AI in Manufacturing

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The Industrial Revolutions

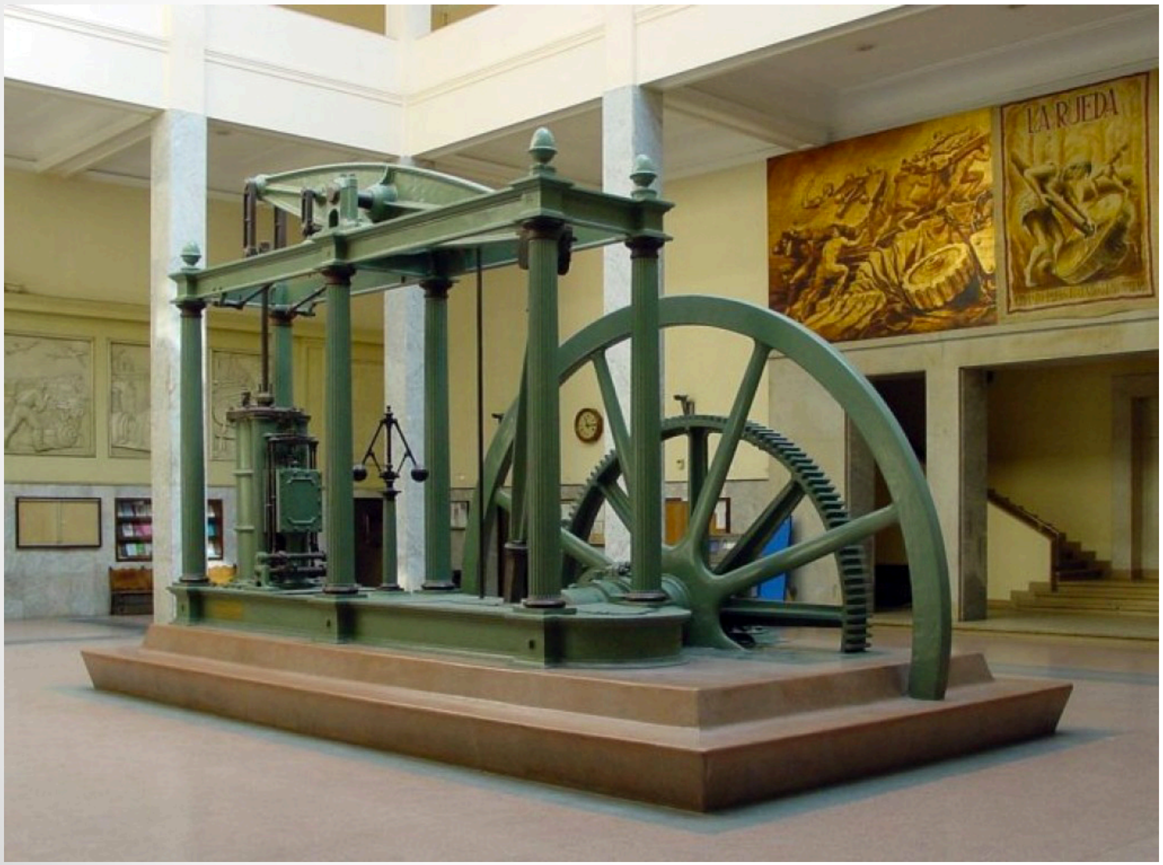
- 1st Industrial Revolution: 1760-1830
- 2nd Industrial Revolution: 1870-1914
- 3rd Industrial Revolution: 1970-2000
- 4th Industrial Revolution: 2015 -2050?

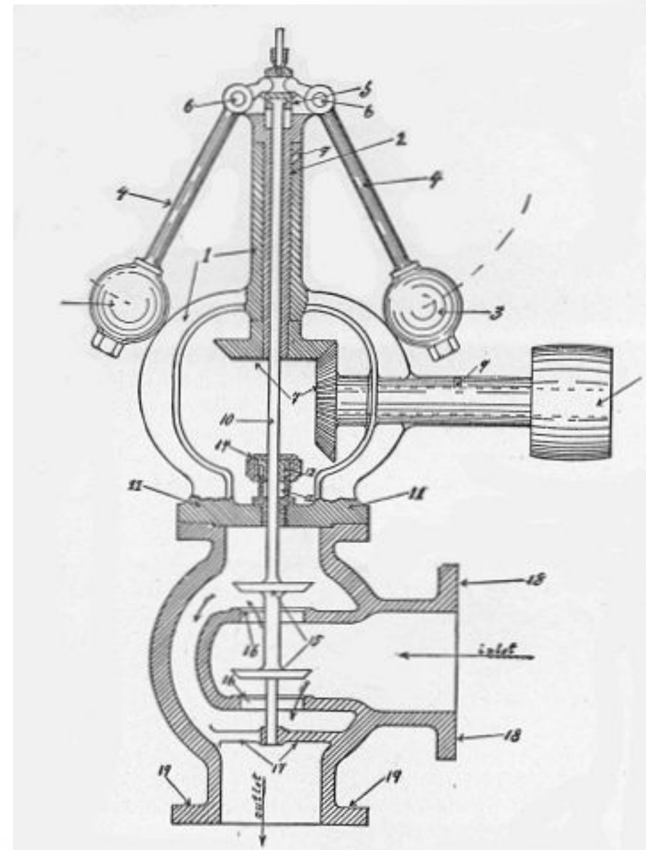
1st Industrial revolution - 1760

- Energy revolution: Steam power
- Mechanization of processes: development of mechanical machines
- Establishment of factories
  - Textile
  - Iron
  - Chemical
- Locomotives improving logistics

1st Industrial revolution

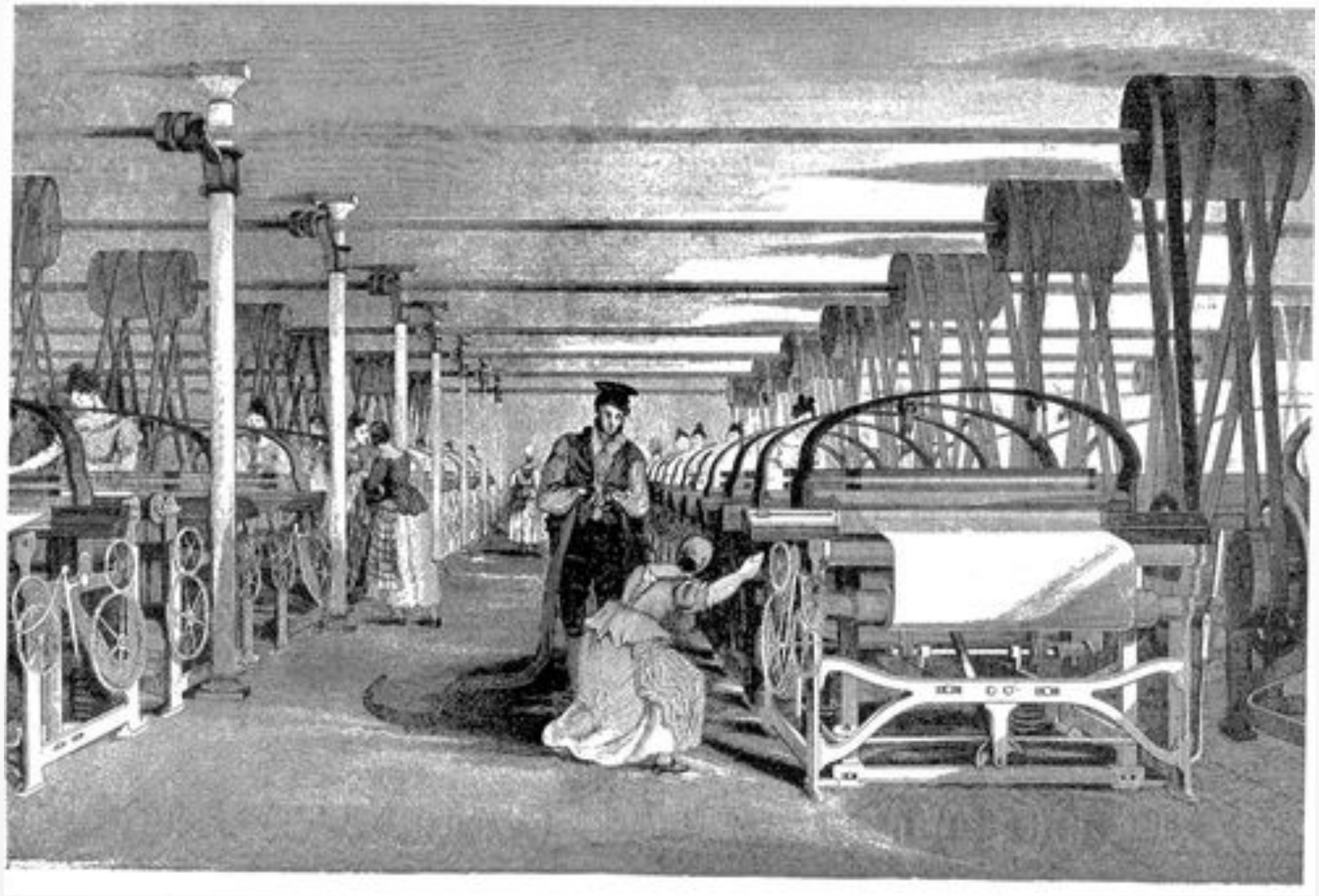
- James Watt Steam Engine – 1770. Feedback speed control – Centrifugal Governor.





