International Master in Industrial Management

Industry 4.0

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POLITECNICO DI MILANO
GRADUATE SCHOOL
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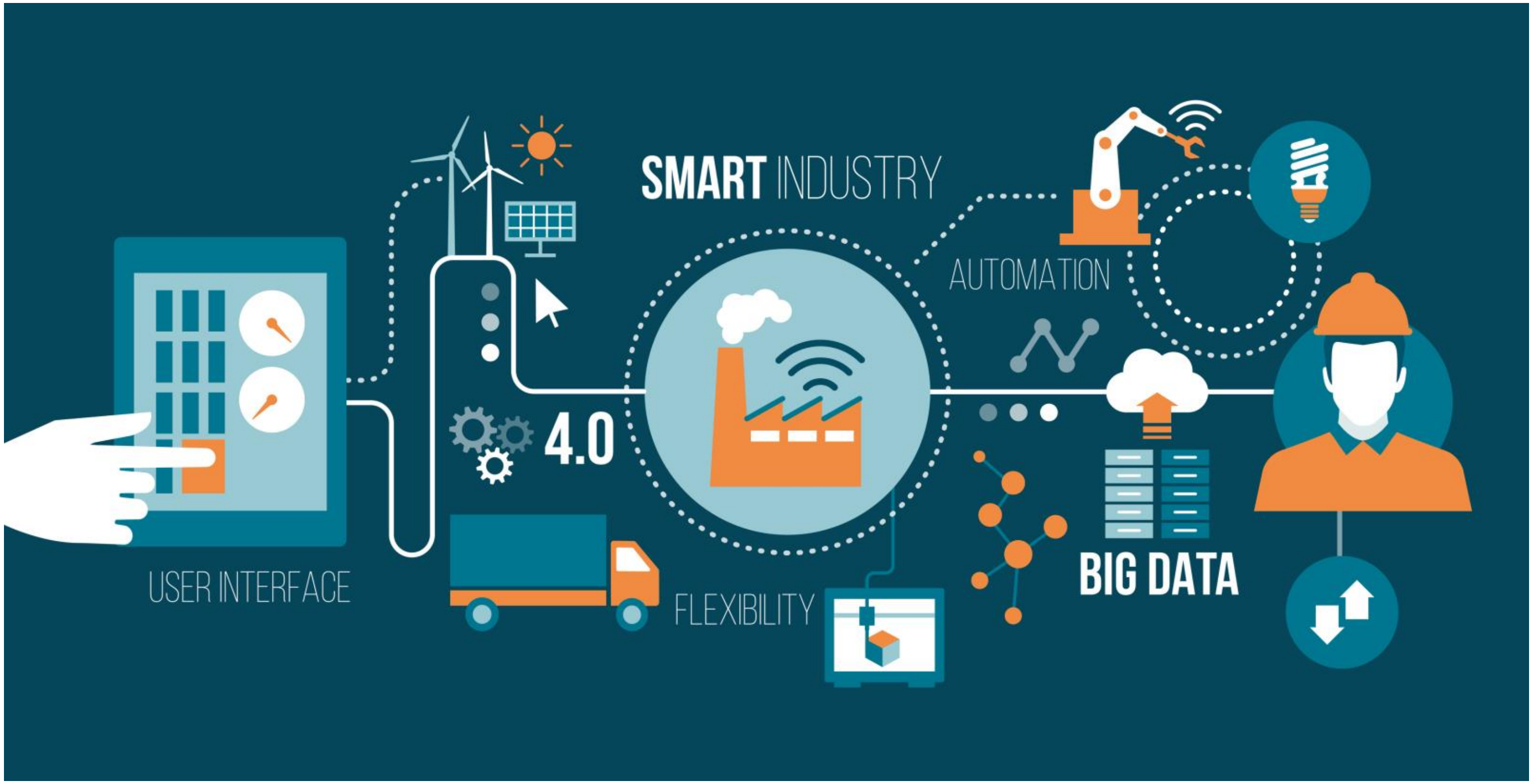
Agenda

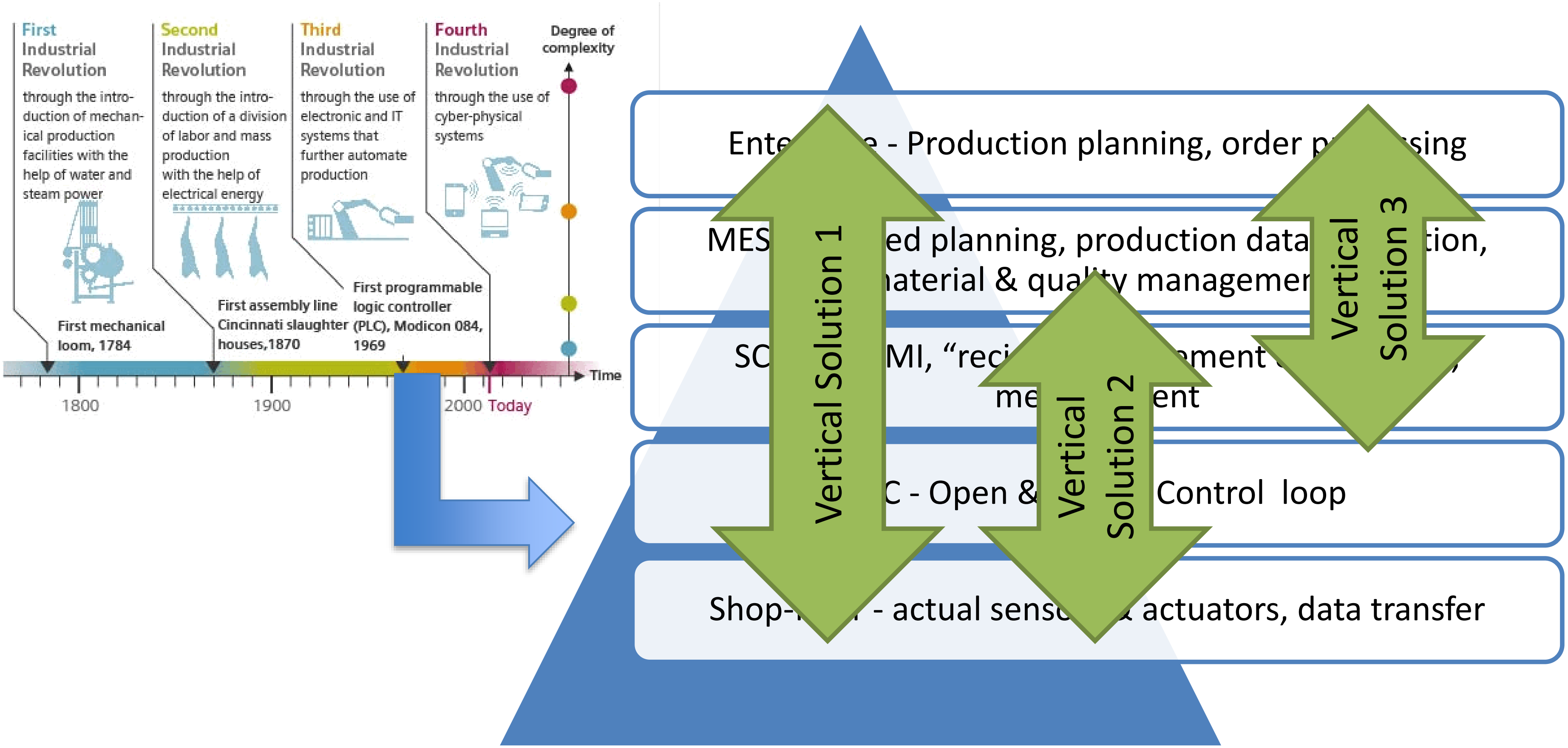
- Historical perspective and trends
- Smart Manufacturing (SM)
    - SM Technology Enablers
    - SM Technologies
    - Cyber Physical Systems CPS

Industry 4.0 paradigm



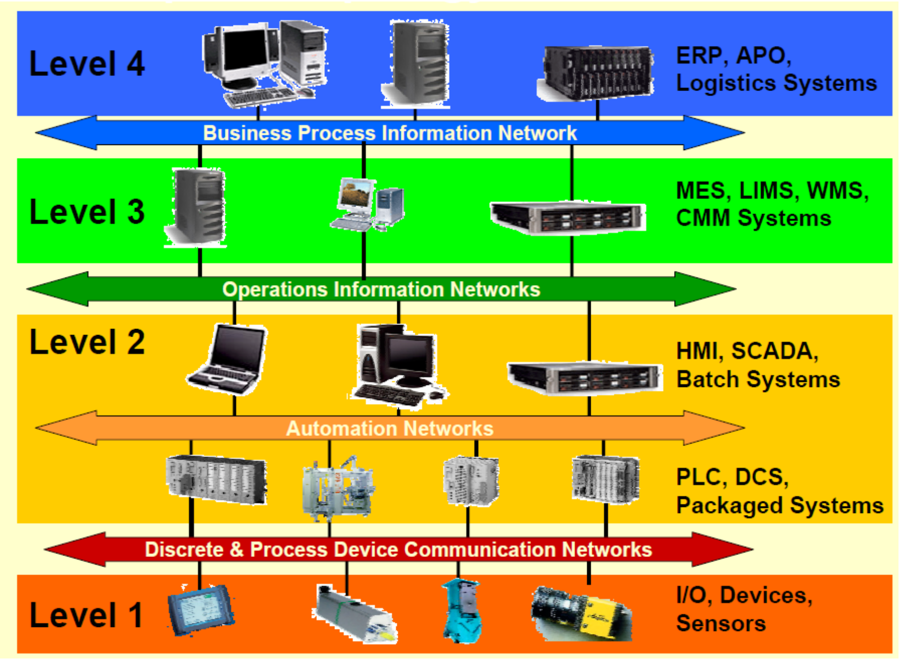
Historical Perspective and Trends

CIM Model

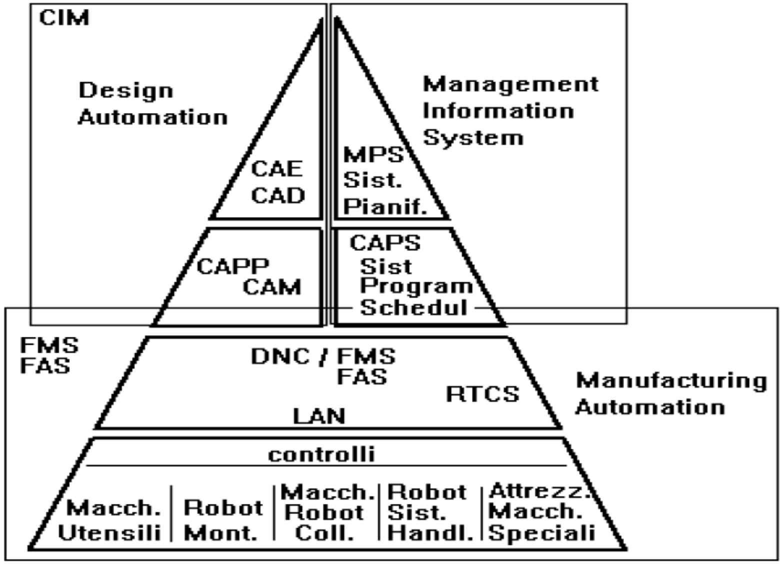


Multilayered, hierarchical, functional oriented

CIM Model

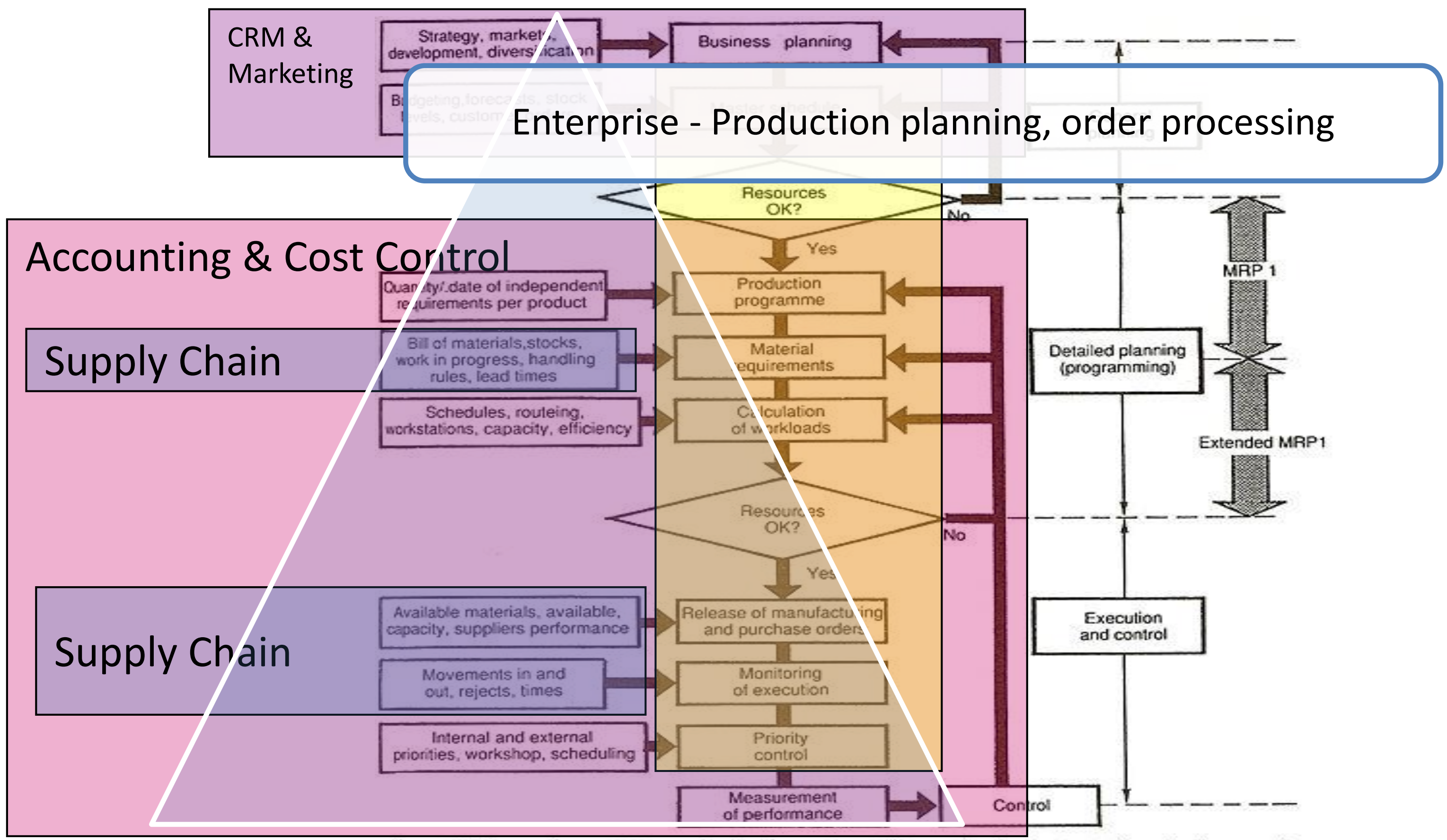


ISA 95 model



ISO model

ERP Model



Around 1980, over-frequent changes in sales forecasts, entailing continual reajustments in production, as well as the unsuitability of the parameters fixed buy the system, led MRP (Material Requirement Planning) to evolve into a new concept : Manufacturating Resource Planning or MRP2

Source : "CIM: Principles of Computer Integrated Manufacturing", Jean-Baptiste Waldner, John Wiley & Sons, 1992. Reproduced with author's authorization

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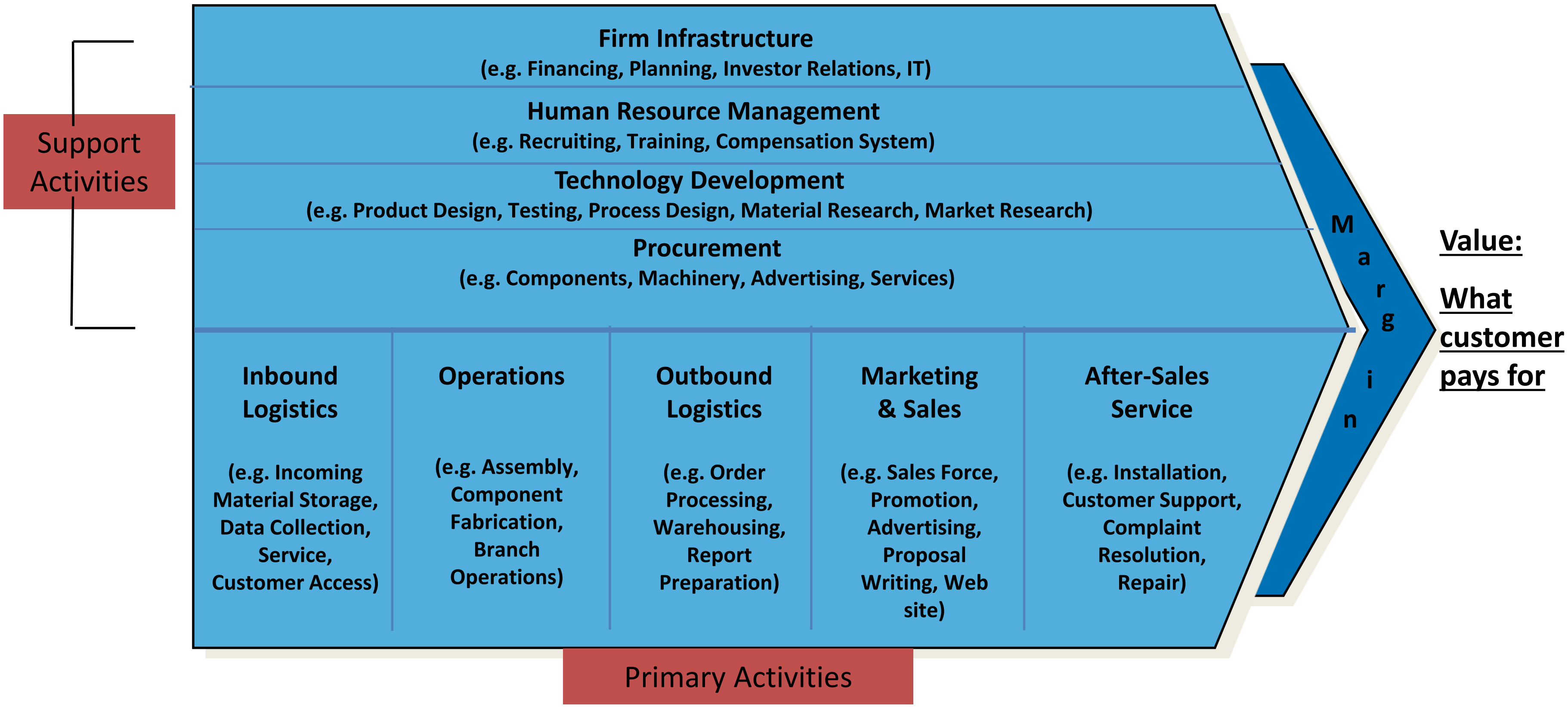
Production Management Systems Evolution

- MRP I Materials Requirements Planning (1965-1980)
  - PP Production Planning
  - INV Inventory Control
  - MTS/MTO Make-to-stock/ Make-to-order (discrete production)
- MRP Il Manufacturing Resources Planning (1980-1990)
  - MPS Master Production Schedule
  - CRP Capacity Requirements Planning
- ERP Enterprise Resource Planning (1990-2000)
  - FIN Global Finance
  - HRM Local Human Resource Management
  - SD Multi Sales & Distribution
- Extended ERP — ERP II (2000-)
  - Data warehouse
  - Supply chain Management
  - E-business

Fully integrated company



Source: M. Porter

European IT Forum 2001

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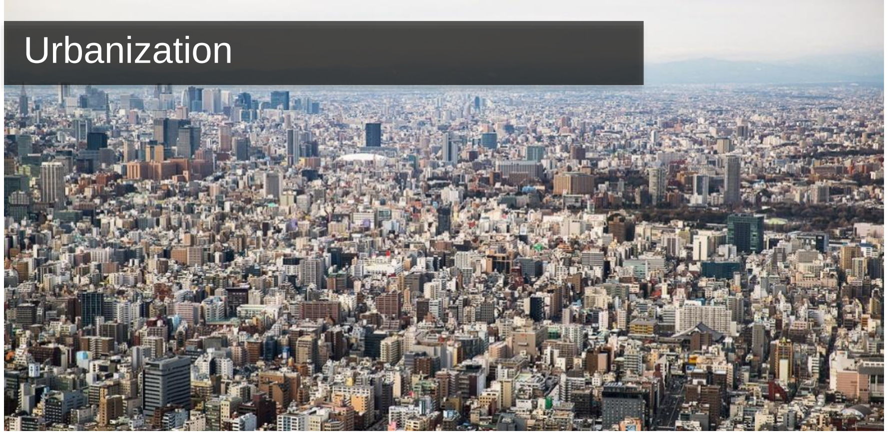
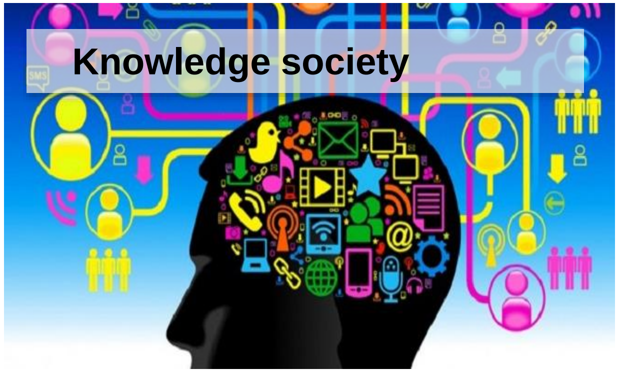
Socio-enviromental Megatrends

