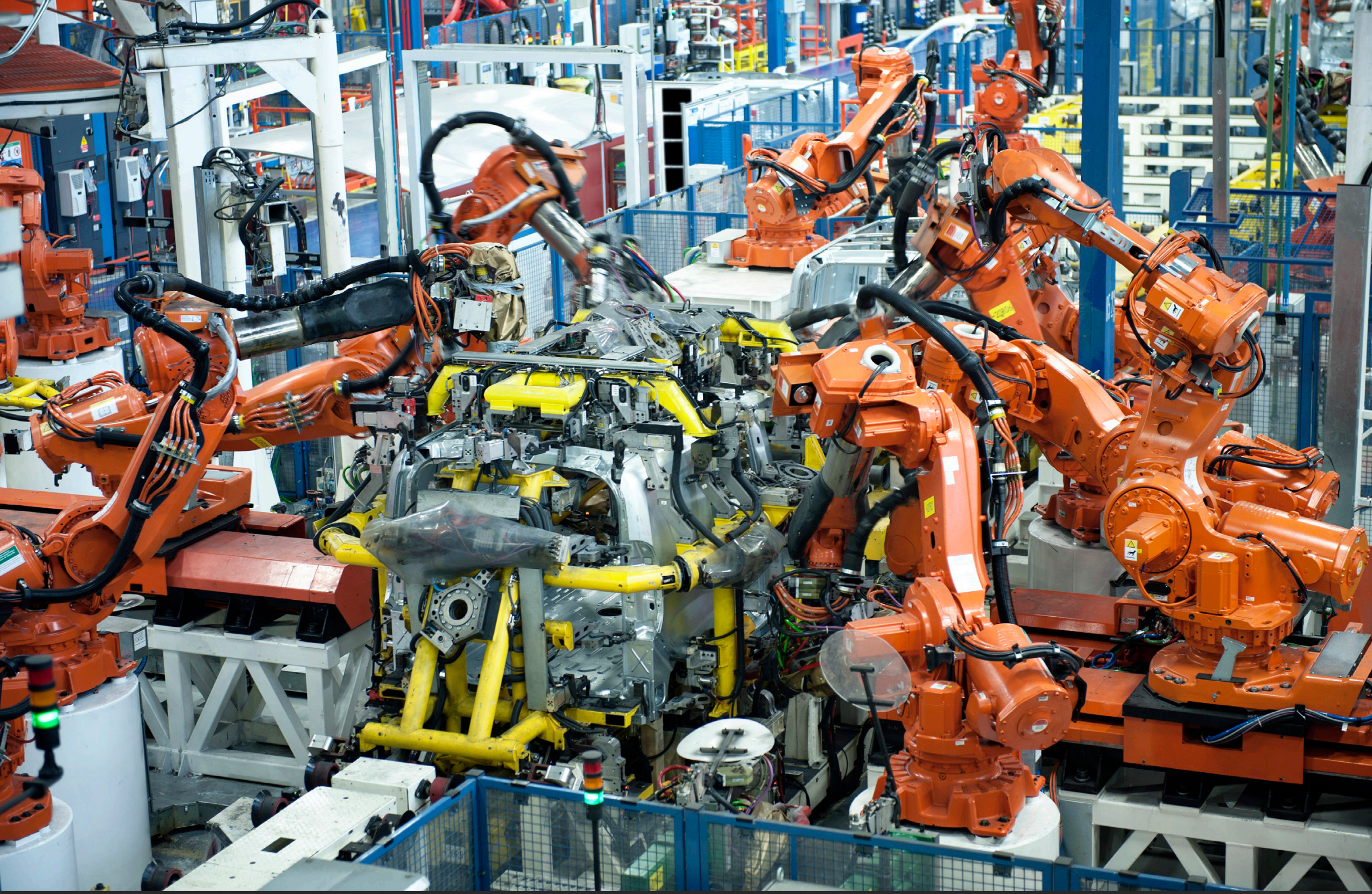


Industry 4.0 and Cognitive Manufacturing

Architecture Patterns, Use Cases and IBM Solutions

Serge Bonnaud, Christophe Didier and Arndt Kohler

IBM

Table of contents

Nomenclature

AI	artificial intelligence
CMMS	computerized maintenance management system
DL	deep learning
EAM	enterprise asset management
ERP	enterprise resource planning
ESB	enterprise service bus
ICP	IBM Cloud Private
IoT	Internet of Things
IIoT	Industrial Internet of Things
IT/OT	information technology/operational technology
KPI	key performance indicator
MES	manufacturing execution system
ML	machine learning
MVP	minimum viable product
OEE	overall equipment efficiency
PLC	programmable logic controller
PoC	proof of concept
PSB	plant service bus
SCADA	supervisory control and data acquisition
SIEM	security information and event management
SOC	security operation center

Forewords

Hubert Lalanne
IBM Distinguished Engineer
Industrial Sector Technical Leader for Europe
Member, IBM Academy of Technology

I am delighted to write the foreword for the first edition of Industry 4.0 and Cognitive Manufacturing: Architecture Patterns, Use Cases and IBM Solutions.

Industry 4.0 is generally referred to as the fourth industrial revolution. Another perspective would be to consider it as the transformation of the industrial world due to the global digital revolution, which already impacted many other industries.

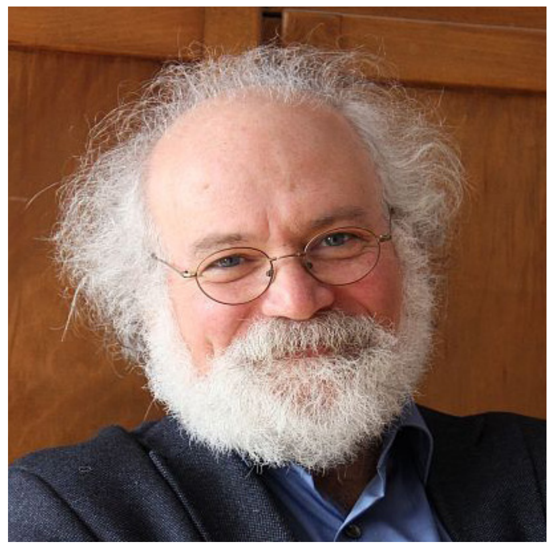
According to a 2015 study from McKinsey (Industry 4.0: How to navigate digitization of the manufacturing sector), the majority of value created in prior industrial revolutions came from upgrading manufacturing assets. The promises of this new revolution are to enable productivity gains and new business models by introducing disruptive technologies in the industrial space not linked to major machinery upgrades.

Value lies in end-to-end optimization of the "digital thread" – that is, making better use of information and eliminating inefficiencies caused by information losses at the interfaces of functions, sites and companies.

To make this happen, we should converge the cyber world of digital technologies and the physical world of operational industrial technologies, integrating and analyzing data across sources and companies, sharing outcomes across the value chain and ensuring integration with physical production assets.

Industry 4.0 introduces new concepts, such as digital threads to ensure efficient information from initial product design to end-of-life and recycling; "digital twin" to transform dispersed data elements in consistent and intangible assets; and "cyber physical systems" to enable decentralized, self-controlled systems and processes.

Multiple disruptive technologies make this transformation possible now in the area of computational capacity: the emergence of the cloud, big data, and blockchain; connectivity with Internet of Things; advanced analytics with machine learning and artificial intelligence; human-machine interaction with mobile and wearable technologies; augmented and virtual reality, or cognitive HMI; and digital-to-physical conversion with advanced robotics or 3D printing.



John Cohn
IBM Fellow, IBM Research

I strongly recommend reading this Industry 4.0 document written by Serge Bonnaud, Christophe Didier and Arndt Kohler. It's the most succinct and comprehensive description of Industry 4.0 I've read. It quickly takes the reader from concept to implementation, with practical advice on how to take this journey.

The use cases are very solid and take the reader from shop floor, with industrial machines and PLC, up to analytics, with advanced solutions in the cloud impacting the business. A lot of good insights are clearly described and illustrated with examples with customers. It's a very good read. Congratulations to Serge, Christophe and Arndt for putting this together!

Introduction

Increasing the productivity of production systems has been at the heart of every industrial revolution. The fourth industrial revolution brings an increase in productivity in both production and management systems.

From a business perspective, the goal of the fourth industrial revolution is to be able to manufacture personalized products at mass cost. To achieve this goal, it is necessary to rethink the production tools and bring more automation and productivity to the factories, but also to improve collaboration between supply chain, engineering, and sales and operations.

From IBM's point of view, we're really entering, at this moment, the fourth revolution of industry, or the cognitive manufacturing era, and it is fully differentiated from any that came before it.

The digital transformation of production processes creates new opportunities to achieve levels of productivity and specialization not previously possible.

A timeline of industrial revolutions

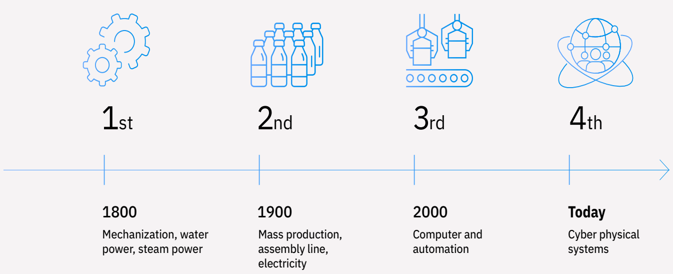


Figure 1: A timeline of industrial revolutions.

Data and, more importantly, analytics, are changing the way we see our machines, processes, products and operations. Analytics combined with big data approaches can identify patterns in the data, uncover model behaviors of equipment and predict failures or product quality issues.

These capabilities, known as predictive maintenance and quality, enabled by Industry 4.0 technologies, have an important place in companies' strategies. As more factories and equipment are instrumented with Internet of Things (IoT) and connected devices, data will continue to amass.

Conventional computing will struggle to scale with the large influx of data and the complexity of the analytics. Computing must become cognitive to process, analyze and optimize the information at the shop floor level.

In order to truly pave the way forward to Industry 4.0 and beyond, manufacturing must evolve into the concept of an information technology (IT)-based digital factory – into cognitive manufacturing. Manufacturing must enable the cognitive capabilities inside the factory, particularly around two key issues: production quality insights and production optimization.

Transforming and improving manufacturing through production quality insights and production optimization is realized through the concept of an Industrial Internet of Things (IIoT) platform. This paper will attempt to explain the principles of an IIoT platform, as well as explore use cases.

Concept of IIoT platform

The diversity of shop floor manufacturing

Many factories have a broad range of equipment, layouts and processes with legacy devices, sensors, systems and applications that span multiple ages and generations.

In addition, many of them probably rely on different operation technology (OT) providers for machinery, equipment lines and robotic technology. A factory is mainly composed of OT machines, equipment lines and robots not always connected to the IT network.

The programmable logic controller (PLC), supervisory control and data acquisition (SCADA) and manufacturing execution system (MES) orchestrate the production flows and have a demonstrated history of contributing to the performance levels that must be achieved.

The trend visible at the manufacturing level is to make the shop floor more and more IT-based; the convergence of OT and IT is a reality. This creates more opportunity to achieve one global common architecture encompassing several dimensions: equipment, edge, shop floor and cloud.

In such a context, an IIoT platform has recently emerged as a new, innovating concept for manufacturing. An IIoT platform is supported by technologies that include analytics, big data, industry-specific content and, more recently, cognitive, a discipline emerging from artificial intelligence.

An IIoT platform acts as a central system to gather data, provide analytics and expose new services to internal business units, partners and manufacturing operators. An IIoT platform is never connected directly to operators, products or equipment, but through a connectivity layer or plant service bus (PSB). Discussion of this matter will be resumed later in this paper.

System context diagram

The below system context diagram illustrates the dependencies of an IIoT platform from the standpoint of an automotive manufacturing process involving welding, body assembly and painting equipment lines. It could be easily applied to other manufacturing processes as most concepts are relevant across industries.

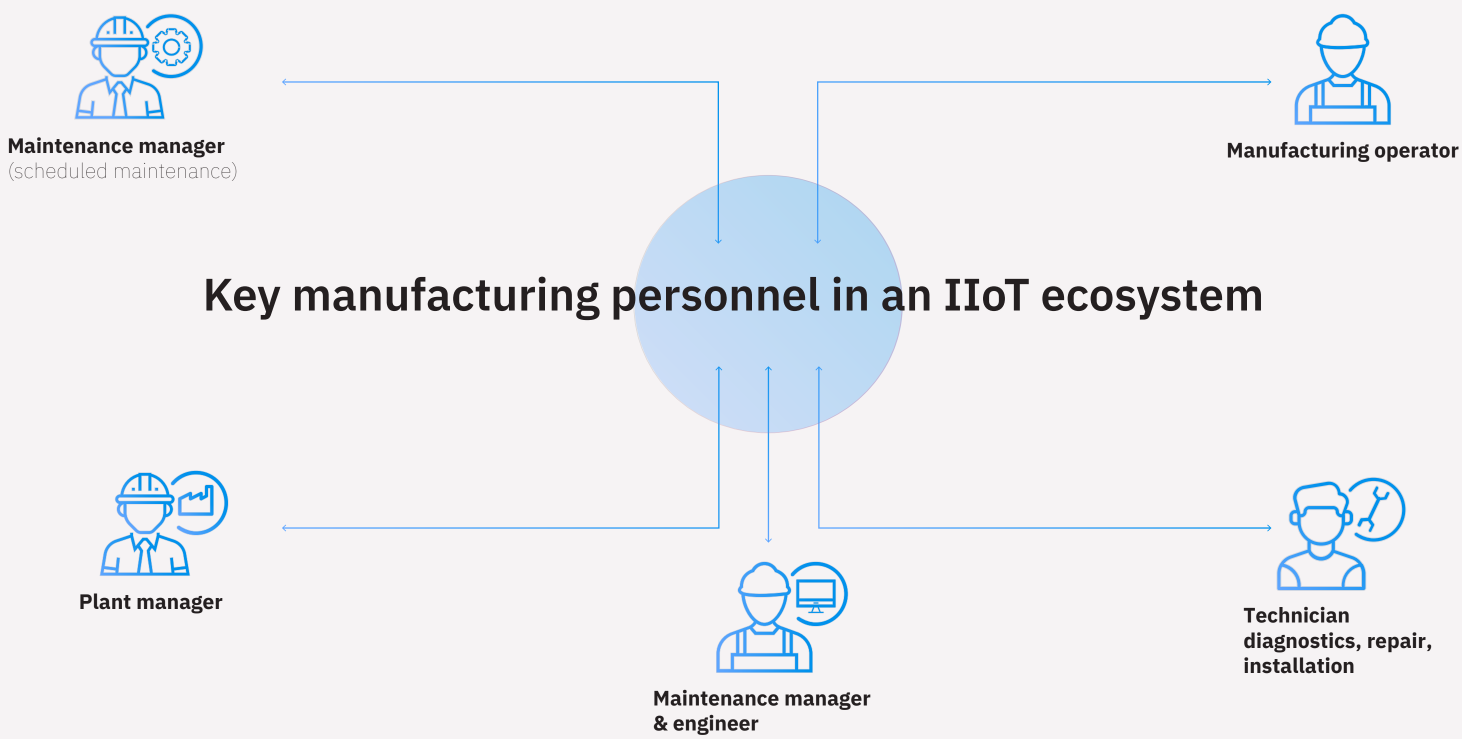


Figure 2: Key manufacturing personnel in an IIoT ecosystem.

Personae and pain points

In manufacturing, there are different roles, or profiles, that contribute to the global performance and quality of production. The roles are linked to the concept of persona. A persona is a stakeholder of the system (IIoT platform) who is accountable for ensuring KPIs are reached. The personae and pain points table can be found on the next page.

