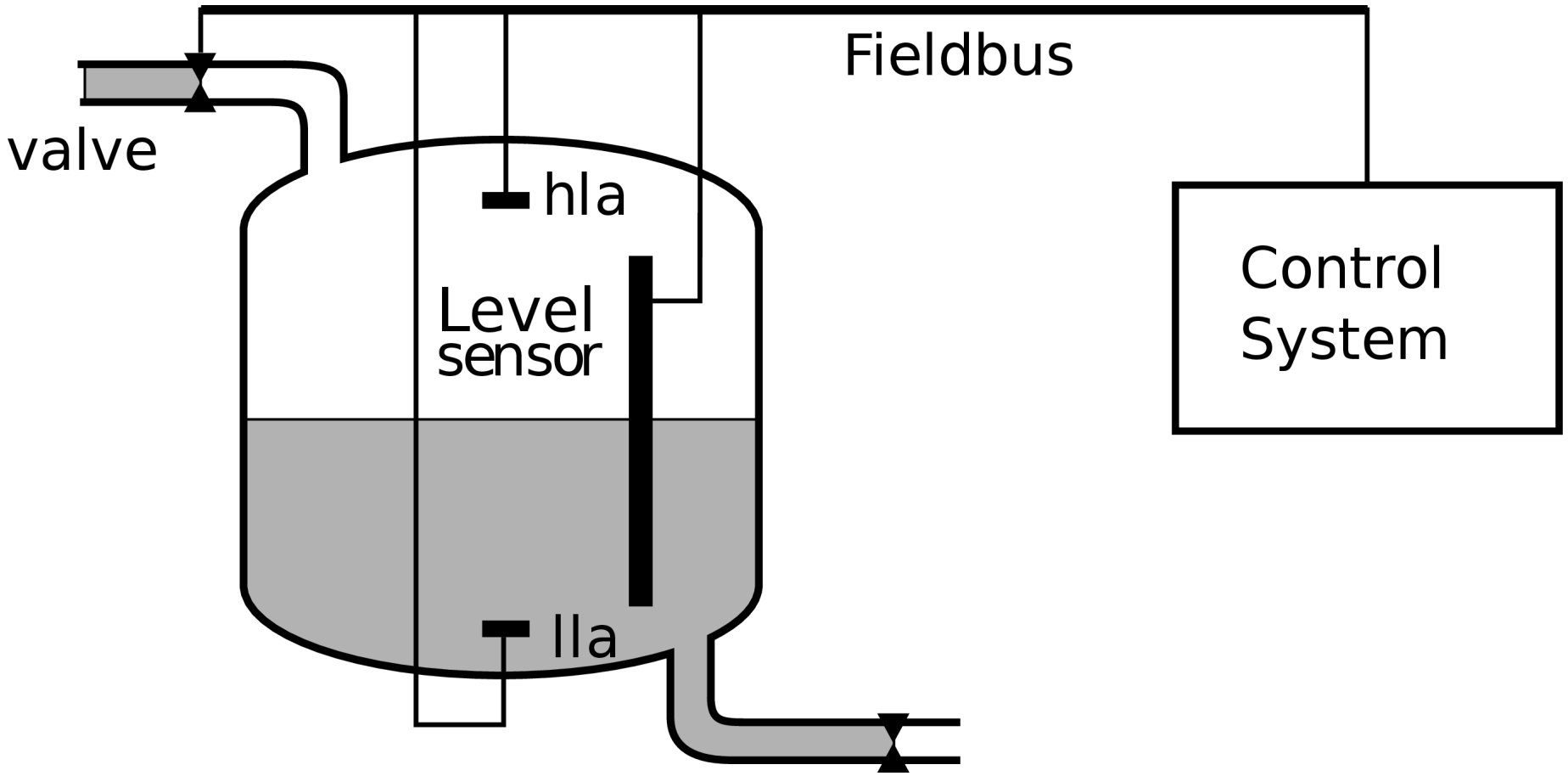
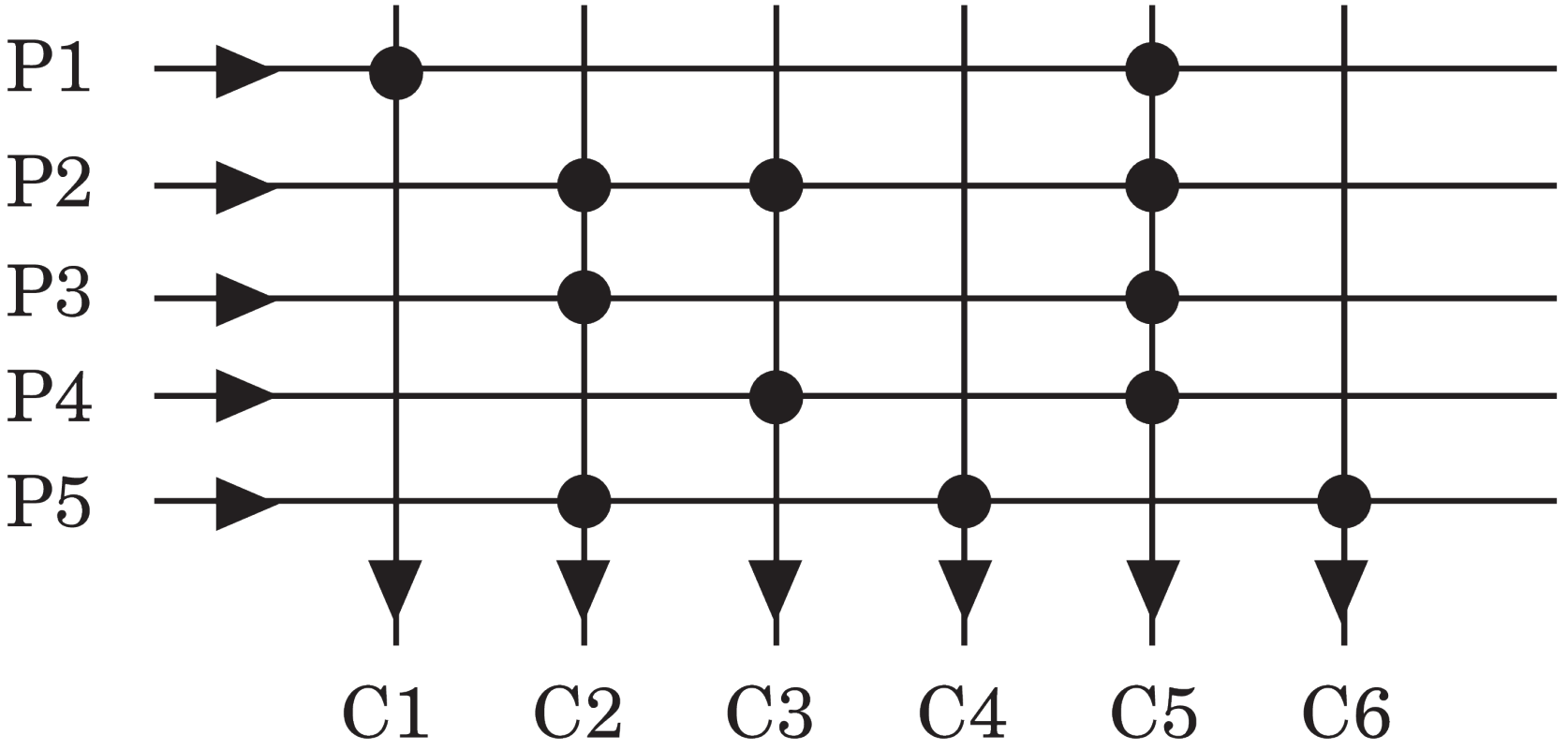


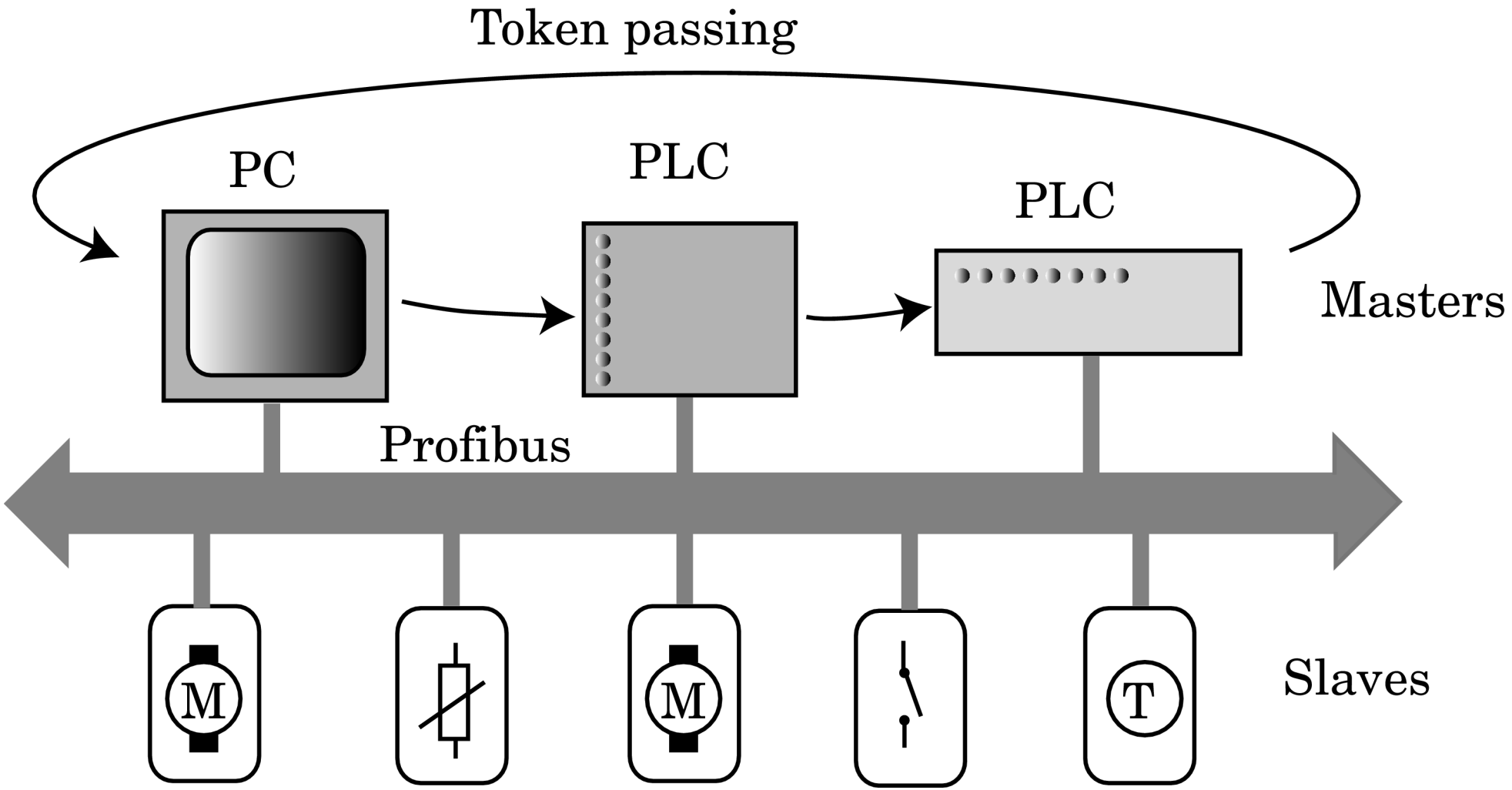
Intermezzo Fieldbus



Producer-consumer network



Profibus



SCADA

- Supervisory Control And Data Acquisition
- Operates at a lower level than the Manufacturing Execution System (MES)
- Several commercial solution providers
- Connection with production system generated data
- Control at operator level.

