Translation

The following document details China's plans to develop domestic standards for the smart manufacturing industry.

Title
Guidelines for the Construction of a National Smart Manufacturing Standards System (2021 Edition)
国家智能制造标准体系建设指南（2021版）

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The PRC Ministry of Industry and Information Technology (MOST; 工业和信息化部; 工信部) and the Standardization Administration of China (SAC; 国家标准化管理委员会)

Source
Website of the Central People's Government of the People's Republic of China. The Guidelines are dated November 17, 2021 and were uploaded to the website on December 9, 2021.

The Chinese source text is available online at:
http://www.gov.cn/zhengce/zhengceku/2021-12/09/5659548/files/e0a926f4bc584e1d801f1f24ea0d624e.pdf
An archived version of the Chinese source text is available online at: https://perma.cc/56QG-GKPL
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Guidelines for the Construction of a National Smart Manufacturing Standards System

(2021 edition)

November 2021

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I. Smart Manufacturing System Architecture

Smart manufacturing is an advanced production method based on the in-depth integration of advanced manufacturing technology and new generation information technology. It extends throughout the entire product life cycle, including design, production, management, and service, and has the characteristics of self-perception, self-decision-making, self-execution, self-adaptation, and self-learning. Smart manufacturing aims to improve the quality, benefits from efficiency, and flexibility of the manufacturing industry.

The smart manufacturing system architecture describes the elements, equipment, and activities involved in smart manufacturing from three dimensions: life cycle, system levels, and intelligent features. It is mainly used to clarify the standardized objects and scope of smart manufacturing. **The smart manufacturing system architecture is shown in Figure 1.**

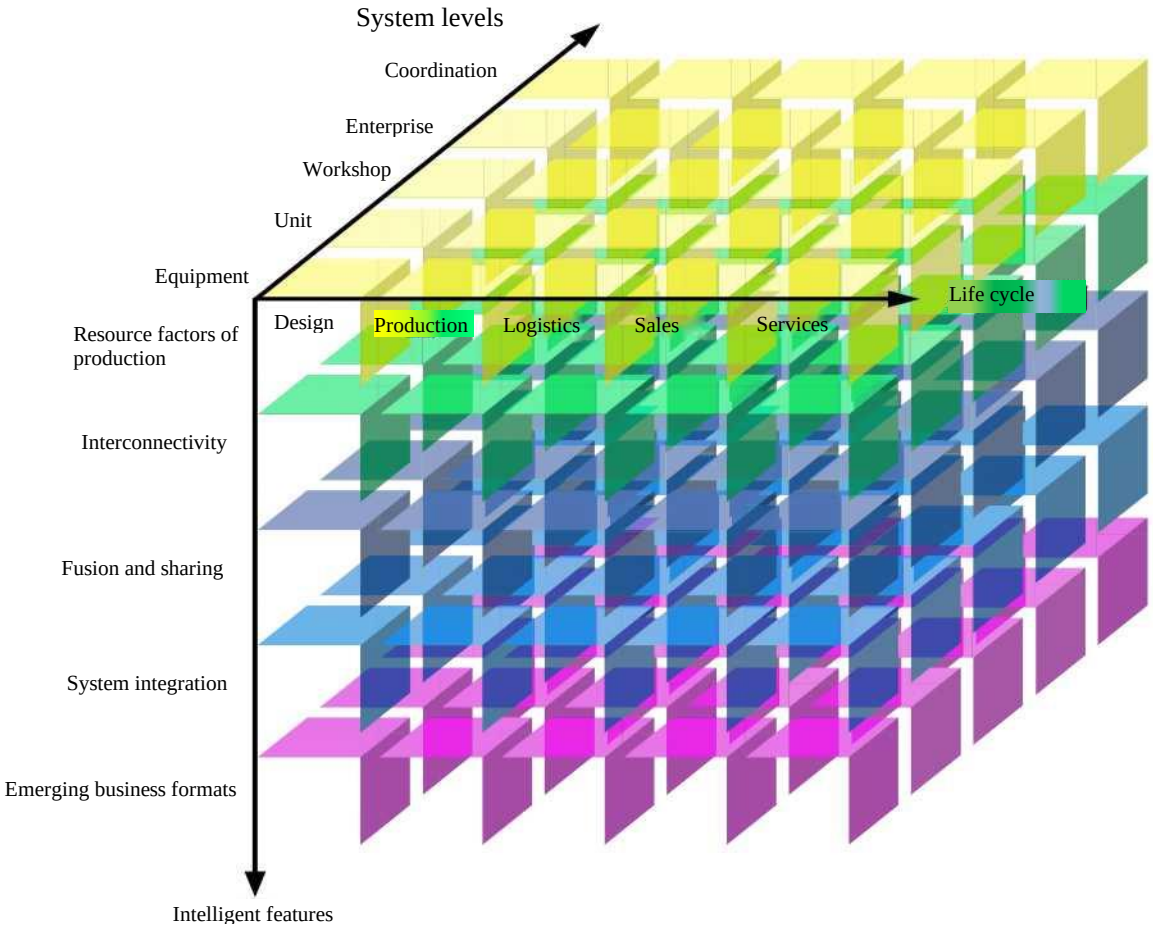

Figure 1. Smart manufacturing system architecture

1. Life Cycle

The life cycle covers the various stages from product prototype development to product recycling and remanufacture, including mutually linked value-creation activities such as design, production, logistics, sales, and service. The various activities of the life cycle can be iterated and optimized, featuring characteristics such as sustainable development. The life cycle composition and time sequence will differ between different industries.

(1) Design is the process of implementing and optimizing requirements based on all enterprise constraints and selected technologies.

(2) Production is the process of creating a product, including activities such as the processing, transporting, assembling, and testing of materials.

(3) Logistics is the process by which goods physically flow from the place of supply to the place of receipt.

(4) Sales refers to the business activities by which products or goods are transferred from enterprises into the hands of customers.

(5) Service refers to the series of actions produced by the interaction between product provider and customer as well as their results.

2. System levels

The system levels refer to the different levels of the organizational structure that correspond to production activities of the enterprise, including the equipment level, unit (单元) level, workshop level, enterprise level, and collaboration level.

(1) The equipment level is the level that implements the actual physical processes and physical process perception and operational control for the sensors, instrumentation, machines, and devices used by the enterprise.

(2) The unit level is the level used to process information within the enterprise and implement monitoring and control of physical processes.

(3) The workshop level is the level that implements production management for factories or workshops.

(4) The enterprise level is the level that implements business management for the enterprise.

(5) The collaboration level is the level at which the enterprise implements interconnection and sharing of internal and external information and business collaboration between enterprises.

3. Intelligent features

Intelligent features refer to the characteristics of self-perception, self-decision-making, self-execution, self-learning, self-adaptation, and other functions of manufacturing activities, including five layers of intelligentization (智能化) requirements: resource factors of production (资源要素), interconnection, fusion and sharing, system integration, and emerging business formats (新兴业态).

(1) Resource factors of production refer to the level that contains the resources or tools that an enterprise needs to use when engaged in production, and their digitized models.

(2) Interconnection refers to the level of data transfer and parameter semantic exchange between resource factors of production through wired or wireless networks, communication protocols, and interfaces.

(3) Fusion and sharing refers to the level of information collaboration and sharing based on interconnection and the use of new generation information and communication technologies such as cloud computing and big data.

(4) System integration refers to the level of data exchange and functional interconnection between equipment, production units, production lines, digitized workshops, smart factories, and smart manufacturing systems in the process by which an enterprise implements smart manufacturing.

(5) Emerging business formats refer to the level established by the data, models, and systems based on the integration and fusion of resource factors of production at different levels of physical space and digital space in order to cover functions such as cognition, diagnostics, prediction, and decision-making and support virtual and real iteration and optimization.

II. General Requirements

We must be guided by Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era, fully implement the spirit of the 19th Party Congress and the Second, Third, Fourth, Fifth, and Sixth Plenums of the 19th Central Committee, base ourselves on the new stage of development (新发展阶段), implement the new concept of development (新发展理念), and build the new pattern of development (新发展格局), proceed in accordance with the deployment requirements of the *Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035*[1] and the *National Standardization*

[1] For an English translation of the 14th Five-Year Plan Outline, see: https://cset.georgetown.edu/publication/china-14th-five-year-plan/

Development Outline,[2] unswervingly implement the manufacturing powerhouse[3] strategy and the cyber powerhouse[4] strategy, strengthen the top-level design of standards work, increase the effective supply of standards, strengthen the application and implementation of standards, coordinate the promotion of domestic and international standardization work, continue to improve the national smart manufacturing standards system, guide the construction of the smart manufacturing standards system in various sub-sectors, and effectively allow standards to play their supporting and leading roles in smart manufacturing.