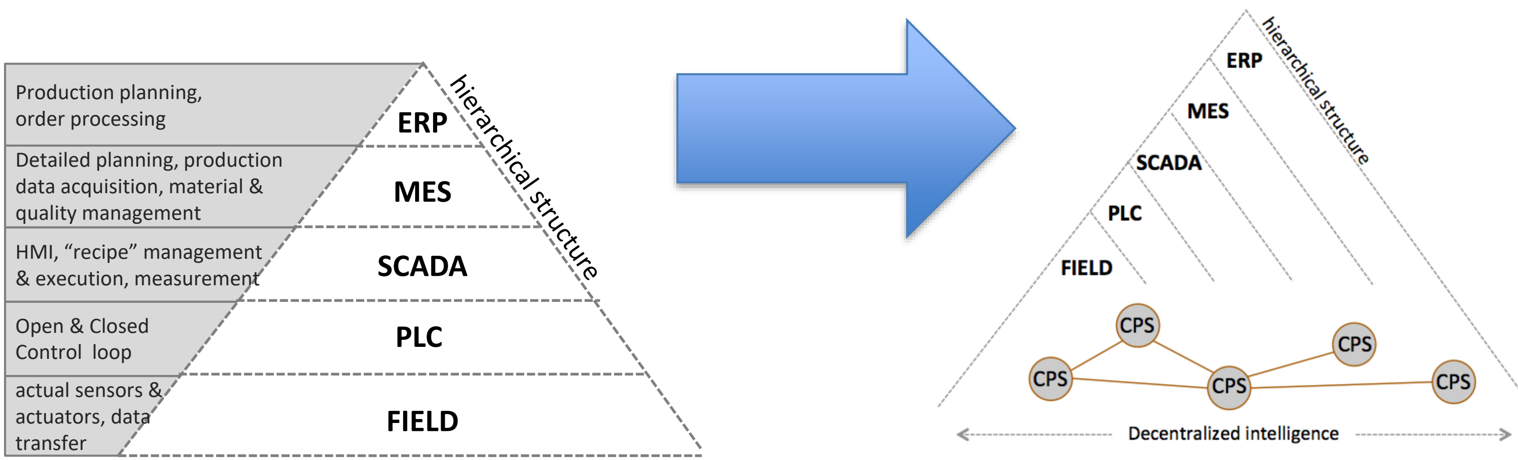


Economical Political Megatrends



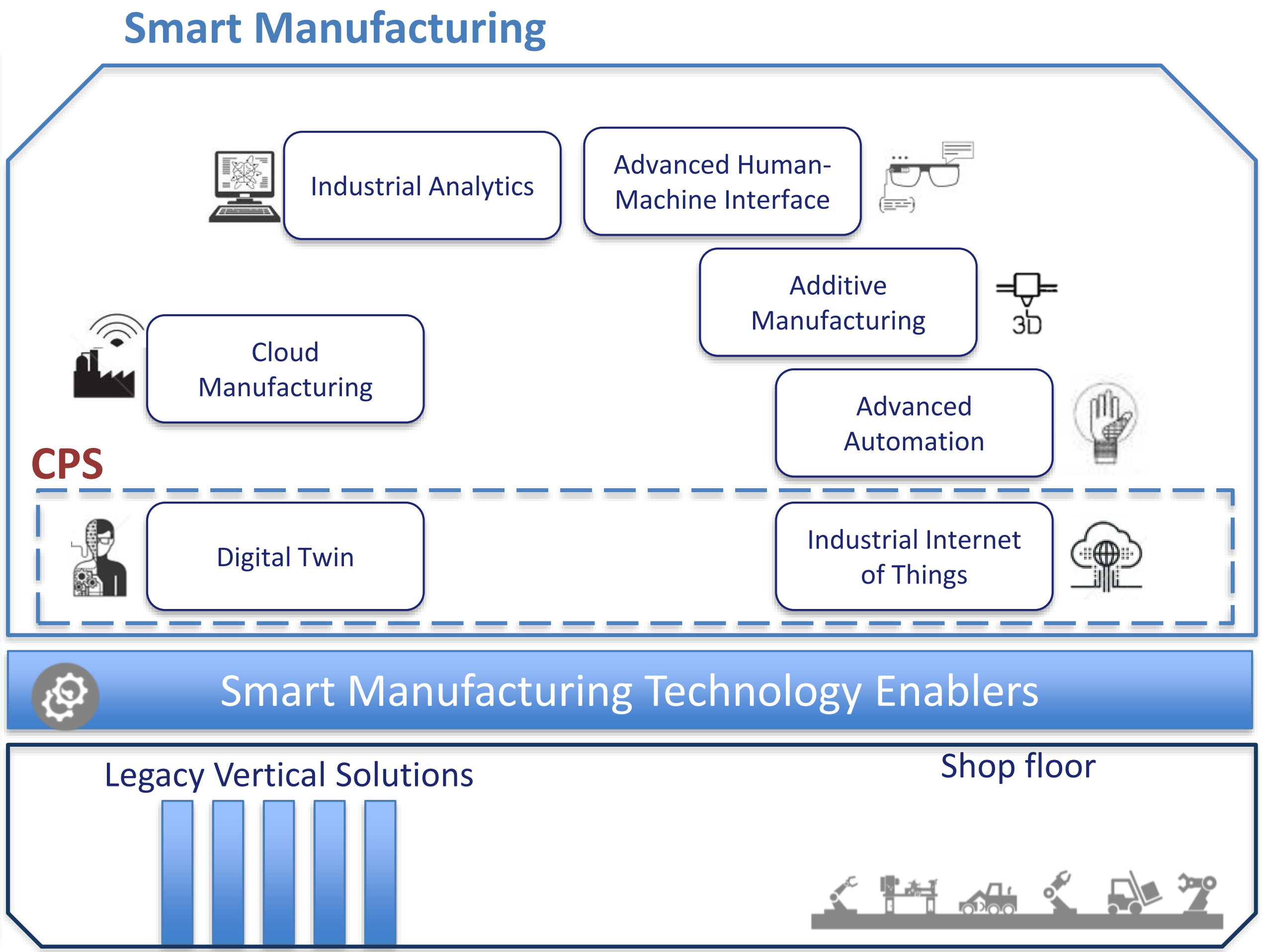
CPS paradigm shift

- The Automation pyramid concept, traditionally used to describe the different system levels of an overall automation solution, needs to evolve.
- CPS overcome the concept of rigid hierarchical levels, being each CPS capable of complex functions across all layers.



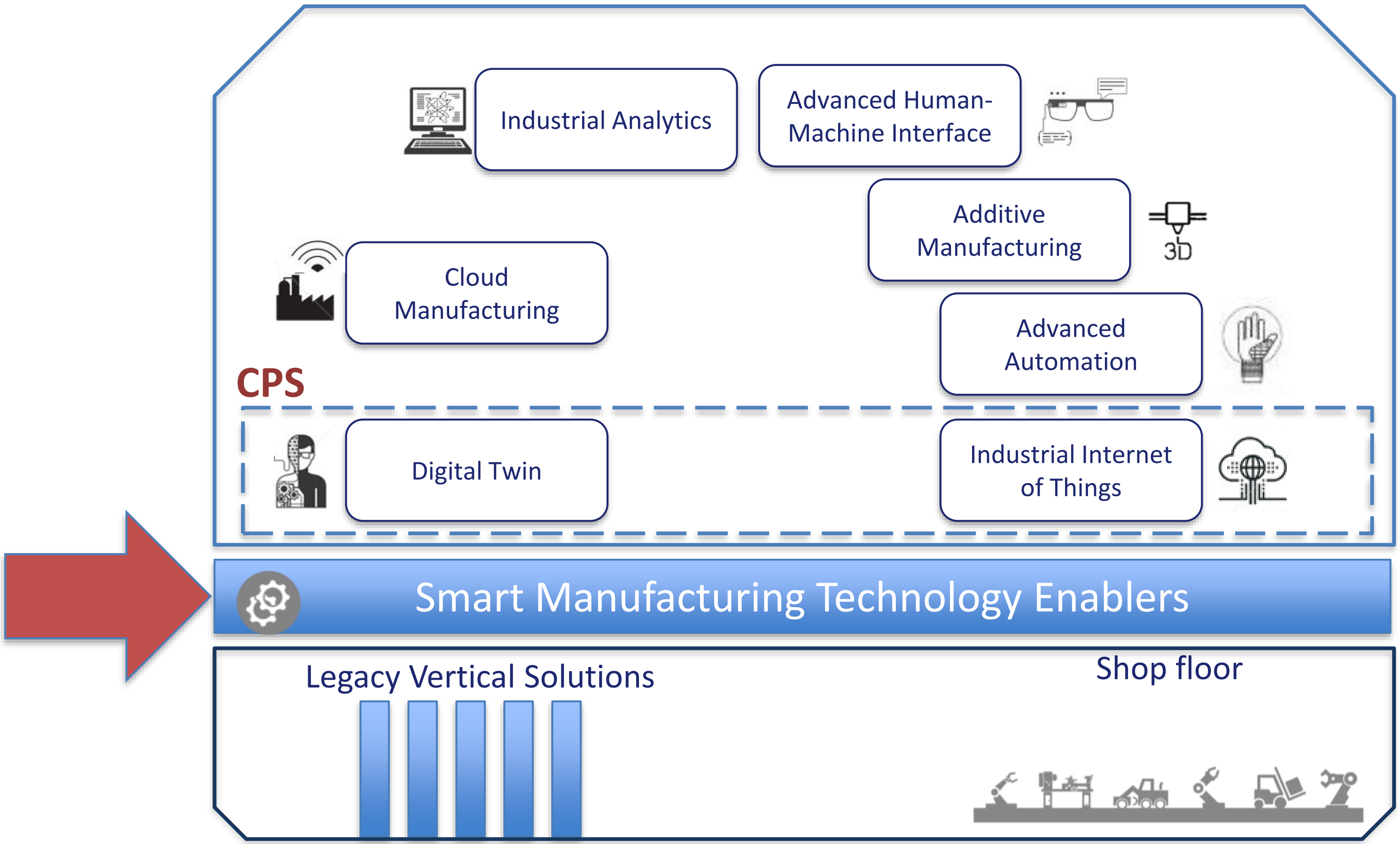
Towards Smart Manufacturing

The term «Smart Manufacturing» refers to a future vision enabled by digital technologies where industrial and manufacturing companies will improve their competitiveness thanks to a better integration of their assets (machines, workers, information) both inside the factory and along the whole value chain.



Smart Manufacturing Technology Enablers

Towards Smart Manufacturing

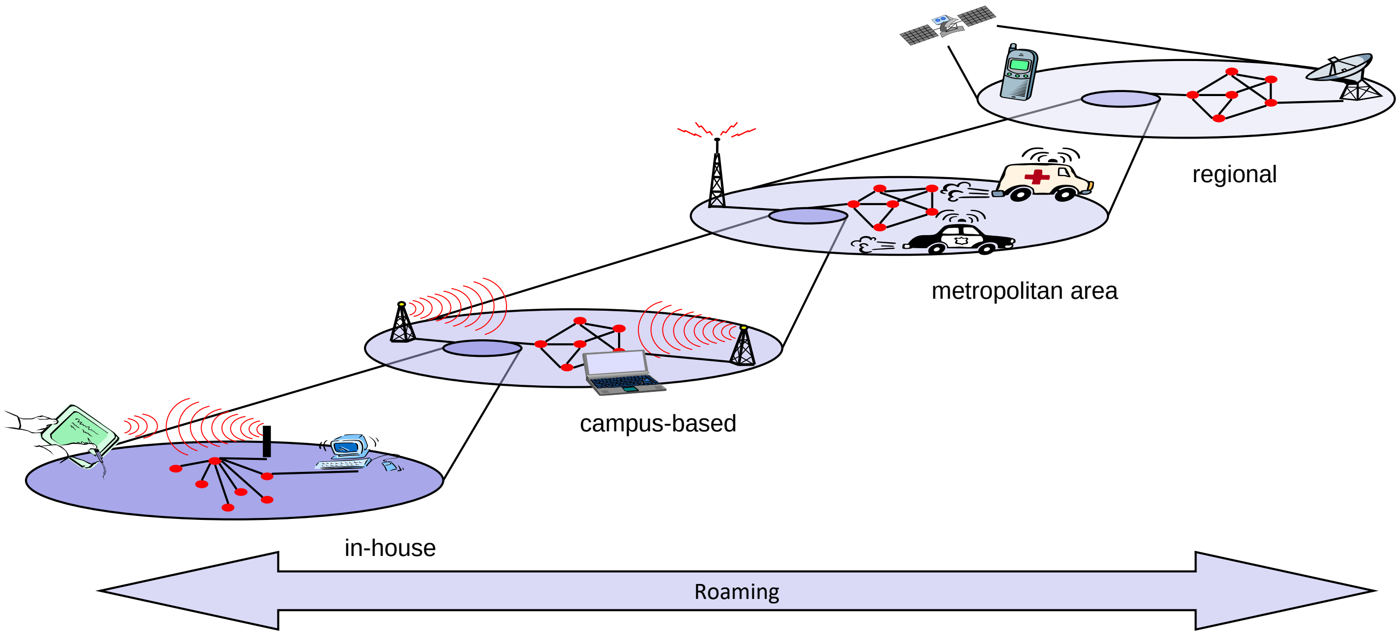


New technology trends– Mobile & Wireless

- It is connected to the Mobile & Wireless technologies, including those related to:
  - Cellular networks (GSM, GPRS, UMTS, etc..)
  - Networking Bluetooth, Wi-Fi, WiMax, ...
  - Positioning Systems
- Differ in extent of coverage and communication speed

Areas of use of wireless technology

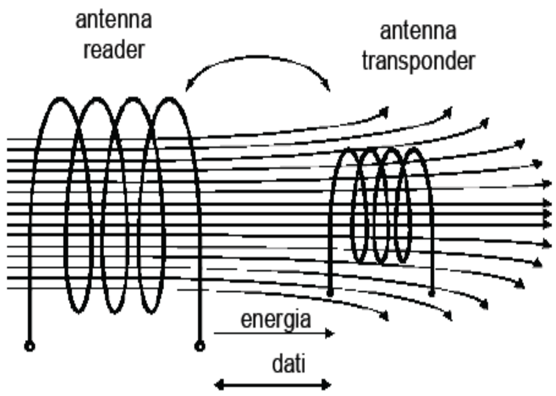
The radius of coverage is a fundamental dimension

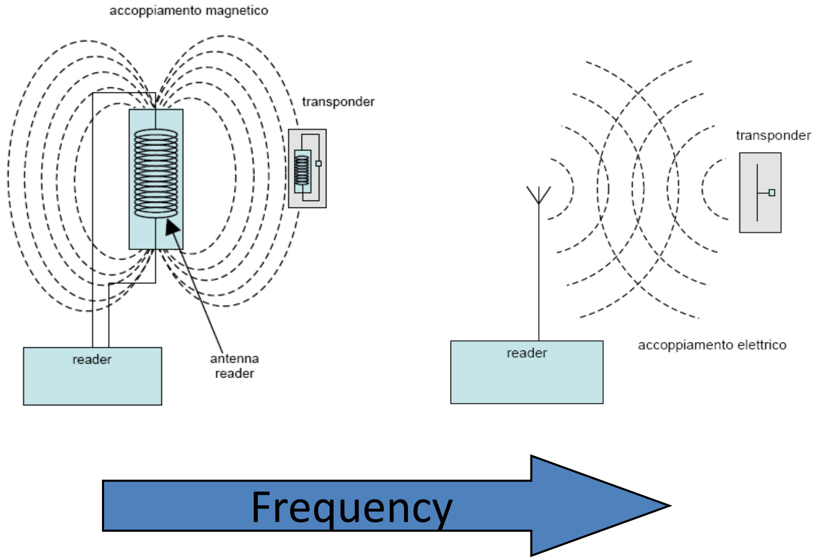


- Different technologies respond effectively to the different requirements (distance, mobility, channel characteristics, ...):
- It requires a transparent interaction between the different network segments using disparate solutions and technologies

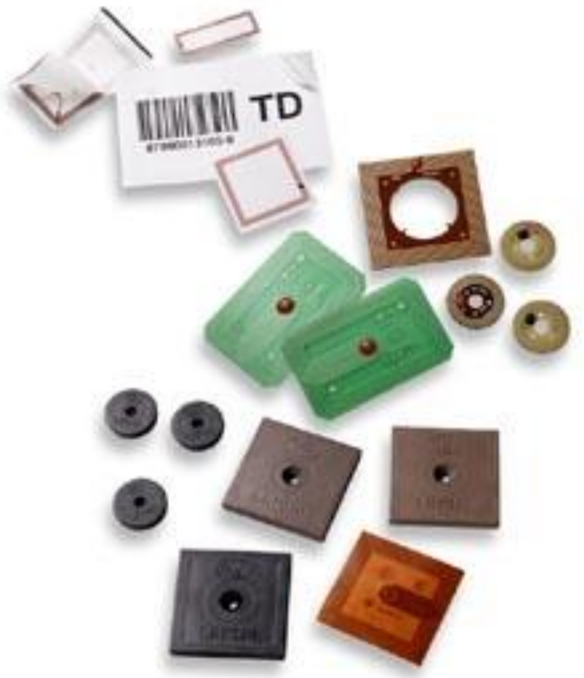
The new technological trends RFID Technology

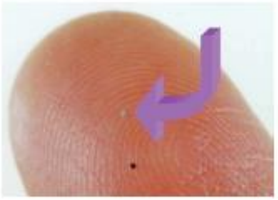
- Electro-Magnetic coupling
- The reader emits an electromagnetic field on which is coupled a transponder
- Fields in low frequency can pass through liquids and thus be suitable in some types of industrial applications
- In high frequency fields are suitable for payment applications as they work well at short range
- Fields in very high frequencies are used for logistics, sensing over long distances and high speeds.

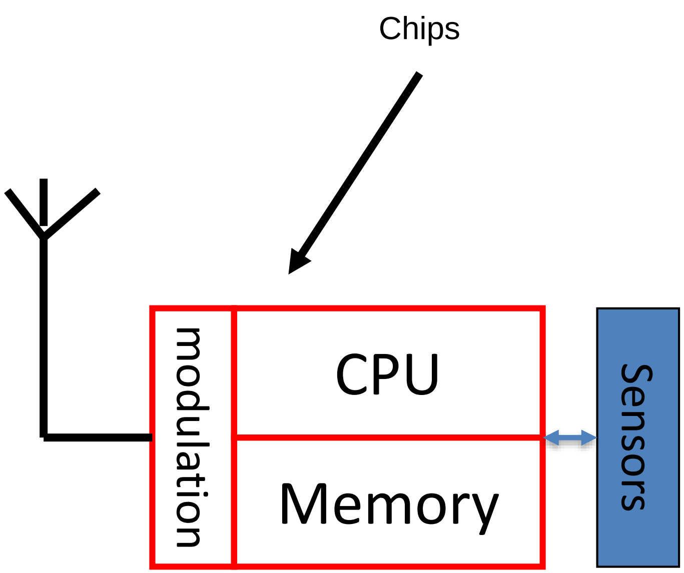




RFID Technology







RFID Technology
Radio Frequency Identification

- The RFID TAGs (smart tags, smart labels, transponders, e-tags ...) are basically memories equipped with a transmitter-receiver device.
  They are composed of 4 elements:

  – **Chip**: a memory that contains the information related to the physical object on which is applied

  – **Antenna**: receives and transmits information, it collects energy from the electromagnetic field

  – **Capacitor**: It is loaded by the reader and then work as a battery

  – **Packaging**: contains and protects the chip and antenna

Fonte Innovation Center

RFID-NFC

- The protocol is based on a wireless interface. There are always two parties to the communication; hence the protocol is also known as peer-to-peer communication protocol. The protocol establishes wireless network connections between network appliances and consumer electronics devices.
- The interfaces operate in the unregulated RF band of 13.56 MHz. This means that no restrictions are applied and no licenses are required for the use of NFC devices in this RF band.
- Operating distances of <20 cm.
- The communication is half-duplex. The devices implement the “listen before talk” policy – any device must first listen on the carrier and start transmitting a signal only if no other device can be detected transmitting.

