

Siemens
Industry
Online
Support

APPLICATION EXAMPLE

IT/OT Framework

Version 1.0

Siemens
Industry
Online
Support

© Siemens 2026 |

Legal information

Use of application examples

Application examples illustrate the solution of automation tasks through an interaction of several components in the form of text, graphics and/or software modules. The application examples are a free service by Siemens AG and/or a subsidiary of Siemens AG ("Siemens"). They are non-binding and make no claim to completeness or functionality regarding configuration and equipment. The application examples merely offer help with typical tasks; they do not constitute customer-specific solutions. **The application examples are not subject to standard tests and quality inspections of a chargeable product and may contain functional and performance defects or other faults and security vulnerabilities. You are responsible for the proper and safe operation of the products in accordance with all applicable regulations, including checking and customizing the application example for your system, and ensuring that only trained personnel use it in a way that prevents property damage or injury to persons. You are solely responsible for any productive use.**

Siemens grants you the non-exclusive, non-sublicensable and non-transferable right to have the application examples used by technically trained personnel. Any change to the application examples is your responsibility. Sharing the application examples with third parties or copying the application examples or excerpts thereof is permitted only in combination with your own products. Any further use of the application examples is explicitly not permitted and further rights are not granted. You are not allowed to use application examples in any other way, including, without limitation, for any direct or indirect training or enhancements of AI models.

Disclaimer of liability

Siemens shall not assume any liability, for any legal reason whatsoever, including, without limitation, liability for the usability, availability, completeness and freedom from defects of the application examples as well as for related information, configuration and performance data and any damage caused thereby. This shall not apply in cases of mandatory liability, for example under the German Product Liability Act, or in cases of intent, gross negligence, or culpable loss of life, bodily injury or damage to health, non-compliance with a guarantee, fraudulent non-disclosure of a defect, or culpable breach of material contractual obligations. Claims for damages arising from a breach of material contractual obligations shall however be limited to the foreseeable damage typical of the type of agreement, unless liability arises from intent or gross negligence or is based on loss of life, bodily injury or damage to health. The foregoing provisions do not imply any change in the burden of proof to your detriment. You shall indemnify Siemens against existing or future claims of third parties in this connection except where Siemens is mandatorily liable.

By using the application examples you acknowledge that Siemens cannot be held liable for any damage beyond the liability provisions described.

Other information

Siemens reserves the right to make changes to the application examples at any time without notice and to terminate your use of the application examples at any time. In case of discrepancies between the suggestions in the application examples and other Siemens publications such as catalogs, the content of the other documentation shall have precedence.

The Siemens terms of use (https://www.siemens.com/global/en/general/terms-of-use.html) shall also apply.

Cybersecurity information

Siemens provides products and solutions with industrial cybersecurity functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial cybersecurity concept. Siemens' products and solutions constitute one element of such a concept.

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

For additional information on industrial cybersecurity measures that may be implemented, please visit www.siemens.com/cybersecurity-industry.

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply the latest updates may increase customer's exposure to cyber threats.

To stay informed about product updates, subscribe to the Siemens Industrial Cybersecurity RSS Feed under https://www.siemens.com/cert.

Table of contents

1. Introduction 4

1.1. Purpose 4

1.2. Structure of the document 6

2. Architecture for data integration 7

2.1. Evolution towards Next-generation manufacturing integration architecture 7

2.1.1. ANSI/ISA-95 Enterprise-Control System Integration 7

2.1.2. Requirements of a modern architecture 7

2.1.3. Change from ISA 95 functional architecture to network structured architecture 8

2.1.4. Broker as a central data distributor 9

2.1.5. Unified Namespace based on central message broker 10

2.1.6. Smooth data integration and storage of data 11

2.1.7. Summary of new approach 13

2.2. Manufacturing Integration Levels 14

2.2.1. Mapping functions to systems on Manufacturing Integration Levels 15

2.2.2. Functions on enterprise level (enterprise IT system apps) 16

2.2.3. Functions on site level (site IT system apps) 17

2.2.4. Functions on line level (line apps) 18

2.3. Next generation solution architecture in detail 18

2.3.1. Introduction of blueprint architecture 18

2.3.2. Functions of Data integration layer in general 22

2.3.3. Definition of namespace 26

2.3.4. Architecture decision: Data integration layer and broker 27

2.3.5. Role of AI in the new integration architecture 29

2.3.6. Architecture decision: On premise vs. cloud 30

2.3.7. Data repository 31

2.3.8. Security requirements and administration 33

3. Appendix 35

3.1. Service and support 35

3.2. Links and literature 36

3.3. Change documentation 36

© Siemens 2026

1. Introduction

As a leading industrial automation system and operations software provider, Siemens intends to standardize production processes and workflows to increase efficiency and reduce engineering and operations efforts of our customers. For this, structured and networked data from IT systems as well as from OT systems are an important prerequisite.

1.1. Purpose

The purpose of the IT/OT Framework is to describe a **blueprint / reference architecture** for state-of-the-art, standardized IT/OT data integration to perform production control, operation and optimization/analytics use cases with **minimal efforts** and **minimum integration risks** – in the first version based on a product agnostic approach. In future versions this document combined with other guidelines will offer a best practice solution – based on released Siemens products and explaining necessary implementation steps. Internal interfaces and internal systems of Siemens systems are not considered in this document.

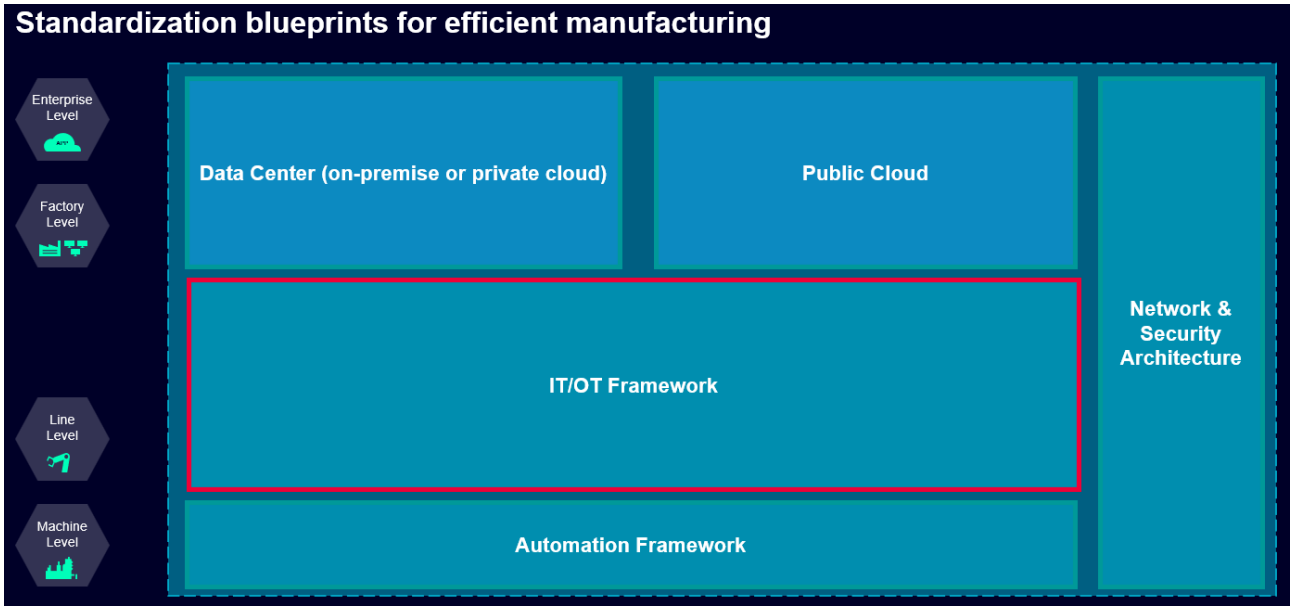


Figure 1 Standardization blueprints for efficient manufacturing

The IT/OT framework is aligned with a bigger set of blueprints. Siemens offers industry-specific standards such as SICAR - a framework for standardizing automation in the automotive industry - as well as generic standards such as the Siemens Automation Framework. The Automation Framework provides the basic structure of a PLC and HMI program and a standardized interface for controlling and monitoring the machine status from higher-level IT systems. It is a TIA Portal project for machine or line builders that helps with the implementation of the automation program for different machines.

With increasing digitalization, an increasing number of devices leads to a higher number of connections and increasing amounts of data that needs to be transferred inside a plant's network. A recommended **Network & security architecture** is described in Network concept for discrete manufacturing. The network concept is intended to provide an example network concept. Based on the same architecture Siemens Sales representatives additionally have access to further details of the security reference architecture.

The **IT/OT framework** represents a central connecting element between these concepts and is fundamental for a deeper understanding of the requirements, challenges and solution approaches within an IT/OT integration. This creates the basis for an optimal operation of the factory. It describes the essential key elements of an IT/OT architecture, makes IT technology understandable to the OT reader and OT technology understandable to the IT reader.

© Siemens 2026

The main target groups of this document are

- IT/OT technical decision makers and plant operators from a mid-size to large scale customer
- System integrators and line builders
- Consultants for IT/OT architecture
- Siemens Sales Specialists, Technical Consultants and Technical Account Managers

Additionally, machine builders and others can extract relevant information about standardized shopfloor interfaces.

Goals

- Simplify tasks related to the specification of the data integration architecture
- Reduce efforts for implementation of data integration architectures and standardized data models
- Reduce risk for misconfiguration, performance bottlenecks or scaling issues during project rollouts
- Avoid vendor-locking through vendor-specific solutions and enable easier scaling based on market standards
- Supports a land (start small) and expand concept
- Improve system diagnostic to detect system issues faster
- Create offers faster and more cost-effectively with fewer resources for better quality

Key features

- Product agnostic blueprint for IT/OT integration.
- Building block like approach can be integrated in Greenfield environment but also in steps into existing brownfield environments

Benefits for responsible plant operators

The application of the framework to a production facility may offer improvements to …

- plant productivity and product design with data driven decision-making.
- faster Know-how ramp-up and easier operation through standardized approach in visualizations and integration interfaces.
- benefit from new developments and applications that can easily be integrated into standardized architecture.

Benefits for OEMs/System Integrators

- Standardized data access & management on shopfloor level enables
  - Fast implementation of value adding use cases
- Increases flexibility to **meet** the **diverse** IT demands of plant operators **across industries** (e.g., supporting different cloud providers, integrating with customer-specific MOM systems)"Faster integration of systems thanks to defined handover points and handover format between OT and IT
- Flexibility to adapt data for consumption by IT without interfering with OT availability
- Recommendation how to achieve flexibility to adapt system when integrating further use cases
- Special cases are also considered, such as how these can be mapped to a standard
- Aligned with Siemens Secure Reference Architecture and network concept for a secure production aligned with necessary standards to avoid competing workstreams

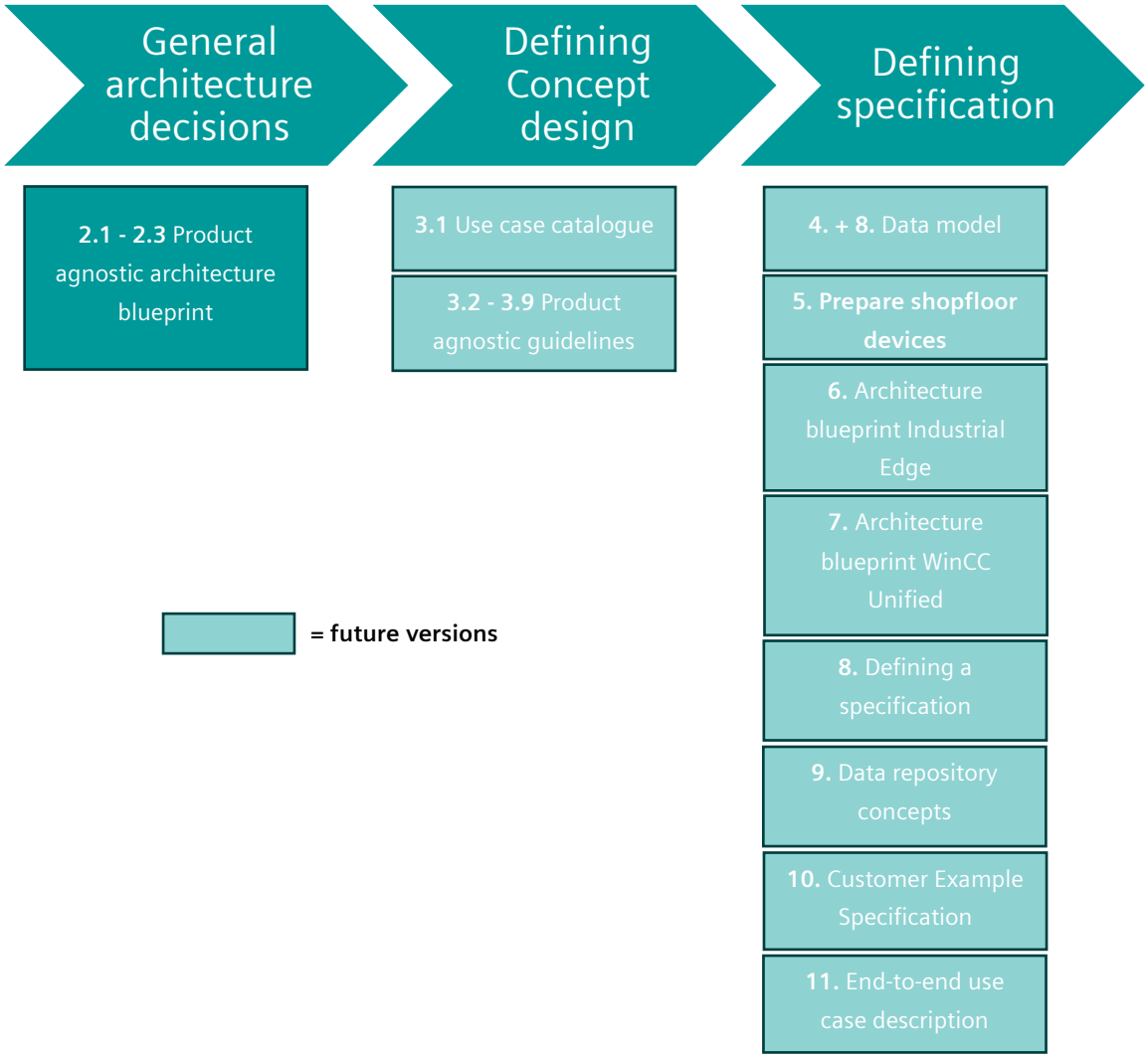
Out of scope

- The scope is **not** to provide step by step instructions for the configuration of individual systems. Therefore, application examples exist in Siemens Industry Support webpage and Siemens GitHub.

