PATHFINDER Vision on Simulation and Forecasting Technologies – A three layers approach

Dissemination Level	Public

Grant n°:	608777
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Version:	1

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n 608777

1. ATHFINDER Vision – A three layers approach

PATHFINDER specifically focuses on the role of Simulation and Forecasting Technologies and does not propose a new vision for manufacturing as a whole. PATHFINDER thus embraces the current efforts achieved by accredited industrial, institutional and academic groups, in the definition of a Manufacturing Vision for 2020. The roadmap proposes a three layer vision on SF&T that is progressively more detailed and takes up the efforts made by the aforementioned stakeholders.

1.1. Layer 1 - Manufacturing vision for 2020

The long term direction embraced by PATHFINDER is consistent with the one anticipated within the "Factories of the Future Strategic Multi-Annual Roadmap" developed within EFFRA[1]. Four paradigms have been there identified as to guide the transformations of European Manufacturing:

I - Factory and Nature -> green - sustainable production

- Lowest resource consumption
- Closed loops for products
- Production and scares resources
- Sustainability in materials and production processes

II - Factory and the Neighbourhood -> production close to the worker and to the customer

- Manufacturing close to people (in cities / metropolitan areas)
- Factory integrated and accepted in the living environment

III - Factories and the value chain -> collaborative production

- Highly competitive distributed manufacturing (flexible, responsive, high speed of change)
- Design oriented products, mass customized products
- Integration of the product and process engineering

IV - Factory and Humans -> human centred production

- Human oriented interfaces for workers: process-oriented simulation and visualization
- Products and work for different type of skilled an aged labour, education and training with IT-Support
- Regional balance: work conditions in line with the way of life, flexible time- and wage- systems
- Knowledge development, management and capitalization

PATHFINDER envisions current challenges and future role of Simulation and Forecasting Technologies as a key lever to empower this long term vision (Fig. 1)

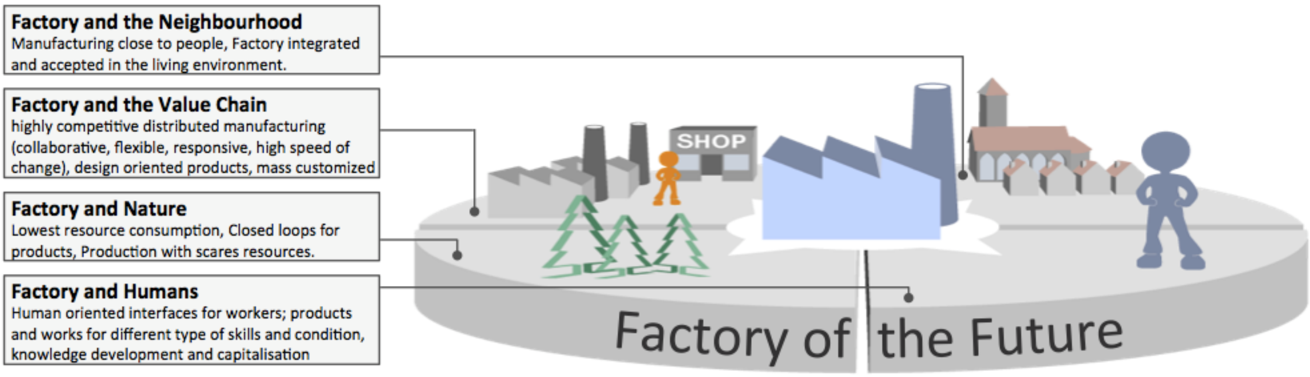

Fig. 1 - Factory of the Future layer

Within the "Factories of the Future Strategic Multi-Annual Roadmap", three cluster of ***manufacturing challenges*** are identified. Those challenges need to be efficiently addressed in order for the long term vision to come true:

[1] EFFRA – European Factories of the Future Research Association. Factories of the Future Strategic Multi-Annual Roadmap. www.effra.eu

I - Economic sustainability of manufacturing

- Addressing economic performance across the supply chain
- Realising reconfigurable, adaptive and evolving factories capable of small scale production
- High performance production, combining flexibility, productivity, precision and zero-defect while
- Remaining energy- and resource-efficient Resource efficiency in manufacturing - including addressing the end-of-life of products.

