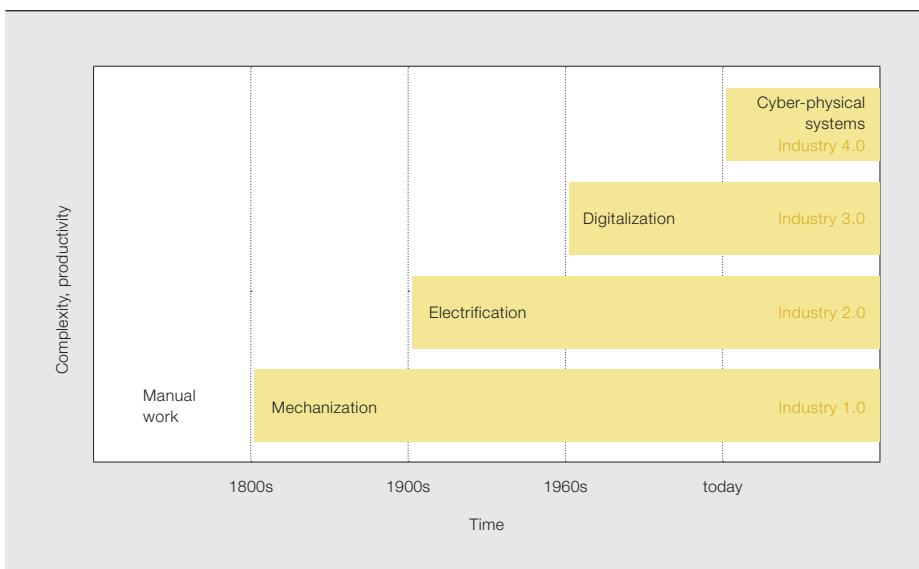


A new era

ABB is working with the leading industry initiatives to help usher in a new industrial revolution

MARTIN W. KRUEGER, RAINER DRATH, HEIKO KOZIOLEK, ZIED M. OUERTANI –
A new era of industrial innovation is upon us. Referred to as the fourth industrial revolution, the deeper meshing of the digital world with the world of machines holds the potential to bring about profound transformation to global industry. This new industrial stage, where the Internet meets production, is a major topic of discussion at production and process industry conferences and meetings. The Industry 4.0 initiative is one of several projects working to bring the fourth industrial revolution to fruition. ABB is collaborating with the Industry 4.0 initiative group and the respective working groups of related industrial associations¹ to investigate the impact of this new and highly anticipated industrial stage as well as the technical feasibility of bringing it to ABB's customers.



The world is on the threshold of another industrial revolution – this one a result of the convergence of the global industrial system with the power of advanced computing, analytics, low-cost sensing and new levels of connectivity permitted by the Internet.

The industrial revolution began when manual labor was replaced with mechanical power, starting late in the 18th century, with the invention of the mechanical loom.

This revolution continued to develop in stages over the next 150 years, with further mechanizations and through the combination of steam and water power. The second stage dates to the emergence of electrification and automation. At every stage productivity accelerated sharply beyond what had preceded.

Title picture

Robotics is just one area in which ABB is moving toward the fourth industrial revolution.

Footnotes

- 1 The working groups include associations such as VDMA, ZVEI, and BITKOM.
- 2 The automation pyramid groups the devices and systems of a production environment into levels.

The third, and most recent, industrial revolution stage began in 1969 with the first digital and freely programmable control systems, which replaced the traditional hardwiring of analog logic and control programs. This stage built the foundation of today’s automation pyramid² and modern process control systems and has continued right up to the present day. An overview of these industrial revolutions is presented in → 1.

The next industrial stage

The arrival of the Internet in the consumer world in the 1990s brought unprecedented change to daily life: social networks, online TV and almost instant access to huge amounts of information.

A similar revolution is now expected in industry, as government and industrial consortiums around the world see a trend of increased utilization of Internet technology in industrial production systems. Devices in the production environment are increasingly being (wirelessly) connected to each other and a network, eg, a private network or the Internet. Eventually industrial production systems will be capable of autonomously exchanging information, triggering actions and controlling each other more independently.