Persona	Role	KPI	Pain points
Plant manager	· Watch over and organize daily operations of manufacturing plants and similar places. · Oversee employees, production and efficiency to make sure plant is running smoothly, quickly, efficiently and safely.	· OEE · Budget · Safety · Innovation · Productivity	· Lack of skilled people · Collaborative interaction · Vendor relationships · Frequent changes & demanding plans · User-friendly access to information
Maintenance manager (scheduled maintenance)	· Ensure that facilities, layout and machinery run at maximum efficiency and output. · This includes total preventive maintenance, managing breakdowns of mechanical, electrical and robotic equipment (including software programming). · Includes people management and budgetary/cost reporting.	· Budget · Complete to-do	· Limited time to perform maintenance tasks · Pressure on costs (optimal cost effectiveness)
Maintenance engineer (operational maintenance)	· Assure optimization of the maintenance organization structure. · Analyze repetitive equipment failures. · Estimate maintenance costs and evaluation of alternatives. · Assess needs for equipment replacements and establish replacement programs when due.	· Uptime OEE · Budget	· Diagnostic takes too long because of various systems · Missing spare parts · Administration & analysis leads to longer downtime · Time-consuming process to find supporting information
Technician	· Assist in the installation of new manufacturing equipment. · Routinely inspect and test equipment and machinery. · Respond to alerts and operation messages, carrying out corrective procedures and repairs in line with standard operating procedures (SOPs) and maintenance protocols. · Clear documentation of both routine checks and repairs needed, in line with both internal and external protocols and procedures.	· Activities duration · Compliance · Safety	· Often under pressure and stress (work faster, improve quality) · Lack of assistance during the diagnostic stage · Complex documentation to understand · Lack of expertise sharing
Manufacturing operator	· Set up the production equipment and supplies before executing the job orders. · Operate equipment safely and effectively for production processing.	· Quality & performance levels · Safety	· Often under pressure and stress (work faster, improve quality) · Lack of knowledge · Lack of support when incident occurs · Lack of information for reporting

Current manufacturing architecture

The following picture depicts the current way shop floor activities are organized. We overlaid the main building blocks from a logical architectural standpoint.

Simplified view of a factory based on MES, PLC & SCADA

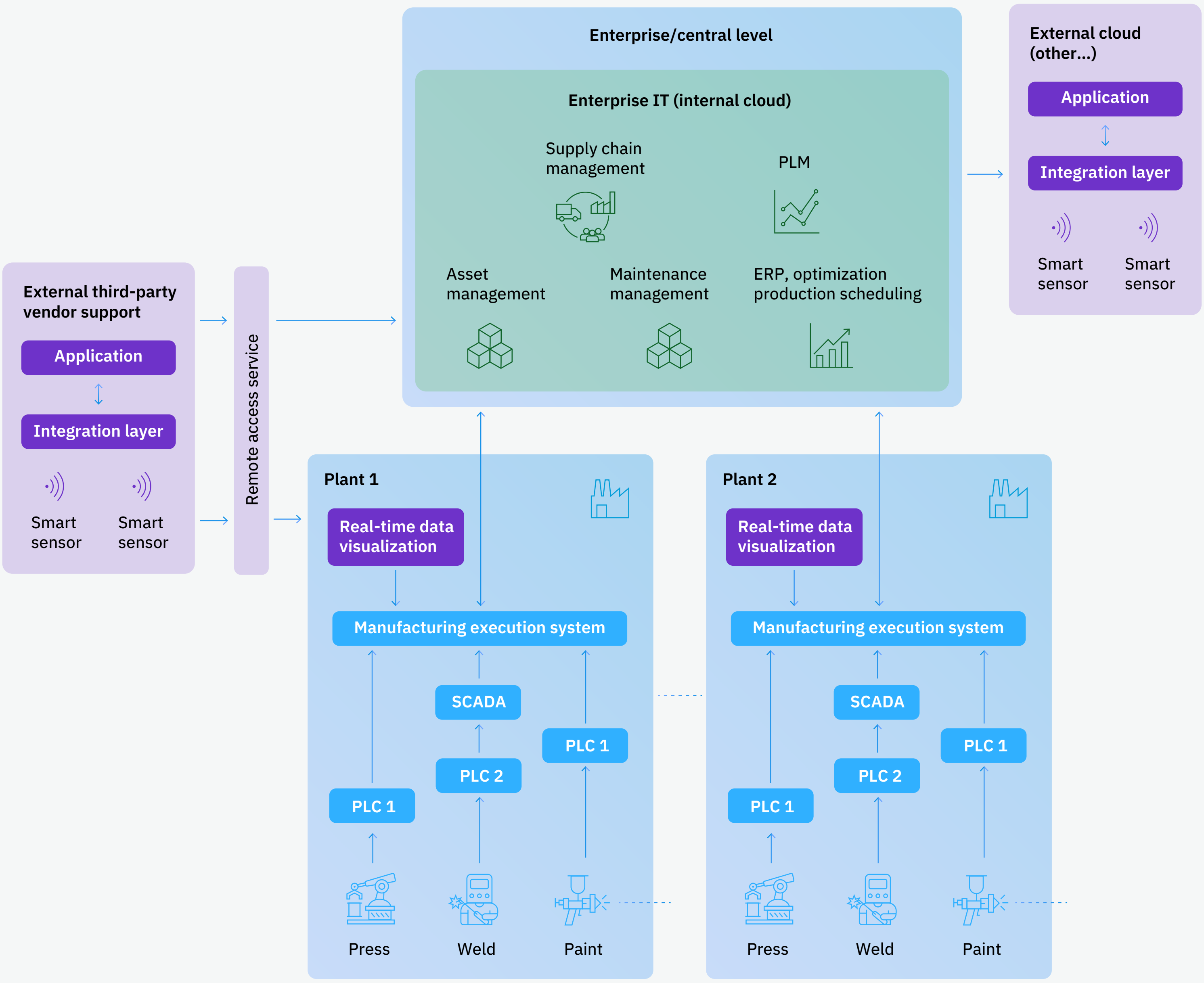


Figure 3: Simplified view of a factory based on MES, PLC & SCADA.

Each plant is equipped with manufacturing and assembly lines from different OT providers. A line is composed of a set of stations, which are composed of robots, a chain of devices and machines. Operators execute predefined, sequenced tasks that are usually formalized through written instructions based on the conventional documentary formats.

A programmable logic controller (PLC), or programmable controller, is an industrial digital computer that has been ruggedized and adapted for the control of manufacturing processes such as assembly lines, robotic devices or any activity that requires high reliability control, ease of programming and process fault diagnosis.

Supervisory control and data acquisition (SCADA) refers to industrial control systems (ICSs) that are employed to control and keep track of equipment or a plant in industries like water and waste control, telecommunications, energy, transport, and oil and gas refining. SCADA is a computer system used to gather, analyze and present real-time data to operators. Additionally, it can sometimes control back equipment. SCADA gives notifications by sounding alarms if situations develop into hazardous scenarios.

Manufacturing execution systems (MESs) are computerized systems used in manufacturing to track and document the transformation of raw materials to finished goods. MESs provide information that helps manufacturing decision makers understand how current conditions on the plant floor can be optimized to improve output.

Some MESs can operate in real time to enable the control of multiple elements of the production process (e.g., inputs, personnel, machines and support services). Some well-known MESs are provided by companies such as Dassault Systems, SAP, Siemens and ABB.

Real-time data visualization is a component that can collect raw data and telemetry data, perform data preprocessing, and visualize through graphical and intuitive synoptics a large volume of time-series data from multiple sources for people and systems across all operations.

A performing data visualization component could connect with many interfaces and collect data from multiple formats or protocols. It could be both time series-based and event-based, including multiple systems like PLC, SCADA, gateways, devices and sensors.

Similar to SCADA and MES, the real-time data visualization component helps operators move from reactive to proactive decision-making. Some well-known components in that area are provided by companies like OSIsoft or Wonderware.

Asset management consists of the activities and practices used to track the work of a company's assets and effectively use those assets to gain value. Asset management assists in identifying and prioritizing the work necessary for specific assets not only for the ROI of the asset, but also to analyze and coordinate strategically with work on other opportunities.

Maintenance management is the use of intelligent computer software to better track your business's resources (e.g., labor, materials and equipment). Using a computerized maintenance management system (CMMS) for your maintenance management ensures that your company's equipment will always remain in top working order, thus preventing unexpected repairs and operational downtime.

While maintenance management and asset management are technically different, they are still interrelated and flow well together. Maintenance management helps guide the physical performance of maintenance equipment and activities efficiently, while asset management helps analyze all the data for the work needed to be performed on the assets themselves.

Embracing IoT for manufacturing through logical steps of value gradation

Digitalizing manufacturing through an IIoT platform assumes that four logical steps should be covered through a timely, sequenced roadmap to ensure value.

- **Data gathering:** Data can come from systems such as enterprise asset management (EAM), enterprise resource planning (ERP) and MES. (This paper will describe EAM in greater detail in subsequent sections.) It can also come straight from equipment/robots/sensors.
- **Pattern visualizing:** This can be done through dashboards, UI and other representations to see data.
- **Analytics-driven insight development:** This can include predictive analytics, prescriptive analytics and industry-specific analytics models.
- **Cognitive:** This involves new ways to process unstructured information, including imagery, video and audio, as well as machine-learning algorithms.

The four-step road map

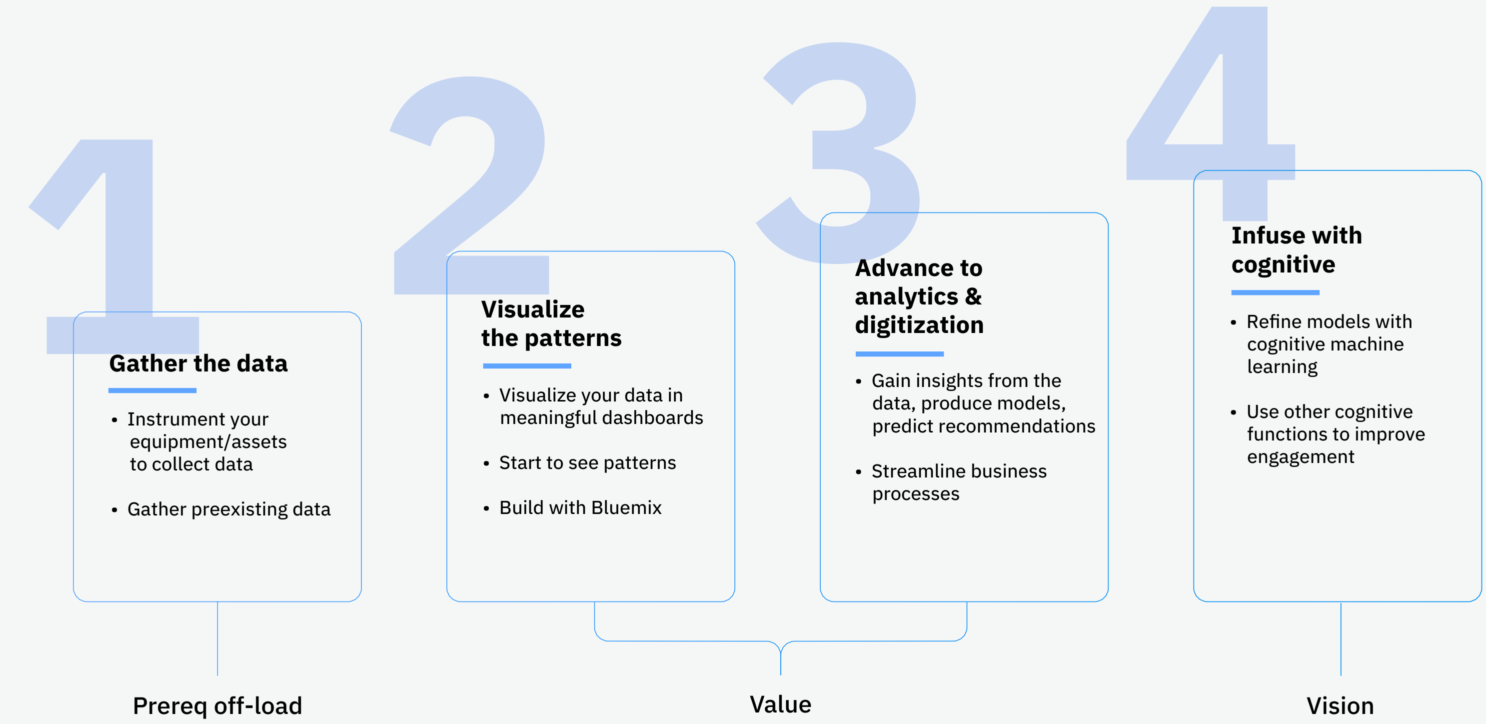


Figure 4: The four-step roadmap.

The benefits expected from the four-step roadmap are the following:

- **Productivity gains:** This approach leads to higher throughput and efficiency, eliminating non-value-adding activities.
- **Failure prevention:** The roadmap also results in the highest overall equipment efficiency (OEE), avoiding rework, scrap, outages and poor product quality.
- **Flexibility:** Other benefits include hiding complexity, low configuration and reconfiguration efforts, the capacity to plug and produce, and the avoidance of technology gaps.

Extend the current manufacturing architecture with a three-tiered, layered approach

In industrial manufacturing and Industry 4.0, the best practice is to adopt a three-layered distributed architecture. A good architecture model considers the requirements for autonomy and self-sufficiency of each production site and balances the workload between the different levels (edge, plant and enterprise).

To achieve a good architecture model in the solution, it is key to solve the integration problem, both vertically and horizontally.

Figure 5 shows what the integration problem typically looks like in a manufacturing context.

At the device level, information is siloed in the control layer and is accessible through a variety of industry-specific protocols (e.g., operations planning and control (OPC), OPC unified architecture (OPC-UA), Skid, Bacnet, Profibus and Ethernet-IP) and may also be contained in file systems or production databases.

Extended factory with IBM capabilities: Architecture overview

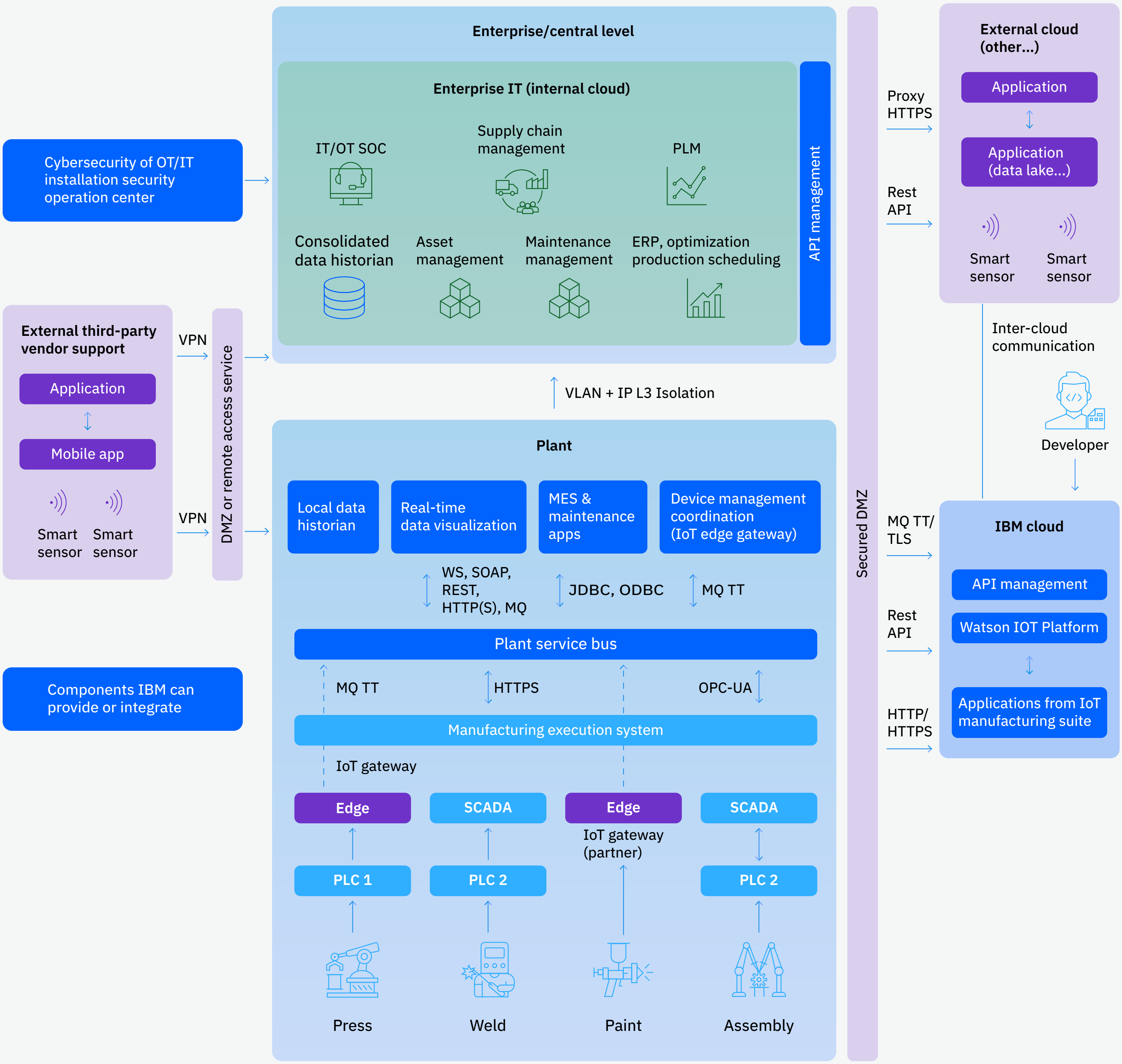


Figure 5: Extended factory with IBM capabilities: Architecture overview.

