Molde University College
Specialized University in Logistics

The Industrial Internet / Industry 4.0

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Outline

1. Origin of the terms “Industry 4.0”, “Industrial Internet”
2. Why 4.0? What was there before?
3. Underlying technologies and principles:
   - Smart Objects / Things
   - Internet of Things / Industrial Internet of Things
   - Cyber-Physical Systems (CPS)
   - Smart Factory
4. Implications of Industry 4.0 paradigm:
   - for production processes
   - for the role of people in CPSs and Smart Factory production
   - for supply chains
5. Problems:
   - Cyber-security
   - Privacy
   - Acceptance
6. Conclusions. Are we there yet?

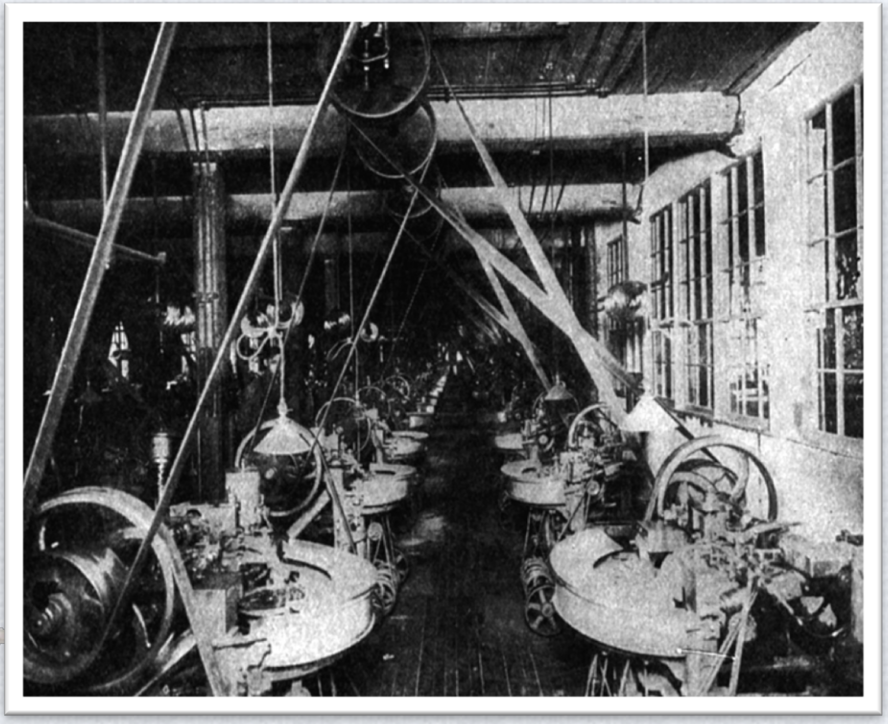
Origin of the Terms

- The term "***Industry 4.0***" (***Industrie 4.0***) was introduced in 2011 on the Hanover Fair (Hannover Messe). The term refers to the forth industrial revolution.
  H. Kagermann, W. D. Lukas, & Wahlster, W. (Apr., 2011). Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution. VDI nachrichten, (13), 2011.
- The term "***Industrial Internet***" was introduced in 2012 by General Electric (GE).
  J. Leber. (Nov., 2012). General Electric Pitches an Industrial Internet. MIT Technology Review. https://www.technologyreview.com/s/507831/general-electric-pitches-an-industrial-internet/
- Other terms: I4.0, Smart Manufacturing, Digital Manufacturing, Manufacturing Industrial Internet, Smart Factory, Digital Factory, Internet of Everything.
- Some argue that the German *Industrie 4.0* refers primarily to manufacturing, while the American *Industrial Internet* refers to a broader context (industry + civil engineering, power grids, etc.).
- The terms may be used interchangeably. The underlying principles and technologies are the same regardless of the context (industrial or not).

Before "4.0"

- **First industrial revolution**: steam engine and mechanization.
- Time: started 1780s, lasted throughout 1800s.

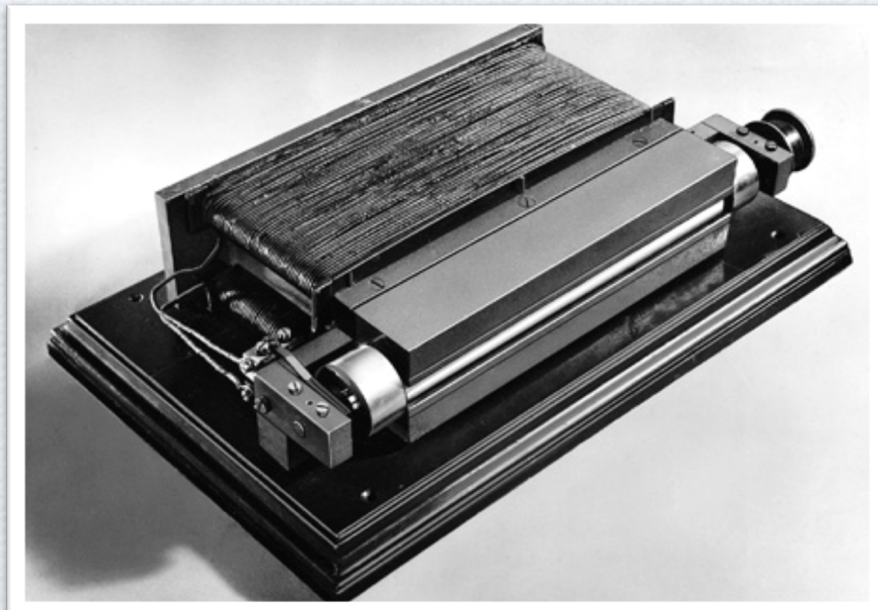
Steam engine powered factory
Source: www.locallocalhistory.co.uk/brit-land/power/page08.htm



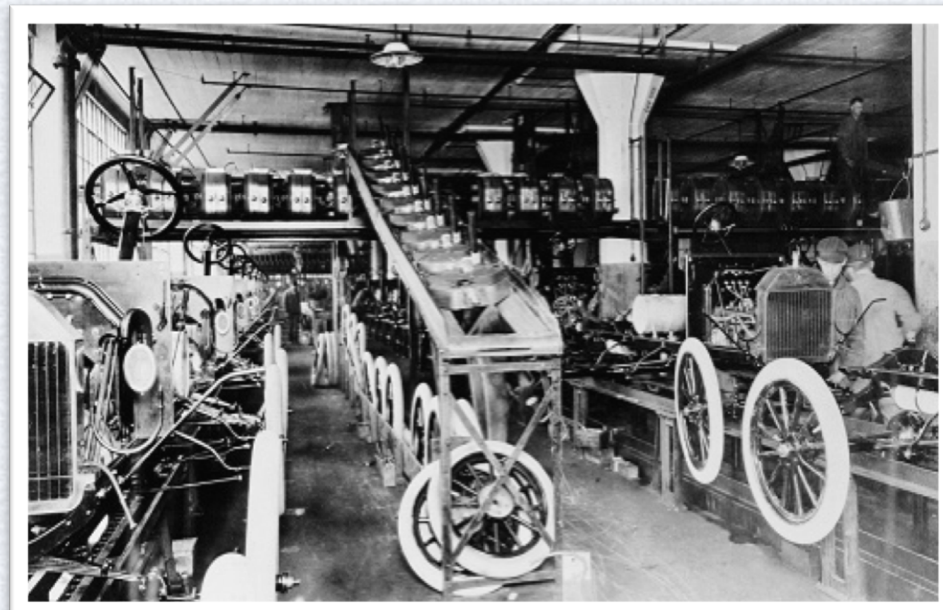
Steam engine powered factory
Source: www.richardreeve.info/pages/industrial-revolution-factory-machines.awp

Before “4.0”

- **Second industrial revolution**: electric motors.
- Time: from mid-19th century till mid-20th century.
  In 1920s, only half of the factories were powered by the electricity.