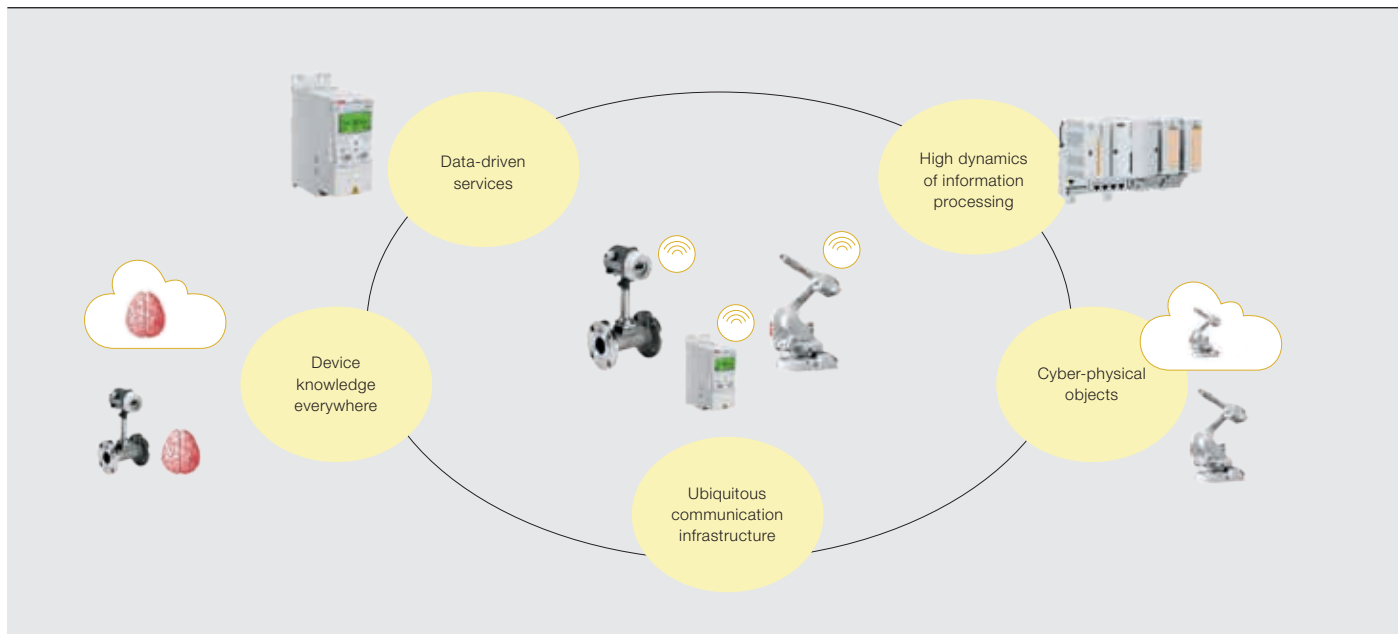
The working groups developing this new concept are widely diverse, so the description of the concept, and even its name, varies. For example, the name Industry (Industrie in German) 4.0 was conceived by the German-led working group, while in the United States a similar initiative is called Industrial Internet [1,2]. Both initiatives are based on technologies associated with the Internet of Things (the ubiquitous connection of all devices to the Internet, eg, watches, cars, fridges) and cyber-physical systems, a combination of physical objects and software systems. The initiatives mark efforts aiming to prepare global

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industry for what is expected to come. Besides actively participating in the related initiatives and committees, ABB’s research and development projects are shaping the technical possibilities for the future.

Technical drivers for Industry 4.0

A number of technical developments are driving the efforts of Industry 4.0 [3] → 2. Communication infrastructure will become ubiquitous throughout industrial production facilities as it becomes cheaper and readily available. This network availability



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builds the basis for tasks such as data acquisition, engineering, operation, maintenance and advanced services.

Once a network is in place, more devices, machines, facilities and plants will be connected, either on the Internet or on a private company network. All connected physical objects will be represented by data objects in the network. As a result, these data objects form a second virtual identity within the cyber world, the cyber-physical objects. These objects will be easy to locate, explore and analyze and will hold information about their functionality as well as their requirements.

Devices, machines, facilities and plants will be able to store knowledge about themselves beyond the physical representation and directly at the data object in the network. Each will publish updates on their current status, history, related documentation or technical requirements in the network. Such information can then easily be updated by the device's owner, service technician or parent system.