MES (11 tasks)

- Resource allocation
- Operations scheduling
- Dispatching production units
- Document control
- Data collection
- Quality management
- Labor management
- Process management
- Maintenance management
- Product tracking
- Performance analysis

Concepts and hot topics

- What are concepts and hot topics in modern manufacturing?
  - Lean manufacturing
  - Agile manufacturing
  - RMS
  - Personalizing products
  - Short time to market

Lean Manufacturing

- TPS
- What is the product value for the consumer?
- Discover where this value is added during production
- Determine waste in the process, remove it and shorten the duration of lead time
- Apply pull-driven production
- Keep the waste away

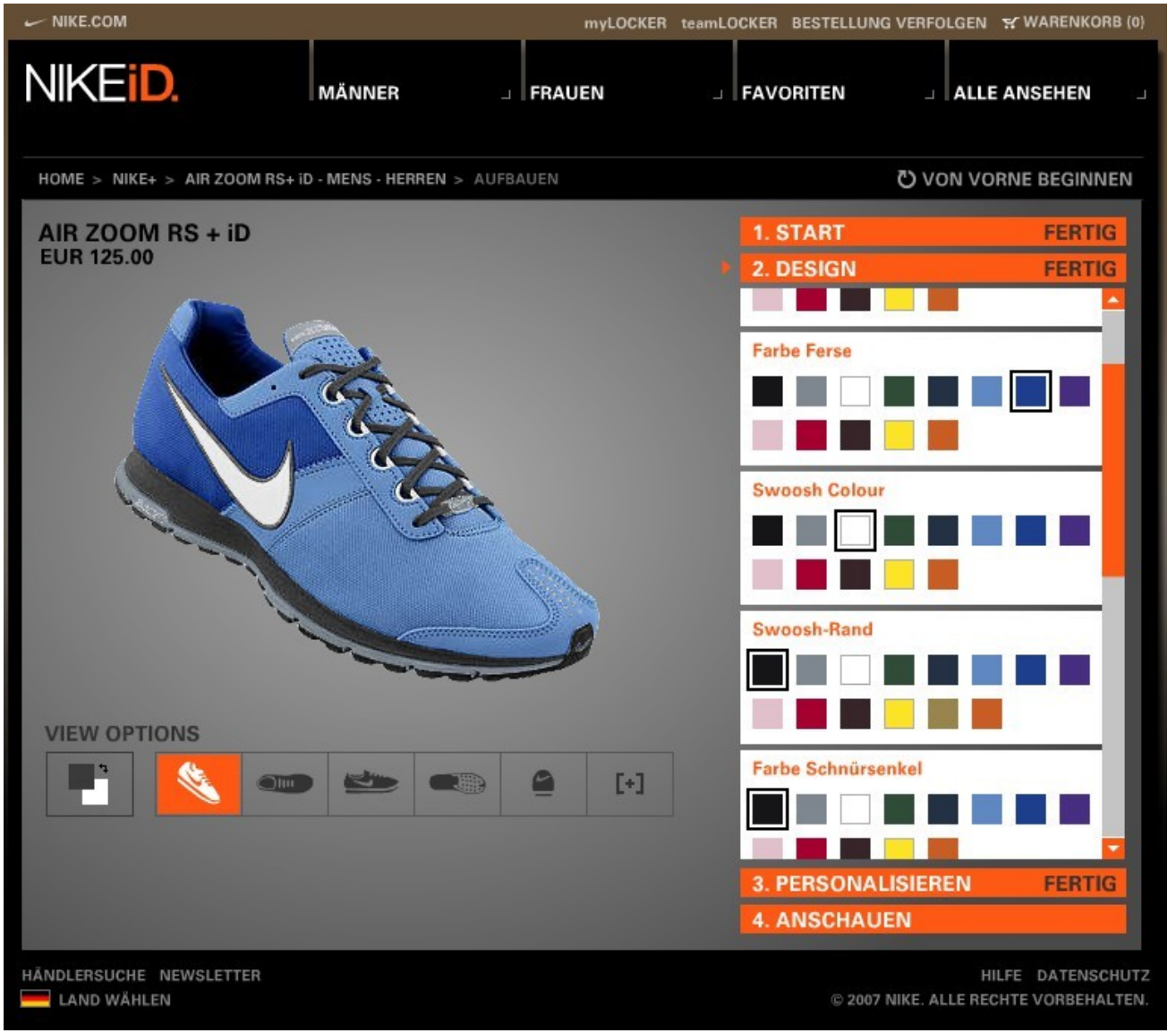
Agile Manufacturing and RMS

- **Definition:** *An agile manufacturing system is a system that is capable of operating profitably in a competitive environment of continually and unpredictably changing customer requirements.*
- **Definition:** *A reconfigurable manufacturing system is a manufacturing system that is designed for fast changes, both in hardware as well as software components, in order to quickly adjust production capacity and functionality in response to sudden changes in market or in changes in requirements.*

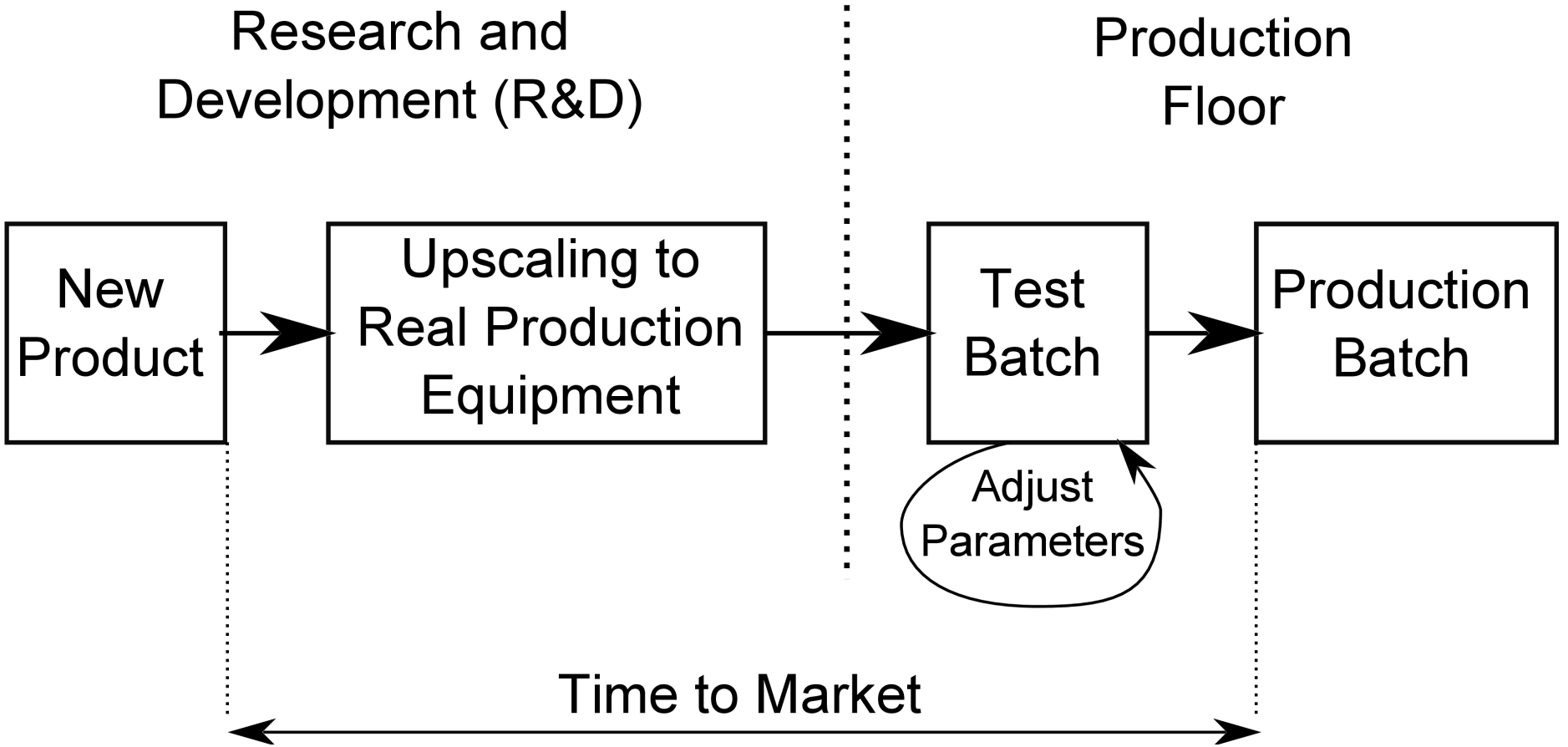
Personalizing 1(3)

Personalizing 2(3)

Personalizing 3(3)