(i) Basic Principles

Strengthen overall coordination and implement policies by category. We will improve the top-level design of the national smart manufacturing standards work and coordinate the promotion of the formulation and implementation of national standards and industry standards, domestic standards, and international standards. We will integrate the technical characteristics and development requirements of key industries (fields) and promote the construction of smart manufacturing standards systems for industry sub-sectors in an orderly manner.

Lay a solid foundation and strengthen collaboration. We will accelerate the formulation of key standards for basic and general purpose technologies, key technologies, and typical applications. We will integrate the characteristics of smart manufacturing, such as its cross-industry, cross-field, and system integration characteristics, and promote the joint formulation of standards for all links of the production chain and by all parties across industry, academia, research institutes, and users.

Open cooperation based on national conditions. We will integrate the current situation of China's smart manufacturing technology and industrial development and encourage Chinese enterprises and institutions to actively participate in international standardization activities. We will strengthen exchanges and cooperation with global industry circles, actively contribute China's technical solutions and practical experience,

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[2] For an English translation of the National Standardization Development Outline, see: https://cset.georgetown.edu/publication/the-chinese-communist-party-central-committee-and-the-state-council-publish-the-national-standardization-development-outline/

[3] Translator's note: This translation renders the Chinese word 强国 qiángguó—which literally means "strong nation"—in English as "powerhouse," as in the phrase "manufacturing powerhouse" (制造强国).

[4] Translator's note: Alternate English translations for the Chinese term wǎngluò qiángguó (网络强国)—here translated as "cyber powerhouse"—include "cyber superpower," "network powerhouse," "network superpower," and so on. For a more thorough discussion in English of the meaning of the term wǎngluò qiángguó, see: https://www.newamerica.org/cybersecurity-initiative/digichina/blog/lexicon-wangluo-qiangguo/

and jointly promote the formulation of international standards for smart manufacturing.

(ii) Construction Goals

By 2023, we will formulate and revise more than 100 national standards and industry standards and constantly improve an advanced and suitable smart manufacturing standards system. We will accelerate the formulation of smart equipment standards for human-computer collaboration systems, processing equipment, and inspection and testing equipment, smart factory standards for smart factory design and integration optimization, smart supply chain standards for supply chain collaboration and supply chain evaluation, smart service standards for networked collaborative manufacturing, intelligent enabling technology standards for digital twins and artificial intelligence (AI) applications, and industrial network standards for industrial network integration. We will also support the development of smart manufacturing to raise it to a new level.

By 2025, we will form a relatively complete standard cluster in the areas of digital twins, data dictionaries, human-computer collaboration, smart supply chains, system reliability, cybersecurity, and functional safety and gradually build a smart manufacturing standards system that adapts to the trends of technological innovation, meets the requirements of industrial development, and is benchmarked against the international advanced level.

III. Construction Philosophy

(i) Structure of the Smart Manufacturing Standards System

The structure of the smart manufacturing standards system includes three parts: "(A) foundational and general purpose", "(B) key technical", and "(C) industry application". These mainly reflect the constitutive relationships of components of the standards system. The structure of the smart manufacturing standards system is as shown in Figure 2.

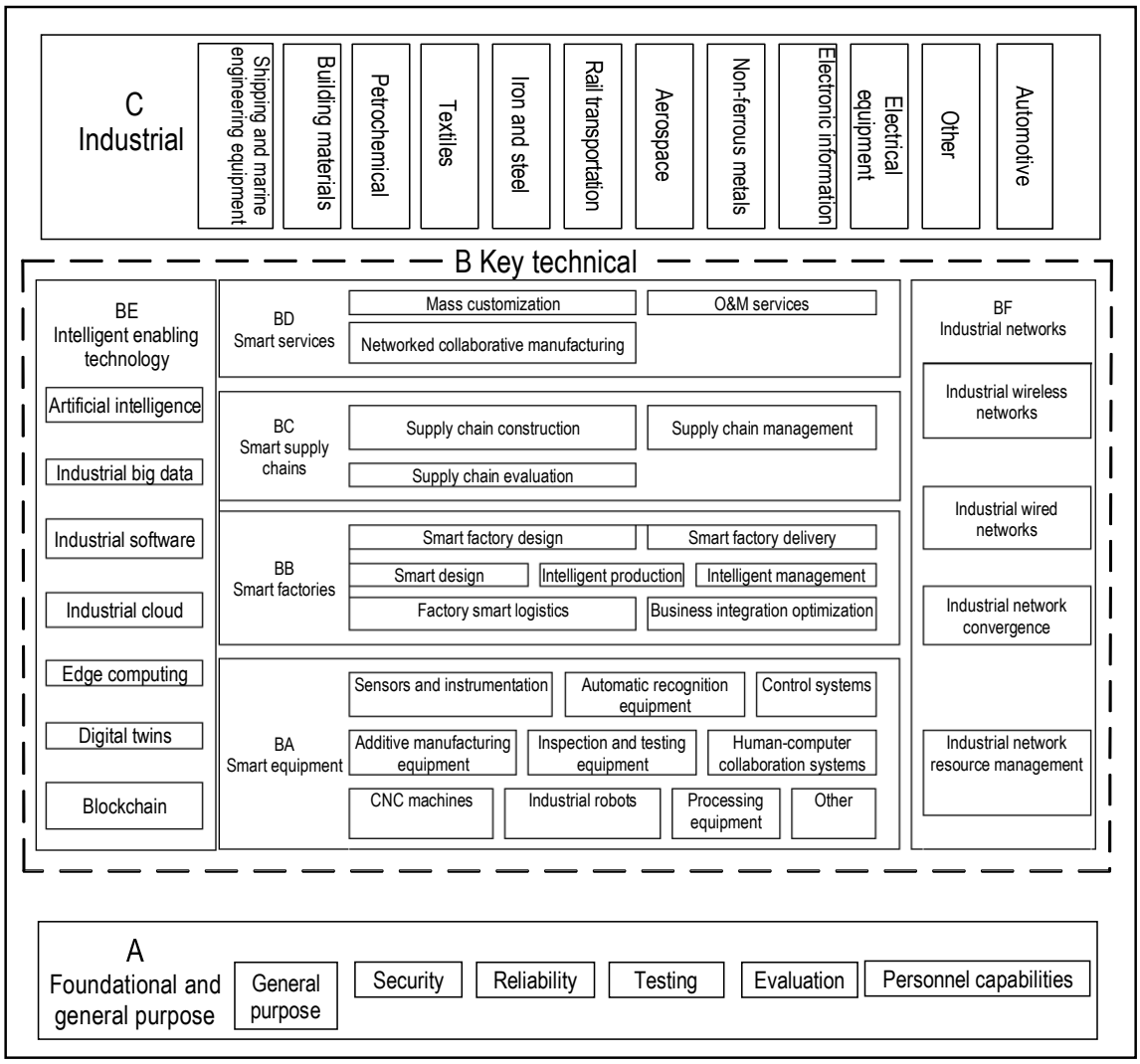

Figure 2. Smart manufacturing standards system structure

Specifically, (A) foundational and general purpose standards include six categories: general purpose, security, reliability, testing, evaluation, and personnel capabilities. These standards are located at the bottom of the smart manufacturing standard system structure diagram and support (B) key technical standards, and (C) industry application standards. (B) Key technical standards are the projection of the intelligent feature dimension of the smart manufacturing system structure on the manufacturing plane composed of the life cycle dimension and the system level dimension. Among these standards, the BA smart equipment standard mainly focuses on the resource factors of production of the intelligent feature dimension, the BB smart factory standard mainly focuses on the resource factors of production and system integration of the intelligent feature dimension, the BC smart supply chain corresponds to the interconnection, fusion and sharing, and system integration of the smart feature dimension, BD smart service corresponds to the emerging business formats of the

smart feature dimension, BE intelligent enabling technology corresponds to resource factors of production, interconnection, fusion and sharing, system integration, and emerging formats of intelligent feature dimension, and BF industrial network corresponds to interconnection and system integration of the intelligent feature dimension. (C) Industry application standards are located at the top of the smart manufacturing standards system structure and are oriented to the specific requirements of industry. They refine and implement (A) foundational and general purpose standards and (B) key technical standards and guide the advancement of smart manufacturing in various industries.

(ii) Smart Manufacturing Standards System Framework

The framework diagram of the smart manufacturing standards system includes the basic component units of the smart manufacturing standard system, including the (A) foundational and general purpose, (B) key technical, and (C) industry application parts, as shown in Figure 3.