1st Industrial revolution

- Weaving factory powered by central steam machine

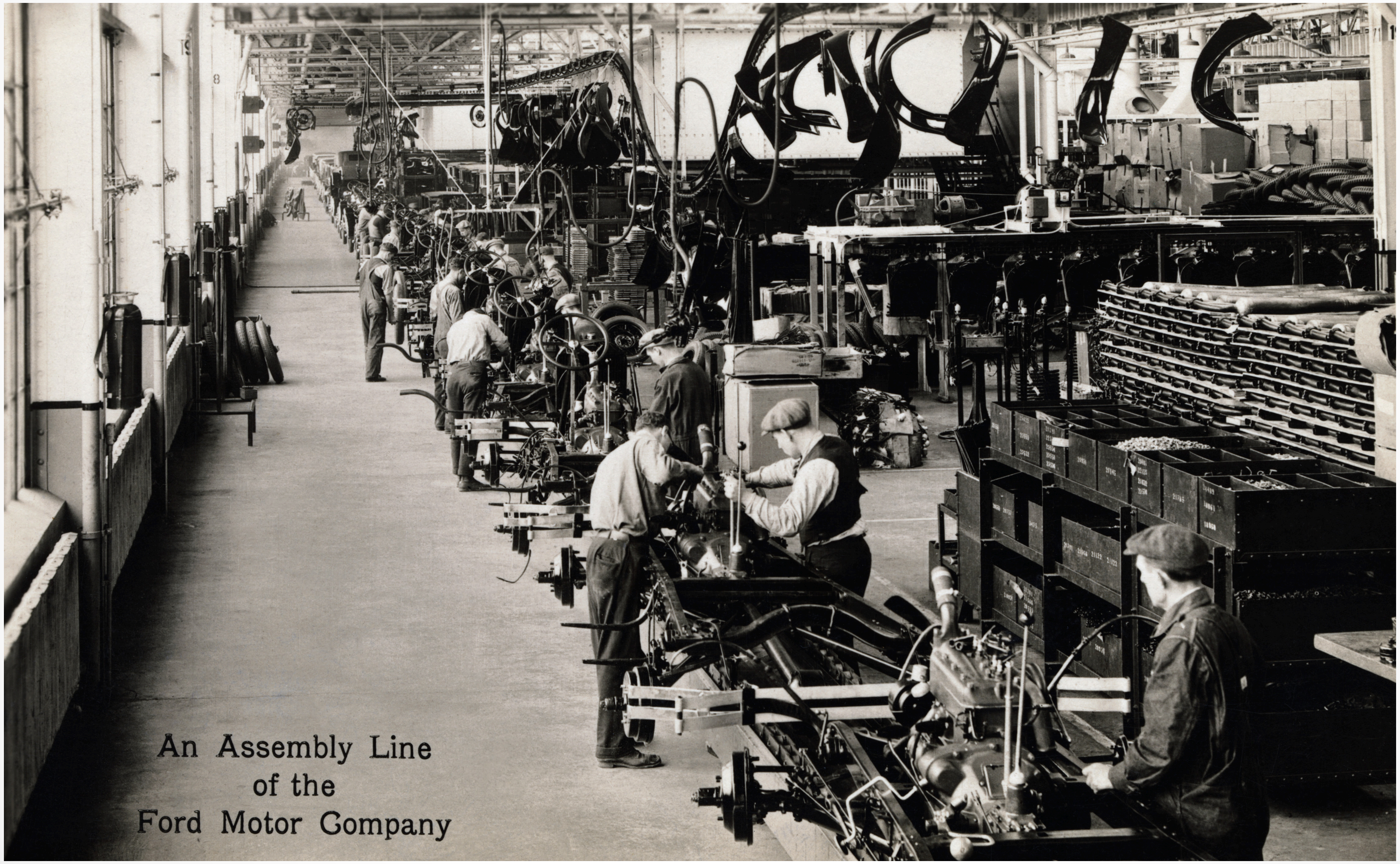


2nd Industrial revolution - 1870

- Electrical Power in factories
- Telecommunications: Telegraph/telephone
- Machining: turning, drilling, milling
- Automotive Industry – serial large production
  - Manufacturing Methodologies
  - Study of time and moves within operations
  - Better management perspective
- Electromechanical controls - Relays
- Petroleum
- Open Loop control. Or closed loop through operator