In most cases, new instrumentation may be required (e.g., acoustic sensors on robots or RFID tags on equipment). To solve this integration problem, the best practice is to combine the integration technology with edge/gateway devices from different providers.

The retained architecture pattern described below therefore proposes a solution based on three levels:

- **Edge level**
- **Plant, factory or shop floor level**
- **Enterprise or back-end level**

At the factory level, the practice is to implement in each plant a service bus, often called a plant service bus (PSB), to manage local activities and connectivity with the physical environment (e.g., PLC, SCADA, Skid, OPC, edge).

In addition to the service bus, we recommend deploying embedded analytics software technology at the edge level. Physical edges are boxes (gateways, hubs, connectivity boxes, etc.) that allow for connection of the OT network to the IT network and transform the signals and events emitted by the PLC/SCADA to secured digital data visible on the IT network.

At the enterprise level, enterprise- or industry-specific applications will be deployed for various needs (e.g., asset management, maintenance management, overall equipment efficiency control and predictive maintenance). Some of the applications may require installing local pieces of their solution at the shop floor level.

The infrastructure to support those applications may be supported by a combination of different cloud models and local IT in a hybrid model. The level of hybridization must be determined very early in the project.

The level of hybridization is widely considered a trade-off and balance between enterprise constraints, management and operations considerations, latency and performance requirements, and data privacy constraints, not to mention cost (data retention costs).

The full, extended three-tiered architecture

Once the shop floor middleware is deployed and the technical pieces have been considered, it is a good opportunity to focus on the business pieces of the solution.

The business components are materialized though specific applications that contribute to improvements in productivity, increases in uptime, reductions in downtime and enhanced flexibility to dynamically reconfigure shop floor equipment.

IBM's suite of EAM solutions provides industrial businesses with insights to optimize production operations and improve the quality of production. The goal of these solutions is to reduce risk, lower costs and improve efficiency by adding the power of analytics, IoT and AI to industrial operations.

The suite covers two complementary fields and IBM provides solutions for each domain:

– **Production quality insights:** IBM solutions can improve production quality by finding even the smallest defects faster and more accurately. They can also reduce dependency on manual inspections, identify quality defects sooner and respond in real time.

  Find out more here.

  To improve product and process quality, as well as find quality problems faster and reduce costly false alarms, IBM offers credible alerts you can act on quickly, using far fewer data points. Through a solution called IBM Prescriptive Quality on Cloud, we use prescriptive analytics to improve the quality of manufacturing processes, materials, components and products.

  - IBM can bring the power of AI to your inspection line to identify visible defects faster and accurately identify points of failure so you can continuously improve over time. Through a solution called IBM Visual Insights, we harness machine learning, edge processing, image capture and human expertise to transform visual inspection and reduce production costs.
  - To more efficiently and effectively recognize and detect quality defects and equipment malfunctions, IBM combines acoustic data with machine learning and AI technology. Through a solution called IBM Acoustic Insights, we use AI algorithms for real-time acoustic recognition and early detection of equipment degradation.

– **Production optimization:** The use of advanced analytics and AI helps optimize production processes. When factories are instrumented through the IoT, available data surges. In a digital factory, operators can use data insights to identify potential production losses and act to balance quality, cost and throughput.

  Find out more here.

  - Core enterprise asset management (EAM)
    - Core EAM refers to the combination of software, systems and services an organization uses to control and optimize its physical, technological and human resources across business units and geographical locations. We bring these capabilities together in a solution called Maximo.

    Find out more about IBM's EAM solutions here.

  - Asset performance management
    - Asset performance management plays a crucial role in improving equipment operations. In this domain, IBM offers the following solutions:
      - IBM Maximo APM – Asset Health Insights
      - IBM Maximo APM – Predictive Maintenance Insights
      - IBM Maximo APM – Equipment Maintenance Assistant

    Learn more about IBM's asset performance management solutions here.

  - Maintenance, repair and operations (MRO) inventory optimization
    - Optimizing your MRO inventory can help significantly cut inventory-related costs and reduce asset downtime. IBM's MRO solution is called IBM Maximo MRO Inventory Optimization.

    Find out more about it here.

Additional considerations and advice per building block

Based on our experience and research, here are additional perspectives and best practices:

- **Plant service bus (PSB):** The PSB is a very important structuring block that monitors, orchestrates and governs flows inside the plant but also between enterprise and plant. This is typically a critical component of a cross-plant integration layer between plants and enterprise systems, as well as processes and humans, and it provides information routing, transformation, mediation, configuration and workflow. An efficient PSB is expected to provide OT/IT adaptor and gateway capabilities to implement functionality, integration logic, aggregation and mapping with externalized rule-based configuration.

The IBM PSB (IBM Integration Bus and Manufacturing Pack) allows on-the-fly data filtering, computations, aggregation, compression and preparation for further processing. The PSB must be deployed in the very early stages of the project and must therefore be considered a strong prerequisite before deploying data visualization, analytics and cognitive applications.

- **Enterprise service bus (ESB):** To govern the manufacturing flows between plants and central IT, an ESB often automatically applies. From a functional standpoint, an ESB has the same role as the PSB and may be supported by the same kind of solution.
- **IoT platform:** An IoT platform hosted in the IBM Cloud will enable the creation of data lakes at lower costs, create new industrial dashboards, integrate client analytical models, manage the application programming interface (API) life cycle and expose data to external partners. The platform could be fed from different data sources, such as data lakes, back-end apps, partners or other cloud providers (e.g., Azure).
- **Edge analytics:** It could be relevant to deploy services to the edge, where process performance would be impacted, evaluate the event in the cloud and return an action to the edge/work cell. We use edge-deployed analytical scoring services when we have a very high frequency of events flowing from a production cell and it's critical to evaluate abnormalities quickly to initiate an interception and remove a potential defect from the line. We would also use an edge service in scoring and classifying visual images, particularly when inspecting components at high speed (e.g., when defect identification is time critical). We would also look at using edge services when aggregating or filtering large volumes of telemetry data that can be consolidated into a smaller event. This would be done to reduce network load and reduce the cost of transmitting large volumes of data. A typical business application that makes use of edge capabilities is the visual inspection solution and its analytical scoring services. In general, the thinking must focus on establishing which service would best support an edge-deployed compute node. There are several potential technologies (e.g., SDK and Execution Engine) on the market for implementing edge analytics.
- **Local MES (manufacturing execution system):** In many cases, this component is already in place for production scheduling and optimization. It is often considered a working assumption during the integration project and must be part of the final solution. The MES or plant maintenance application is potentially connected to the PSB. By managing data flow transformation and protocol interconnection, the PSB helps to reduce the coupling level of the overall architecture. In general, there is one instance of the MES at the central IT level – it prepares the scheduled batch commands for all the plants. It can be the same as at the shop floor level or a different level, which reinforces the need to deploy a connectivity layer to reduce coupling and control and monitor the flows between the enterprise level and plant level.
- **Industry applications (e.g., visual inspection, acoustic insights, AI assistant, etc.):** These are examples of industry apps included in IBM's suite of IoT and Watson AI solutions for industrial businesses. These applications are described in the Industry 4.0 Security section of this paper.
- **Overall equipment effectiveness (OEE):** This component is very important. It tackles productivity constraints by analyzing data generated from machine controllers, sensors and transaction systems to give current or predictive visibility into factors that contribute to OEE loss. It predicts statistical probability of equipment failures, process failures and line slowdowns. Additionally, it quantifies the impact of such potential failures to plant or line OEE, then identifies root causes and offers optimized maintenance plans.

OEE definition: availability, quality and performance constraints

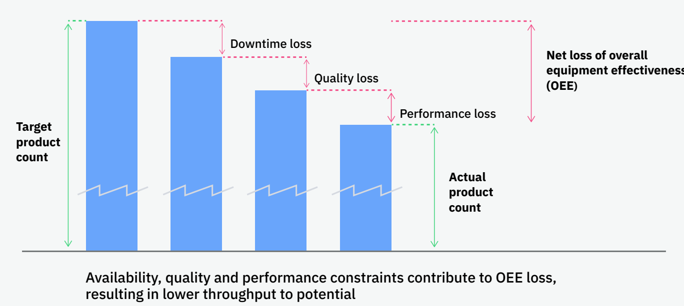


Figure 6: OEE definition: availability, quality and performance constraints.

- **Partner IoT project:** An observed trend is to make the manufacturing production system more open to facilitate the exposition of data/services securely to the ecosystem of partners. Considering that each manufacturing company collaborates with many partners, a best practice is to use a portfolio of application programming interfaces (APIs). In general, APIs are supervised through a specific application that manages the different policy rules and associated service-level agreements (SLAs). To increase security and flow monitoring, the exposition of the APIs could be done at the ESB or PSB levels.

- **API management (internal):** Another subsequent evolution and component of added value will be to deploy this application, which relates to the end-to-end API life cycle solution. It will enable the automated creation of APIs, simplify the discovery of systems of record and provide self-service access for internal and third-party developers with strong built-in security and governance.
- **API management (external):** Another extension will naturally be the exposure of APIs to external partners that have the same coverage as APIs for internal systems. This results in value by widening the client base by facilitating access to the information and even monetizing data or processes.

Edge analytics

Increasingly, many customers are opting for an IIoT strategy completely agnostic in the gateway, network and device space. It is important to be able to partner with all of the key players to ensure interoperability and maximum choice and flexibility for the future. These goals of interoperability and flexibility can only be reached through the global architecture model explained in this paper. We recommend a service-oriented approach that wraps the edge, shop floor and enterprise levels through APIs and a micro-services approach. Each layer must be able to expose clear, documented, instantiable and operable single interfaces (APIs). While IBM is primarily not in the adapter and physical edge market, IBM has many partners working in the area of IoT and Industry 4.0. They include ABB, KUKA, Enocean, Intel, Cisco, Schneider, Hilscher, Festo, Minitec, TE, Softing and PRO ALPHA Sigfox.

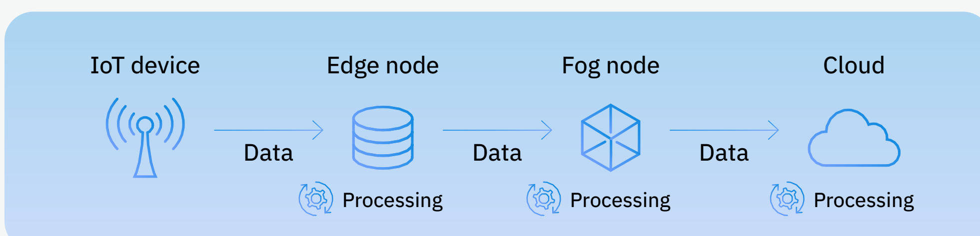
IBM partnering on edge analytics and computing

What do we do at edge level?

IBM

Enable cognitive IoT at the edge

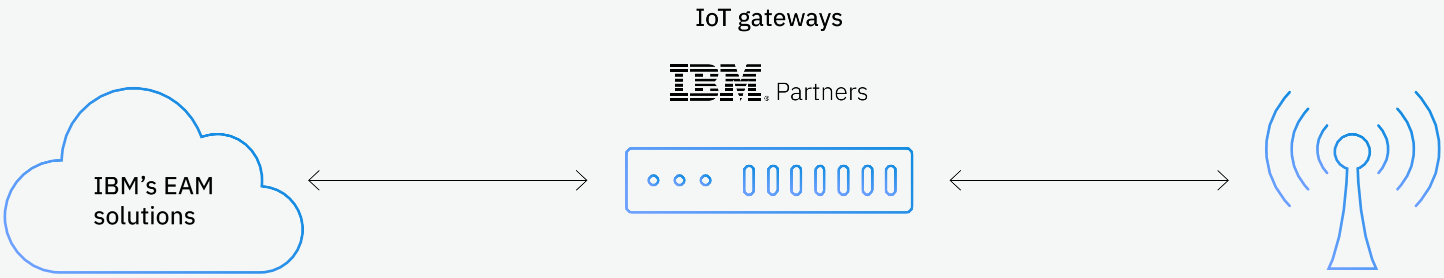
Enable edge analytics — route to the cloud



- **Pre-process data** and avoid congesting the network.
- **Score** and **classify** visual images or sound.
- **Execute** local business logic (aggregation, filtering, frame filling, frame timing, single compute).
- **Inspect** components at high speed as defect identification is time critical.
- **Aggregate** or **filter** large volumes of telemetry.

Figure 7: IBM partnering on edge analytics and computing.

Inside an IBM edge analytics solution



- IBM Edge Analytics Agent will run on IoT gateway devices made by companies we partner with.
- IBM is partnering with Cisco and other gateway providers.

Figure 8: Inside an IBM edge analytics solution.

Cisco: IBM and Cisco Systems have a dedicated relationship that spans more than seven years and includes multiple disciplines, with a strong focus on business transformation, solutions and services. Cisco and IBM can provide an end-to-end platform that enables a hybrid approach to IoT analytics at the network edge or in the cloud through Watson IoT technologies. With this common solution, it becomes possible to analyze business performance at the point of data collection so we can tightly monitor and control how the environment, assets and people are performing against their missions. Our technology uses an analytic evaluation that is based on defined business rules to recommend corrective actions. Edge-level analysis is used to perfect performance models in the cloud, continuously learning and improving operating condition models. Analysis at the edge of the network reduces the amount of data pushed to the cloud, freeing transmission capacity and driving down costs of communications for remote monitoring.

KUKA Robotic: IBM and KUKA have partnered to improve manufacturing operations and processes with adaptive robotics.

You can find more information here.

Apache Edgent: Apache Edgent is a programming model and micro-kernel-style runtime that can be embedded in gateways and small footprint edge devices to enable local, real-time analytics on the continuous streams of data coming from equipment, devices and sensors of all kinds. This is an example of open-source technology to leverage edge analytics.

Sierra Wireless Legato® Platform: This platform is a combination of a Linux-based OS distribution, board support package (BSP), customized development tools and robust APIs delivered through platform services to enable software development on IoT devices.

You can find more information here.

IBM's IoT Center in Munich: This production-related industry lab showcases cognitive industrial robotics by utilizing Project Intu middleware and 6D visual cognition, as well as machine, deep and reinforcement learning. It also uses cognitive speech and cognitive maintenance for robotics with Watson Speech to Text, Watson Translation and Watson Natural Language Classifier.

Hilscher (digital twin based on Hilscher netIOT Rules CPS): This is a rules-based integration and collaboration of cyber-physical systems within the framework of IBM's Industry 4.0 architecture. It is a bidirectional integration between a physical device and its digital representation that leverages IBM Visual Insights.

Sigfox: This is one of the world's leading IoT service providers that offers a global low-power wide-area network. Sigfox brings down cost and energy consumption required for securely connecting IoT sensors to the cloud. With the Sigfox solution, you need little energy to collect and transmit information for long-lasting objects. The Sigfox network is compatible with the IBM Watson IoT Platform. Some recent joint collaborations between Sigfox and IBM have successfully implemented various use cases, including asset management and tracking, infrastructure monitoring and maintenance, and facilities management.