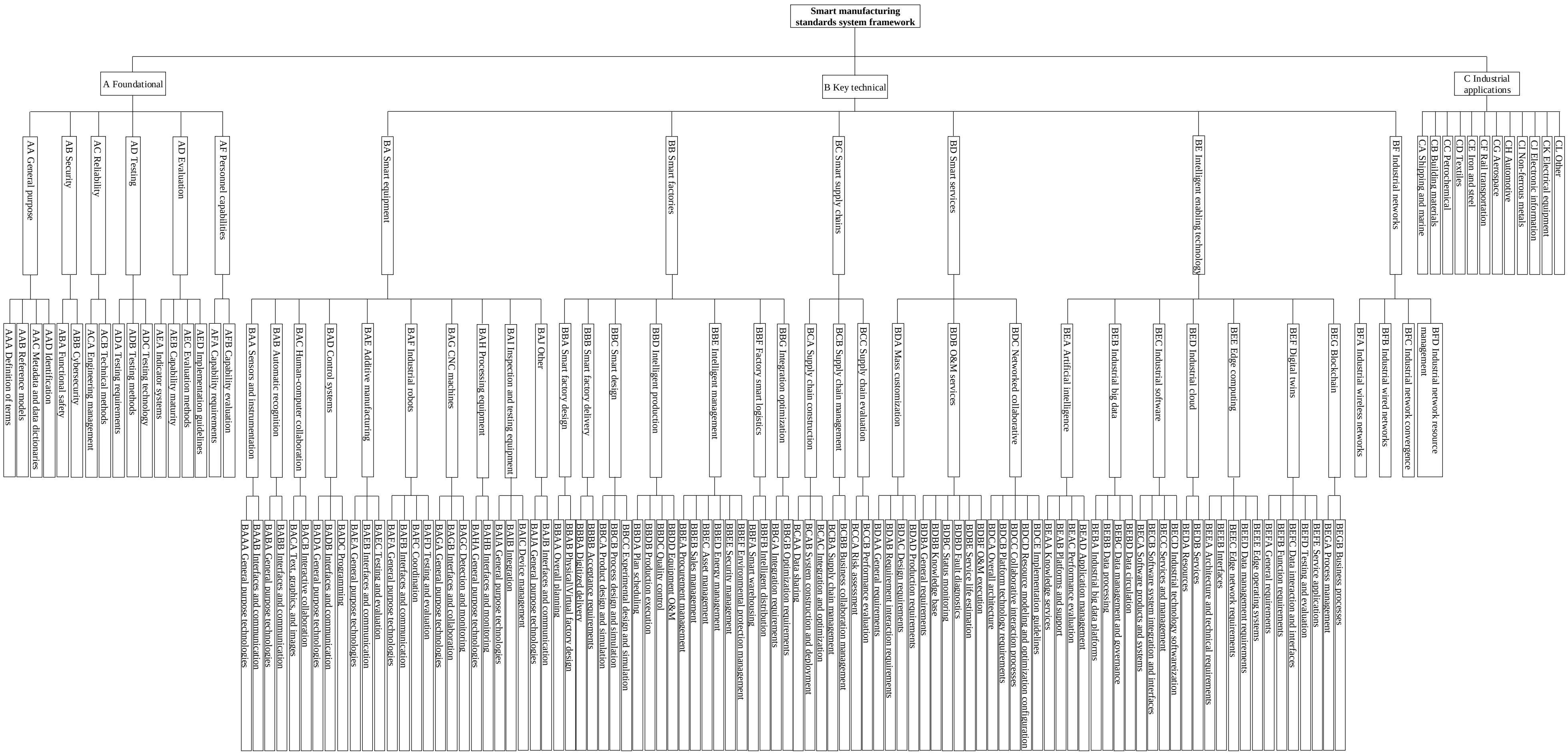

Figure 3. Smart manufacturing standards system framework diagram

IV. Construction Content

(i) Foundational and General Purpose Standards

These standards mainly include six parts: general purpose, security, reliability, testing, evaluation, personnel capabilities, as shown in Figure 4. These standards are mainly used to unify smart manufacturing concepts and resolve basic, general purpose, and key problems.

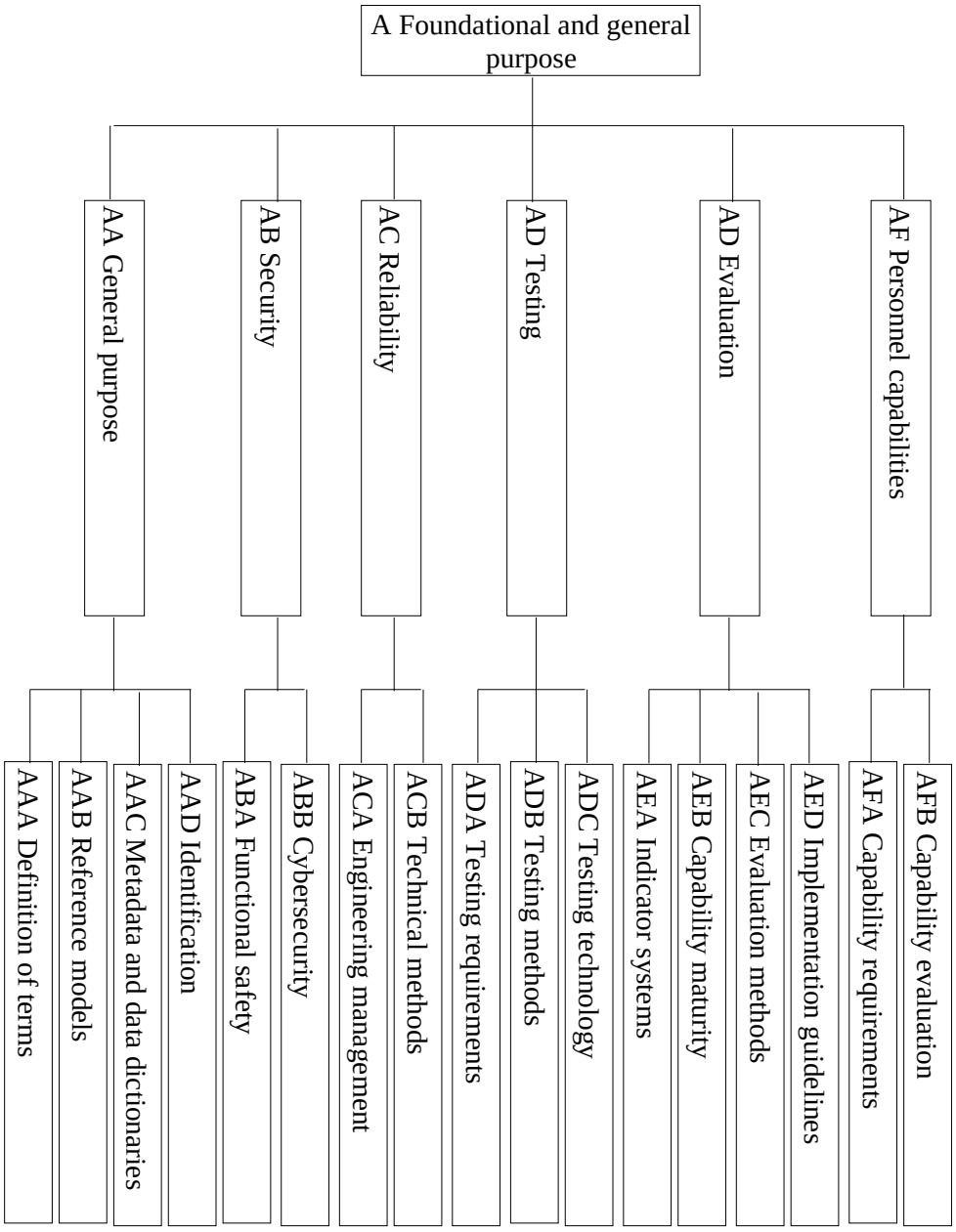

Figure 4. Foundational and general purpose standards sub-system

1. **General purpose standards**

These standards mainly include four parts: definition of terms, reference models, metadata and data dictionaries, and identification. Definition of terms standards are mainly used to unify smart manufacturing concepts, in order to provide support for the formulation of standards in each other part, including standards for terms, vocabulary, symbols, and codes. Reference model standards are used to help all parties recognize and understand the objects, boundaries, and the hierarchical relationships and internal connections of various parts in smart manufacturing standardization, including standards for reference models and system architectures. Metadata and data dictionary standards are used to specify the categorization, naming rules, description and expression, registration, and management and maintenance requirements of industrial products, manufacturing processes, and other industrial data involved in the design, production, circulation, and other stages of smart manufacturing products as well as data dictionary establishment methods, including standards for metadata and data dictionaries. Identification standards are used for the identification and parsing of various types of objects in the field of smart manufacturing, including standards for identifier coding, coding transmission rules, object metadata, and parsing systems (解析系统).

2. **Security standards**

These standards mainly include two parts: functional safety and cybersecurity. Functional safety standards are used to ensure that control systems perform their safety functions correctly and reliably when danger occurs, so as to avoid production accidents caused by system failure or conflicts between safety facilities, including standards for smart manufacturing-oriented safety collaboration requirements, functional safety system design and implementation, functional safety testing and evaluation, functional safety management, and functional safety operations and maintenance (O&M). Cybersecurity standards are used to ensure the availability, secrecy, and integrity of relevant information systems in the field of smart manufacturing, so as to ensure that the systems can operate safely and reliably, including standards for networked equipment security, control system security, network (including identifier analysis systems) security, industrial internet platform security, data security and related security product evaluation, system security construction, security maturity evaluation, and password applications.