© Siemens 2026

1.2. Structure of the document

For defining & implementing a state-of-the-art data integration layer, various phases are required. The first step involves clarifying general architectural questions. The next-generation manufacturing integration architecture serves as the basis for this. The next step, the concept design phase, involves considering which use cases will be implemented and which products can be used for them. Subsequently, the appropriate data models are selected based on the use cases, and the necessary elements are identified from the product architecture blueprints.



Structure

The document is structured in the following chapters:

- **Chapter 1** describes the objective of the document, the target group and the relationship with other documents
- **Chapter 2** describes target use cases and a product-neutral architecture based on industry proven concepts. This chapter gives an overview of key elements for IT/OT integration and therefore can support readers with IT background to understand key elements when integrating IT and OT minded readers to understand the IT landscape in a production company.

Chapter 2 is recommended to get an overview of the architecture and is relevant for all target groups.

© Siemens 2026

2. Architecture for data integration

2.1. Evolution towards Next-generation manufacturing integration architecture

This chapter describes how the hierarchical functional structure according to ISA95 has opened towards a more direct communication in the shop floor network. Impediments from point-to-point communication led to a new approach introducing a central message broker, a data integration layer, central data repository and standardized namespace.

2.1.1. ANSI/ISA-95 Enterprise-Control System Integration

The integration of many systems with another has proven to be very complex. Standards help to reduce complexity and support in defining the requirements for customers, suppliers, internally as well as externally. Over the years, several standards have emerged that describe use cases, goals, and data models for integrating enterprise and industrial control systems. One widely used and known standard is ISA-95.

ISA-95 is the international standard for the integration of enterprise and control systems. It consists of concepts and terminology. The official name is "ANSI/ISA-95 Enterprise-Control System Integration".

ISA-95 provides a functional hierarchy defining activities within a manufacturing organization. This hierarchical model has traditionally taken the form of a pyramid, also known as the automation pyramid.

Additionally, the standard also provides a concept for how to structure manufacturing equipment. The grouping of equipment such as machines, production lines and warehouses in a hierarchical order helps to standardize workflows and information flows.

The conceptual model of ISA 95 does not include specifications for data models. Therefore, the precise implementation of interfaces in each product can vary. However, the standard helps by creating a common understanding of what kind of information is needed.

2.1.2. Requirements of a modern architecture

It is not enough to get data. The statement "*Each system can access the right data at the right time in good quality for which they are authorized*" refers to an ideal state in a data management and integration context. It emphasizes the following key points:

1. **Right Data**: Each system can access the specific data it needs. This means data is relevant and aligned with the system's requirements.
2. **Right Time**: The data availability is timely, meaning the systems can retrieve the data exactly at the right time, enabling efficient operations and decision-making.
3. **Good Quality**: The data accessed is of high quality, implying it is accurate, consistent, and reliable, which is essential for maintaining trust in the data-driven processes. All data-driven use cases require cleanly structured (e.g. local allocation) and contextualized data (assignment to an event).

To ensure effective data utilization, data should adhere to the **FAIR principles**: **Findable, Accessible, Interoperable, and Reusable**.

- **Findable:** Both data and their associated metadata must be easily discoverable by humans and computational systems.
- **Accessible:** Once data is found, users require clear information on how to access it, including any necessary security mechanisms.
- **Interoperable:** Data should be readily integratable with other datasets and compatible with various applications or workflows for analysis, storage, and processing.
- **Reusable:** The overarching goal is to maximize the potential for data reuse in future analyses and applications.

In the context of data integrity, **ALCOA** is an acronym that stands for **Attributable, Legible, Contemporaneous, Original, and Accurate**. These principles are used to ensure the reliability and trustworthiness of data, particularly in regulated industries like pharmaceuticals and healthcare.

© Siemens 2026

Here's a breakdown of each component:

- **Attributable:** All data should be traceable to the individuals (user and systems) and originators who created or modified it. This means there should be clear identification of who recorded the information and when.
- **Legible:** Data should be clear, readable, and understandable, both at the time of recording and for future reference. This applies to both paper and electronic records.
- **Contemporaneous:** Data should be recorded at the time the activity or observation occurs, or as close to it as possible.
- **Original:** Data should be the original record or a verified copy, not a copy of a copy, to minimize the risk of errors or alterations.
- **Accurate:** Data should be correct, truthful, and free from errors.

Overall, this statement underscores the importance of efficient data management practices, ensuring that data is accessed securely, efficiently, and effectively. Only with efficient data management the successful implementation of the above use cases is possible.

2.1.3. Change from ISA 95 functional architecture to network structured architecture

Traditionally communication was limited from one hierarchical level of the ISA 95 pyramid to the next. Limiting the communication in such a way makes it **difficult to realize** new use cases or adapt existing use cases. Systems remain isolated like **data silos**. Each system operates properly only within its own layer.

Data Communication through several layers of the ISA95 pyramid can lead to **information loss, additional delay and transaction cost**. New technologies like AI applications or cloud computing require **cross-layer data access.**

These challenges led to a rethinking of the previous ISA95 architecture. It is better that the communication partner can communicate to all participants to avoid frequent adoption in the systems in between

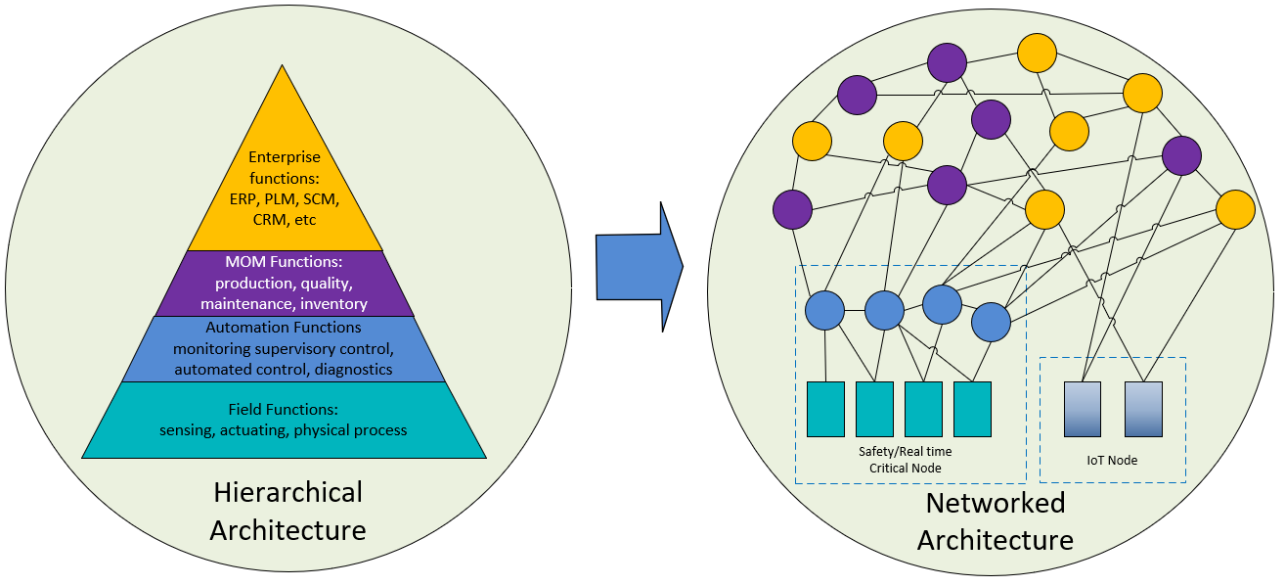


Figure 2 From old hierarchical architecture to new distributed networked architecture

The image above shows the evolution of models from the old functional hierarchical architecture towards a non-hierarchical point to point structure. In this architecture all systems communicate with the other systems that they need to exchange data with.

© Siemens 2026

Opening the communication in that way by using a lot of point-to-point connections has **several negative implications**:

- **Scalability Challenges**: Adding new systems requires establishing multiple new connections, which becomes unsustainable as the network grows.
- **Cybersecurity Risks**: Increasing the number of connections increases the potential attack surface of the OT system landscape.
- **Data Loss:** Each communication pair is responsible for its own flow, and failures in individual connections (e.g., dropped packets or interrupted connections) can lead to lost data.
- **Interoperability Challenges**: IT and OT systems often use different communication protocols and standards, which can create compatibility issues when integrating new applications.
- **Change Management**: Updates or modifications require changes to multiple connections, leading to significant effort, making the change process inefficient.
- **Maintenance and Diagnostic Challenges:** Point-to-point systems lack centralized tools for diagnostics, making routine maintenance and issue identification cumbersome.
- **Complex configuration:** The system integrator must know which information is necessary in which systems, where is it available and where not, and from where it could be retrieved. This leads to increased effort and contributes to a higher risk of misconfigurations in complex system architectures.

2.1.4. Broker as a central data distributor

A solution for the challenges mentioned in the previous chapter is to use one central broker which acts as data distributor and exchange of information.

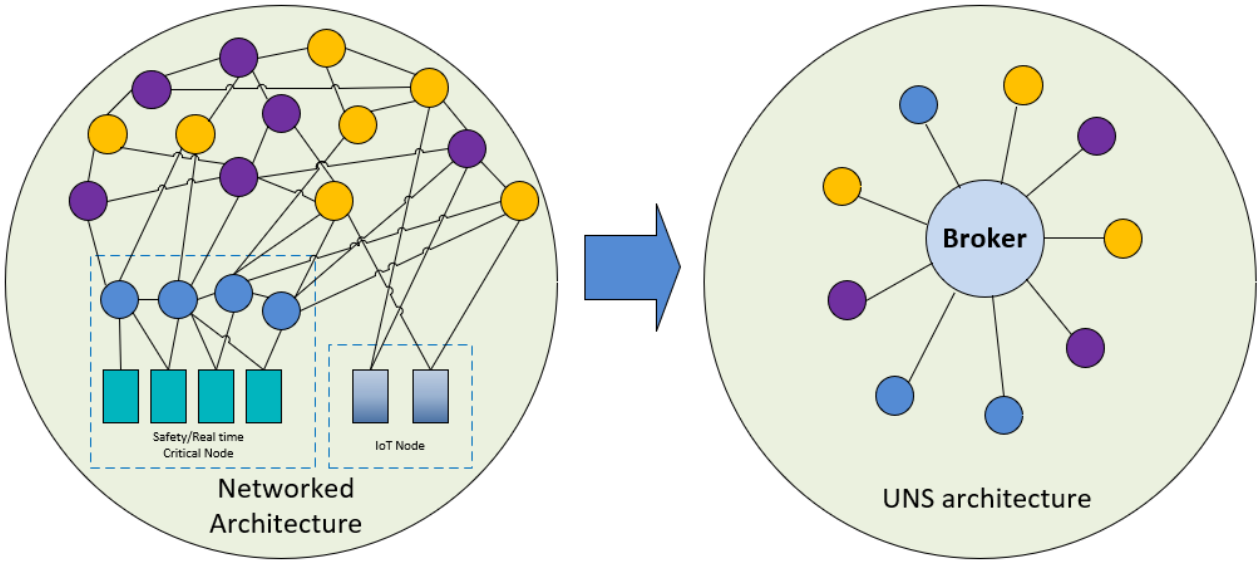


Figure 3 From point to point to broker-based architecture

A **Message Broker** is a software that enables applications, systems, and services to communicate with each other by exchanging messages. It acts as an intermediary that receives messages from senders (producers) and forwards them to the appropriate recipients (consumers). The main goal of a Message Broker is to **decouple** and make the communication between different systems **asynchronous**.

How Does a Message Broker Work?

1. **Producers (Publisher/Sender):** An application that wants to send a message sends it to the Message Broker. It doesn't need to know who will receive the message or how many recipients there are.
2. **Messages:** The data exchanged between systems is packaged in a standardized format (e.g., JSON, XML) as a "message."

3. **Queues:** Messages are stored in an ordered sequence and processed by a single consumer (point-to-point communication). Once a message is processed, it is removed from the queue.
4. **Topics:** Messages are published to all interested consumers who have subscribed to that topic (publish/subscribe communication). A message can be received by multiple consumers simultaneously.
5. **Consumers (Subscriber/Receiver):** Applications that want to receive messages subscribe to specific queues or topics with the Message Broker. As soon as a new message is available, the broker delivers it to the consumer.

Advantages of a Message Broker:

- **Decoupling:** Senders and receivers don't need to know each other directly or be available at the same time. They only communicate with the broker. This increases the flexibility and maintainability of the systems.
- **Asynchronous Communication:** Senders can send messages and immediately proceed with other tasks without having to wait for a response from the receiver. The receiver processes the message when it's ready.
- **Reliability:** Messages are stored by the broker until they are successfully delivered and processed. This prevents data loss, even if recipient systems are temporarily unavailable.
- **Scalability:** It's easier to scale systems because new producers or consumers can be added without changing the existing architecture.
- **Load Balancing:** Multiple consumers can listen to the same queue, distributing the message processing load.
- **Error Handling & Retries:** Many brokers offer mechanisms for redelivering messages in case of errors or moving failed messages to "dead-letter queues."
- **Single source of truth**: containing all the data about the structure and current state of the entire enterprise.