Time-to-market



Security is a point of concern

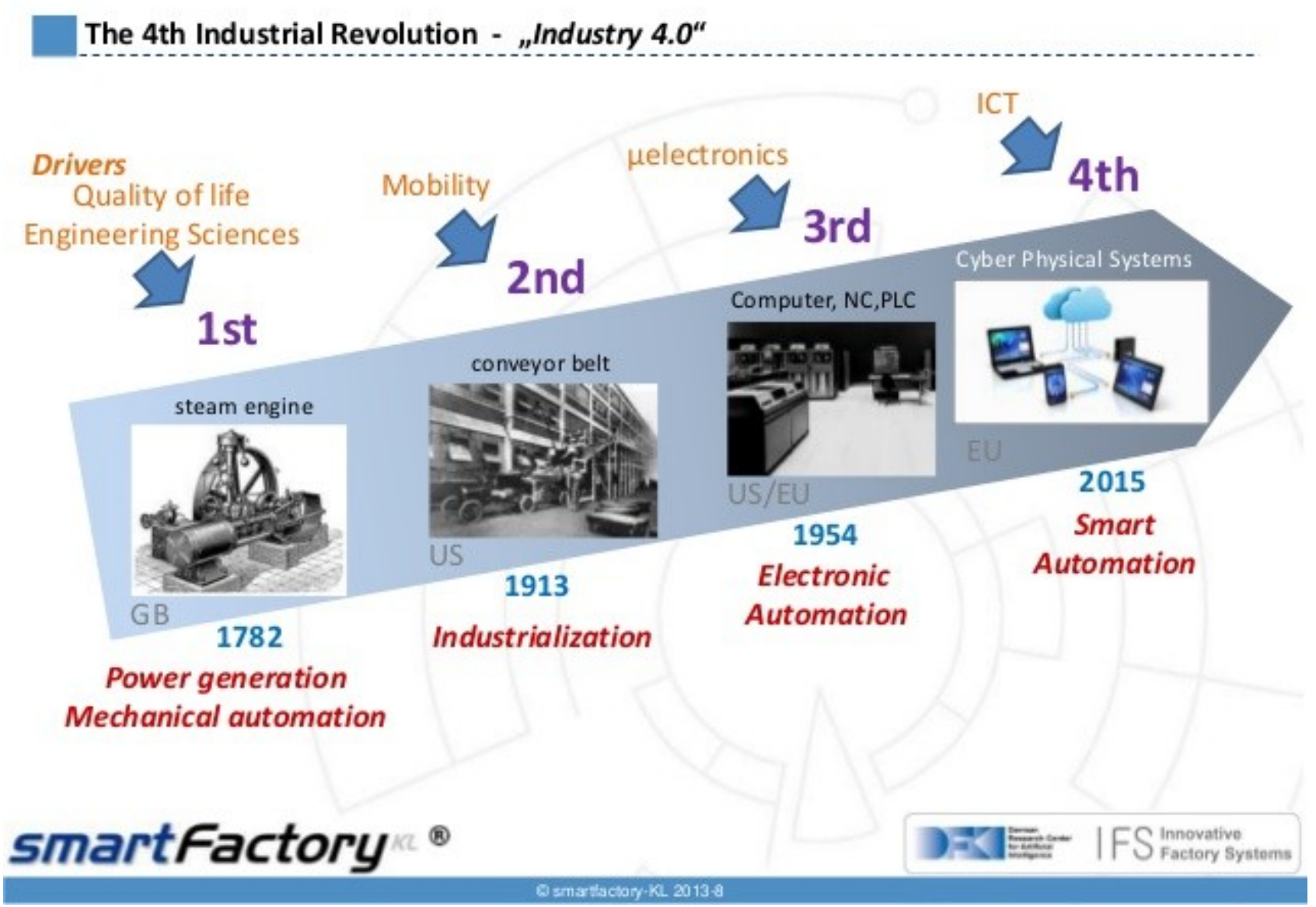
Conclusion so far

- Standard manufacturing automation is mostly based on industrial production (batch processing and continuous processing).
- This kind of manufacturing will not disappear but other solutions might be useful.
- Why is there a need for other solutions?
  - Customers want personalized products
  - New technologies available
  - Short time-to-market needed

Overview of part 2

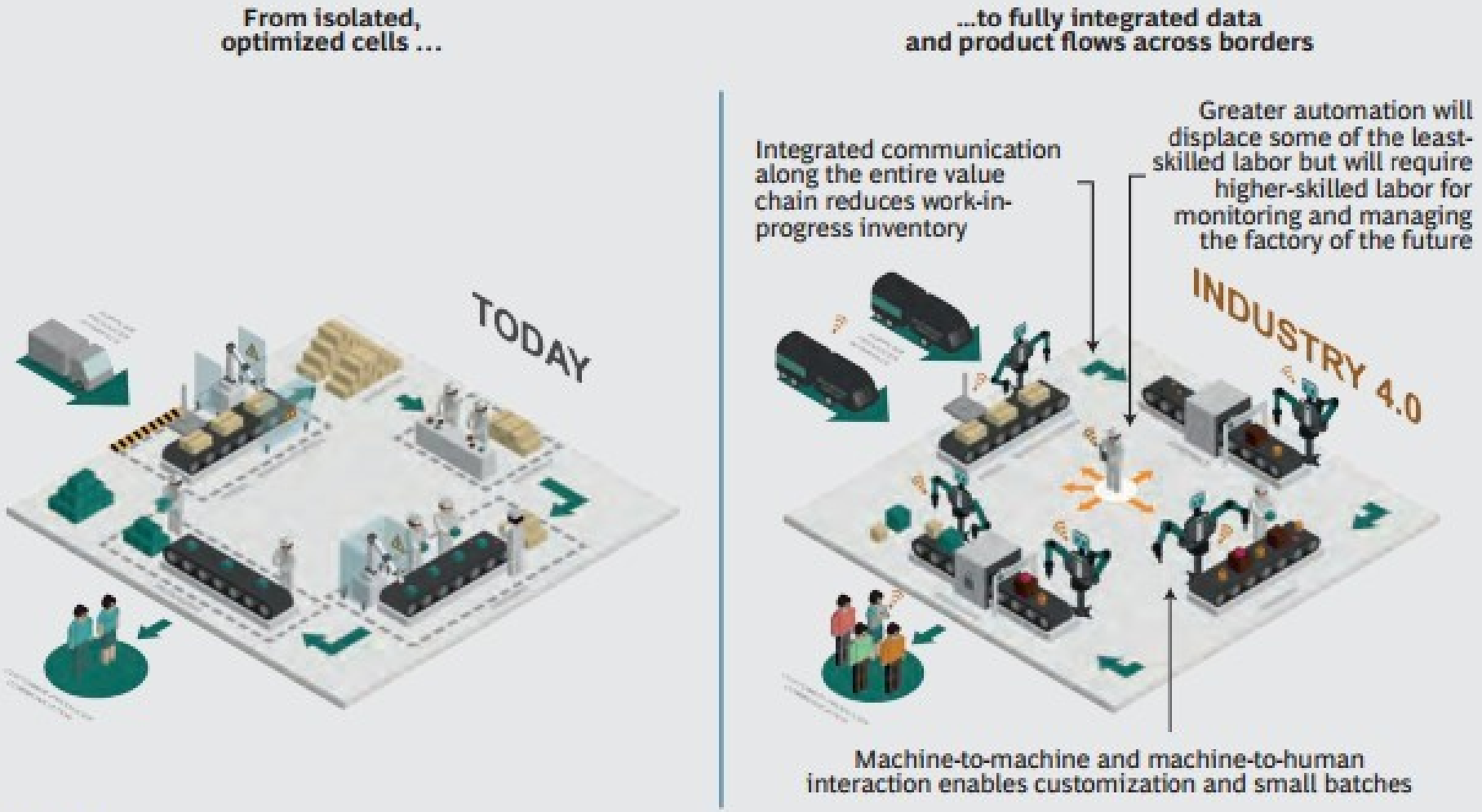
- Industry 4.0
- Agent-based manufacturing
- Production grid
- Product flow in the grid
- Grid adaption
- Results

Industry 4.0


The 4th Industrial Revolution - „Industry 4.0“
Drivers
Quality of life
Engineering Sciences
1st
steam engine
GB
1782
Power generation
Mechanical automation
Mobility
2nd
conveyor belt
US
1913
Industrialization
µelectronics
3rd
Computer, NC,PLC
US/EU
1954
Electronic
Automation
ICT
4th
Cyber Physical Systems
EU
2015
Smart
Automation
smartFactory KL ®
DFKI
IFS Innovative Factory Systems
© smartfactory-KL 2013-8

Industry 4.0

EXHIBIT 2 | Industry 4.0 Is Changing Traditional Manufacturing Relationships



Source: BCG.

Initiatives everywhere

Manufacturing Challenges Resumed

- Short time to market
- Customer specific products
- Small quantities

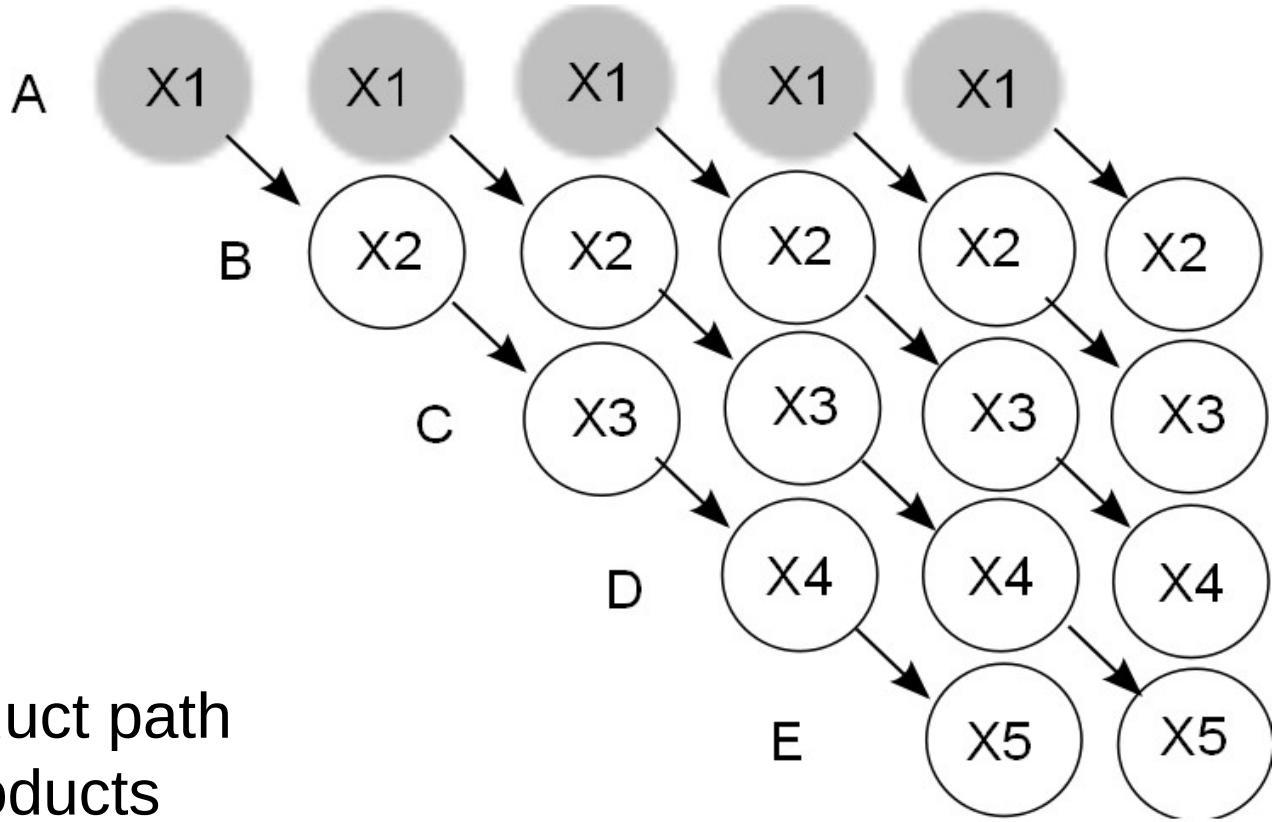
Possible solution: Grid production

- Based on a grid of versatile production platforms (called equiplets)
- Agile and scalable software infrastructure