3. **Reliability standards**

These standards mainly include two parts, engineering management and technical methods. Engineering management standards mainly plan, organize, coordinate, and supervise the reliability activities of smart manufacturing systems,

including standards for the reliability requirements, reliability management, comprehensive assurance management, and life cycle cost management of smart manufacturing systems and their various system-level objects. Technical method standards are mainly used to guide the performance of specific reliability assurance and verification work by smart manufacturing systems and their various system levels, including standards for reliability design, reliability prediction, reliability testing, reliability analysis, reliability growth, and reliability evaluation.

4. **Testing standards**

These standards mainly include three parts: testing requirements, testing methods, and testing technology. Testing requirement standards are used to guide the scientific ordering and effective management of smart equipment and systems in the testing process, including standards for the indicators and requirements for consistency and interoperability, integration and interconnection, system energy efficiency, electromagnetic compatibility, and other test items of different types of smart equipment and systems. Testing method standards are used for the testing of different types of smart equipment and systems, including standards for test content, methods, steps, processes, calculations, and analysis as well as standards for performance, environmental adaptability, and parameter calibration. Testing technology standards are used to regulate testing technologies for smart manufacturing, including judgmental testing (判断性检测), informational testing, and causal testing. The testing methods are not limited to software and hardware testing, online monitoring, and simulation testing.

5. **Evaluation standards**

These standards mainly include four parts: indicator systems, capability maturity, evaluation methods, and implementation guidelines. Indicator system standards are used to evaluate the performance and results of smart manufacturing implementation and push enterprises to continuously improve their level of smart manufacturing. Capability maturity standards are used by enterprises to identify the current smart manufacturing situation and plan smart manufacturing frameworks. They provide a basis for enterprises to identify shortcomings, set goals, and carry out improvements. Evaluation method standards are used to provide relevant parties with consistent methods and bases, standardize the evaluation process, and guide relevant parties to carry out smart manufacturing evaluation. Implementation guideline standards are used to guide enterprises to improve their manufacturing capabilities and to provide references for enterprises to carry out intelligentized construction and increase productivity.

6. **Personnel capability standards**

These standards mainly include two parts: smart manufacturing personnel capability requirements and capability evaluation. Smart manufacturing practitioner capability requirement standards are used to regulate the capability management of practitioners and clarify the requirements for occupational categorization, capability levels, knowledge reserves, technical capabilities, and practical experience, including standards for capability requirements and personnel capability training. Smart manufacturing capability evaluation standards are used to regulate the capability levels of personnel in different occupational categories and guide the evaluation of the capability levels of smart manufacturing practitioners, including standards for practitioner evaluation and appraiser evaluation.

(ii) Key Technical Standards

These standards mainly include six parts: smart equipment, smart factories, smart supply chains, smart services, intelligent enabling technology, and industrial networks.

1. Smart equipment standards

These standards mainly include ten parts: sensors and instrumentation, automatic recognition equipment, human-computer collaboration systems, control systems, additive manufacturing equipment, industrial robots, computer numerical control (CNC) machines, processing equipment, inspection and testing equipment, and other, as shown in Figure 5. These standards mainly set out requirements for smart equipment information models, data dictionaries, communication protocols and interfaces, integration and interconnectivity, O&M services, performance evaluation, and test methods.

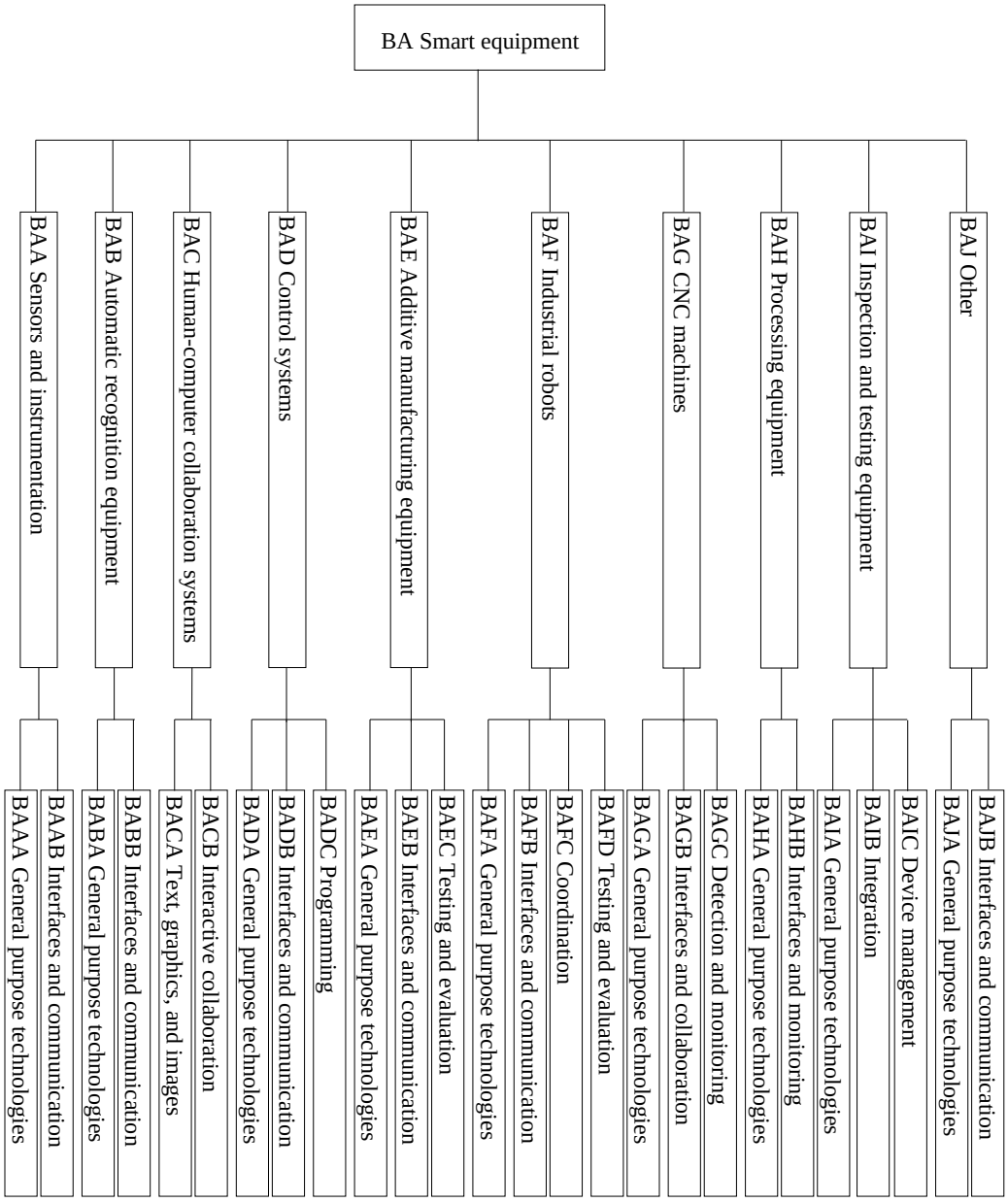

Figure 5. Smart equipment standards sub-system

(1) Sensor and instrumentation standards. These standards mainly include standards for general purpose technology for features and categorization, reliability design, service life estimation, system and component full-life-cycle management, and performance evaluation, and interface and communication standards for information models, data interfaces, field equipment integration, semantic interoperability, communications protocols, and protocol consistency.

(2) Automatic recognition equipment standards. These standards mainly include standards for general purpose technology for data encoding, performance

evaluation, and device management, and interface and communication standards for interface specifications, communications protocols, information integration, fusion perception, and collaborative information processing.

(3) Human-computer collaboration system standards. These standards mainly include text, graphics, and images for virtual reality/augmented reality (VR/AR), categorizations and definitions of professional graphic symbols for human-computer collaboration systems such as industrial intelligent interactive terminals, visual image acquisition and recognition, and virtual/real fusion information displays; and interactive collaboration standards for cooperation mode requirements, task assignment requirements, and human-machine interfaces in human-computer collaboration processes.

(4) Control system standards. These standards mainly include standards for general purpose technology for control methods, data acquisition and storage, human-machine interface and visualization, and testing; interface and communication standards for control equipment information models, clock synchronization, interfaces, system interconnection, and protocol consistency; and programming standards for engineering data exchange, control logic programs, control program architecture, control labels and data streams, and function blocks.

