

White Paper

Introduction to Smart Manufacturing / Industry 4.0

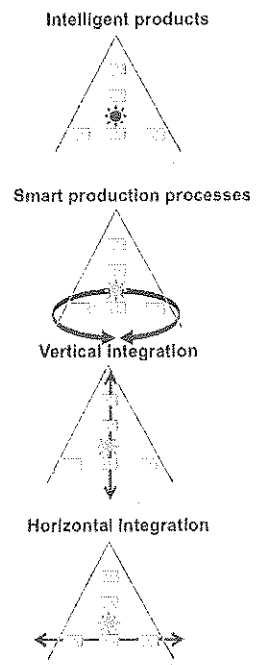
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Are you interested in production and manufacturing and the new concepts of Smart Manufacturing / Industry 4.0, then this whitepaper is for you. In the following four pages you will learn the basics about Smart Manufacturing / Industry 4.0, and you will understand how you and your organization can benefit from it. For a deeper understanding we recommend that you read the reference literature listed in the end of this whitepaper.

Smart Manufacturing / Industry 4.0 aims at advancing today's manufacturing

Smart Manufacturing / Industry 4.0 is often presented as the fourth industrial revolution; after the steam powered mechanical machines, the electrically powered mass-production, and the electronically/IT powered automated manufacturing. It focuses on the establishment of intelligent products and smart production processes, as well as on vertically and horizontally integrated manufacturing systems (see Fig.1 with the four integration perspectives of SM/I4).

- Intelligent products: Smart products (and work-in-progress) are uniquely identifiable, may be located at all times and know their own production and testing history, current status and alternative requirements needed to achieve their targets.
- Smart production processes: in an intelligent production process, the various steps in the business lifecycle (from design phase to retirement phase) should be well integrated with each other and define the capability of the production processes. This enables to pair the process capability with the requirements of the products.
- Vertical integration: vertically integrated manufacturing systems implies that the systems involved in the business value chain (from strategic management level to operational plant floor level) are integrated.
- Horizontal integration: horizontally integrated manufacturing systems implies that the systems involved in the supply chain (from procurement to shipping) are integrated.



Ultimately, Smart Manufacturing /Industry 4.0 should result in more rapid product development, facilitated customized production, improved handling of complex production and testing environments, more efficient supply chains, better use of production resources, and more holistic life-cycle management.

Figure 1: The four integration perspectives of Industry 4.0

Smart Manufacturing / Industry 4.0 – are there other similar initiatives?

Industry 4.0 (German term: Industrie 4.0) is originally a German initiative with the aim of securing the future of German manufacturing industry. It is believed that Industry 4.0 will allow Germany to increase its global competitiveness and preserve its domestic industry. Related research activities in Germany are currently supported by government funded bodies. Smart Manufacturing is a term used in many other countries such as the US.

Additionally, there are many other similar initiatives in other countries, industry branches, research domains, geographical areas and standardization organizations. A few of them are listed below:

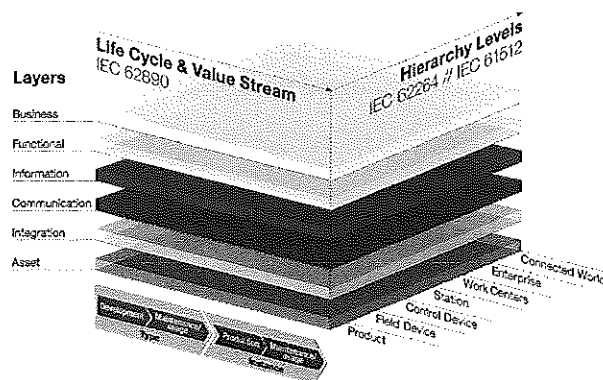
- Research initiatives:
 - Internet of Things (IoT) refers to a world in which a web of everyday objects and devices are completely interconnected with seamless interoperability.
 - Industrial Internet of Things (IIoT) is what you get when you apply the concepts of IoT to an industrial setting, e.g. to production, testing, warehouses, and maintenance.
 - Factory of the Future is a large research initiative supported by the EU, in which new technologies (e.g. IoT, Data Analytics, etc) should be applied to EU factories.
 - PiiA, Production2030 and IoT Sweden are Swedish initiatives supported by Vinnova (the Swedish research and innovation agency).
 - Manufacturing.gov, a USA national advanced manufacturing portal and information clearinghouse highlighting the National Network for Manufacturing Innovation, now known as Manufacturing USA.
- National initiatives:
 - Smart Industry is a term used in Sweden and which stresses the impact and potentials of digitalization in the (discrete and process) industry.
 - Made in China2025 is a Chinese initiative aiming at upgrading the industry.
 - Industrie du Future is the French initiative, managed by Alliance Industrie du Future, and includes e.g. the Standards Landscape Mapping.
 - Industrie 4.0 is the German initiative, managed and developed by the organization “Plattform Industrie 4.0), and includes e.g. the reference architecture model RAMI4.0.
 - The Smart Manufacturing Leadership Consortium (SMLC) to lead a public-private partnership focused on applied research and development of smart manufacturing technologies.
 - USA National (NIST) supports smart manufacturing through many programs in public-private partnerships.
- Company initiatives:
 - Industrial Internet (General Electric), Connected Enterprise (Cisco), etc.
- Standardization initiatives
 - IEC and ISO are two of the international standardization bodies acknowledged by United Nations. Both organizations have ongoing initiatives.
 - ISO TC184 (Automation Systems and integration) has Smart Manufacturing Coordinating Committee
 - IEC TC65 has AhG3 Industrial-process measurement, control and automation - Smart Manufacturing Framework and System Architecture
 - IEC TC65 and ISO TC184 have recently launched a joint working group (JWG21) focusing on Reference Architecture(s) for Smart Manufacturing.