ABB: ABB and IBM have announced a strategic collaboration that brings together ABB's digital offering, ABB AbilityTM, with the cognitive capabilities of IBM Watson IoT to accelerate the adoption of industrial artificial intelligence. You can find more information on this partnership here.

SmartFactoryKL: A learning and showcase factory for IBM and its Industry 4.0 technology, SmartFactoryKL addresses the full scope of the IBM Industry 4.0 Reference Architecture. IBM's main contributions include the flexible integration of all different machines, IT systems and applications; a digital twin realization of the whole production line based on IBM's Analytics and IoT technology; and a demonstration of the Cognitive Factory capabilities based on Watson.

Connected to the edges and devices, the PSB standardizes the communications (protocol management, mediation flows, monitoring and API exposition) between the edge and device layers and the rest of the shop floor components. Through PSB, the manufacturing operations will reduce the number of point-to-point connections and thus make the global solution more evolved, consistent and modular by reducing the overall coupling level.

Shop floor middleware: Plant service bus

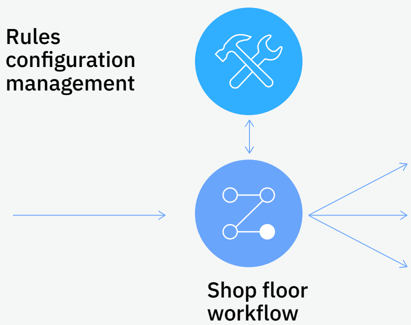
IBM PSB is a software component used to implement the factory-level integration layer between the shop floor and IT floor. It enables service-oriented, modular, nonintrusive connectivity between machines, systems, processes and humans. It provides routing, transformation, mediation, configuration and workflow based on events.

It also delivers the base for in-factory microservices based on the device-independent data model and shop floor data model.

• Transformation and connectivity: This refers to classic service bus functionality for the decoupled integration of systems and machines taking over integration logic, systems/machines and relief from integration-specific logic, and enabling standardization of maintenance and release management. PSB supports various OPC standards, but also Modbus and others.

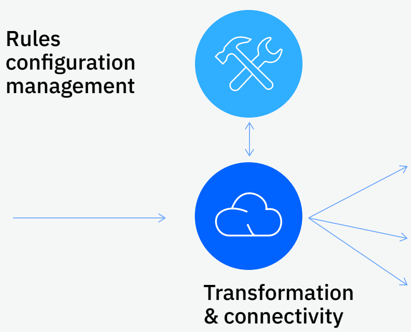
• Rules configuration management and composition: This refers to flexible configuration at the shop floor, integration layer and machine levels based on rules defined in natural language and validated and deployable by production planner (non-IT) staff. It also enables the streamlining of change management and is a plug-and-produce enabler.

Manufacturing rules logic deployed at PSB level



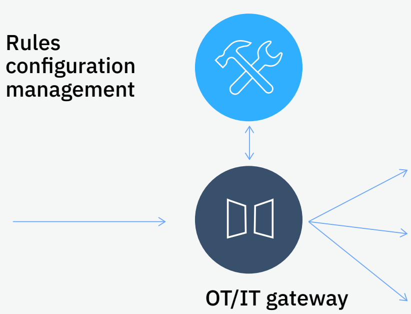
Shop floor decision logic:

- Handling by product type, prioritization, sequencing, (re)sequencing
- Reaction on exceptional situations (quality, continuity control)
- Display alerts resulting from factory predictive analytics loop



Integration decision logic:

- Routing based on message content and business situation (alerts, priority, exceptions)
- Business context message validation
- Flexible message content enrichment



Edge decision logic:

- Configuration management, mapping storage area to shop floor data model, plug and produce
- Dynamic behavior control (alerting, signal forwarding, screwdriver program depending on product parameters)
- Machine behavior control based on predictive analytics events

Figure 9: Manufacturing rules logic deployed at PSB level.

PSB architecture overview

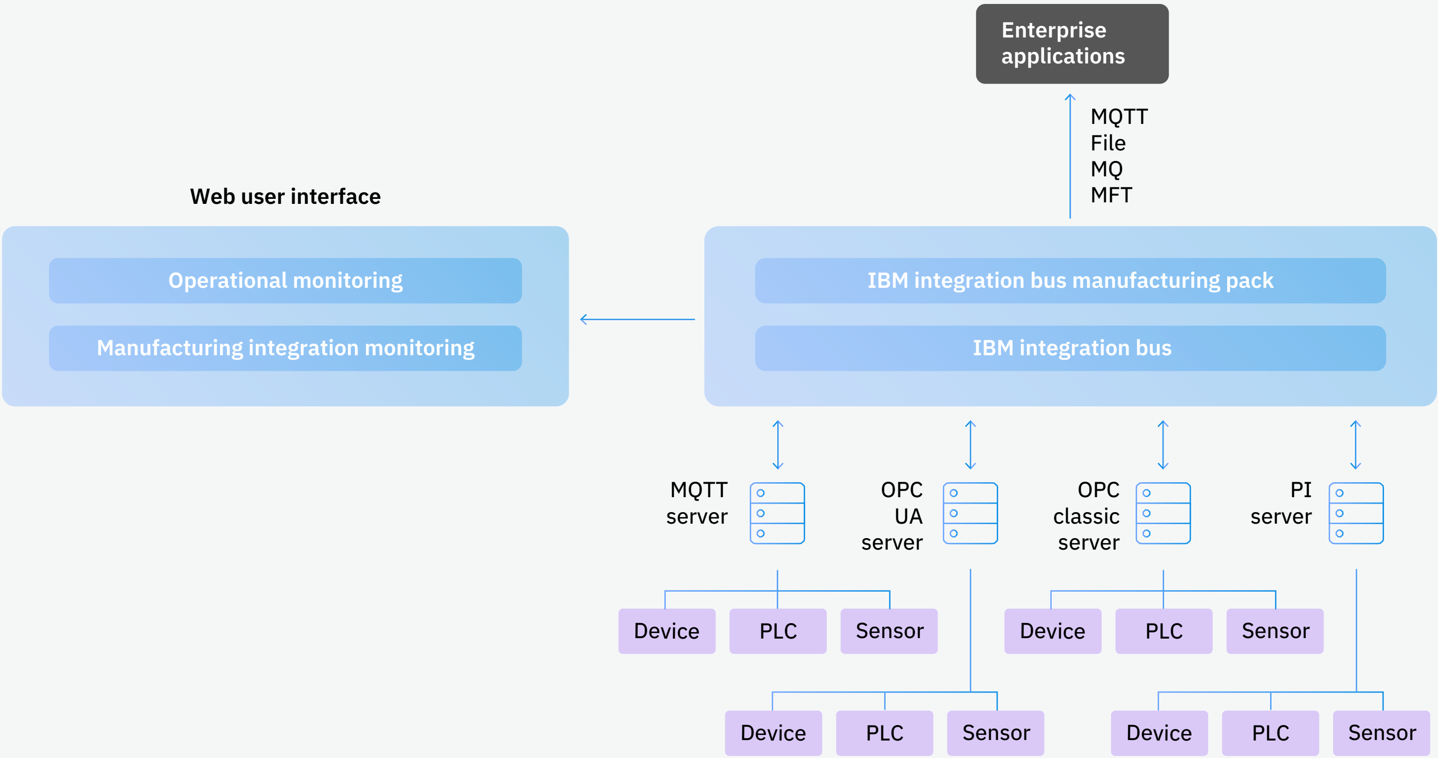


Figure 10: PSB architecture overview.

PSB enables its users to create business rules that are executed in the integration server (figure 14). Business rules provide a natural means for line-of-business users to manage policies that determine how to automate frequently occurring decisions.

The automation of complex business decisions has many applications at the manufacturing level, such as data transformation, protocol routing, protocol transformation, message validation or enrichment and dynamic behavior control.

Click here to get started.

The IBM® Integration Bus Manufacturing Pack builds on the IBM Integration Bus to provide support for applications in the manufacturing industry.

The IBM Integration Bus Manufacturing Pack provides the following features:

- **Integration of your OPC servers with the IBM Integration Bus applications.**
- **Integration of the data sources with the IBM Integration Bus applications by using a PI server.**
- **Use of the MQ Telemetry Transport (MQTT) connectivity protocol for enabling a publish/subscribe service.**
- **Visibility of information about the status of the deployed message flows.**
- The PSB enables the digital transformation of production processes and system connectivity and can deliver shop floor systems that are 30% faster and 25% more efficient. It can accelerate process automation, eliminating the need for more than 95% of manual operations and 90% of custom-built applications.

Enterprise level

Enterprise-level solutions analyze all information provided by lower levels and provide information storage for visualization and analytics. For enterprise-level solutions, IBM works with partners to provide field protocols, real-time high-definition indoor localization solutions and advanced tag capabilities to scan machines and display interactive information with augmented reality.

IBM's suite of EAM solutions for industrial businesses includes an array of devices and industrial analytics solutions provided as apps to the final user. They focus on manufacturing and industrial use cases offered in multiple deployment models.

This suite will drive cost savings and operational efficiency across the factory value chain by analyzing a variety of information from workflows, context and environment to drive quality and enhance operations and decision-making.

The industry applications are intended primarily for the manufacturing director, plant manager, OEE manager, operators, field engineers or technicians.

This suite of solutions enables manufacturing transformation through production-quality insights and production optimization:

- Production-quality insights use IoT and cognitive capabilities to sense, communicate and self-diagnose issues so businesses can optimize their performance and reduce unnecessary downtime.
- Production optimization brings more certainty to businesses by analyzing a variety of information from workflows, context and environment to drive quality, improve OEE, increase uptime and enhance operations and decision-making.

IBM's suite of EAM solutions

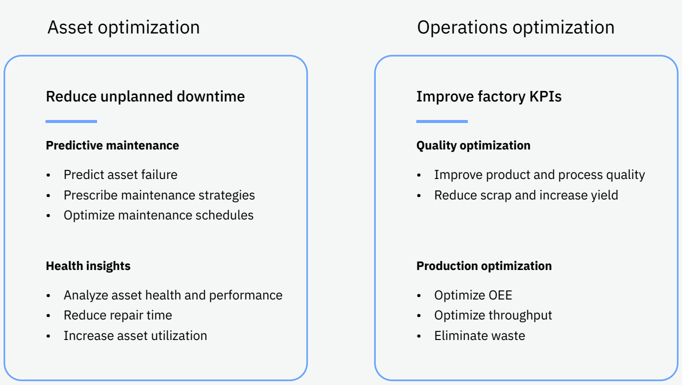


Figure 11: IBM's suite of EAM solutions.

IBM's suite of IoT and AI solutions

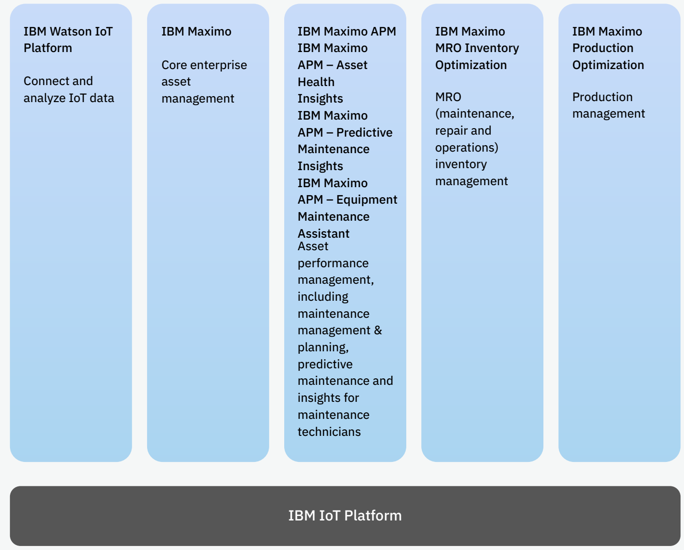


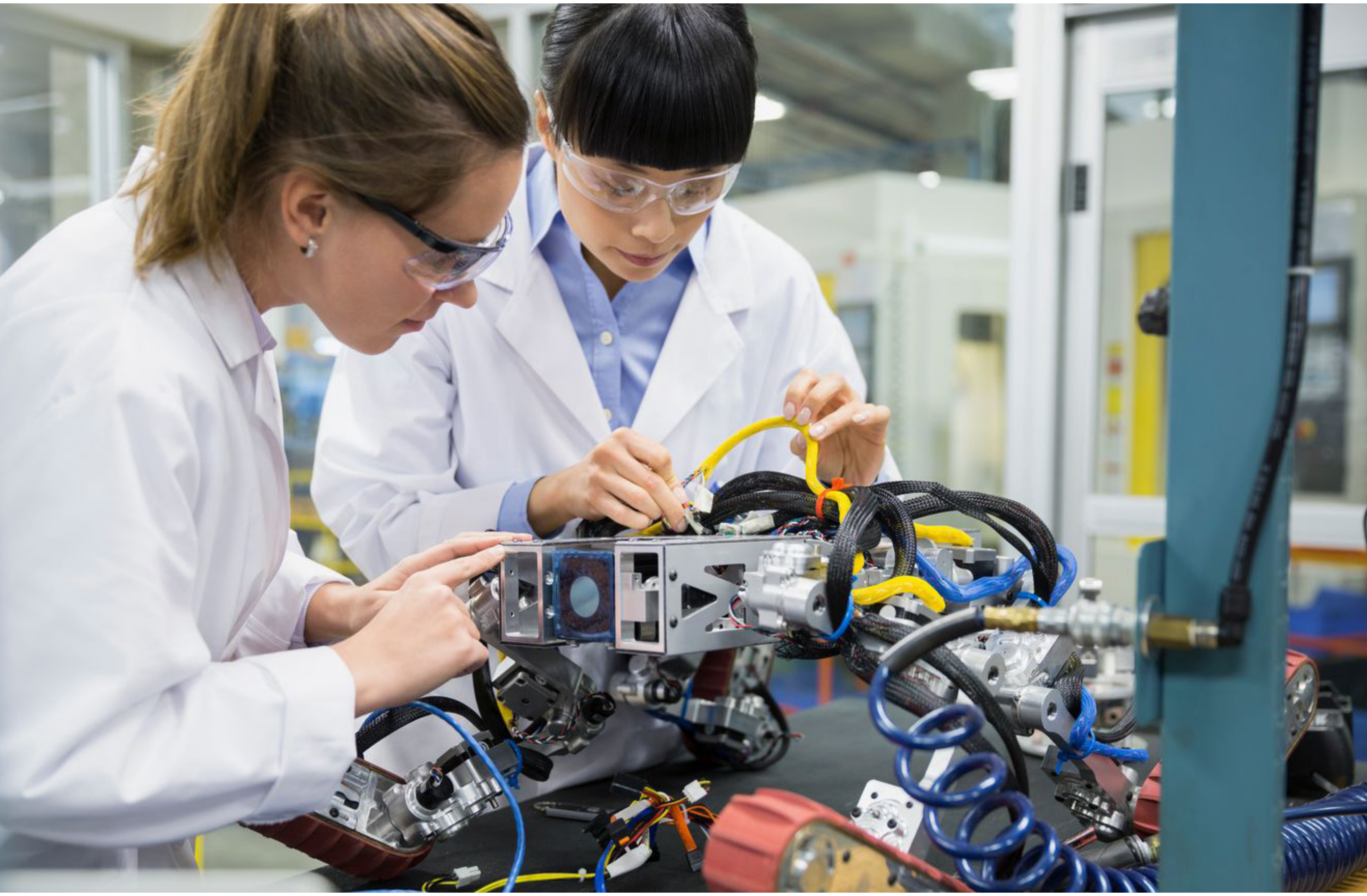
Figure 12: IBM's suite of IoT and AI solutions.