Prototype of a dynamo-machine invented by Werner von Siemens in 1966.
Source:www.siemens.com/history/en/news/1051_werner_von_siemens.htm

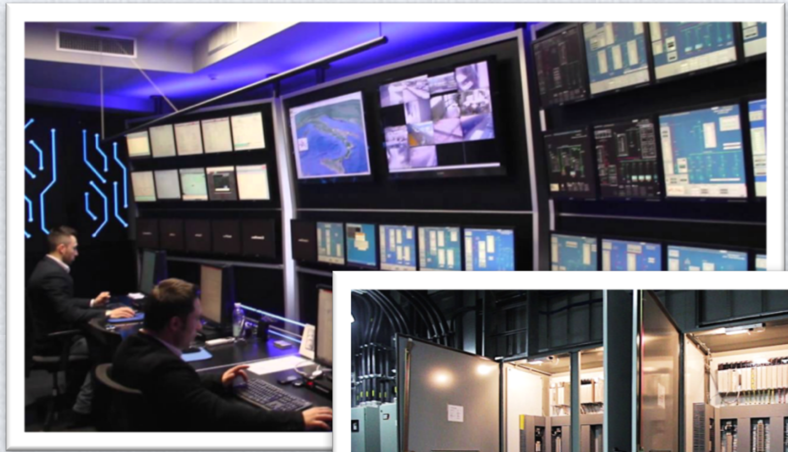


Ford Model T assembly line: machinery is powered by electric motors, introduction of conveyor belts.
Source: corporate.ford.com/innovation/100-years-moving-assembly-line.html

Before "4.0"

- **Third industrial revolution**: electronics, digitalization, computers, highly efficient automation systems.
- Time: mid-20th century – present.

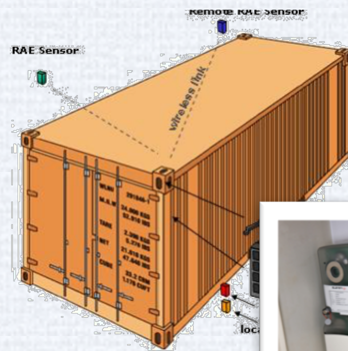
The first programmable logic controller (PLC) Modicon-084, introduced in 1969.
Source: www.tesla-institute.com/index.php/programmable-logic-controllers-plc/history-of-plc

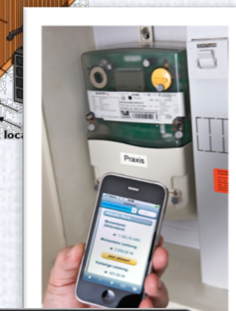


Modern time control room (with computers / workstations for operators) and PLC panels room.
Source: www.meglab.ca/en/products/control-panels-assembly-plc/

Smart / Intelligent Objects

- Drivers of the **fourth industrial revolution** are continuing digitalization and networks development.
- The first step to explaining Industry 4.0 is the *Internet of Things*.
- *Smart / intelligent objects*: smartphones, smart TVs, smart homes, etc.
- Industrial examples: smart sensors, smart actuators.
- Examples:
- Smart container: has the information about where it is at a certain point in time, about its route before, and about where it is going, it also about its content (and, possibly, the history of conditions inside, e.g., the temperature).
- Smart electrical energy meters: measure power consumption, obtain the electricity price information for various period (e.g., for the daytime and the nighttime), run the dishwasher in the night (when electricity is cheaper).
- Smart solutions for food (e.g., frozen products: chicken, fish, prepared meals, etc.): equipped with sensors and memory units with the history of temperature (condition monitoring), equipped with communication units to give to the information to the users, and notify about problems.



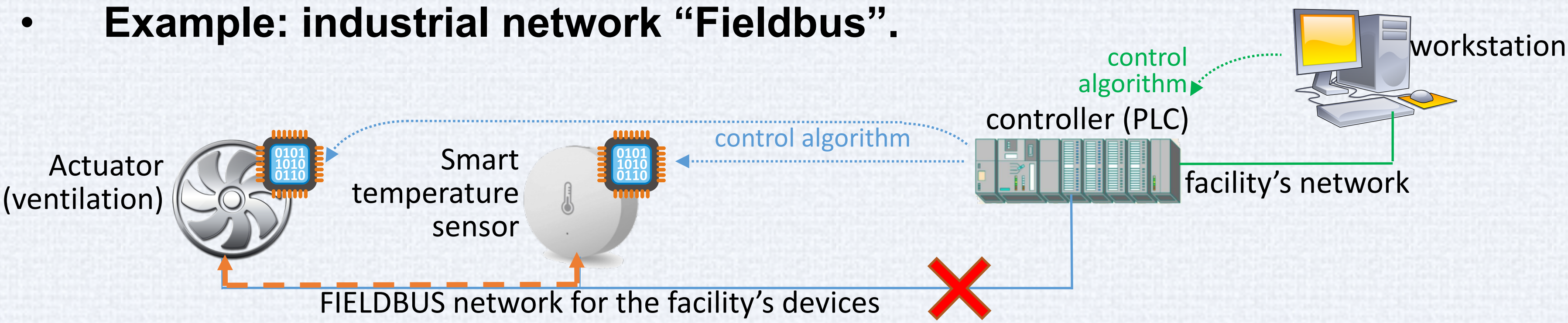


Smart / Intelligent Objects

- The concept of <u>*intelligence*</u> of objects and products:

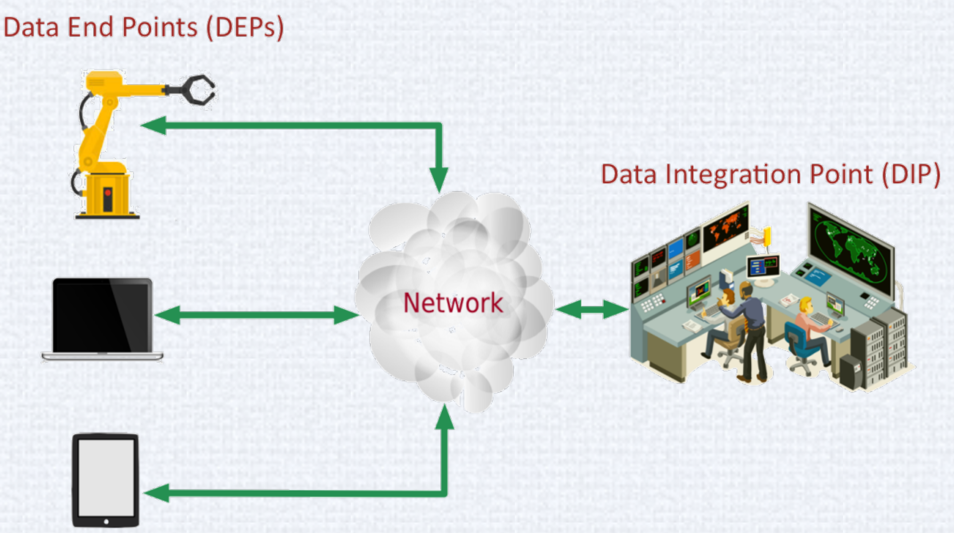
Level of intelligence	Capabilities of smart, connected products (Porter and Heppelmann, 2014)	
	Function	Description
1	Monitoring	sensors monitoring the product and environment
2	Control	control of product's function, potential for personalization
3	Optimization	optimization of products operations: performance enhancement, predictive diagnostics and maintenance
4	Autonomy	autonomous operation, self-coordination with other systems, self-diagnostics

