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Industry 4.0

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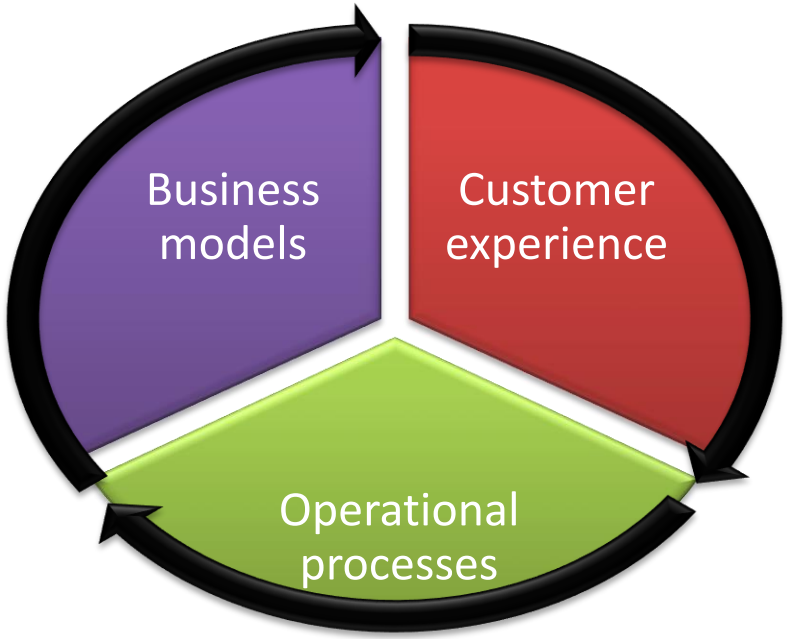
Introduction

Digital transformation in the industry

Use of technology to improve **radically** the enterprises process

Currently

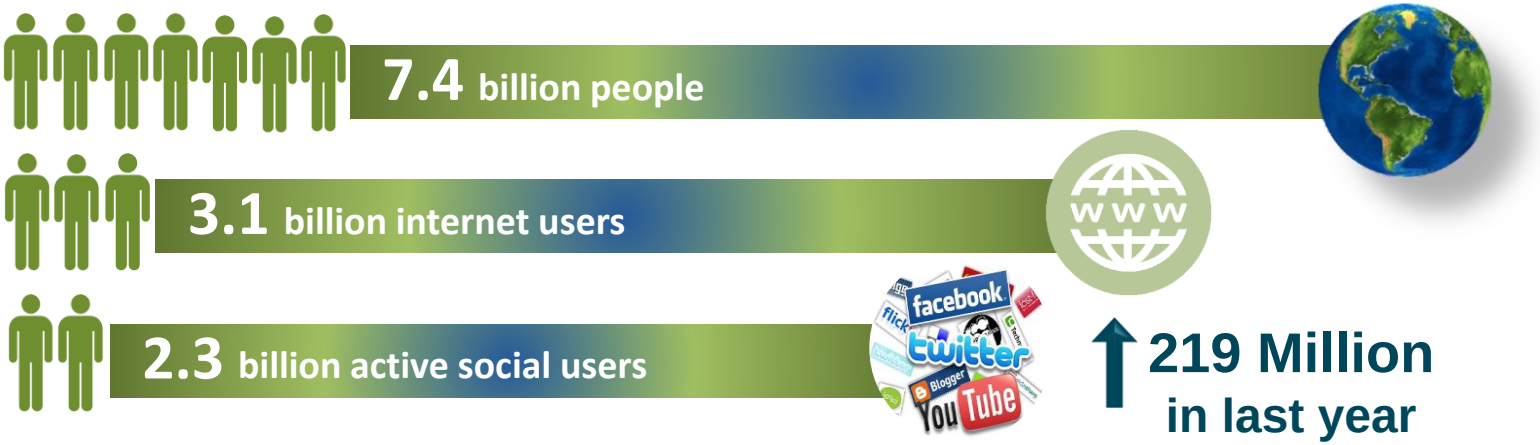
- SMAC (Social, Mobile, Analytics, Cloud)
- Traditional technologies (i.e. ERP, SCADA)



Industry 4.0

Time to reach 100 Million customers

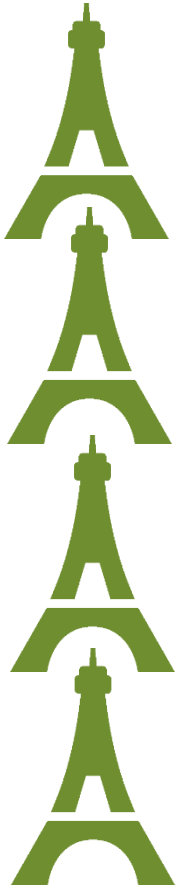
- Telephone 75 Years
- Web 7 Years
- Facebook 4 Years
- Instagram 2 Years
- Pokemon Go 1 Month



90% of adults age **18 to 29** use social media	**2** Hours per day	**5** social media accounts

Production of Data

Data stored grows
4X FASTER THAN THE WORLD ECONOMY



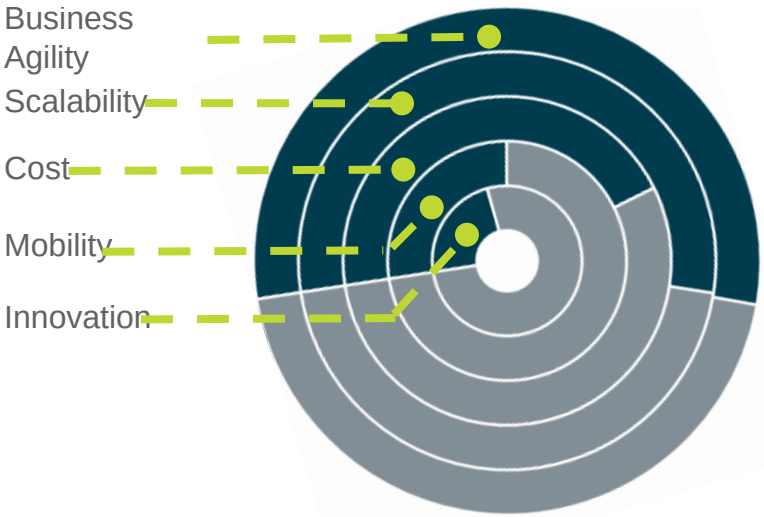
EVERY DAY WE CREATE
2,500,000, 000,000, 000,000
(2.5 QUINTILLION) BYTES OF DATA

*Fill **10 million Blu-ray discs**, the height of which stacked, would measure the height of **4 Eiffel Towers** on top of one another*

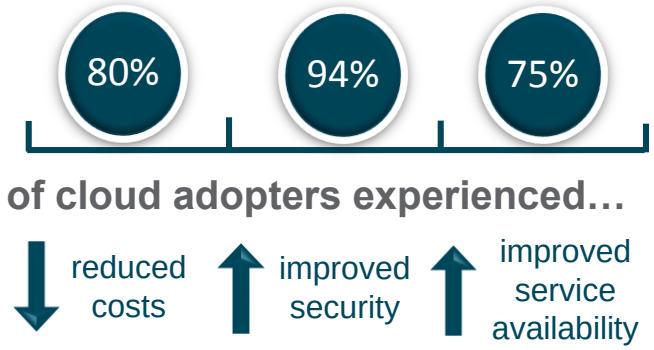
Increasing quantity of data allows DATA-DRIVEN APPROACHES

CLOUD

Top adoption drivers



3 out of **4** decision makers use cloud services for their business



Current Industry: Airbus

- **MiRA (Mixed Reality Application)** tablet
  - Cross between a sensor pack and a tablet

- **Internet Connected Smart Tools**
  - Auto-adjust to different actions
  - Log information
  - Reduces assembly time

- **Augmented Reality** driven instructional & educational tutorials

Photos courtesy of Airbus Factory

Current Industry: Siemens – Shampoo Plant

- Bottle carriers with **RFID tags** can talk to machines in a production line

- **Smart Dispenser Machine**:
  - Reads RFID info
  - Determines type of shampoo to fill
  - Knows how much shampoo to fill

- **Smart Labeling Machine**:
  - Reads RFID info
  - Determines if the bottle is filled
  - Knows what label to put on the filled bottle

- Eliminates the need for **a separate production line for each type of shampoo**

Current Industry

Sensors are attached to components, forklifts, employees and other assets

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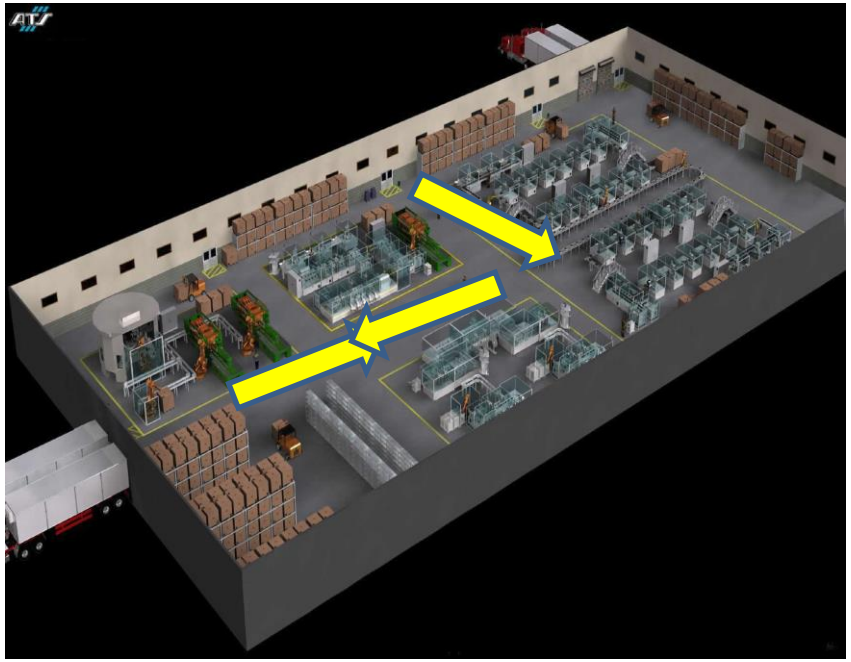
Current Industry

By geolocating the sensors, one can see **how people and products are moving**



Current Industry

SMART Inventory management

- Sensors on containers can determine when a **product is running low**
- The inventory system will be **alerted to proactively re-order the parts** when a certain level is reached or orders can be automatically placed with suppliers

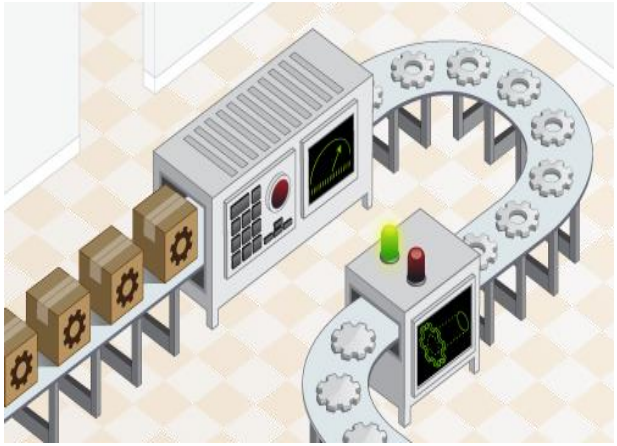
Current Industry

SMART Quality control

- RFIDs attached to products can be used to **tag defective products**

- An automated system **can be alerted** to see if there is a bad batch of components or if an adjustment needs to be made to the machinery