IBM's suite of EAM solutions leverages different categories of analytics:

- Machine learning (ML) automates analytical model building. It uses methods from neural networks. Common applications include image and speech recognition.
- Image analytics relies on pattern recognition and deep learning to recognize what is in a picture or video. When machines can process, analyze and understand images, they can capture images or videos in real time and interpret their surroundings.
- Acoustic analytics enables organizations to use plant and operation sounds to automatically detect anomalies and defects and identify product quality issues.
- Textual analytics is about deriving high-quality structured data from unstructured text. A good reason for using text analytics might be to extract additional data about products, equipment and industrial procedure descriptions from unstructured data sources.

IBM and Red Hat can also be leveraged to deliver a hybrid multicloud platform for Industry 4.0.

IBM's Industry 4.0 addresses current challenges and future needs by clearly defining the three levels – edge, plant/factory and enterprise – and being able to deploy and move functionality across all three. Additionally, the architecture assumes that today's functionality likely needs to be deployed onsite, but that over time, the functionality will evolve to dedicated or public clouds.



At the enterprise level, enterprise- or industry-specific applications can be deployed for various needs, such as asset management, maintenance management, OEE control and predictive maintenance. Some of these functions may require installing local components of the solution at the shop floor level.

It may take a combination of different cloud models and local IT in a hybrid model to support the infrastructure for enterprise-level applications. It is important to determine the level of hybridization early in the project.

Together, IBM and Red Hat deliver a next-generation hybrid multicloud platform. By combining the power and flexibility of Red Hat's open hybrid cloud technologies with the scale and depth of IBM's innovation and industry expertise, any company engaged in an Industry 4.0 project has access to the top tools and talent of both companies.

As previously mentioned, choosing the level of hybridization can be a balancing act of enterprise constraints, management and operations considerations, latency and performance requirements, and data privacy constraints – and can also include costs for key items like data retention.

IBM is flexible in terms of cloud deployment models. In addition to the components installed in the edges or on the shop floor (on premises), our cloud strategy is to leverage Red Hat OpenShift, Docker and Kubernetes technologies to facilitate the deployment of client and IBM components anywhere – not just in the IBM Cloud.

IBM Cloud Private (ICP) and OpenShift are open-source container application platforms for developing, deploying and managing on-premises or cloud-based containerized applications. This integrated environment for managing containers includes the container orchestrator Kubernetes, as well as a private image repository, a management console and monitoring frameworks.

As discussed, the trend for many organizations is to move to a hybrid cloud approach. A solution such as IBM Cloud Private with OpenShift answers that need. In addition, IBM and Red Hat announced they will join forces to accelerate app modernization and cloud-native development.

Illustrations at the three levels

Illustration at factory level: Acoustics analytics use case

Maintenance of the production line is timely and costly. Knowing when to maintain an asset for peak performance is critical. With acoustic analytics, we can listen to equipment to detect faults quickly and recommend maintenance. This applies in many areas of equipment operation, from windmills, trains, lifts and elevators to major industrial machinery.

Acoustics analytics "listens" to the factory equipment and devices and determines if there is a fault by detecting anomalies in the noise it "hears."

This cognitive acoustic IBM application is provided as a service on the Watson IoT Platform. Machine learning builds a knowledge base of sounds to detect anomalies. Combined with hardened mobile solutions, this allows the service's capabilities to be used in the field at the shop floor level.

Illustration at the edge level: Visual inspection use case

Machine learning also enables the visual inspection of the automotive body assembly process for car door handles. Today manufacturers are facing risky challenges associated with complex visual inspection activities. Many human inspectors, operators and engineers are needed at each manufacturer; they have a full workload of repetitive tasks aimed at identifying hundreds of defects. This results in major plant labor costs, issues with inspection accuracy and consistency, a need for employee training and potential health problems for inspections in hazardous areas.

Watson IoT edge AI computing private eyes and ears

Private eyes

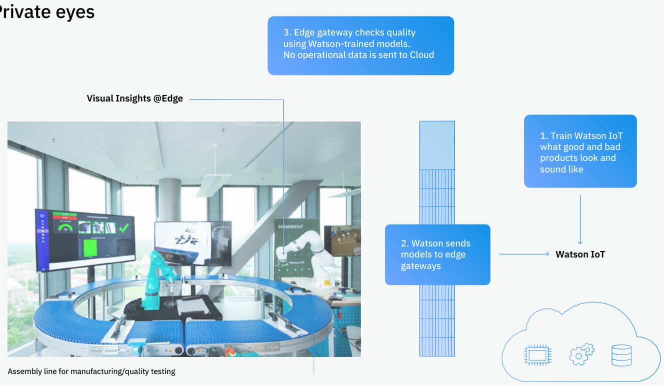


Figure 13: Watson IoT edge AI computing private eyes and ears.

This industry showcase, visible at IBM's IoT Munich Headquarters, was designed with BMW and KUKA. The principles are the following:

- **Gather data from the equipment line and gain real-time insight and scoring.**
- **Prevent issues before they arise with accurate predictions and early warnings.**
- **Improve performance with step-by-step repair guidance.**
- **Apply reasoning and learning systems to continuously optimize the use of equipment.**

The visual inspection system is based on machine-learning algorithms and leverages many patterns of visual inspection, such as impurity/high-contrast areas, geometry detection and verification, abnormal texture and area detection, and color/brightness feature extraction and verification to determine quality defects. (Examples of what this system can detect include brake caliper defects, body shop and paint shop defects or damage, part deformation, spare part bumps and car dashboard scratches.)

The visual inspection capability of IBM's suite of solutions is integrated inside the equipment line and robotics. In this showcase, we are inspecting several door handles from the new BMW 5 Series for manufacturing defects using the Watson Visual Recognition Service.

We also want to make sure that the robotics have high operational availability so as not to impact production. The operator controls the process through an equipment health scorecard (the health score for the robot is computed through a predictive maintenance statistical model).

At the last step of the process, a service technician receives a predictive maintenance alert via mobile app. A conversation using natural language processing and content analytics based on the shop floor documentation guides the technician toward a solution.

Illustration at shop floor level: Heartbeat Car Manufacturing use case

Heartbeat Car Manufacturing is an example of an asset and IP developed for an OEM that allow us to globally monitor the car manufacturing activity across several plants. The application is based on a set of KPIs dynamically adjusted based on the status of the manufacturing processes.

It allows us to manage assembly manufacturing plants located in several countries, as well as display security risk evaluations, fulfillment issues and typical root causes of an OEE deviation. Using a drill-down feature, it enables the plant or production manager to consult the reasons for the deviation and access prescriptions to remedy the issues.

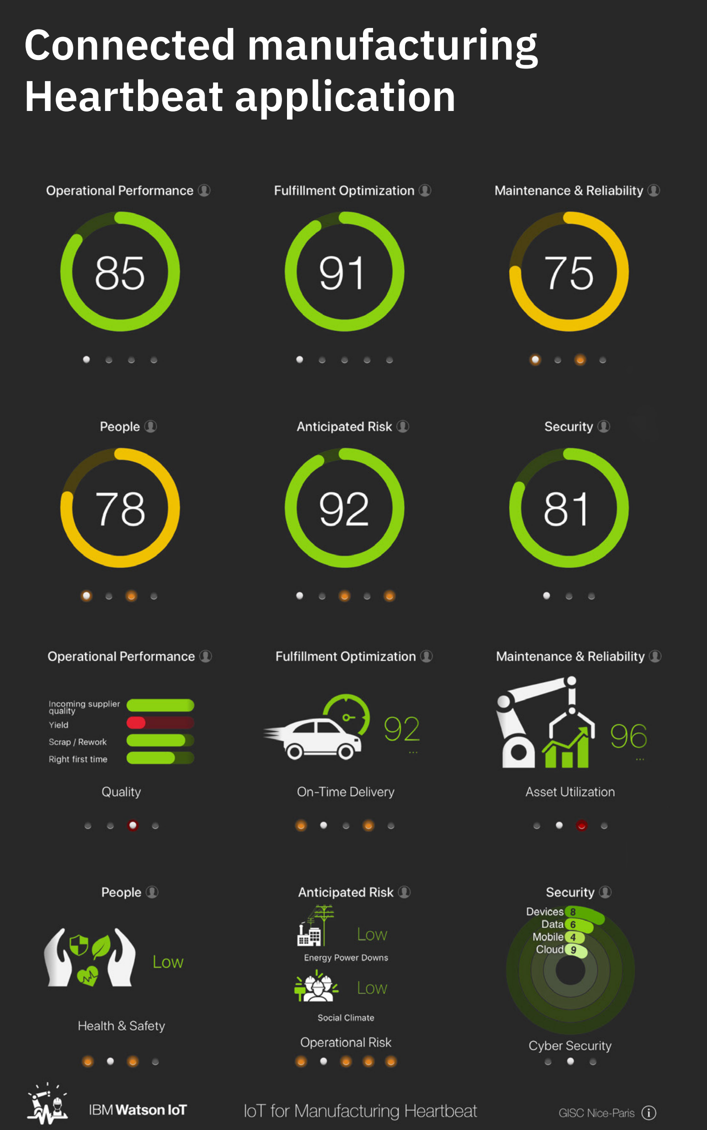


Figure 14: Connected manufacturing Heartbeat application.

Illustration at enterprise level: Increase OEE use case

In the architecture, the OEE component helps the plant achieve its throughput potential. The application enables plant managers, plant engineers, plant maintenance engineers/supervisors, process engineers and quality engineers to obtain unique, relevant, predictive and prescriptive insights that aid their roles in achieving the plant's objectives.

- Plant managers handle meeting target product count. They need visibility into factors that contribute to lost productivity and also must be able to assess the potential impact on downstream operations.
- Maintenance engineers ensure that maintenance tasks are carried out in a timely manner, thereby keeping the plant running uninterrupted. The OEE component is expected to predict machine issues, prioritize maintenance tasks and recommend the best times to repair. Consequently, it helps maintenance engineers carry out necessary maintenance tasks on time.
- Process engineers are concerned with the yield of different processes and their efficiency and relative variability. In particular, they are focused on OEE component process parameters, process cycle times and KPIs from different processes and machines, which can be compared and analyzed.
- Quality engineers are tasked with reducing scrap and rework. OEE components give early warnings of process variations and quality failures and thereby help quality engineers mitigate issues and reduce scrap and rework.

See figure 15 on the next page.

Advantages of IBM's enterprise-level solution for key personnel

Plant manager

Identify constraints to OEE.

Pinpoint potential constraints in the plant floor before they occur. Be proactive.

ME/supervisor

Drive to predictive maintenance with prioritized maintenance tasks.

Get predictive maintenance alerts and optimized "best time to repair" recommendations. Drive toward zero downtime with targeted maintenance.

Process engineer

Optimize processes.

Identify process and performance failures. Perform root cause analysis by visualizing historic process and performance data.

Link actions to performance

Predicted OEE is calculated at machine, line and plant levels to link all actions toward improvement of operational effectiveness.

Figure 15: Advantages of IBM's enterprise-level solution for key personnel.

Through OEE, we can apply different maintenance strategies. Every strategy has different benefits when applied to the right equipment and, on the contrary, generates high costs when applied to the wrong one.

- Reactive maintenance focuses on restoring the already broken-down equipment by replacing or repairing its faulty parts and components to their normal operating conditions.
- Preventive maintenance focuses on inspecting (tests, measurements, adjustments, recording deterioration and parts replacement) based on time (e.g., after a certain number of days, hours of use or cycles). It does not consider the actual usage of maintained assets.
- Condition-based maintenance uses the actual condition of the asset and dictates that maintenance should only be performed when certain indicators show signs of decreasing performance or upcoming failure. Condition data can be gathered through noninvasive measurements, visual inspection, performance data and tests scheduled at certain intervals or continuously (if a machine has internal sensors).
- Predictive maintenance uses advanced algorithms to look for patterns in how a piece of equipment is used and the environment in which it is operating, then correlates this sensor-driven information with known past failures.

When predictive maintenance is working effectively, maintenance is only performed when it is required, so just before failure is likely to occur. Several criteria of asset criticality must be evaluated when deciding whether to apply a certain maintenance strategy. In general, the more critical a piece of equipment is for smooth production processes and optimization of maintenance costs, the higher the business value it must maintain through predictive maintenance.

The maintenance approach specification should be reassessed once the relevant analytical models are built. Analytics outcomes can help to determine how well particular assets are being maintained.

Evaluation of an analytical model for specific equipment can show that:

- **there does not seem to be immediate benefit in changing to a predictive metric for maintenance scheduling;**
- **models are accurate enough to reduce maintenance costs and unscheduled downtime (use of predictive metrics to schedule maintenance is justified);**
- **there is not enough data.**

Industry 4.0 security

Security within manufacturing is influenced by multiple factors. On one hand, IT being connected to OT may not be designed to face cyberthreats. On the other hand, manufacturing equipment being integrated on IIoT platforms may not be designed in accordance with security principles or be equipped with security controls. IoT-enabled devices within manufacturing are opening further attack surfaces and associated risks that are difficult to judge for client OT infrastructure. Figure 16 illustrates threats and potential security approaches in further detail.

Security within OT environment

A shop floor can typically be seen as a mixture of IT and multivendor manufacturing equipment. The ISA95 Control Hierarchy Model shows system interdependencies: modular and off-the-shelf elements combined. Compared to a data center, there are limited to no security controls in place, and standards comparable to ISO 27001 do not exist.

ISA95 control hierarchy

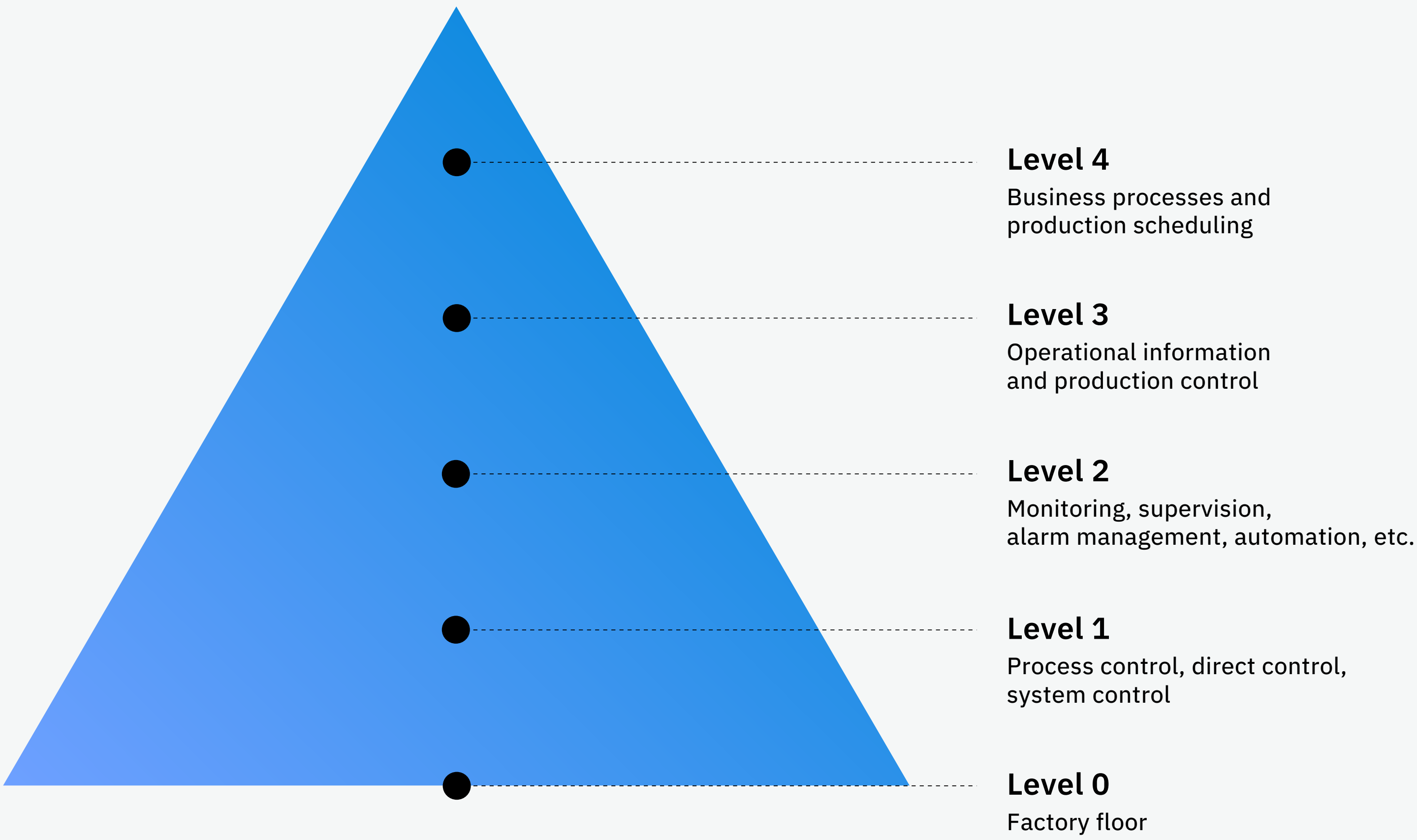


Figure 16: ISA95 control hierarchy.