- Smart/intelligent objects' characteristics: CPU, memory (essentially, a mini-computer on board), capability to connect, to be identified, and to operate in a network, capability to adjust the performance to the requirements, capability for recognizing/measuring their environment (with sensors).
- **Example: industrial network "Fieldbus".**



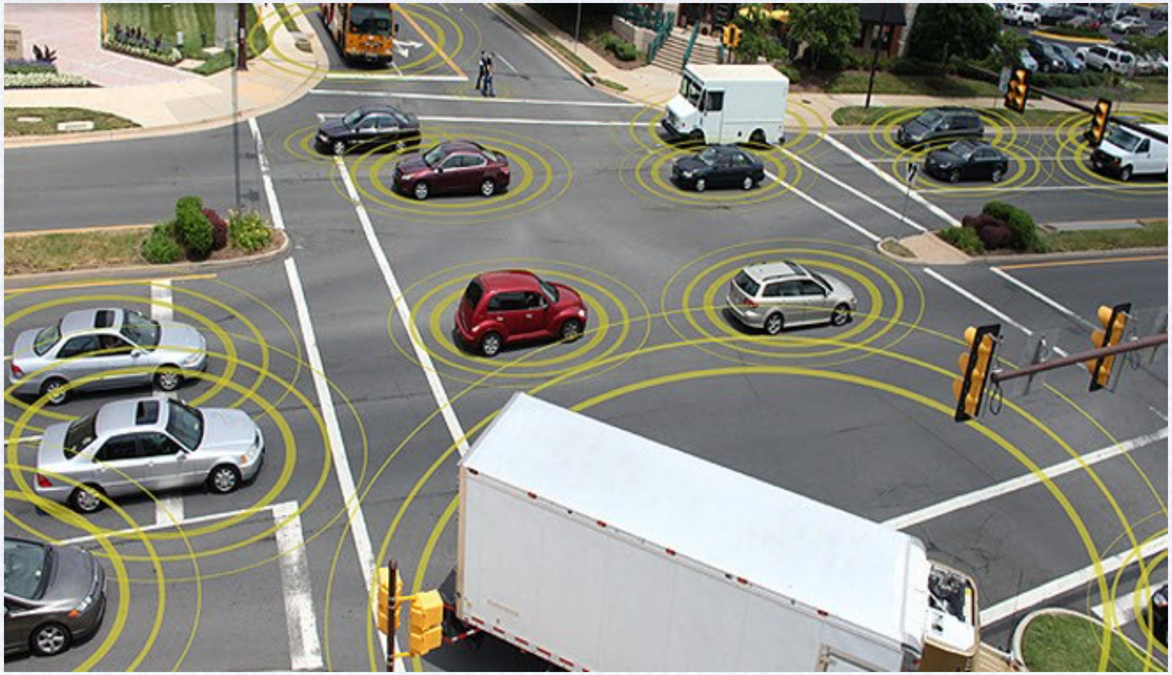
Internet of Things

- The term "*Internet of Things*" is proposed by Kevin Ashton (MIT) in 1999 as the extension of the Internet (already existing "virtual world") to communication between machines (or things in the physical world) between each other, and with people through the Internet (heterogeneous system).
- Smart things are basically "computers with sensors". Example: car with a GPS navigation, with proximity sensors (recognizing distances to objects, recognizing parking spots, computing parking trajectory).
- **Machine-to-machine (M2M) communication**
- <u>Relevant issues:</u>
  - *Identification.* Several Data end-points (machines, devices, computers, users) are the participants.
  - *Interface* between the real objects / machines and the communication network (e.g., Internet).



Internet of Things

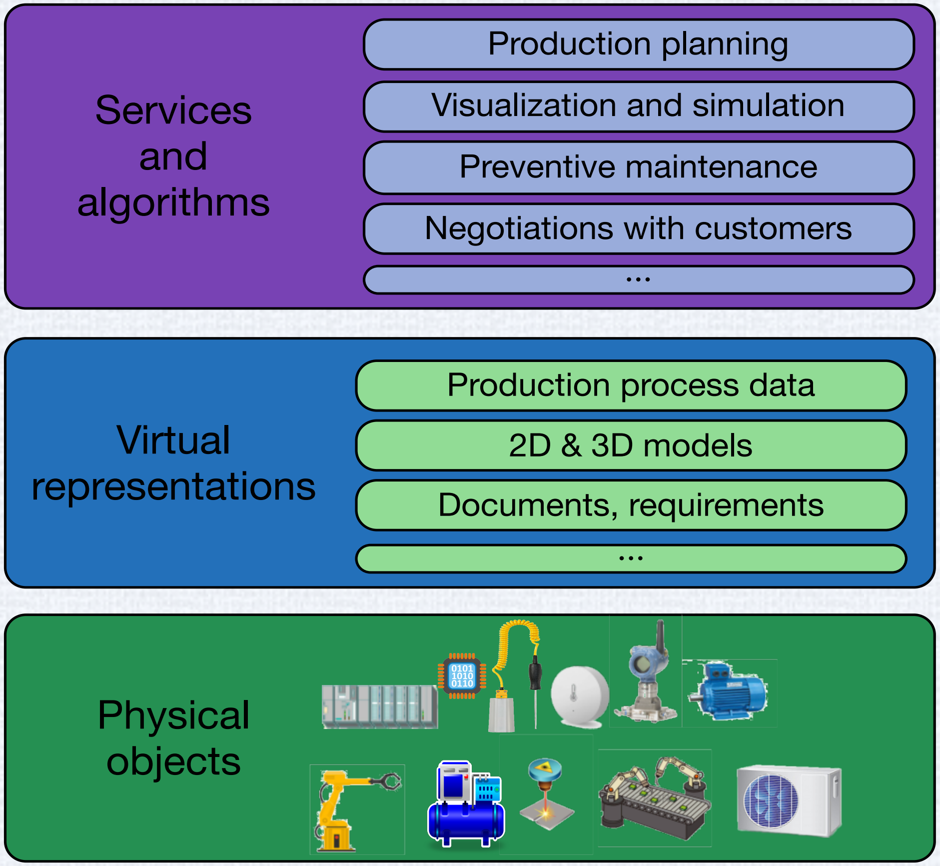
- **Example: traffic control and future possibilities.**
- Traffic lights today either act independently from each other or are controlled by a central traffic control system.
- The physical traffic lights have an virtual representation in the network monitoring their color and their schedule in real-time.
- The cars (if they are "smart" and connected to the same network) can operate according to the plan the traffic light ahead, *adjust the speed*, or (given the cars have models of their efficiency) in can *optimize their energy consumption and/or emissions*.
- Once cars feed their position, speed, and destination back into the network, the *traffic lights could "orchestrate" their behavior to ensure the best possible traffic flow*.
- *Police, ambulances, and fire squats could be granted the green lights* for their routes automatically.



Cyber Physical Systems

- CPS represent “computations and communications deeply embedded in and interacting with physical processes to add new capabilities to physical systems. These cyber-physical systems range from miniscule (pace makers) to large-scale (a national power-grid).” (ACM Digital Library: tcps.acm.org/about.cfm)

- Industrial controllers, sensors, switches, drives and other actuators cooperate with physical objects, machines and processes. CPS plays the role of the interface between the physical world and its virtual representation providing the capability autonomous performance, decision-making and assisting the actions and goals of people.