2.1.5. Unified Namespace based on central message broker

Using a broker makes it easier to connect one system (e.g., machines from different manufacturers, ERP, MES) to another. However, this is not enough to implement data flows that allow systems to communicate efficiently with each other. This requires defining a common message format and common semantics. Using common message format and common semantics make it easier to scale and having consistent data.

The best-known concept to extend the broker concept with standardized messages is **Unified Namespace (UNS)**. There is no official standard or central authority that clearly and formally defines the term Unified Namespace. The Unified Namespace provides a modern, distributed architecture in which data is accessible in a unified manner. Unified namespace does not describe a specific data model but describes that data should be offered in a standardized way. The proposal from Unified namespace is to use ISA 95 to standardize and structure data so all levels of the ISA 95 functional hierarchical model are mapped in the UNS architecture. It acts as a central interface for the exchange of information, especially in IT.

Benefits of the UNS architecture are:

- Organized Structure

  The data stored in the Unified Namespace shall reflect the structure of the business. The equipment hierarchical model of the standard ISA-95 shall be used as a basis for the data organization. The resulting standardized integration data model speeds up the integration of new systems.

- Reduced Communication Load

  UNS reduces the communication load on the network and OT components that tend to be more sensitive when it comes to data access. This is especially relevant when several systems are interested in the same information. Some examples are listed below:

  - Information about *work order*: ERP system, APS system (Scheduling system), analytics system, ...
  - Information about *intra-plant logistic transport*: WMS system, APS system, MOM system, analytics system, ...
  - Information about *machine status*: APS system, MOM system, analytics, CMMS systems...

2.1.6. Smooth data integration and storage of data

The successful usage of broker with unified namespace shall be supported by the complete chain, beginning from data acquisition to data integration. While the UNS specifies the general data exchange principles, it does not specify how to efficiently connect equipment related data sources on the shopfloor (like sensors, IIoT devices, machines, robotic system, ...) and how to store or retrieve UNS-external domain objects like data for historical analysis.

Especially in the brownfield environment unstructured and inconsistent data sources pose a significant problem for data quality. This is particularly challenging in the Industrial IoT and for multiple plants. Data sources use vendor-specific data structures, formats, and inconsistent semantics. Furthermore, data is provided without context. It is not clear to which equipment, order, ... process parameters belong to.

For this reason, the existing UNS concept is mainly supplemented by two additional elements: the Data integration layer and a data repository that manages all UNS-external domain objects. This also includes the functionalities of a historian.

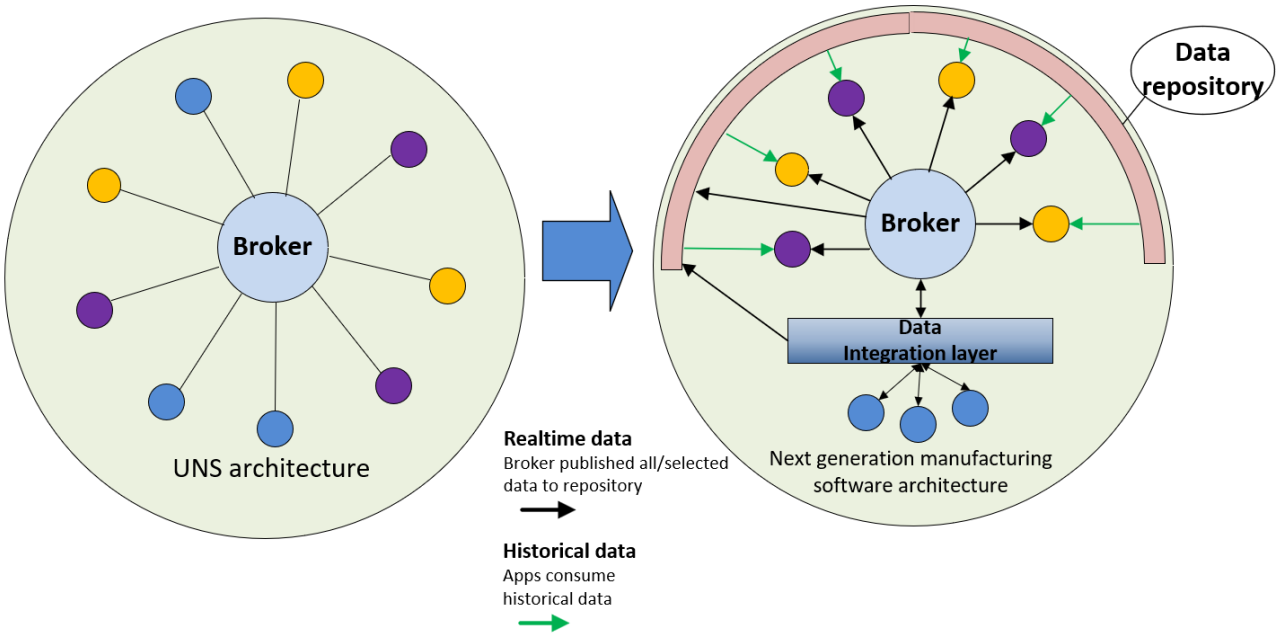


Figure 4 From UNS architecture to the next generation manufacturing software architecture

Data integration layer

The Data integration layer serves as the critical interface between the physical layer of the shop floor (machines, sensors, PLCs, etc.) and the digital layer of the Unified Namespace. Without an integration layer, complex data transformations must be performed on the PLC. This requires the PLC to be configured so that fewer resources are available for its actual tasks, or a larger PLC must be used.

© Siemens 2026

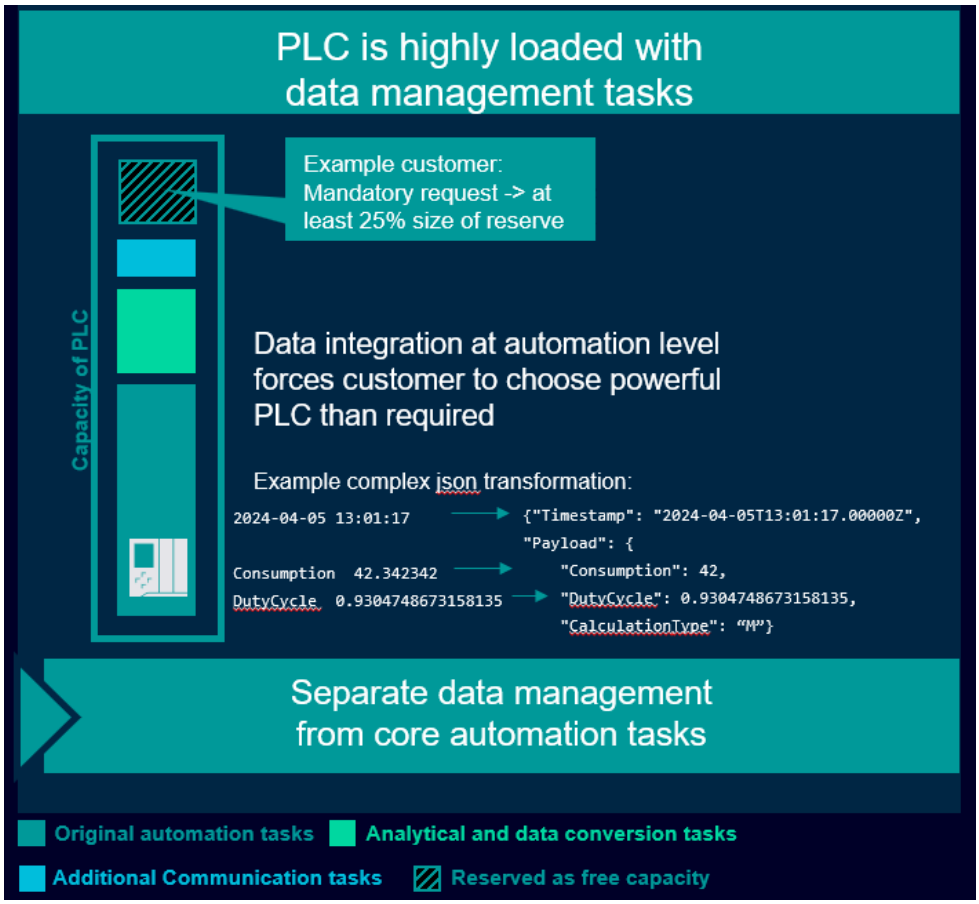


Figure 5 PLC is highly loaded with data management tasks

A Data integration layer is essential, especially given the wide variety of different equipment. If the data is standardized, the connection to UNS and thus to IT systems (such as MES, ERP) is relatively simple. Its main purpose is to extract, transform, and publish operational data into the UNS in a structured and contextualized way. Due to the appropriate IT resources, these types of tasks are considerably easier to perform than on a PLC.

Overarching data repository

A data repository in a UNS-based architecture serves as a long-term storage and access layer for structured data that has been published into the UNS, including metadata or structured references to semi-structured and unstructured data. While the UNS itself typically hosts the latest values and works event-driven, the repository ensures that historical data and other UNS-external domain objects remain persisted, query able, and analysable.

Example: the current machine status is sent to a SCADA to display it on the screen and to a scheduling system to carry out any job rescheduling. However, to increase the availability of the system, the historical data is important for analytics.

The data repository enables long-term retention for compliance, traceability, and analysis. The data repository also contains the functionality of an historian. Apps can also modify and add historical data to the data repository. Further details of the data repository can be found in chapter 2.3.7

Challenges of Unified Namespace

As for every possible architecture, the Unified Namespace approach also brings challenges such as persistency of objects for usage within various systems, dependency on network, system availability or version and change management. Many of them can be overcome if they are considered during the design phase.

© Siemens 2026 |

2.1.7. Summary of new approach

In previous chapter the advantages of using a central Data integration layer and a message broker were pointed out. The various benefits are completed by using standardized data according to UNS and data repository.

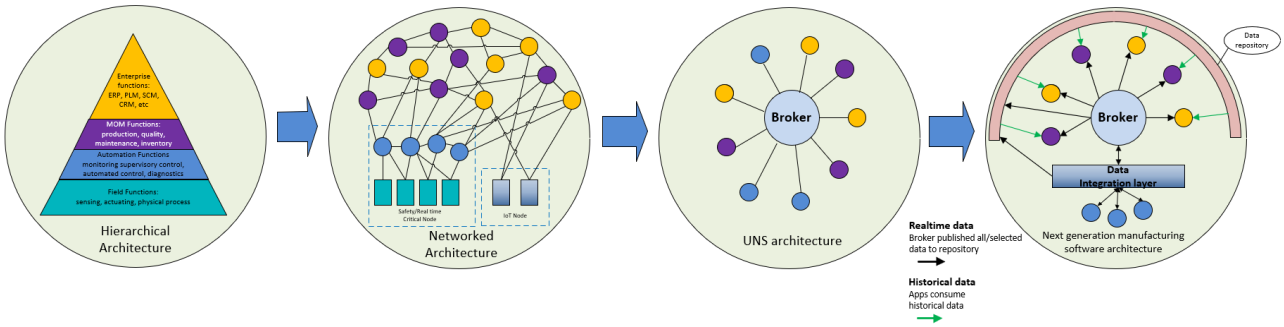


Figure 6 From common architecture based on ISA95 to the next-generation manufacturing integration architecture

The following table summarizes the benefits of Next generation manufacturing software architecture over the traditional ISA 95 approach:

Aspect	Next generation manufacturing software architecture	Common architecture based on ISA 95
Data Accessibility	Real-time, centralized access to all data across the enterprise.	Data is siloed across hierarchical levels
Integration	New added systems can access to all existing event-based data without connecting to each single system and using just one protocol.	Complex and rigid integration between layers.
Scalability	Easily scalable with plug-and-play capabilities.	Scaling requires significant reconfiguration.
Flexibility	Decoupled architecture allows for dynamic system changes.	Changes are constrained by fixed layer definitions.
Latency	Low latency due to direct data publishing/subscribing.	Higher latency due to layer-by-layer data flow.
Contextualization	Data is contextualized as close as possible at the source, provided the contexts are available and shared in a unified model. The unified model is not given by default and must be specified or developed by the user.	Context is often added later, increasing complexity.
Maintenance	It is easier to maintain and update components independently.	Maintenance often affects multiple layers.
Modernization	Aligns with Industry 4.0 and IIoT principles.	Based on older industrial automation paradigms.
Reliability	Single Point of Failure of UNS/Broker → Risk of network or software issue can lead to failure of the complete data integration	If one element of the pyramid is broken all components can be affected if the component is critical for data transfer..
Mitigation	It can be addressed through redundant brokers, failover mechanisms, and local caching.	More distributed reliability risk, but failures in one layer can block information flow to all bordering levels.

© Siemens 2026

Aspect	Next generation manufacturing software architecture	Common architecture based on ISA 95
Security	Centralized security management with granular access controls at the data level. But at the same time the broker is a „man in the middle" -risk. Someone can manipulate data in the broker as the single source of truth.	Security implemented at each layer boundary with inconsistent models and potential gaps but also offering a defence in depth approach.
Implementation complexity	Higher initial setup complexity but simplified ongoing integration.	Lower initial complexity but accumulating integration debt over time."

One of the leading institutes in the field of IT markets Gartner confirm that the above-described approach fits as a future reference architecture. They overcome challenges from hierarchical levels and point-to-point connections in their reference architecture for Integrating OT and Modern IT.