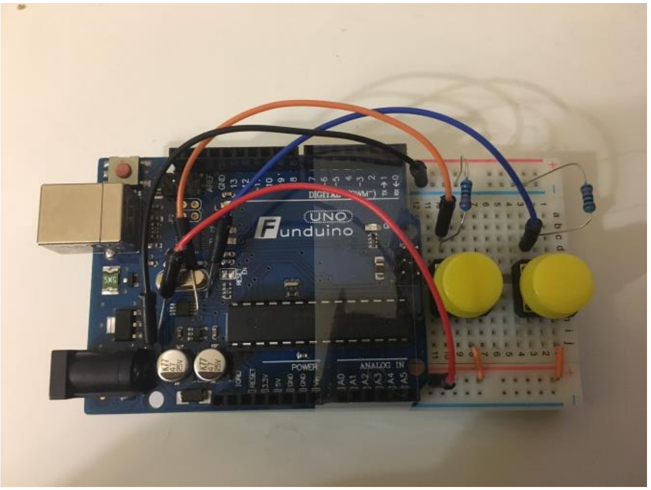
RFID-NFC

- In the Active mode communication both devices generate their own RF field to carry the data.
- In the Passive mode communication only one device generates the RF field while the other device uses load modulation to transfer the data. The protocol specifies that the Initiator is the device responsible to generate the RF field.
- Three operational modes:
  - Card Emulator
  - Peer-to-peer
  - Reader mode

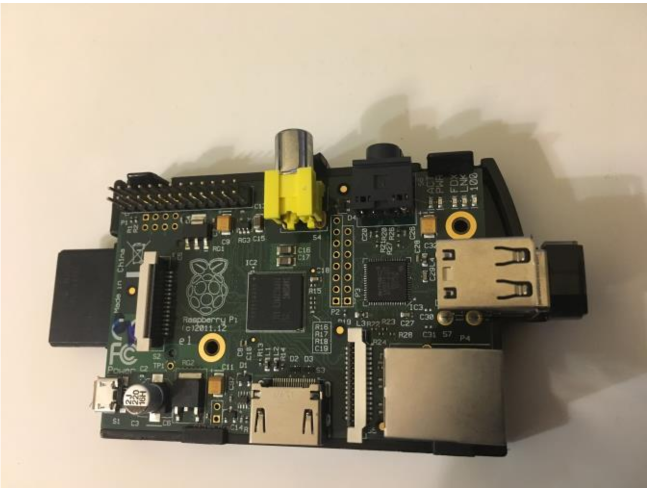
Other Technologies

- Carbon nano-tube ink patterns with special electric properties
- Electric field reader can read the pattern
- Characteristic:
  - Invisible
  - Can be covered with color paint
  - Identification (just like BarCode or RFID)
  - Anti-contrafaction applications

Micro Controllers



Arduino Card



Raspberry Pi Card

RFID The potential benefits

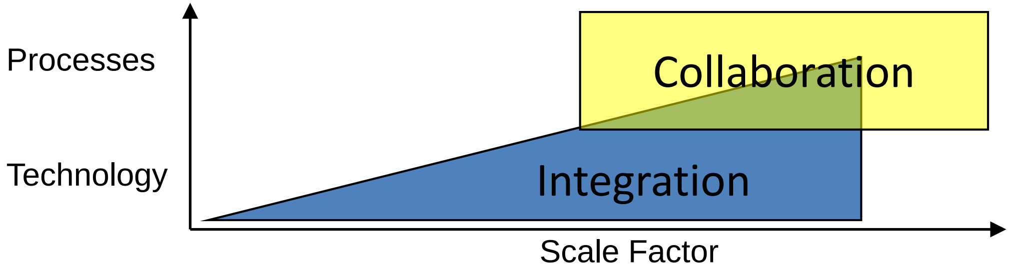
Maximize Company objectives

Business Objectives	**Increase revenues**	**Operating Costs Reduction**	**Optimize assets utilization**	**Improve security And quality**
Benefits From RFID adoption	Increased availability on the shelf Improved level of service: •Reduction times of supply •Automatic replenishment •Increased collaboration Customer loyalty ...	•Elimination of physical manual count •Increase efficiency and accuracy of operations for the receipt / dispatch •Faster warehouse operations •Improvement in the visibility and traceability of the stock •Reduce obsolescence phenomenon •...	•Reducing the average level of stocks •Improve the accuracy of forecasts •Better visibility •Reduction of warehouse space Improving productivity through JIT deliveries and information sharing...	•Reduce theft •Reduce Contrafaction •Better management of any product recalls and food safety •Increased control over the chain of disposal ...

Integration, Collaboration and Interoperability

Integration and Collaboration

- *Includes technologies and applications:*
  - *Integration*
  - *Collaboration*
    - *Internal (between the different components of the Company)*
    - *External (between the company and its industry partners, customers and in particular suppliers).*



Integration

1. Portal integration: with the goal to "access" Web functionality already present in the company, integrating into a single web interface for presentation, more or less homogeneous, of the use of different functional areas.
2. Data integration: Intranet assume the role of connective tissue that allows to "consolidate" the data managed by different information systems, through the use of infrastructure integration tools that address specific needs.
3. Application integration: Intranet and IT Systems interact with each other at application level for managing data streams in a coordinated manner, through the use of advanced tools for integration with a high level of sharing.
4. Process Integration : coordination of information systems and Intranet is implemented in a configurable and flexible way , allowing to "orchestrate" the support they give to business processes with the implementation of flexible and efficient process workflows.
5. Configurable integration: this level of integration enables, through the application of SOA (Service Oriented Architecture) – or similar technologies - approaches and logics of Business Process Management (BPM) to "reconfigure the processes" with the support of technology.

Intra company collaboration

- **Employee Service space**: provides to people services in support of working life, such as HR service desk and services for the facilities management
- **Internal Communication space**: provides the means of communication (formal or informal) and socialization
- **Business Community space**: it provides access to corporate knowledge and collaboration
- **Operational Work space**: it gives tools and services (informational or transactional) useful to the conduct of typical activities of his job

Collaboration - Around the company

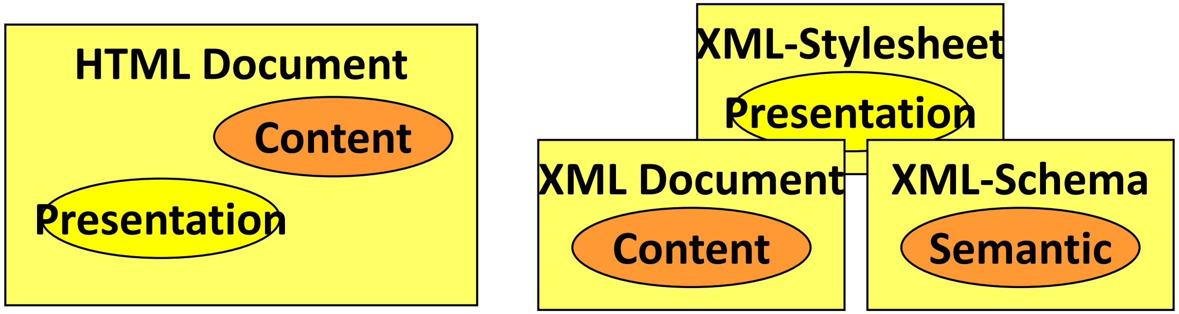
- eCommerce b2b Applications and services that allow to sell their services online, through catalog sales or auctions
- eProcurement
  - eSourcing Finding new suppliers and their qualification and certification
  - eCatalog purchase recursive process, Web-based catalog
- eSupply Chain
  - eSupply Chain Execution: activities to support the integrated management of order-delivery –billing cycle (including the logistics and administrative and accounting
  - eSupply Chain Collaboration: collaborative activities between customer and supplier, in terms of production planning and supply, development of new products, etc.. (for example, Collaborative Planning, Forecasting and Replenishment and Vendor Managed Inventory)
- ePLM applications and processes that enable the shared management of data relating to products and services along the complete life cycle of the same (from the Concept to Dismissing)

New technology trends
Service Oriented Architectures

- *New architectures and technological infrastructure:*
  - *Server virtualization*
  - *Business Process Management (BPM) Systems*
  - *Service Oriented architectures (Web Services and SOA)*
  - *Event Stream Processing (ESP)*
  - *Real-Time Infrastructure (RTI) and Cloud*
- *As special aspect of this trend is worth of particular attention: open-source*

HTML vs XML

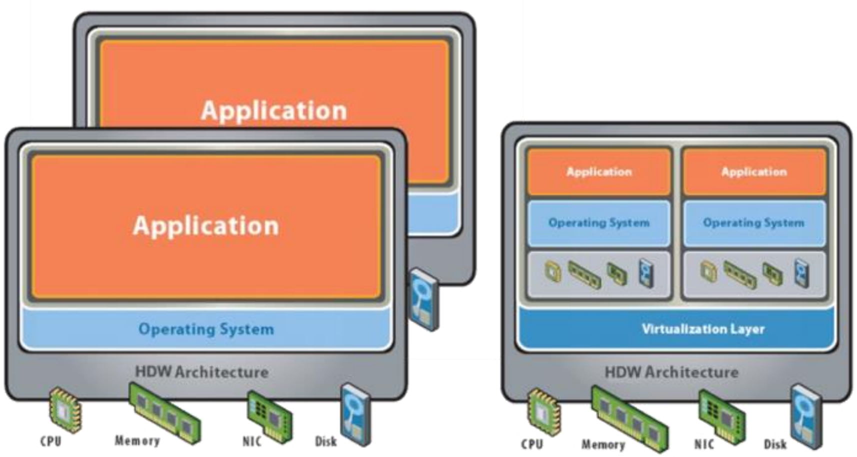
- Both XML and HTML contain markup symbols to describe the contents of a page or file
- HTML describes the contents of a Web page in terms of how it should be displayed and how the interaction should be done
- With XML the content is separated from presentation and interaction aspects, that delegates to the templates or style sheets XSL (eXtensible Stylesheet Language)
- XML describes the semantic content, using a special set of markers described in a DTD (Document Type Definition) or an XMLSchema
- XML is extensible because the markers are unlimited and self-defined



Server Virtualization

Before Virtualization:

- Single OS image per machine
- Software and hardware tightly coupled
- Running multiple applications on same machine often creates conflict
- Underutilized resources
- Inflexible and costly infrastructure



Advantages:

1. Decrease TOC
2. Management
3. Business Continuity & Security
4. Energy and Space savings

After Virtualization:

- Hardware-independence of operating system and applications
- Virtual machines can be provisioned to any system
- Can manage OS and application as a single unit by encapsulating them into virtual machines

BPMS

- The BPMS (Business Process Management System) are intended to provide organizational/operational flexibility required by context changes in which the company operates, as well to effect the daily optimization of operations of the enterprise.
- From the functional point of view, BPM systems consist of multiple software applications that operate in series:
  – Analytical tools, able to provide estimates on the characteristic parameters of the process, and enable the redesign, possibly with the help of graphical tools (typically Business Activity Monitoring and Business Process Modeling and Analysis product);
  – Workflow tools enabling automation of the process through the translation of new rules in routing tables (Workflow Automation);
  – Integration layer (Enterprise Application Integration) to ensure the information flow between heterogeneous systems.
- The BPMS, if integrated with business management and legacy applications, allows to change the flow of processes in accordance to what happens in the company, without being bound by the rigidity of the integrated information systems.

SOA

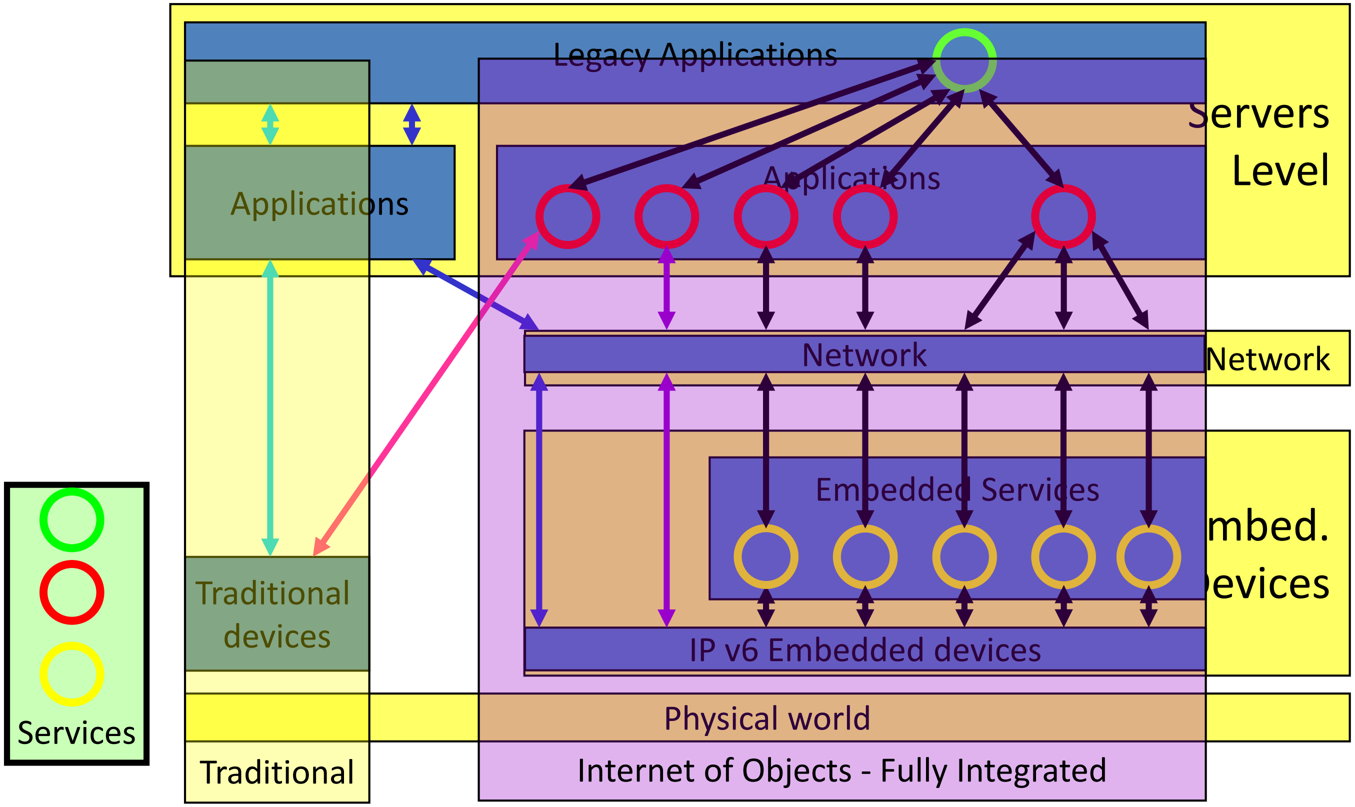
- The acronym SOA (Service Oriented Architecture) refers to a software architecture that transforms "monolithic" business objects to sets of services that provide functionality based on business needs.
- This is an evolution of the concept of middleware:
  - from the integration of applications of the single company
  - to the integration of internal and external services through extra-company networks.
- The adoption of an SOA architecture is particularly advantageous for companies with complex structures, both in terms of business processes (core) and support applications, being able to ensure the integration of various business silos (software applications written in different languages and implemented on different hardware platforms).

SOA

The main advantages of a SOA are:

- in the integration of IT assets: all pre-existing business applications can be reused and integrated into a SOA architecture type;
- in reducing the cost: after the initial launch costs, the IT spending decreases by reducing the implementation costs of the new features, their integration and maintenance;
- the reusability of services: a service may be used by multiple applications, both internal and external to the company;
- interoperability of different platforms: the presence of a standardization layer (typically done with web services) provides a common language of communication to the various information systems.

Embedded Devices & SOA

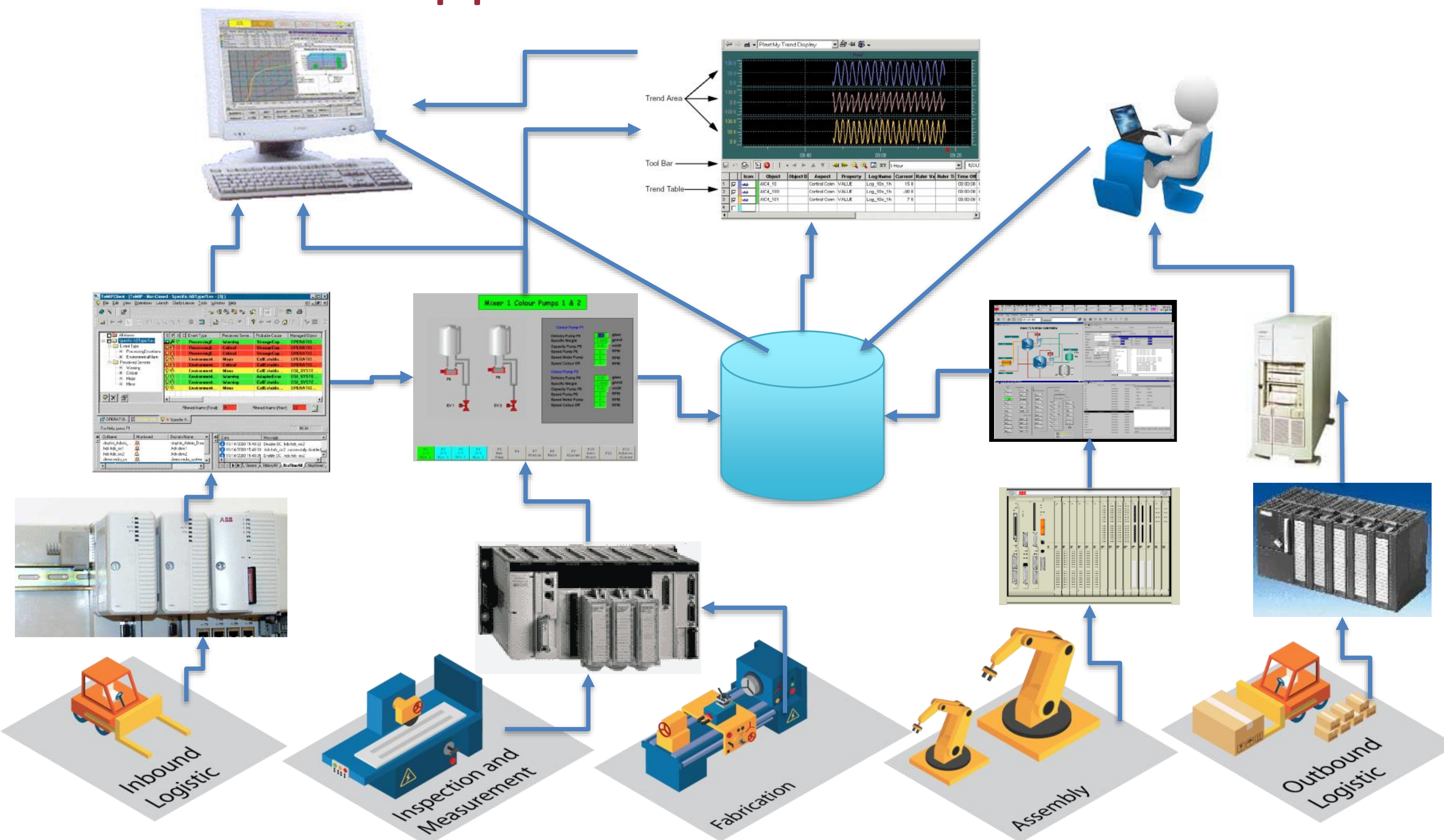


OPC UA

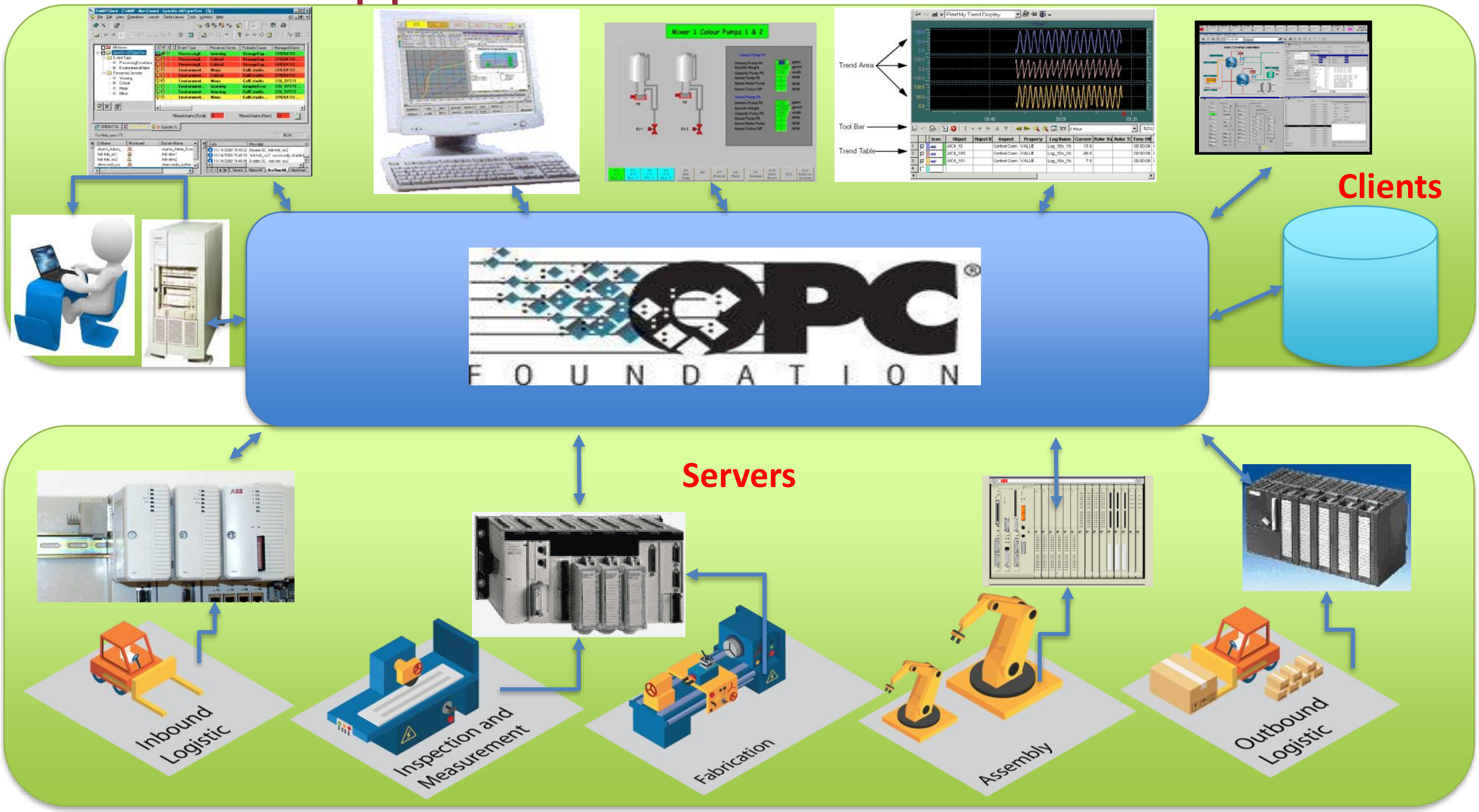
- OPC Unified Architecture (OPC-UA) is the data exchange standard for safe, reliable, manufacturer- and platform-independent industrial communication. It enables data exchange between products from different manufacturers and across operating systems. The OPC-UA standard is based on specifications that were developed in close cooperation between manufacturers, users, research institutes and consortia, in order to enable safe information ex- change in heterogeneous systems.