(5) Additive manufacturing equipment standards. These standards mainly include standards for general purpose technology for model data quality and processing requirements, processing knowledge base establishment and categorization, data dictionaries, coding requirements, multi-material and array-type additive manufacturing, and composite and micro-nano structure additive manufacturing technical requirements; interface and communication standards for system and equipment information models and communication protocols; and testing and evaluation standards for test methods and performance evaluation.

(6) Industrial robot standards. These standards mainly include standards for general purpose technology for data formats and object dictionaries; standards for interfaces and communication between information models, programming systems, users, and industrial robots; standards for collaboration between industrial robots and people, environments, systems, and other equipment; and testing and evaluation standards for performance and site suitability.

(7) CNC machine standards. These standards mainly include standards for general purpose technology for languages and formats of machine tools and functional components, failure information dictionaries, categorization, and control requirements; interface and collaboration standards for programming interfaces, physical mapping models, and interconnection and interoperability; and detection and monitoring

standards for manufacturing inspection, status monitoring, and optimization based on industrial clouds.

(8) Processing equipment standards. These standards mainly include standards for general purpose technology such as technical requirements for process equipment used in processes such as casting, forging, welding, heat treatment, and special processing as well as intermittent manufacturing (离散型制造); and interface and monitoring standards for data interfaces and status monitoring.

(9) Inspection and testing equipment standards. These standards mainly include standards for general purpose technology for online detection system data formats, performance, and environmental requirements; integration standards for interconnection and interfaces between inspection and testing equipment and other production equipment and systems; and equipment management standards for performance status detection and calibration, and failure diagnostics.

(10) Other standards. These standards mainly include standards for general purpose technology for data coding, data formats, performance, and environmental requirements for warehousing, logistics, printing, and other smart equipment, and interface and communication standards for information models, interconnectivity, interface norms, communication protocols, and protocol consistency.

Key points in smart equipment standard construction
Sensor and instrumentation standards. Standards for general purpose technology for reliability design and performance evaluation; and interface and communication standards for information models, data interfaces, and protocol consistency.
Automatic recognition equipment standards. Standards for general purpose technology for data encoding and performance evaluation; and interface and communication standards for interface specifications, fusion perception, and collaborative information processing.
Human-computer collaboration system standards. Text, graphics, and images for visual image acquisition and recognition; and interactive collaboration standards for cooperation mode requirements, task assignment requirements, and human-machine interfaces.
Control system standards. Interface and communication standards for control equipment information models, system interconnection, and protocol consistency; and programming standards for engineering data exchange, control labels and data streams, and function blocks.
Additive manufacturing equipment standards. Standards for general purpose technology for model data quality and processing requirements, data dictionaries, and coding requirements; and interface standards for system and equipment information models and communication protocols.

Industrial robot standards. Standards for general purpose technology for data formats and object dictionaries; standards for interfaces and communication between programming systems, users, and industrial robots; and standards for collaboration between industrial robots and people, environments, systems, and other equipment.

CNC machine standards. Standards for general purpose technology for languages and formats of machine tools and functional components and failure information dictionaries; interface and collaboration standards for programming interfaces, physical mapping models, and interconnection and interoperability; and detection and monitoring standards for status monitoring, and optimization.

Processing equipment standards. Processing equipment technical requirements and interface and monitoring standards for data interfaces and status monitoring.

Inspection and testing equipment standards. Standards for general purpose technology for online detection system data formats, performance, and environmental requirements. Integration standards for interconnection and interfaces; and equipment management standards for performance status detection and calibration, and failure diagnostics.

Other standards. Standards for general purpose technology for data coding, data formats, performance, and environmental requirements; and interface and communication standards for information models, interconnectivity, interface norms, communication protocols, and protocol consistency.

2. Smart factory standards

These standards mainly include seven parts: smart factory design, smart factory delivery, smart design, intelligent production, intelligent management, factory smart logistics, and integration optimization, as shown in Figure 6. These standards mainly regulate the smart factory design and delivery processes and design, production, management, logistics, and system integration in factories.

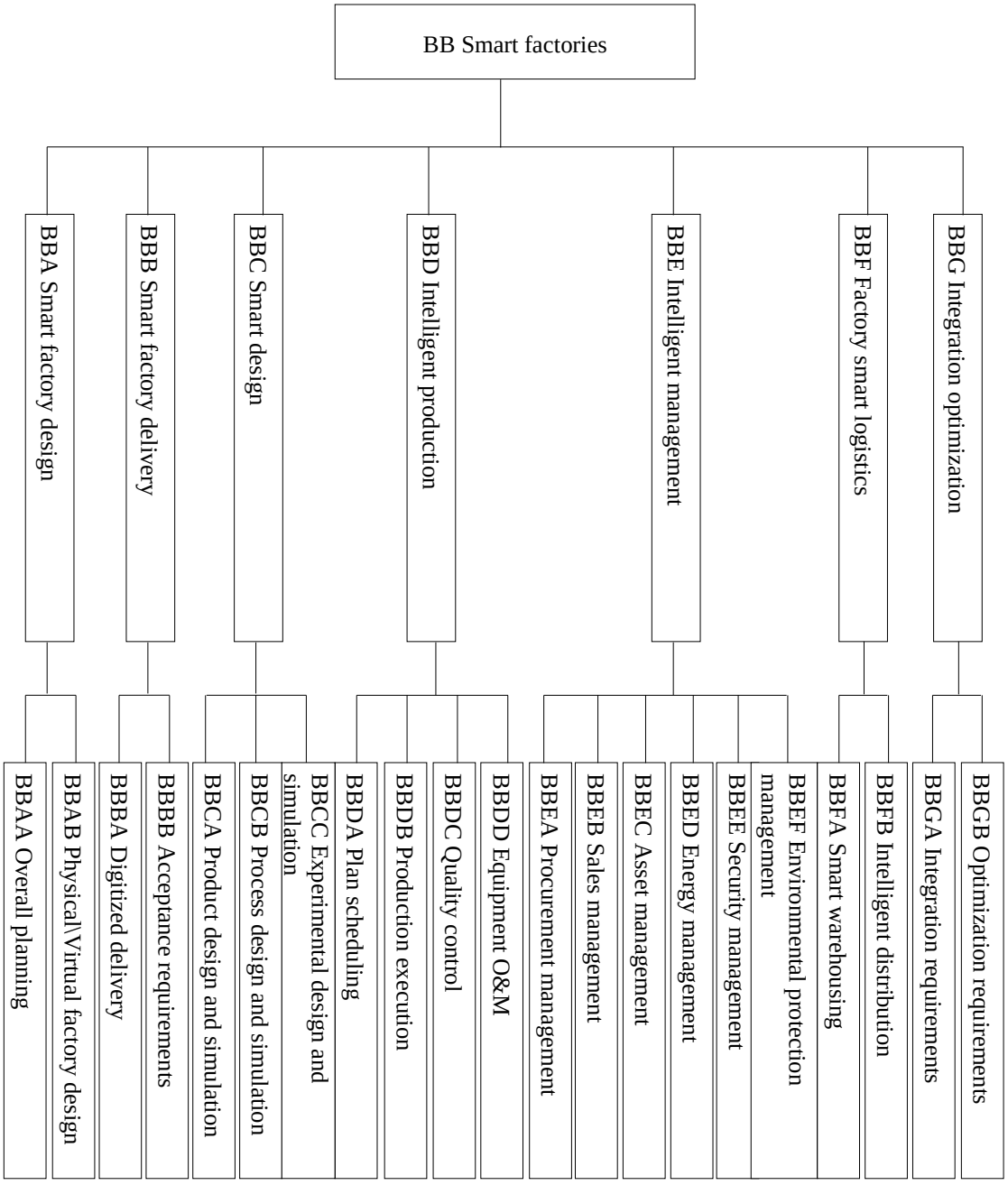

Figure 6. Smart factory standards sub-system

(1) Smart factory design standards. These standards mainly include overall planning standards for smart factory design requirements, design models, design verification, depth requirements of design documents, and collaborative design; and physical/virtual factory design standards for physical factory data collection, factory layout, virtual factory reference architecture, process flow and layout models, production process models and organization models, simulation analysis, and the implementation of information interaction between physical factories and virtual

factories.

(2) Smart factory delivery standards. These standards mainly include digitalized delivery standards, such as common requirements for digitized delivery in the design and implementation stages, and completion and acceptance requirements for smart factory projects.

(3) Smart design standards. These standards mainly include product design and simulation standards based on data-driven parametric modularized design, model-based systems engineering (MBSE) design, collaborative design and simulation, multi-specialty coupling simulation optimization, and digitized design of formula products; process design and simulation standards based on digitalized models of manufacturing resources; and test design and simulation standards for test methods, test data, and process management.