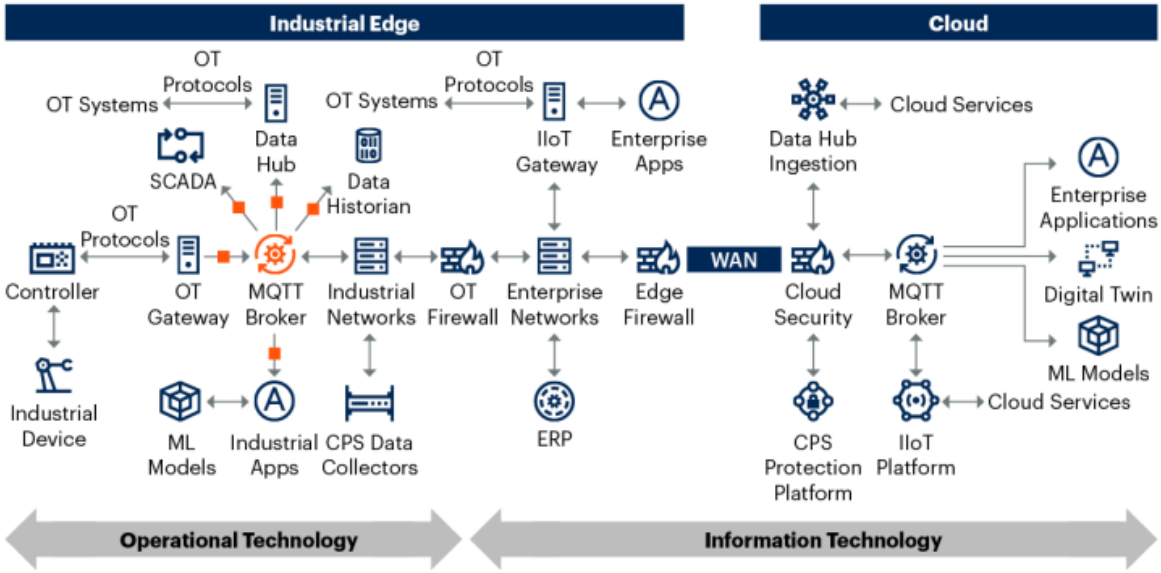


Figure 7 Exemplary analyst view - source: Gartner Research - Reference Architecture for Integrating OT and Modern IT

2.2. Manufacturing Integration Levels

Today's manufacturing environments require flexible communication and seamless data exchange, while maintaining clear organizational structures. While the ISA 95 pyramid is deprecated, working with levels to clarify which stakeholders in the company are working with which systems and data is still helpful to gain an overview and clarity about dataflows, usage of data and data storage. A level-based approach maps the structure of the company and visualizes areas of responsibility.

To gain structure but reduce complexity, we utilize a four-level framework:

- Enterprise Level: corporate-wide applications
- Site Level: plant-specific applications
- Cell/Line Level: production line applications
- Machine Level: equipment-specific applications

This structure provides a logical organization of manufacturing applications while acknowledging that data and communication can flow freely between all levels through central message brokers.

© Siemens 2026 |

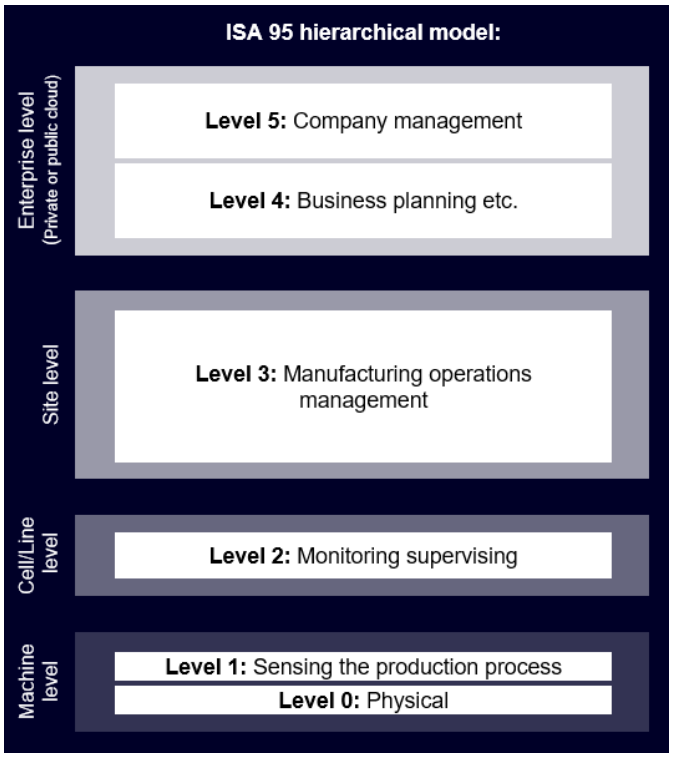


Figure 8 functional levels in this document

The manufacturing integration levels do not define at which level the systems are physically running, but what scope of equipment the respective function has. A SCADA can run on Cloud, a virtual PLC as a line controller can run on a datacenter.

In the following chapters, we will use these levels to map applications and functions to their most suitable manufacturing integration layer within the manufacturing landscape.

2.2.1. Mapping functions to systems on Manufacturing Integration Levels

In modern manufacturing environments, the integration of various applications and systems is crucial for efficient operations, data-driven decision making, and maintaining competitive advantage. This chapter outlines the four fundamental hierarchical levels and their associated applications and illustrates how they support the overall manufacturing process. This also provides an overview of where which system and software is maintained and who is responsible for it in the company structure.

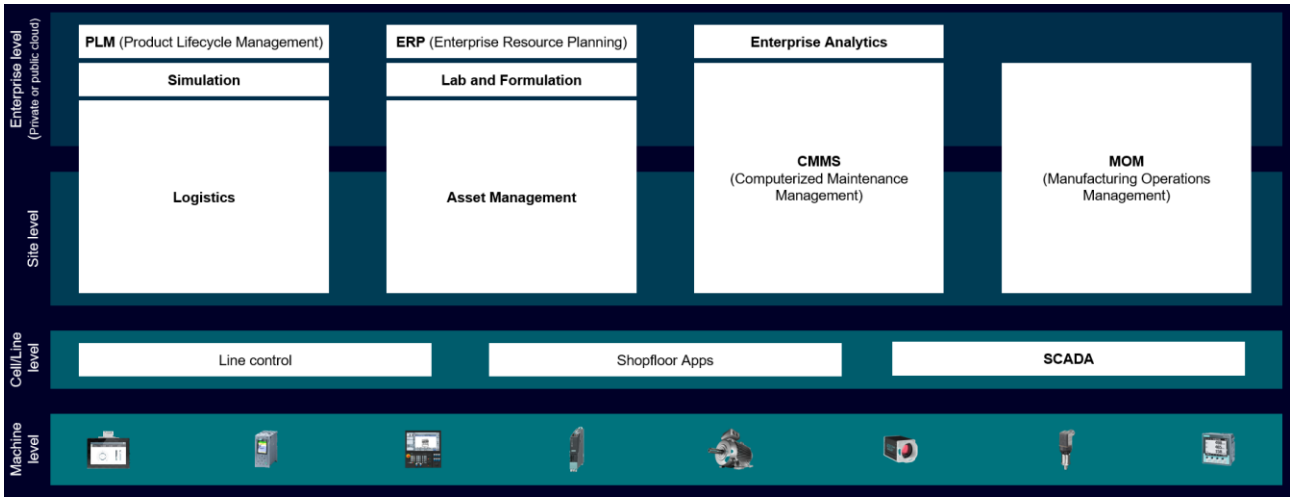


Figure 9 Overview of functions

© Siemens 2026 |

The following sections detail each level's specific applications and their roles in supporting manufacturing operations, starting from the strategic enterprise level, down to the operational machine level.

As a fundamental principle, applications should be placed at the highest possible level (e.g. Site or enterprise level) to ensure centralized management, standardized processes, and simplified maintenance. Applications should only be implemented at Line Level when specific requirements exist, such as timely response needs (e.g. alarms), high-frequency data collection, apps to run a complete line/area, like line coordination (independent by upper systems) or autonomous operation requirements. This typically applies to applications directly involved in process control, immediate operator interaction, or time-critical safety functions. KPI calculation on the other hand is a good example that makes sense to run at a higher level. On the higher level further data sources available for contextualization and the scalable IT resources allow more extensive analyses to be carried out.

2.2.2. Functions on enterprise level (enterprise IT system apps)

The Enterprise Level represents the highest tier in the manufacturing systems hierarchy, where corporate-wide processes are managed. At this level, applications focus on managing the entire organization's resources, operations, and strategic initiatives. These applications provide the foundation for company-wide standardization, decision-making, and process optimization.

The following image shows the functions in the enterprise level.

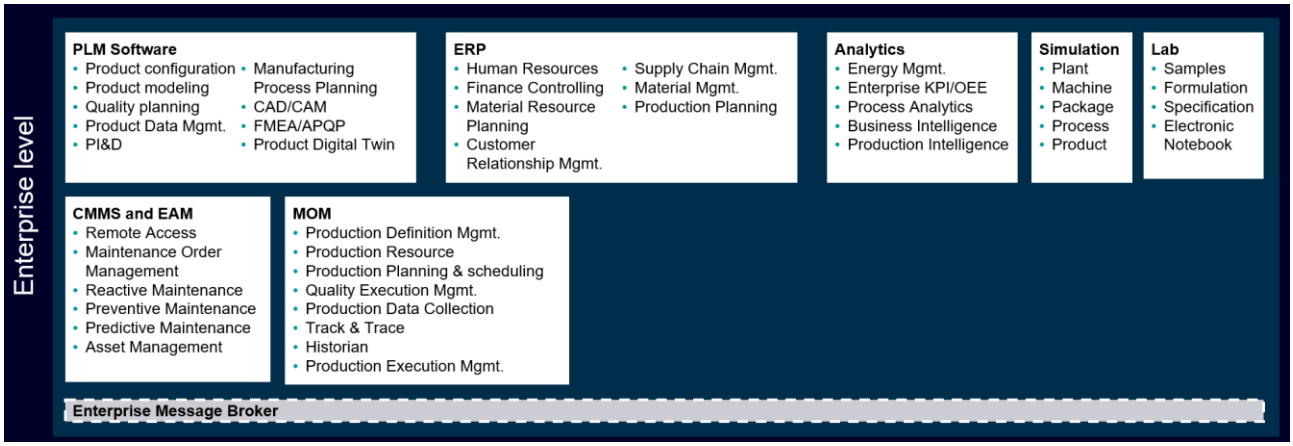


Figure 10 functions on enterprise level

The following function clusters run at enterprise level:

- **Product Lifecycle Management (PLM)** software forms the backbone of product, process development and management processes. This also includes quality planning, which determines what parameters should be checked and how often. Furthermore, it also contains the digital twin of the product.
- **Enterprise resource planning (ERP):** Software system that helps companies streamline their core business processes—including finance, human resources, manufacturing, supply chain, sales, and procurement — with a unified view of activities and a central source of truth.
- **Enterprise analytics** provide enterprise-wide dashboarding (KPI) and big data analytics software for different purposes like energy consumption, production efficiency and quality analytics.
- **Simulation Systems** execute comprehensive simulation capabilities across multiple domains like plant, process, machine, package and product simulation. It mimics the function of real or planned systems to test, analyse and optimize their behaviour under different conditions before they are implemented in the real world.
- **Lab and Formulation Management** involves the structured, systematic, and documented process of developing, creating, standardizing, and managing recipes or formulas for various products, integrating scientific laboratory work with production management to ensure quality, consistency, compliance, and efficient scalability from initial concept to finished product.
- A **Computerized Maintenance Management System (CMMS)** is software that helps companies manage their maintenance activities. It assists in planning, executing, and tracking maintenance work, which can lead to increased asset availability and reduced costs.

© Siemens 2026 |

- **Manufacturing Operations Management**, or **MOM** for short, is a holistic concept that aims to manage, optimize and digitally model the manufacturing processes within a company. This includes order scheduling and execution, quality and execution and production data collection. Quality planning could be executed in PLM or MOM system.

AI is not shown in the diagram, as it can be assigned to different levels and different apps according to its tasks. AI assists in **training** and **running ML models** in industrial environments. Structured time-series data, audio and video data are used to train models in **clouds** like AWS and Azure or **on-site level**, while the running models are executed reliably **on the shopfloor**.

NOTE In the hierarchy diagram above **MOM** can be replaced by **MES**. MOM can be seen as the natural evolution of MES, providing a more complete solution for modern manufacturing operations while maintaining core MES functionality. While a MES is specifically designed for real-time control and monitoring of production processes, a MOM system offers a holistic management solution, integrating a wider range of functions and modules to optimize the entire production environment even more comprehensively.

Rather than deploying a standalone MOM, companies often rely on their ERP system enhanced with MES add-ons.

The following functions can be placed on site level or on enterprise level:

- **MOM software** is executed on enterprise level, when its function is not tightly aligned with shopfloor operations. MOM functionalities like order scheduling and production analytics can run on the enterprise level.
  If the production process relies on data from MOM, for example for so called "lot-size 1 productions", MOM should be deployed on site level The advantage is that the shopfloor is continuously running independently from the enterprise level e.g. cloud level. Typical site apps for Manufacturing Operation Management are production execution management, track and trace, dynamic scheduling and quality execution management. See diagram in the next chapter.
- **Maintenance functionality** is provided by a CMMS system (Computerized Maintenance Management System). A CMMS is software that supports companies in centralized control and management of their maintenance processes. It serves as a digital center for maintenance and connects all relevant processes. The key functionality is maintenance orders. Maintenance solutions, that require data from multiple plants, are often hosted in the cloud and therefore part of the enterprise level.
- **Logistics systems**, that manage all material movement and storage operations within the facility.
  The placement of logistics and asset management at the site level ensures that organizations can effectively manage their physical resources while maintaining optimal operational efficiency and supporting broader business objectives. This includes both the inbound process of receiving materials into the factory (goods receipt) and the outbound process (delivery). AGV control systems are used to support this process.
- An **Enterprise-asset-management-system (EAM)** extends CMMS with additional functionality that takes the whole lifecycle of an asset into view – from acquisition to disposal. While a CMMS focuses on maintenance management, EAM addresses the bigger picture of asset management beyond maintenance. The automatic recording of assets is also part of asset management.