Industry 4.0: Smart Factory

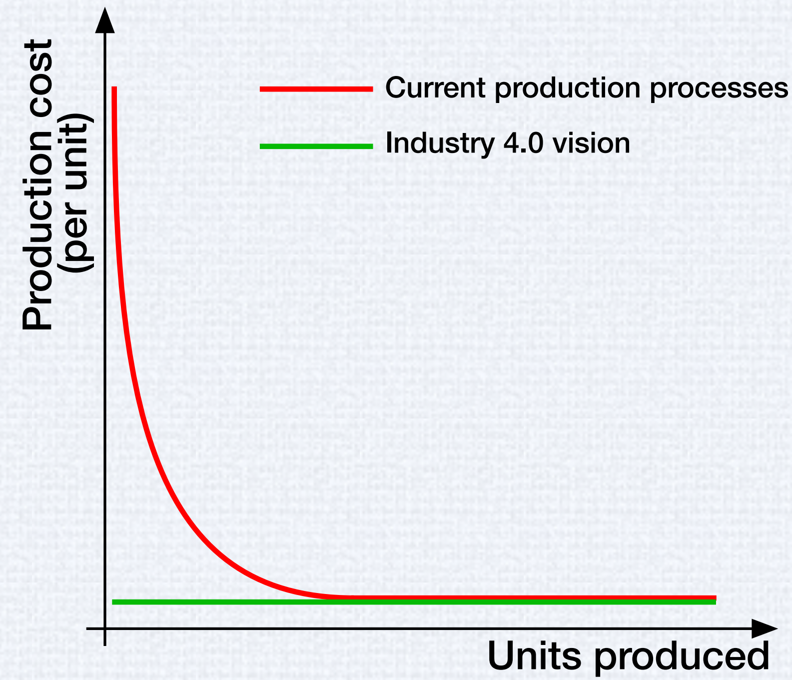
1) Smart machines / devices / production units working within the industrial internet of things environment.

2) "Smart Factory" implies that ***the product gets smart*** and thereby becomes a participant in the industrial internet of things.

- If the product is intelligent, it organizes its production process: it communicates with machines and organizes its path through the factory.

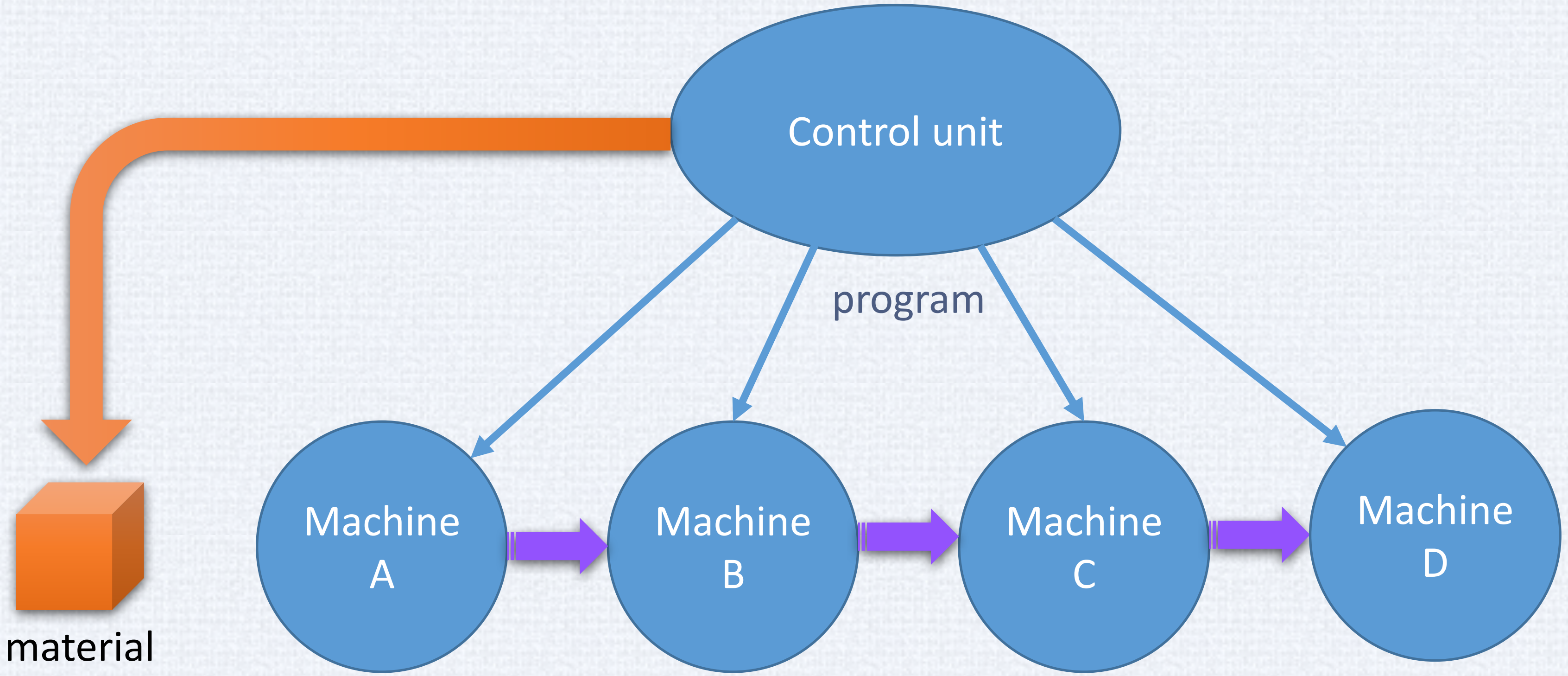
- Background of the approach: mass production is quite cheap; however, the production of a singe customized/personalized product (or a small batch) requires a lot of organization (changeover: machines reconfiguration, production lines testing, etc.).

- The aim: to organize the processes, so that the *production efficiency*, *production flexibility* and the *product's quality* are no longer mutually exclusive.