II - Social sustainability of manufacturing

- Increase human achievements in future European manufacturing systems
- Creating sustainable, safe and attractive workplaces for ‘Europe 2020’
- Creating sustainable care and responsibility for employees and citizens in global supply chains

III - Environmental sustainability of manufacturing

- Reducing the consumption of water and other process resources
- Near to zero emissions, including noise and vibrations, in manufacturing processes.
- Optimising the exploitation of materials in manufacturing processes
- Co-evolution of products-processes-production systems or ‘industrial symbiosis’ with minimum need
- of new resources

In order to efficiently tackle the previously identified challenges and opportunities, the EFFRA roadmap classifies ***6 groups of key technologies*** and enablers for the factories of the future:

I - advanced manufacturing processes

II - mechatronics for advanced manufacturing systems

III - information and communication technologies

IV - manufacturing strategies

V - modelling, simulation and forecasting methods and tools

VI - knowledge-workers

The “Factories of the Future Strategic Multi-Annual Roadmap” identifies eventually the research priorities to be addressed in order to develop the key technologies and enablers afore mentioned. Those priorities are grouped in six domains:

DOMAIN 1 - Advanced manufacturing processes

DOMAIN 2 - Adaptive and smart manufacturing systems

DOMAIN 3 - Digital, virtual and resource-efficient factories

DOMAIN 4 - Collaborative and mobile enterprises

DOMAIN 5 - Human-centred manufacturing

DOMAIN 6 - Customer-focused manufacturing

PATHFINDER focuses the fifth set of Key Technologies and Enablers (modelling, simulation and forecasting methods and tools) and further details the research priorities addressed in Domain 3 and, to a lesser extent, Domain 1, 4 and 6.

1.2. Level 2 - Industrie 4.0 vision

The high level vision afore introduced, that depicts the future relations among the factory, humans, neighbourhood and value chain, must be framed in a lower level vision capable to endow it. PATHFINDER supports the foresight brought forward by the Industrie 4.0 Initiative[2], as a consistent framework for the actual fulfilment of the Factory Of the Future vision.

Industrie 4.0 envisions a fourth industrial revolution. The first three industrial revolutions came about as a result of mechanisation, electricity and IT. Now, powerful and autonomous microcomputers are increasingly being wirelessly networked with each other and with the Internet. This is resulting in the convergence of the physical world and the virtual world in the form of Cyber-Physical Systems (CPS). CPS are ICT systems (sensing, computing, actuating, and communicating) embedded in interconnected physical objects providing applications and services. This means that it is now possible to network resources, information, objects and people to create the Internet of Things, Services and Brains. In the realm of manufacturing (where CPS comprise smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently), this technological evolution is described as the fourth industrial revolution. In conjunction with smart production, smart logistics, smart grids and smart products, this revolution will transform value chains and lead to the emergence of new business models.

Industrie 4.0 thus depicts the factory as part of a smart networked world (Fig. 2)