The difference between these initiatives does not lay in the overall aim and goal; they all strive for similar end-results. However, the difference is the selection of enabling technical solutions (e.g. wireless or not, use of internet or proprietary networks, point-to-point communication or not, cloud-based or not, etc.), and the scope of the deliverables (e.g.. discrete manufacturing, supply chains, intelligent equipment, etc).

What terminology is often used and what does it mean?

Some of the key terminology used in relation to Smart Manufacturing / Industry 4.0 are explained below.

- Physical objects and Virtual objects; It is previewed that for each physical object or asset, a corresponding virtual object (sometimes called a Digital Twin) exists. The virtual object can be a placeholder (directly or indirectly) for data and information related to the physical object, and it exists throughout its full life or possibly longer.
- Cyber Physical Systems; There is no exact definition of cyber physical systems (CPS). Common explanation ranges from more basic mechatronics to fully connected and simulated systems. A basic explanation states that CPS is a system composed of physical entities such equipment controlled or monitored by computer-based algorithms. According to this explanation, CPS is closely related to Embedded Systems, however in embedded systems the emphasis tends to be on the control and computational elements, and less on the link between the computational and physical elements and connections to other equipment. Following to the same explanation, CPS can also be seen as related to Internet of Things (IoT), however, in IoT the fact that the computer-based algorithms are connected to the internet is stressed. A more elaborated definition states that, in addition to a physical entity controlled by computer-based algorithms, and network connections, a CPS also has a digital twin.
- Digital Twin; The digital twin of the real machine operates in the cloud platform and simulates the operations and conditions of the machine. The simulation is based on an integrated knowledge from both data driven analytical algorithms as well as other available physical knowledge. Digital Twins of real products (and work-in-progress) is also envisioned.
- Reference Architecture; The Reference Architectural Model Industrie 4.0, abbreviated RAMI4.0, consists of a three-dimensional coordinate system that describes all crucial aspects and standards of Industrie 4.0. In this way, complex interrelations can be broken down into smaller and simpler clusters. It also provides a framework for understanding where current standards can be used.



- Internet of Things and Services; The Internet of Things (IoT) is the network of physical objects (e.g. devices, vehicles, buildings and other items) embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data. The functionalities that these objects provide are referred to as services. IoT devices commonly use standard internet communication models, such as REST (Representational State Transfer) or MQTT (Message Queue Telemetry Transport).
- Self-optimized value-chains; This concept implies that processes in value-chains do not have to be repeated, non-value-add processes are eliminated, and processes can be optimized based on each individual product.
- Circular information life-cycles; data and information that is gathered throughout the entire lifecycle of the objects/assets in a loop, i.e. allowing future objects to use gathered information to improve products or processes.

What are the greatest challenges?

The most important challenges for realizing Smart Manufacturing / Industry 4.0 , as identified through an industrial survey are (most important challenge given first); standardization, work organization, product availability, new business models, security know-how protection, lack of specialist staff, research, training and Continuing Professional Development (CPD), regulatory framework. Fortunately, many of the listed organizations are working on challenges, working to provide the best practices in each of these areas.

The most important assistance for implementing Smart Manufacturing / Industrie 4.0 as identified though a survey are (most important challenge given first); sharing experiences, regular newsletter, involvement in working groups, training courses, involvement in research projects, and online forums.

Business Impact?

It is believed that Smart Manufacturing / Industry 4.0 will have a major impact on the business models used by manufacturing companies. Response times (e.g. development and engineering, production, and usability) will drastically shorten. Because of horizontal and vertical integration and smart product and production, new business models will emerge. These models will enable new industries, new manufacturing roles, higher productivity, and mass produced customized products.

More info

Examples of useful documents if you want more information about Smart Manufacturing / Industry 4.0:

- Industrie 4.0 Working Group. 2013. "Recommendations for implementing the strategic initiative INDUSTRIE 4.0." Acatech
- Industrie 4.0: The Reference Architectural Model Industrie 4.0 (RAMI 4.0), ZVEI German Electrical and Electronic Manufacturers' Association

- MESA White Paper #52: Smart Manufacturing - The Landscape Explained (www.mesa.org)
- More ...

Concluding remarks

This whitepaper aims to provide you an introduction to Smart Manufacturing / Industry 4.0. SM/I4 is representative of a global movement aimed at advancing the industrial sector in the internet age. Many proprietary and national efforts are in place, usually with different names, but similar goals. They all foresee tighter integration of four integration perspectives and they therefore share common research issues and challenges. Our belief is, that only by collaborating globally and across companies, organizations and nations, the aim of the fourth industrial revolution can be achieved.