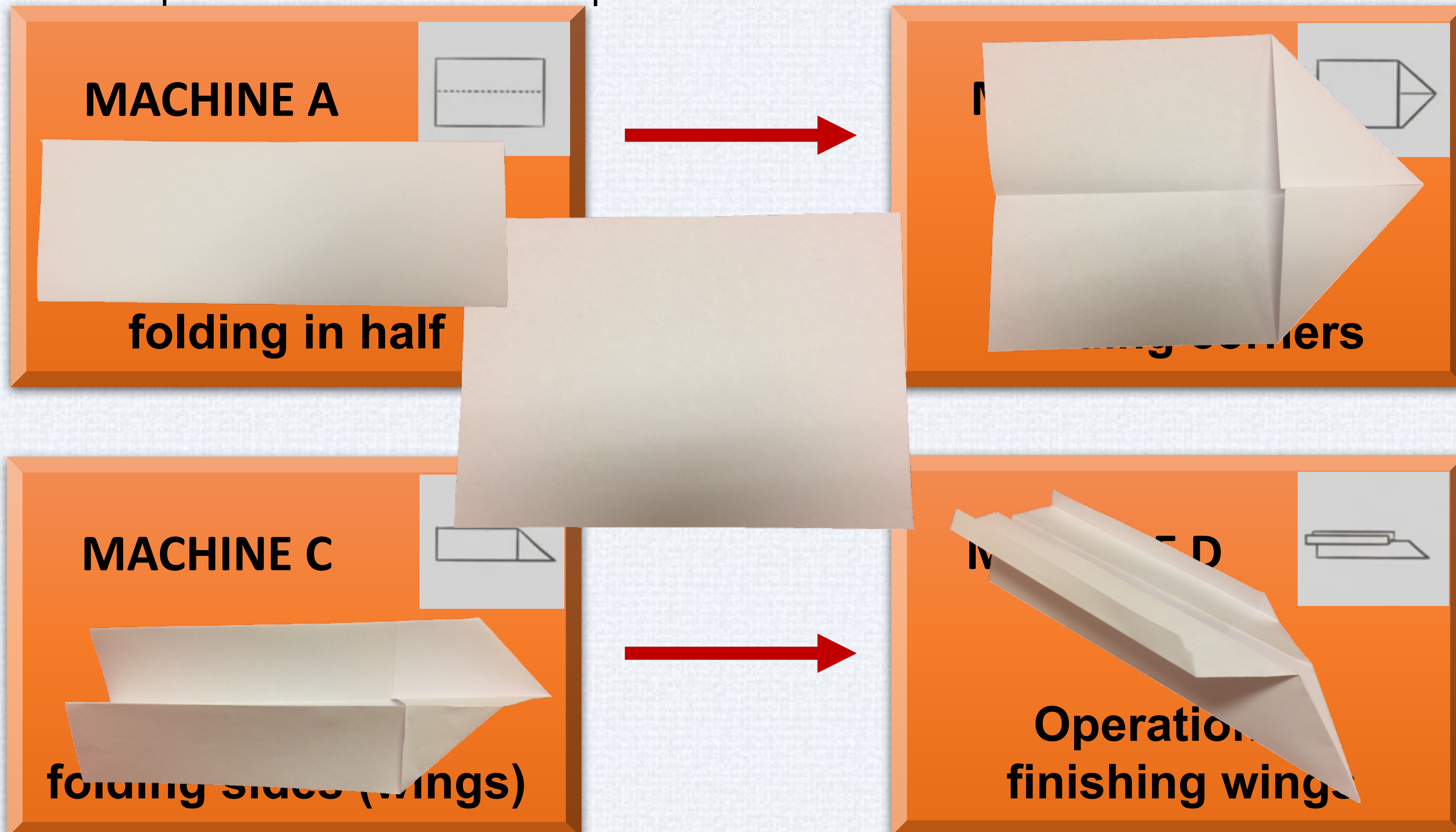
Industry 4.0: Smart Factory

- **Example.** Today's factory (standard manufacturing).
- Centralized control approach:
  - machines are programmed and controlled by a centralized "brain"
  - the production line is fixed and set up for one product



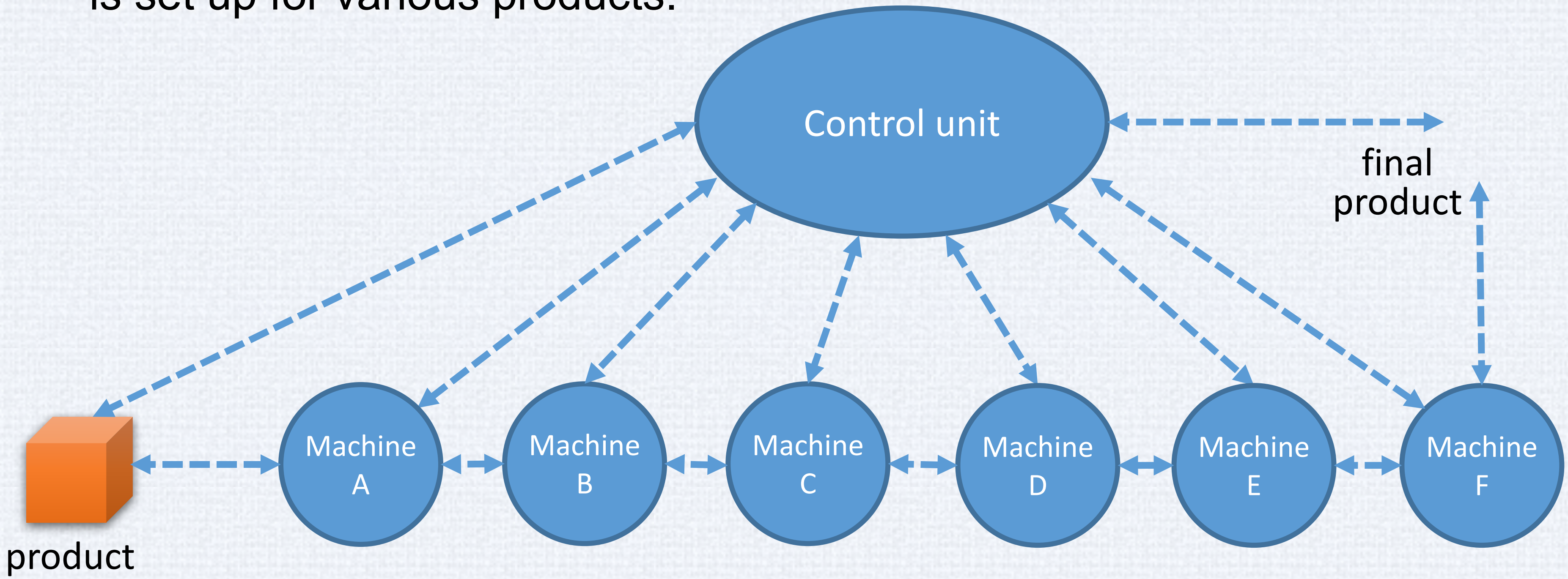
Industry 4.0: Smart Factory

- **Example:** production of a paper plane. Standard manufacturing.
- Sequence of operations on the production line is fixed. Production line works only for the product it has been set up for.



Industry 4.0: Smart Factory

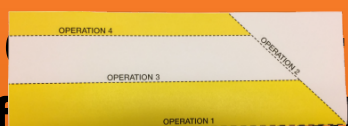
- **Example.** Smart Factory
- Decentralized control approach:
  - control unit, machines, and the produced product – all have “brains” and communicate with each other through the factory’s network;
  - the production line consists of many machines with various functions, it is set up for various products.



Industry 4.0: Smart Factory

- **Example:** production of a paper plane on a Smart Factory

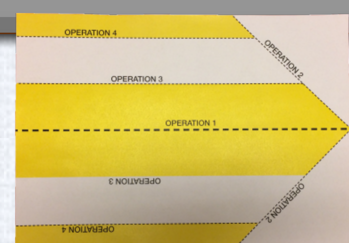
MACHINE A



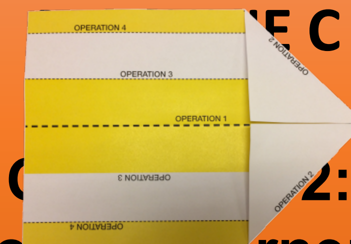
MACHINE B

Operation 5:

……



E C



2:

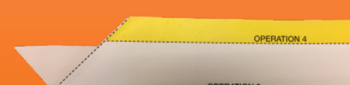
folding corners

MACHINE D

Operation 6:

…

MACHINE E



Operation 3:

folding wings

ACHINE F

Operati 4:

finishing wings

The example is adopted from “Industry 4.0 – Smart Factory explained” with necessary modifications and explanations.