The threat landscape is made up of OT equipment and industry networks, people operating equipment, the IT connected to OT, and IoT-enabled devices. Vulnerability management, identity and access control, and unused functionality are use cases to start establishing security and gaining security insight into OT infrastructure. Dedicated security appliances on level 1 enable access to industrial networks; security information and event management (SIEM) systems enable supervision, helping to improve maturity (see figure 17).

If applicable, further security controls used within IT environments could be used too. Identity and access management for people and equipment, the separation of control levels, and equipment within – or data protection in line with – functional operation have the potential to face cyberthreats and mitigate risk. In any case, OT security is a common effort of operational manufacturing units and IT security departments.

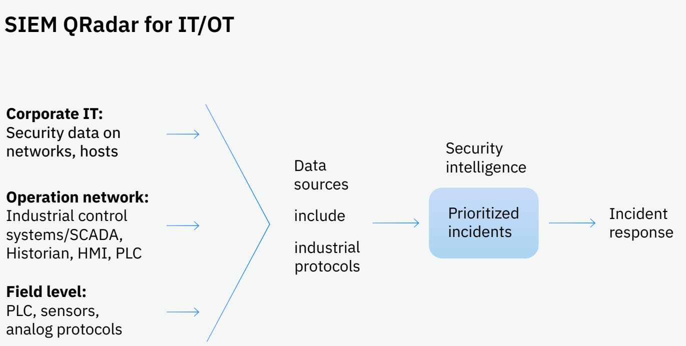


Figure 17: SIEM QRadar for IT/OT.

Security within Industry 4.0

The next level of industrial revolution – Industry 4.0 – follows different design principles, such as interoperability, information transparency, technical assistance, autonomy and distributed decisions. It introduces flexible systems whose functions are not bound to hardware but are spread throughout the infrastructure. In these new systems, internal communication can now be observed across architectural levels (see figure 16 on the ISA95 Control Hierarchy).

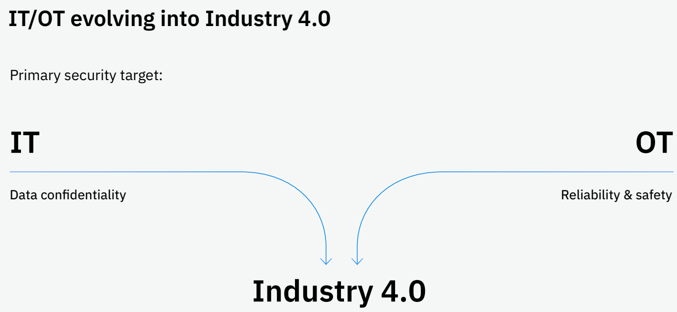
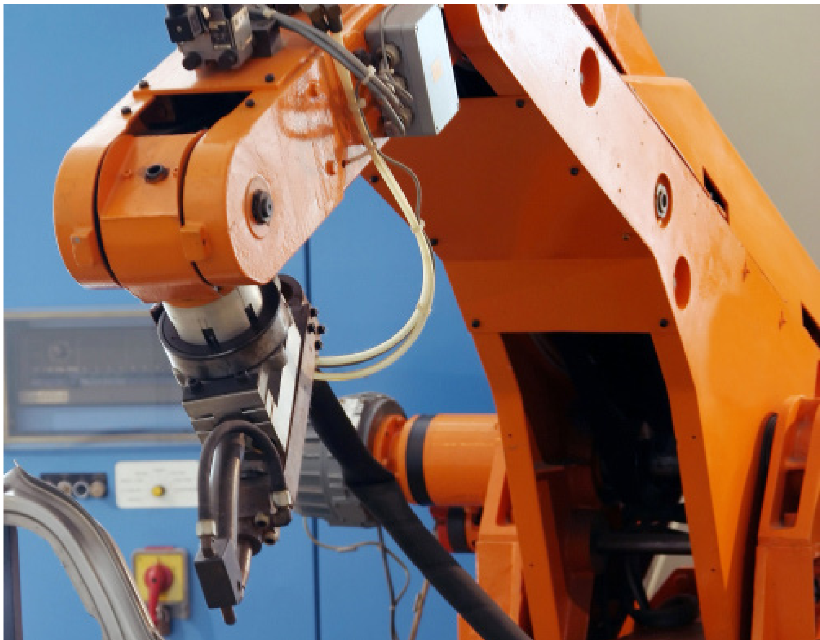


Figure 18: IT/OT evolving into Industry 4.0.

Industry 4.0 merges the end user with machine data and enables machine-to-machine communication so that components can manage production autonomously.

In contrast to the OT environment, Industry 4.0 introduces additional security challenges. First of all, security operation needs to be changed from a device to a process view that reflects a far-reaching demand and requires comparable security controls across the entire architecture (e.g., identity and access management). Distributed and interoperable Industry 4.0 architecture generates additional connections, increasing monitoring efforts. Existing legacy systems, vulnerable components or insecure protocols can all endanger security operations.

In general, Industry 4.0 infrastructure distributed across multinational facilities is facing numerous cyberthreats. Industry control systems, IoT gateways, sensors and actuators are currently judged to be the most critical by IBM Security. Given that the impact of an attack can be significant – from production outage to severely damaging equipment and staff – it's worth paying the most attention to this topic.



The best practices for securing Industry 4.0 infrastructure combine policy, organization and technology. Select best practices are listed below.

Best Practices for Industry 4.0 security

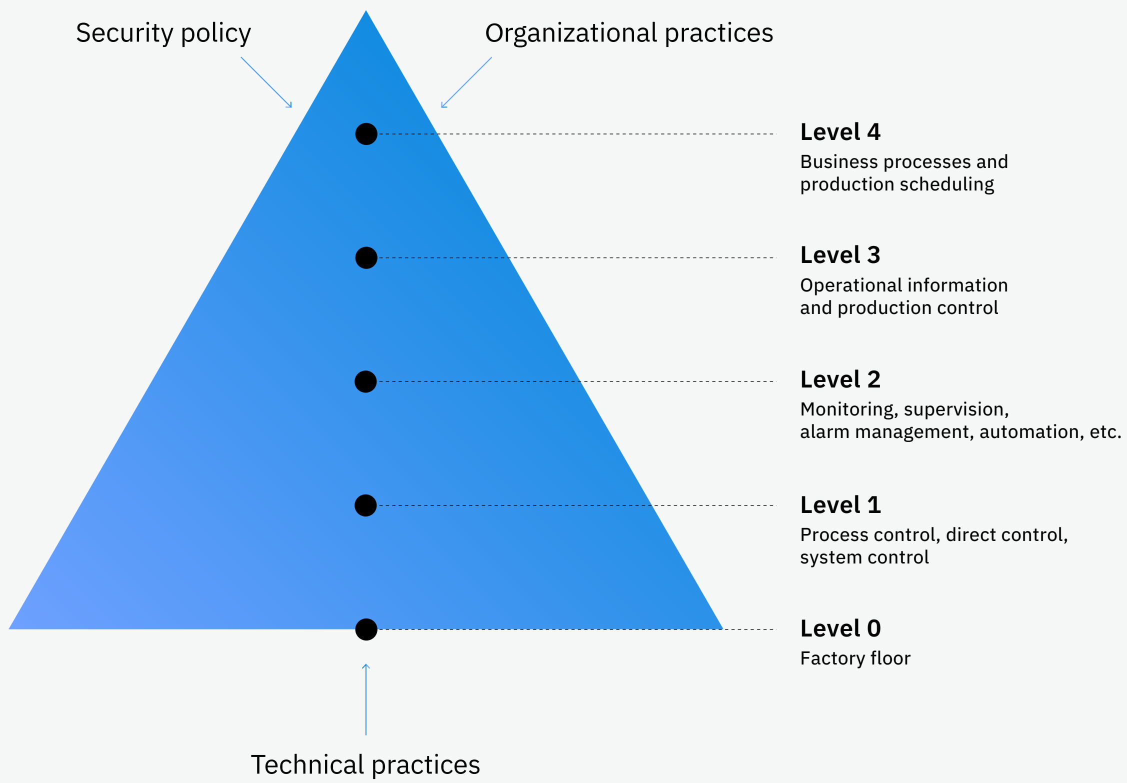


Figure 19: Best Practices for Industry 4.0 security

Policy

- Threat and risk assessment: Continuous efforts to analyze cyberthreats and related risks for manufacturing
- Secure by design: Essential guiding principle

Organization

- Life cycle management: Managing multiple devices of different ages that come from diverse third parties
- Incident handling: Being prepared to resolve incidents that will inevitably occur
- Vulnerability management: Managing and removing vulnerabilities across Industry 4.0 infrastructure

Technology

- The security controls below are well known in IT but are not holistically available for Industry 4.0 infrastructure.
- Security monitoring
- Data security
- Infrastructure security
- Identity and access management
- Software/configuration management

Companies addressing OT security in industrial environments today will greatly benefit from those with experience in security for Industry 4.0 needs. IBM is part of the Industry 4.0 Security Workgroup, which develops security best practices.

Deployment model

The components must be deployable at the edge, shop floor and central IT or IBM Cloud level. Regarding IBM Cloud, we offer a platform as a service (PaaS) and develop toolchains to build, run and manage apps on top of the IBM IoT Platform. Built on Cloud Foundry and Docker open-source technology, it could serve as a place for developers to go and quickly create, deploy and manage applications in the cloud without dealing with underlying infrastructure. In any event, the level of cloud hybridization would need to be determined depending on functional and nonfunctional requirements. The physical deployment of the architecture is always a trade-off between costs (e.g., storage, volume, SLA) and functionalities.

IBM is very flexible in terms of cloud deployment models since we leverage key market-recognized infrastructure technologies. In addition to the components installed in the edges or on the shop floor (on premise), our cloud strategy leverages Open Shift, Docker and Kubernetes technologies to facilitate the deployment of client and IBM components anywhere (not only in the IBM Cloud). ICP (IBM Cloud Private) leverages Docker and Kubernetes since many of our customers are moving to a hybrid-cloud approach.

How we deliver

Start quickly with design thinking and Garage Method

The IBM Cloud Garage Method is IBM's approach to enable business, development and operations to continuously design, deliver and validate solutions from edge to plant and central IT. The practices, architectures and toolchains cover the entire product life cycle from inception through capturing and responding to user feedback.

The IBM Cloud Garage Method has been successfully leveraged on many digital manufacturing transformations by combining assets such as industry standards, dedicated analytics on manufacturing space, delivery services and design-thinking approach. IBM Cloud Garage Method is relevant for quickly delivering a first proof of concept (PoC).

Develop the first minimum viable product (MVP) or pilot

The first MVP or pilot must be driven by the highest-priority use cases and the outcomes of the data readiness activities (i.e., IT/OT strategy review, data sources evaluation and security issues).

Any MVP must be based on a solid architecture foundation. To achieve this goal, IBM recommends a bottom-up approach: Install and deploy all the middleware pieces at the shop floor and edge analytics levels before starting any use case development. This step must be considered a prerequisite.

The approach must stay agile, using an incremental and iterative process that likely starts from use cases such as production visualization, data modeling or third-party integration. We help our clients sequence the use cases through a roadmap and a measured project plan. To implement the MVP or pilot, IBM proposes that clients leverage our MVP product method.

Minimum viable product method overview

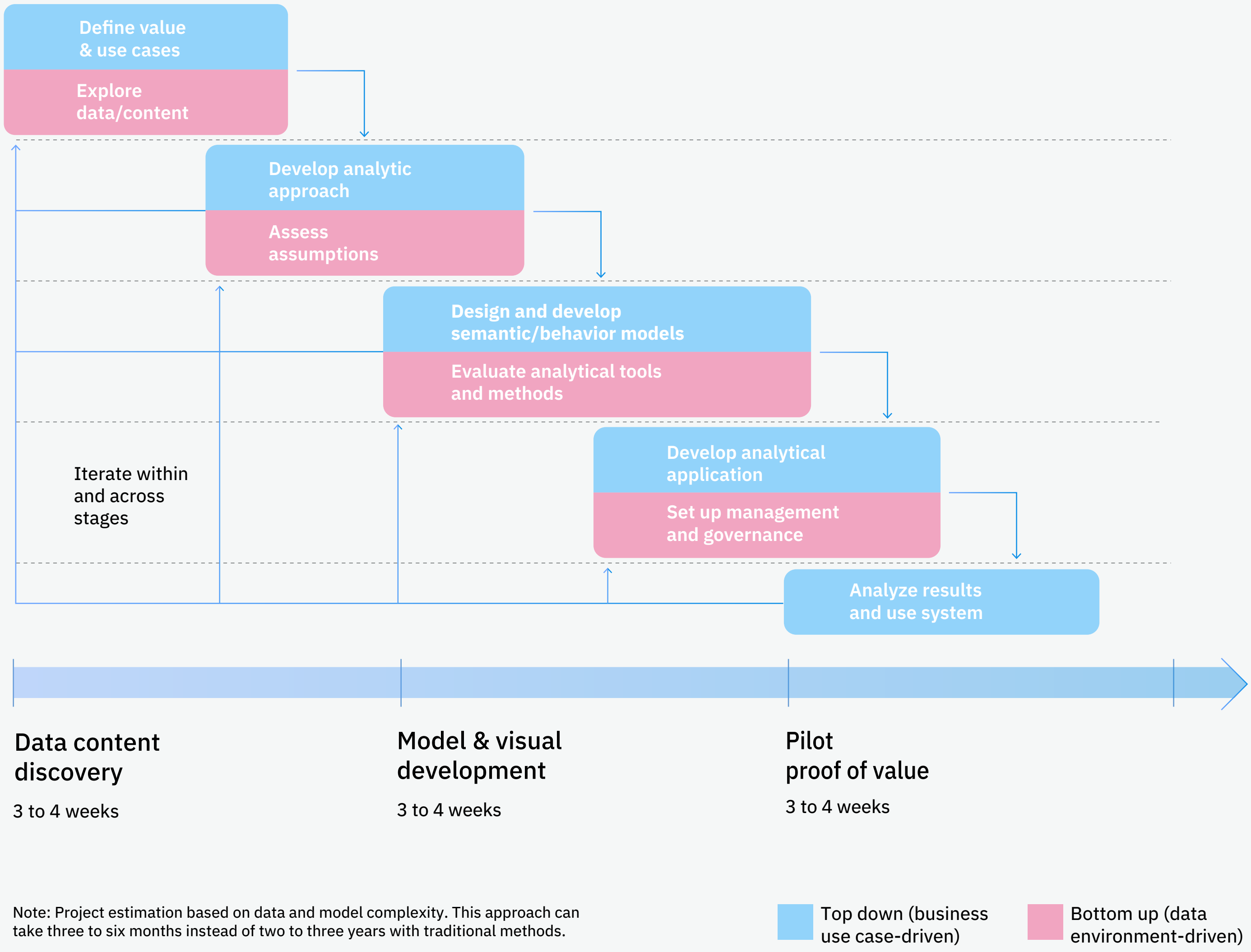


Figure 20: Minimum viable product method overview.

Once the middleware pieces are in place with the first MVP, an effort must be made to analyze each use case and evaluate 1) how complex it will be to design the data flow transformations, 2) the complexity of modeling the algorithms, and 3) how difficult the dashboard will be to develop.