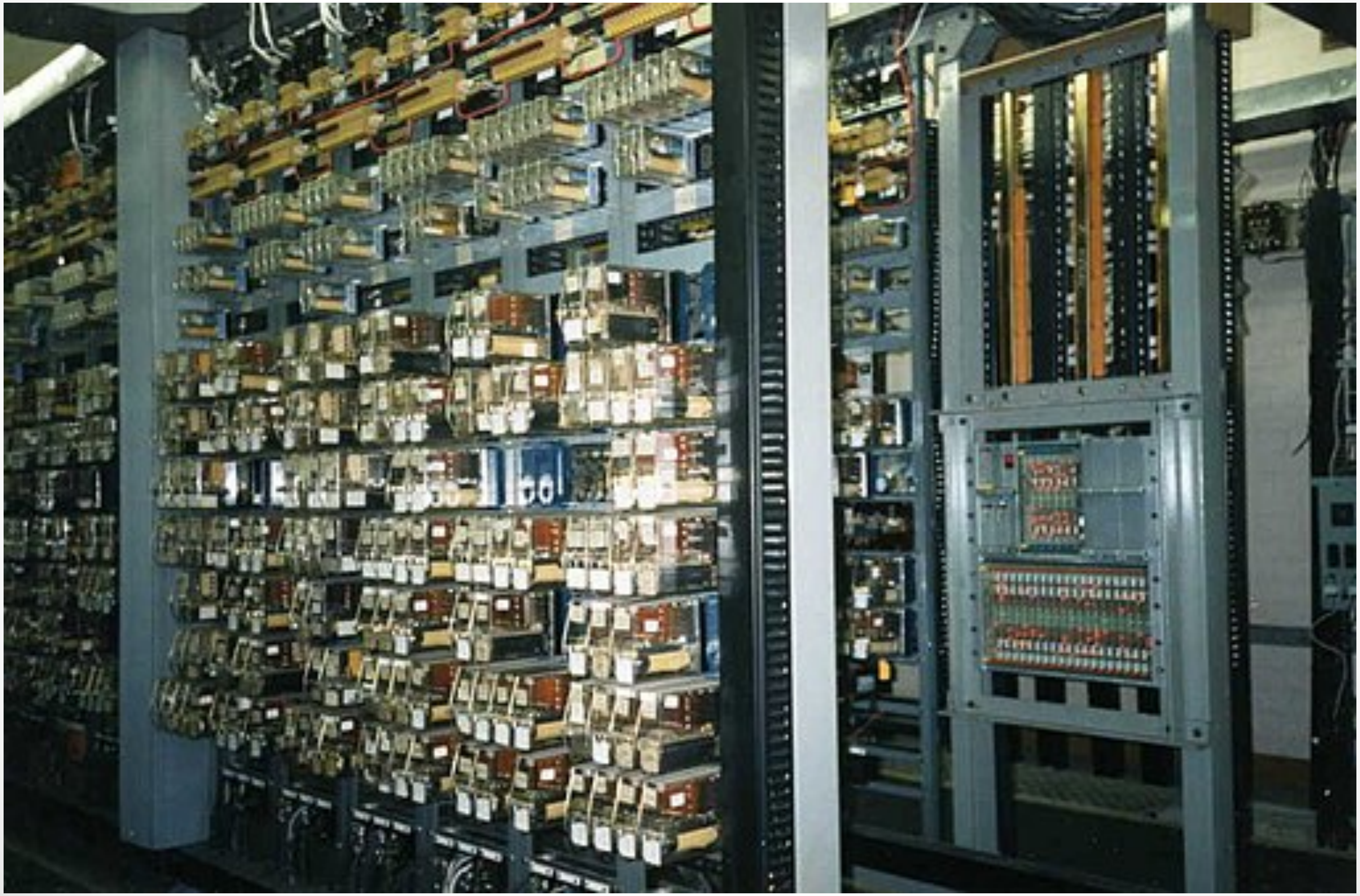
2^{nd} Industrial revolution

- Automotive assembly line



2nd Industrial revolution

- Electromechanical controls in a factory

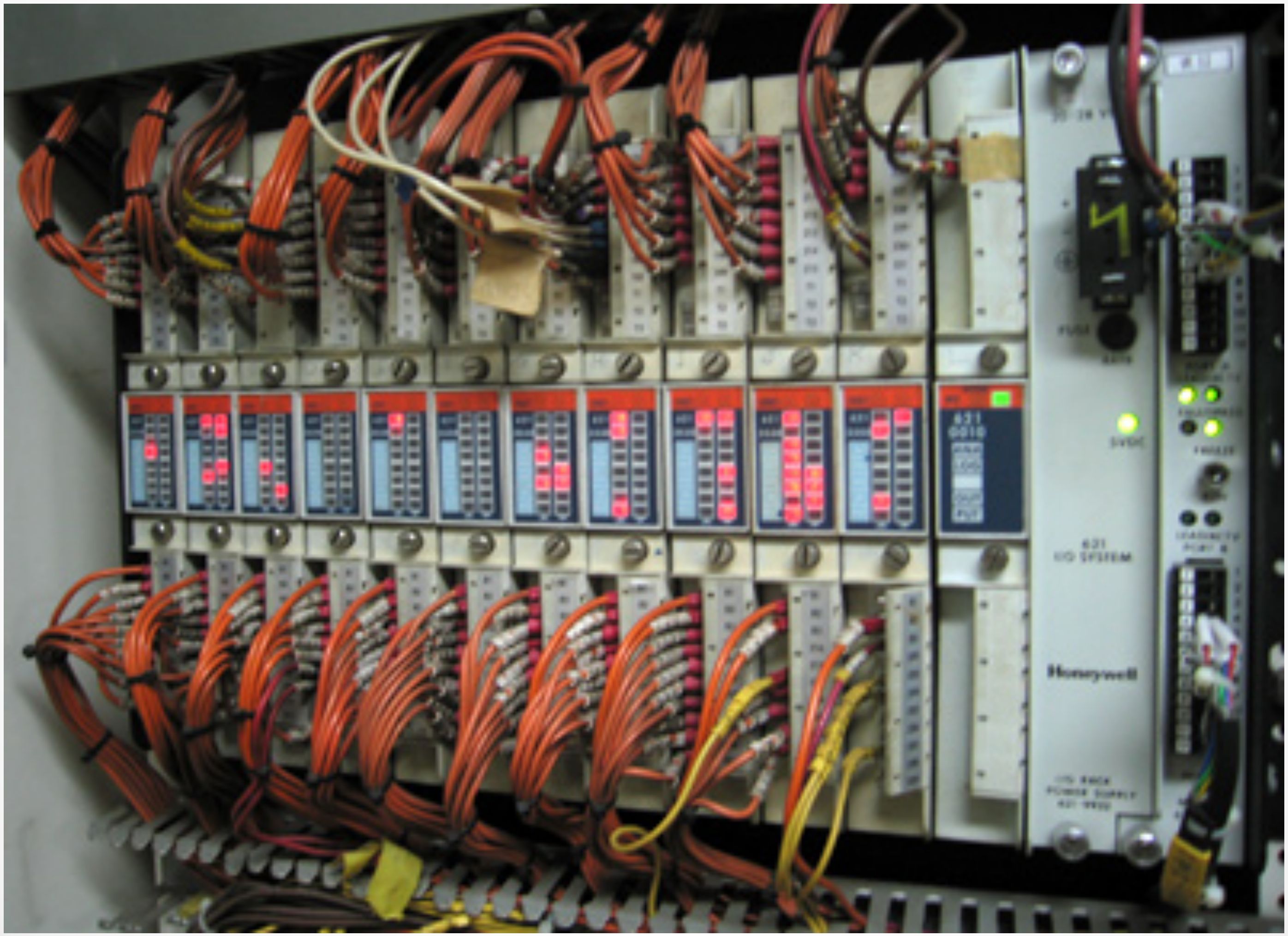


3^{rd} Industrial revolution - 1970

- Process automation – feedback loop control, **Sensors** and Actuators.
- CNC machines
- PLC, robotics, industrial **communication** protocols
- Synoptic, **Data** logs, production history
- **Relative flexibility**: production batches
- Efficiency and quality assurance