Industry 4.0: Smart Factory

- **Example: Siemens Amberg Plant**, producing SIMATIC industrial equipment (programmable logic controllers, network switches, interfaces, etc.)
- **Productivity**: more than 1 million SIMATIC products per month
- **Flexibility**:
  - 1 300 different products
  - 60 000 customer companies
  - 24-hour lead time
- **Quality and efficiency**: 11 defects per million (99.9989% perfect quality products)

Industry 4.0: Smart Factory

- **"Digital Twin"** is a virtual representation of physical objects and production processes. It is a digital profile of the history and the current state of the objects/processes.
- ***Product definition:*** product design (with customers' involvement) and testing the products without creating physical prototypes (and resolve possible issues).
- ***Virtual model of the plant:*** designers and engineers collaborate to design the product's path through the plant, to redesign the factory and equipment to identify the plant's bottlenecks.
- ***Bill of Process:*** the result of the product design and production execution uploaded into the plant's manufacturing execution system.
- ***Execution monitoring:*** gathering the real-time data for analysis of quality, material consumption, & verification of the product's compliance.

Source: Siemens Amberg Factory. "Industry 4.0 and the Digital Enterprise."

Industry 4.0 Definitions

- Industry 4.0 is "*the integration of complex physical machinery and devices with networked sensors and software, used to predict, control and plan for better business and societal outcomes*." (Consortium II. Fact Sheet, 2013, www.iiconsortium.org/docs/IIC_FACT_SHEET.pdf)
- Industry 4.0 is "*a new level of value chain organization and management across the lifecycle of products*." (Industrie 4.0 Working Group. Recommendations for implementing the strategic initiative INDUSTRIE 4.0, April 2013)
- Industry 4.0 is "*a collective term for technologies and concepts of value chain organization*." (Hermann et al. 2016, Design principles for Industrie 4.0 scenarios. 2016, IEEE.)
- "With a network connection and an open interface that masks its underlying complexity, a machine becomes a Web service, ready to be coupled to software intelligence that can ingest broad context and optimize entire systems of machines. *The industrial internet is this union of software and big machines – what you might think of as the enterprise Internet of Things*, operating under the demanding requirements of systems that have lives and expensive equipment at stake." (Bruner, J. Industrial Internet, O'Reilly, USA, 2013).

Industry 4.0 Implications

Implications for production processes:

- Improvement of the production's operational efficiency and productivity. The "*power of 1%*": a small 1% improvement in efficiency would result in significant operational cost saving as well as gains for the industries.
- Communication infrastructures and its components become highly affordable. Technologies such as wired and wireless networks, radio frequency identification, & barcoding, become widely spread.
- Service orientation of the industries would bring the high level of product customization. The concept of "*batch size 1*" signifies moving from mass production towards individualized products by reducing the changeover/reconfiguration times and costs, and improving efficiency.
- Decentralization of control brings flexibility to the production.
- Self-diagnostics of machines allows executing preventive maintenance to avoid disruptions in production. Quality control of products leads to identification and correction of the defects.
- Virtualization: the "*digital twin*" allows designing, testing and reconfiguring products and factories in the virtual environment.

Industry 4.0 Implications

Implications for the role of people in future industry:

- Human dimension of complex industrial and civil engineering systems. Collaboration environments (applications and services of CPS, the “digital twin” of a Smart Factory) require the workforce skills like engineering design, data analytics, and digital culture.
- Many operations (e.g., quality control in industry, diagnostic conclusions in medicine, etc.) still require and will continue to require human expertise.
- High level of customization brings advantages of individualized products to the consumers.

Implications for supply chains:

- Service orientation of Industry 4.0 would bring advantages to the customers.
- Improving “transparency” of the supply chains: sharing information, collaborating of producers and consumers for product design and testing, improvement of the operational efficiency.
- Shift to just-in-time production. Smart Factories don’t operate under the mass production principles, they are not keeping the stock of their products they are producing.
- Large companies that previously used the approach of outsourcing their production to developing countries are now contemplating bringing production (in the form of Smart Factories) back to their countries.

Problems raised by Industry 4.0

- **Data security (cybersecurity)**: industrial engineering networks should be protected from unauthorized access. Hacking into such systems may lead to processes' disruptions, and in the worst cases, to significant destructions and harm to facilities' personnel. In the civil engineering context, malicious access may lead to traffic disruptions, electricity black-outs, harm to cities, businesses and common people.
- **Data privacy**: the access to the production-related data should be controllable to protect companies intellectual property. Misuse of data may lead to damaged relationship with the partners and even damaged reputation for companies.
- **Acceptance**: industries, governments, standardization bodies need to accept the path of Industry 4.0 and to collaborate to achieve success. People (workforce) should shift their training towards the skills in the area of digital culture, organization, design, data analytics, etc.

Conclusions

- **What novelty is Industry 4.0 expected to bring?**

- Industrial revolutions 1.0 – 3.0: *inventions* lead to reorganization of production processes and reorganization of labor.
- The 4.0 revolution is not driven by a new invention. It only regards reorganization of production and business processes with expanded role of digital technologies. The aim is to *improve productivity, flexibility and efficiency by combining the available technology in a new way*.

- **Has the forth industrial revolution happened? – Yes and no.**

- Yes, partly. There are several examples of smart factories: Siemens Amber Factory, Phillips electrical shaver factory in Drachten, BASF's shampoos and soaps factory in Kaiserslautern, and some others.
- No, it is still an anticipated revolution. There are still gaps in technological capabilities and in workforce skills.

- **Why it is happening?**

- Many business are looking into the innovations to improve their efficiency.
- Politics and demographics: working age population in developed countries is expected to decrease in the upcoming decades. The industries in the developed countries must use the labor force and the resources efficiently to maintain or improve their positions on the market. Governments invest in research and study programs related to Industry 4.0.

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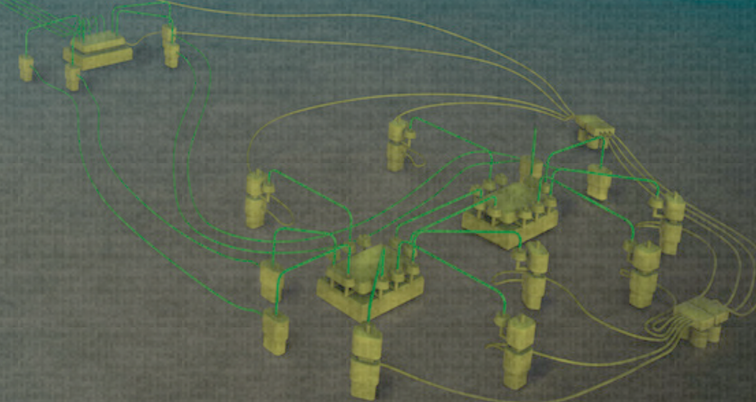
Thank you!

7th International Conference on Sustainable Energy Information Technology (SEIT2017)