As part of a cyber-physical system, intelligent algorithms and embedded software will be able to explore these new data sets to generate value-added services that would not have been feasible or economical before → 3. This field is a topic of ongoing research [4], but from today's perspective, remote or data-driven services mark the first steps toward these new services.

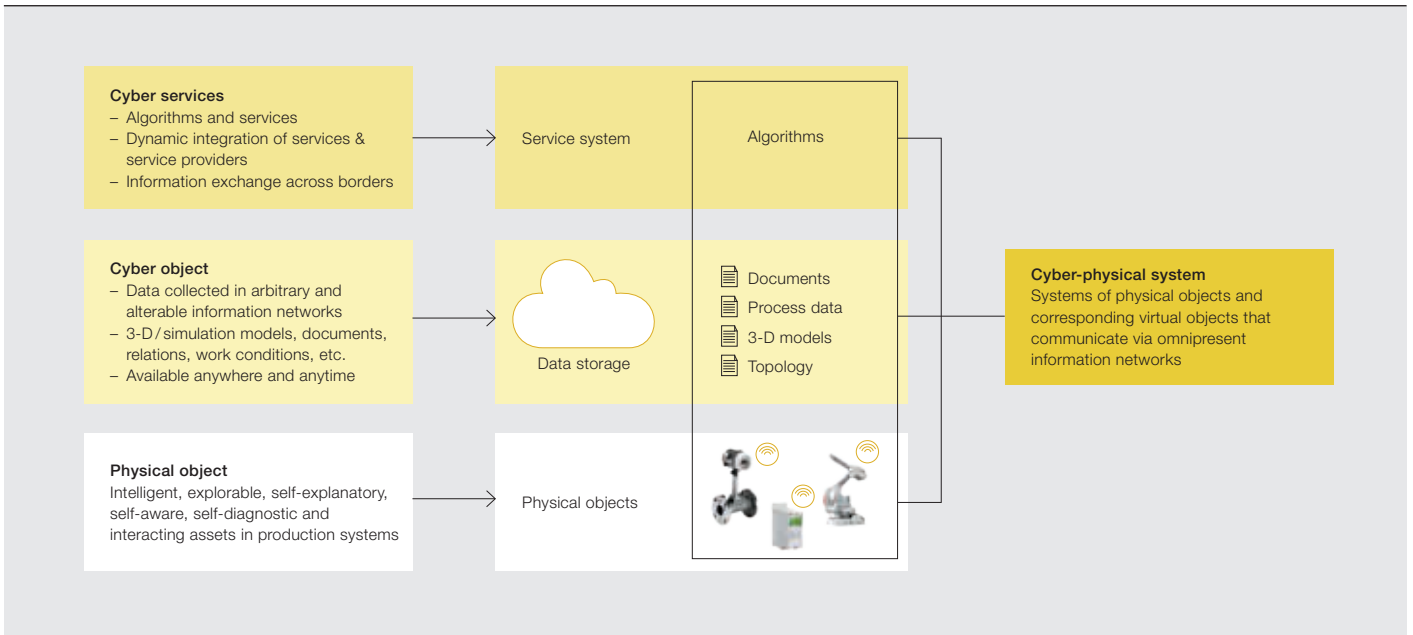
The increasing level of integration of cyber-physical objects in an Internet-technology-enabled network will inevitably lead to higher levels of information processing. This will then open new doors for widely known concepts from the consumer market to enter the business-to-business market such as plug and play, eg, plugging a USB mouse into a computer with drivers being automatically downloaded from the Web and

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always kept up to date, or plug and produce, eg, exchanging an old device with an equivalent new one, which then functions automatically, without the need of manual engineering, commissioning or servicing.

Cyber-physical systems have been present in the business-to-consumer market for some time. One application of the concept is the purchasing of gas by consumers from German gas stations. Gas prices are submitted to a central data repository, where all gas stations are represented as data objects in the network.

3 Cyber-physical system



4 Industrial demands on the fourth industrial revolution



The value of isolated data objects alone is minimal. However, with the advances of mobile technologies and smartphone applications, millions of users can now make informed decisions for purchasing gas by consulting the current gas prices at their individual locations. In this example the architecture of the cyber-physical system breaks down in the following way: the physical object (gas station), the cyber part (the data object with prices) and the software layer (the smartphone apps).