To accelerate those activities, IBM proposes leveraging the industry apps contained in IBM's suite of IoT and Watson AI solutions for industrial businesses and evaluating their coverage level to determine which use cases to implement.

The nonfunctional requirements analysis must also be covered during the first MVP to scope out, as soon as possible, the development plan. That analysis is very important because it supports the decision process related to the different deployment scenarios between edge, plant and enterprise levels.

In this regard, we need to consider:

- **the level of resiliency architecture with high availability,**
- **security standards required for a connected shop floor, and**
- **the choice of local plant/manufacturing analytics with low latency at the plant or central level with more powerful capabilities (data lake).**

Design the roadmap: Project approach for deployment

After the first MVP implementation and delivery, the core architecture foundations (i.e., scalability and performance management evaluation) are supposed to be in place. The main architecture decisions should be validated and documented.

In this regard, IBM considers that the three use cases – production visualization, data modeling and third-party integrations – are key inputs for establishing the architecture during the first MVP.

At a minimum, from a final user perspective, the architecture must be able to:

- **monitor equipment and systems health and**
- **visualize the data and alert operators.**

From a solution perspective, it must be able to:

- **obtain good-quality data from output devices,**
- **have robust sensors and edge capabilities in terms of performance,**
- **be sure the flows are passing through the PSB,**
- **expose a first minimum set of standardized interfaces between edge, plant and central IT, and**
- **operate ideally through an executable pattern-based approach for speeding up development.**

Afterward, other use cases could be implemented and sequenced on subsequent phases. An example of a roadmap and project approach is provided in Figure 21.

Roadmap: Illustrative project approach for deployment

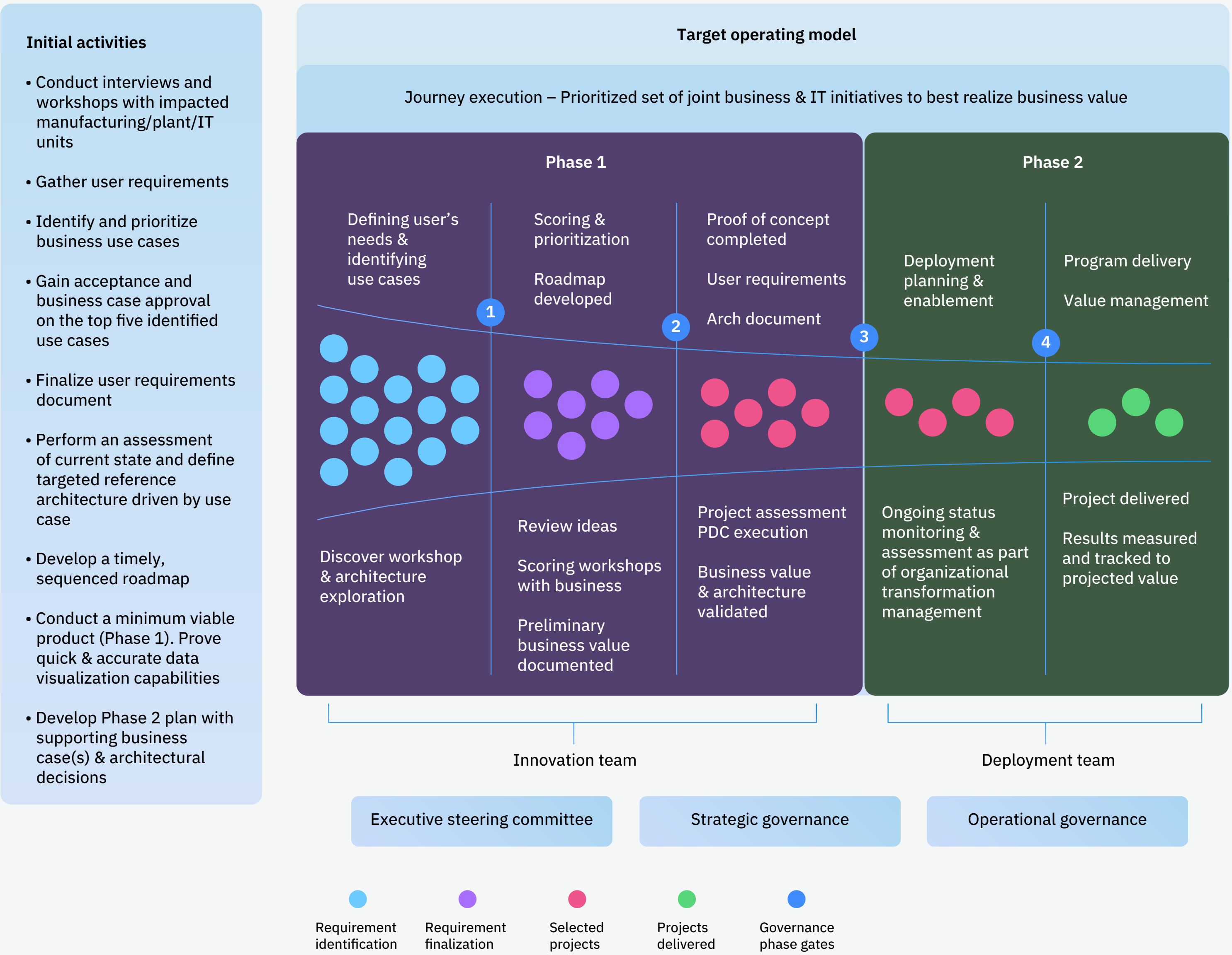


Figure 21: Roadmap: Illustrative project approach for deployment.

Exploration and innovation: User-centric design and DevOps factory

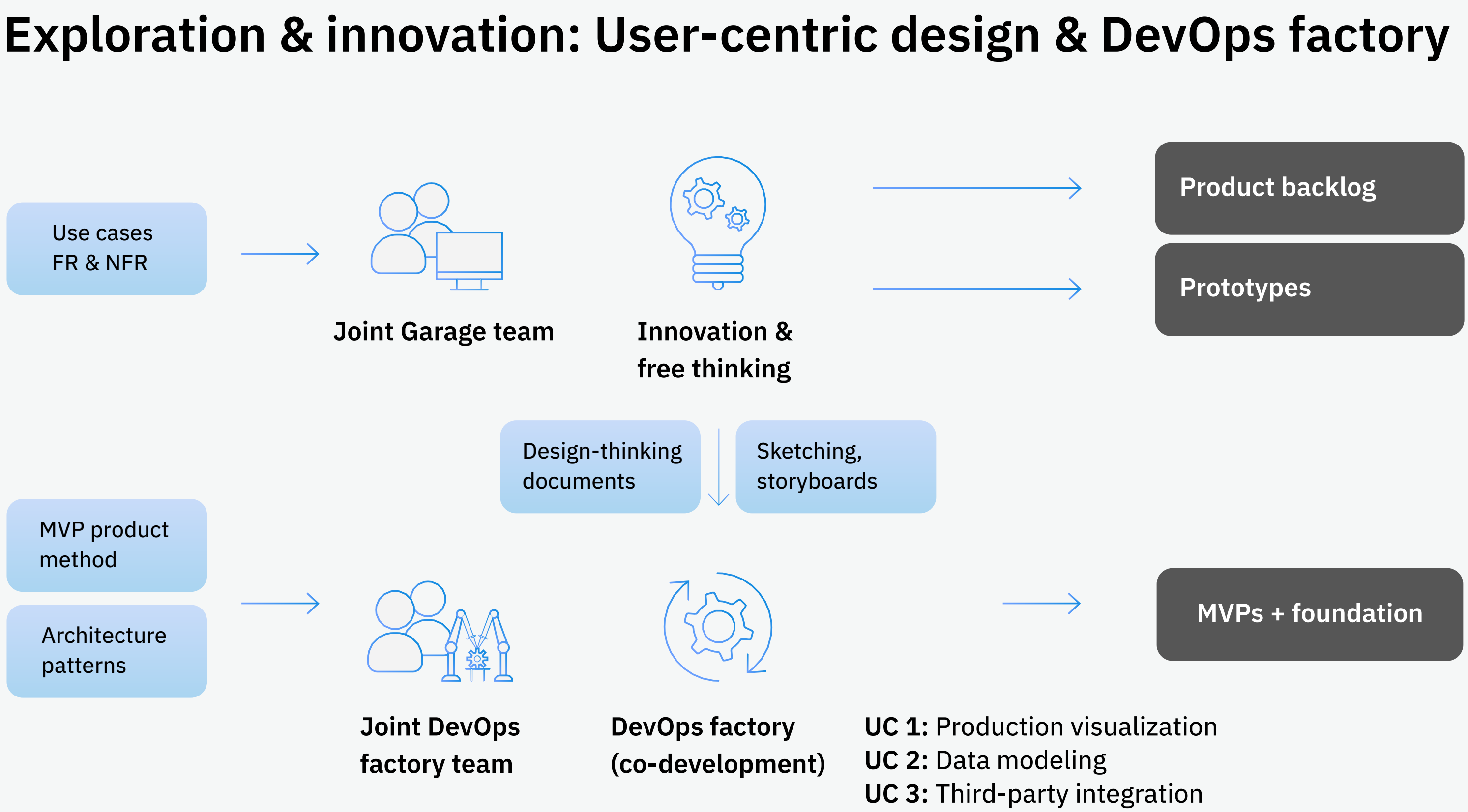


Figure 22: Exploration & innovation: User-centric design & DevOps factory.

At the Garage, IBM focuses on defining user stories and prototypes through three key components: methodology, designers and facilities.

- **Our design-thinking methodology effectively defines user stories, personae's services, use cases and prototypes.**
- **Experienced engineers, designers and user experience experts consult with subject matter experts to develop the respective user stories and prototypes.**
- **Our specific facility areas effectively execute design-thinking workshops and prototype-related sprints.**

The Garage will be used by different project teams and specialists to fill the product backlog for brainstorming, thinking and development.

IBM Architecture Center

To speed up the architecture elaboration and design process, IBM proposes leveraging one of its specific intellectual property assets.

The IBM Architecture Center offers reference architectures that are based on our expert team's interaction with our clients. The solutions and samples in each architecture provide a roadmap to build, extend and deploy an application. Find out more about the IBM Architecture Center here.

A reference architecture is a template of a solution that uses a set of practices, services and tools. Reference architectures leverage customer use cases and are based on open industry standards. The implementations show how to extend, build, deploy and manage code samples by using suggested services, toolchains and tools.

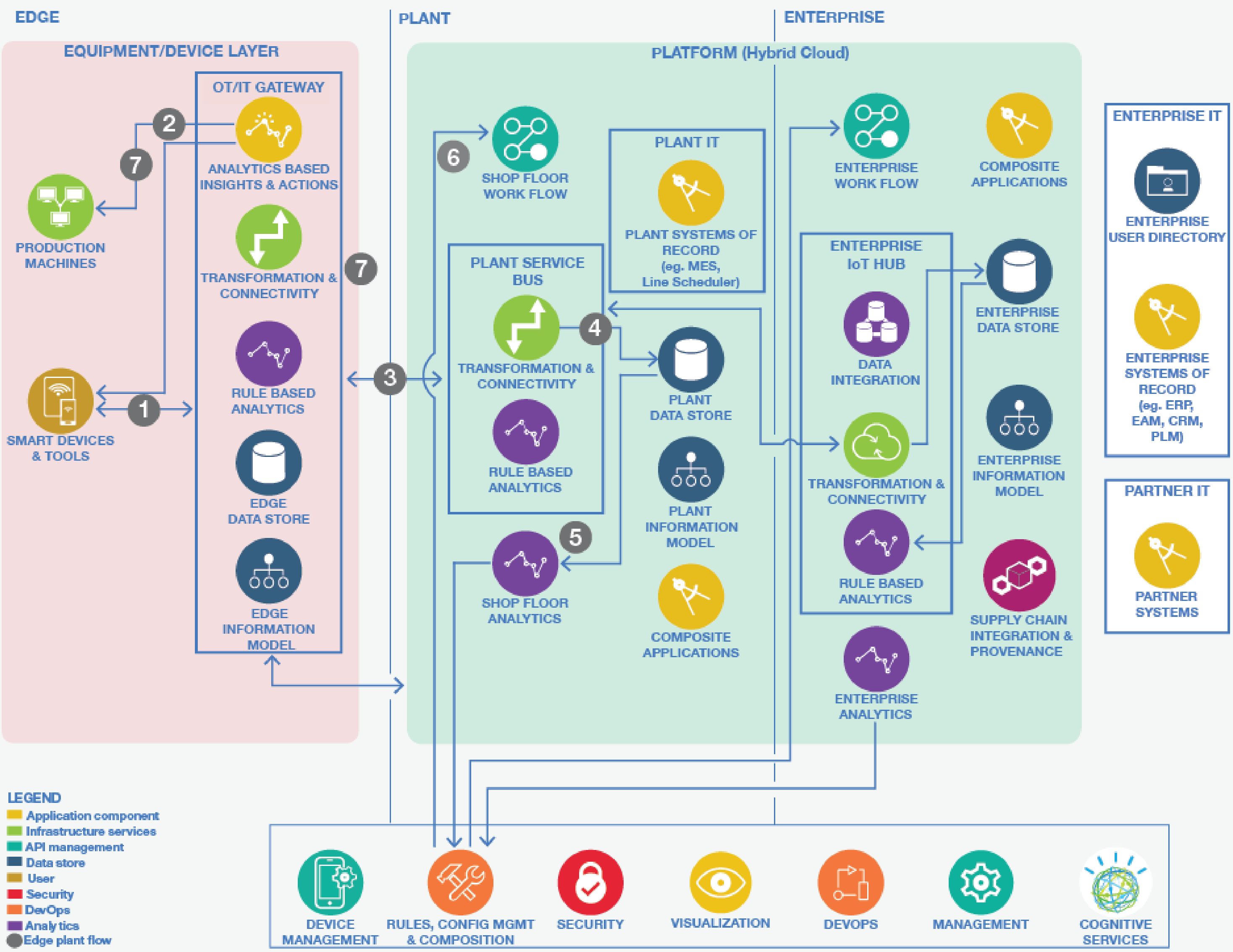


Figure 23: Industry 4.0 architecture pattern.

Conclusion

IBM has all the capabilities, references, methodologies and functional/technical expertise required to ensure industrial customers the best implementation of Industry 4.0 technologies.

The best IBM practice is to propose building a long-term strategic partnership in which IBM and its customers jointly deliver projects, programs and managed operations over the coming years.

From a solution standpoint, IBM will stay agnostic and neutral regarding physical equipment and manufacturing systems; IBM has proved it can help the market standardize the variety of systems, equipment and providers already deployed.

In the context of the industrial market, IBM can be a strategic partner to provide industry-leading solutions and expertise, manage a complex ecosystem of partners, and support each step of the customer journey globally and locally.

Appendix and use cases

Case study: Fictitious shop floor transformation

A fictitious company we'll call Smart ManDevFactory has acquired a program that will leverage components of the digital transformation to improve its manufacturing performance and efficiency. It will do this by capitalizing on a set of disrupting technologies, such as big data, analytics and cognitive techniques.

The overall initiative is woven through the creation of a new enterprise program called Digital Factory Industry 4.0. The main objective of the digital transformation at the manufacturing level is to determine a main supplier that can support each step of the roadmap on a worldwide basis.

Smart ManDevFactory wants to harmonize processes and best practices, secure business activities and distribute the most innovative technologies across its worldwide production installations.

To start the journey with agility, IBM and Smart ManDevFactory conducted a design-thinking workshop. Part of the workshop included an innovation and ideation session, which was dedicated to informing Smart ManDevFactory members of the latest market trends in terms of analytics and cognitive solutions, including IBM perspectives and latest advances.

Several solutions that covered the industry of Smart ManDevFactory – as well as side industries that could still be inspirational to the participants – were presented. The session was followed by interactive exercises that focused on uncovering Smart ManDevFactory pain points by leveraging the personae's approach and selected exercises from the IBM design-thinking framework.

Figure 24: Design-thinking spaces.

To deliver quickly visible and quantifiable business results, Smart ManDevFactory has decided to launch three MVPs (minimum viable products) extracted from a list of digital shop floor opportunities identified at the corporate level.