Generally, functions should be performed at the highest level. Sometimes there exist restrictions so that functions must be run at the site level.

2.2.3. Functions on site level (site IT system apps)

The site level represents the crucial layer between enterprise systems and shopfloor operations, focusing on plant-specific applications and systems that manage daily manufacturing operations, quality control, and facility management. This level translates enterprise-level strategies into operational execution while collecting and aggregating data from the line and machine levels. These functions normally run on a private cloud.

As described in the previous chapter MOM and Maintenance can also be realized on the site level depending on the process complexity, plant independence, real time demands or other technical and network considerations. The decision to move MOM and Maintenance functions to the site level should be based on a careful analysis of operational requirements, technical constraints, and business needs.

The advantage of placing Apps on site level rather than line level, is that at site level, data from the entire plant is available and can be utilized. This enables the comparison of KPIs and dynamic scheduling.

2.2.4. Functions on line level (line apps)

The line level serves as a critical interface between operational management and machine-level execution, that ensures seamless production flow and data management. At the line level, these systems are generally deployed on IPCs or on industrial datacenters.

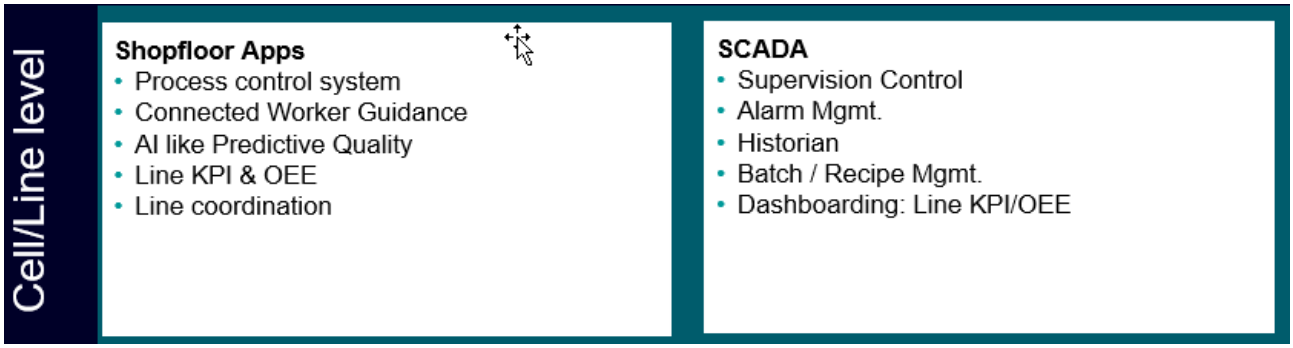


Figure 11 functions on line level

- **Shopfloor apps:** Process control systems are used to monitor and control industrial processes, including manufacturing processes, chemical processes, oil and gas production facilities, water treatment plants, and power generation facilities. Typical app is the line coordinator, that controls the speed of the complete line, handovers data from one station to another one when an operation is complete, buffers order data and traceability data.
  Connected worker guidance refers to the use of digital technology to link frontline workers with people, processes, and products in real-time, enhancing their ability to perform tasks, collaborate, and contribute to operational improvements.
  Line coordination control synchronizes and controls the speed of different machines of one line. Order management, which is a typical MES functionality, can also be partially distributed to a line computer or line controller.
- **SCADA**: Supervisory Control: Operators can use the system to monitor processes, respond to alerts, and send commands to control equipment or adjust settings remotely. Data Processing and Logging: Analysing the collected data and logging events and alarms for later review, which helps in identifying issues, optimizing processes, and creating reports. Alarm management is the systematic detection, prioritization, and notification of critical conditions in a SCADA system, to ensure the safety and efficiency of industrial plants. A recipe management system is a software application that manages the complex relationships and processes related to a company's production recipes. Historian software is a software that collects, stores, and retrieves large volumes of operational data from industrial processes for analysis, monitoring, and optimization

2.3. Next generation solution architecture in detail

This chapter describes a proposal of a general IT/OT integration architecture without specifying vendor specific solutions. The aim here is to make data available so that the use cases can be implemented in the best possible way. This requires connecting equipment with IT systems as well as transforming data into a standardized, semantic data model. This creates the basis for supplying the business logic of the applications with the appropriate data. Each component of this architecture will then be described in the following chapters.

2.3.1. Introduction of blueprint architecture

Based on the findings in Chapter 2.1 the following next generation architecture was developed. Engineering and administration systems are not included but will be considered in additional chapters.

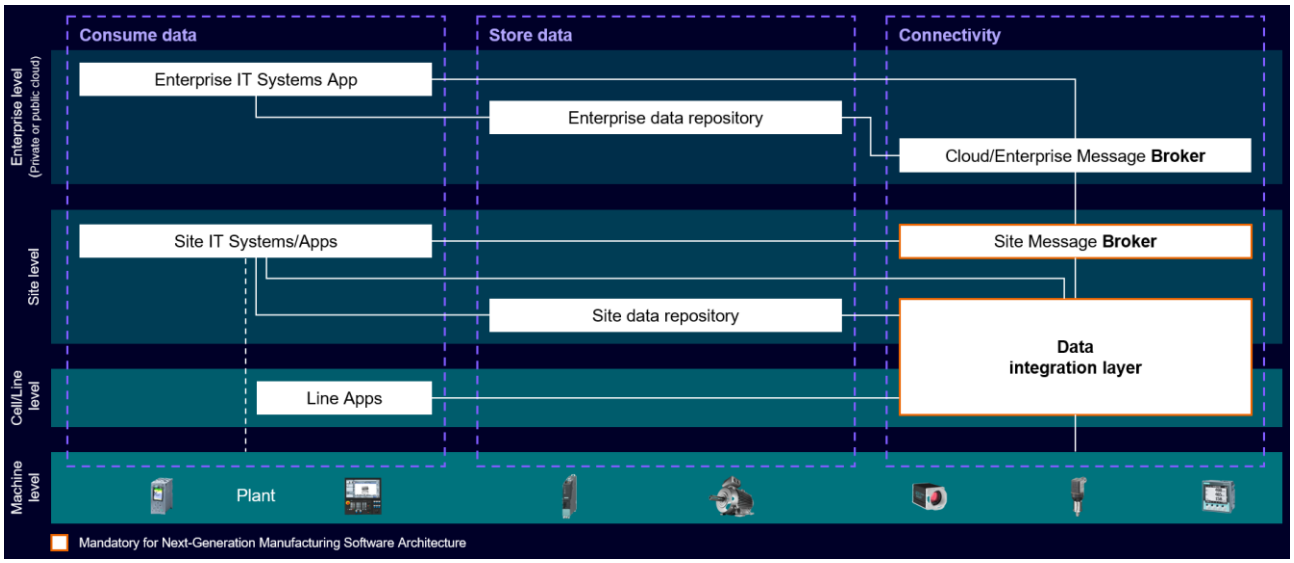


Figure 12 High level system architecture

Data producers and consumers are not connected directly. OT Sources are connected to the data integration layer, which is then connected to Apps, to a central data repository or to message broker. IT systems itself can connect directly to the data integration layer or using an IT data integration layer. e.g. for converting protocols MQTT to RestAPI and data structures.

The paragraphs below describe the hierarchical levels in the IT-OT-framework:

Machine level

The machine level is either connected to the Integration layer utilizing standardized interfaces (greenfield scenario) or non-standardized interfaces need to be connected (brownfield scenario).

Depending on the use cases that the production owner aims to implement, the integrator needs to decide if only the “brain” of the machine -the PLC, is connected or also field devices.

Cell/Line level

Central component is the Data integration layer, which connects to the shopfloor. The data integration layer is responsible to provide data to the broker in a standardized and contextualized format.

Site level

The data integration layer also located on site level. A data repository is in place as well, which can store and manage time series data, structured or unstructured data like images or videos. They are needed to collect data for performance monitoring, process tracking or business analytics. The site message broker routes all messages between IT systems, databases and data integration layer. The site message broker connects site level via bridging with the enterprise level.

Site IT systems/apps rely on current data from message broker as well as on UNS-external domain objects like historical data from data repository.

This level is often referred to as fog computing in the context of IIOT/cloud computing. The systems are often used in virtualized environments and can run in a private cloud environment.

Enterprise level

Enterprise level functionality can run on a private cloud or on a public cloud. Enterprise message brokers are used to connect to cloud systems, site broker or other enterprise IT Systems. Like the site level, it also includes databases and IT apps, which has the focus on multiple plants.

Key rules

The use of the framework components in the different layers depends on the manufacturing infrastructure, its size and the short- and long-term goals. The following summary describes examples in which components are essential or where they might not be needed.

- The integration layer can be designed in different ways: as an integration layer at site level and/or at line level.
- A s*ite message broker* is necessary for companies with more than one production facility
- If any applications on site level are necessary, then at least *Site IT System* and/or *Site Apps* can be used. When a company has only one production site: site and enterprise level can be combined.
- If there are any applications on enterprise level necessary, then the *Enterprise IT System App* is needed. When a company has only one production site: site and enterprise level can be combined.
- The enterprise level is optional. Therefore, IT systems like ERP can also run on Site level.
- To benefit from digitalization in the production, store the data in the data repository and access it there for analytics with different systems.
- IT systems that cannot access the MQTT broker natively require an IT integration layer. E.g. translation to REST Api

The following architecture drills down the above high-level architecture to a more detailed architecture, which includes typical systems and apps.

© Siemens 2026 |

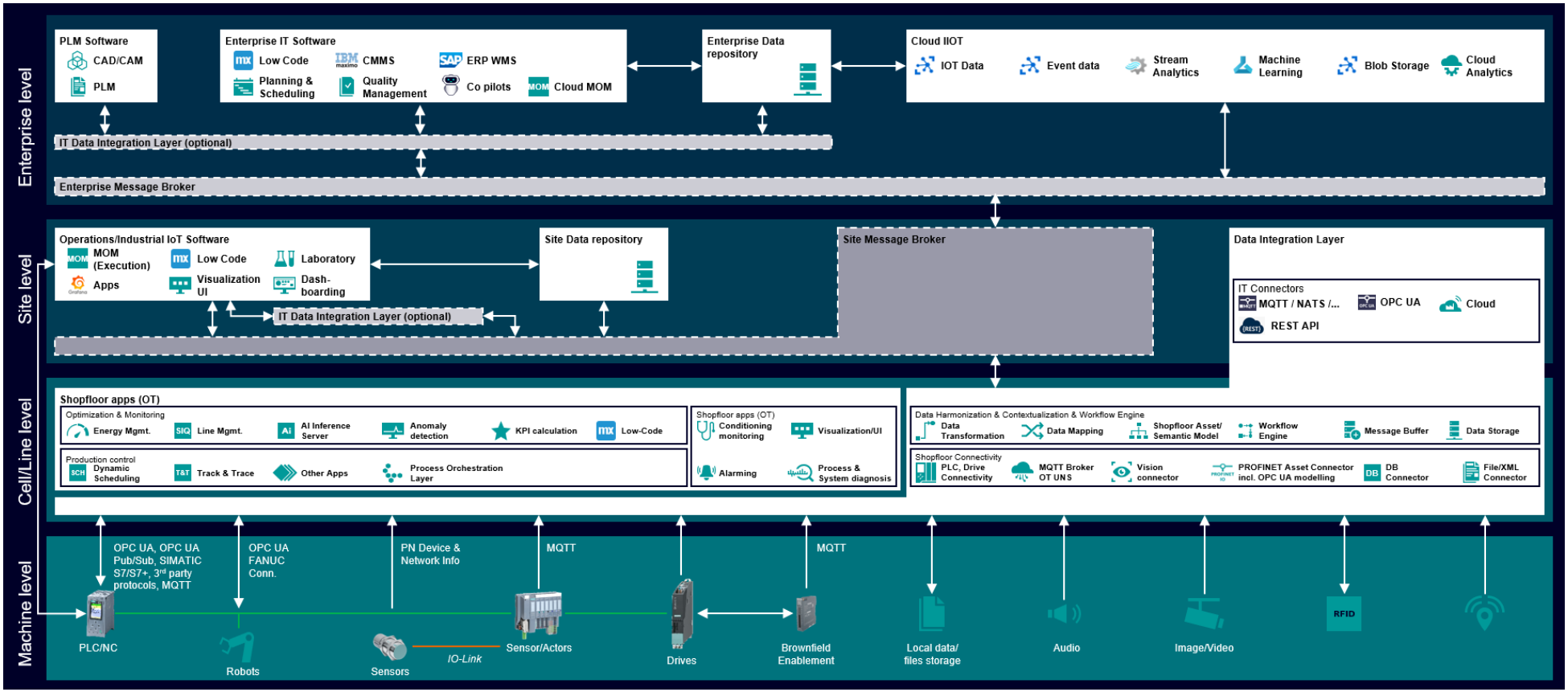


Figure 13 Blueprint architecture in detail

© Siemens 2026 |

2.3.2. Functions of Data integration layer in general

The DIL (data integration layer) connects and integrates many ISA95 level 1 and 2 pieces of equipment to ensure centrally available data to the IT level. It solves the problem of the lack of connectivity and complex integration in brownfield- and greenfield scenarios. This chapter describes the functions and the purpose.