Industrial demands

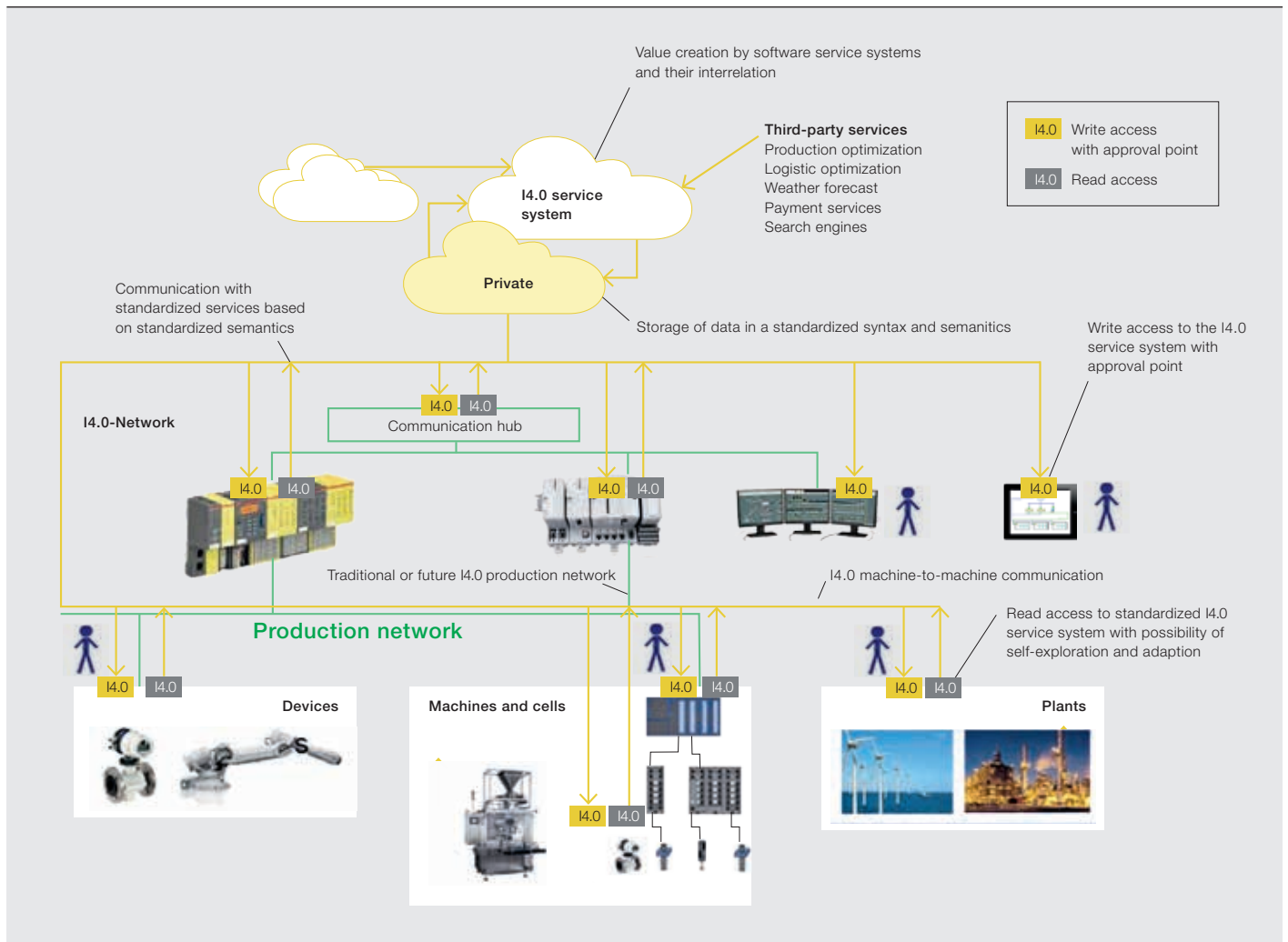
The introduction of communication and Internet technologies into industrial production has tremendous potential to increase productivity and flexibility, but it

also raises concerns, in particular for plant owners, who combine investments, know-how, production capabilities and profit in their plants. Among the current visions of Industry 4.0, the value propositions still need to be identified. To create a sustainable acceptance of the next industrial revolution, some practical requirements need to be fulfilled → 4.