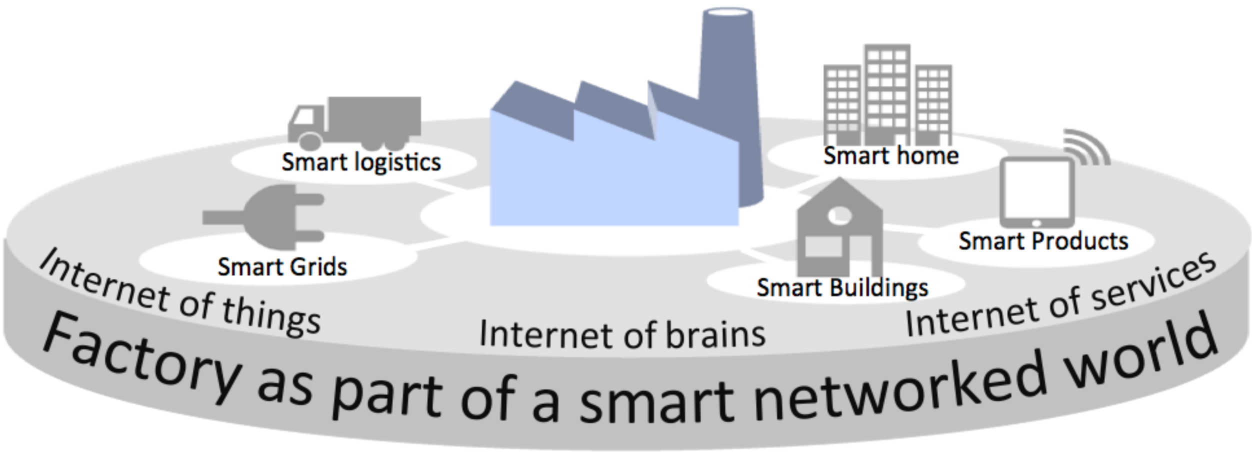

Fig. 2 - Factory as Part of a smart networked world

1.2.1. Future Factory Settings

Clear trends, shaping the future settings for manufacturing, can be derived from Industrie 4.0 analysis:

- Prevalence of Internet technologies also at manufacturing level. Communication everywhere and every time, where future infrastructure will also support access to information without any specific installation / parameterization needs.
- Prevalence of Cyber-Physical Systems for monitoring & controlling. Powerful, autonomous microcomputers (embedded systems) increasingly wirelessly networked with each other along with the Internet allow the convergence of the physical world and the virtual world (cyberspace) in the form of Cyber-Physical Systems.

[2] Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group. www.plattform-i40.de

- Big Data Everywhere (World, Enterprise, shop-floor). The availability of technologies able to efficiently gather and process large quantities of data and the increasing use of data-intensive technologies at every level of the factory will enable a faster and more insightful decision-making.

- Increasing Complexity (also System of Systems). Increasing functionality (e.g. coming from System of Systems, that is a collection of task-oriented systems that pool their resources and capabilities together to create a new, more complex system which offers more functionality and performance), increasing product customization, increasingly dynamic delivery requirements, increasing integration of different technical disciplines and organizations and the rapidly changing forms of cooperation between different companies make more and more complex the products and their associated manufacturing systems.

- Vertical Collaboration (shop-floor and Enterprise systems). End-to-end digital integration of actuator and sensor signals across different levels right up to the ERP level will allow the setting of IT configuration rules that make possible a case-by-case reconfiguration of the manufacturing structure that will not be fixed and predefined anymore.

- Horizontal Collaboration (system-to-system). New business strategies, value networks and business models will exploit a higher, IT-based integration through different stages of the value chain to deliver end-to-end solutions.

- Rapidly evolving technologies (additive manufacturing, high precision manufacturing, etc) and systems (integration standards, no-vendor-lock, no monolithic systems, mobile system integration, etc.). The ever-rapidly-changing technological infrastructure will lead to the use of flexible and non-monolithic IT systems whose evolution is facilitated by the introduction of integration standards.

1.3. Level 3a - The evolution of the automation pyramid

The Automation pyramid concept is used to describe the different system levels of an overall automation solution[3] (Fig. 3)