Enabling technologies

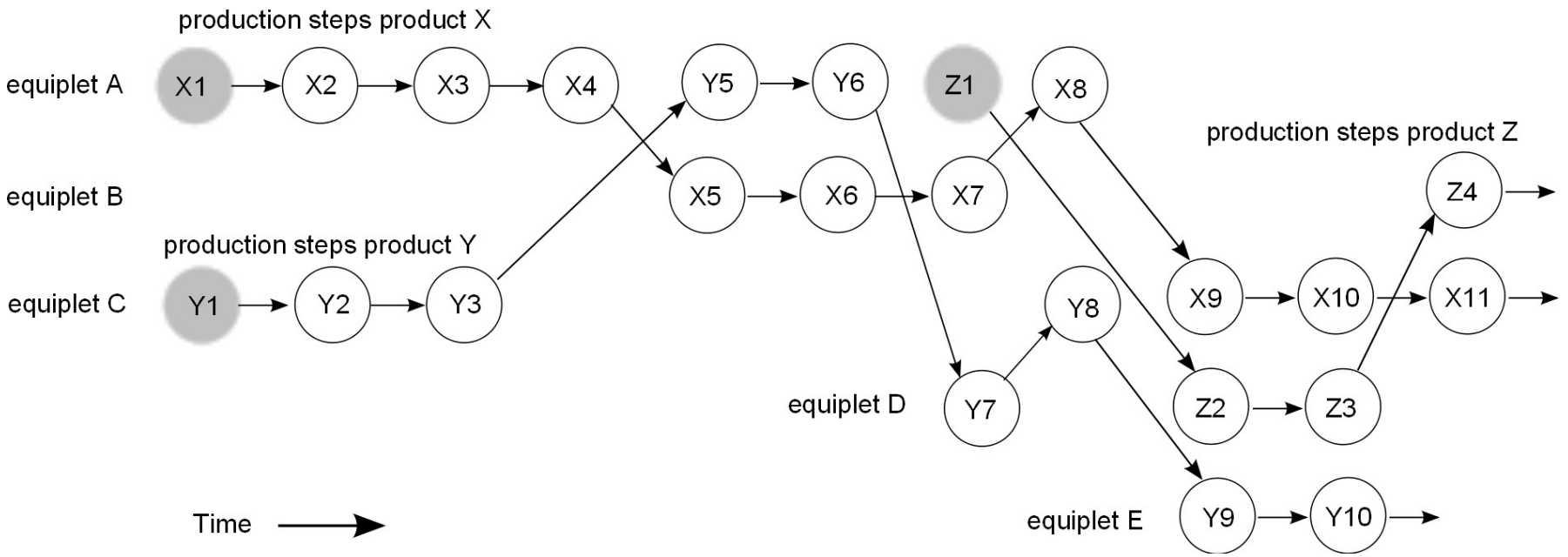
- 3D printing (additive manufacturing)
- Fast and reliable (wireless) networking
- Cheap powerful single board computers
- Cheap robotics

Classic pipeline production



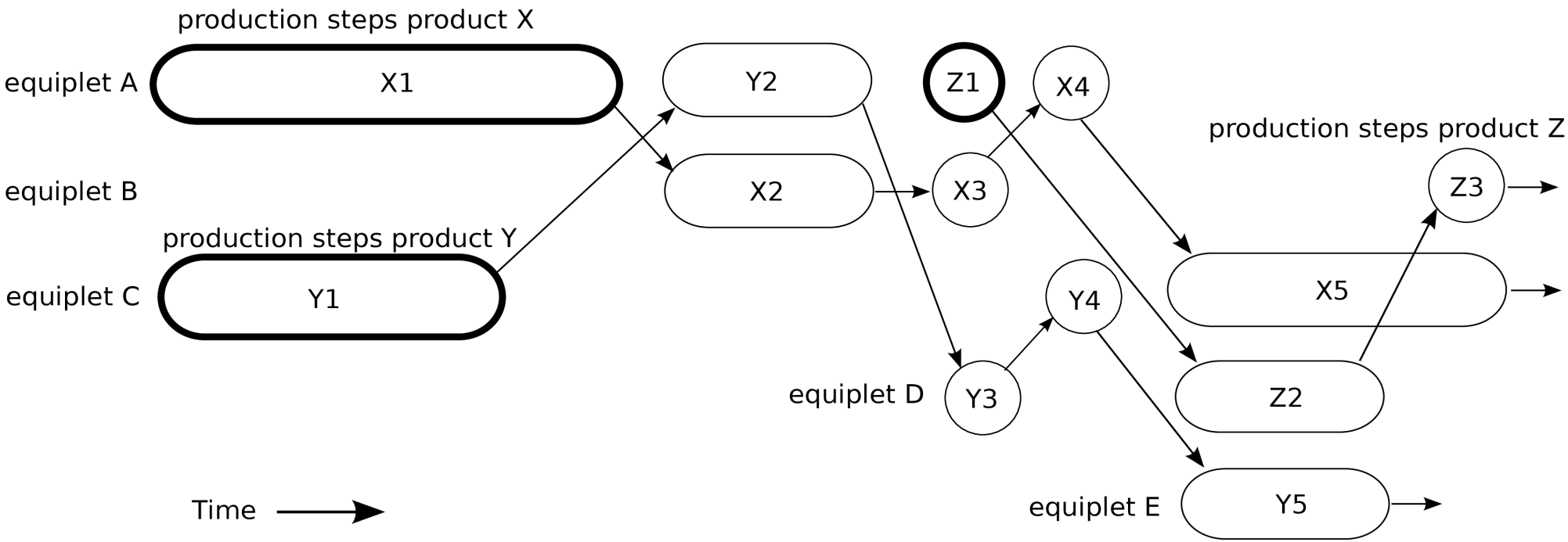
Fixed product path
Similar products
Huge batch size

Grid production 1(2)

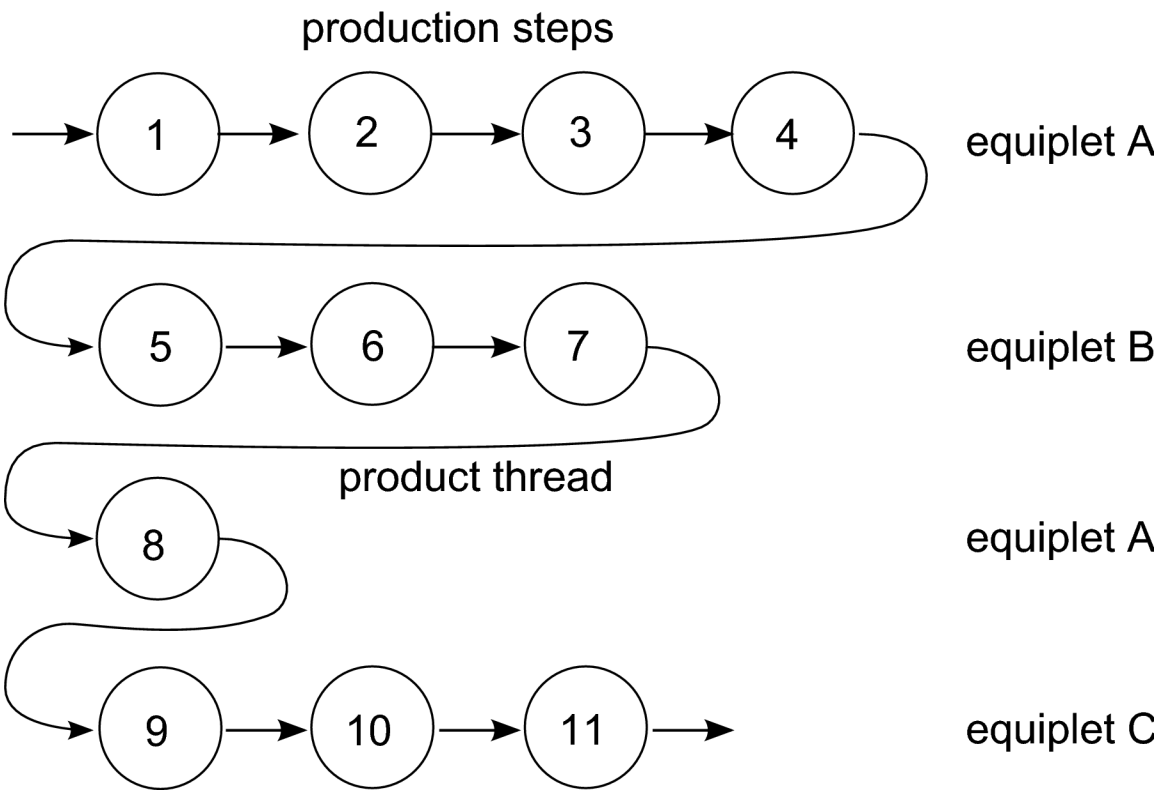


Different product paths (product threads)
Different products (multi parallel production)
Small batches or single product manufacturing

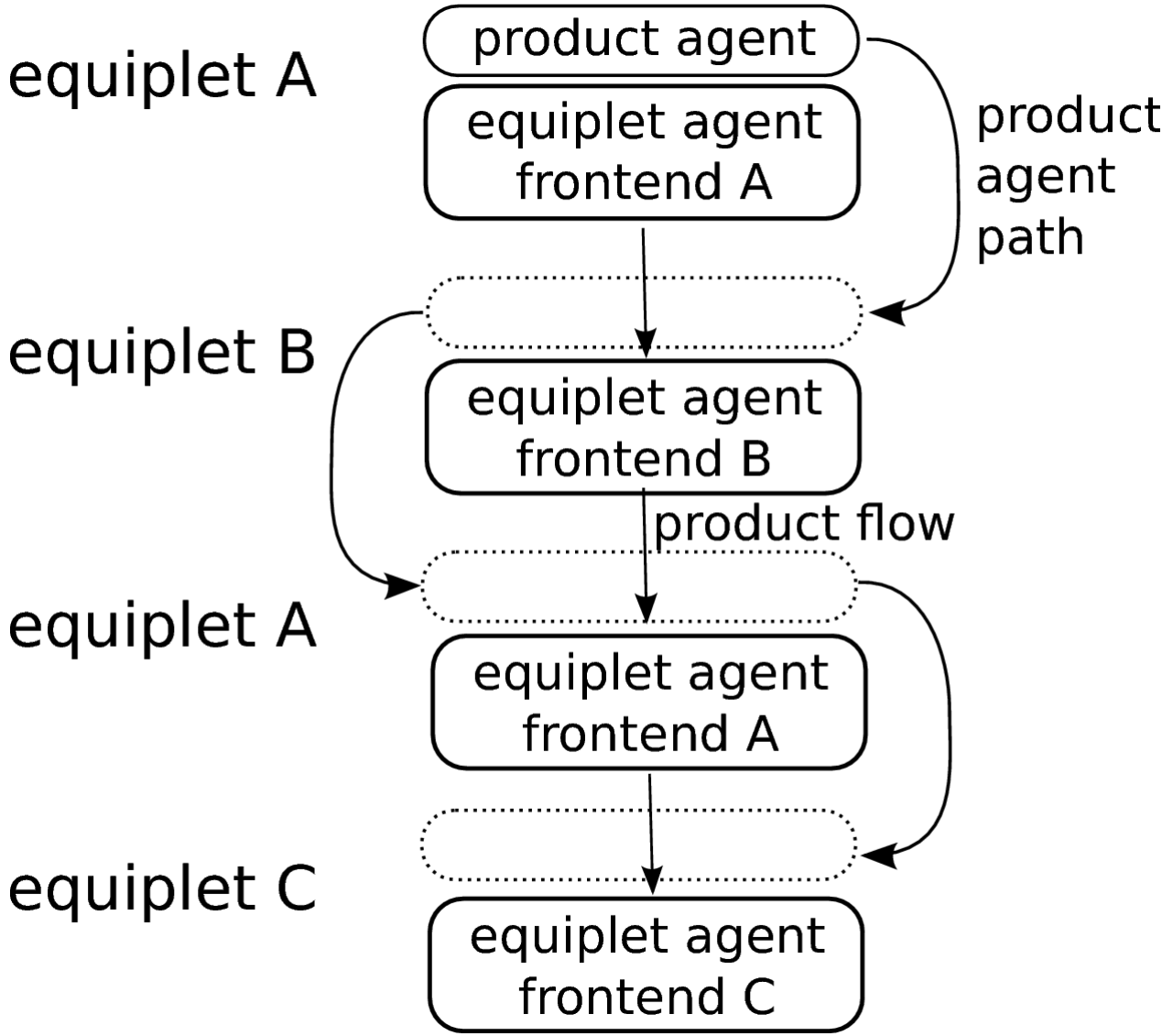
Grid production 2(2)