(4) Intelligent production standards. These standards mainly include planning and scheduling standards for plan modeling and simulation, multi-level planning coordination, visualized scheduling, and dynamic optimization scheduling; production execution standards for automatic issuance and execution of job documents, design and manufacturing collaboration, dynamic organization of manufacturing resources, process simulation, production process control and optimization, exception management, and fool-proofing and error-proofing mechanisms; quality control standards such as intelligent online quality monitoring, early warning and optimization control, quality archives, and quality traceability; and device O&M standards for knowledge-based equipment operation status monitoring and optimization, repair and maintenance, and failure management.

(5) Intelligent management standards. These standards mainly include procurement management standards for quality inspection and analysis of raw materials and auxiliary materials; sales management standards for sales forecasting and customer service management; asset management standards for equipment health and reliability management and knowledge management; energy management standards for energy flow management and energy efficiency assessment; safety management standards for operation process control, emergency management, and hazardous chemicals management; and environmental protection management standards for real-time environmental protection monitoring, forecasting, and early warning.

(6) Factory smart logistics standards. These standards mainly include intelligent warehousing standards for material status identification and information tracking in the factory, job assignment and scheduling optimization, and warehousing system functional requirements; and intelligent distribution standards for material

sorting and distribution path planning and management.

(7) Integration optimization standards. These standards mainly include integration standards for software and hardware integration and system solution integration services to meet the needs of business activities in the factory; and optimization standards for operation and control optimization and data-driven full-life-cycle business optimization.

Key points in smart factory standard construction
Smart factory design standards. Overall planning standards for smart factory design requirements and collaborative design requirements; and standards for information interaction between physical factories and virtual factories. **Smart factory delivery standards.** Delivery standards, such as common requirements for digitalized delivery in the design and implementation stages, and completion and acceptance requirements for smart factory projects. **Smart design standards.** Product design and simulation standards based on data-driven parametric modularized design, MBSE design, and collaborative design and simulation; and process design and simulation standards based on digitalized models of manufacturing resources. **Intelligent production standards.** Planning and scheduling standards for plan modeling and simulation and multi-level planning coordination; production execution standards for design and manufacturing collaboration, dynamic organization of manufacturing resources, and production process control and optimization; quality control standards for online quality monitoring and early warning, quality archives, and quality traceability; and device management standards for knowledge-based equipment operation status monitoring and optimization, repair and maintenance, and failure management. **Integration optimization standards.** Integration standards for software and hardware integration and system solution integration services to meet the needs of business activities in the factory; and optimization standards for operation and control optimization and data-driven full-life-cycle business optimization.

3. Smart supply chain standards

These standards mainly include three parts, supply chain construction, supply chain construction, and supply chain evaluation, as shown in Figure 7. These standards mainly regulate the technical and management requirements for data, processes, and evaluation in the process of cooperation between upstream and downstream enterprises in the supply chain, guide the design and development of supply chain management systems and platforms, and ensure horizontal integration and efficient collaboration in the supply chain.

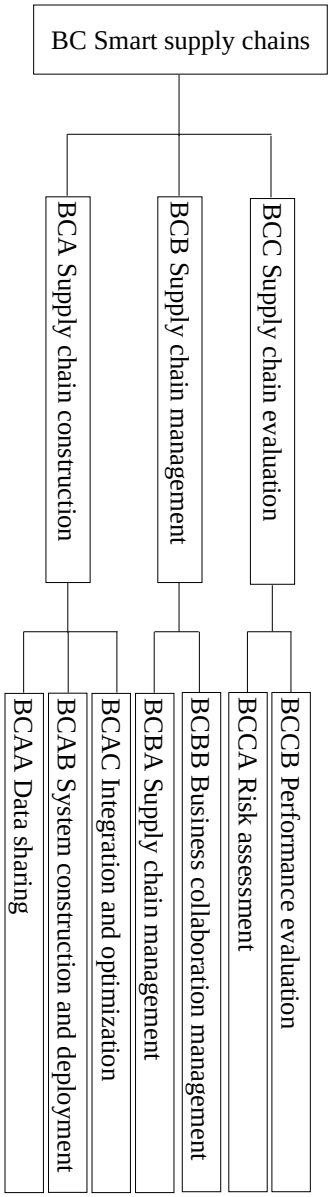

Figure 7. Smart supply chain standards sub-system

Supply chain construction standards mainly include standards for upstream and downstream data sharing, system construction and deployment, and integration and optimization of internal and external enterprise resources; supply chain management standards mainly include supplier management standards for supplier categorization & grading and performance evaluation, and business collaboration management standards for supply chain upstream and downstream design, production, logistics, sales, and services; supply chain evaluation standards mainly include risk evaluation standards for supply chain risk identification and evaluation, risk early warning, prevention, and control, and performance evaluation standards for supply chain performance index systems, testing, and evaluation methods.

Key points in smart supply chain standard construction
Supply chain construction standards. Standards for supply chain upstream and downstream data formats, system construction and deployment, and resource integration and optimization. **Supply chain management standards.** Standards for supplier categorization and grading and performance evaluation and supply chain upstream and downstream design coordination, production coordination, logistics coordination, sales coordination, and service coordination. **Supply chain evaluation standards.** Standards for supply chain risk identification and assessment, risk early warning, and prevention and control, as well as supply chain performance index systems, testing, and evaluation methods.

4. Smart service standards

These standards mainly include three parts, mass personalized customization, O&M services, and networked collaborative manufacturing, as shown in Figure 8. These standards are mainly used to implement the integration of products and services, the organic integration of decentralized manufacturing (分散化制造) resources, and the high degree of coordination of their respective core competitiveness. The standards solve the problems of comprehensively utilizing various internal and external enterprise resources and providing various standardized and reliable new services.

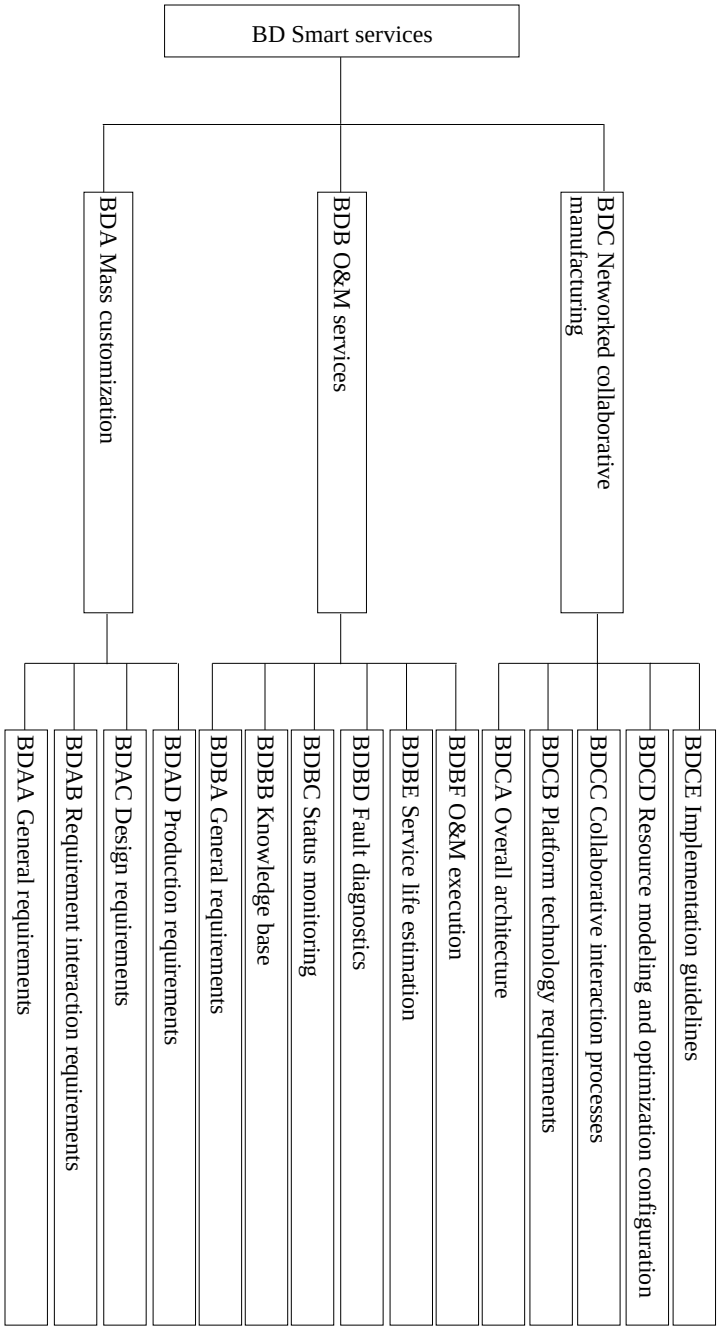

Figure 8. Smart service standards sub-system

Mass customization standards mainly include general purpose requirements, requirements for requirement interaction, design requirements, production requirements, and evaluation and diagnosis standards; O&M service standards mainly include general purpose requirements, knowledge base, status monitoring, failure diagnostics, service life estimation, and O&M execution standards; networked collaborative manufacturing standards mainly include overall architecture, platform technical requirements, collaborative interaction process, resource modeling and

optimization configuration, and implementation guideline standards.