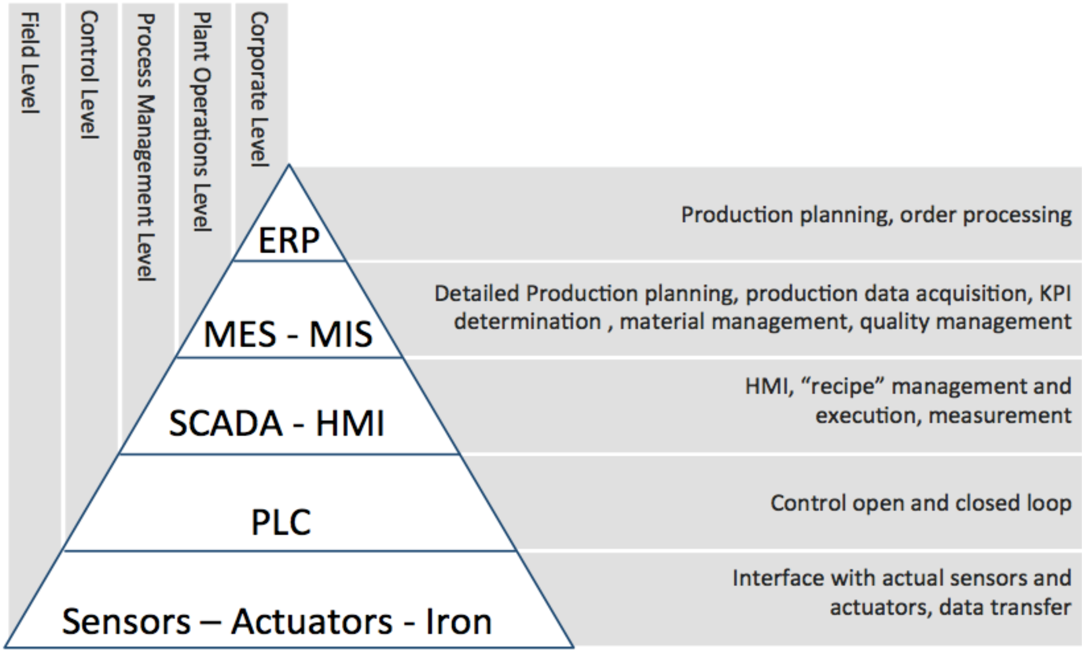

Fig. 3 – The automation pyramid

The current classical approach, as depicted above, has been recently addressed several times

[3] IEC 62264, ISA-88.01, ISA-95

(Manufuture2013[4], ICT2013 conference[5], CPS workshop[6]) and deemed by RTD experts and industrial key players to be inadequate to cope with current manufacturing trends and in need to consequently evolve.

PATHFINDER acknowledges that CPS intrinsic existence defies the concept of rigid hierarchical levels, being each CPS capable of complex functions across all layers. PATHFINDER thus proposes an updated version of the pyramid representation, where the field level features CPS capable of articulated functions (thus in contact with all the pyramid layers) while still a hierarchical structure is preserved (Fig. 4).

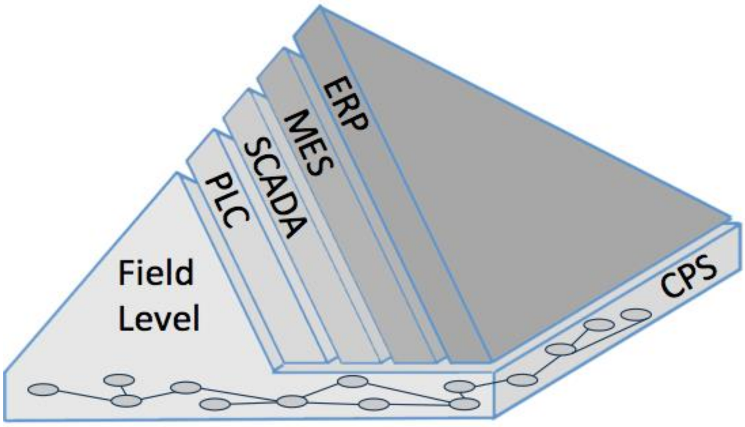

Fig. 4 - The evolved pyramid

1.4. Level 3b - Product & factory lifecycle and its digital representation

The representation of the factory and product lifecycles as per the picture below (Fig. 5) has been extensively discussed (e.g.[7] and later[8]) and it is today well understood. The horizontal set of arrows depicts the factory's life along the Design, Engineering, Construction and Ramp-up, Production, and Dismantling Refurbishment phases. Simultaneously, the product, which will be manufactured in the factory, are traced vertically passing through the main phases of its life cycle: Design, Product Development, Engineering, Production, Usage and Service and the Recycling phase. The central part of Figure, the overlapping of the factory life-cycle and of the product life-cycle is indeed the production phase. It is today widely accepted that Simulation and Forecasting tools support simultaneously both the life-cycles.