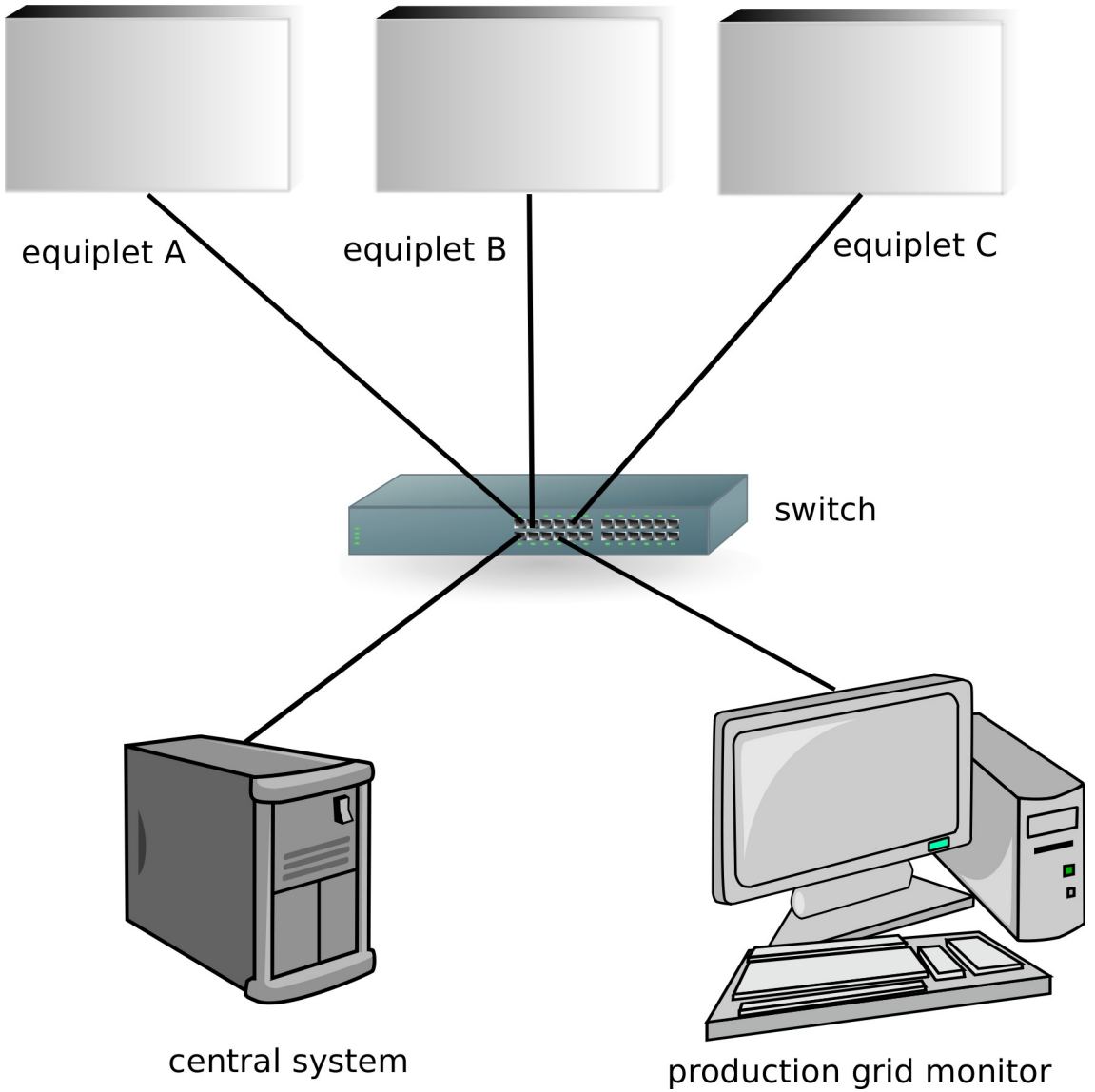
Example of a product path



Product agent and equiplet agents



Grid production



Equiplets with different frontends

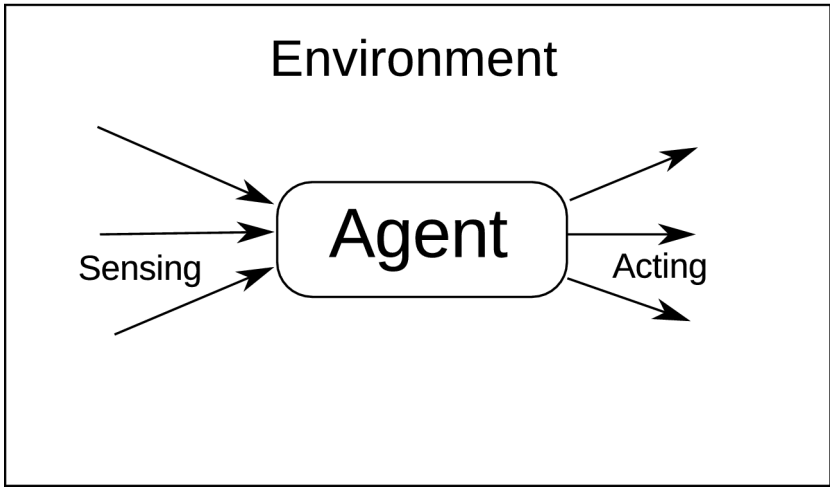
ICT infrastructure solution

- Every product is (possibly) unique
- Every product has its production steps
- Distributed system

- A product agent **represents the product** and knows **what** (production steps) to do
- An Equiplet agent **represents the equiplet** and knows **how** to do (certain production steps)

Agents

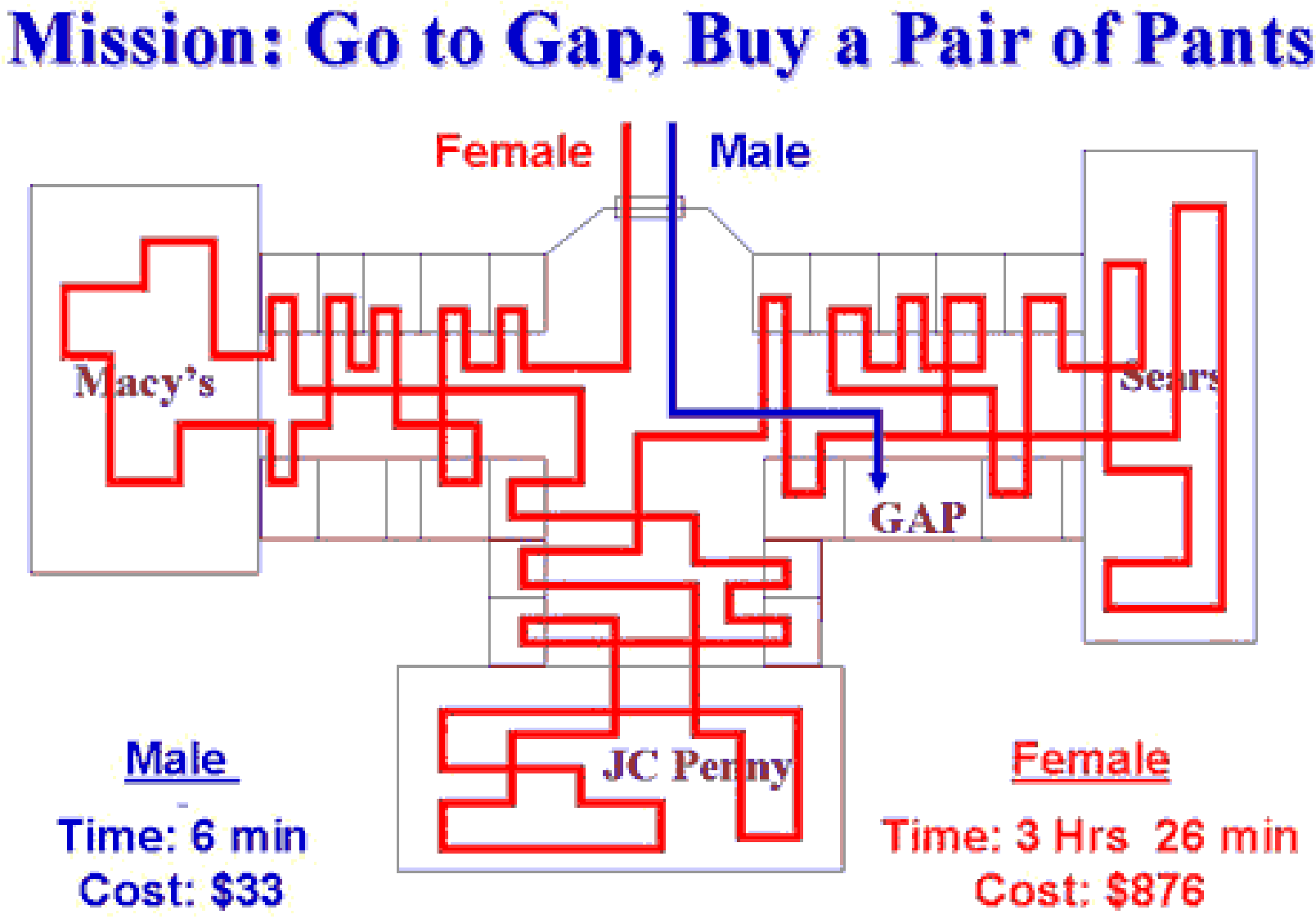
- Autonomous systems
- “Living” in an environment
- Sensing, acting, reacting



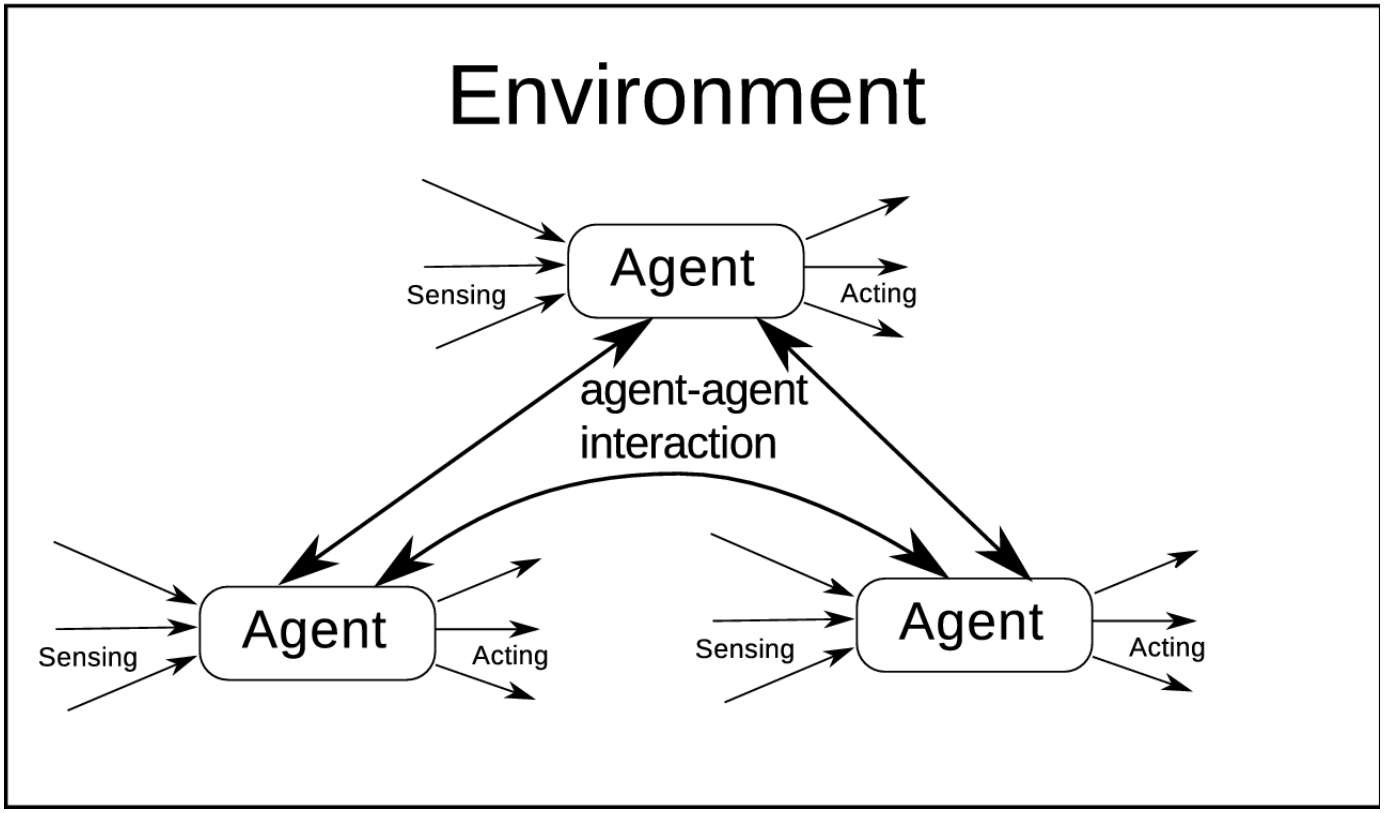
Definition by Wooldridge and Jennings:

“An agent is a computer system *that is* situated *in some* environment *and that is capable of* autonomous action *in this environment in order to meet its* design objectives*”*

Agent design objective or goal



MultiAgents



- Interacting agents
- Roles, communication
- Cooperation, negotiating

Multiagent production 1(2)

Equiplet agents publish their production steps on a blackboard

Product agents choose the equiplets and make reservations for these equiplets

Product agents negotiate to find a solution in case of scheduling problems

Product agents collect production information to build a product log.

Multiagent production 2(2)

Equiplet agents have a frontend (thus a set of production steps)

Equiplet agents publish these production steps on a blackboard

Equiplet agents wait for product agents to arrive

Equiplet agents send production information to product agents when performing a production step

Problems to be solved

Path planning

Production scheduling

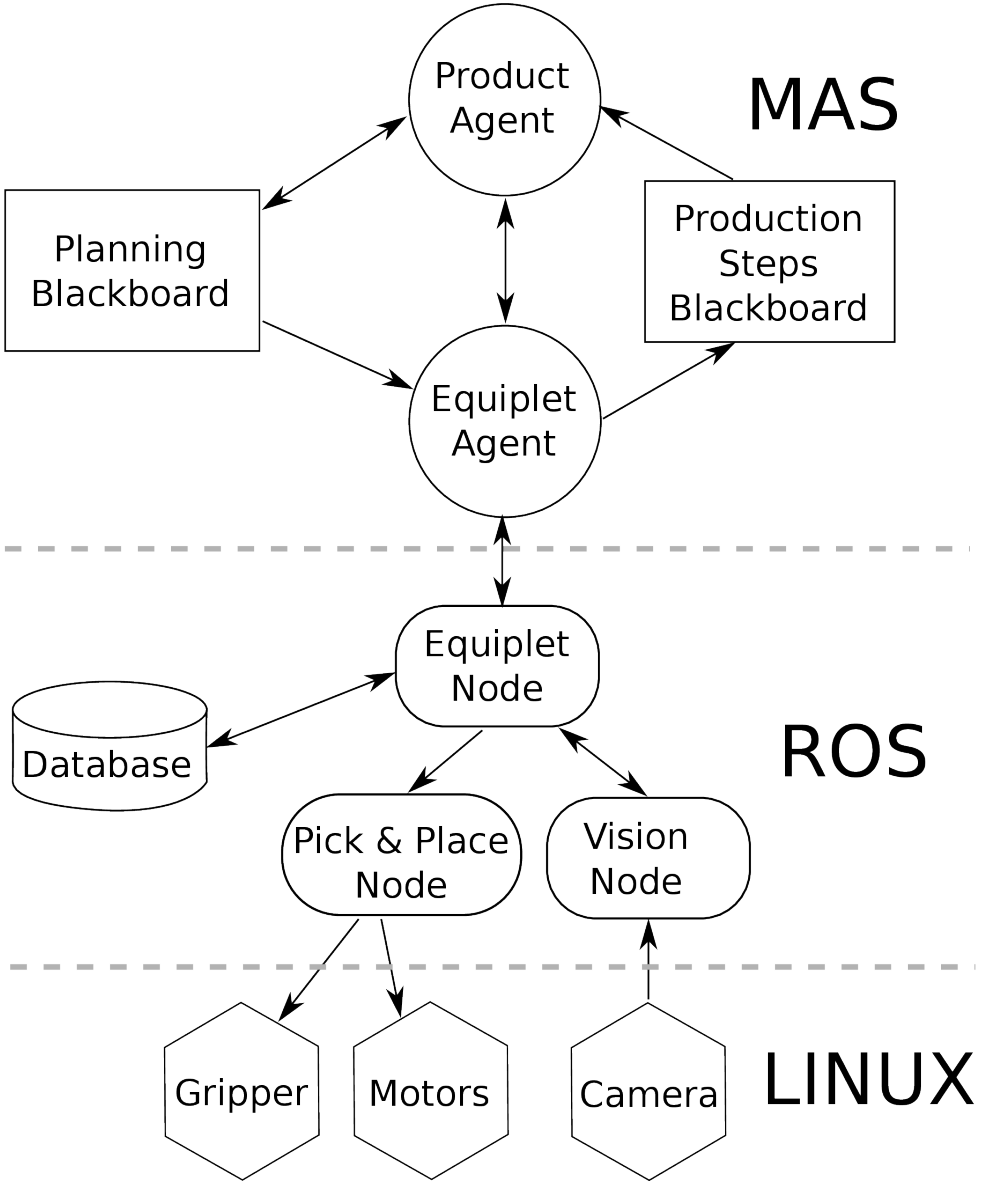
Product logging

Transport (materials and products)