CONCEPTUALIZATION OF SMART SOLUTIONS IN OIL AND GAS INDUSTRY



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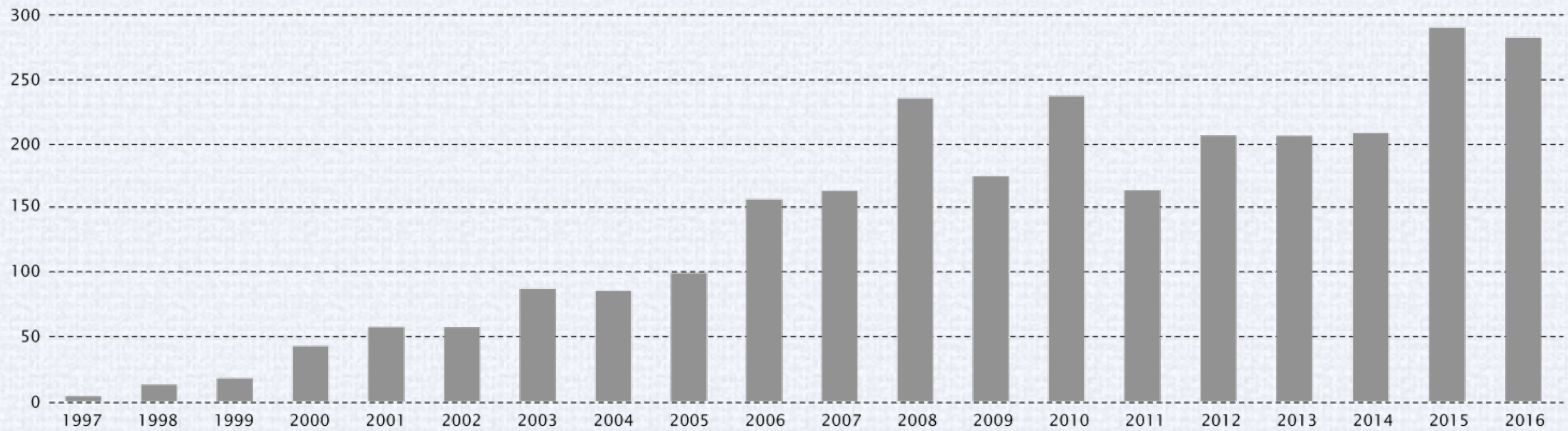
Research background and purpose

- Since 1997, the term "smart well/field" has gain fair recognition in business and academia.
- Problems:
  - complexity of the term leads to one-sided implications of the term meaning (depending on the purposes).
  - variety of synonyms: "smart field", "intelligent field", "i-Field", "digital field", "field of the future", "integrated operations" and "intelligent energy".
- The accumulated theoretical and practical research results require analysis and synthesis.
- Research methodology: literature review and definitional approach.

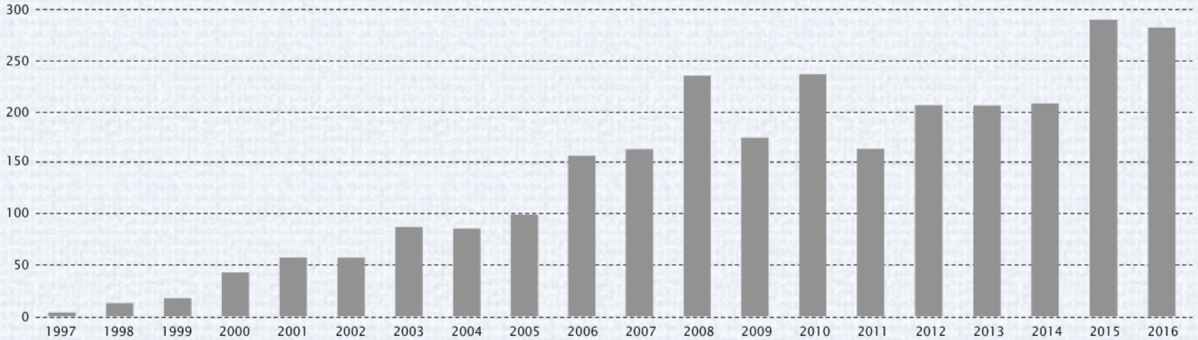
Literature review

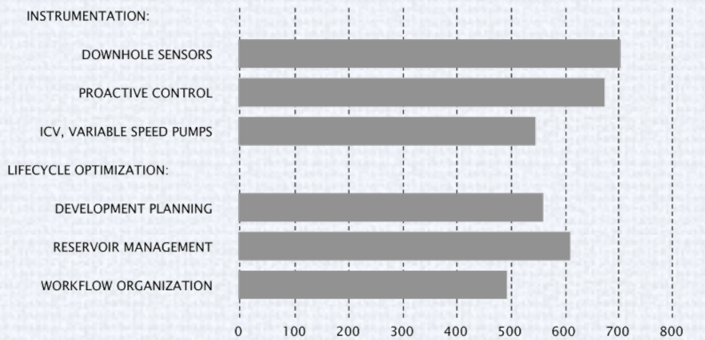
- Literature review is based on the ideas of Webster and Watson, 2002
- Scope of the review:
  papers published in academic journals available in the databases: OnePetro, ScienceDirect, SpringerLink, Emerald Insight and ProQuest. Timespan: 1997 – 2016.
- The search was run over the titles, abstracts and keywords.
- Search operands: “smart well”, “intelligent well”, “i-Well”, “smart field”, “intelligent field”, “i-Field”, “digital oilfield”, “digital field”, “field of the future”, “integrated operations” and “intelligent energy”.



Results of the literature review. Characteristic attributes of the technology

Attribute	Standard solutions	Smart solutions
Instrumentation: measurements and control		
Sensors	located at the wellheads	located at the wellheads and distributed inside the wells
Control strategy and control loops	reactive (passive) control; low sampling rate; control loops ensure control and safety of each single well	reactive (passive) and proactive (predictive) control; higher sampling rate; control and safety of well segments
Actuators	0/1 controlled devices (open/closed valves and on/off artificial lift pumps)	continuous control with inflow control valves (ICVs); variable frequency pumps
Attitude to the project lifecycle		
D&P planning	development and production (D&P) are regarded as separate projects	development and production are regarded as a field or reservoir lifecycle
Operations	reservoir is drained through wells	movement of oil, water and gas is monitored; reservoir modeling is employed.
Software and workflows	telemetry system, supervisory control and data acquisition (SCADA) system, operative control	SCADA in the loop of lifecycle optimization (strategic, tactical and operative control levels); information system for collaborative work environment





Smart fields implementation. Marketed companies' solutions

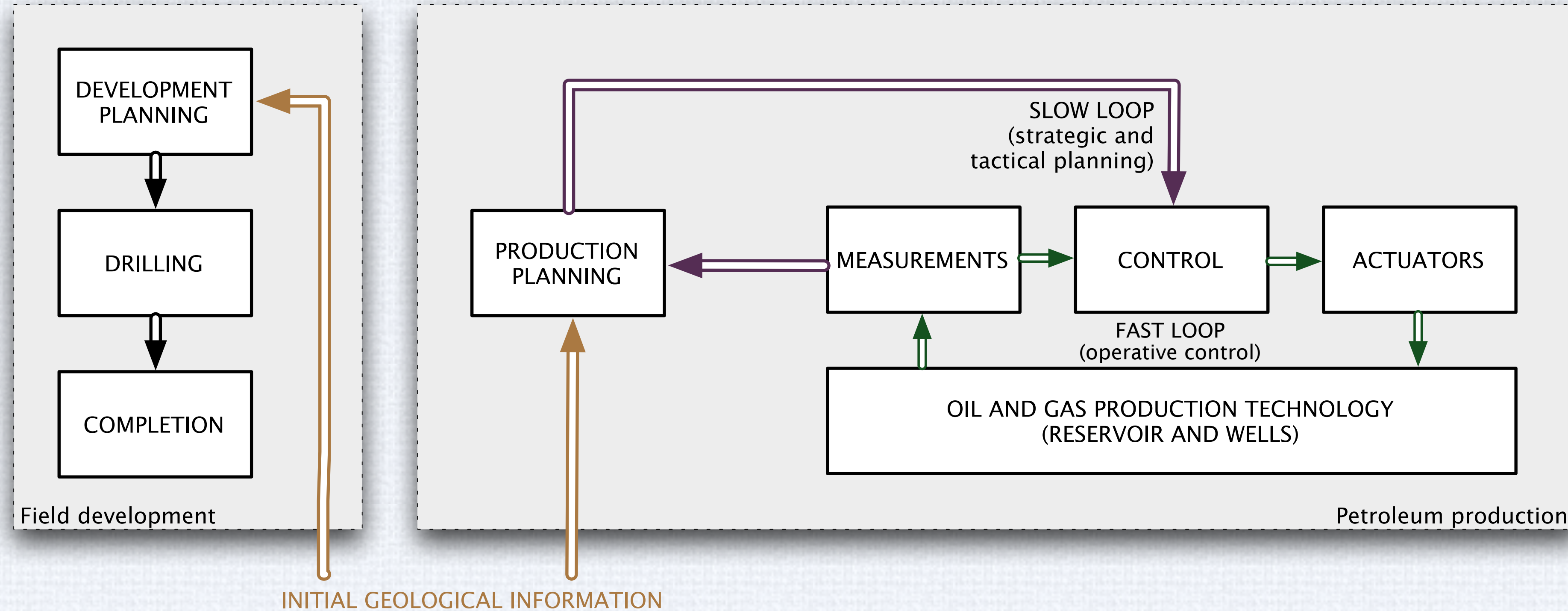
- Marketed solutions offered by major oil and gas engineering companies