Data integration layer translates two basically different concepts for data management in PLC and IT systems:

In the context of PLC (Programmable Logic Controller) systems, determinism refers to the predictability of the PLC's response time. This means the system can guarantee that a specific action will occur within a known time frame, even in the presence of network traffic or other system events. Deterministic PLC systems are crucial for real-time applications where precise timing is essential, such as in industrial automation and robotics. Therefore, PLC tags are more based in cyclical communication. In comparison to that, IT Systems are based on event-driven-communication.

The DIL connects to the OT equipment to read out the data, harmonizes the data types and structures the data to a standardized format that the IT system expects. That way every IT system only needs to be configured to connect to the DIL and is independent of the various devices in the shopfloor.

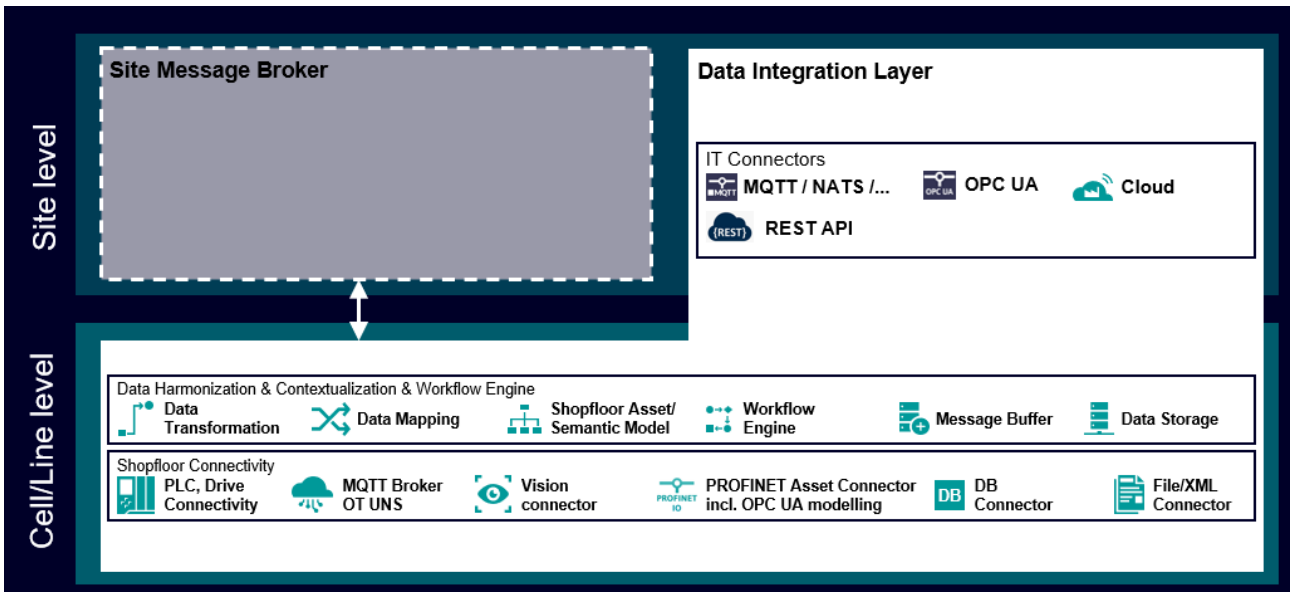


Figure 14 Detail view of Data integration layer

The benefit of using a central **Data integration layer** is listed below:

- Centralized data management on shopfloor level to reduce complexity
- Data contextualization creates the digital image of equipment, but also of the product and process
- Scalable and future-proof infrastructure that reduces load on the OT equipment

Functions of the Data integration layer are:

- Standard and stable data model interface to the shopfloor for the IT
- Efficient integration of brownfield installations (majority)
- Data preparation, normalization, validation

The components of the Data integration layer are described below – starting from the connection to the shopfloor through to the northbound connection to IT systems:

A. **Southbound connectors** (protocol adapters) connect several devices to the OT-network e.g.:
   - PLCs (Programmable Logic Controllers), NCs (Numerical Control)
   - Periphery e.g. Sensors
   - Label printers, barcode-RFID-readers
   - Drives

© Siemens 2026 |

- Cameras
- Custom-specific / proprietary adapters
- Complex shopfloor systems (like SCADA system, PC based line systems, ...)
- Local data bases from historical systems on line level e.g. Database from weighing control application

The **protocol adapters** provide access to operational and process data from systems, machines, control, sensors, meters to be leveraged/enabled to IT/OT integration use cases.

Examples for protocols are EtherNet/IP, PROFINET, Modbus, OPC UA, Simatic S7 and Simatic S7+.

Easy configuration: Browsing and importing configuration files is a fundamental building block to speed up the configuration of objects (e.g., tags, alarms, etc.). Configuration files should be generated automatically due to the PLC block structure or out of engineering databases. This enables automated configuration workflows. Existing standards like MTP (Modular type packages) or OPC UA Companion Specifications can speed up configuration.

Different protocol adapters offer different advantages. Some are necessary to connect to equipment of certain vendors, others are vendor-independent and offer methods for standardization.

B. **Data harmonization & filtering** transforms diverse, non-standardized data from various shopfloor devices, especially in a brownfield environment, to a standardized data model. The result is consolidated data which relies on a unified and coherent dataset. Then the processing of data inside applications is much easier and the data that is forwarded the next levels is standardized. The harmonization of data should happen as early as possible.

   Examples for data harmonization are:

   - Field name mapping: Field name in shopfloor is renamed to field name in integration layer. Example: MachState is renamed to MachineStatus. This includes also mapping from flat list of parameters to complex data structures.
   - Value (Re-)Mapping: Value of shopfloor is mapped to another value in the integration layer (e.g. a machine state on a controller is often an integer value which corresponds to an enum in the IT)
   - Conversion like linear scaling or substitute with other values (at start, low or high limits or communication error). Conversions of units like Fahrenheit and Celsius happen often.
   - Smoothing is used to reduce noise or rapid fluctuations in a data stream or parameter value. It helps to reveal underlying trends and patterns by averaging out short-term variations.
   - Complex data formation can be managed by scripting or by libraries like JOLT, JSONPath und JSoniq.
   - Data cleansing: Error and inconsistency check. Validate of incoming messages by message schema.
   - Filtering of data: not all data will be forwarded to broker; filtered data will remain on the level and can be used by line apps.

   The Workflow engine can execute a certain logic, for example based on a trigger from a machine, an incoming alarm or other events. The Engineering of these workflows can be done in a graphical way or by writing scripts. Workflows should be designed in a flexible manner so that they can be used multiple times for similar equipment.

The following picture shows an example workflow:

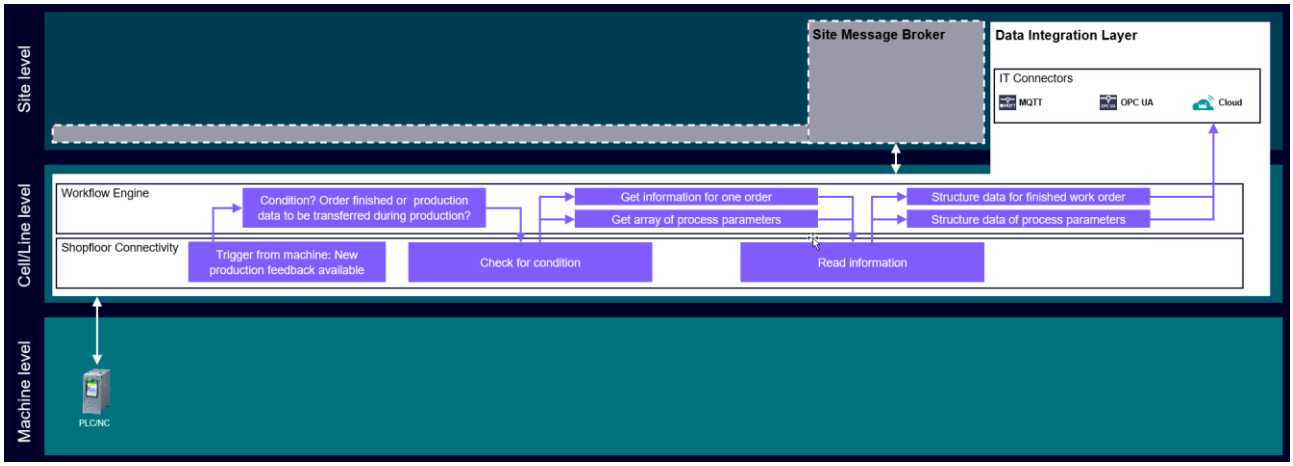


Figure 15 Workflow engine

In this example the machine sets a trigger that new production feedback is available. This trigger is received by the southbound connectors. The Workflow engine checks this condition whether the machine has data for a finished order or production feedback that needs to be collected while working on an order. For this, the relevant data from the machine is read and then analysed. Depending on the result of this check, the shopfloor connectivity is triggered by the workflow engine to pick up the relevant data. After harmonization, this data is forwarded to the northbound connectors.

- **Data contextualization** enriches the data with context information (e.g. 32 bits are of data type float. They describe a temperature which has the unit °Celsius). As a first step, the data is mapped to the ISA 95 equipment structure. This contextualization is mandatory so IT systems can identify where the data comes from. Additional data for the contextualization can come from IT systems (like MOM or ERP systems) and can be added in the DIL for further context, like the used tools or fixtures.
- Additionally, to contextualize data in the Data integration layer, IT systems can also do a secondary contextualisation by adding data available in the IT system. Therefore, not all contextualising must be done in the Data integration layer.

Benefits of contextualization

- **Better comprehension:** Contextualizing data helps to understand the underlying factors that might be contributing to a particular trend or pattern. It helps to avoid misunderstandings of data that can lead to faulty conclusions. Therefore, data contextualization allows more informed decisions based on the data to be made.
  - To achieve the goal that each IT system can access the data from the process **without needing individual configuration for certain shopfloor** data a mapping to a semantic data model is necessary.
  - To reduce effort required for contextualizing, the usage of machine learning algorithms can help to automatically classify, categorize, or tag data, based on patterns and context.

An example of mapping to a sematic data model is the following

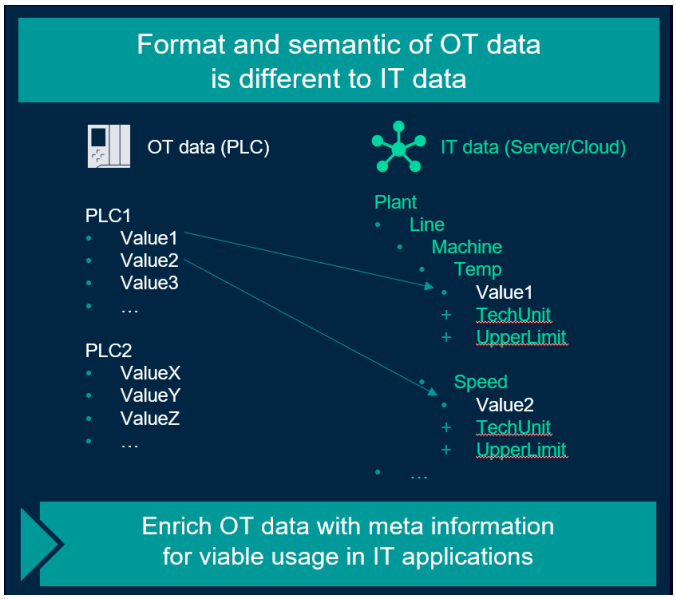


Figure 16 Enrich OT data with meta information

Different PLCs and their data like process parameters are linked to the respective equipment levels. The incoming data are enriched with additional accompanying information such as the unit of measurement, limits, description, and dependencies on other tags. This data is also called metadata.

C. Storage

The storage inside the Data integration layer is used to store the data from the shopfloor for a certain time and with a specific granularity. However, it does not replace a central data repository.

The following features are necessary:

- Aggregation (calculation of statistical information based on time → e.g. calculate the average of process parameter of last 15 minutes) and usage of statistical functions such as summarize, average or counting
- Data backup / recovery for buffering
- **Store & Forward** ensure that all data is buffered if the connection to the IT system is disrupted. After the connection is reestablished again the data should be delivered.

D. Northbound connections

The Data integration layer connects the data northbound to following systems:

- line/cell apps
- Cloud endpoints
- Broke

Another function is the creation of messages.

In general, **various protocols** are used to connect data northbound e.g.: MQTT, Rest-API, OPC UA, KAFKA, NATS, ...

The goal in this architecture is to use mainly the connection to a message broker as a single source northbound connector. Even if a PLC is supporting MQTT, it's not advisable to connect PLC for complex data structure directly to the site level. Instead, it is advisable to set up a gateway to manage several controllers for bi-directional data exchange with the upper Message broker. This ensures scalability and additionally each gateway and protocol transformation increases security.

Configuration of payload structure should be flexible: It should contain multiple attributes with a timetable and quality information. Also, the trigger of forwarding data to the broker or sending it to an IT system needs to be configurable (e.g. collect information of one produced order and send it all once the state of the machine changes).

General considerations

Since while using UNS all data is exchanged via the broker, the broker represents a single point of failure. So, it is crucial that availability is always guaranteed, even when a connector or a component is updated.

2.3.3. Definition of namespace

As already mentioned, it is fundamentally important to standardize content in the Unified Namespace (UNS). This requires organizing data from various sources (IT, OT) into a uniform, hierarchical data structure. This is achieved through data harmonization using uniform naming conventions and data formats, often based on standards such as ISA-95, to create a consistent and interpretable data structure. When introducing the next new integration architecture, the effort involved should not be underestimated.

When transferring messages, topics serve as addresses or communication channels structured like paths in a file system, while the payload is the actual, arbitrary data of a message that is transferred from client to client. A message topic specifies where the message belongs and where it should be sent, whereas the payload is the content that is sent through that topic.