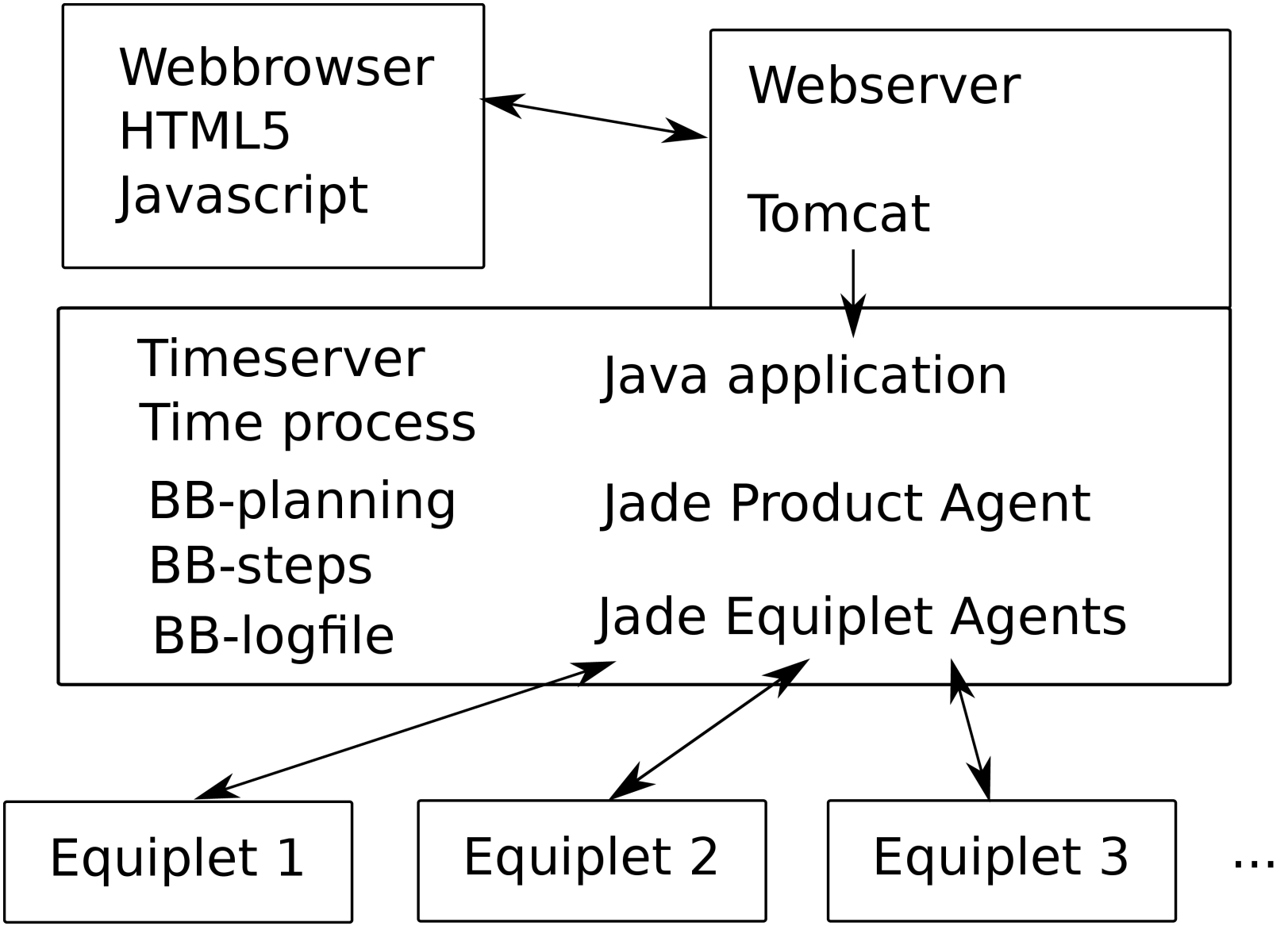
Error recovery

Software architecture

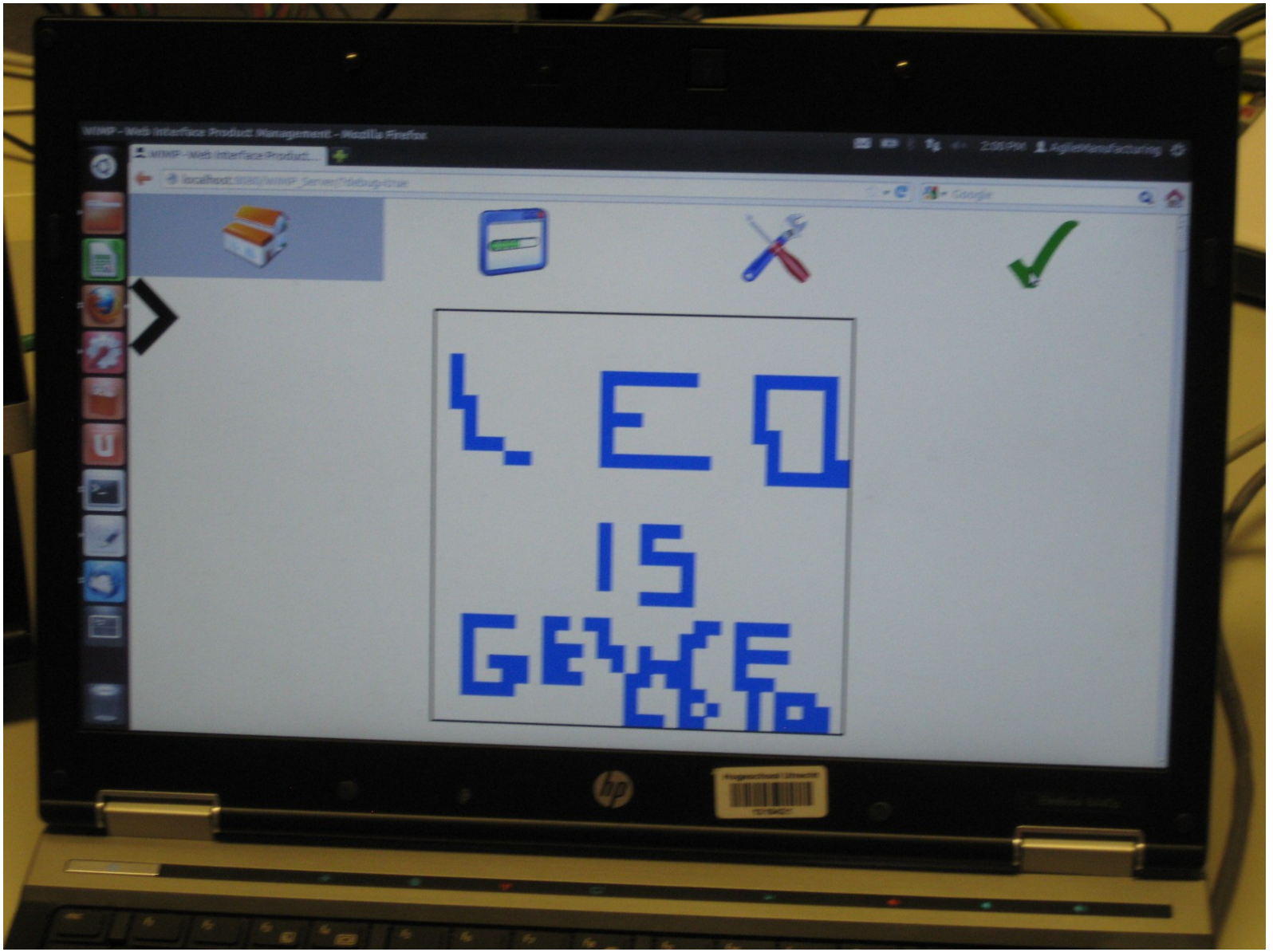
Architecture



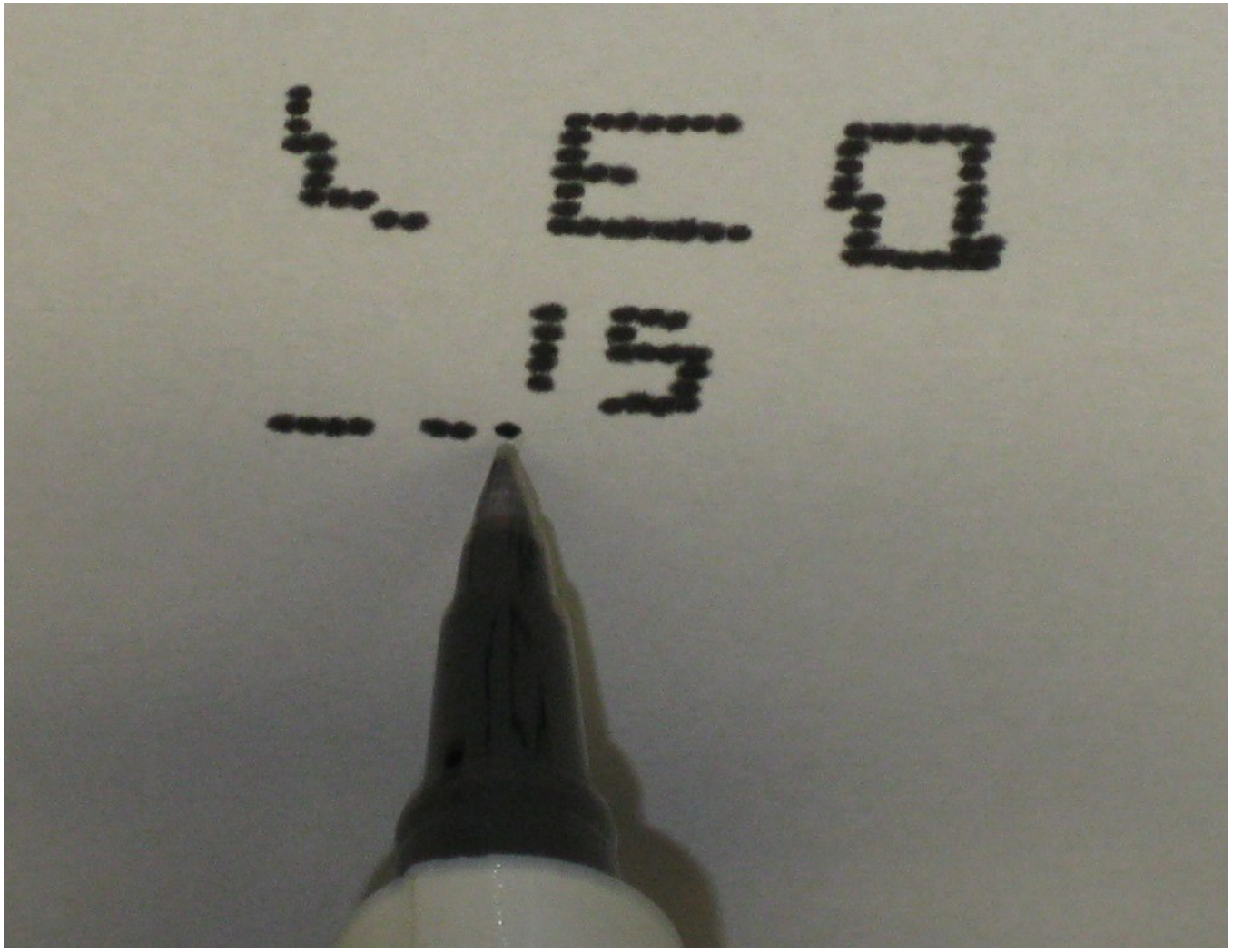
Implementation



Web interface



Result

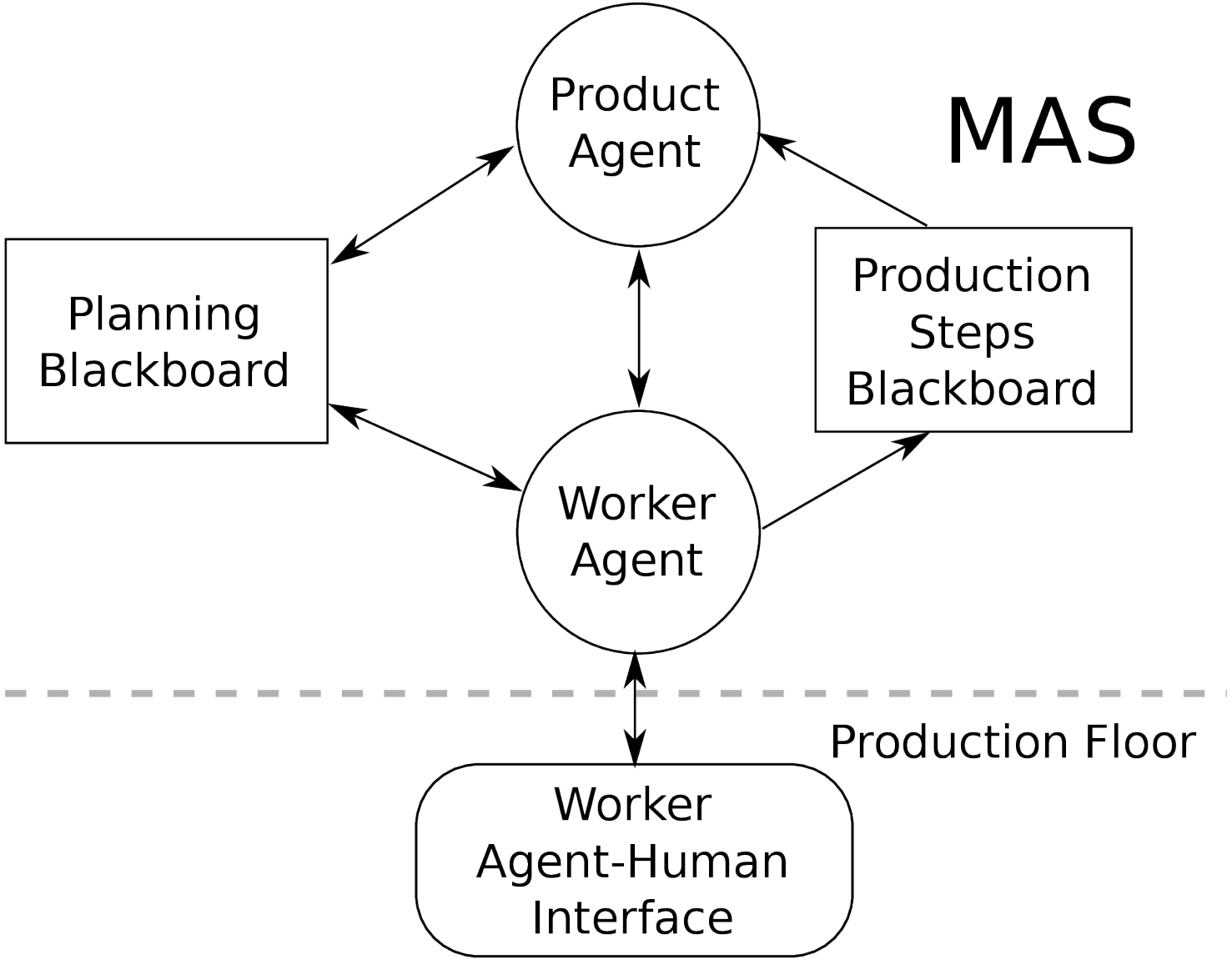


Using this model in a hybrid environment

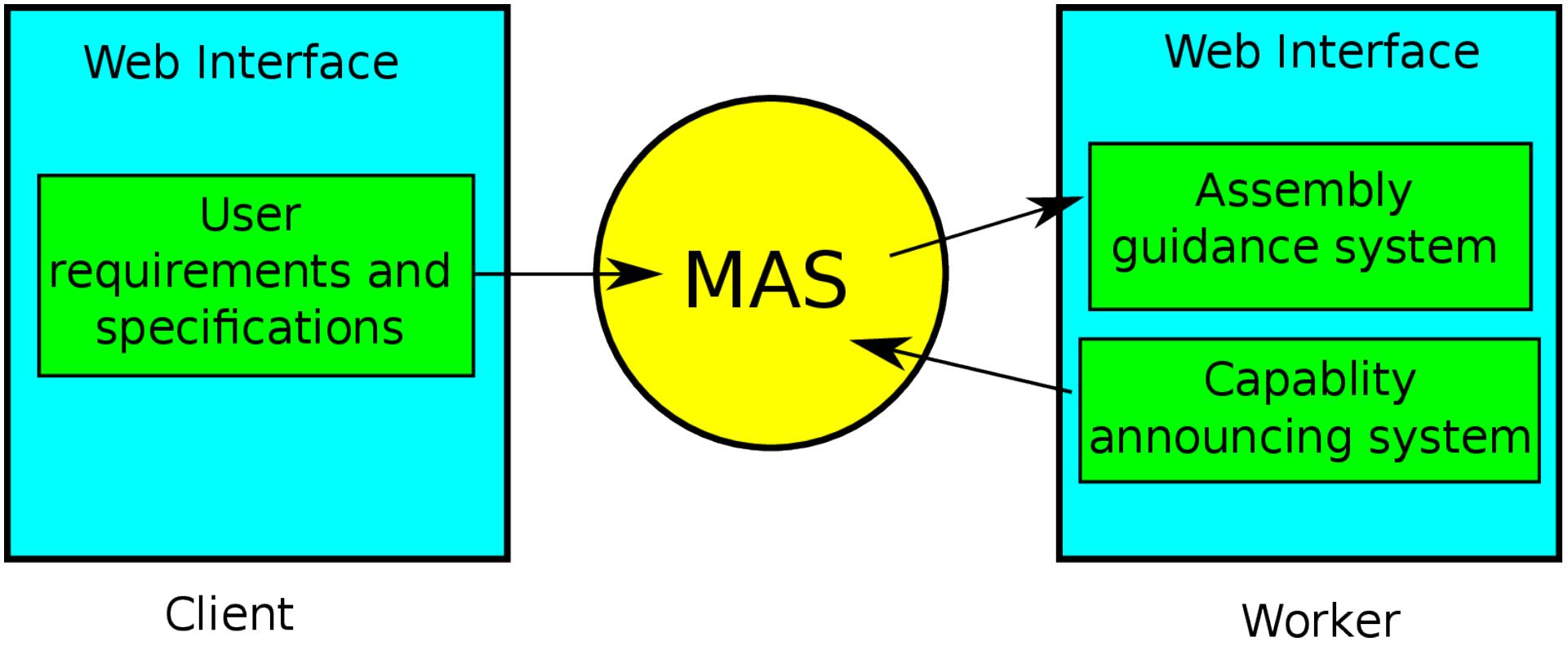
- **What to do** versus **how to do**
- This model can also be used in the situation of human workers instead of equiplets.

- A product agent **represents the product** and knows **what** (production steps) to do
- A worker agent **represents the human worker** and knows **how** to do (certain production steps)

Hybrid architecture



Implementation



Conclusion so far

The concept has been implemented in an experimental setup

Agent technology fits well to a distributed infrastructure

Concept can be the basis of product agents in the life cycle of a product

The product agent is a good candidate to represent the product in the Internet of Things