- OPC is popular in the industry and also becoming more popular in other markets like the Internet of Things (IoT). With the introduction of Service-Oriented-Architecture (SOA) in industrial automation systems in 2007, OPC-UA started to offer a scalable, platform-independent solution which combines the benefits of web services and integrated security with a consistent data model.
- OPC-UA is an IEC standard.

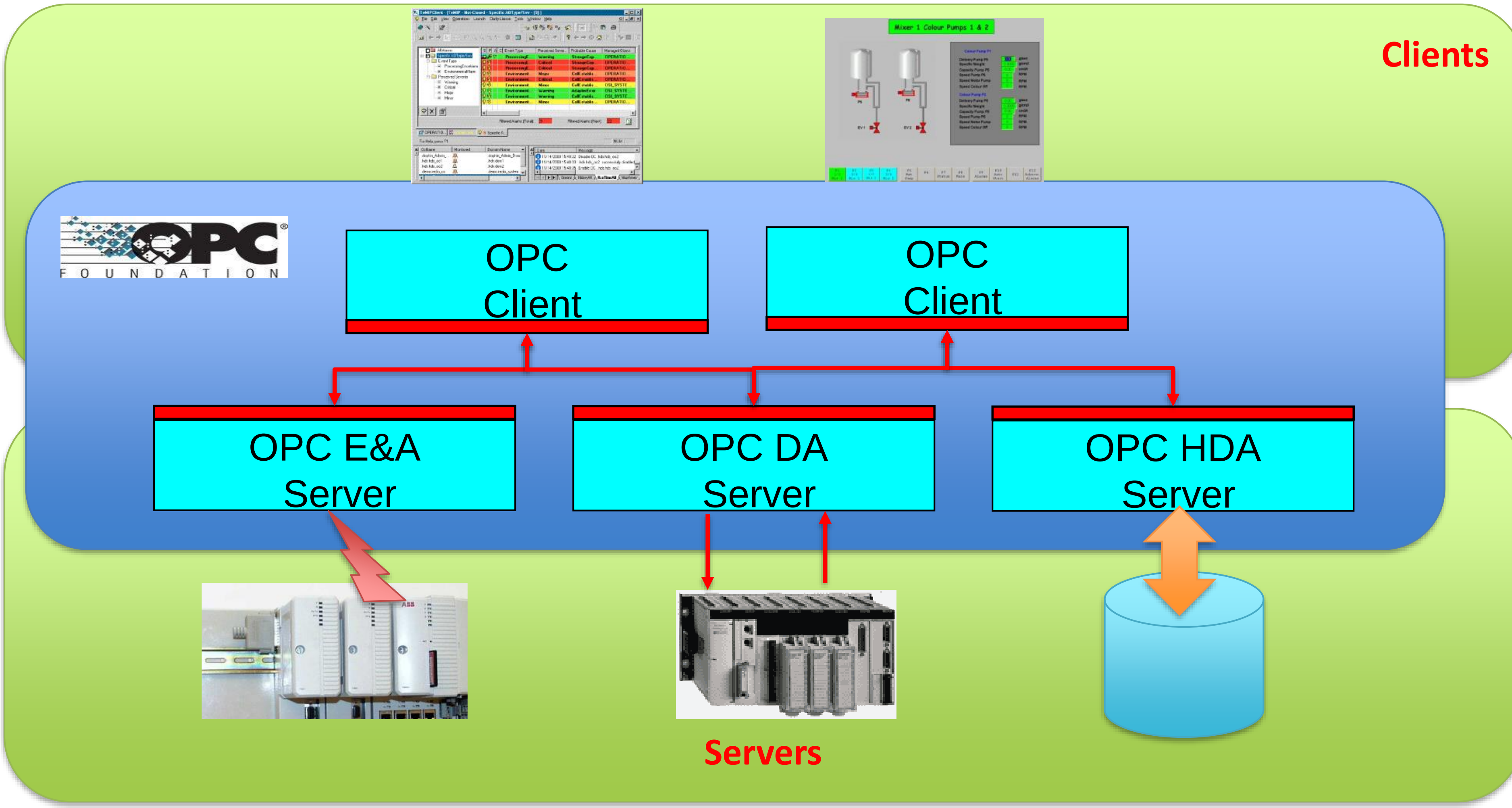
Factory Interoperability
Traditional Approach



Factory Interoperability
OPC UA Approach



OPC-UA Reference Architecture



OPC UA Characteristics

- Independent Platform For Information Exchange
- Vendor Independent
- Standardized Communication
- Service-oriented Architecture
- Semantic Annotation of Information
- Protection Against Unauthorized Access
- Reliable

www.opcfoundation.org

Automation ML (Automation Mark-up Language)

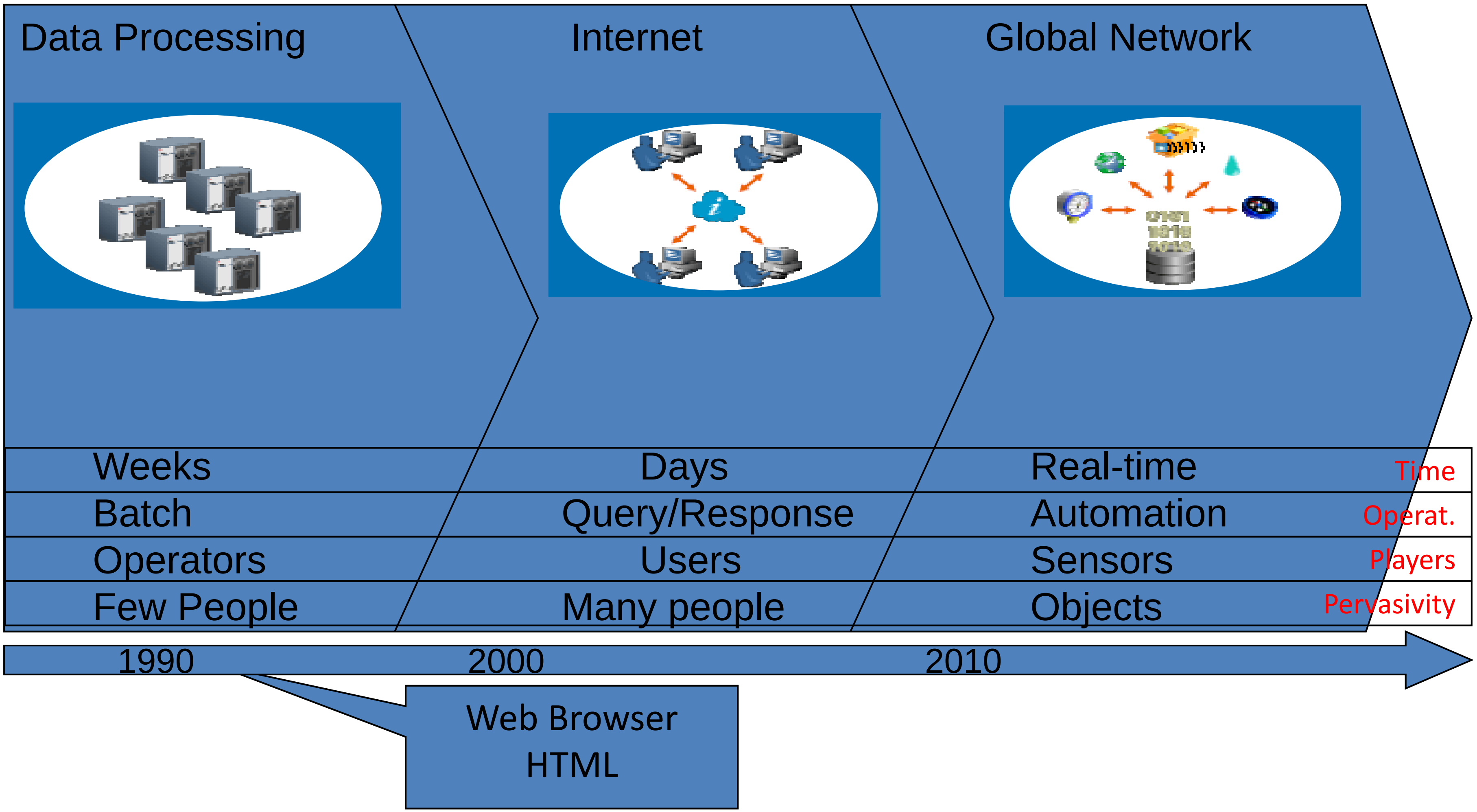
- AutomationML (Automation Mark-up Language) is developed in the field of production systems engineering and commissioning to optimize costs and efforts.
- The detailed **engineering phase** is related to the functional engineering of the production system Finally leading to a detailed engineering of all production system parts reflecting the factory hall layout restrictions. It covers the mechanical, electrical, piping , control, robot, and HMI engineering, the process replanning, and the virtual commissioning.
- The **commissioning and use phase** is related to the final set up of the production system at its intended location and its use for product production

Factory Interoperability
Automation ML and OPC UA

- A central idea of Industrie 4.0 is that objects involved in production comprehensibly describe their unique identity and their capabilities. If then new components, machines or equipment are brought into the production system or changes appear in production, the appropriate software modules can quickly and efficiently adjust the configuration of ICT systems.
- Self-configuration can be achieved by
- using Automation ML to describe the capabilities of components and machines and
- OPC-UA to enable them to communicate with each other

https://opcfoundation.org/wp-content/uploads/2016/05/OPC-UA-Interoperability-For-Industrie4-and-IoT-EN-v5.pdf

Evolution ICT features and horizons



Cloud Computing

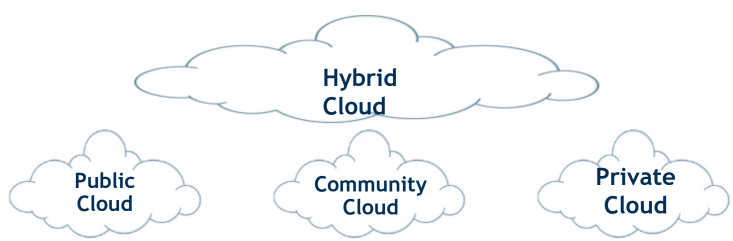
Definition and applications

Set of **on-demand self-service ICT services** made available through the Internet tecnologies and based on **shared resources**. These services are characterised by the rapid scalability of resources and the accurate evaluation of levels of performance, so that they can be used as **pay-per-use**.

Key characteristics

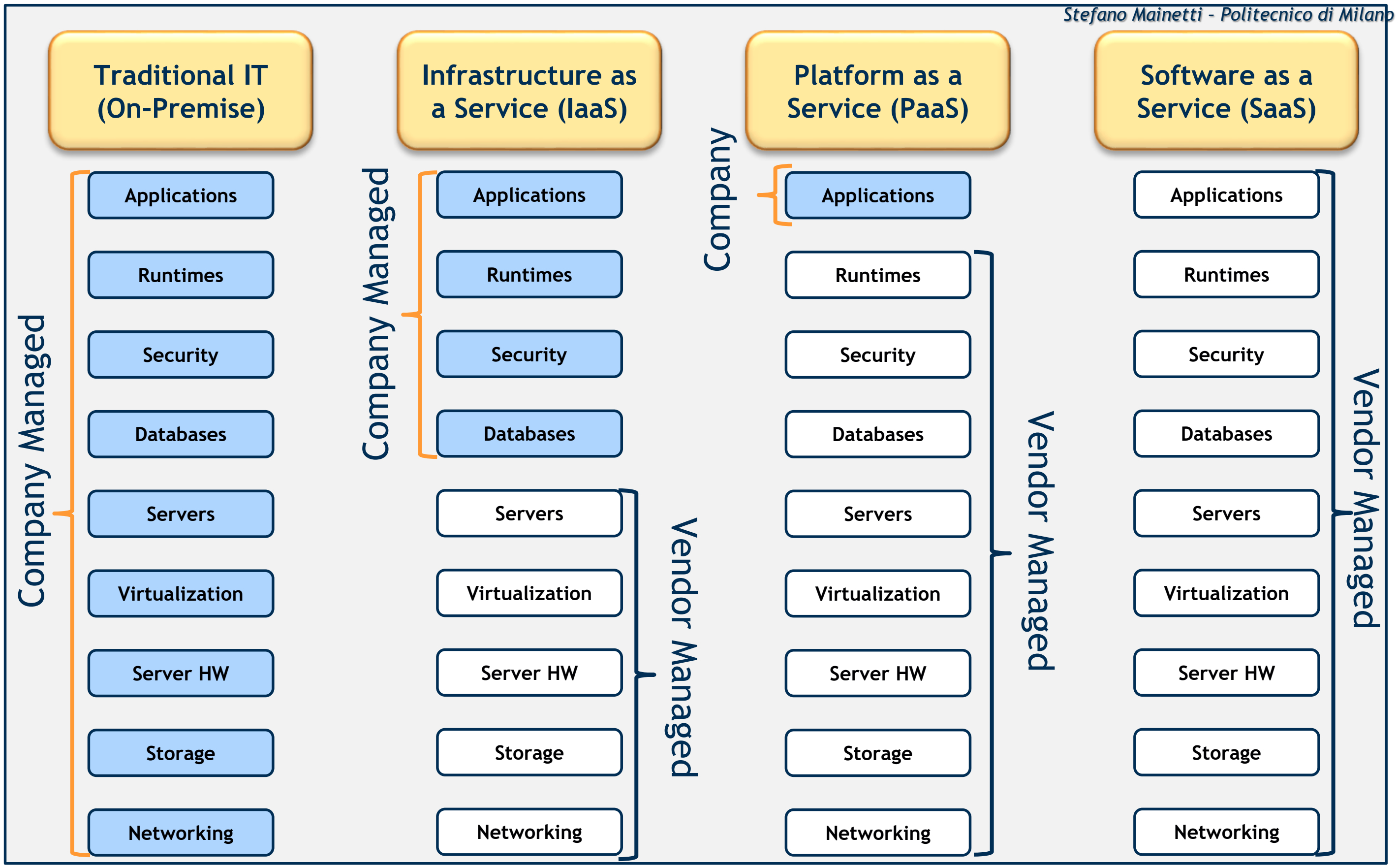
- Self-Service On Demand
- Ubiquous access to net
- Elasticity
- Shared virtual Resource
- Measurable Service - SLA

Sourcing models



Cloud Computing

Interpretation for manufacturing companies



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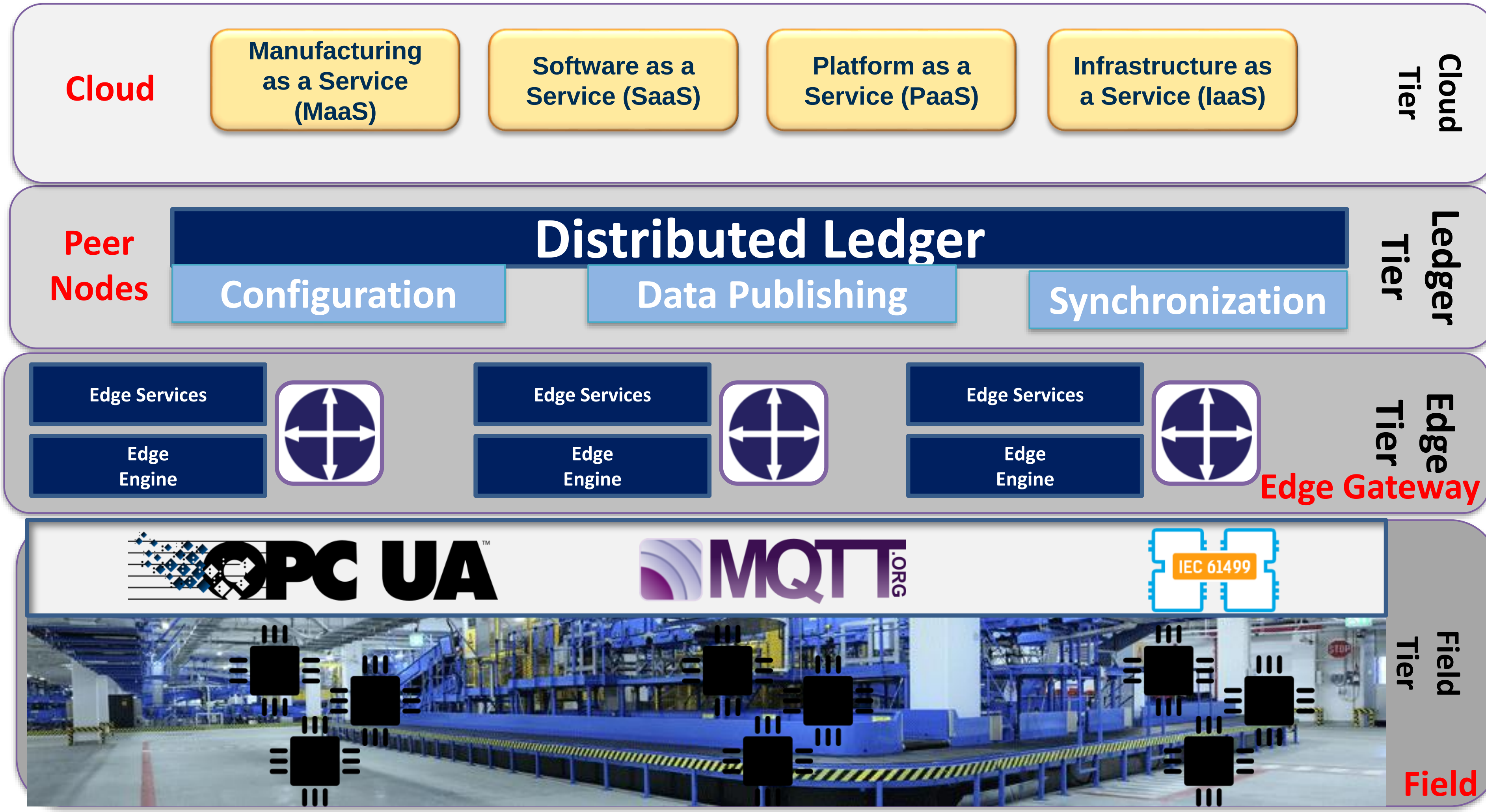
Cloud Computing

From Cloud Computing to Edge Computing

Edge Computing

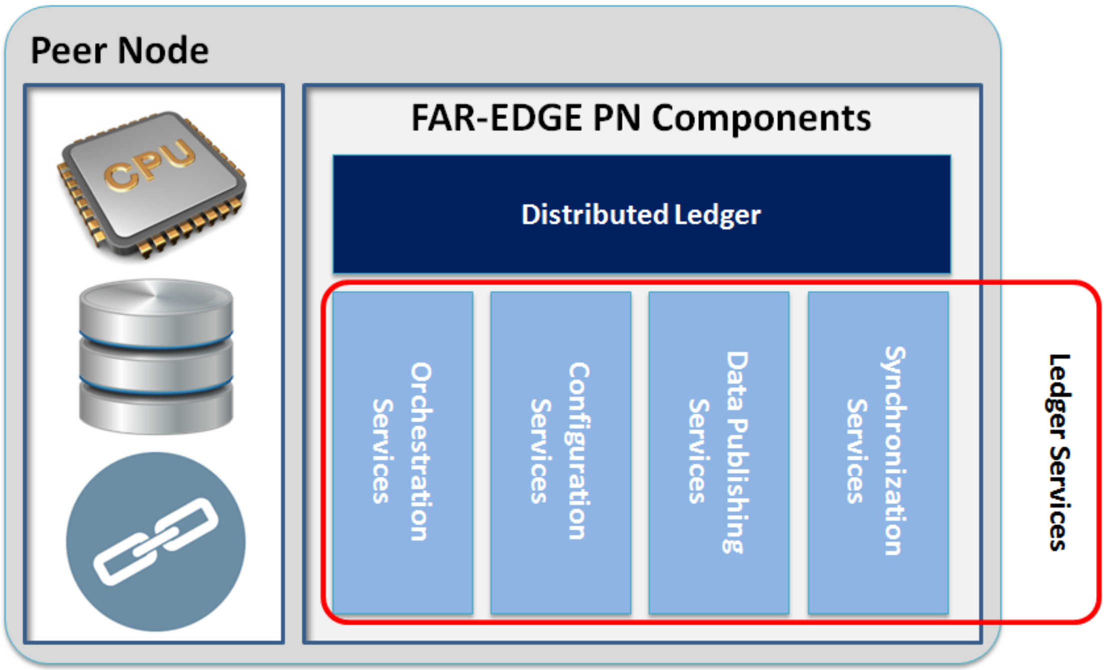


FAR-EDGE Project - http://far-edge.eu/

EDGE Platform: Peer Nodes

- The *Distributed Ledger* a *transactional ledger* that is *replicated on all PNs* and automatically *kept in-sync* across all instances, using *peer-to-peer communication* only.