- If an **adjustment is needed**, it can be automatically made in real-time



Evolution

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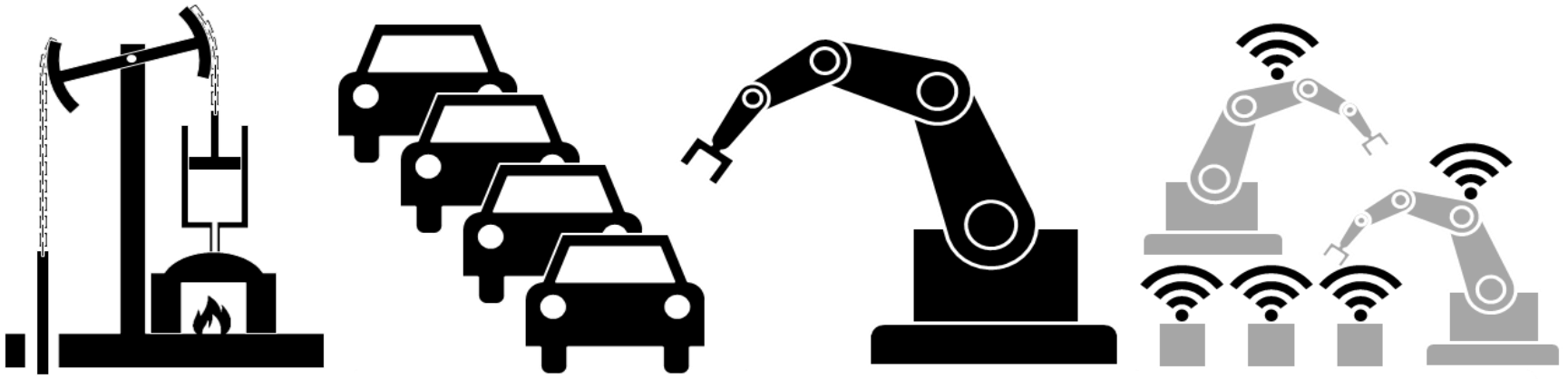
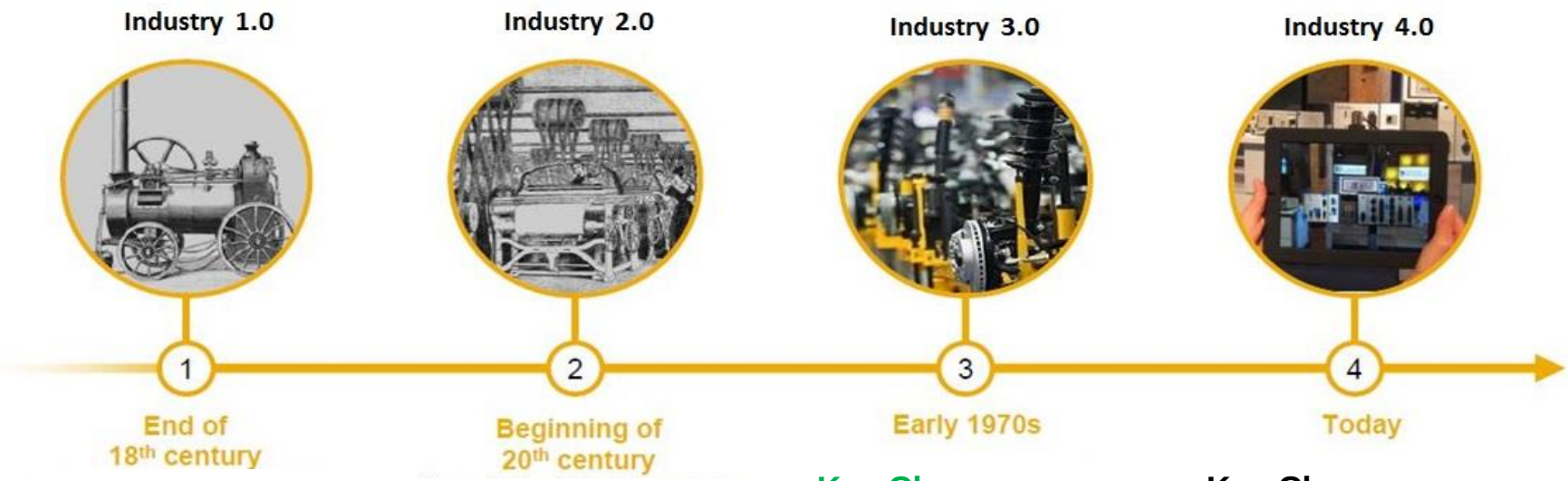
Phases of Industrialization



1st	2nd	3rd	4th
Mechanization, water power, steam power	Mass production, assembly line, electricity	Computer and automation	Cyber Physical Systems

Phases of Industrialization



Key Change:

Introduction of Mechanical Production Equipment driven by Water and Stream Power

Key Change:

Introduction of mass Manufacturing Production lines powered by Electric Energy

Key Change:

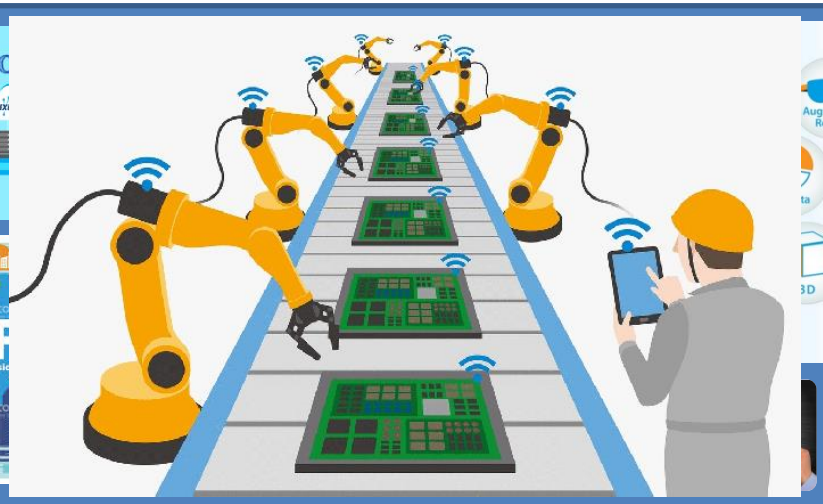
Introduction of Electronics, PLC Devices, Robots and IT to automate Production

Key Change:

Introduction of IoT and Cyber-Physical Systems driven by Augmented Reality & Real Time Intelligence

Industry 4.0: Introduction

4 XXI -



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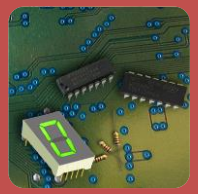

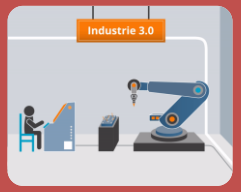

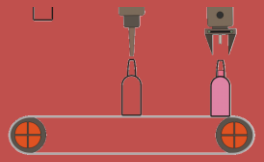

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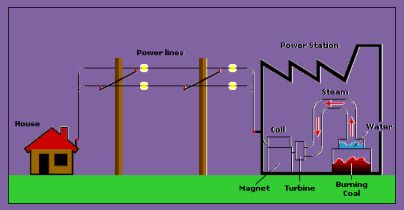
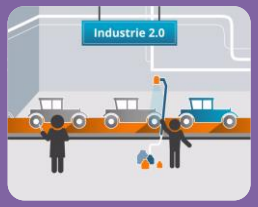
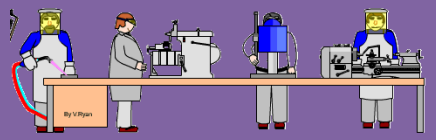
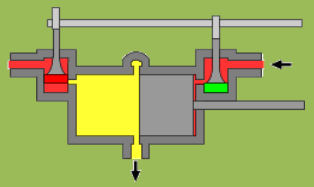
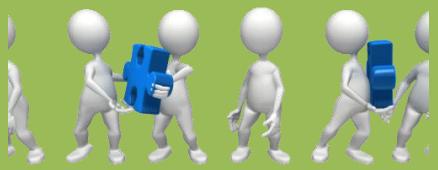






1 1760 – 1840





Characteristics

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Industry 4.0

Emerges as a combination of new technologies, such as Cyber Physical Systems (CPS), Internet of Thing (IoT), Cloud computing, Internet of Services (IoS), Augmented Reality (AR), Big Data Analysis, among others.

These technologies are applied in the Industry 4.0, in order **to control the production process autonomously** and **to increase its productivity, flexibility, adaptability, and efficiency.**

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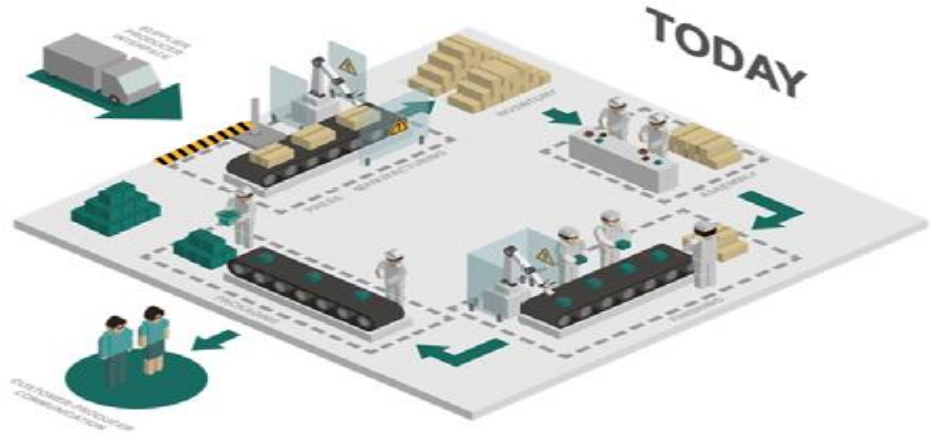
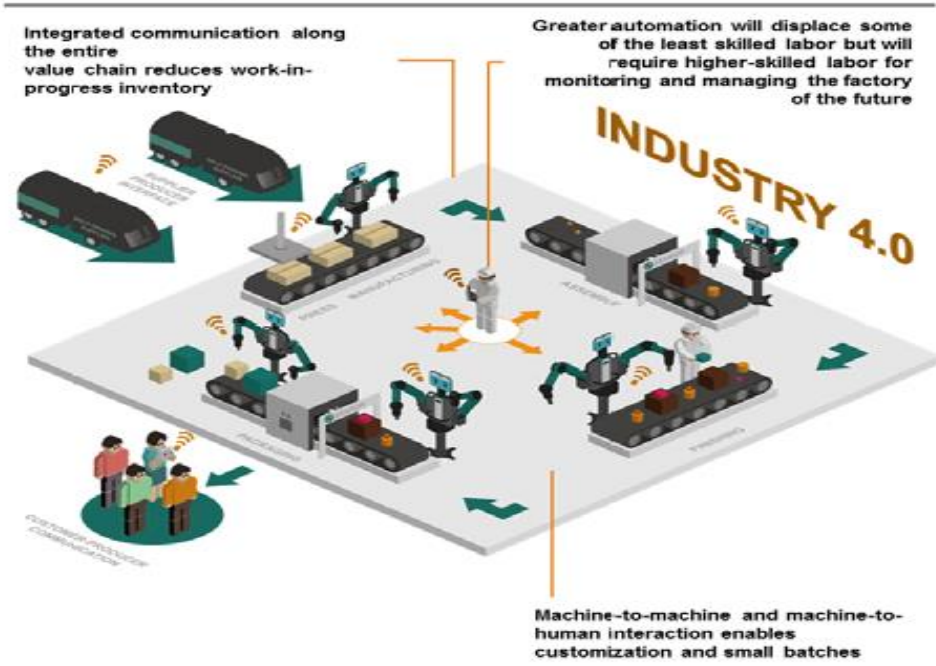
Core idea of Industry 4.0:
Integrated, automated and optimized production flow

From isolated, optimized cells …



…to fully integrated data and product flows across borders



Source: BCG.