Agent-based Product Support

Life cycle of a product

- Design
- Manufacturing
- Distribution
- Usage
- Recycling

Note: the product life cycle is a different concept

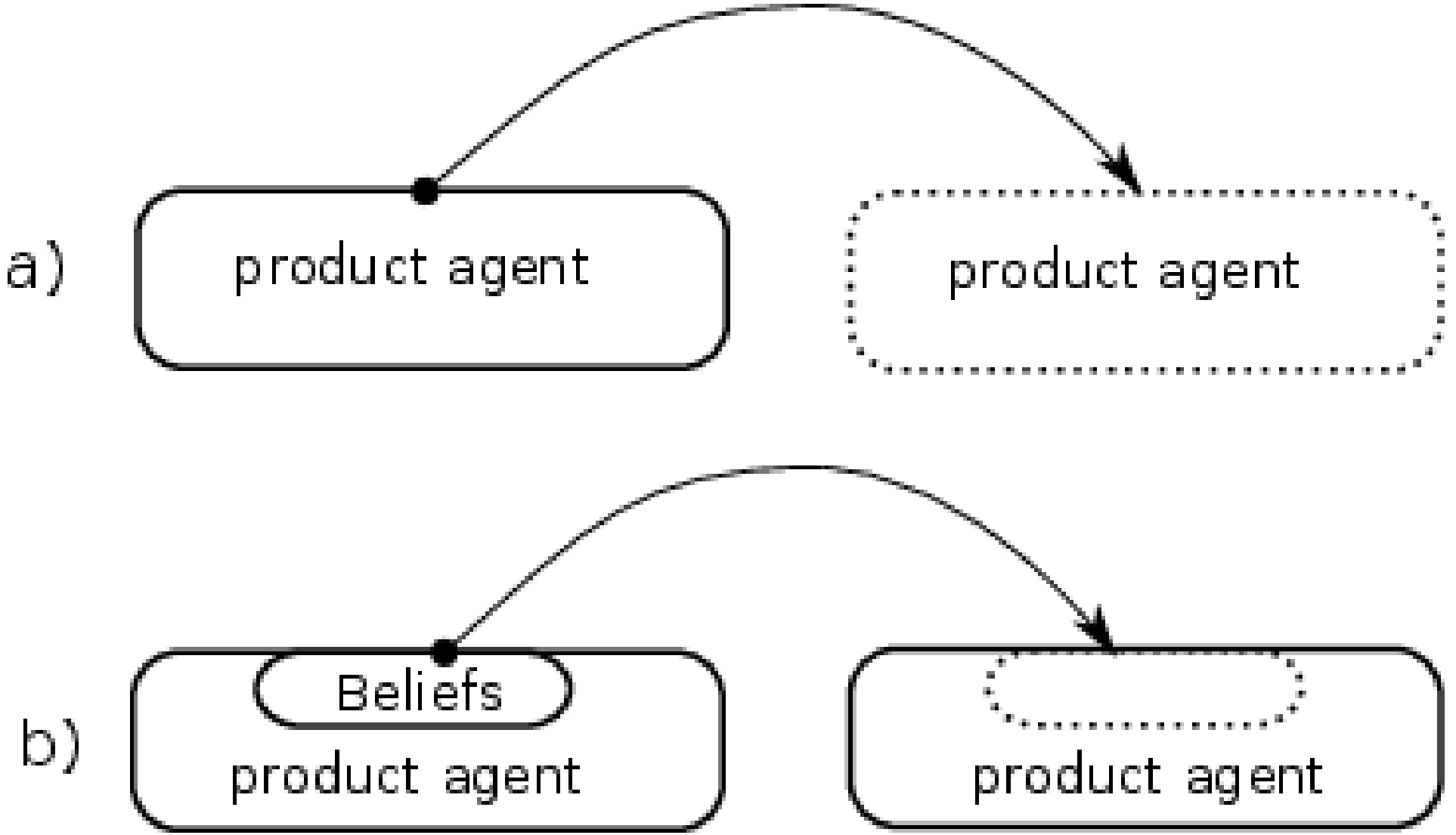
What to do with the product agent when the manufacturing is done?

- Embed the agent with its information in the product
- Or transfer the information to another embedded agent
- Keep the product agent alive in cyberspace

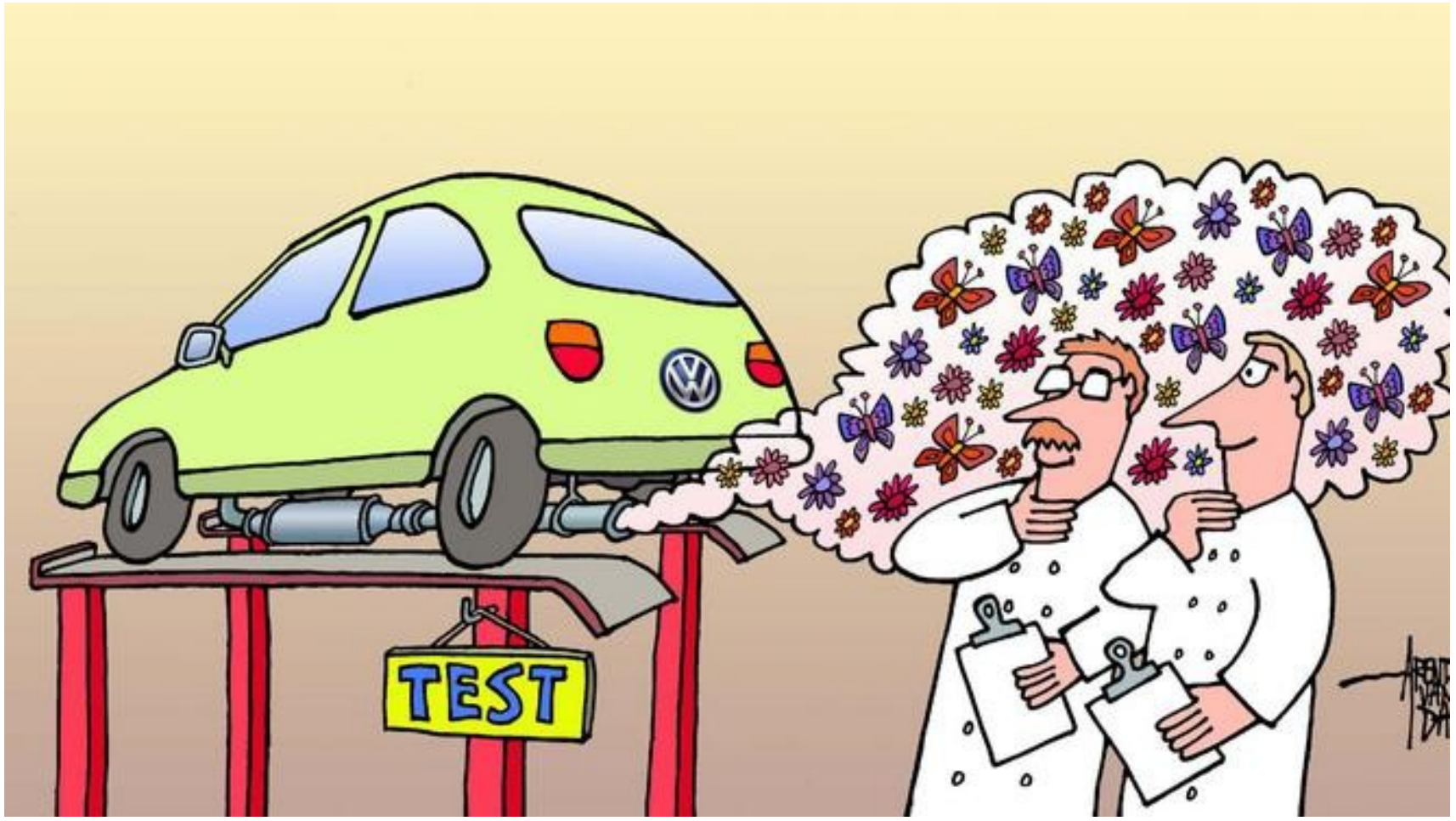
Benefits of embedded agents

- Depends on the phase in the life cycle
- All information about a specific product is availabe
- Basis for implementing the Internet of Things

Embedding a product agent



Risk of trusting embedded software



Conclusion

Agents can play an important role in all parts of the life cycle of a product

A product agent is a good basis for the Internet of Things (IoT)

An aspect of IoT can be recycling and repair support

A product agent acts like a guardian angel (except for the spiritual aspects)

Thank you!
Questions?