- *Ledger Services* are implemented on top of the Distributed Ledger as *smart contracts.* They support Automation, Analytics and Simulation Services

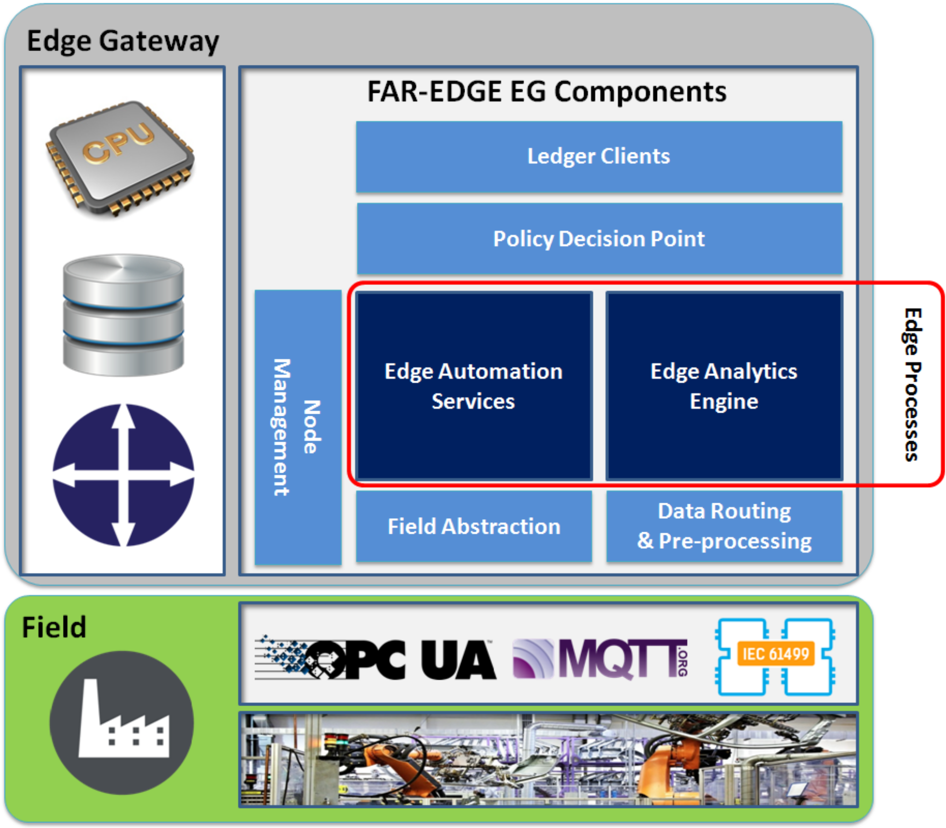


FAR-EDGE Project - http://far-edge.eu/

FAR-EDGE Platform: Edge Gateways

- The *Edge Services* implements a runtime environment for *local automation workflows*.

- The *Edge* provides a runtime environment for *local data analysis algorithms*.



FAR-EDGE Project - http://far-edge.eu/

COMMUNICATION/RELATION WITH THE ENVIRONMENT: VIRTUAL AND AUGMENTED REALITY

- ‘Virtual reality’ (VR) refers to the creation of a completely artificial visual world, while ‘augmented reality’ (AR) refers to the addition of some artificial graphical elements to the (picture of) reality.

AUTOMATIC TRANSLATION

- Its coupling with optical character recognition and cameras on a smart-phone as made it possible to provide everybody with automated translation of texts and signs, which, by use of augmented reality, provides an easy-to-use and widespread tool.

HEAD-UP DISPLAYS IN CARS

- Since 2012, many more brands offer HUDs in a wider range of cars, including Audi, BMW, PSA Peugeot Citroën, Nissan, Mazda, Mercedes, Renault, and Volvo. Today they are available in high-end models

AUGMENTED REALITY GAMES

- Various games have taken a shot at Augmented Reality (e.g Lyteshot AR FPS [98]), but Pokémon Go [105], released in July 2016, is the first to have achieved widespread use [

SMART GLASSES

- Optical Head-Mounted Displays (OHMD), the precursors of ‘smart glasses’, have existed for a long time (available in 1997). At the time, none of these, however, became widespread, despite the involvement of several large players in the consumer market

DEEP LEARNING

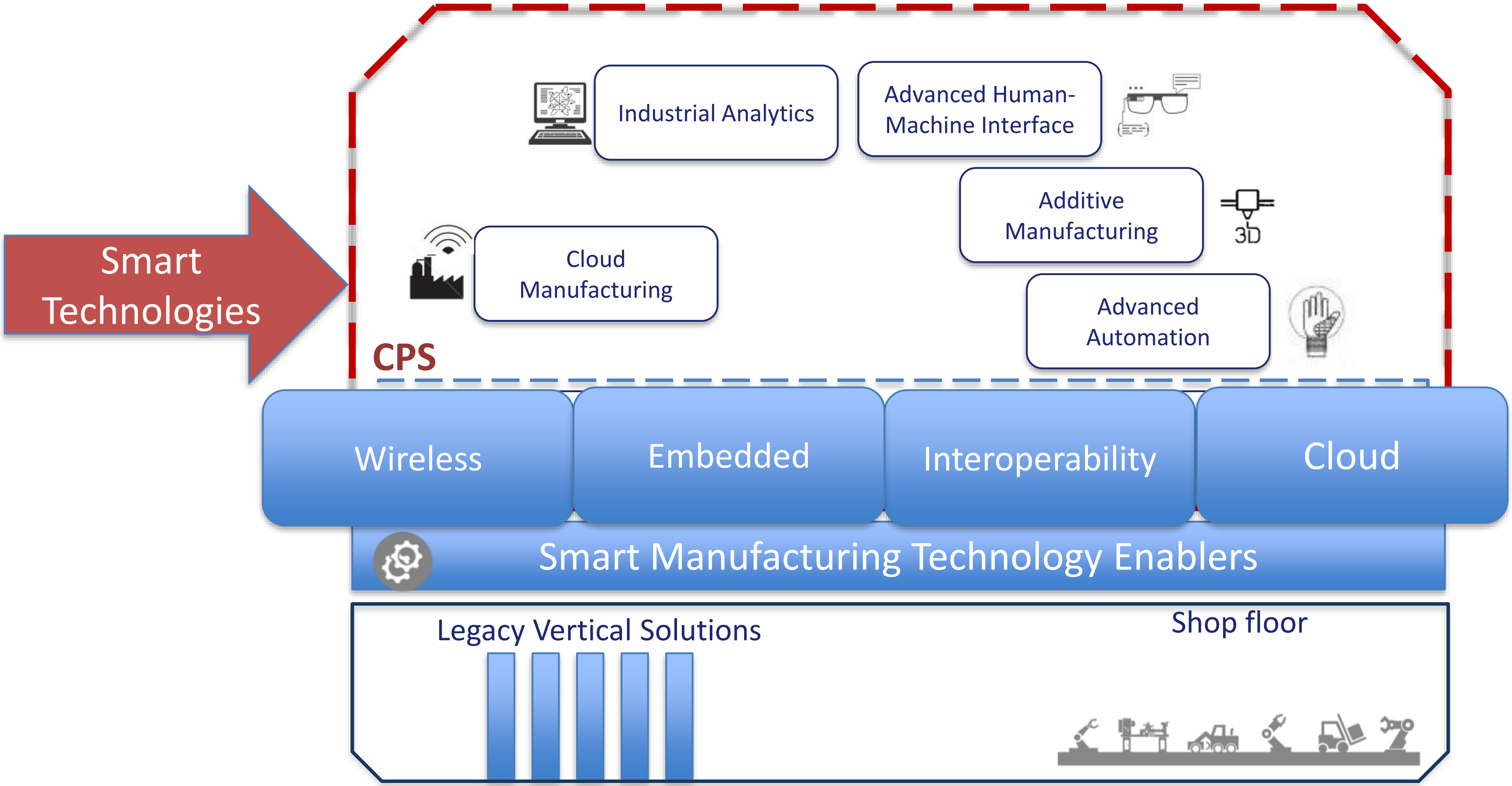
- Deep learning, or the use of Deep Neural Networks is a machine learning approach based on learning representation of data, using structures of Artificial Neural Networks.
- Various deep learning architectures such as deep neural networks, convolutional deep neural networks, deep belief networks and recurrent neural networks have been applied to fields like computer vision, automatic speech recognition, natural language processing, audio recognition and bioinformatics where they have been shown toproduce state-of-the-art results on various tasks.

DATA ANALYTICS

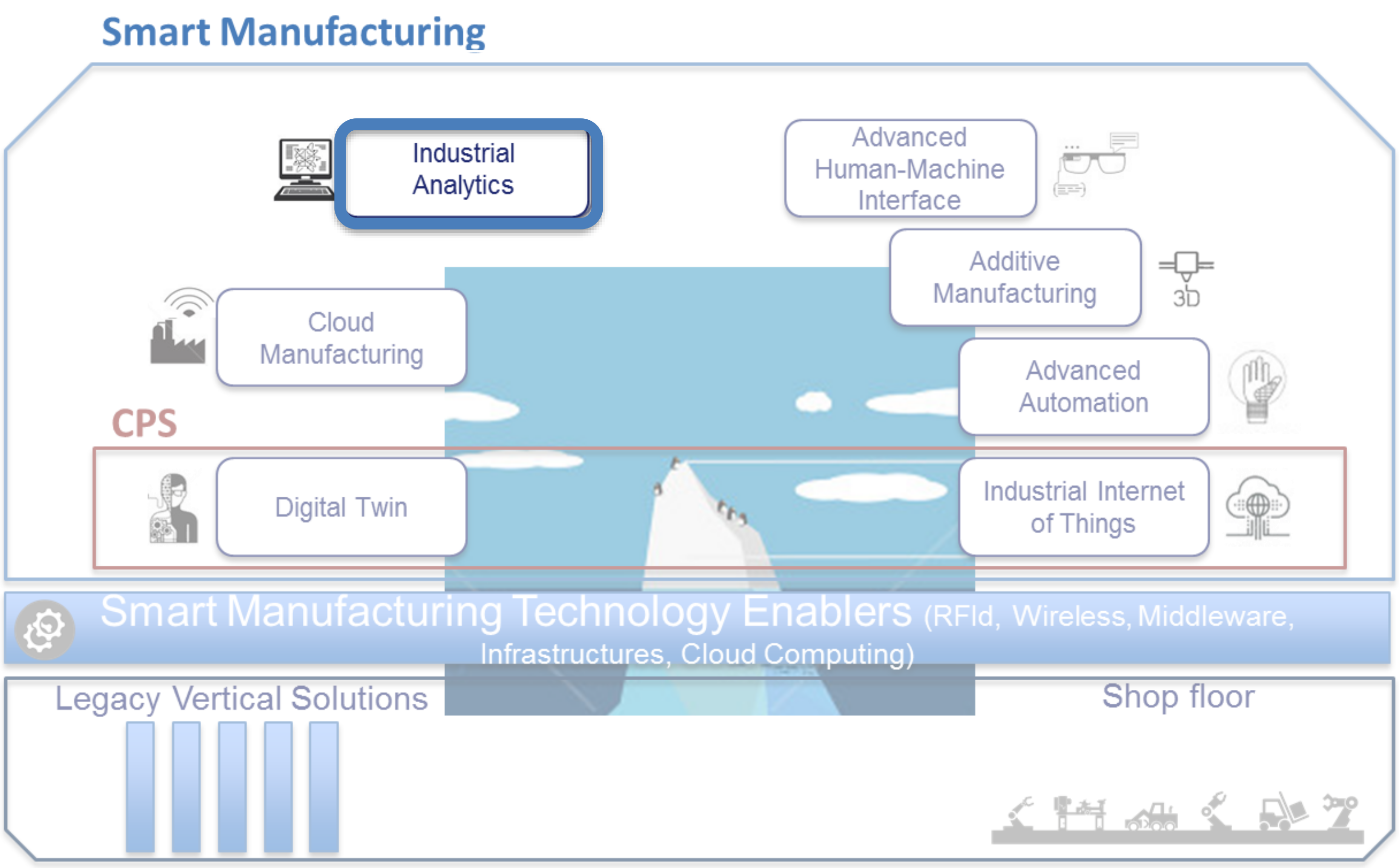
- The universe of IoT systems will create ZetaBytes of data, but most of it will be 'dark data': data that is written once and never read again, possibly because it gets overwritten or because access is lost. The current 'gold rush' consists of trying to extract meaningful information from this data using various data analytics approaches, mostly running in the cloud. Big data analytics examines large amounts of data to uncover hidden patterns, correlations and other insights. It is the ingredient to transform the 'data deluge' into meaningful information. It is currently being developed by many companies in order to optimize processes or improve their business.

Smart Technologies

Towards Smart Manufacturing



Smart Manufacturing technologies



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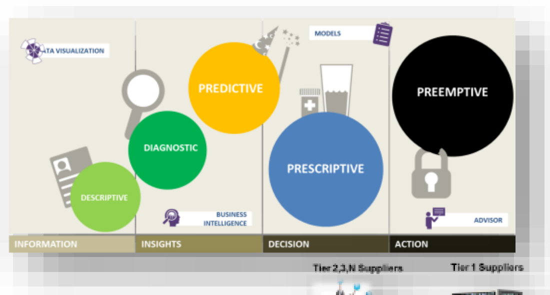
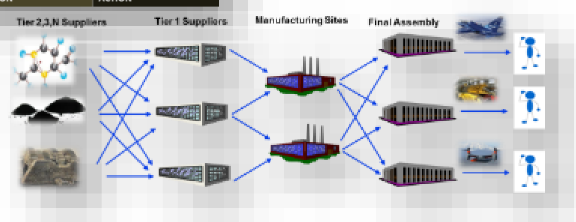
Industrial Analytics

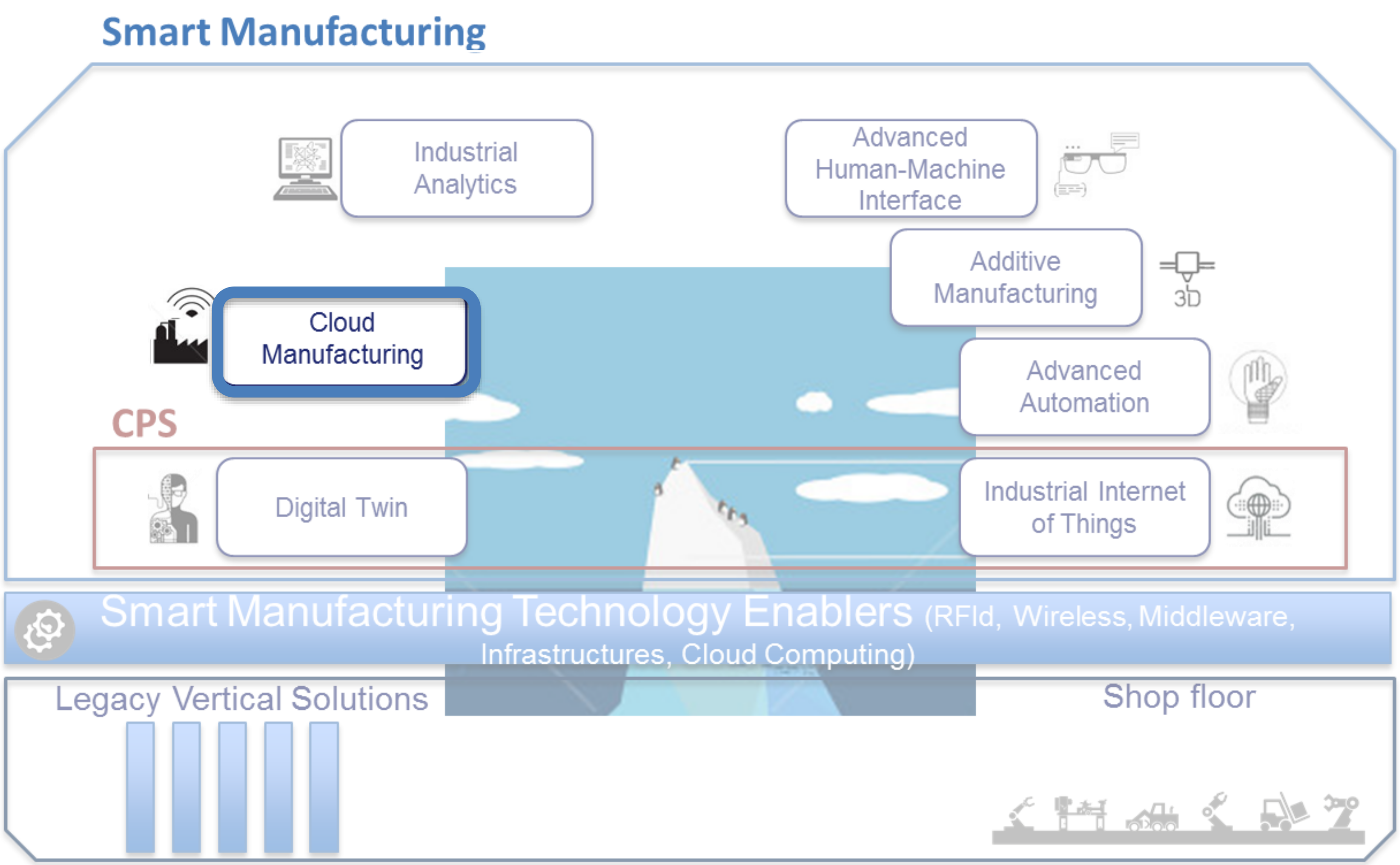
Definition and applications

«Methodologies and tools for managing and elaborating Big Data coming from IoT systems connected to manufacturing layers or from data exchanges among IT systems supporting production and logistic flow planning and syncronization. Industrial Analytics applications include new techniques and tools of Business Intelligence, Visualization, Simulation and Forecasting and Data Analytics able to transform data into information aiming to facilitate rapid decision processes.»





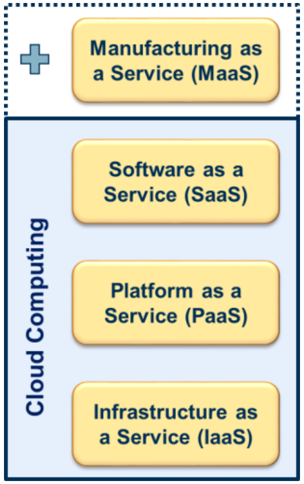
Smart Manufacturing technologies

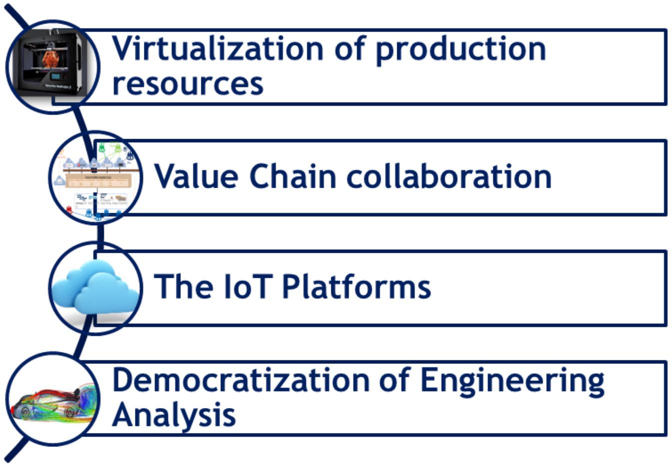


Cloud Manufacturing

Definition and applications

«Model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (*)»





(*) From National Insitute of Standards and Technology

Cloud Manufacturing

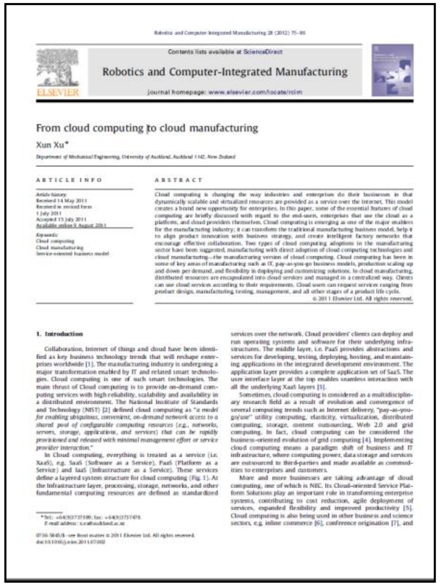
Definition and applications

- Xun Xu, 2012, “From cloud computing to cloud manufacturing”, Robotics and Computer-Integrated Manufacturing.