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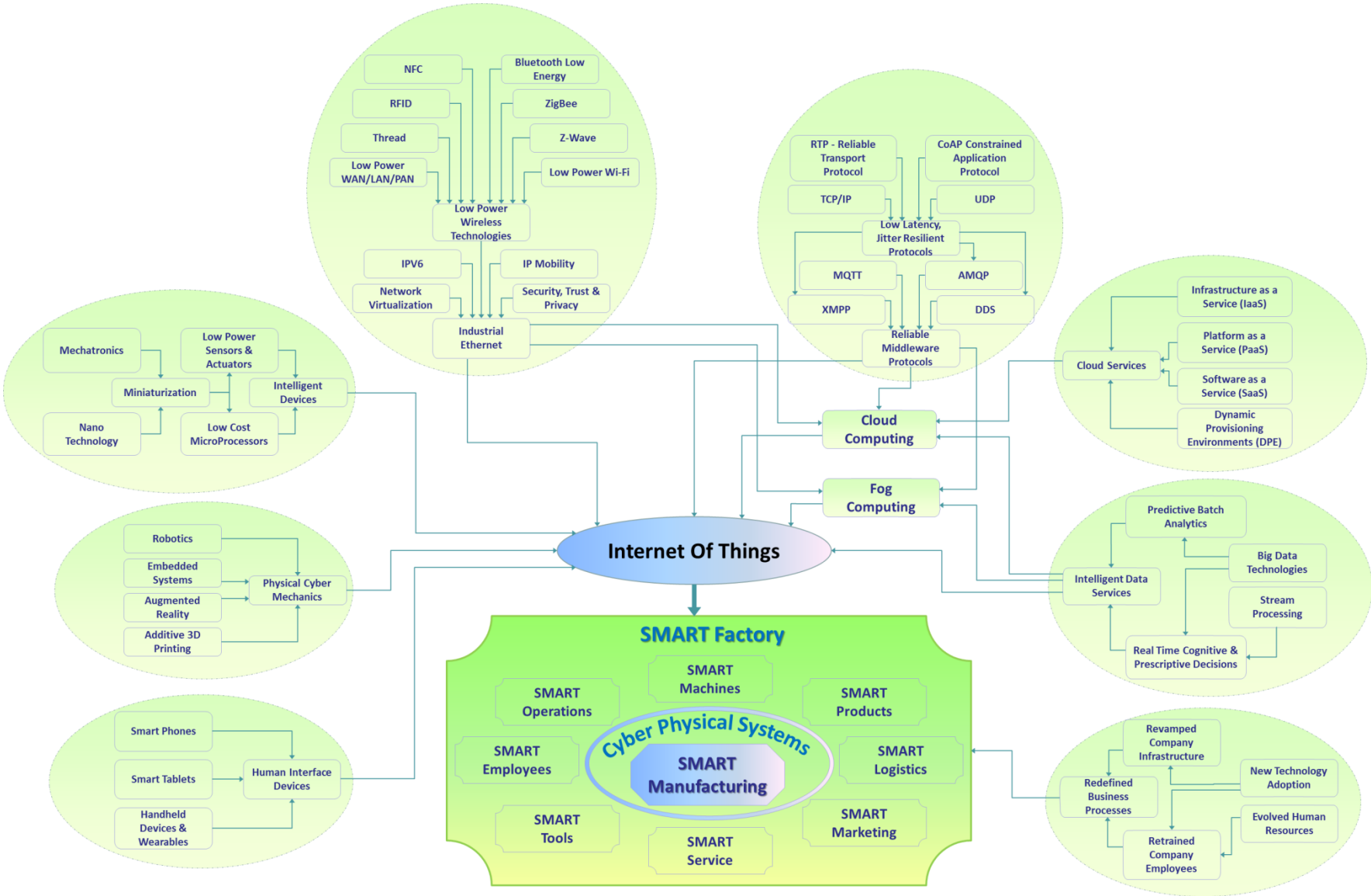
Blocks of Industry 4.0



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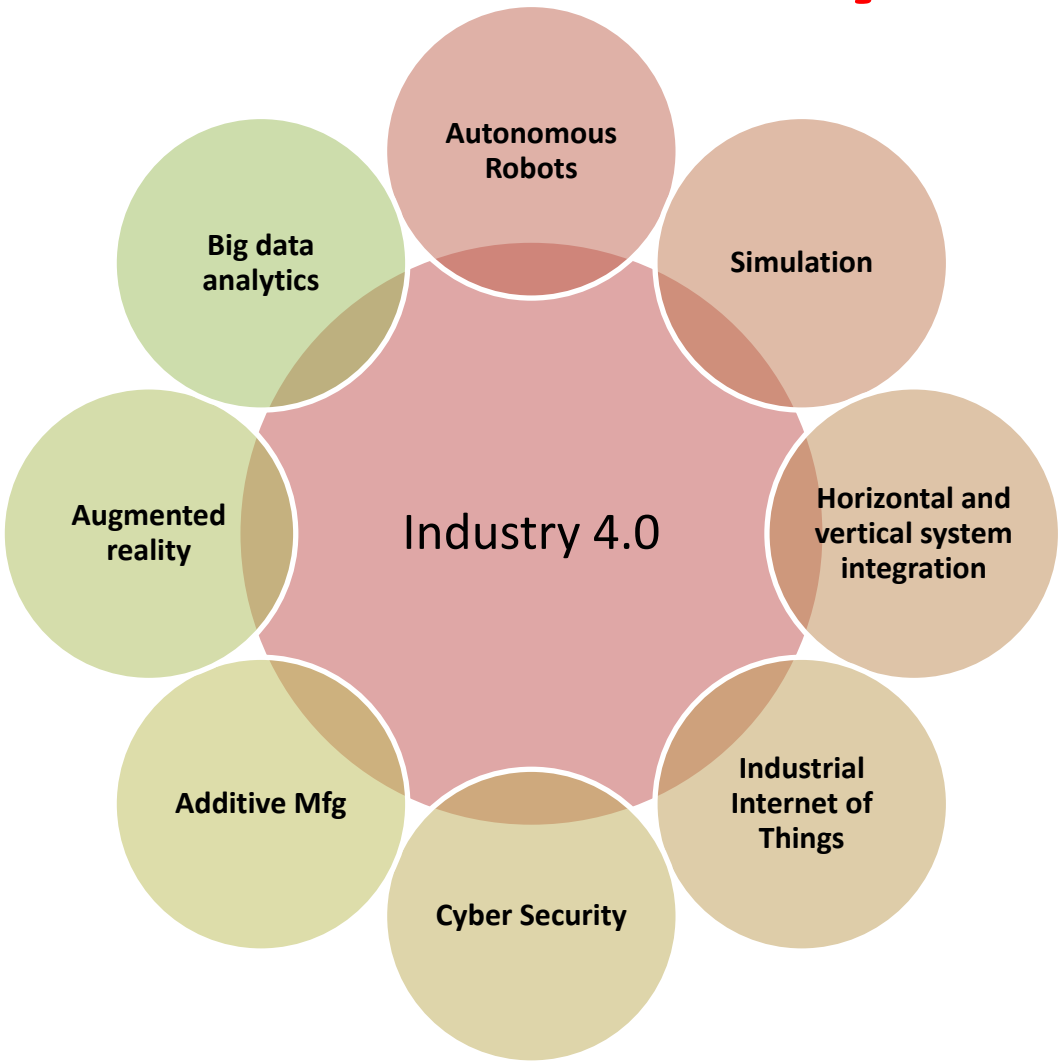
Blocks of Industry 4.0



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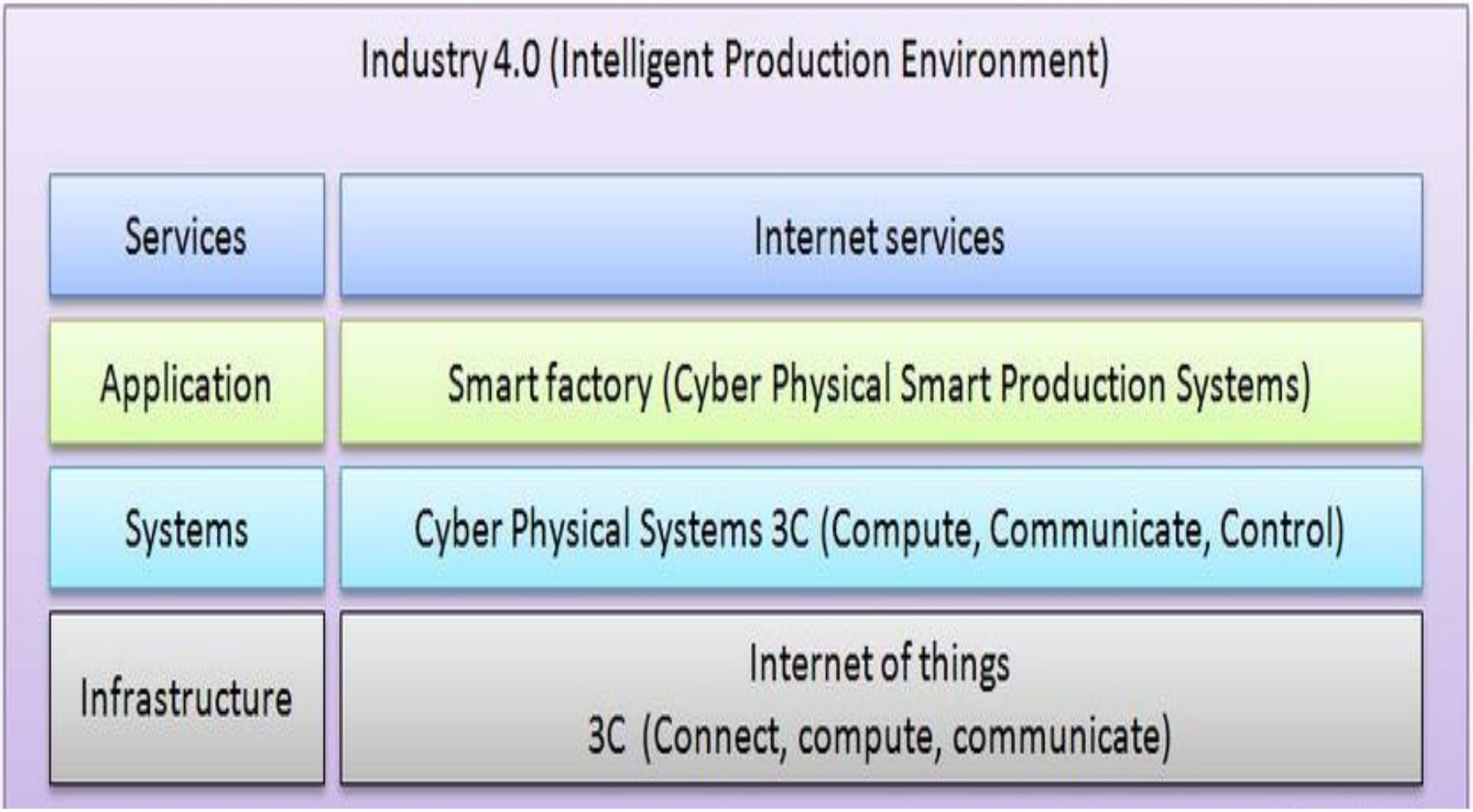