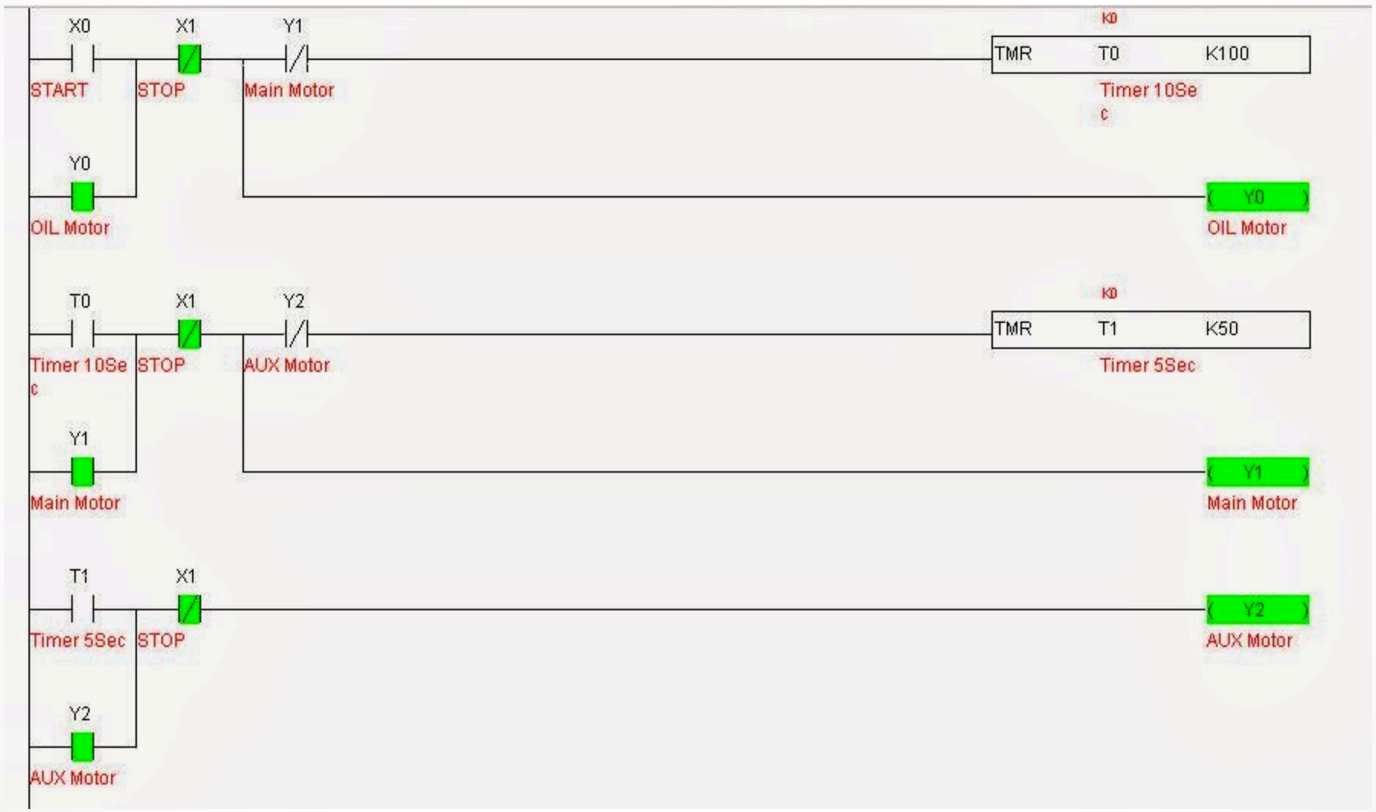
3rd Industrial revolution

- Industrial Automation: PLC



3rd Industrial revolution

- Industrial Automation: Ladder programming

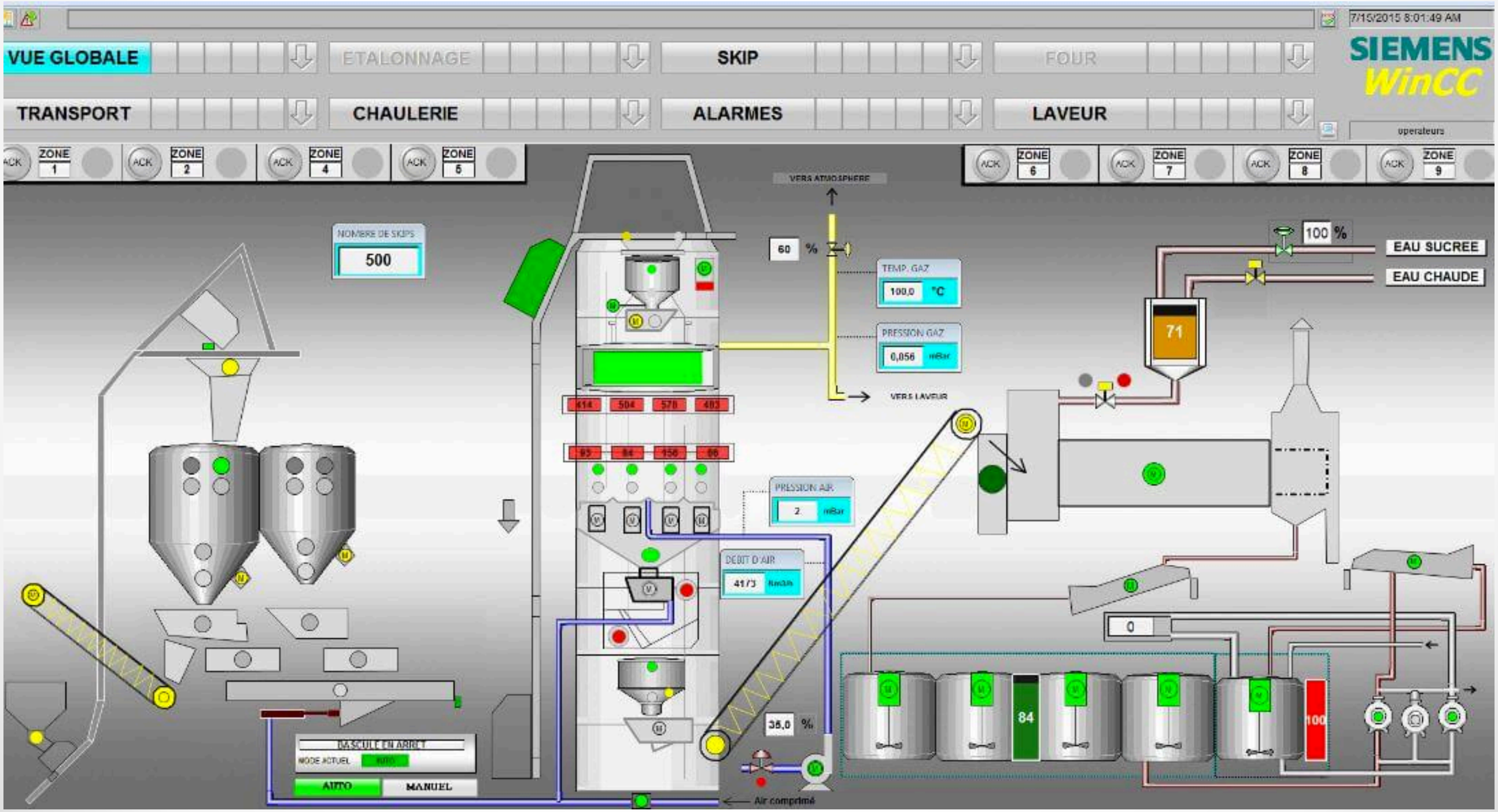


3rd Industrial revolution

- Industrial Automation: modern PLC cabinets

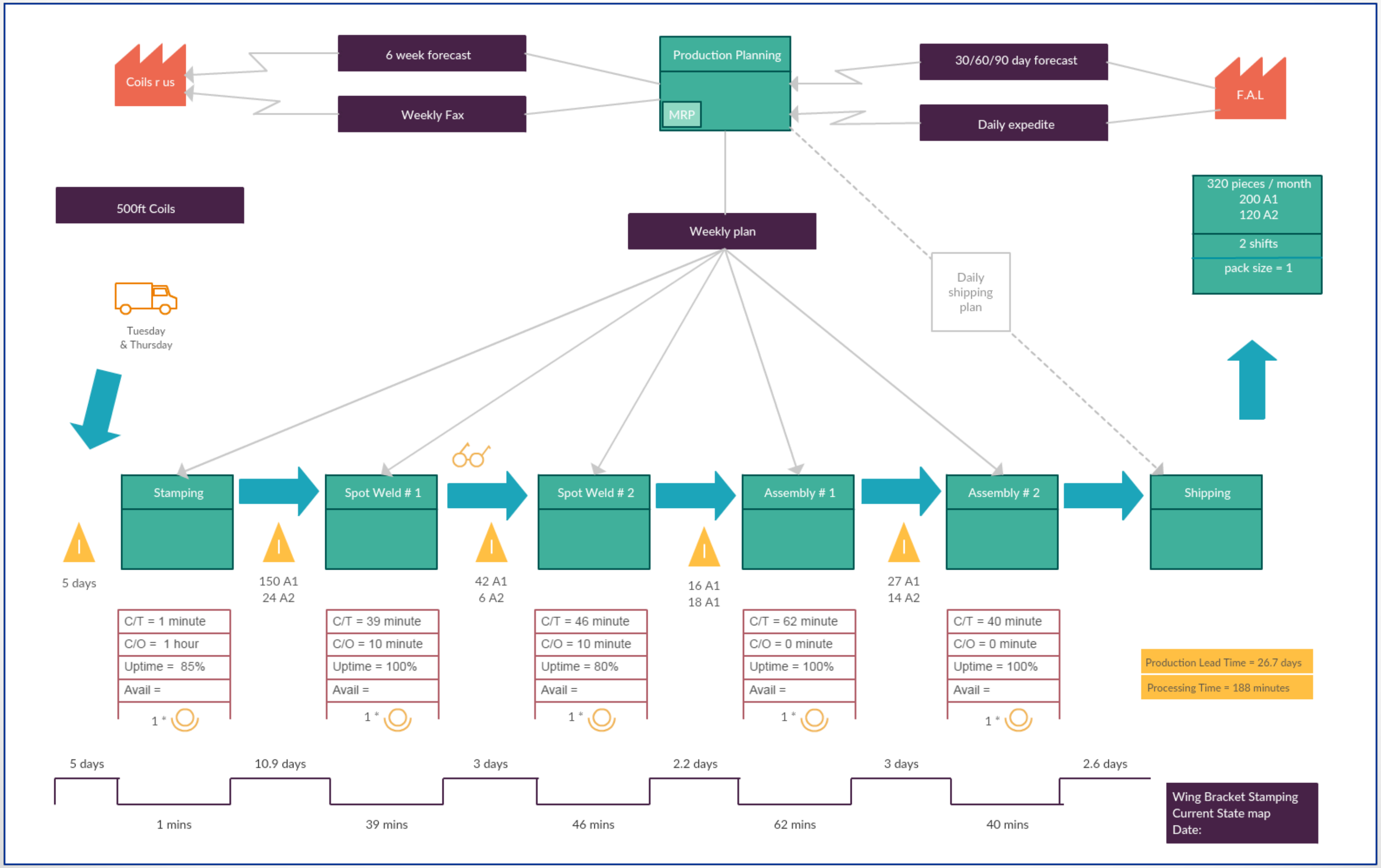
3rd Industrial revolution

- Industrial Automation: SCADA, MES, ERP - synoptic and data log for shop-floor.



3rd Industrial revolution

- Manufacturing organization: VSM



3rd Industrial revolution

- Improved productivity, product quality and cost reduction through automation and high level of discipline and management methodologies