- *“Two types of cloud computing adoptions in the manufacturing sector have been suggested: manufacturing with <u>direct adoption</u> of cloud computing technologies, and* ***<u>cloud manufacturing,</u>* *the manufacturing version of cloud computing*****.*

- …

- *In cloud manufacturing,* ***distributed resources are encapsulated into cloud services and managed in a centralized way****….*
  Cloud users can request ***services ranging from product design, manufacturing, testing, management and all other stages of a product lifecycle****.“*


Robotics and Computer-Integrated Manufacturing 28 (2012) 75–86
Contents lists available at ScienceDirect
Robotics and Computer-Integrated Manufacturing
journal homepage: www.elsevier.com/locate/rcim

From cloud computing to cloud manufacturing

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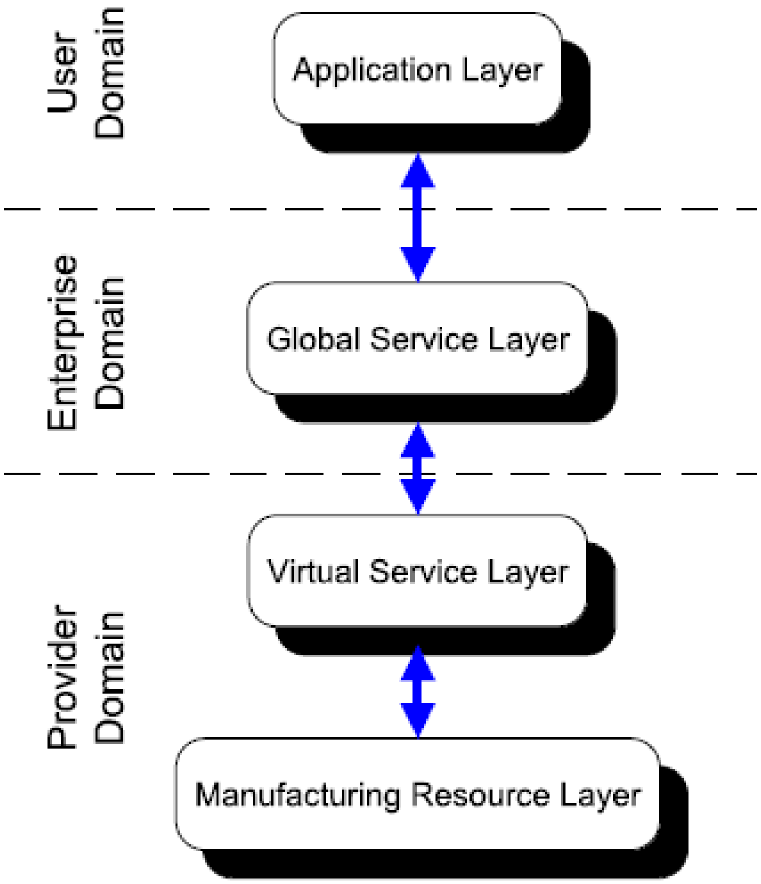
ARTICLE INFO
Article history:
Received 14 May 2011
Received in revised form
1 July 2011
Accepted 15 July 2011
Available online 9 August 2011
Keywords:
Cloud computing
Cloud manufacturing
Service-oriented business model

ABSTRACT
Cloud computing is changing the way industries and enterprises do their businesses in that dynamically scalable and virtualized resources are provided as a service over the Internet. This model creates a brand new opportunity for enterprises. In this paper, some of the essential features of cloud computing are briefly discussed with regard to the end-users, enterprises that use the cloud as a platform, and cloud providers themselves. Cloud computing is emerging as one of the major enablers for the manufacturing industry; it can transform the traditional manufacturing business model, help it to align product innovation with business strategy, and create intelligent factory networks that encourage effective collaboration. Two types of cloud computing adoptions in the manufacturing sector have been suggested, manufacturing with direct adoption of cloud computing technologies and cloud manufacturing—the manufacturing version of cloud computing. Cloud computing has been in some of key areas of manufacturing such as IT, pay-as-you-go business models, production scaling up and down per demand, and flexibility in deploying and customizing solutions. In cloud manufacturing, distributed resources are encapsulated into cloud services and managed in a centralized way. Clients can use cloud services according to their requirements. Cloud users can request services ranging from product design, manufacturing, testing, management, and all other stages of a product life cycle.

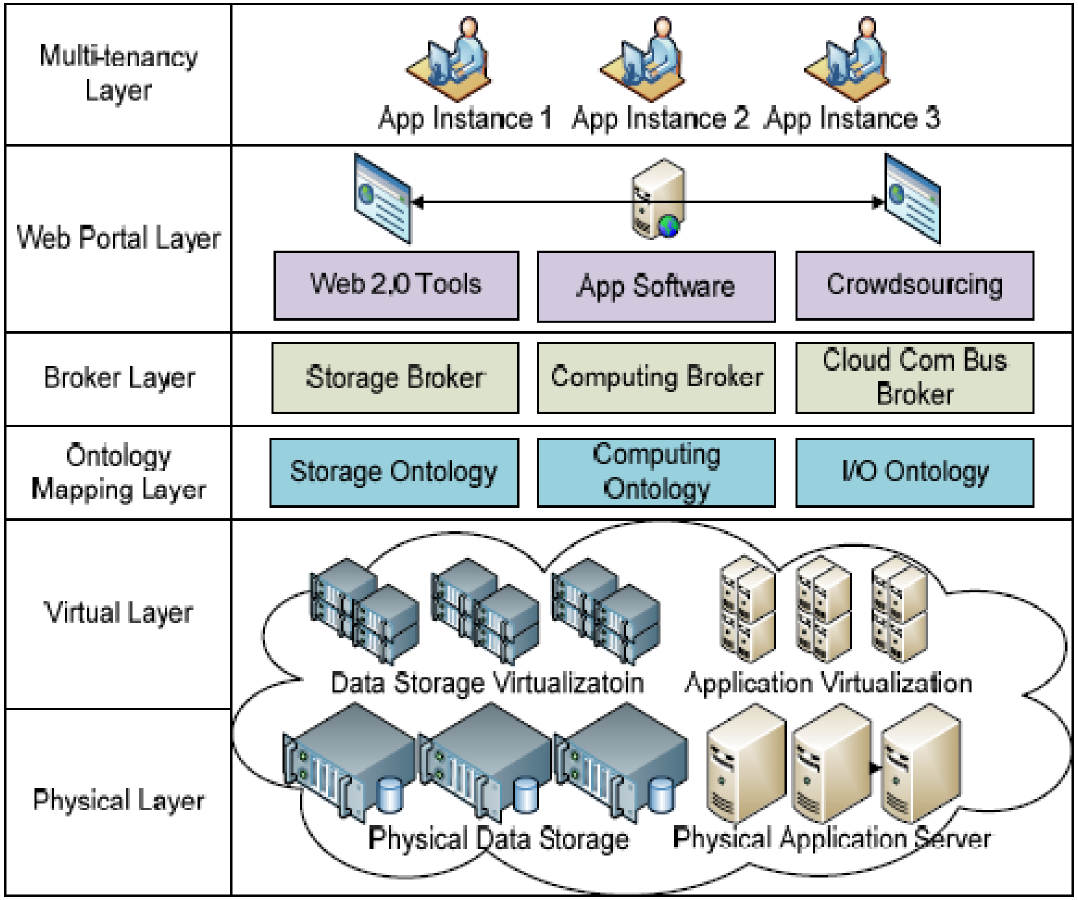
Cloud Manufacturing

MaaS architecture



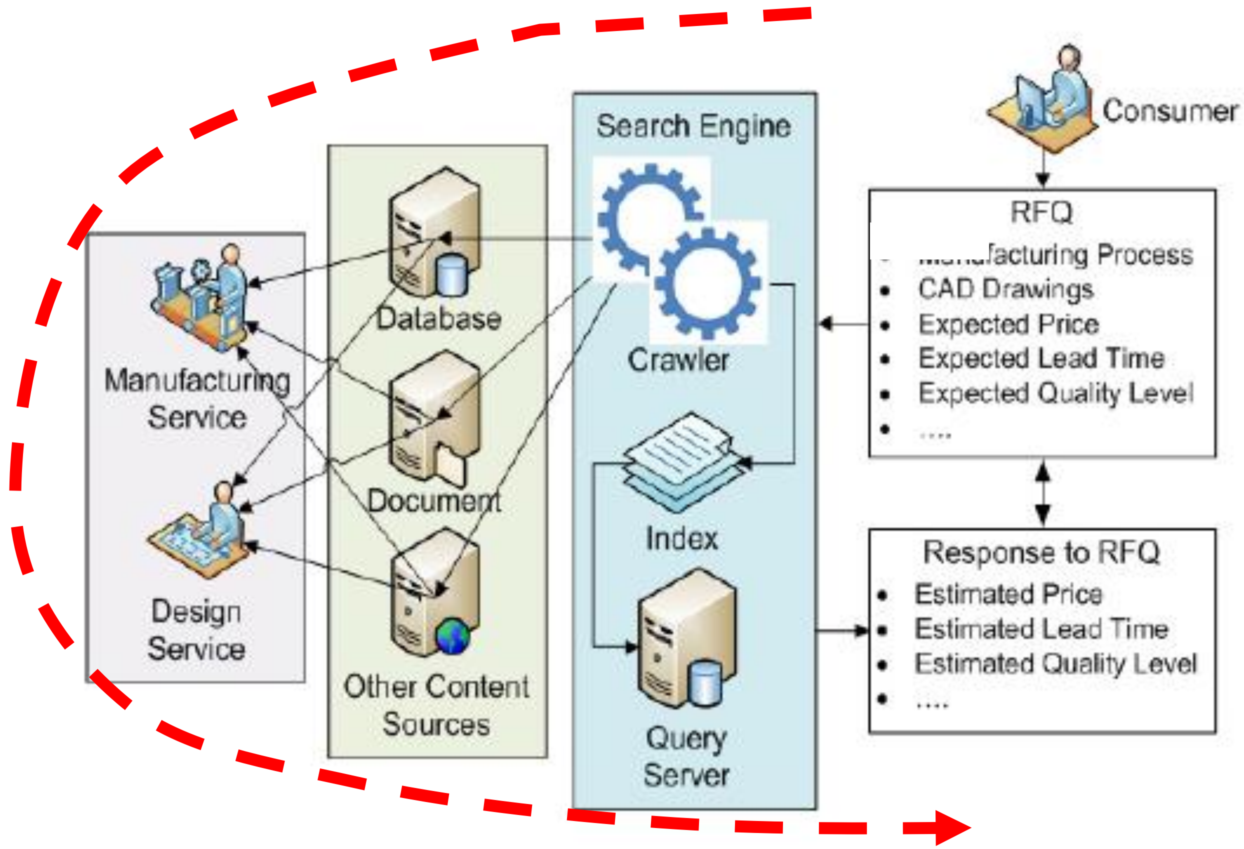
Cloud Manufacturing

MaaS architecture

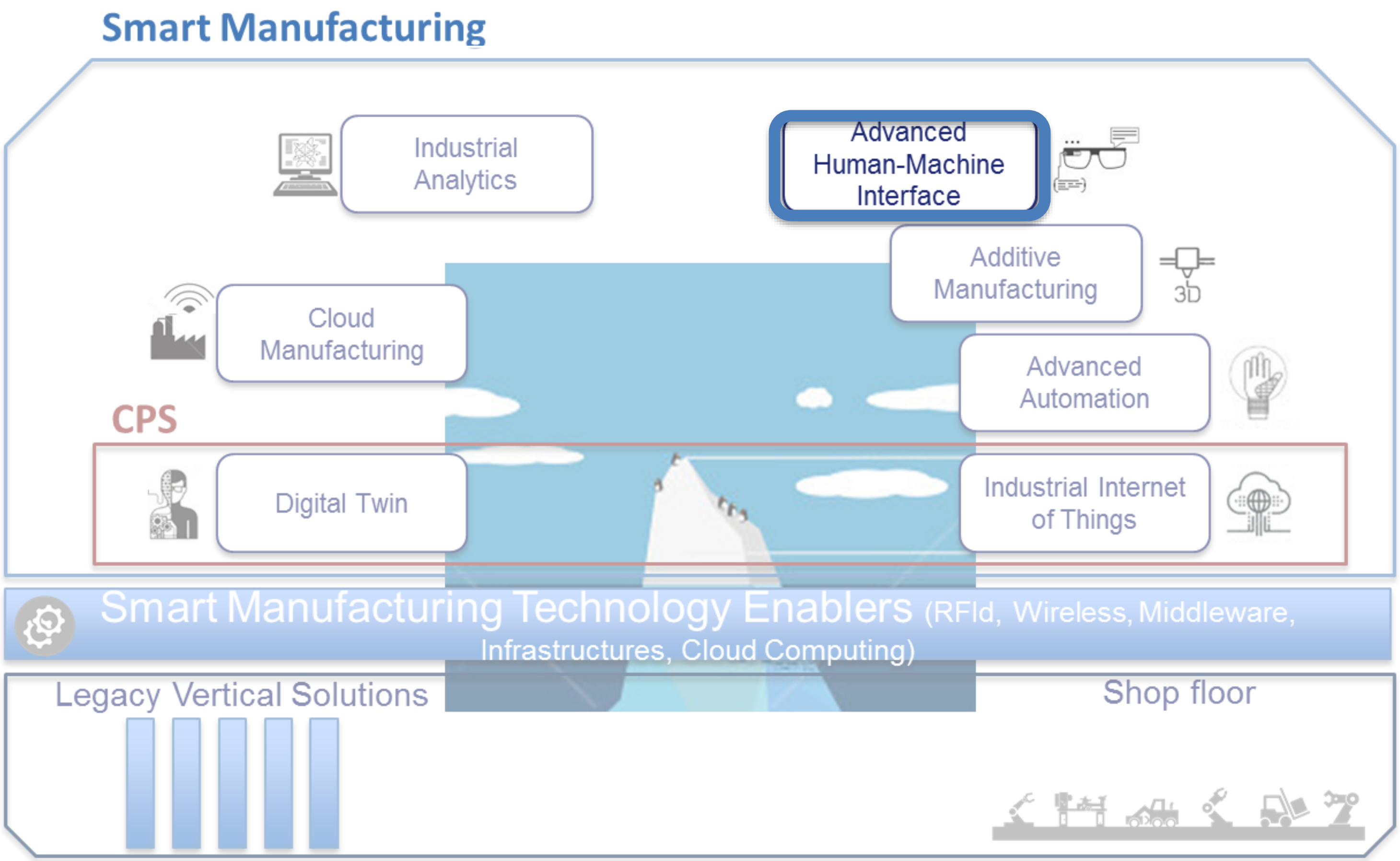


Cloud Manufacturing

MaaS workflow



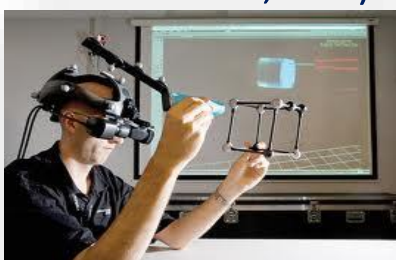
Smart Manufacturing technologies

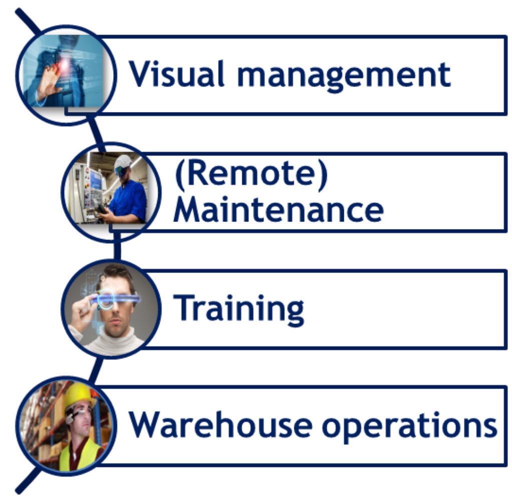


Advanced Human-Machine Interface

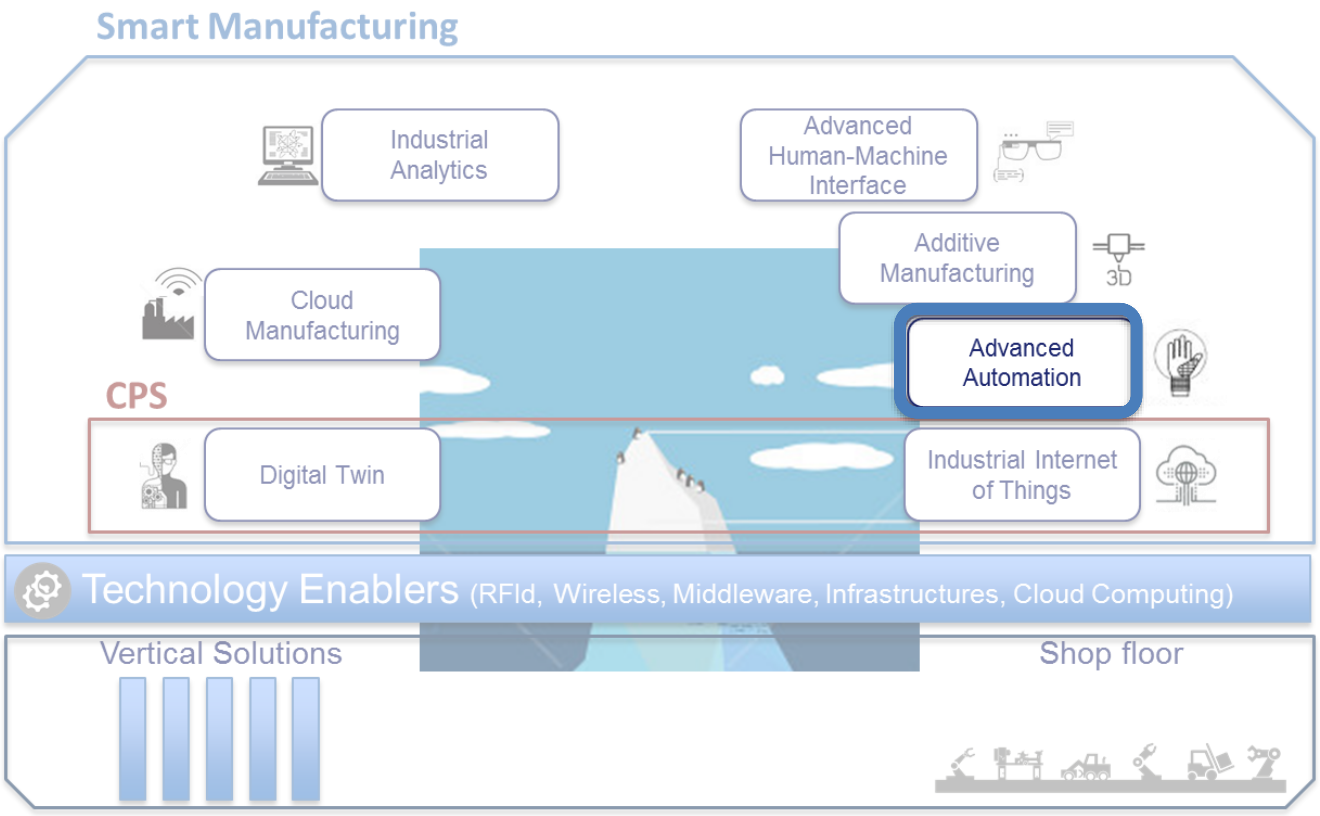
Definition and applications

Wearable tools and technologies and new human-machine interfaces to collect and share information in vocal, visual and tactile way. They include both already utilized systems (touch displays, 3D scanners, etc.) and more innovative and bidirectional solutions (AR/VR glasses, Performance Support Systems, interactive technical instructions, etc.)





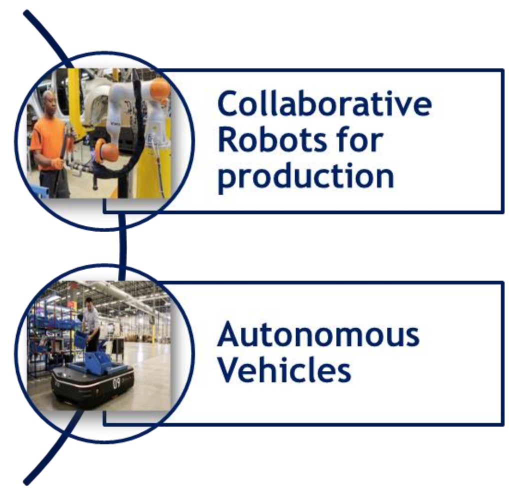
Smart Manufacturing technologies



Advanced Automation

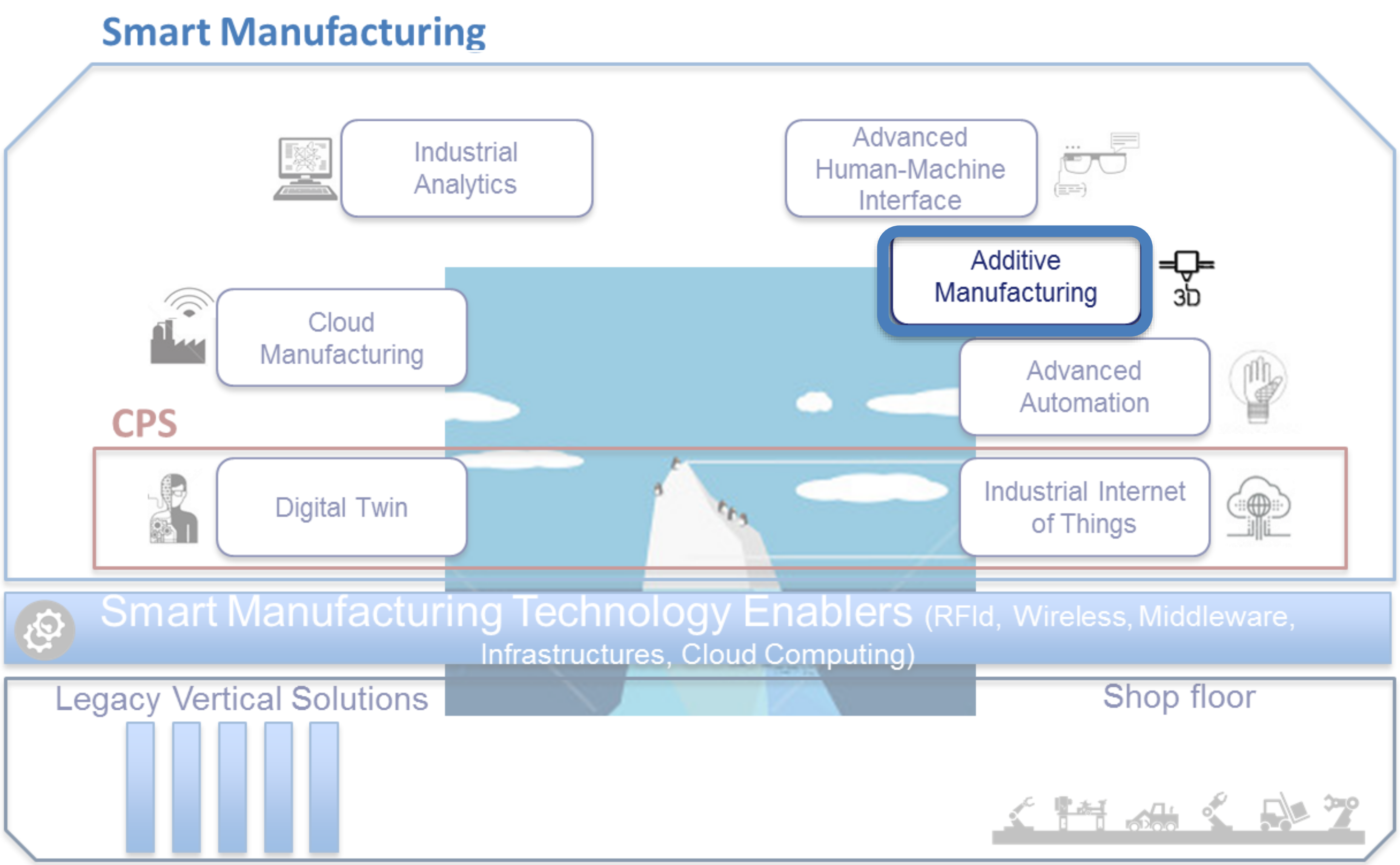
Definition and applications

It refers to the latest advancement in automation production systems characterized by a high cognition ability, high context interaction and adjustment, self-learning and reconfigurability. The most famous example of these tecnologies is the collaborative robot (co-bots), which are desinged to work with operators/workers.