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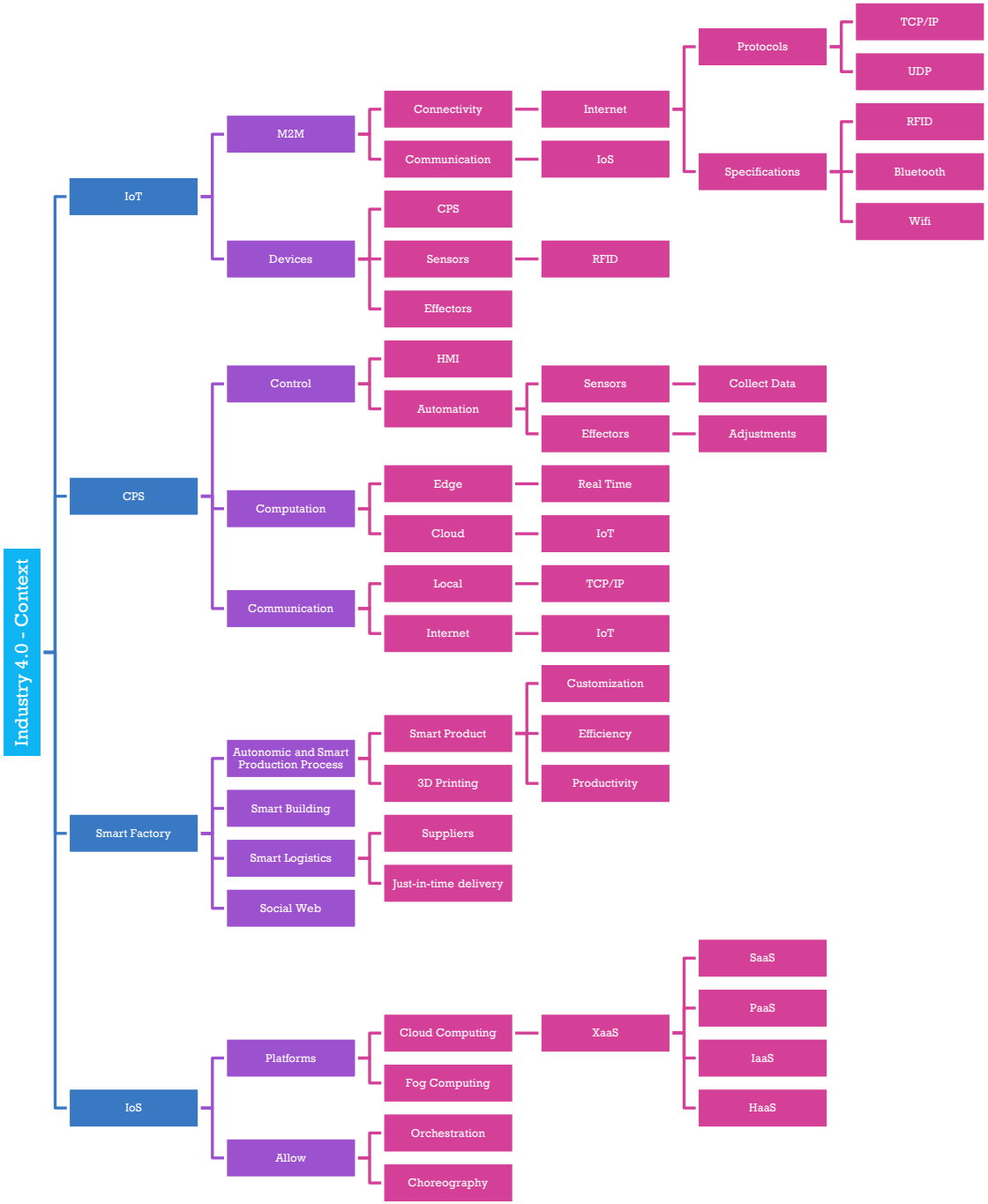

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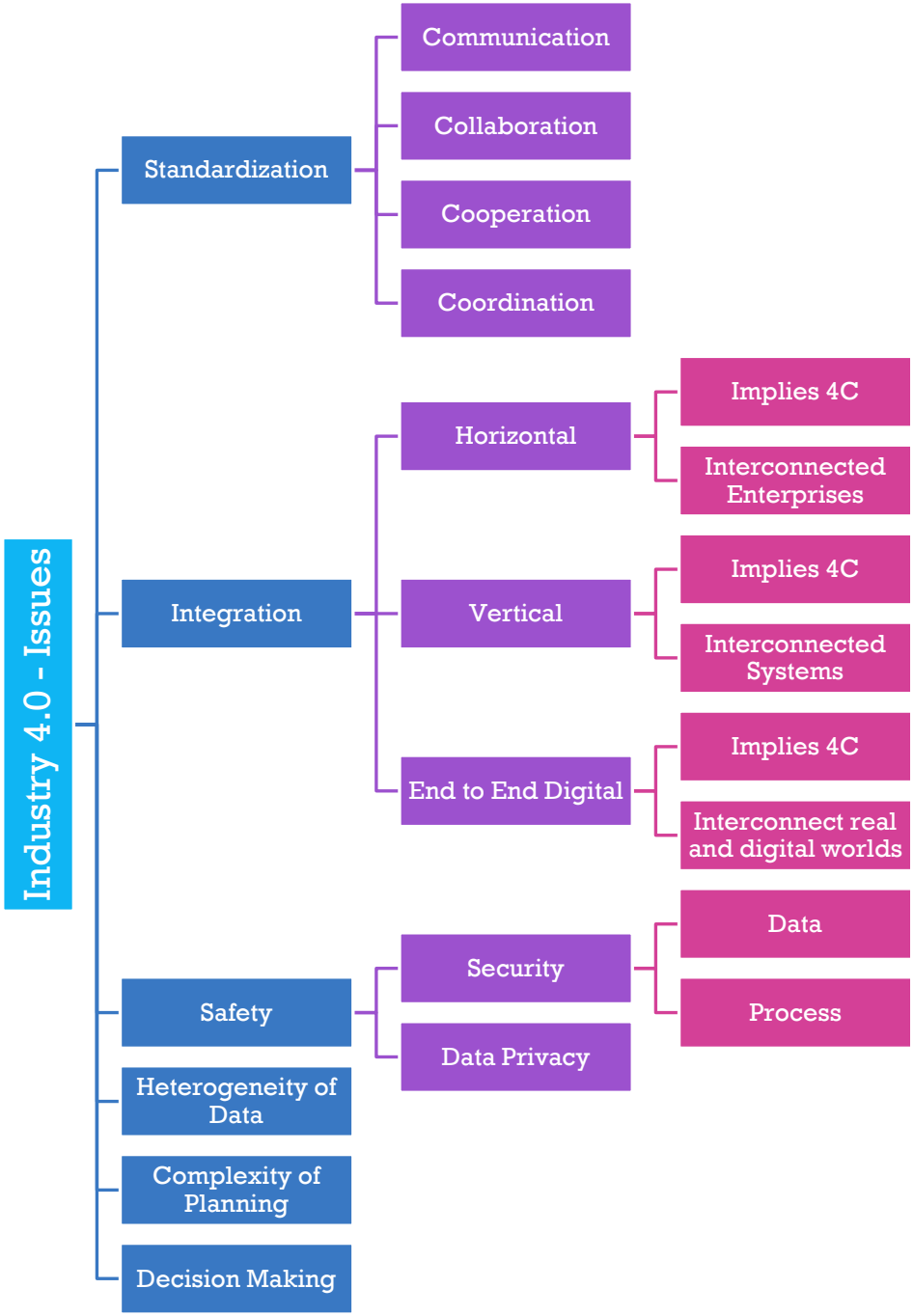
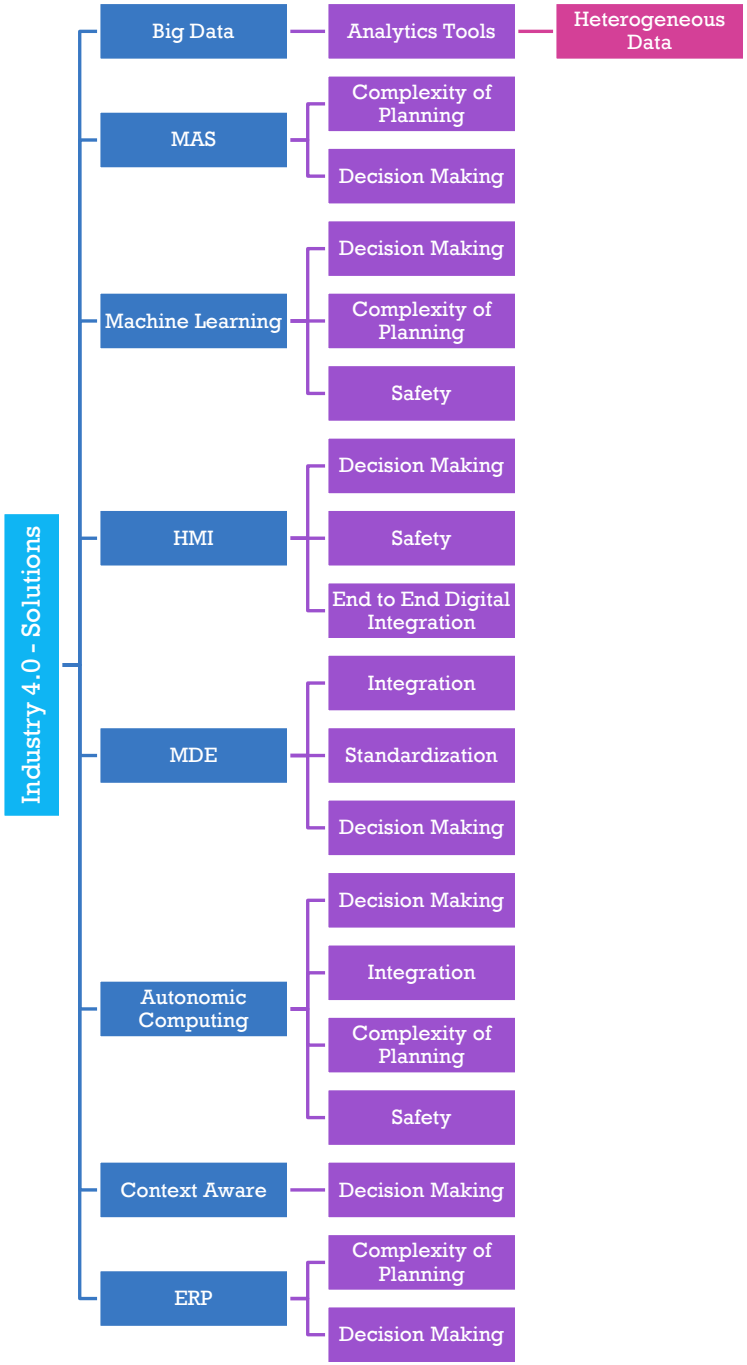
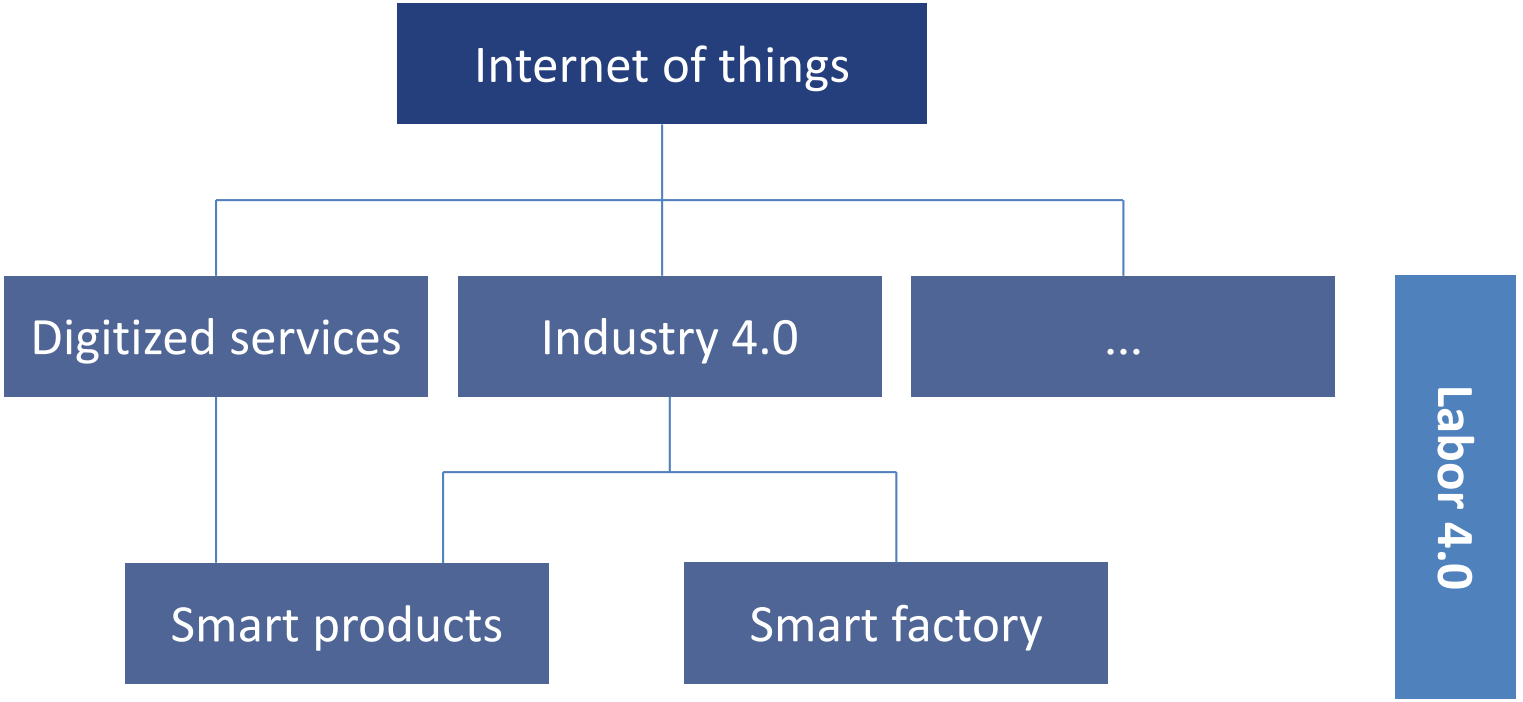