- Sensors, actuators, data acquisition. But still no machining reasoning. What's the best decision when some unexpected event happens?
  - Shortage of raw material, demand changing, etc. Machines only following orders

- Still highly dependable on human:
  - Data analysis
  - Production control and planning. Forecast analysis and production ordering.
  - Definition of manufacturing sequencing, grouping of operations, set up for production.

4th Industrial revolution - 2015

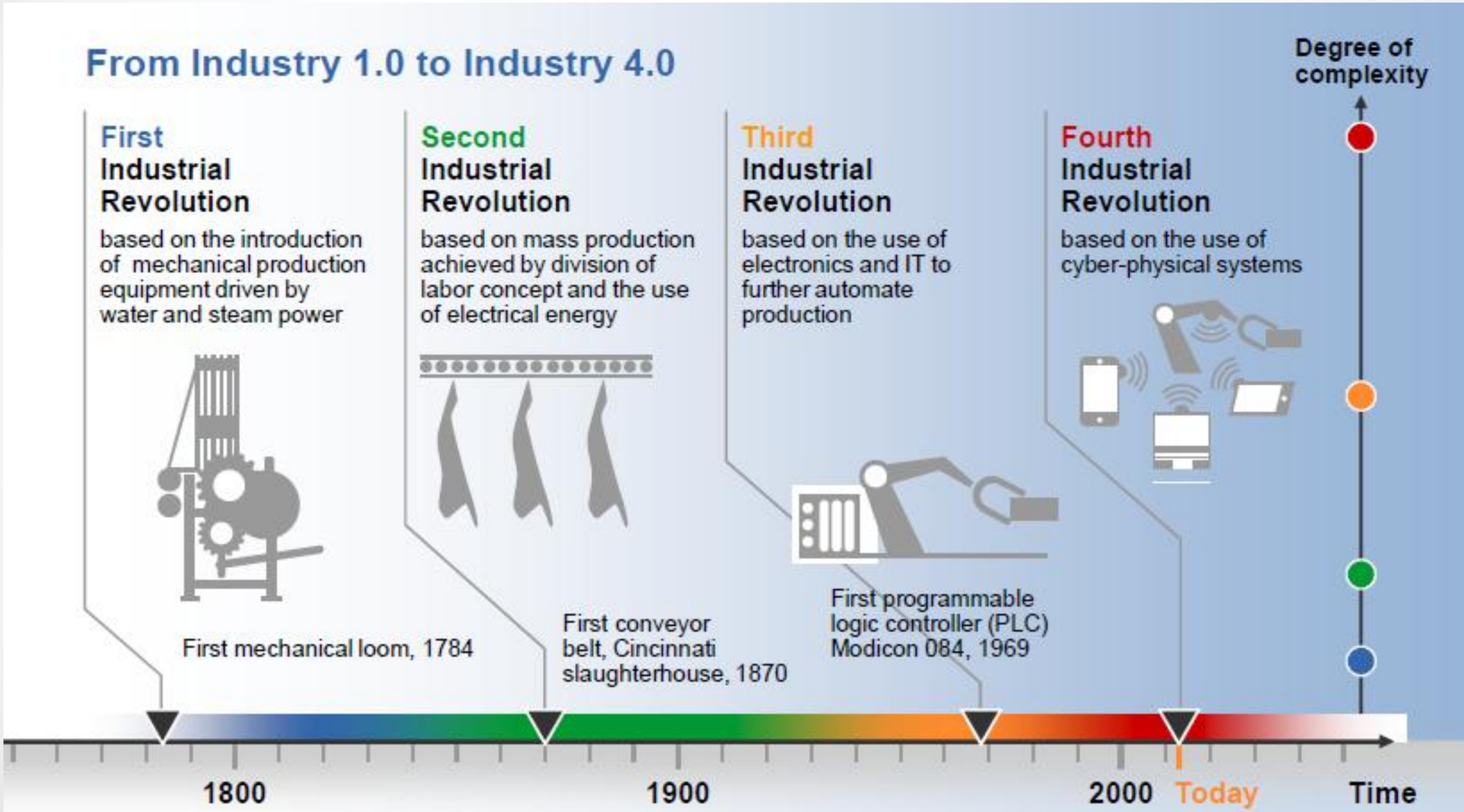
- Scenario
  - Demand for highly customized products
  - Short product life cycle
  - Highly competitive markets
  - Environmental restrictions

- Customization
  - Highly flexible production lines
  - Productive and cost effective
  - Make to order