Solution	Advanced measurements and control			Lifecycle optimization		
	downhole sensors	proactive control	ICV	development planning	reservoir management	workflow organization
Halliburton's Digital Oil Field	✓	✓	✓	✓	✓	✓
Weatherford's Field Office and i-DO	✓	✓	✓	✓	✓	✓
Honeywell's Digital Suites for Oil and Gas	✓	✓	✓	✓	✓	✓
Schlumberger's Integrated Project Management	✓	✓	✓	✓	✓	✓
Emerson's Intelligent Fields	✓	✓				✓
ABB's Collaborative Operations		✓			✓	✓
IBM's Integrated Operations						✓

- Not all solutions cover the full scale of smart field attributes.
- Responsibility of deploying an appropriate technology lays on the companies operating oil and gas fields.

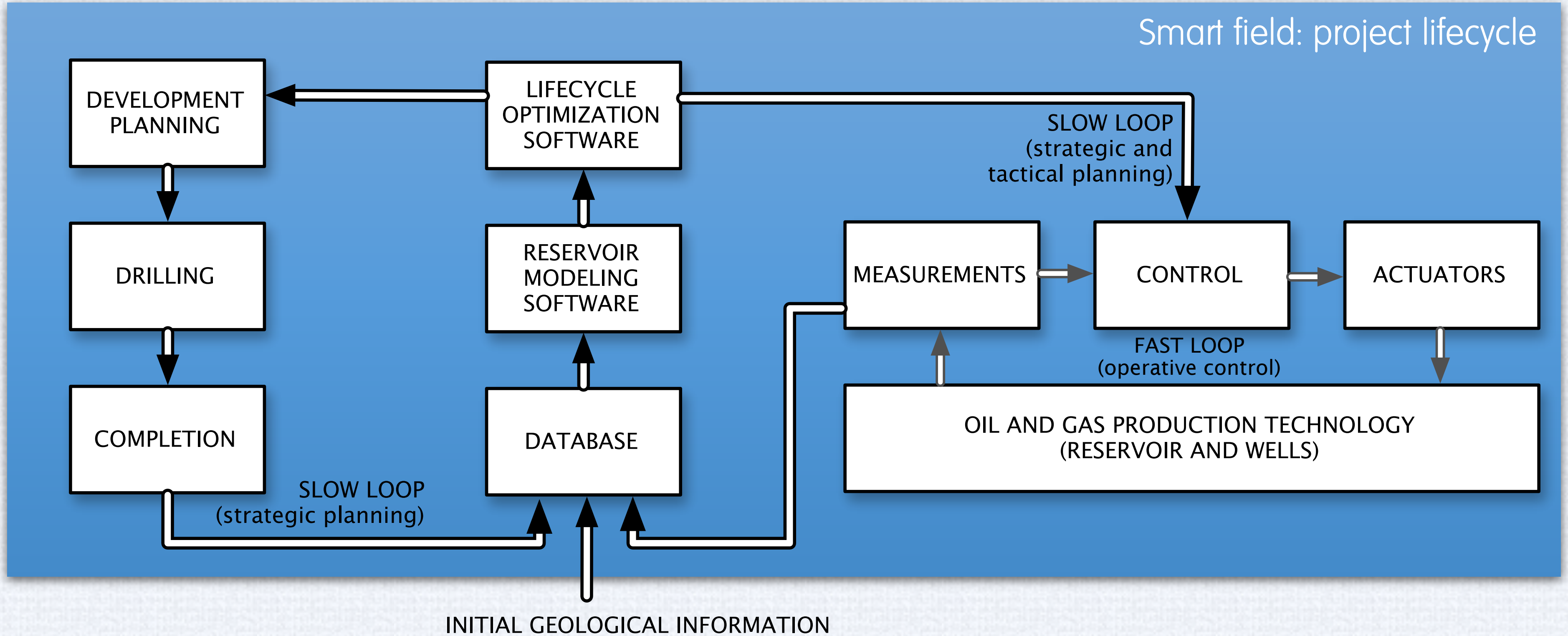
Definition (1)

- Attitude to the field lifecycle. Development and production.



Definition (2)

- **Attitude to the field lifecycle. Development and production.**



DEFINITION:
A smart solution is an approach to field development management involving two closely related aspects:

- lifecycle optimization based on development and production operations research and defined strategic, tactical and operative goals
- advanced instrumentation as an enabling technology for precise monitoring and control of operations.

Beyond oil and gas industry…

- **Placing smart solutions in a broader industrial and scientific context:**
- The term "***cyber-physical system***" **(CPS)** is often used to account for computation and communication solutions integrated into physical processes, contributing to the range of process capabilities. Usage: energy industry (especially electric power grids), civil engineering, manufacturing, etc.
- The terms ***"Industry 4.0"*** and ***"Industrial Internet"*** describe smart solutions and integrated IT products incorporated into production processes.
- *Modern* management science views <u>*business processes*</u> as <u>*networks with flows*</u> of various nature (materials, human resources, information and money). <u>*Logistics*</u> is the discipline that covers the questions "related primarily to the configuration and organization of these networks, and to the mobilization and control of flows" (Delfmann et al., 2010).
- Organization of production processes and operations is often called "*production logistics*" (Nyhuis and Wiendahl, 2008).

Beyond oil and gas industry...

A smart industrial solution (in a broad sense) is an approach to project management when facilities, infrastructures and workflows are established and operations are planned, scheduled and conducted with clearly set objectives, meanwhile a control functionality for self-coordination of the system components (i.e. facilities, units, devices and people) is employed to follow these objectives over the entire solution lifecycle, thereby ensuring the system sustainability and autonomy.

Practical implications

- Importance of *lifecycle thinking* in operations research and decision-making in petroleum sector:
  - Joint consideration of <u>strategic planning models</u>:
    - Well placement
    - Well structure design
    - Drilling scheduling
    - Gathering infrastructure design
    - Production scheduling
    - Maintenance planning
  - Joint consideration of <u>tactical/operative planning models</u>:
    - Production rates choice
    - Water-flooding
    - Resource distribution
    - Formation stimulation (injection of chemicals)
- Importance of *lifecycle thinking* in petroleum engineering. Avoiding the conservative approach to field development and production operations planning.
- A proper definition is the first step to facilitate the companies' managers in understanding that smart fields is not only advanced instrumentation, but rather a strategy of establishing, organizing and mobilizing the upstream petroleum sector.
- Understanding the achievable benefits: advanced instrumentation and modelling provides better knowledge of operations and control precision. This aims to compensate for the geophysical uncertainty.
- Energy supply chain perspective: coordinating energy markets to achieve sustainability.

Thank you

for your attention