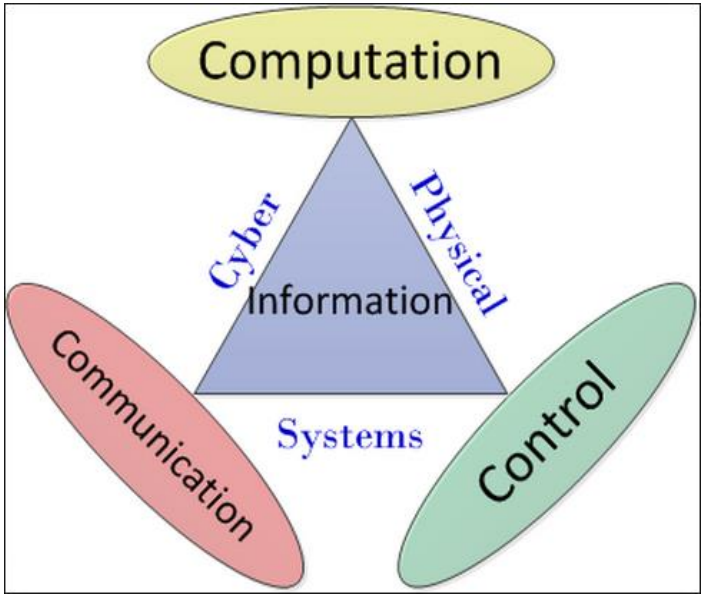

Industry 4.0 - Solutions
Big Data
Analytics Tools
Heterogeneous Data
MAS
Complexity of Planning
Decision Making
Machine Learning
Decision Making
Complexity of Planning
Safety
HMI
Decision Making
Safety
End to End Digital Integration
MDE
Integration
Standardization
Decision Making
Autonomic Computing
Decision Making
Integration
Complexity of Planning
Safety
Context Aware
Decision Making
ERP
Complexity of Planning
Decision Making

Industry 4.0 as part of a digitized economy



Product innovation | Process innovation | Autonomous agents | Digital networking

Cyber Physical Systems



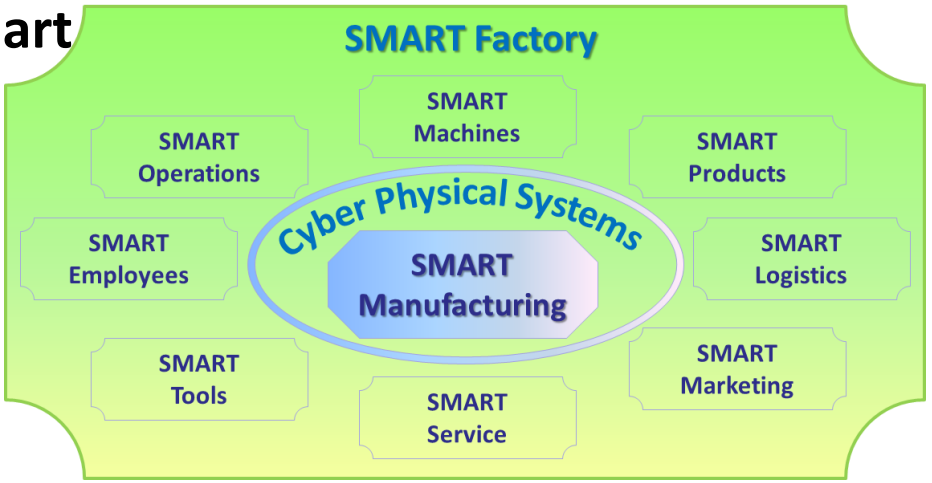
It is a system of **collaborating computational elements controlling physical entities**.

- CPS are physical and engineered systems whose operations are **monitored, coordinated, controlled and integrated** by a computing and communication core.
- They allow us to add capabilities to physical systems by merging computing and communication with physical processes.

SMART Factories….

- Smart factories are connected in a network through the use of **cyber-physical production** systems which lets factories and manufacturing plants react quickly to variables, such as demand levels, stock levels, machine defects, and unforeseen delays

- This networking also involves the **smart logistics and smart services**



- The whole value chain in such **integrated network** is subjected to through-engineering, where the complete lifecycle of the product is traced **from production to retirement** through the use of IoT technologies

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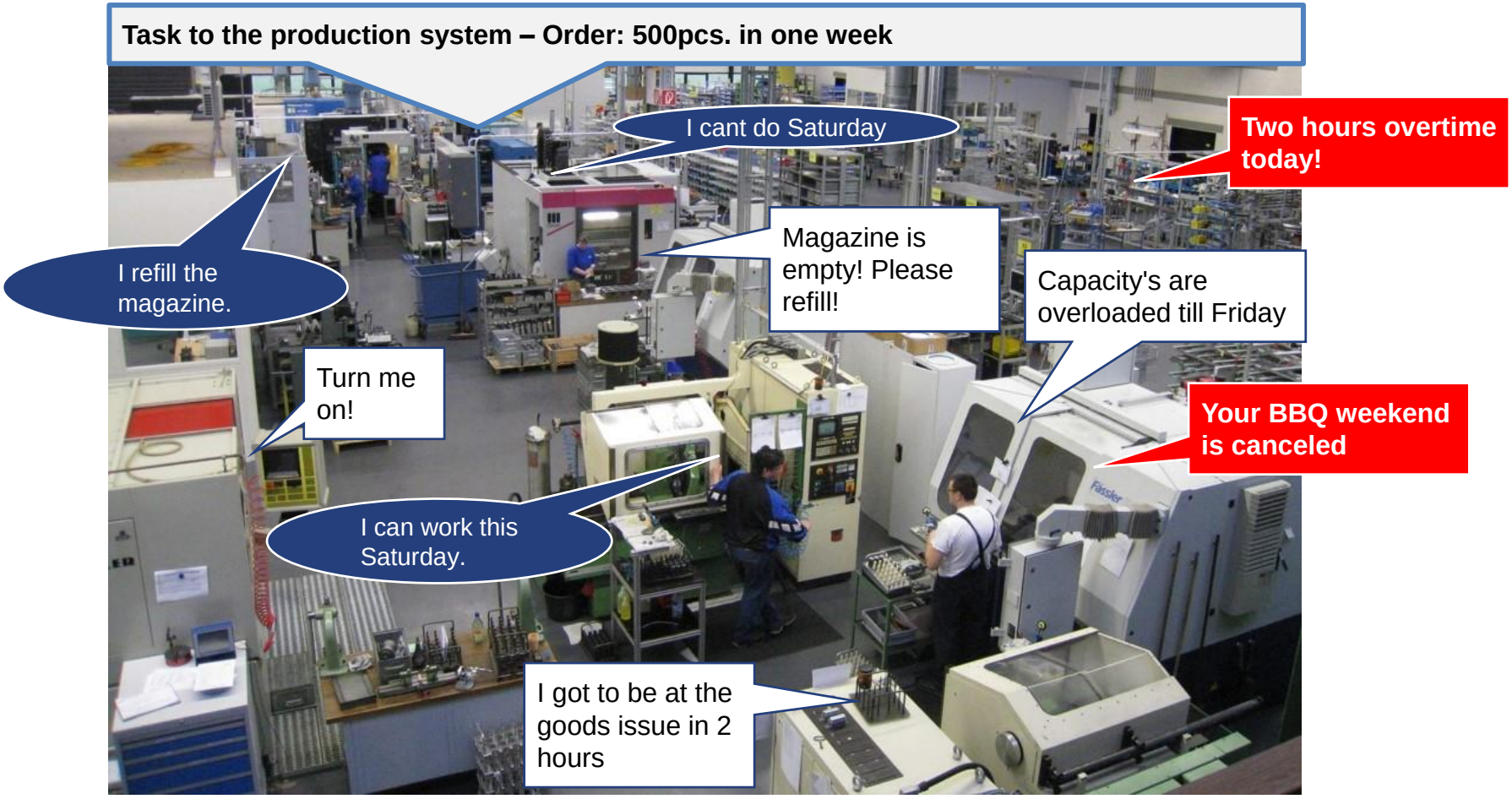
SMART Factories….