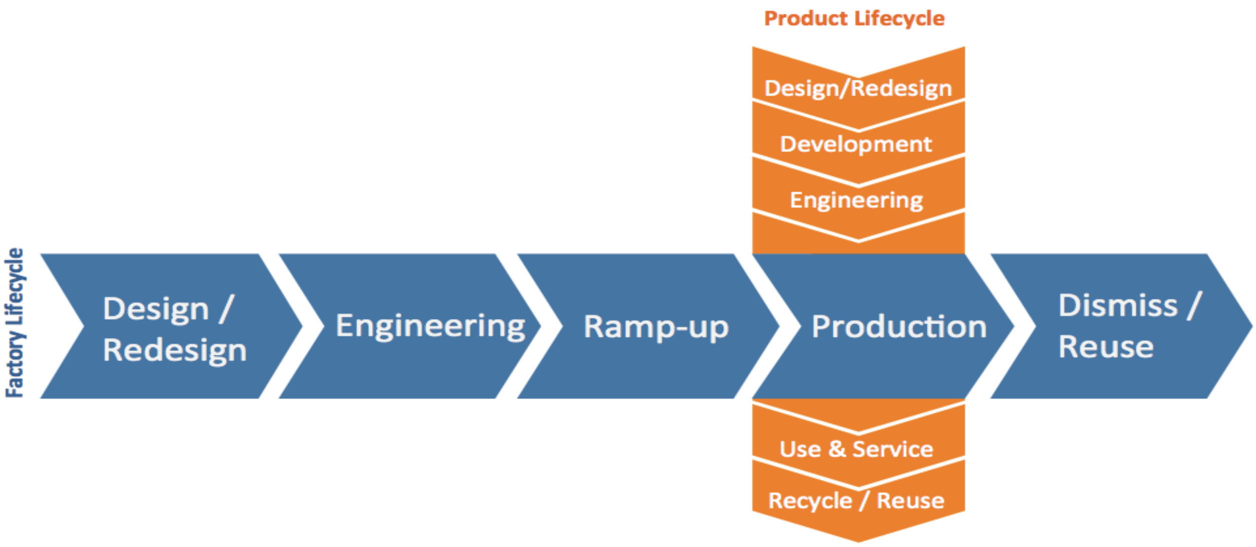

Fig. 5 - Product and Factory life-cycles

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[4] ManuFuture 2013 - www.manufuture2013.eu - Vilnius, 6th – 8th October 2013

[5] ICT2013 Conference - ec.europa.eu/digital-agenda/en/ict-2013 – Vilnius, 6th – 8th November 2013

[6] Cyber-Physical Systems: uplifting Europe's innovation capacity. Brussels, 29th – 30th October 2013

[7] Westkämper, E., Constantinescu, C.,and Hummel, V. "New Paradigm in Manufacturing Engineering: Factory Life Cycle", Production Engineering, 2006, 1,143-146.

[8] P.Pedrazzoli, D.Rovere, C.Constantinescu, J.Bathelt, M.Pappas, P.Dépincé, G.Chryssolouris, C.R.Boër, E.Westkämper, "High value adding VR tools for networked customer-driven factory", 4rd International CIRP Sponsored Conference on Digital Enterprise Technology 2007

Focusing on the Factory life-cycle (Fig. 6), at the very beginning the factory exists only in its digital representation. Through the later phases, also the real factory comes into existence, defined by the digital tools used. In production the real and digital factory interacts in order to make manufacturing possible and efficient. While in the early phases the digital representation of the factory is prominent, it logically paves the way for the real equipment development and role later in manufacturing.

Fig. 6 - Digital and Real Factory interaction over the factory life-cycle

The evolutionary concept of the automation pyramid, afore presented, refers to the production phase, as it represents a novel CPS based manufacturing. The following picture (Fig. 7) provides a synoptic view over the product-process life-cycles, the interaction of digital and real factory and the automation pyramid. The overall framework of factory operations is defined by the future factory settings defined in paragraph 1.2.1.