Metadata and payload

For the message to be interpreted correctly by the recipient, it is important to define metadata per message type. It is descriptive information about a dataset, including its fields, their data types, names, and other properties. It serves to help a subscriber understand and decode the messages it receives from a Publisher. This metadata is crucial for establishing and maintaining communication, allowing the subscriber to correctly interpret the published data, especially since communication is broker-based and the publisher and subscriber may not have prior knowledge of each other.

For messages containing the actual content, it is necessary to define which single data fields are transferred in one message (e.g. sending all data of an operation after finishing of it). To do this, define message types (e.g., process parameters, work orders, material master data) and their structure.

Furthermore, it is possible to specify which types of data do not need to be exchanged via brokers (e.g., CAD files).

Message topic and ISA95 Equipment hierarchical model

The topic is organized in a structured manner, often using hierarchical models such as the ISA-95 model, that reflects the physical and logical structure of the business (e.g., plant, production line, machine). The equipment levels make sure that IT systems know where data is from. This is important to draw the right conclusions from the data.

The following diagram shows the hierarchy according to ISA 95 of different equipment levels.

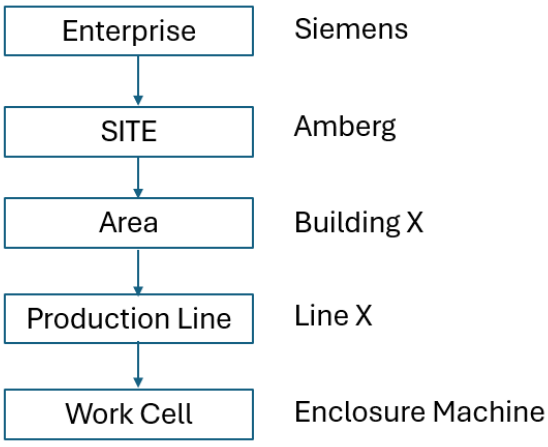


Figure 17 Example of an ISA S95 equipment model

The complete specification is accessible here [1]. The individual scope and meaning of the individual equipment levels are described there. Additional levels beyond the ISA95 standards can be added if required e.g. department below the SITE und AREA level.

[1] ISA-dS95.00.01 / ISA.ORG login is required

© Siemens 2026 |

2.3.4. Architecture decision: Data integration layer and broker

The Data integration layer can be designed in different ways: as an integration layer at site level and/or at line level. In every architecture a *Line data integration layer (customer who preferred a decentralized approach)* or *Site Data Integration layer (customer who preferred a centralized approach)* is mandatory. **The recommendation is to use a *Site Data Integration Layer*.**

Only ON-SITE level

The data integration layer as well as apps exists only on-site layer. We assume that no apps are running at line level because there is no need for it and all functions can be managed by the Site IT systems.

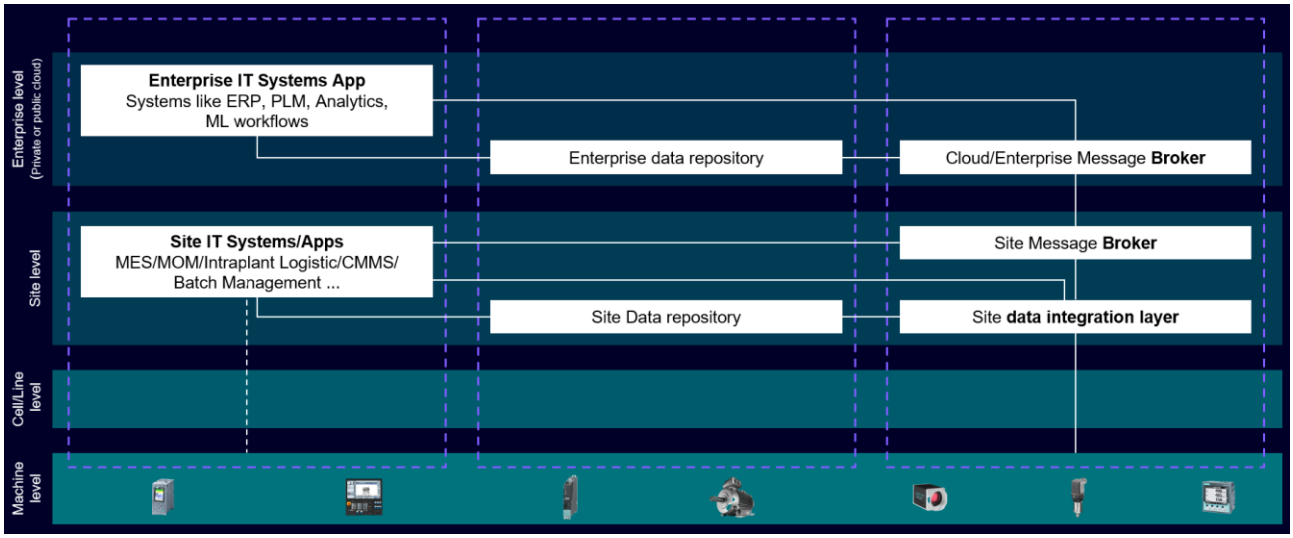


Figure 18 Only site data integration layer

On site level and line level

In architectures where both data integration layers are used, each level has different tasks. The cell/line integration layer is responsible for retrieving data from the shopfloor, standardizing the data and then passing them on to the site level integration layer. The site integration layer aggregates information from different line data integration layers for example from several lines.

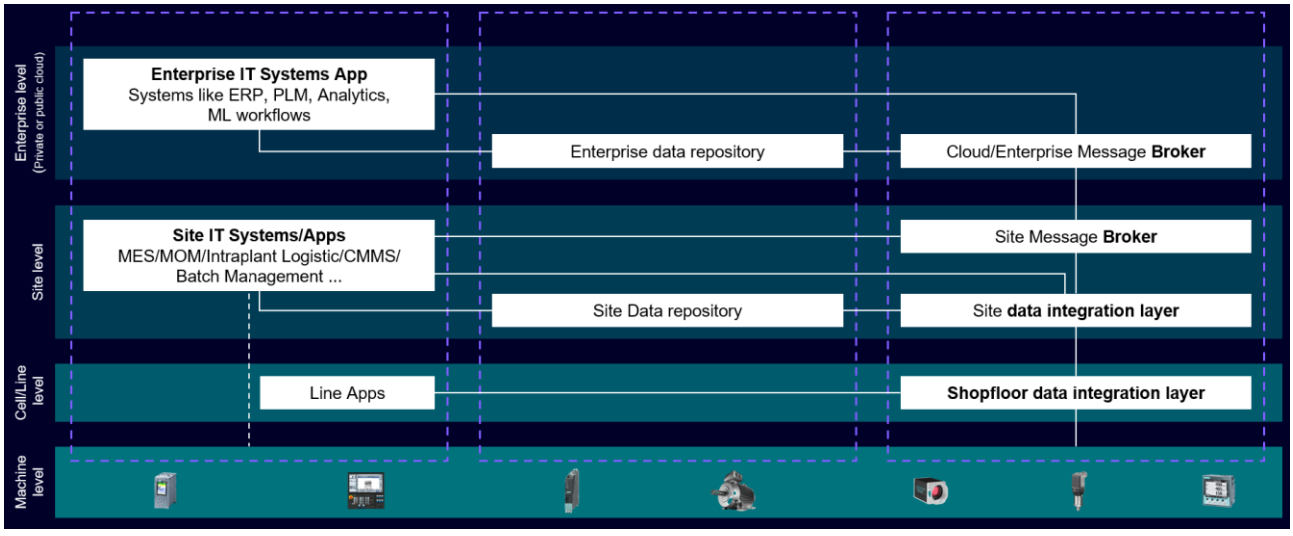


Figure 19 Site data integration AND line data integration layer

The Line Data integration layer AND Site Data Integration layer can be used in the following circumstances and has the following benefits:

- **Higher security due to network separation (Southbound-Northbound)**: It is not recommended to connect to a cloud broker or enterprise broker directly from the line data integration layer in case for customers who follow the Purdue model.
- More suitable for **high number of tags and larger number of connections** and therefore recommended for bigger plants. Only the aggregated data are forwarded to this site level.
- Connectivity for shopfloor devices that support certain protocols that require a specific connector hardware – like **serial ports**
- **Reduced Latency**: Line data integration layer processes data locally, minimizing latency time critical applications. This is particularly beneficial for applications requiring immediate feedback or control actions.
- **The failure of one line integration layer affects only some machines** and not all
- **keep data adaptation and structuring close to the data sources** to benefit from standardization in all levels.
- Data that is only intended for line apps does not have to be forwarded to site level, therefore **data traffic is optimized.**
- **OEM deliver the line data integration layer; but the end customer would like to use their own apps.** This can be accomplished via the Site Integration Layer.

The connection between both data integration layers shall support persistent sessions and thereby ensure a store and forward mechanism to avoid data loss to the site message broker and data repository in case of network or connectivity issues.

This scenario leads to higher complexity, licensing cost, installation effort of higher amount of devices and engineering effort.

Only ON-LINE level

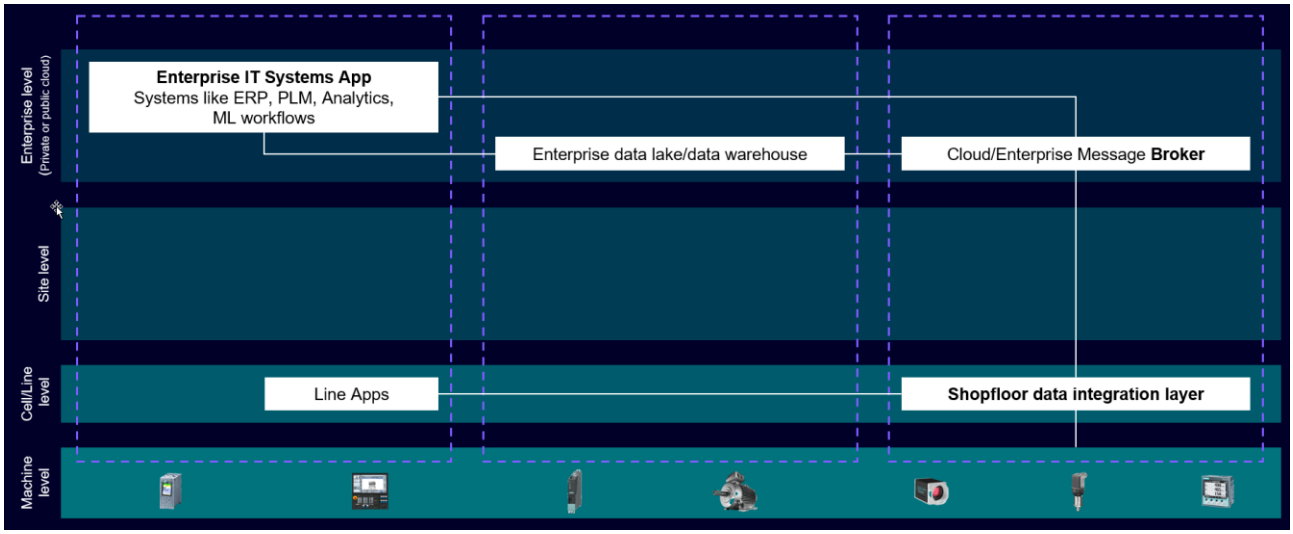


Figure 20 Line data integration layer

The Data integration layer exists only on shopfloor layer; and no site system is in use. In this scenario the site functionalities are running in cloud (public or private; cloud first approach) or on enterprise data center. Only the functions which must run only on-premises (like shopfloor protocols) are running on the cell/line level.

This approach has security disadvantages in comparison to the other two approaches as the Shopfloor data integration layer communicates directly into the Cloud Message Broker. A DMZ is required for communication to the cloud and ideally the DMZ should be located between two firewalls as described in the secure reference architecture. With this setup, the DMZ is only located underneath one firewall.

2.3.5. Role of AI in the new integration architecture

AI plays a transformative role at the **data integration layer**, by enhancing how the data from diverse sources is combined, cleaned, and made available for downstream applications. Here's a detailed description of its role:

Data connectivity

- **Automatic creation of configuration of connectivity**
  The configuration of both southbound and northbound connectors can be created based on PLC datablocks and further configuration. The workflows in the integration layer are also generated.

Data management

- **Intelligent data classification and tagging**
- **Data Cleansing and Quality Improvement**
  Machine learning models can detect anomalies, missing values, duplicates, and inconsistencies in data. AI can then suggest or automatically apply corrections, improving the overall quality of integrated data.
- **Entity Resolution and Deduplication**
  AI helps in identifying and merging records that refer to the same entity across different datasets, even when identifiers or attributes vary. This is crucial for creating a unified view of customers, products, or transactions.
- **Semantic Understanding and Enrichment**
  Natural Language Processing (NLP) enables AI to understand the meaning behind unstructured or semi-structured data. It can enrich data by adding metadata, categorizing content, or linking it to external knowledge graphs.
- **Automated Data Mapping and Schema Matching**
  AI algorithms can intelligently identify relationships between different data schemas, even when naming conventions or formats differ. This reduces manual effort and speeds up integration across heterogeneous systems.

Data orchestration

- **Real-Time Data Integration and Stream Processing**
  AI models can be used to process and integrate data in real time, identifying patterns or triggering actions as data flows through the system. This is especially useful in IoT, finance, and operational monitoring.
- **Predictive Data Transformation**
  AI can learn from historical transformations and recommend or automate future data transformation steps, making integration pipelines more adaptive and intelligent.
- **AI optimizes data flows between IT and OT systems**
- **Provides intelligent routing of critical information**
- **Enables dynamic resource allocation for data processing**
- **Automates workflow triggers based on operational patterns**

Data contextualization

- AI enriches raw data with operational context
- Identifies relationships between disparate data points
- Creates meaningful connections across IT/OT boundaries
- Transforms isolated data into actionable insights

Security and Compliance Monitoring

- AI can monitor data integration processes for compliance with data governance policies, flagging potential breaches or unauthorized access in real time.