Key points in smart service standard construction
O&M service standards. Knowledge base, status monitoring, failure diagnostics, service life estimation, and O&M execution standards. **Networked collaborative manufacturing standards.** Overall architecture, platform technical requirements, collaborative interaction process, resource modeling and optimization configuration, and implementation guideline standards.

5. Intelligent enabling technology standards

These standards mainly include seven parts: AI, industrial big data, industrial software, industrial cloud, edge computing, digital twins, and blockchain, as shown in Figure 9. These standards are primarily used to guide the integration and application of new technologies in the manufacturing field and improve the intelligentization level of the manufacturing industry.

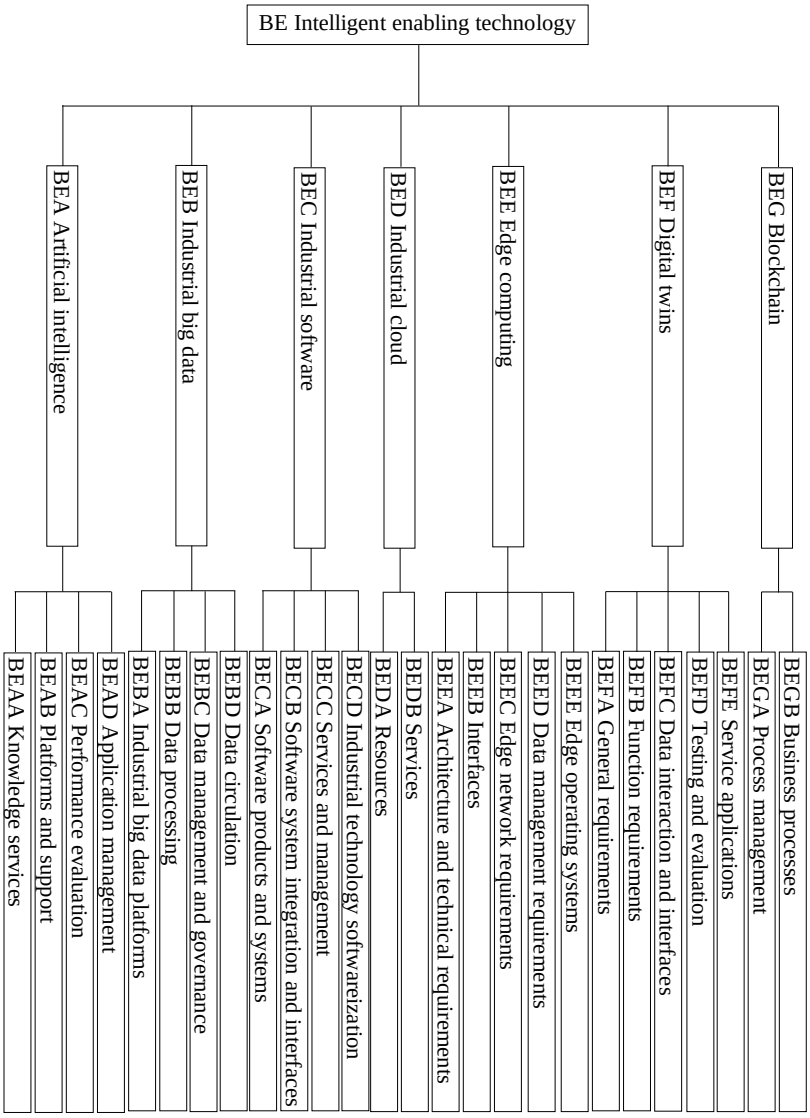

Figure 9. Intelligent enabling technology standards sub-system

(1) AI standards. These standards mainly include knowledge service standards for machine learning, knowledge representation, knowledge modeling, knowledge fusion, and knowledge computing; platform and support standards for application platform architectures and integration requirements; performance evaluation standards for training data requirements, test guidelines, and evaluation principles; and application management standards for the full product life cycle, such as intelligent online inspection and operational management optimization.

(2) Industry big data standards. These standards mainly include industrial big data platform standards for platform construction requirements, O&M, and inspection and evaluation; data processing standards for industrial big data collection, preprocessing, analysis, visualization, and access; data management and governance standards for data management systems, data resource management, data quality

management, master data management, and data management capability maturity; and data flow standards for factory internal data sharing and factory external data exchange.

(3) Industrial software standards. These standards mainly include software product and system standards for products, tools, embedded software, system and platform function definitions, business models, quality requirements, and maturity requirements; software system integration and interface standards for industrial software interface specifications, integration procedures, and product line engineering; service and management standards for life cycle management, quality management, asset management, configuration management, reliability requirements, and testing and verification; and industrial technology softwareization (软件化) standards for industrial technology softwareization reference architecture and industrial application software encapsulation.

(4) Industrial cloud standards. These standards mainly include resource standards for platform construction and application and access to, configuration of, and management of industrial cloud resources and service capabilities; and service standards for implementation guidelines, capability evaluation, and performance evaluation.

(5) Edge computing standards. These standards mainly include standards for architecture and technical requirements, interfaces, edge network requirements, data management requirements, and edge operating systems.

(6) Digital twin standards. These standards mainly include common requirements standards for reference architecture and information models; functional requirement standards for different system levels; data interaction and interface standards for the integration and collaboration between digital twins systems; testing and evaluation standards for performance evaluation and compliance testing; and digital twins service application standards for different manufacturing scenarios.

(7) Blockchain standards. These standards mainly include process management standards for industrial product R&D and traceability and service and quality management based on blockchain technology; and business process standards for blockchain-based supply chain finance, cross-border trade and electronic contracts, procurement, and logistics for manufacturing enterprises.

Key points in intelligent enabling technology standard construction
AI standards. Service standards, performance evaluation standards, and platform and support standards for scenarios through the product life cycle such as intelligent online inspection and

operational management optimization.

Edge computing standards. Standards for architecture and technical requirements, interfaces, edge network requirements, data management requirements, and edge operating systems.

Digital twin standards. General requirements, reference architecture, data interaction and interface, and service application standards.

Blockchain standards. Blockchain-based industrial product traceability, industrial design copyright protection, trusted quality management, supply chain finance, and electronic contracts.

6. Industrial network standards

These standards mainly include four parts, industrial wireless networks, industrial wired networks, industrial network convergence, and industrial network resource management, as shown in Figure 10. These standards are mainly used to meet the requirements of low latency and high reliability within and between different system levels of a factory, implement networking between different levels and heterogeneous networks under the industrial network architecture, and standardize the technical requirements used for network addresses, service quality, radio frequency, and other resources as well as network operation management.

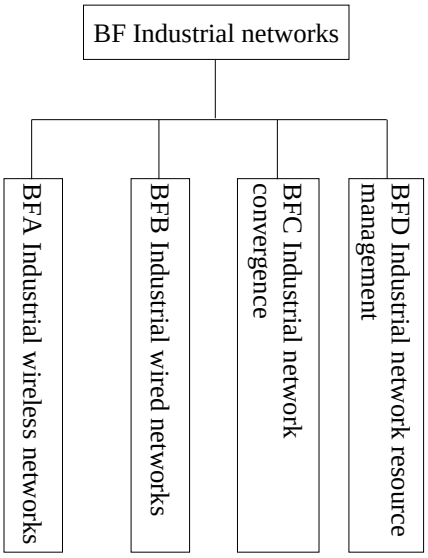

Figure 10. Industrial network standards sub-system

Industrial wireless network standards mainly include wireless local area network (WLAN), wireless Highway Addressable Remote Transducer Protocol (WirelessHART), Wireless Networks for Industrial Automation—Factory Automation/Process Automation (WIA-FA/PA), narrowband Internet of Things (NB-IoT), and 5G application standards. Industrial wired network standards mainly include fieldbus, industrial Ethernet, industrial passive optical network (PON), and industrial integrated wiring standards. Industrial network convergence standards mainly include

deterministic network (DetNet), information technology/operational technology (IT/OT) convergence, and heterogeneous network interoperability standards. Industrial network resource management standards mainly include network management, network address management, network spectrum management, and software-defined networking (SDN) standards.

Key points for industrial network standard construction
Industrial wireless network standards. 5G applications standards.
Industrial network convergence standards. IT/OT convergence and heterogeneous network interoperability standards.
Industrial network resource management standards. Network management, network address management, network spectrum management, and SDN standards.

(iii) Industry Application Standards

These standards mainly include 12 parts: shipping and marine engineering equipment, building materials, petrochemicals, textiles, iron and steel, rail transportation, aerospace, automotive, non-ferrous metals, electronic information, electrical equipment, and other, as shown in Figure 11. Give full play to the guiding and supporting role of foundational and general purpose standards and key technical standards in the formulation of industry standards, pay attention to the coordination and alignment between industry standards and national standards, focus on formulating application standards such as specifications, procedures, and guidelines in combination with industry characteristics, and further promote or improve the industrial smart manufacturing standards system. Analyze the key directions of smart manufacturing standardization such as light industry, the food industry, agricultural machinery, construction machinery, nuclear energy, and civil explosives.