Smart factory concept is intended **to enable extremely flexible production, and self-adaptable production processes**, with machines and products that act both intelligently and autonomously, by implementing concepts such as the Internet of Things (IoT) and Cyber Physical Systems

The main features of a smart factory are:

- **Connected:** a network of sensors and actuators allows detecting needs and collaborating in real time.
- **Optimized:** the production and material handling highly automated allow increasing production with minimal human interaction
- **Transparent:** new tools are used to support quick and consistent decision making, as well as to track appropriately the orders**.**
- **Proactive:** early identification of quality issues, anomalies and rescheduling in real time.
- **Agile:** adaptable layouts and equipment's

A normal day in the smart factory



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Cloud Computing and Internet of Services (IoS).

Cloud computing as a revolutionary paradigm to deliver computing resources, ranging from data storage/processing to software, as a service over the network, typically using Internet technologies.

Internet of Services (IoS) is related to services provided over the Internet, and its vision is to develop Internet for delivering interoperable and readily available services that cover all facets of a client's life and his business.

IoS presents everything as a service on the Internet, including software applications (SaaS), the platform to develop and deliver these applications (PaaS), and the underlying infrastructure (IaaS).

everything as a service (XaaS),

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Internet of Things (IoT) and Internet of Everything (IoE)

IoT is a mean for the integration of smart devices, allowing those devices to connect, communicate, and interoperate autonomously, and to take decisions as support to the activities of the users in the environment.

IoE is an extension of IoT, which not only allows things to communicate, but also, people, data and processes.

IoE is related to the interconnection of people, data, things, and services

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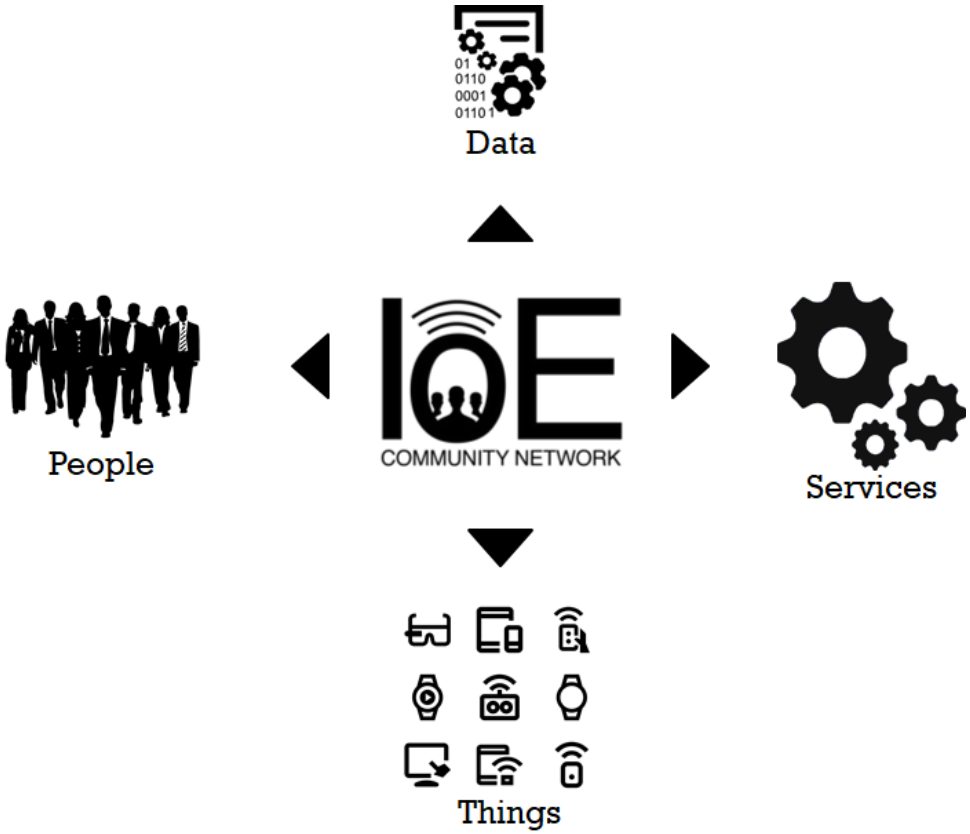
Internet of Everything (IoE)



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System Integration

Systems Integration is related to link together system components (like software, hardware or other systems or sub-systems), in order they can interoperate and provide solutions according to his goals (common or individuals).

In the context of the Industry 4.0, the systems are usually integrated using technologies like IoT, enabling the interoperability between people, data, services and things and allowing them to Connect, Communicate, Coordinate, Collaborate and Cooperate.

System integration

- Horizontal Integration (inter-company integration):
- *Vertical Integration (inter-company integration):*

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Industry 4.0

Six Design Principles

- **Interoperability**: the ability of **cyber-physical systems** (i.e. work piece carriers, assembly stations and products), humans and Smart Factories to connect and communicate with each other via the **Internet of Things** and the **Internet of Services**
- **Virtualization**: a virtual copy of the Smart Factory which is created by linking sensor data (from monitoring physical processes) with virtual plant models and simulation models
- **Decentralization**: the ability of **cyber-physical systems** within Smart Factories to make decisions on their own
- **Real-Time Capability**: the capability to collect and analyze data and provide the insights immediately
- **Service Orientation**: offering of services (of **cyber-physical systems**, humans and Smart Factories) via the **Internet of Services**
- **Modularity**: flexible adaptation of Smart Factories for changing requirements of individual modules

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Steps to go industry 4.0

Manufacturing

- replacing human work
- man-machine collaboration
- 3D - Printing
- Augmented Reality (training / support / advice through dataglasses)
- Shift/working hours-coordination over the internet
- Remote control of production equipment

Engineering

- Computer based simulation
- extended usage of cloud-computing and crowd-sourcing

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Steps to go industry 4.0

Maintenance

- Remote controlled maintenance
- Data-glasses, computer based support for decision making
- Exensive use of sensors to monitor the state of production equipment

Production control

- paperless logistics
- traceability of products and parts (realtime information of inventory)
- RFID
- digital memory of the product
- optimisation of production with BIG DATA

Implications

Potential Implications

- Robot Assisted production
- Predictive Maintenance
- Additive manufacturing of complex parts
- Machines as a service
- Big data drive quality control
- Production line simulation
- Smart supply network

Robots as colleagues instead of work tools

Robots as training partner? Or as gateway to complex jobs?

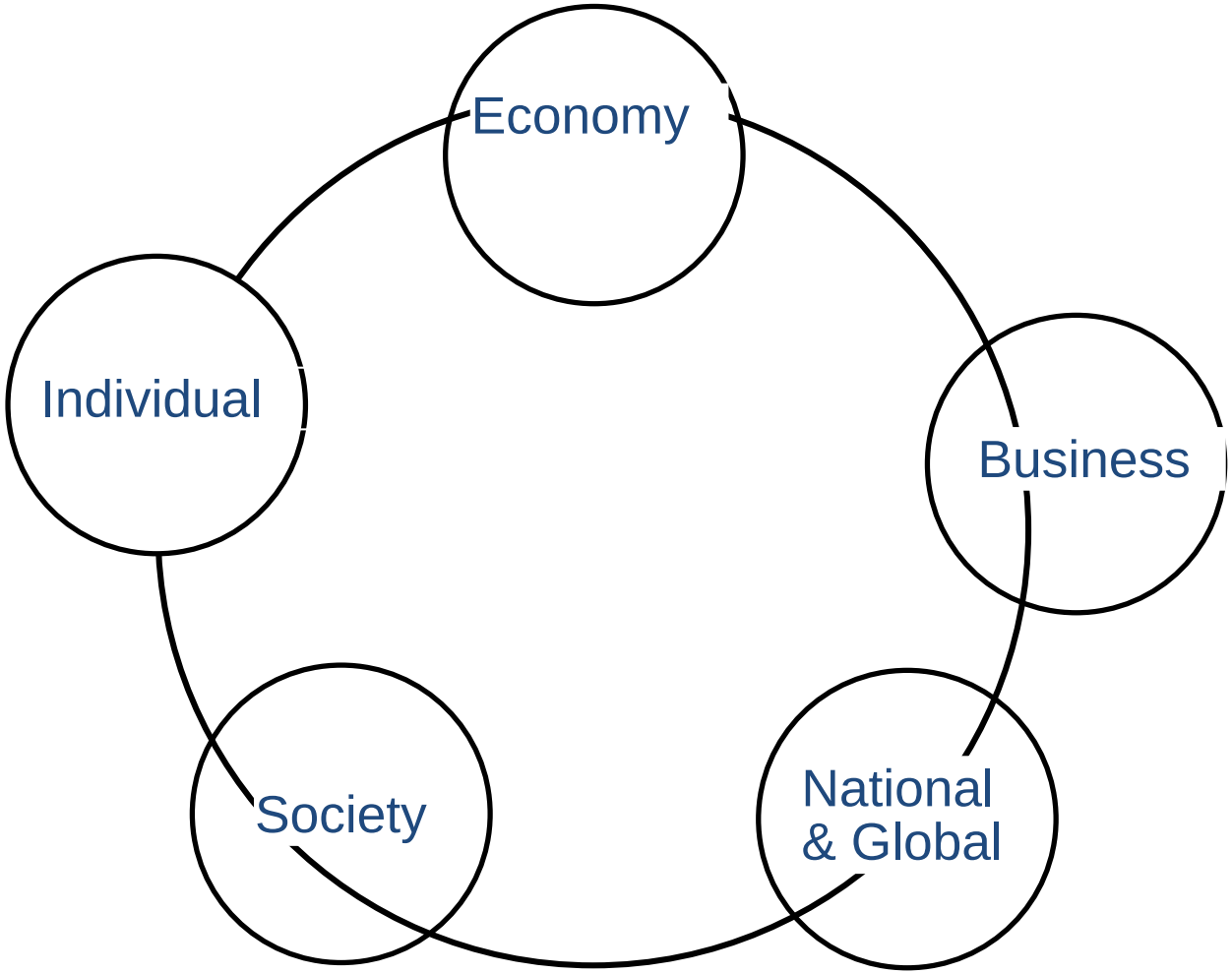
THREE ASPECTS OF DIGITIZATION THAT FORMS THE HEART OF INDUSTRY 4.0

- THE **FULL DIGITIZATION** OF A COMPANY'S OPERATIONS, INTEGRATED VERTICALLY AND HORIZONTALLY

- THE **REDESIGN OF PRODUCTS** AND SERVICES TO BE EMBEDDED WITH CUSTOM-DESIGNED SOFTWARE

- **CLOSER INTERACTION WITH CUSTOMERS**, ENABLED BY THESE NEW PROCESSES, PRODUCTS, AND SERVICES

Impact



Impact

Economy

Growth

Ageing

Productivity

Employment

Labour substitution

The nature of Work

Business

Customer expectations

Data enhanced products

Collaborative innovation

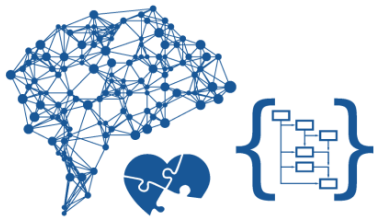
New operating models

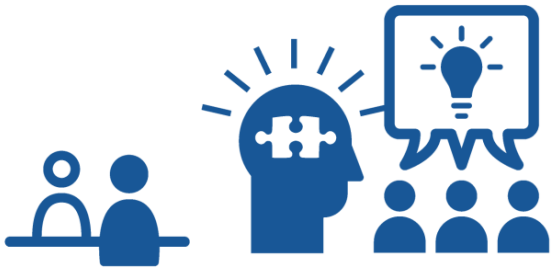
Impact

- **National & Global**
  - Governments
  - Countries, regions & cities
  - International security
- **Society**
  - Inequality
  - Community
- **Individual**
  - Identity, morality & ethics
  - Human connection