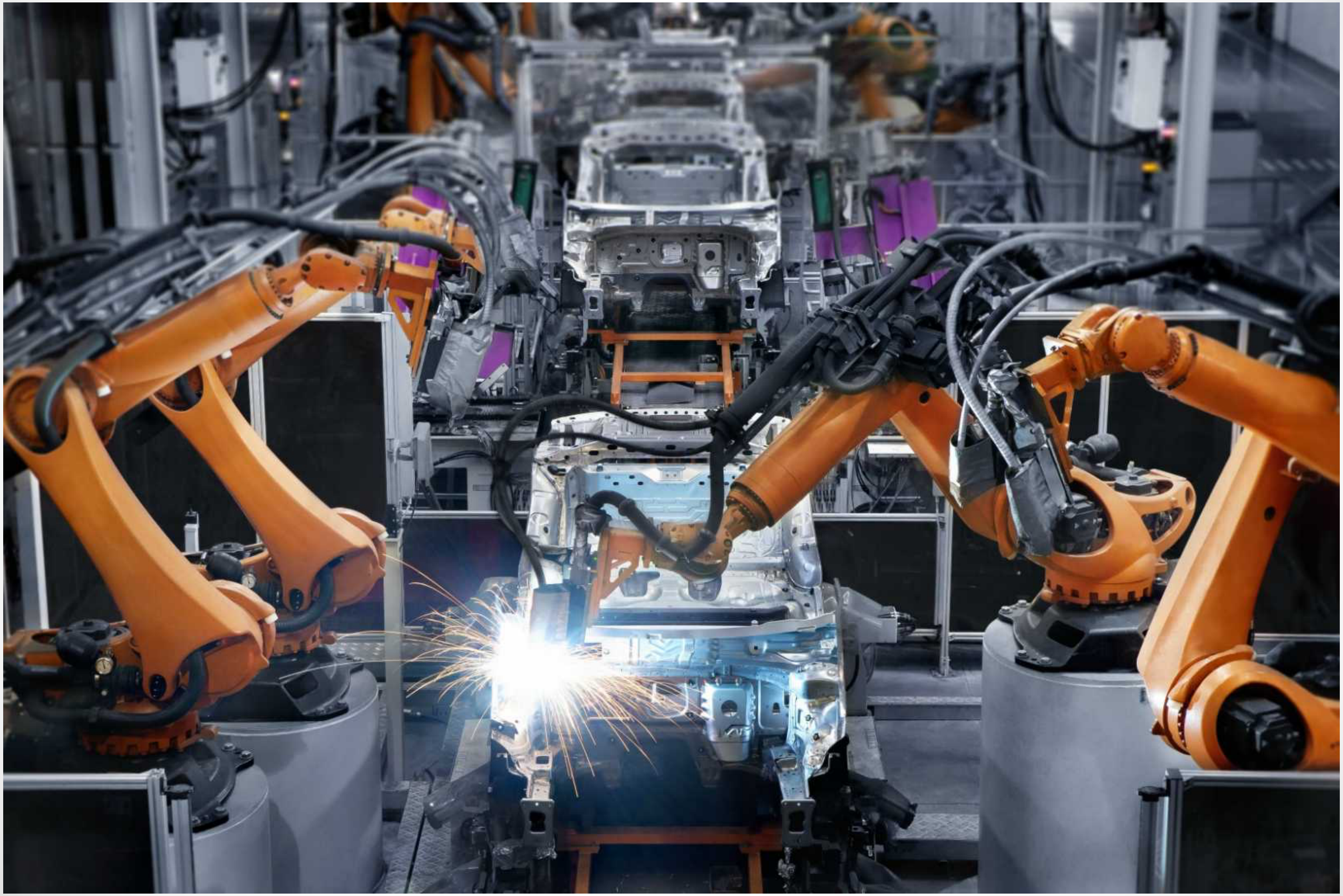
- Technologies
  - Automation and Robotics
  - AI, Big Data, Cloud Computing, Simulation
  - IoT, Cyber Security

- Is this something important?
  - According to PwC, European Industries plan to invest 140 billion euros/year by 2020.

Industry 4.0

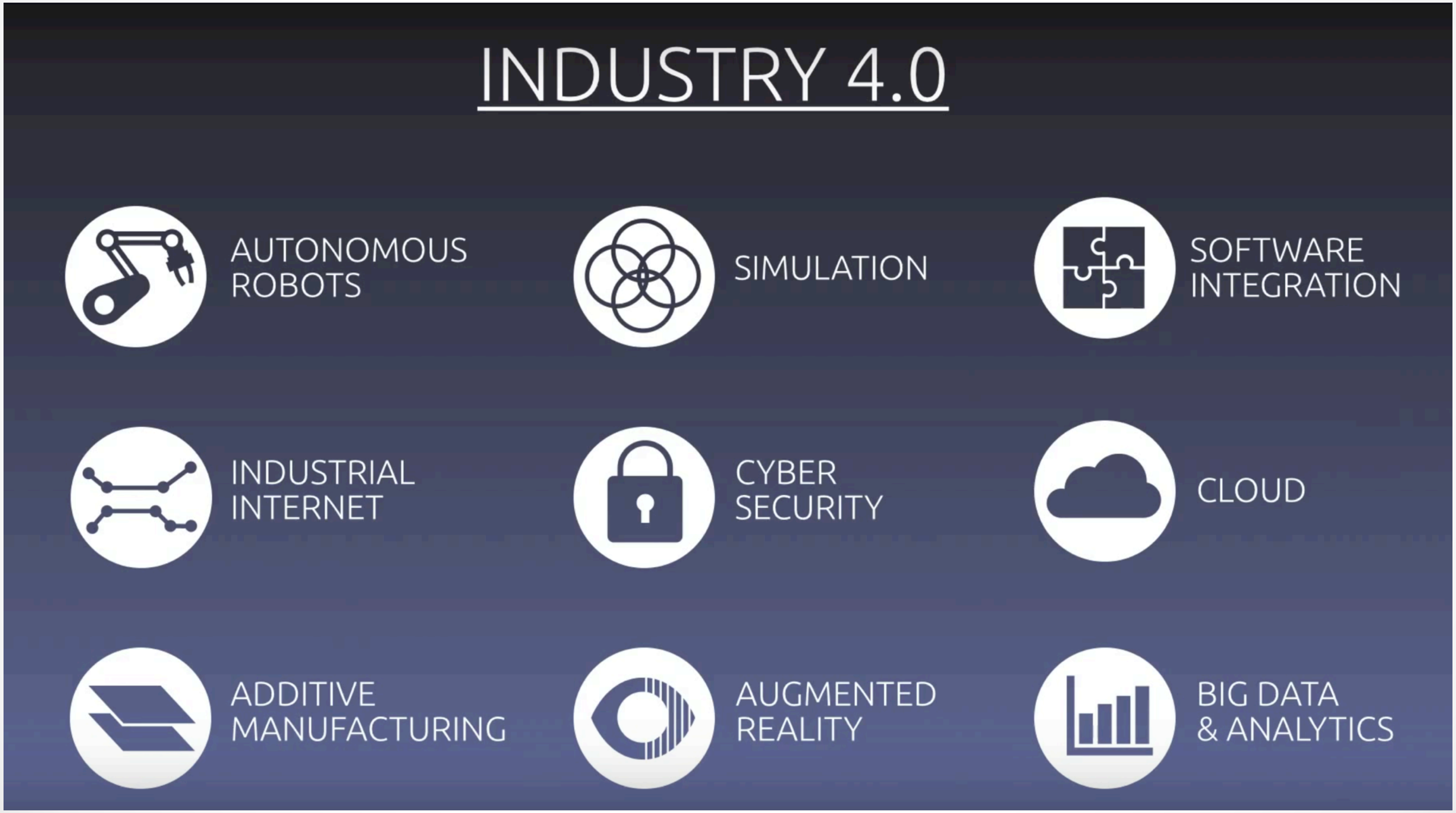

From Industry 1.0 to Industry 4.0
First Industrial Revolution
based on the introduction of mechanical production equipment driven by water and steam power
Second Industrial Revolution
based on mass production achieved by division of labor concept and the use of electrical energy
Third Industrial Revolution
based on the use of electronics and IT to further automate production
Fourth Industrial Revolution
based on the use of cyber-physical systems
Degree of complexity
First mechanical loom, 1784
First conveyor belt, Cincinnati slaughterhouse, 1870
First programmable logic controller (PLC) Modicon 084, 1969
1800
1900
2000
Today
Time