The MVPs represent typical use cases that Smart ManDevFactory would like to address with a unified IIoT Solution (Industrial IoT).

Smart ManDevFactory expected a technical proposal based on a unique platform that can cover current and future use cases and serve the needs of the shop floor with the possibility to install local middleware.

More than adding a new toolchain in Smart ManDevFactory shop floor's IT environment, the request is to integrate a fluid and simple solution in Smart ManDevFactory's existing information systems landscape with the automation side in Smart ManDevFactory plants but also with their MES (manufacturing execution system, like Delmia Apriso) and the ERP (enterprise resource planning system, like SAP).

IBM is therefore proposing a solution based on three levels: edge (shop floor), plant and enterprise.

1. Edge (shop floor) level

This is the most physical part of the factory, where activities related to products are performed by operators, workers and technicians. For innovative projects, it is key to make the link here between OT (operation technology) and IT (information technology). Industrial gateways (or SCADA systems) will bridge the two worlds from field protocols (Modbus, ProfiNet, etc.) toward IT standards (MQTT/JSON, REST API, etc.), getting most information in real time from PLC managing machines. A first level of transformation, filtering or analytics can occur at the edge when it is advisable to execute activities as close to the source as possible.

2. Plant level

Inside each plant, a service bus (plant service bus, or PSB) orchestrates local activities and connectivity with the physical environment via IIoT gateways or SCADA communications. The PSB therefore has visibility on both sides (OT and IT), enriching information with local applications, MESs or any applications involved in the manufacturing process.

3. Enterprise level

IBM Maximo APM Predictive Maintenance Insights is one of the modules in IBM's suite of EAM solutions that analyzes all information provided by the lower levels. This part provides information storage for visualization and analytics. Because the scope of this project is not only "virtual digital" IT oriented, IBM has selected three partners to complete the end-to-end solution: **Hilscher** (partner 1) provides field protocols via an MQTT Gateway (Modbus, EtherNet/IP, ProfiNet); **Arenzi** (partner 2) deploys a real-time, high-definition indoor localization solution; and **Ubleam** (partner 3) provides advanced tag capabilities to scan machines and display interactive information with augmented reality. **Sigfox** network is used directly between sensors and the IoT platform for some specific use cases.

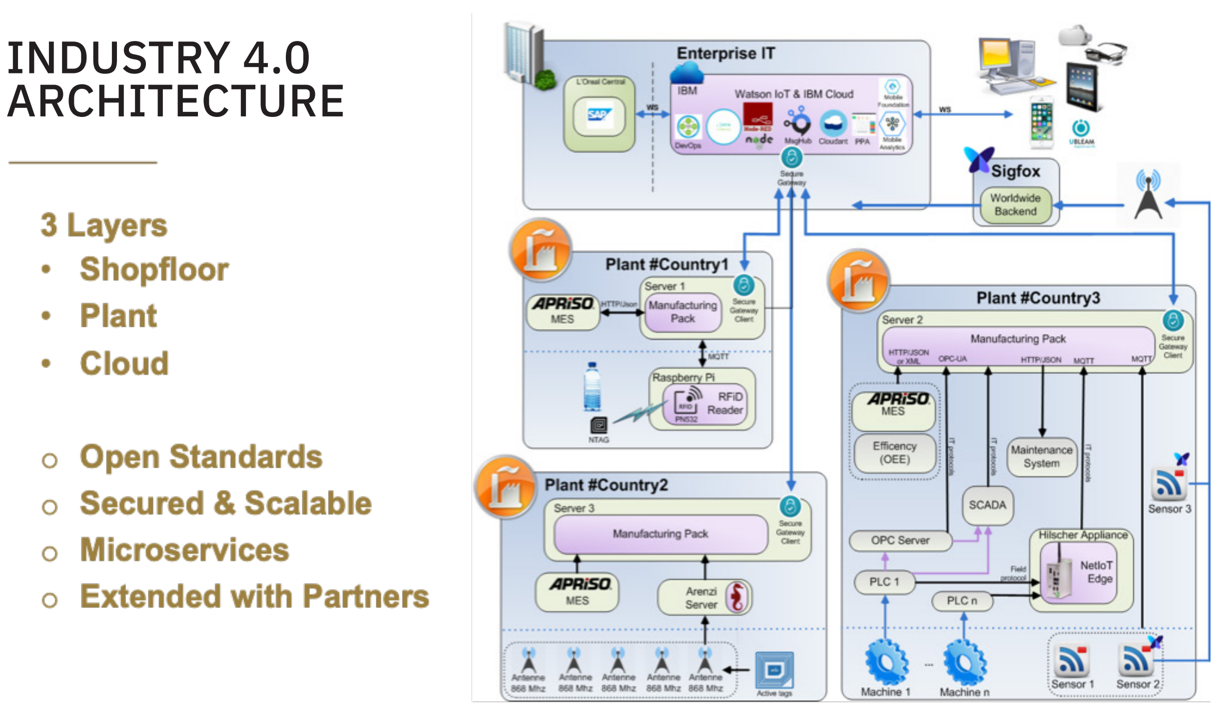


Figure 25: Industry 4.0 typical architecture.

1. Introduction of use cases

As mentioned in previous sections, Industry 4.0 is not only about connecting machines to the cloud; it is also about focusing on connecting the “factory activities.” As a first step, this approach means concentrating on products, machines and people.

Manufacturing and producing end products is undoubtedly a factory’s purpose. However, to do its job, factory machines need to be efficient, meaning they have the right raw material inputs, the right output bandwidth, the appropriate temperature, the right pressure, etc. In addition to machines, operators, technicians and managers are there to perform their jobs and maximize global efficiency.

The approach is to augment the capabilities of all involved entities to make them more efficient and more productive, with fewer errors, stops and faults, and with a better understanding of all information.

2. Use Case #1 – Augmented Product

Focusing on bringing more value to the end customer and gaining agility in its operations, Smart ManDevFactory is willing to increase traceability at the product level, from supply chain to outlets, streamlining retail activities and leveraging the customer experience.

Objective: This use case is mainly for marketing purposes. It will be used to validate technical capabilities of the solution from product identification capture, to storage and information presentation, to end customer, such as a targeted promotion.

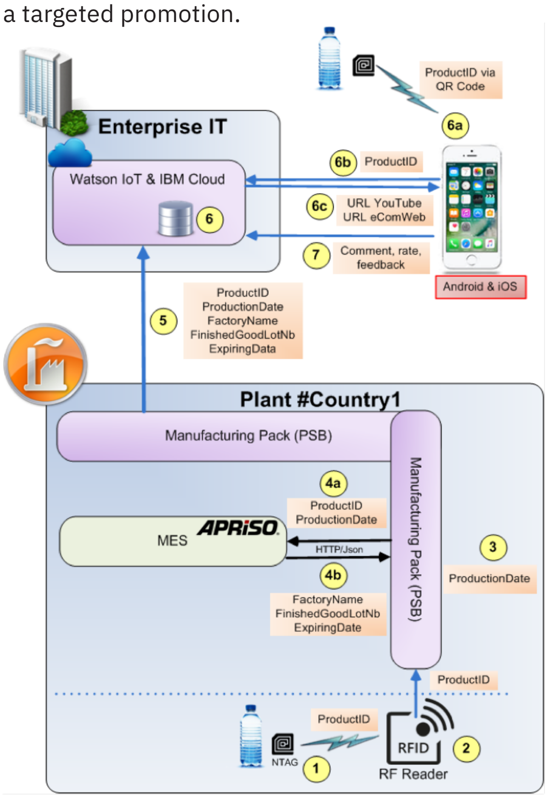


Figure 26: Use case 1: Augmented product.

It is very important to keep the product ID unique. This illustration is based on a unique near-field communication (NFC) tag linked to a product. IBM can demonstrate solutions based on QR code or barcode as well.

These three alternatives should be challenged during design-thinking and architecture sessions. This unique ID can be at the product or lot level depending on business needs and volumes.

3. Use Case #2 – Augmented Equipment

The goal of this use case is to collect data from machines and use them to optimize their piloting and performances with a real-time dashboard and analytics.

Objective: This use case will show the ability to connect to a PLC, collect data, publish it in a real-time dashboard and process it with analytics, correlations analysis, root causing and predictive maintenance.

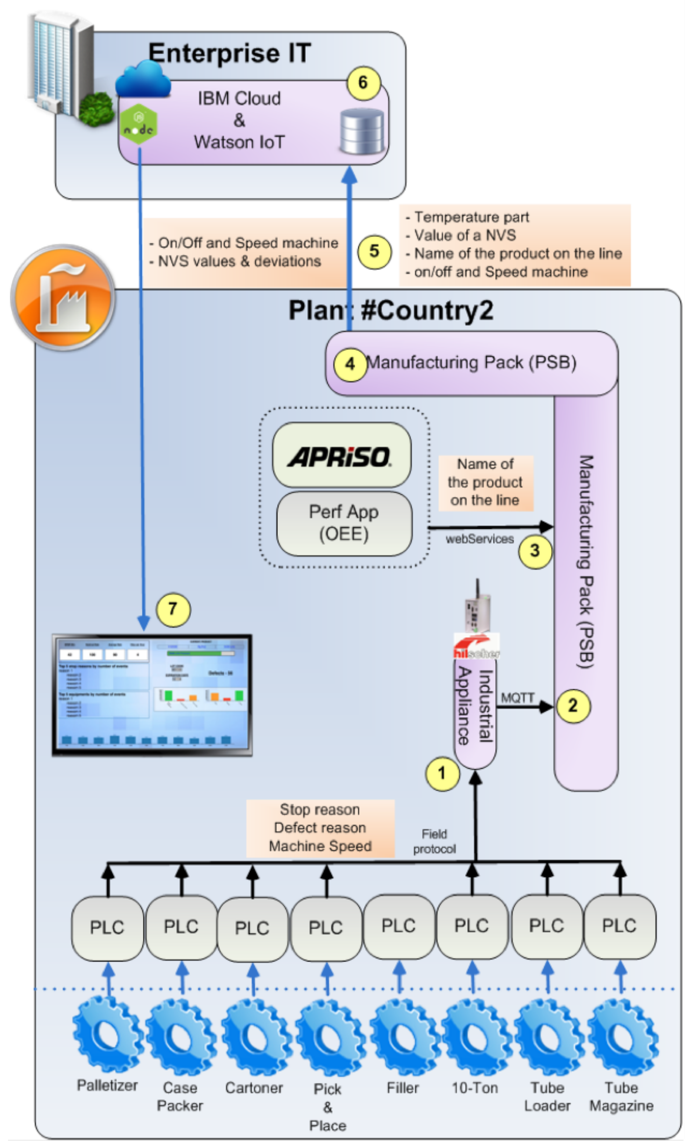


Figure 27: Use case 2: Augmented equipment.

4. Use Case #3 – Augmented Operator

The Changeover use case will help the packaging line operators perform the changeover tasks in compliance with Smart ManDevFactory EHS and performance standards. The focus here is when operators are to move from a Series A to a Series B.

There are many activities needed to run “Clean Product A” task then “Clean Product B.” But to reach the target quality benchmark, activities for the two tasks cannot be combined.

These operations can be plugging/unplugging pipes, cleaning, sanitizing and changing packaging, as examples.

All these are dependent on what was produced before and what must be produced afterward. This phase can last for a couple of hours. If the least-efficient operator can perform close to the fastest operator, it has a huge impact on productivity for a line.

Objective: Improve agility in producing short production runs and in changing quickly finished goods produced while maintaining quality.

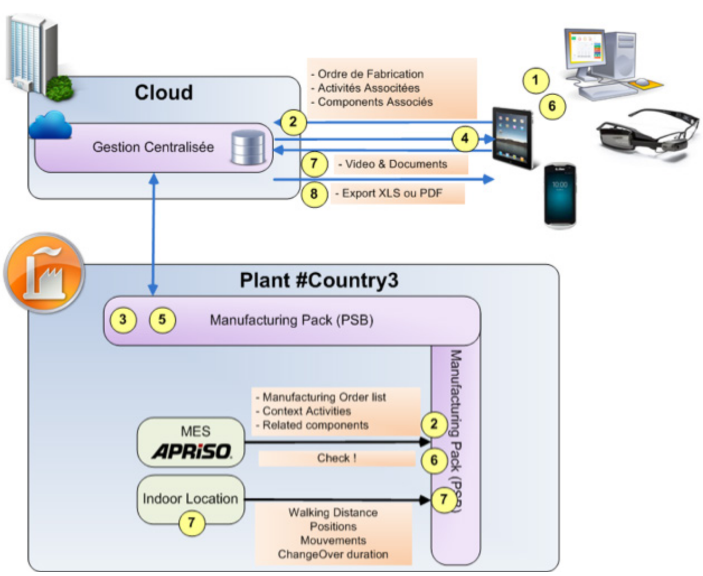


Figure 28: Use case 3: Augmented operator.

A cognitive assistant could help make this use case more efficient using Cognitive API provided by IBM Cloud for a conversation or picture recognition. During the IBM Design-Thinking phase, it is very important to challenge what is the most appropriate device for operators for their daily activities: It can be mobile phones, tablets, big screen or augmented reality devices.

5. Other Considered Use Cases

The previous three use cases can be considered good candidates for an MVP to use to understand, check and validate the Industry 4.0 approach in only a couple of months.

In addition to them, there are other ones that can be selected, such as the following:

- **drones to check buildings with image recognition**
- **building management of temperature and humidity**
- **water consumption efficiency**
- **tracking connected parts between sites**
- **cognitive assistants to support maintenance technicians**
- **deep learning to better understand recipes and processing faults**
- **artificial intelligence to globally improve the OEE**

Many use cases for an Industry 4.0 digital transformation can be tested and implemented with heavy involvement of the people who will be using them on a daily basis (i.e., people who work inside factories). It is very important to design everything from the outset with a range of job types in mind (operators, technicians, managers, directors, IT people, manufacturing people, consultants and business stakeholders).

Authors

Serge Bonnaud
Technical Leader, IBM Europe, Industrial Sector
IBM

Since 1998, Serge has worked in the field of software development and system engineering. He has also been involved in the healthcare industry, with the development of medical data analysis systems or the automation of the activity of pharmacies.

He joined IBM in 2004 after working at Verilog, CSEE, Rational Software and Thomson Software Products. Serge has participated as an architect in various Internet of Things (IoT) projects using big data and analytics technologies.

He also worked in the deployment of IBM Watson IoT for Automotive, the IBM solution for connected vehicles. Since 2016, he has held the position of technical leader in the field of industry at IBM Europe.

LinkedIn https://fr.linkedin.com/in/serge-bonnaud-97b1527;
Twitter @serge_bonnaud

Christophe Didier
Technical Director France for Internet of Things
IBM

Christophe has been working on complex integration projects for the last 20 years as a specialist, a technical project manager, an architect and a subject matter expert for Integration, Mobile and Smarter Cities.

He has spent 16 years at IBM Global Business Services, analyzing mainly EAI, SOA, BPM and Smarter Cities issues and designing and implementing innovative solutions for customers in the industry and public sectors.

He was appointed executive architect in 2013 and is the technical director for IoT (Internet of Things) at IBM France.

He has a master's degree in artificial intelligence (EPITA, France) and an MBA (Warwick Business School, England).

LinkedIn https://www.linkedin.com/in/christophe-didier-bb9b425/;
Twitter @ChristofDidier

Arndt Kohler
Head of Internet of Things Security, Europe
IBM Security

Since 1995, Arndt has been active at IBM in systems integration and solution development within multiple environments, such as Mobility, Radio Frequency Identification, Unified Communications and Security. He is a certified executive consultant and architect and has been appointed associate partner.

Over the past few years, Arndt developed IBM's Internet of Things Security portfolio and practice and is acting as Head of IoT Security in Europe, focusing on Industrial Products, Vehicles and Buildings.

LinkedIn https://www.linkedin.com/in/arndt-kohler-227590151/;
Twitter @SecurityIoT

Figures

IBM Corporation
New Orchard Road
Armonk, NY 10504

Produced in the United States of America
September 2019

M8J5BA6R