Top 10 Skills to be relevant in Industry 4.0

in 2020	in 2015
1. Complex Problem Solving	1. Complex Problem Solving
2. Critical Thinking	2. Coordinating with Others
3. Creativity	3. People Management
4. People Management	4. Critical Thinking
5. Coordinating with Others	5. Negotiation
6. Emotional Intelligence	6. Quality Control
7. Judgment and Decision Making	7. Service Orientation
8. Service Orientation	8. Judgment and Decision Making
9. Negotiation	9. Active Listening
10. Cognitive Flexibility	10. Creativity





Source: Future of Jobs Report, World Economic Forum

Challenges

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Challenges

. Big data analysis and use for quality control

· Flexible production equipment and interconnections

· Joint Cognitive Systems for decision support

· Engineering Platform for design/operations continuum

· Customer and demand data gathering for analysis

· Product and service co-design with customer

· Supply chain visibility and decision assistance

· Security solutions for collaborative networks

· Open data and system integration platform for unstructured data environment

Heterogeneity

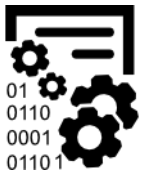
Security

Privacy

Real time

...

...

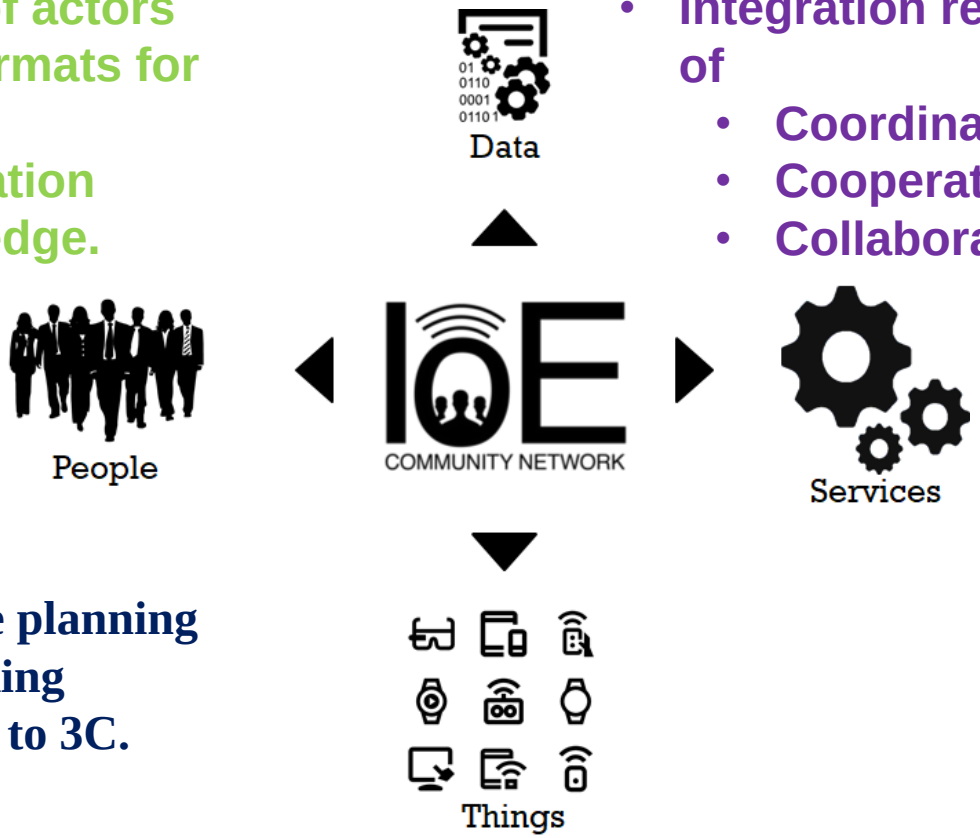


IoE
COMMUNITY NETWORK

The Problem

- Heterogeneity of actors
  - Different formats for
    - Data
    - Information
    - Knowledge.

- Integration requires high levels of
  - Coordination
  - Cooperation
  - Collaboration



- Complexity of the planning and decision-making
  - Also Related to 3C.

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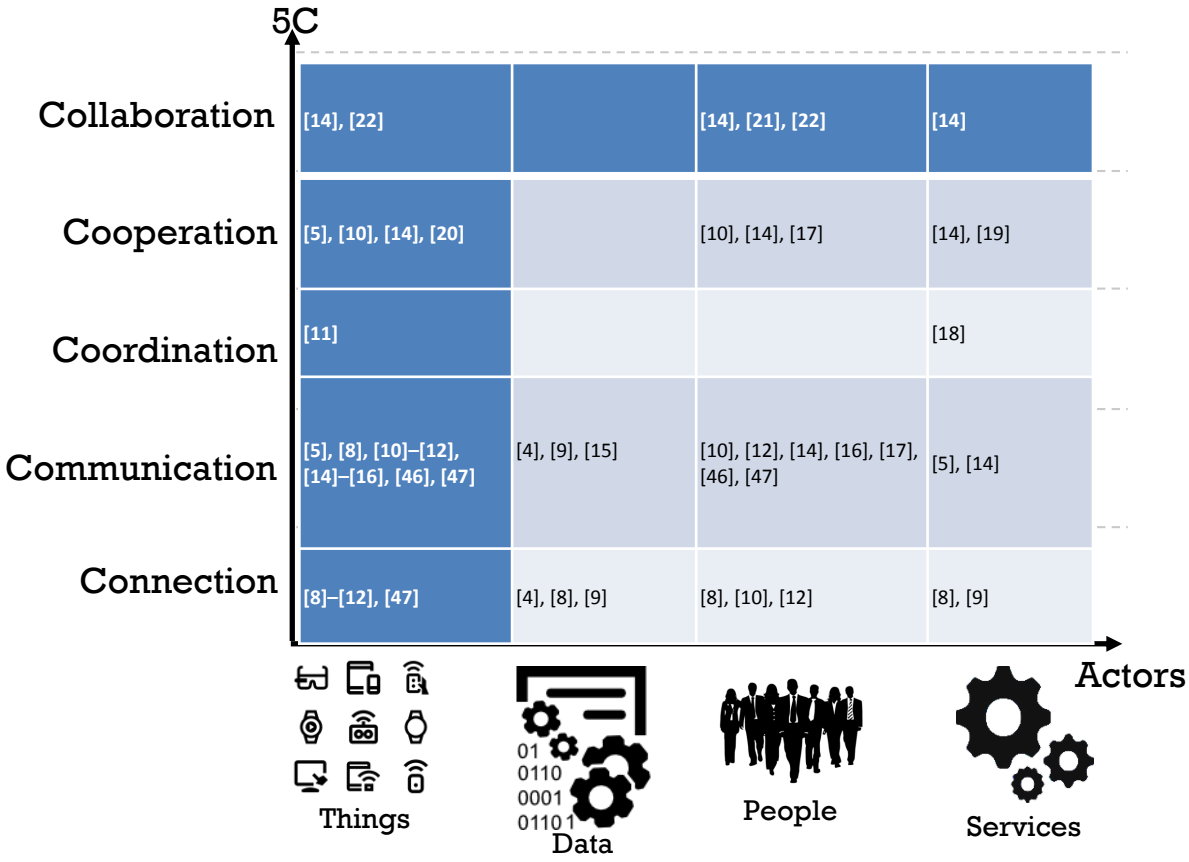
Integration & interoperability requires that entities be able

- **to connect** (to be able to see each other),
- **to communicate** (to be able to understand each other),
- **to coordinate** (to be able to contribute to archive a global goal),
- **to cooperate** (to be able to interact with others to achieve their individual goals) and
- **to collaborate** (To be able to interact with others to achieve common goals).


5C
Collaboration
Cooperation
Coordination
Communication
Connection
[14], [22]
[14], [21], [22]
[14]
[5], [10], [14], [20]
[10], [14], [17]
[14], [19]
[11]
[18]
[5], [8], [10]–[12], [14]–[16], [46], [47]
[4], [9], [15]
[10], [12], [14], [16], [17], [46], [47]
[5], [14]
[8]–[12], [47]
[4], [8], [9]
[8], [10], [12]
[8], [9]
Actors
Things
01
0110
0001
01101
Data
People
Services

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INTEGRATION CHALLENGES IN INDUSTRY 4.0

Level	CHALLENGES
Connection	Standardization, Heterogeneity of data and actors, Safety
Communication	Standardization, Heterogeneity of data and actors, Safety, Vertical Integration, Horizontal Integration, End to End Integration.
Coordination	Standardization, Complexity of Planning, Decision Making.
Cooperation	Standardization, Complexity of Planning, Decision Making.
Collaboration	Standardization, Complexity of Planning, Decision Making.

5C Integration

- The Actors in the industry 4.0 need:

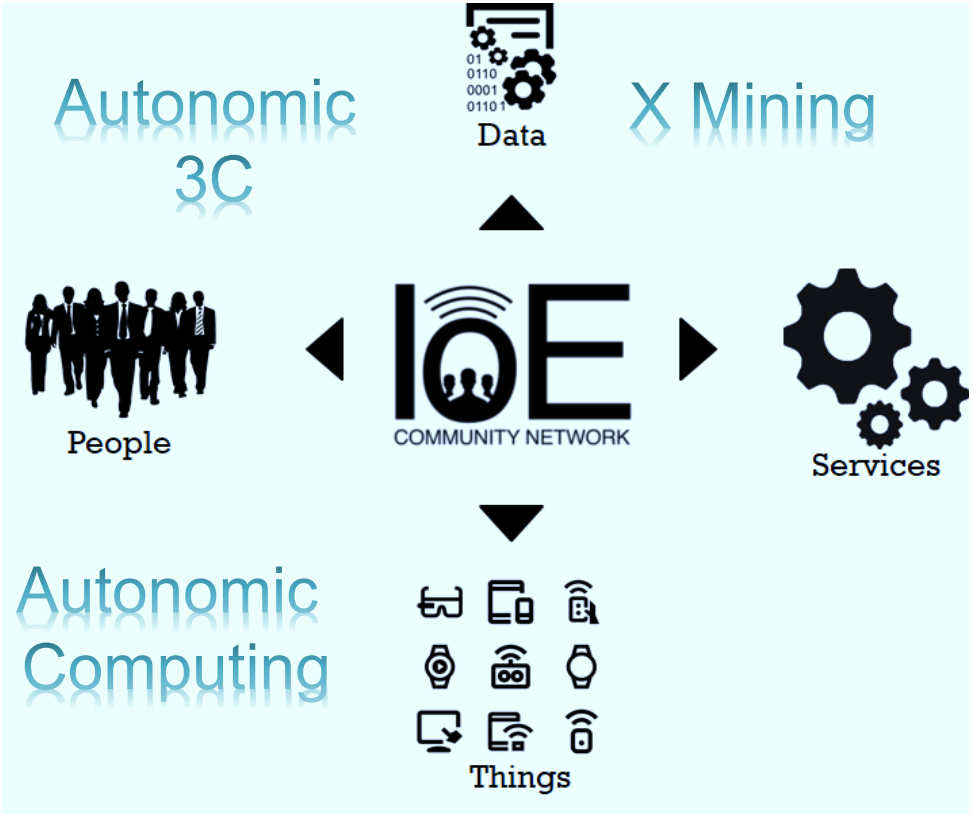
We propose combine **Autonomic Computing** with **Everything Mining**, in order to allow the automation of the 3C (Coordination, Cooperation, Collaboration) levels. While the "Everything Mining" tasks can generate **knowledge** for those process, the autonomic computing will allow it to **self-configure**, **self-heal**, **self-optimize** and **self-protect**, improving the capabilities of the system in a autonomic sense.