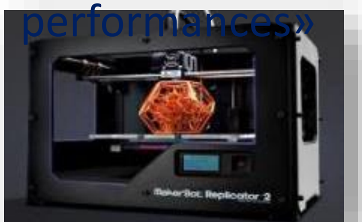


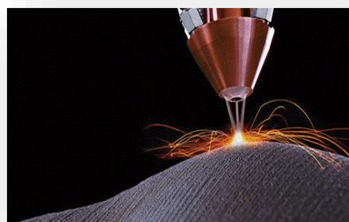
IMIM
International Master of Industrial Management

Smart Manufacturing technologies



«Also known as 3D Printing, it overturns the traditional approach of production processes producing objects through printing them layer by layer. Launched in the first half of ‘80s, during last years it has had a growing interest, enlarging the set of basic technological processes (Selective Laser Sintering, Electron Beam Melting, Fused Deposition Modeling, ecc.) and of working materials (matals and plastics) with good finishing and mechanical resistance performances»

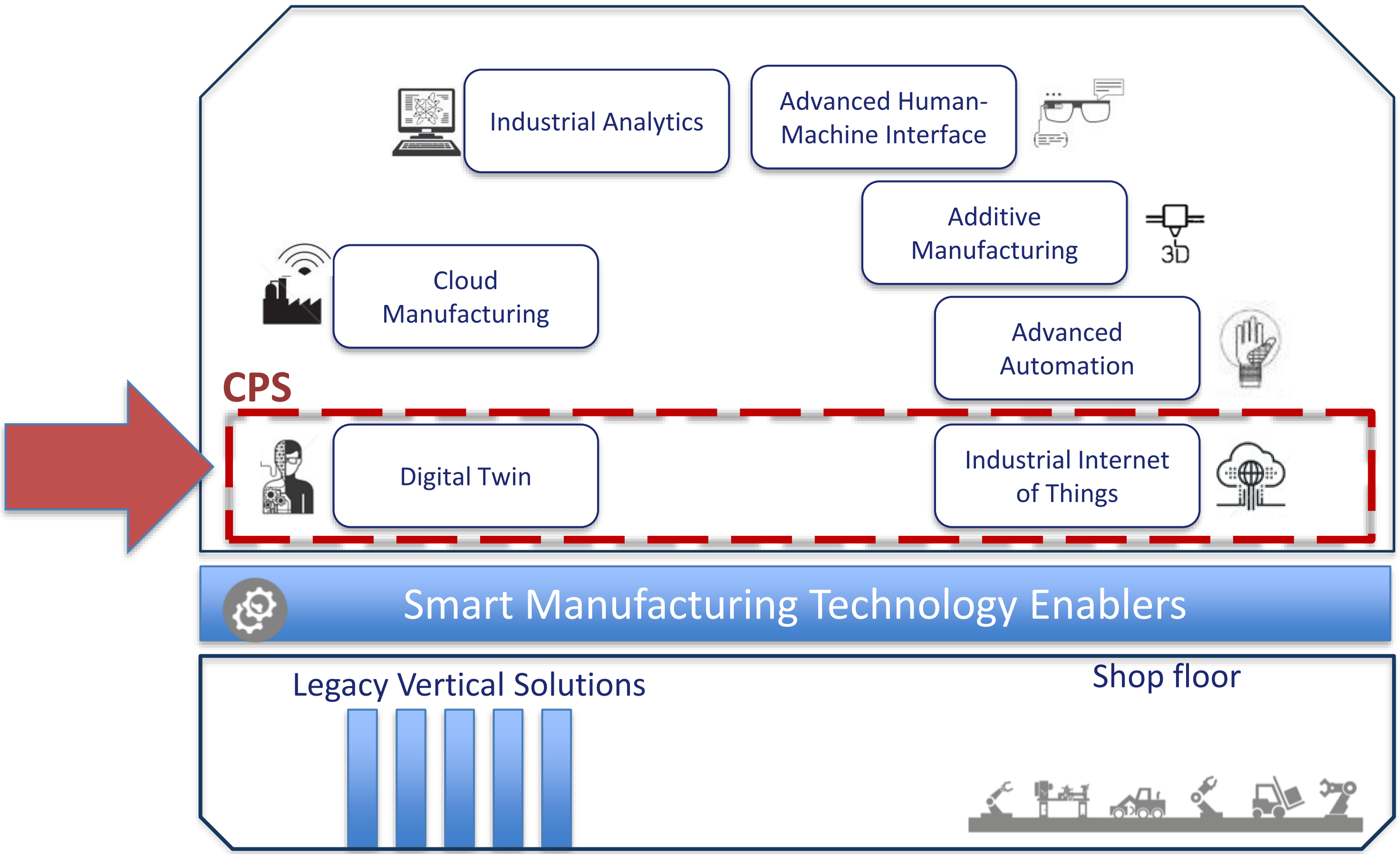




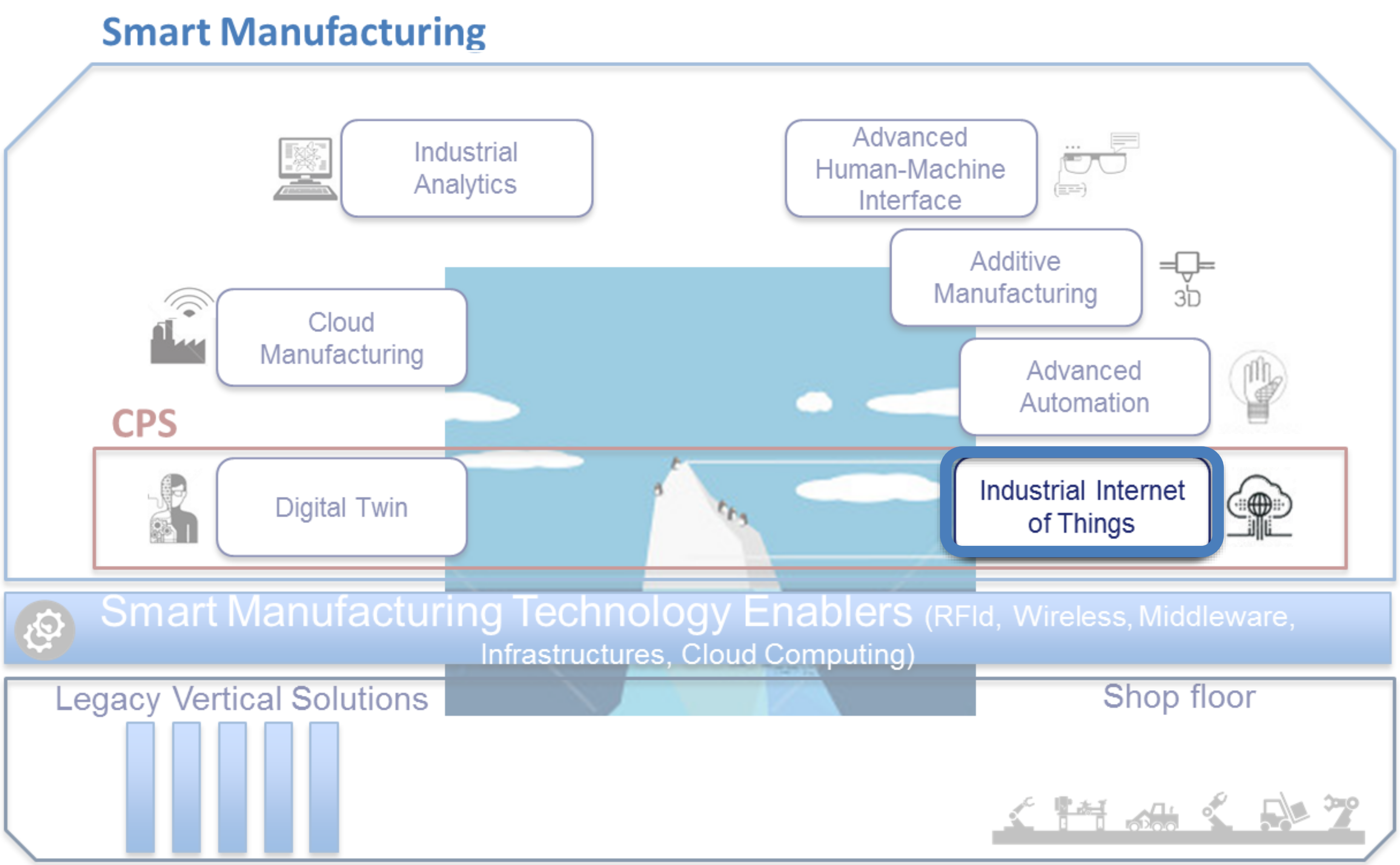
- **Rapid Protyping**
- **Rapid Tooling**
- **Rapid Manufacturing**
- **Maintenance&Repair**

CPS
cyber physical system

Towards Smart Manufacturing



Smart Manufacturing technologies



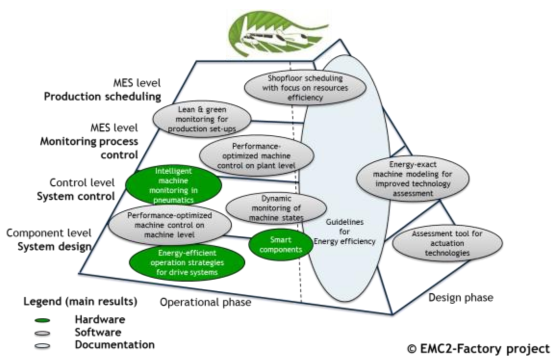
Industrial Internet of Things

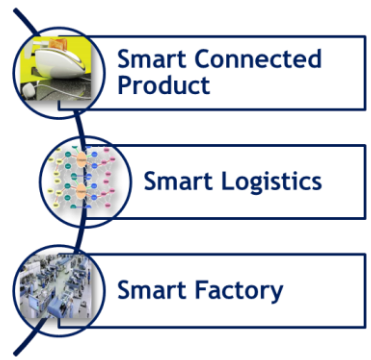
Definition and applications

I-IoT is the **integration** of **complex physical machinery** with **industrial networks** and **data analytics solutions** to **improve operational efficiency** and reduce costs. It comprises advanced sensor technologies, machine-to machine communication, real-time data analytics, and machine learning algorithms to enhance the decision-making capabilities of the industries. – ***Markets&Markets, 2016***

« The I-IoT is a **network of physical objects**, **systems**, **platforms** and **applications** that contain **embedded** technology to **communicate** and **share intelligence** with each other, the external environment and with people – ***Accenture, 2015***

«The Industrial Internet is here: **smart, connected machines** generating prodigious **amounts of data** that can be **analyzed to optimize operations**" – ***BCG, 2014***



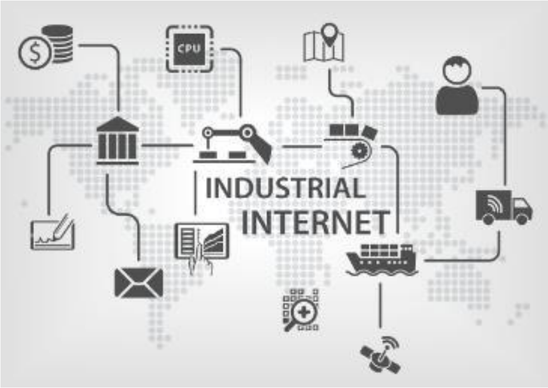


Industrial Internet of Things

Definition and applications

"The integration of **complex physical machinery** with **networked sensors** and **software**.

The industrial Internet on Things draws together different fields(*) to **ingest data** from machines, **analyze** it (often in real-time) and use it to **optimize operations**".



(*) Such as **machine learning**, **big data**, the **Internet of things**, **machine-to-machine communication** and **Cyber-Physical System)**

Industrial Internet of Things
Definition and applications

- According to some estimates there will be 50 billion mobile wireless devices connected to the Internet across the globe by 2020
- The total number of devices connected to the Internet in some way could reach 500 billion.
- By 2020, there will be a quarter billion connected vehicles on the road, enabling new invehicle services and automated driving capabilities.
- Gartner forecasts that 4.9 billion connected things will be in use in 2015, up 30 percent from 2014, and will reach 25 billion by 2020
- By 2020, the connected kitchen will contribute at least 15 percent savings in the food and beverage industry, while leveraging big data analytics.

OECD (2012), "Machine-to-Machine Communications: Connecting Billions of Devices", *OECD Digital Economy Papers*, No. 192, OECD Publishing.

Gartner report "Predicts 2015: The Internet of Things."

- The term “Internet of Things” is mainly associated with applications that involve Radio Frequency Identification (RFID). These make use of so called tags, tiny chips with antennas that start to transmit data when they come in contact with an electromagnetic field. They are passive communication devices, in contrast to active devices, that can transmit because they have access to a power source like a battery.
- The term Machine to Machine communication (M2M) describes devices that are connected to the Internet, using a variety of fixed and wireless networks and communicate with each other and the wider world. They are active communication devices. The term is slightly erroneous though as it seems to assume there is no human in the equation, which quite often there is in one way or another.
- The term embedded wireless devices has been coined, for a variety of applications where wireless communication is used to connect any device with on board intelligence, that is not a phone.

Industrial Internet of Things

Horizons

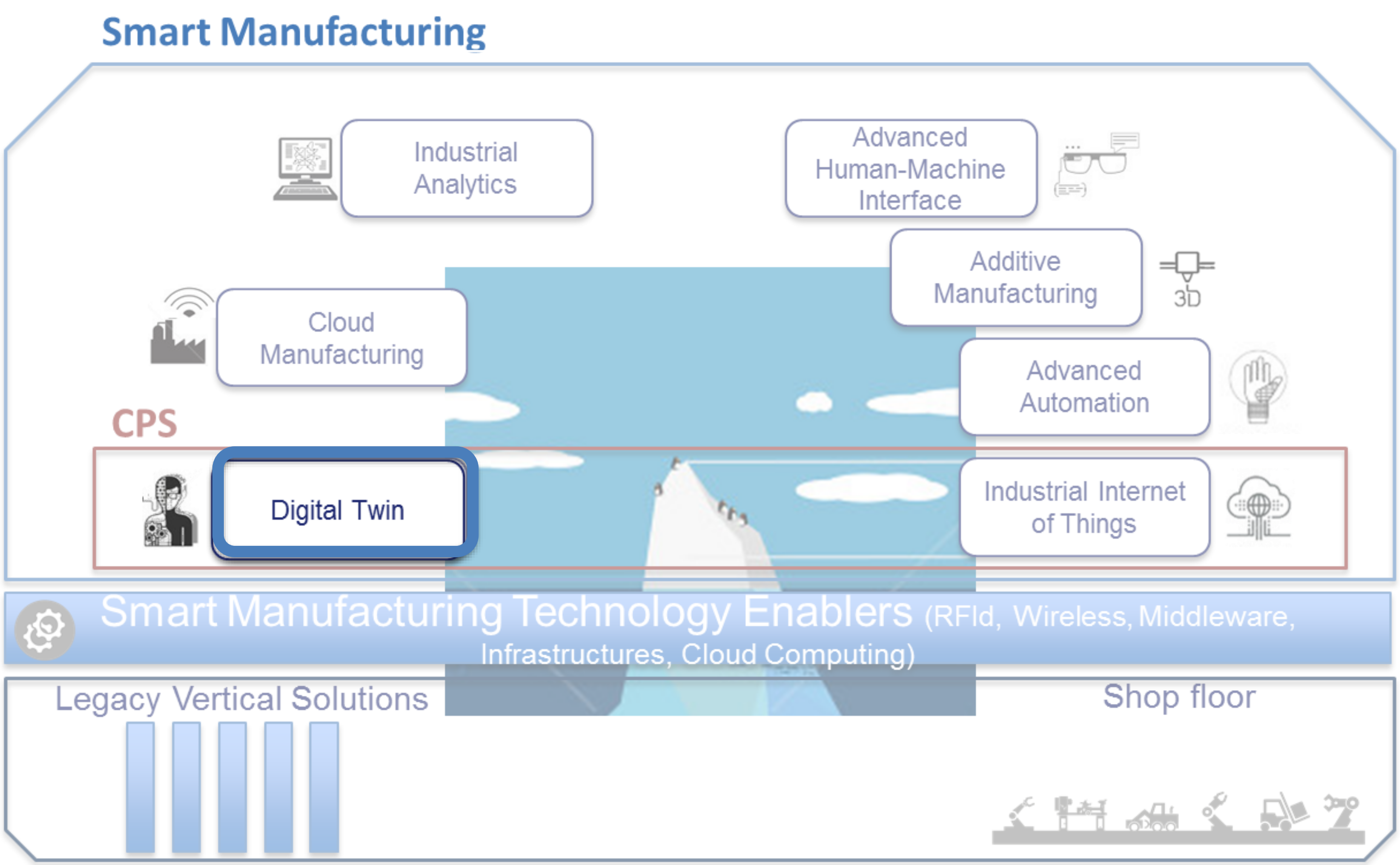


- Smart Cities
- Smart Environment
- Smart Water
- Smart Metering
- Security & Emergencies
- Retail


- Logistics
- Industrial Control
- Smart Agriculture
- Smart Animal Farming
- Domotic & Home Automation
- eHealth


Ref. IERC - Internet of Things European Research Cluster 3rd edition of the Cluster Book
http://www.internet-of-things-research.eu/pdf/IERC_Cluster_Book_2012_WEB.pdf

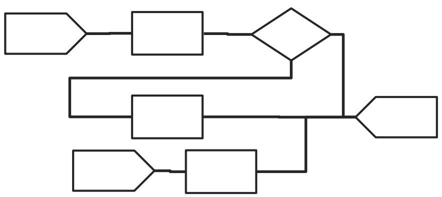
Smart Manufacturing technologies

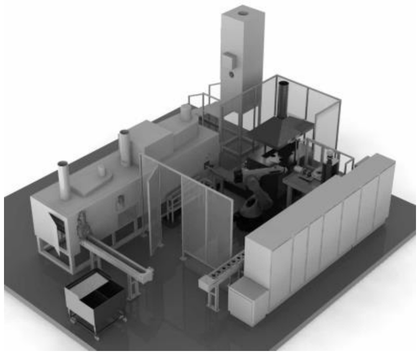


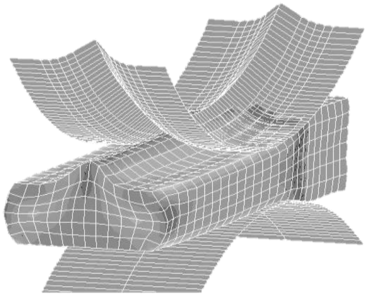
The Digital Twin

The virtual counterpart
- of the **product** and
- of the **production system**

collects each relevant aspect and allows an optimization of the design, building and management of the system, **before the commissioning of the actual system.**

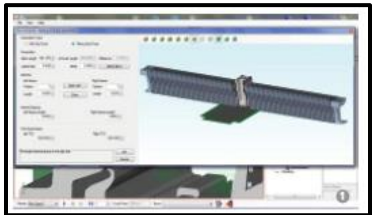






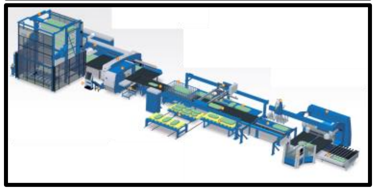
The Digital Twin

Digital Twin recreates a realistic situation thanks to simulation software:
- more and more integrated and **connected to the external** world
- allow to **optimize processes** through virtual simulation