© Siemens 2026 |

Key AI Applications

1. Predictive Maintenance
   - Data Needed: Time series data like sensor data (vibration, temperature, pressure) and PLC data, machine logs, maintenance history.
   - Purpose: Predict equipment failures before they happen to reduce downtime and optimize maintenance schedules.
2. Quality Inspection & Defect Detection
   - Data Needed: Images from cameras, sensor readings, process parameters.
   - Purpose: Use computer vision and anomaly detection to identify defects in products during or after production.
3. Process Optimization (incl. Root cause analysis)
   - Data Needed: Production cycle times, machine settings, throughput, energy consumption.
   - Purpose: Optimize parameters for speed, cost, and quality using reinforcement learning or optimization algorithms.
4. Production Forecasting & Scheduling
   - Data Needed: Historical production data, order data, machine availability, shift schedules.
   - Purpose: Improve planning accuracy and dynamically adjust schedules based on real-time shopfloor conditions.

2.3.6. Architecture decision: On premise vs. cloud

At the enterprise level, it is possible to deploy both in the cloud and on-premise. The following table provides guidance on the advantages of the different approaches.

Choose deployment variants: On public cloud or/and on prem

Business need	On-premises	Public Cloud
Independent updates	☑	☐
Central updates	☐	☑
Capacity easy to scale up and down The resources can be quickly adjusted to match demand, avoiding wasteful overprovisioning. This flexibility is beneficial during busy times or growth spurts.	☐	☑
Pay-as-you-go, usage-based pricing	☐	☑
Security and Privacy Considerations: On-premises setups let companies handle their data and security steps directly. This can be especially important for businesses that must follow strict rules or take private data. By having their data in their own physical surroundings, organizations can put in place and adjust security measures to their exact needs.	☑	☒☐
Built-in, automated data backups and recovery	☐	☑
Predictable Performance and Low-Latency Access to Data With on-premises technology, businesses have direct control over hardware and network settings, which makes performance predictable	☑	☐
Low initial costs and capital expenses	☐	☑
IT management and maintenance simplicity	☐	☑
Global Access and Collaboration	☐	☑
Reliance on Internet Connectivity and Downtime Risk Cloud services rely on Internet access. Operations can halt if the connection to the Internet goes down or the cloud provider experiences an outage	☑	☐
Navigating Compliance in a Global Context	☑	☐

Data hosted in the cloud might be subject to the laws of the countries where the cloud provider operates. This can lead to complexities, especially if data spans various regions with differing legal requirements.		
Easier Diagnostic, data management and manage authorization and authentication	☐	☑

Often, hybrid cloud solutions are recommended. This is a cloud computing model that combines public cloud services (such as Microsoft Azure, AWS, or Google Cloud) with private cloud environments or on-premises IT infrastructure. The goal is to leverage the advantages of both worlds.

2.3.7. Data repository

Efficient storage and management of a vast amount of data is important to implement the IT/OT use cases. There are several suitable options for on premise as well as on cloud IIoT storage.

Data repository is database infrastructure that centrally collects, manages, and stores data sets for data analysis, sharing and reporting.

The most important terms/systems are defined as below:

Data warehouse

The data is stored in relational structures. The data structure and schema are defined in advance to optimize for fast SQL queries, where the results are typically used for operational reporting and analysis. Data is cleaned, enriched, and transformed.

A data warehouse can also contain a time series database, but also other data like order or master data.

Data Lake

system of data stored in its natural/raw format. The data typically comes from multiple diverse sources and can include structured, semi-structured, or unstructured data. The structure of the data or schema is not defined when data is captured. This means that all data can be stored without careful design or the need-to-know what questions might require answers for in the future. Different types of analytics on data like SQL queries, big data analytics, full text search, real-time analytics, and machine learning can be used to uncover insights.

Data Lakehouse

A **Data Lakehouse** represents a newer architectural approach that combines the best features of data warehouses and data lakes. It maintains the flexibility and cost-effectiveness of data lakes while adding the data management capabilities and performance optimizations of data warehouses. This hybrid approach allows organizations to store raw data alongside processed data in a single system, supporting both exploratory analytics and traditional business intelligence workloads.

Time series database

A time series database is any database that is particularly well suited for handling a series of data points indexed in time order (e.g. digital sensor readings).

Operational Historian

- Used time series database of process parameters but enhanced by different features
- Store large volumes of historical data
- Data historians are optimized for fast data access, which is useful when decisions are time-critical
- Business intelligence, analytics, and reporting access controls

In this document, the Operational Historian is considered a subset of Data Warehouse.

Data marts

subsets of the data repository (e.g. only laboratory data for a specific area). These data marts are more targeted to what the data user needs and easier to use. Data marts also are more secure because they limit authorized users to isolated data sets.

Data mesh

A data mesh is an architectural and organizational framework that treats data as a product (referred to in this document as data products). In this framework, data products are developed by the teams that best understand that data and that follow an organization-wide set of data governance standards. Data is stored decentrally.

Data fabric

Data fabric is a holistic architecture that connects and manages data across different systems and platforms, providing a unified view and enabling data access, transformation, and sharing. Like data mesh the data are stored decentrally. Characteristics of data fabric:

- uniform architecture or infrastructure (and not decentralized data architecture)
- data access via one standard interface (and decentralized by the domain teams)
- central security (and not decentralized by the domain teams)
- Built-in / Fine-grained quality control, anomaly detection, and process management system

Mapping to Next generation solution architecture:

On the one hand, most systems (e.g., ERP, MOM, SCADA, batch control systems, etc.) have their own data storage, which are centrally supplied with data by the broker. Even the Data integration layer contains its own data storage to provide data to connected apps. So, the data storages are distributed, and it is more complex for apps to find and retrieve UNS-external domain objects like historical data. Centralized data repositories therefore offer several advantages over distributed systems. They support a single point of truth approach, and the data structures are available to all applications using uniform access methods. The question now is how applications can easily access the data, even though distributed databases are still the common architecture in companies. This is independent of which of the above-mentioned data repository concepts such as data lake, data warehouse, etc. are used.

To avoid point-to-point connections from various apps to various data storages, it is better to use a **data federation** layer instead. Data federation is a technique that enables integration, unification, and governance of data stored in different data stores by using a federated query engine that translates a single query into subqueries that are sent to the source data stores. In case of **complex analytics, it is recommended to use a central repository** to avoid additional workload on the source databases. This should store structured data (data warehouse) as well as unstructured data (data lake). Data ingestion follows the ETL concept: Extract, transform, load is a three-phase computing process where data is extracted from an input source, transformed (including cleaning), and loaded into an output data container.

Data federation can help support the transition from decentralized to centralized database architectures.

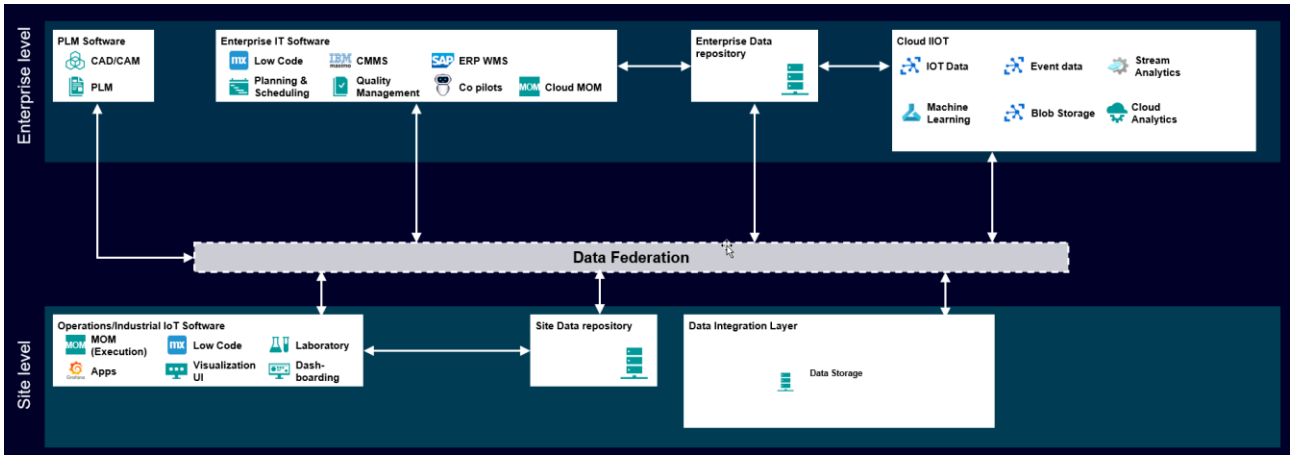


Figure 21 Data federation

© Siemens 2026

Guidelines

- **Store all data only once** → save disc/cloud storage and avoid inconsistency
- **Store the same kind of data at one place** → e.g. all work order related data on MOM
- **Use central data warehouse and operational historian as often as possible.** The advantage of central storage is that the data only needs to be stored once, that the data is consistent, that it is easier to access the data.
- **Access to historical data / on demand rather than continuous communication**
- If apps require current event data, they can be retrieved directly from the broker. All other data are retrieved by data repository like data lake / data warehouses.
- Moves older or less frequently accessed data to **cold storage.** There they are archived in a compressed way which makes them less accessible.

2.3.8. Security requirements and administration

For the overall concept for Cybersecurity, please refer to the secure reference architecture based on IEC 62443 3-3. In this chapter only additional details especially focussing on IT OT aspects are mentioned.

Ensure availability

The most important cybersecurity protection goal is to ensure availability of the plant.

Since this Guideline is built up on the network concept for factory, redundant mechanisms throughout the network are already ensured for example via redundant firewalls and ring topologies.

As mentioned before the UNS Broker and Data Integration Layer can be seen as single points of failure. Depending on the concept, redundant mechanisms should be considered.

Ensure Confidentiality

The goal of the IT/OT framework is to exchange data - critical data is exchanged across various networks up to the cloud level (e.g. recipe data, process know-how). This implies the need for security and to protect the data from unauthorized access, because data can reveal secrets about the automation process, data can control the production, or data might contain personal information. The data processing clients can be exposed to higher security risks (cloud, personal access, remote access).

Therefore, access to this data shall be authorized according to its protection and security level. The question needs to be answered by the customer:

- **Which data is relevant for protection, at which level and for whom?**

The overall architecture is already described in the Security Reference document which is available on SIOS webpage. The authorization/authentication concept is particularly important because much data is available centrally (via brokers or data repository). The security concept is taken up again in various chapters.

Introduction

In a point-to-point connection each User needs authorization to access a resource. With the next-generation architecture using a central message broker, the device authorization is only needed once to connect the resource to the broker. Then the broker is the owner of the data and can bundle the resources according to the protection level. Each client of the broker can then access the data according to its access rights and its assigned roles. This separates the resource from the client using a separate layer. The configurator of the broker becomes a central position of securing the data and administrating its access. In the security concept, the fact that the broker and the data repository represent a central point of attack must be particularly considered with the UNS.

Especially data brokers and repositories need special attention to ensure data security. Configure the broker to limit data availability according to its restrictions. (assign users/user groups to data). A topic can be restricted to clients on the type of data which is the last part of the topic name (type of message) or by the equipment.

Roles and permissions

Authorization specifies access rights to a resource. A resource is something to be protected from unauthorized access. Authorization includes the definition and enforcement of the policies that control who can have or do something with a certain resource. A resource can be a topic of the message broker or data of the data repository. Users want authorization

to do something: writing or reading data (respectively subscribing and publishing messages). Some apps might have higher security risks, or connections to the cloud. See also Chapter 3.6.3 “Identity and Access Management” in Security Reference document.

In the Data integration layer, the user can act with different personalized roles according to their functions.

Role	**Task**
Management Administrator for Data integration layer	installs and maintains the Data integration layer
Shopfloor integration Manager	establishes and maintains connections to devices. He selects the required data and applies data harmonization, contextualization and aggregation, if necessary
Broker Administrator	maintains the broker and the access to the broker
Data Analyst	analyses data generated on the shop floor
Application Administrator	installs and maintains the application
Process engineer	tracks the process-results using the dashboards
Line operator	uses feedback from the dashboard and can give feedback that supports improving the quality

© Siemens 2026

3. Appendix

3.1. Service and support

SiePortal

The integrated platform for product selection, purchasing and support - and connection of Industry Mall and Online support. The SiePortal home page replaces the previous home pages of the Industry Mall and the Online Support Portal (SIOS) and combines them.

- Products & Services
  In Products & Services, you can find all our offerings as previously available in Mall Catalog.
- Support
  In Support, you can find all information helpful for resolving technical issues with our products.
- mySieportal
  mySiePortal collects all your personal data and processes, from your account to current orders, service requests and more. You can only see the full range of functions here after you have logged in.

You can access SiePortal via this address: sieportal.siemens.com

Technical Support

The Technical Support of Siemens Industry provides you fast and competent support regarding all technical queries with numerous tailor-made offers – ranging from basic support to individual support contracts.
Please send queries to Technical Support via Web form: support.industry.siemens.com/cs/my/src

SITRAIN – Digital Industry Academy

We support you with our globally available training courses for industry with practical experience, innovative learning methods and a concept that's tailored to the customer's specific needs.
For more information on our offered trainings and courses, as well as their locations and dates, refer to our web page: siemens.com/sitrain

Industry Online Support app

You will receive optimum support wherever you are with the "Industry Online Support" app. The app is available for iOS and Android:

© Siemens 2026

3.2. Links and literature

No.	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Link to this entry page of this application example https://support.industry.siemens.com/cs/ww/en/view/109998257

3.3. Change documentation

Version	Date	Modification
V1.0	01/2026	First version

© Siemens 2026