Autonomic Processes For Integration in the Context of the Industry 4.0

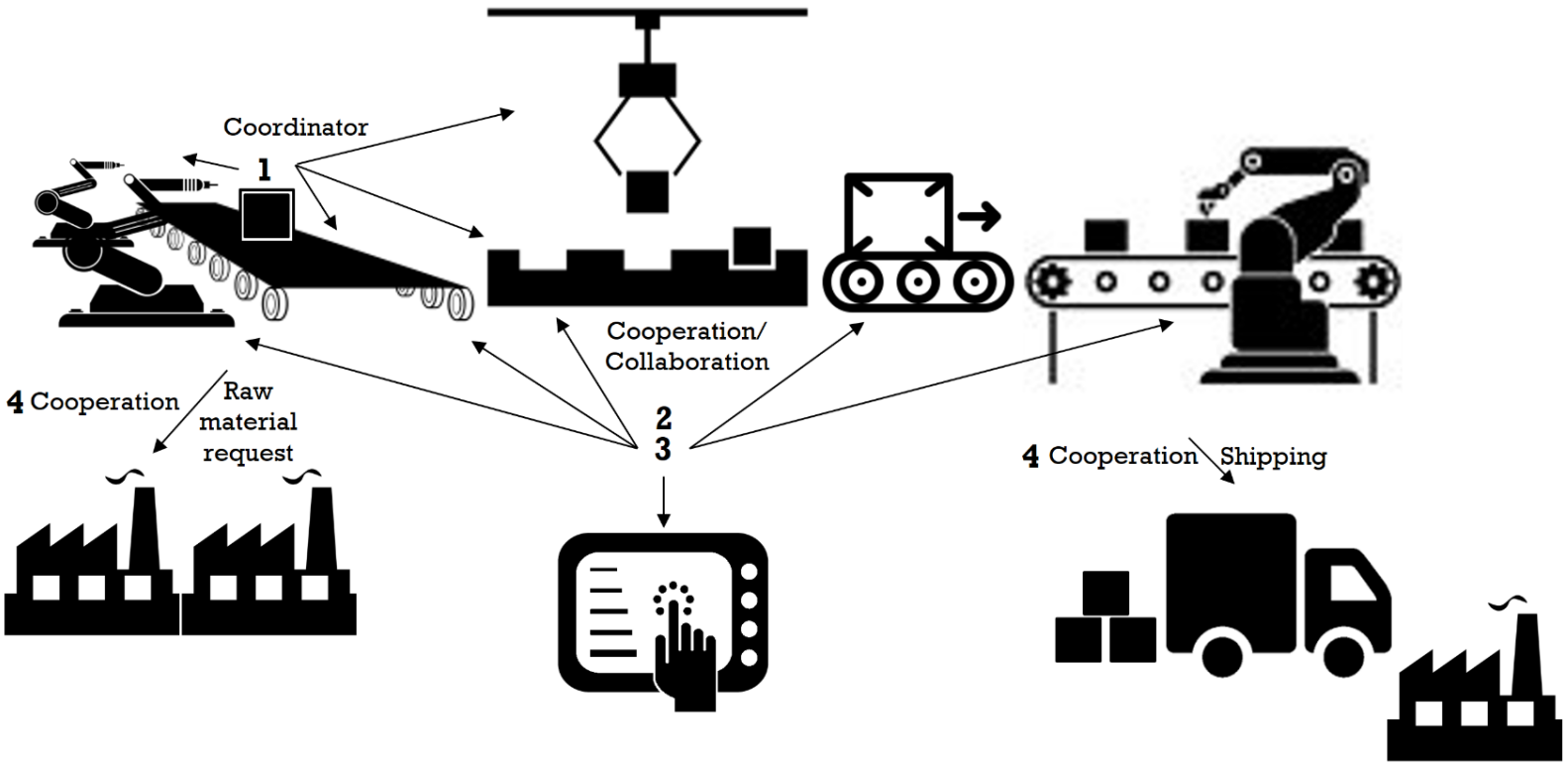
- **Integration requires high levels of**
  - **Coordination**
  - **Cooperation**
  - **Collaboration**

- **Autonomous processes requires**
  - **Autonomous Coordination**
  - **Autonomous Cooperation**
  - **Autonomous Collaboration**

Proposal



Study case


Coordinator
1
Cooperation/
Collaboration
2
3
4 Cooperation
Raw
material
request
4 Cooperation
Shipping

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The company requires several *integration mechanisms* in the 3C levels:

1. Smart products are the ones that coordinate their own production. It is necessary some appropriate *coordination mechanisms*, directed by the smart product.

2 In the same way, the physical elements (things) of the smart factory must use *cooperative mechanisms,* in order to allow them to carry out the production process in an efficient manner.

3 The elements of the production process must take into account the common goal, and *collaborate* among them to achieve it, without neglecting their particular objectives, that is, they must deal with multiple objectives.

4 On the other hand, the intelligent factory can *cooperate* with other organizations, in order to make automatic requests of the raw materials, in such a way that the production process is not stopped because of it.

5. Finally, the smart product can *cooperate* with the shipping organization, so that the products reach the final consumer appropriately and in time

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"Everything Mining" tasks can generate knowledge for the self-configuration processes in the Industry 4.0, in special, for the automation of the 3C levels.

For each level, they can respond to different questions. Some examples of these questions are:

For the coordination level: which are the objectives of the coordination process? Which actors are able to participate in the process?

For the cooperation level: Who want to cooperate with me? With what actors can I trust to cooperate?

For the collaboration level: Who have my same goal? Which actors like to collaborate?

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Autonomic Cycle for Coordination in Industry 4.0 (ACCI40)

Defines a **set of coordination tasks, with the aim of self-creating, self-supervising or self-configuring an autonomous coordination process**, allowing that a production process of a particular product to be coordinated intelligently, where the machines involved in the process, are able to make decisions aimed to improve the efficiency while improving the productivity of the company, among others.

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Autonomic Cycle for Coordination in Industry 4.0 (ACCI40)

- **Build the coordination plan:** This set of tasks, are responsible for obtaining the necessary information in order to allow the creation of a coordination plan adjusted to the objectives and coordination needs in the current context, taking into account the availability of the entities, the execution time of their tasks, among other things, in such a way that all the elements can be perfectly synchronized and avoid, in this way, delays in the production process

- **Supervise the coordination process:** In this case, the tasks are oriented to supervise the coordination process, in such a way we can detect failures and ensure that the plan is being executed properly. .

- **Reconfigure the coordination plan:** In this third autonomic cycle, the tasks are responsible for reconfiguring the coordination plan, when a failure or issue is detected in the supervision cycle.

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ACCI40 1

Build the coordination plan

Step 1: Observation and Analytics

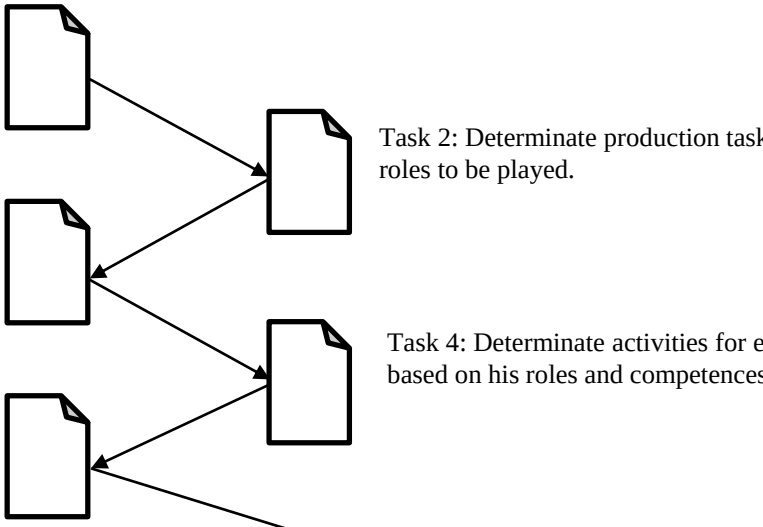
Task 1: Determinate the objectives of the coordination process.

Task 2: Determinate production task and roles to be played.

Task 3: Determinate actors able to participate in the process.

Task 4: Determinate activities for each actor, based on his roles and competences.

Task 5: Determinate technological aspect that must be accomplished.



Step 2: Decision Making

Task 6: Design the coordination plan.

Coordination Process

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Task Name	Everything Mining Technique	Data Source
Determinate the objectives of the coordination process	Process Mining, Data Mining	Bpel Organization BD
Determinate production task and roles to be played	Process Mining	Bpel
Determinate actors able to participate in the process	Things Mining, People Mining, Service Mining, Data Mining	UPnP Services Bpel Social network SOA platform Organization BD
Determinate activities for each actor, based on his roles and competences	Things Mining, People Mining, Service Mining	UPnP Services Bpel Social network SOA platform
Determinate technical aspect that must be accomplished	Data Mining, Service Mining	Organization BD SOA platform
Design the coordination plan	Data Mining	Previous Results

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Integration Level	Question	Everything Mining Technique	Data Source	Technologique Tools	Benchmark
Coordination (build the plan) (modelo prescriptivo)	1. Which are the objectives of the coordination process?	Process Mining, Data Mining	Bpel Organization BD	ProM, Disco, R, Weka, Python, Rapid Miner	
	1. What I need to do (roles, tasks, etc.)?	Process Mining	Bpel	ProM, Disco	
	1. Which actors are able to participate in the process?	Things Mining, People Mining*, Service Mining, Data Mining	UPnP Services Bpel Social network SOA platform Organization BD	ProM, Disco, R, Weka, Python, Rapid Miner	
	1. Which actor is going to execute each activity in the process? (it is an assignment and must be defined criteria)	Things Mining, People Mining, Service Mining	UPnP Services Bpel Social network SOA platform	ProM, Disco, R, Weka, Python, Rapid Miner	
	1. Which technological aspects must be used in the coordination process?	Data Mining, Service Mining	Organization BD SOA platform	ProM, Disco, R, Weka, Python, Rapid Miner	