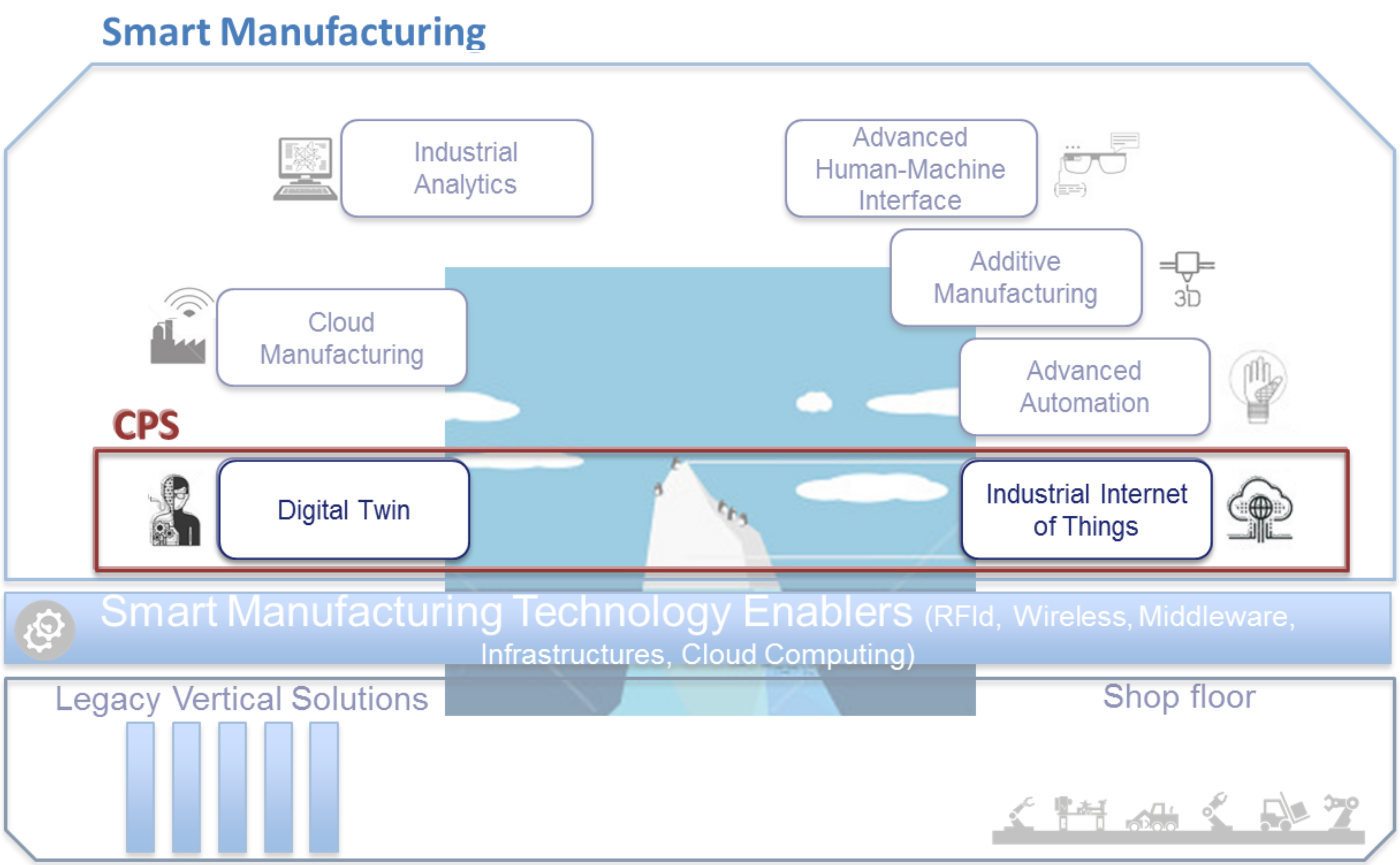
Of the single **operation**
→ Technological-geometric level

Of the **production cell**
→ Timing and interactions between equipment and pieces

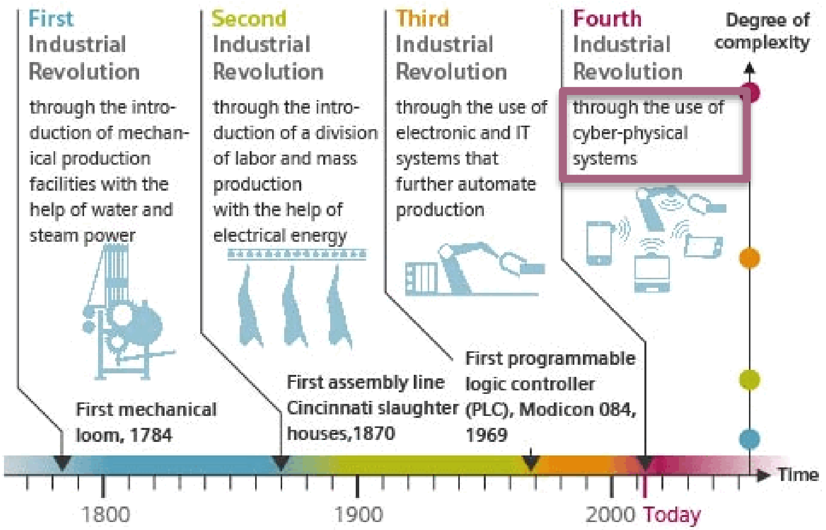


Of the **whole production line**
→ Material flows, lead times, bottlenecks analyses, buffer dimensioning etc.

Smart Manufacturing technologies



Cyber-Physical Systems



http://electric-cloud.com/blog/2014/09/iot-industry-4-0-driving-multi-domain-continuous-delivery/

Reality melts into the digital world

Cyber-Physical Systems

- <u>Main emphasized concepts</u>

Connected objects

Data acquisition and analysis

New

CYBER-PHYSICAL SYSTEMS DEFINITION:

Cyber Physical Systems *are* ***autonomous collaborating entities*** *able to sense, and act as physical objects (embedded systems), as well as communicate on global networks, compute and store data and information in the cyber world through their computerized companion (digital twin).*

European Roadmap for Cyber-Physical Systems in Manufacturing

<u>Key characteristics:</u>

Overall lifecycle approach

Ecosystem approach

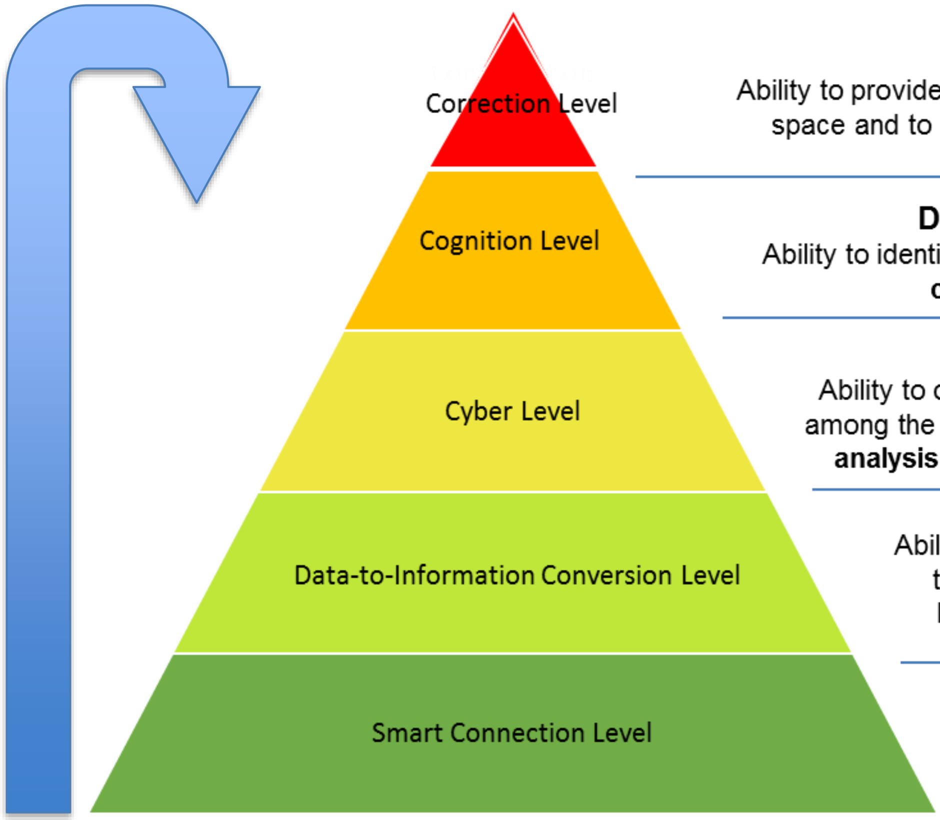
New added value services for customers and operators

Cyber-Physical Systems

Cyber-Physical Systems (CPS) refer to

- ICT systems (sensing, actuating, computing, communication, ..)
- embedded in physical objects,
- interconnected through several networks including the Internet,
- self organizing and self connecting,
- providing citizens and businesses with a wide range of innovative applications and services,
- reshaping the product/process/plant life-cyle.

Cyber-Physical Systems: Functionalities – The 5C Model



(Re)-Configuration:
Ability to provide the **feedback** from CPS to physical system space and to apply **the corrective decision** taken into Cognition Level.

Decision Support System
Ability to identify different **scenarios** and to **support the correct decision** to be taken

Self-Compare:
Ability to obtain **better status** of individual machines among the fleet through **camparison**, **similarities** and **analysis** of historical information of each machine

Self-Aware:
Ability to obtain the self-awareness of machines through **transforming data** into **valuable knowledge** calculating health value and **estimating remaining useful life**

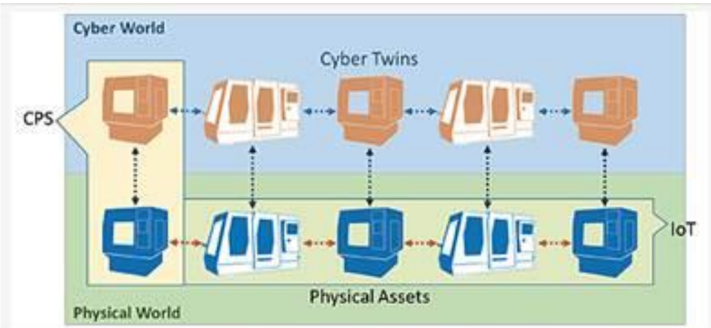
Condition Monitoring:
Ability to manage **data acquisition systems** and **to transfer it** to central server through proper sensors and transferring protocols

J. Lee and B. Bagheri, "Big future for cyber-physical manufacturing systems," 2015

CPS vs IoT

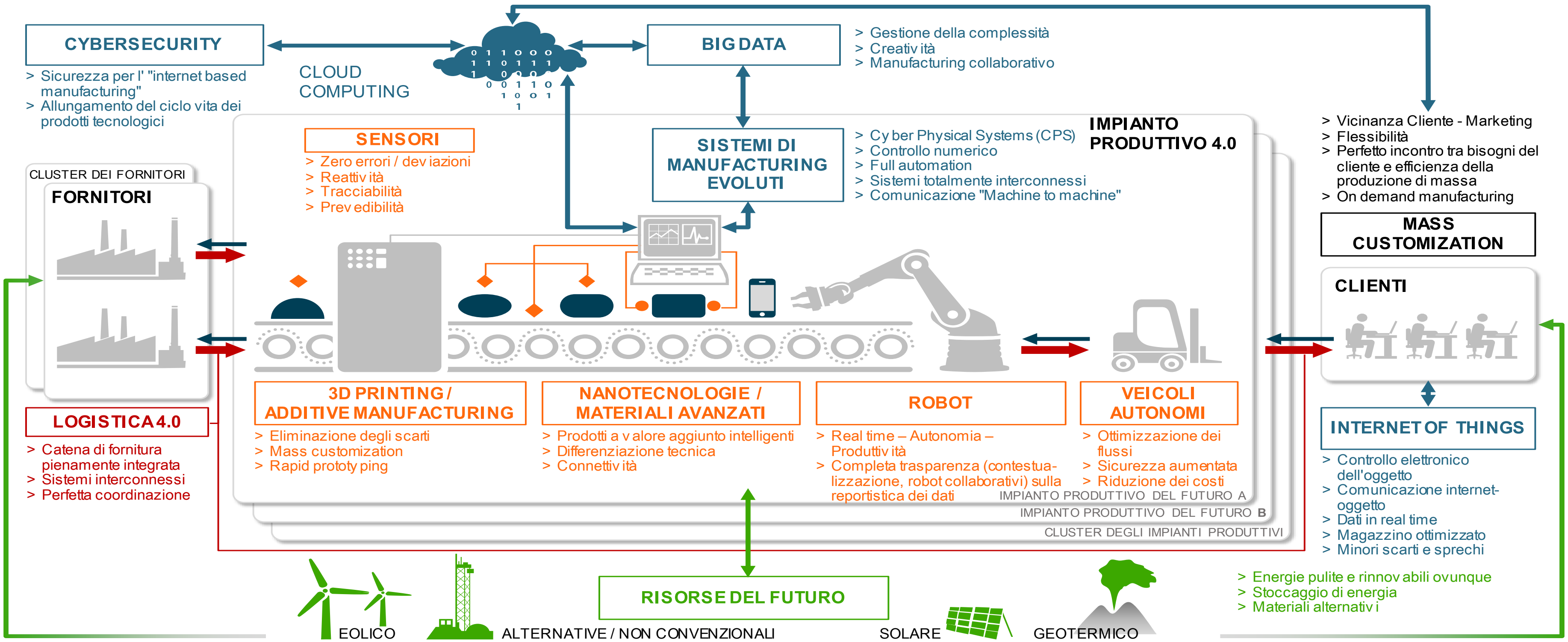
- "The term cyber-physical system usually refers to systems of collaborating computational elements that control physical entities, generally using feedback from sensors they monitor. The similarities of using networking, internet and sensors in definitions of IoT and CPS might lead one to wonder if these two terms are different definitions of the same concept. But though there are similarities, a CPS is not the same thing as IoT.
- The IoT is based on connections between physical assets through which data can transfer. The connections are made possible by the secure implementation of computer networks, internet and communication protocols. This communication is based on normal internet protocols or dedicated protocols such as MTConnect.

But despite the connectivity, the IoT paradigm does not include the idea of information systems or analytics. On the other hand, CPSs are based on connectivity but run complex analytics. Complex inference in a CPS takes place through a centralized analytical hub where knowledge is excavated from raw data. Based on the knowledge inferred from the data, control commands get sent to the physical asset. All in all, it's possible to view the IoT as the infrastructure that makes CPSs possible."



A cyber-physical system is characterized by a physical asset, such as a machine, and its digital twin; basically a software model that mimics the behavior of the physical asset. In contrast, the IoT in common parlance is generally limited to the physical assets, not their digital models.

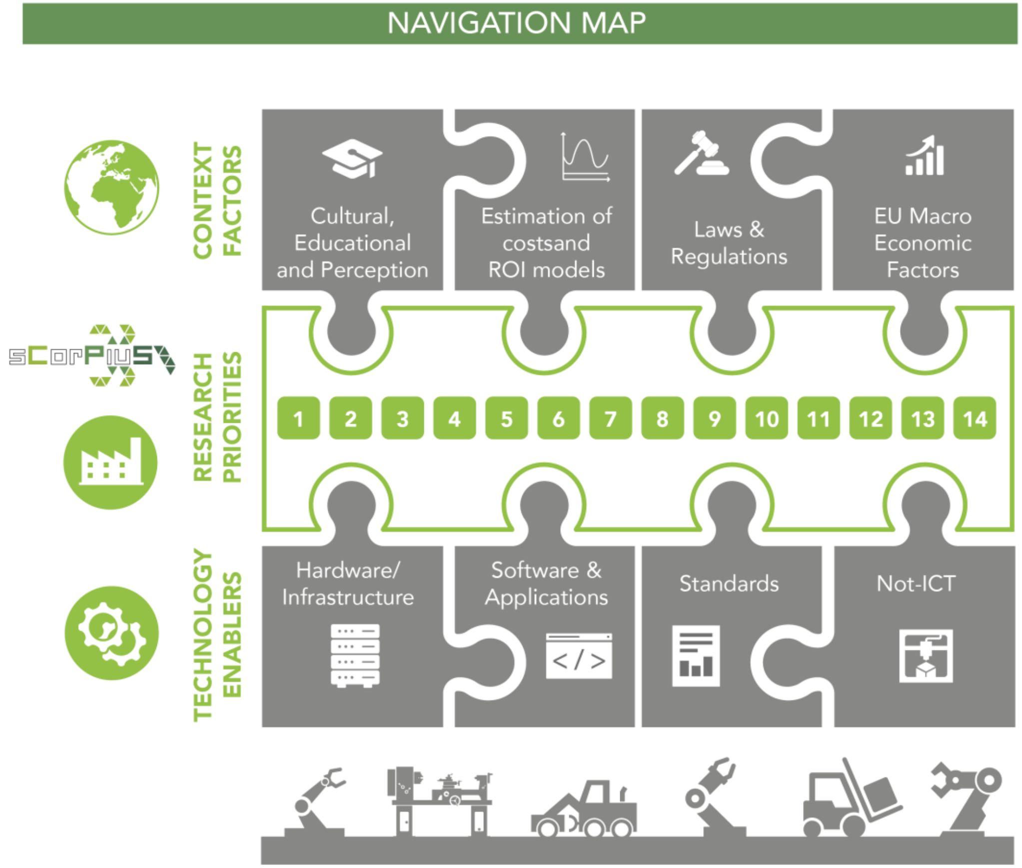
La Fabbrica Intelligente – Smart Factory



* ROLAND BERGER

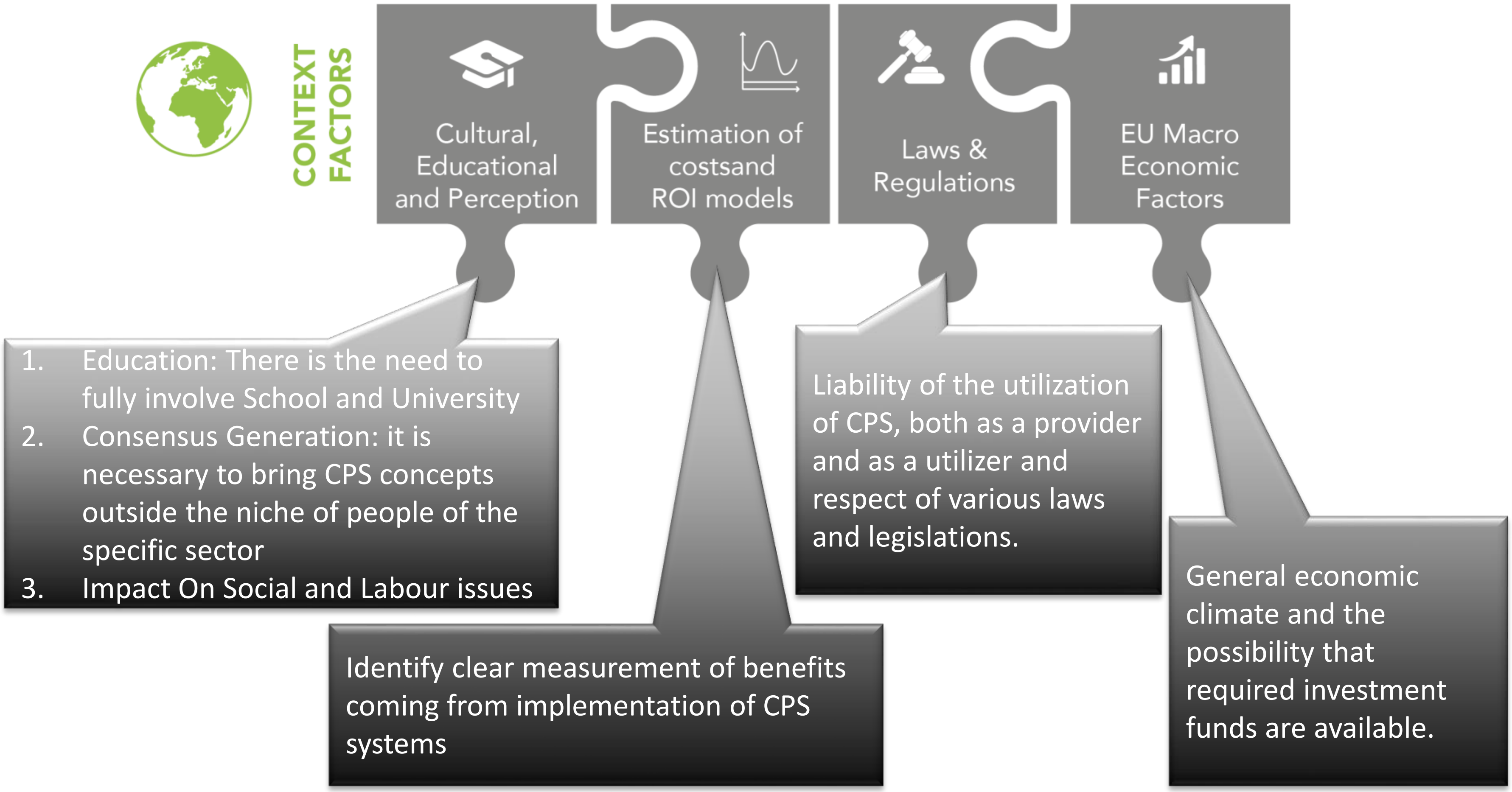
The road to Smart Manufacturing

Smart Manufacturing Implementations



http://scorpius-project.eu/

The road to Smart Manufacturing : Context Factors



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