Industry 4.0



Industry 4.0

- https://www.youtube.com/watch?v=HPRURtORnis - from 2 to 3 min



Industry 4.0 - AI

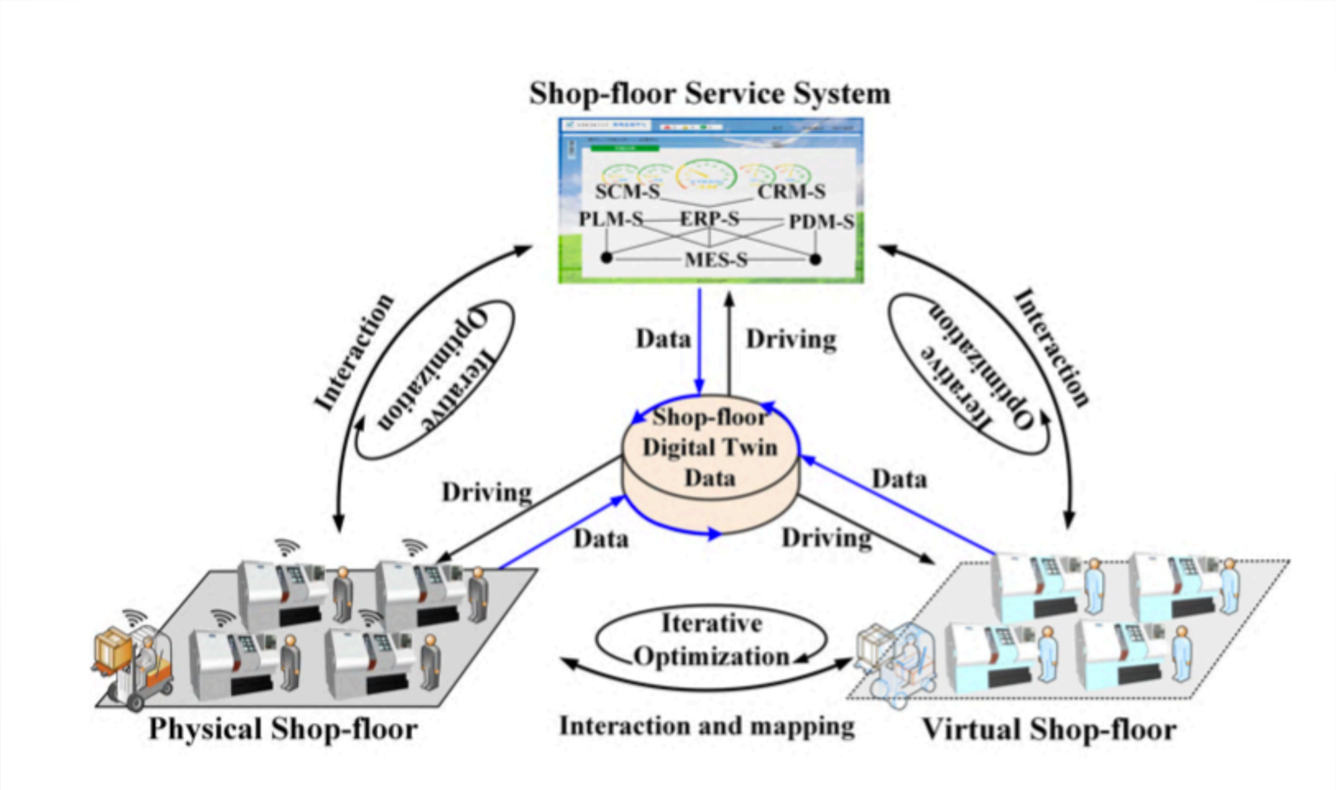
- Machine Learning
  - Failure detection
  - Predictive maintenance
  - Data analysis, augmented reality
  - Quality control – pattern recognintion

- Multi-agent robotics
  - Logistic robots
  - https://www.youtube.com/watch?v=UtBa9yVZBJM 0:00-1:00

- Constraing Satisfaction Problems:
  - Operations sequencing
    - Materials and machines available
    - Marklet demand
    - Inventory allowed

Digital Twin Shop-Floor

How to optimize production and decisions in unexpected situations through intelligent computation? Creating virtual environment integrated to physical production and management system.



Digital Twin Shop-Floor

Architecture of DTS:

Pre-Production:

- Orders transmitted to Planning service. Demand, resources (human, equipment, raw material) Data is provided to Simulation in Virtual Shop Floor. Constraint Satisfaction problem – AI Algorithms. Gives feedbacks and adjust settings for physical production

Production:

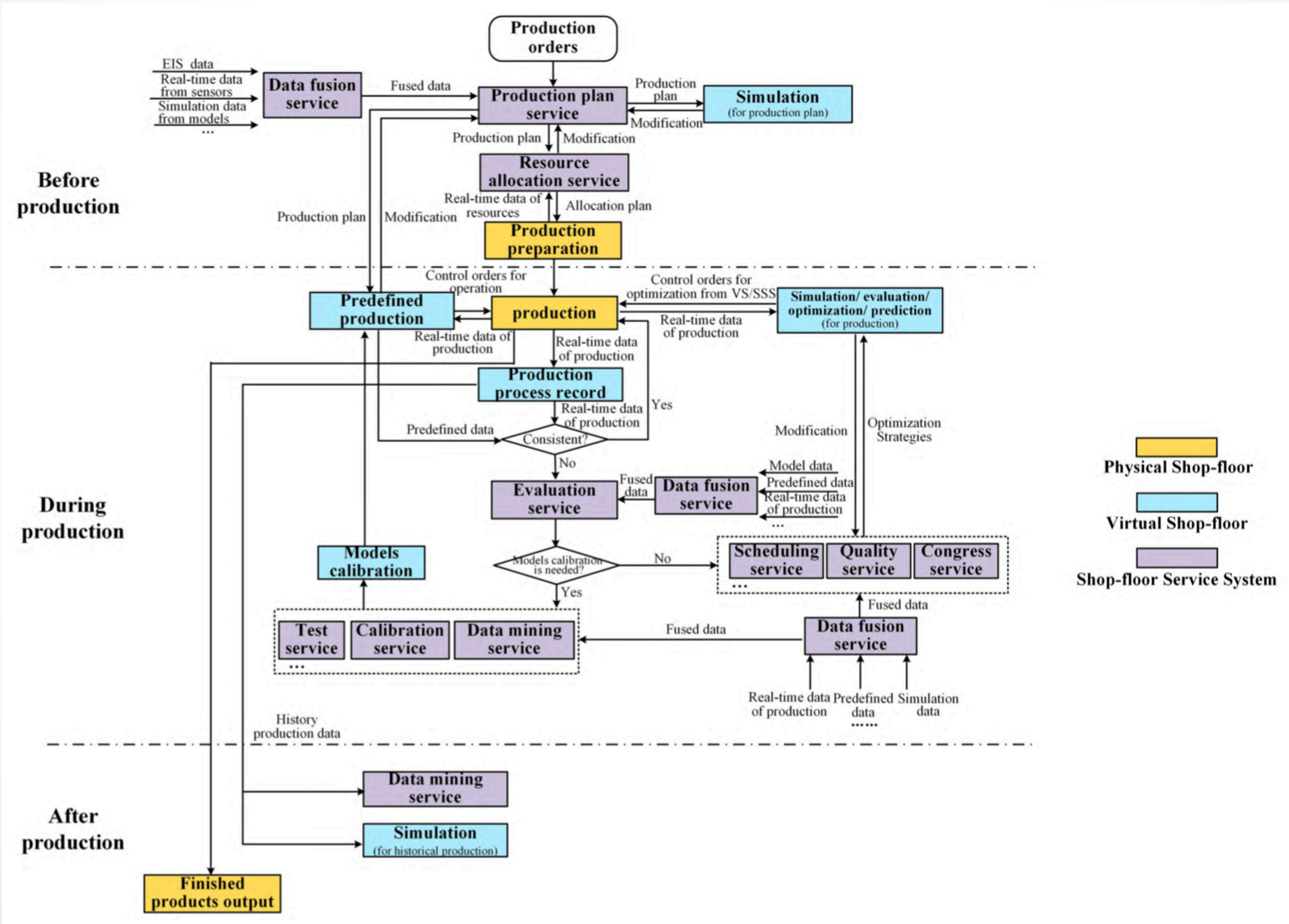
- Real-time data of physical production is recorded in VS, which runs evaluation and optimization models. Any discrepancies between planning made by VS and reality in PS are verified and models are updated.

Post-Production

- Finished products outputted are registered. History of physical production is used to adjust models on VS. Also VS can playback production for post analysis.

Digital Twin Shop-Floor

Architecture of DTS



Digital Twin Shop-Floor

Implementation

Physical Shop-floor:

- Sensors, automation, embedded modules. Generate and integrate data. Challenge: different protocols – Modbus, Profibus, Industrial Ethernet.