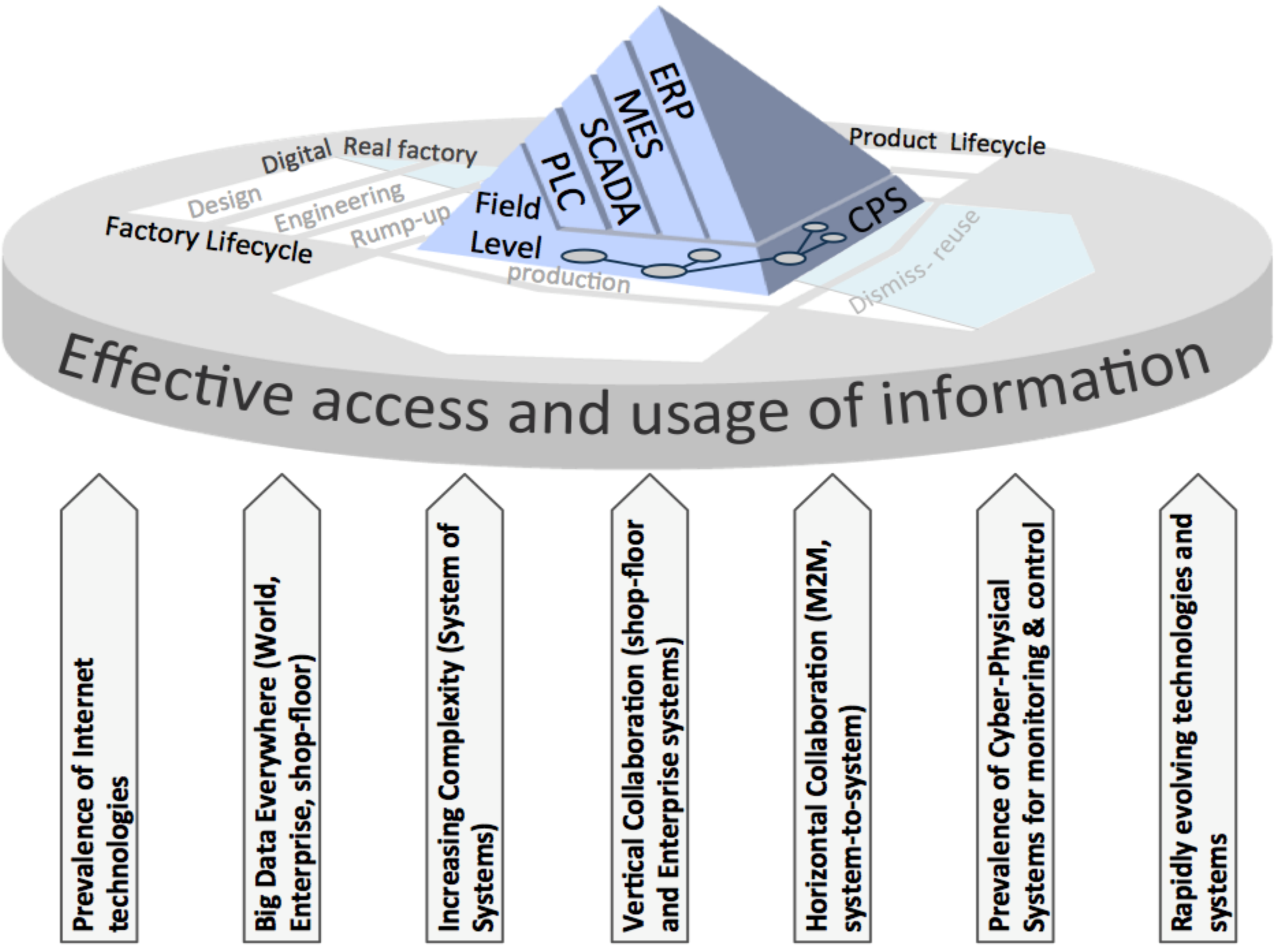

Fig. 7 - Evolved pyramid in relation to the Factory and Product life-cycles

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1.5. PATHFINDER synopsis

The high level vision presented in paragraph 1.1, that depict the future relations among the factory, humans, neighbourhood and value chain, is embraced by PATHFINDER, and recognized as the long term goal. This vision must be positioned in a lower level framework, capable to endow it, as presented in paragraph 1.2 and brought forward by the Industrie 4.0 Initiative. The accordingly envisioned Factory, whose production phase happens at the cross-over intersection of product and factory life-cycles as presented in paragraph 1.4, bases its manufacturing operations on the convergence of physical world and virtual world in the form of Cyber-Physical Systems, framed in the contexts of the evolved automation pyramid, as depicted in paragraph 1.3. This synoptical view is introduced in Fig. 8.