- In order to protect investments, new technology needs to be incrementally introduced into existing production facilities, making sure not to disrupt the existing machines and technology.
- To maintain stability Internet technologies must not disrupt production, neither through network outages nor through intended remote access to assets.
- The access to plant-specific data must be carefully controlled by the plant operator. Write access to production-relevant assets, machines and facilities needs an additional audit to cross-check the validity of the intervention in the context of the running production.
- As always, security is a vital aspect. Unauthorized access to data and services needs to be prevented to ensure information security and to control critical aspects of the production facilities.

Furthermore, production systems in general have stronger requirements on non-functional properties, such as availability, real-time capability, reliability, robust-

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Production systems in general have stronger requirements on nonfunctional properties.

ness, life cycle, productivity or cost compared with IT systems in other markets. ABB is taking these customer requirements into consideration in all of its Industry-4.0-related research and development projects.

Integration topology

To facilitate the further development of Industry 4.0 ABB has developed an integration topology that has been adopted by the German Industry 4.0 initiative [4]. The topology will allow an incremental introduction of new technology and production processes.

The core of the integration topology is the separation of the established production network from the new Industry 4.0 network → 5. From the technical aspect the separation can be implemented by either physically separated networks or logically separated networks within existing Ethernet-based networks. As shown in → 5, the green production network symbolizes an automation sys-

tem that fulfills the industrial requirements on availability, reliability, sustainability and security. The yellow Industry 4.0 network enables new services and provides added value to the user. The production is not dependent on the Industry 4.0 network, therefore failures of the network will not interrupt production.

In the first step of an implementation of the topology, assets, devices, production lines and factories are connected to the Industry 4.0 network with read-only access (yellow markers). Authenticated participants can read, for example, device IDs, diagnostic data, parameters or production data. This data will form the foundation of future Industry 4.0 value-creation processes. In a second step, write access will be introduced with an approval instance to avoid unintended effects on the running production.

The topology will allow an incremental introduction of new technology and production processes.

The data of the yellow Industry 4.0 network is collected in a private, secure storage system. Access to this data is controlled by the data owner, eg, the plant operator. Publication of this data to the Industry 4.0 services system is controlled by interfaces and permission systems. Added value can be created either by services within the private data system, or through third-party services within the Industry 4.0 services system.

This integration topology addresses the industrial requirements of investment protection, system stability, controllability and data security issues. The German Industry 4.0 steering committee has published this topology under the Industry 4.0 umbrella [4].

What needs to come

Many components comprising the fourth industrial revolution are not new. Cloud technology, network devices, communication interfaces and data-driven services are well established in many markets. However, in order for the next stage to move forward, a number of agreements and principles need to be established, such as:

- Cross-vendor agreement of standardized syntax and semantics to identify, collect and store data
- Cross-vendor agreement of standardized services based on standardized interfaces, communication and semantics
- Introduction of principles such as, eg, self-exploration or plug and explore to facilitate cross-vendor value creation
- Availability of services to create added value from the cross-vendor availability of data
- Interlinking of services with other third-party services
- Availability of data throughout the value chain and supply chains in real-time

- Dynamic, partly autonomous adaptation of production services to changes in environmental parameters (eg, plug and produce of replacement devices or update of software during continued production)
- Reorganization of production processes to systematically exploit data and services

This new industrial revolution is a phenomenon that will flourish. The key to bringing added value to the customer lies in better understanding the requirements for standardization enabling the interaction of the Industry 4.0 technologies. It is also important to investigate application cases in different industrial ecosystems to confirm the potential of the trend [5]. New business opportunities will emerge for ABB customers, consolidating their competitive advantages in existing markets and also facilitating new market entries. ABB is developing business cases and investigating the technical feasibility of the next industrial revolution based on its product portfolio. Substantial participation in standardization work is being carried out, while aiming for a better understanding of what customers want and the challenges they are facing.

Martin W. Krueger

Rainer Drath

Heiko Kozioliek

Zied M. Ouertani

ABB Corporate Research

Ladenburg, Germany

martin.krueger@de.abb.com

rainer.drath@de.abb.com

heiko.kozioliek@de.abb.com

mohamed-zied.ouertani@de.abb.com

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