Virtual Shop-floor:

- Gather information from CAD/CAM systems, simulation systems and management system. Example. Able to translate 3D drawings into CNC code, simulating production, sequencing it through virtual copies of actual operational stations.
- Constantly updated by information received from PS.

Service System and Digital Twin Data

- Provides data to PS and VS, as well as receive data from both, generating fused data – convergence of all data received from real production and simulation.

Digital Twin Shop-Floor

- Convergence between Virtual And Physical systems
  - IoT collecting and providing data. Powerful Cloud Computing enabling Big Data and AI.
  - Quick reaction regarding planned and actual production
  - Real time decision making through data analysis
  - Modern industry based on highly connectivity - Cyber-Physical Systems

Security in Cyber-Physical Systems

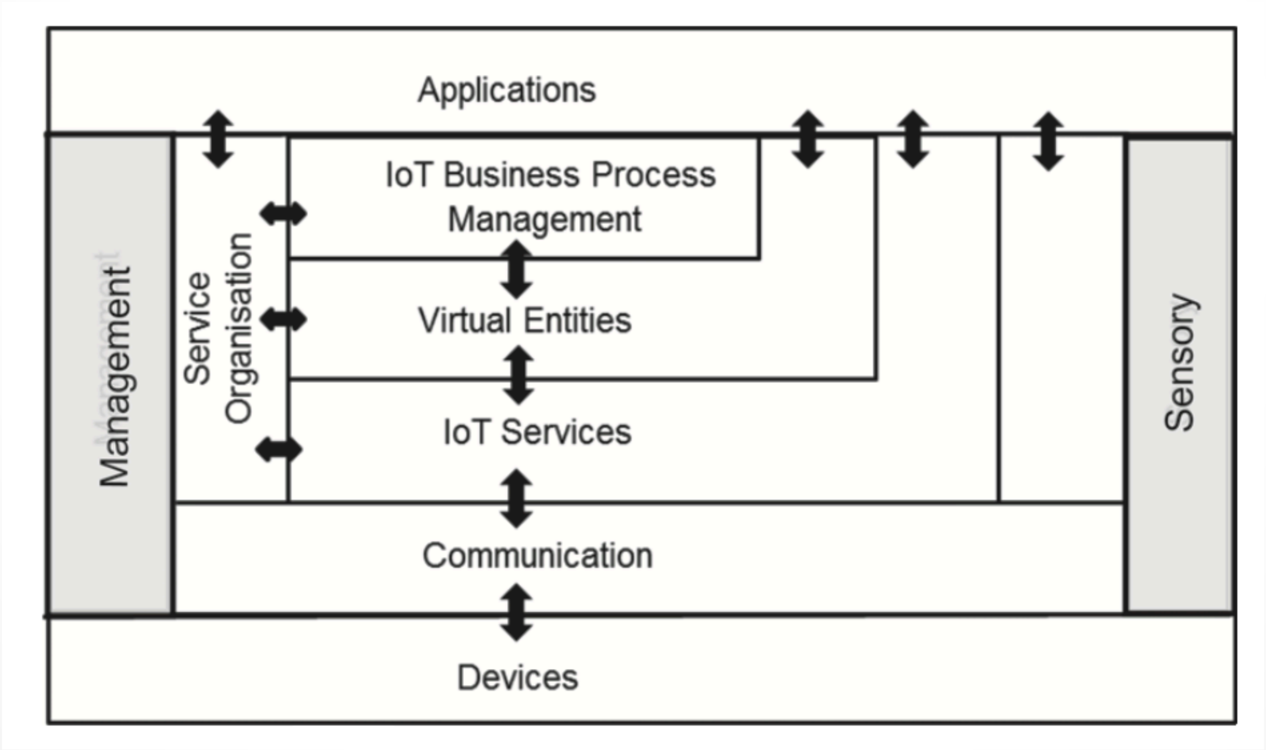
- Sensors and machines communicating
  - Data in shop-floor
- Integrated supply chain
  - Data flowing between companies
- Projects and processes footprints
  - Design secrets
- Managerial sensitivity information
  - Strategical information

It is estimated that the number of connected devices will increase to 40 billion by 2020

Great risk of cyber attacks!

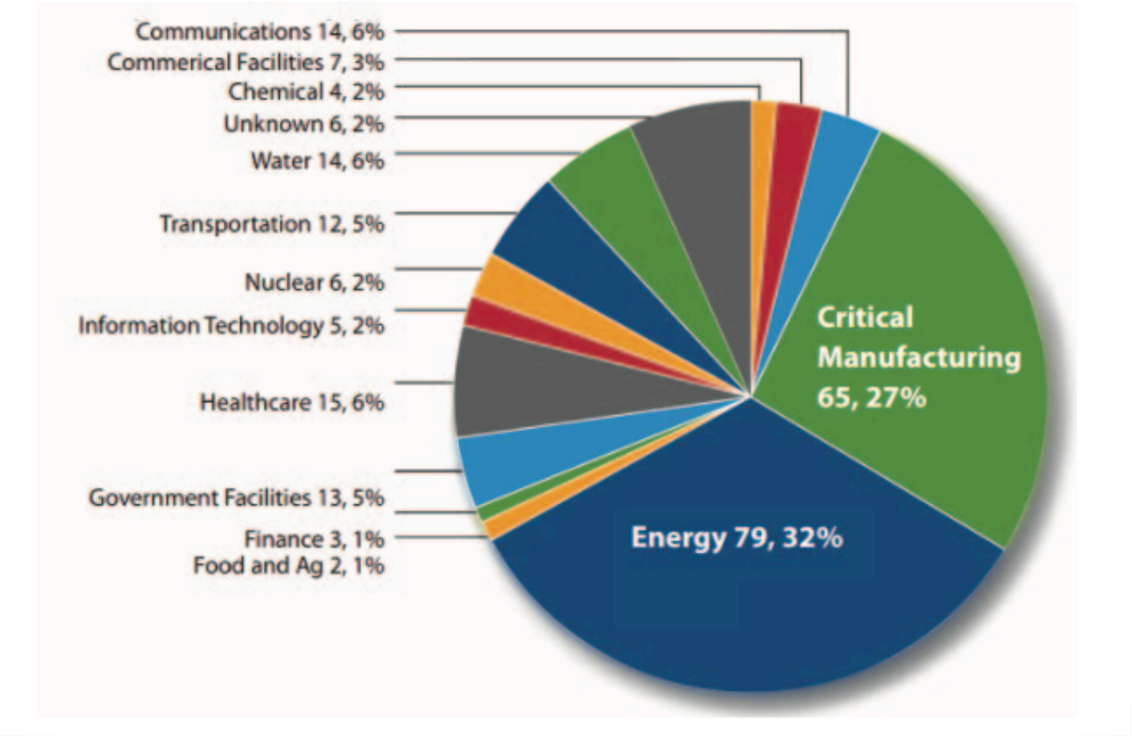
Security in Cyber-Physical Systems

- Manufacturers moving from closed systems (Industrial protocols) into IP-based Cyber-Systems
- IoT – Highly connectivity, high cyber vulnerability.



Security in Cyber-Physical Systems

- **245** incidents reported by US Industrial Control Systems Cyber Emergency Response Team (ICS-CERT) in 2014
- Terrorism, industrial secret stealina.



Security in Cyber-Physical Systems

- Autonomous protection through AI
  - AI systems are meant to be already used in Cyber Systems for optimized production
  - Big data produced by the industry
  - Detect threat through Data Mining – Hack threats lets digital footprints
  - Knowledge-based computational intelligence - fast response and protection.

Other ideas:

- Reconfigurable Cellular Manufacturing
  - Cell Formation is NP-complete
  - AI algorithms provide satisfactory solution – Evolutionary Algorithms and Neural Networks preforms better than simple clustering or graph searches.

- Bioinspired Adaptive Manufacturing
  - Central control providing demand and cost effectiveness analysis
  - Distributed controls ("*hormone regulation*") calculating optimized solutions and giving feedback to central control.
  - Best feasible solution found is used as learning in genetic algorithms.

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