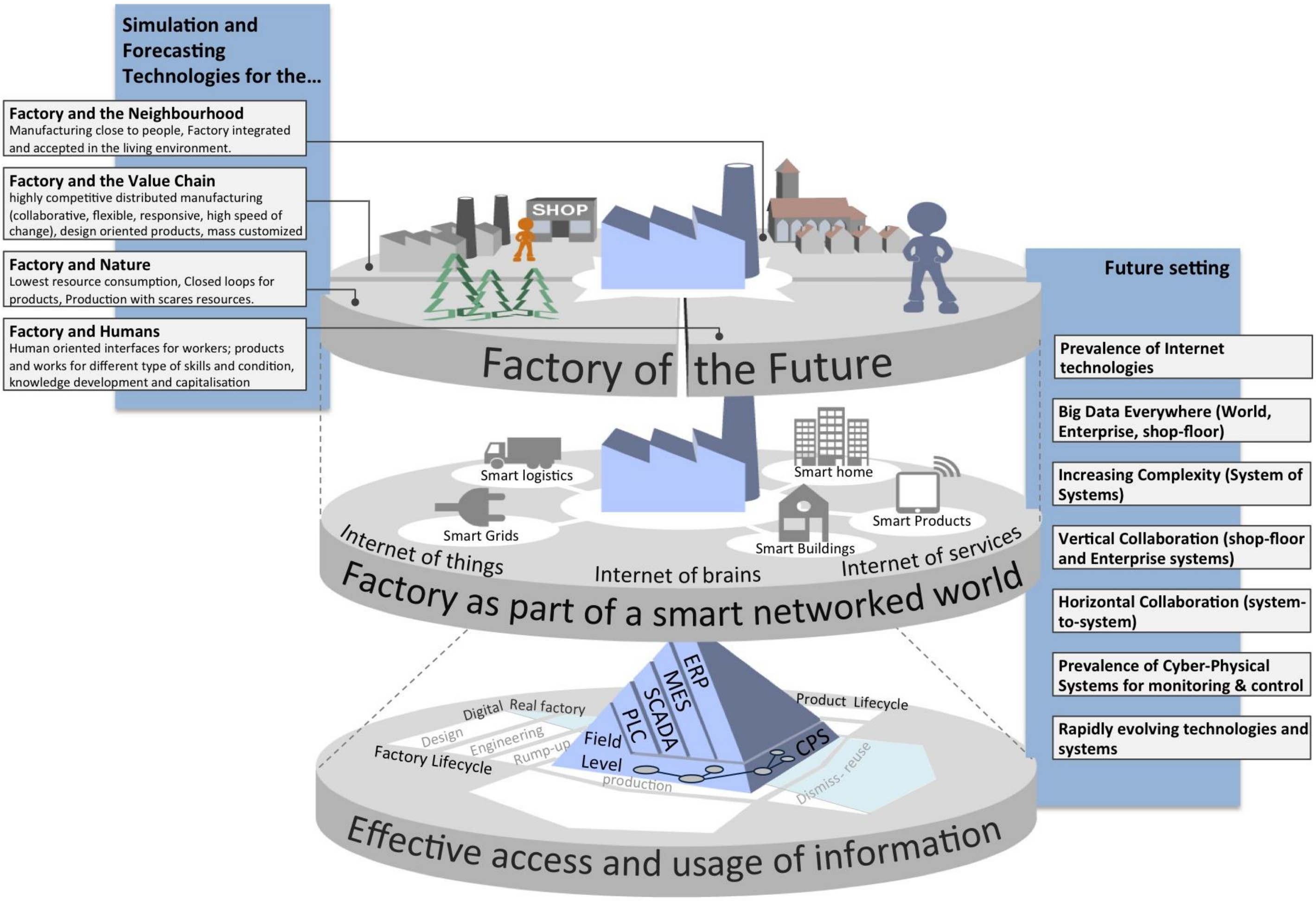

Fig. 8 - PATHFINDER synopsis

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