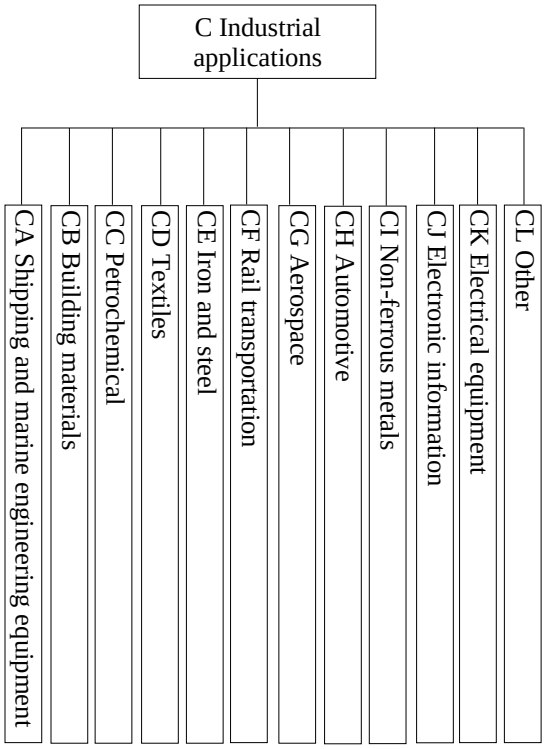

Figure 11. Industry application standards sub-system

1. Shipping and marine engineering equipment

In view of the multiple types, small batches, customization, and other features of shipping and marine engineering equipment manufacturing, taking into account the application requirements of digital "new infrastructure" (“新基建”) such as 5G, and focusing on the final assembly and construction of ships, formulate specification standards for coding, data dictionaries, and 5G application technical requirements; focusing on the construction of intelligent shipyards, formulate specification or regulation standards for information system interfaces, overall planning of production lines, and collaborative product design.

2. Building materials

In view of the many sub-sectors and fields, obvious processing differences, and other features of the building materials industry and focusing on the fields of cement, glass, ceramics, fiberglass, concrete, bricks and tiles, wall materials, and mining, formulate smart factory specification or regulation standards for factory design, process simulation, quality control, and warehouse management. Formulate guideline standards for 5G-based equipment inspection, AI-based defect detection, industrial cloud-based supply chain collaboration, and remote equipment O&M.

3. Petrochemicals

In view of the high safety risks, high actual control requirements, high energy consumption, high environmental protection requirements, and other features of the petrochemical industry, formulate factory design specification standards for smart factory information models. Formulate new technology application specification or regulation standards for processing warnings, on-site personnel positioning, equipment health, and operation alarms. Formulate application guideline standards for remote equipment O&M.

4. Textiles

In view of the overall intermittent manufacturing, partial process manufacturing, and other features of the textile industry and focusing on the fields of spun cloth, chemical fiber, woven, non-woven, printing and dyeing, clothing, and home textiles, formulate specification and guideline standards for the interconnection, information models, and remote O&M technical requirements of specialized equipment. Formulate specification or procedure standards for data, logistics and warehousing, and system integration during the construction of digitalized workshops or smart factories. Develop application norms or guideline standards for new models such as mass personalized customization.

5. Iron and steel

In view of the process manufacturing characteristics of steel production process continuity, processing system complexity, and diversified intermediate states of products and focusing on the application of intelligentized technology in production scenarios, formulate specification standards for 5G applications, unmanned factory cranes (无人行车), and special robot applications. Focusing on the construction of smart factories, formulate specification standards for factory design, digital delivery, and digital twin models. Focusing on intelligent production management, formulate specification standards for quality, logistics, energy, environmental protection, equipment, and global supply chain optimization.

6. Rail transportation

In view of the multiple types, small batches, equal emphasis on new manufacturing and O&M, personalized customization, and other features of the rail transportation equipment industry and focusing on the construction of smart factories in typical business scenarios such as welding, grinding, assembly and commissioning, and logistics, formulate key technical standards for smart equipment testing and certification, 3D model application specifications, industrial robot interfaces, and processing technology requirements. Formulate application standards for smart manufacturing project implementation guidelines and remote O&M of high-speed

electric multiple units.

7. Aerospace

In view of the multiple types, small batches, model-based development mode, multi-party collaboration in design and manufacturing, and other features of the aerospace industry and focusing on the construction or upgrading of smart factories and digitalized workshops, formulate norms and standards for model-based digital design, cloud-based collaborative design platforms, virtual simulation of production lines adapted to complex processes, and environmental monitoring. Formulate application normalization standards for production process state prediction and optimization based on industrial big data.

8. Automotive

In view of the strong technology-intensiveness, numerous parts and components, long industrial chain, many types of subdivided models, complex production processes, and other features of the automobile industry and focusing on the application of intelligent enabling technology in new energy vehicle and traditional fuel vehicle painting, welding, final assembly, and other processes, formulate specification standards for digital twin-based automotive product R&D and design, testing and verification, production line manufacturing, and integration. Formulate application guideline standards for R&D, production, marketing, and supply chain management for mass automotive customization.

9. Non-ferrous metals

In view of the high safety requirements, major variations in the quality of raw materials, complex processing, multiple types and small batches of products, frequent logistics scheduling, and other features of the non-ferrous metal industry, and focusing on specialized smart equipment, smelting, and processing procedures, formulate guideline standards for information coding, information interaction, and operational status management. Formulate application guideline standards for smart factory design, construction, and production procedure monitoring.

10. Electronic information

In view of the high technical complexity, rapid product iteration, obvious multiple type and small batch characteristics, rapid growth of product personalization and customization requirements, and other features of the electronic information manufacturing industry and focusing on the production and processing of electronic information materials, components, and information communication products and systems, formulate standards and norms for information models for, and

interconnection requirements for, specialized smart equipment and systems. Formulate construction guideline standards and system integration specifications for flexible production lines, digitalized workshops, and smart factories. Formulate application guideline standards for new models such as personalized customization.

11. Electrical equipment

In view of the wide variety of products, personalized customization, major O&M needs, and other prominent features of the power equipment industry and focusing on smart grid user terminals and electric motors, formulate smart factory construction guidelines and system integration specifications. Formulate implementation guideline standards for the digitalized simulation of manufacturing processes (processing procedures, production planning and layout, logistics simulation), digitized processing of resources, digitized process control, digitized collaborative manufacturing, remote equipment O&M, personalized customization, and smart manufacturing capability evaluation.

12. Other

For light industry, focus on formulating standards for special process equipment interconnection and online testing for the leather, primary cell batteries, detergents, and other fields; and the formulation of mass personalized customization guideline standards for the household appliance and furniture fields. For the food industry, focus on formulating smart factory design, brewing and filling, processing decision-making, remote O&M, and identifier analysis standards for the dairy beverage, brewing, frozen food, and canned food fields. For the agricultural machinery and construction machinery industries, focus on formulating mass personalized customization design and intelligent O&M service monitoring standards. For the printing industry, focus on formulating standards for flexible printing process design and information exchange between systems. For the nuclear energy industry, focus on formulating standards based on data-driven smart production. For the civil explosives industry, focus on formulating standards related to key processing equipment status monitoring and O&M requirements.

V. Organization and Implementation

Strengthen overall coordination. Under the guidance of the Ministry of Industry and Information Technology (MIIT) and the Standardization Administration of China (SAC), give full play to the role of the National Smart Manufacturing Standardization Coordination and Promotion Group, Overall Group, and Expert Advisory Group, and strengthen the planning and construction of the smart manufacturing standards system.

Accelerate the development of standards. Make full use of mechanisms for coordination among multiple departments and collaboration among multiple standardization technical organizations, coordinate the forces of all production, education, research, and application parties, strengthen the testing and verification of the key technical indicators of standards, accelerate the formulation of key and urgently needed standards, and promote the effective implementation of the standards system.

Strengthen indoctrination (宣贯) and training. Give full play to the role of local departments in charge (主管部门), industry associations, standardization technical organizations, and professional institutions, strengthen indoctrination and training on standards, and guide enterprises to meet the standards in R&D, production, management, and other stages.

Implement dynamic updates. Closely meet the needs of smart manufacturing technology and industrial development, promptly revise the *Guidelines for the Construction of a National Smart Manufacturing Standards System*, and guide the formulation and implementation of smart manufacturing standards in an effective and orderly manner.

Strengthen international collaboration. Regularly hold international forums on smart manufacturing standardization, actively participate in international standardization activities such as the International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), and International Telecommunication Union (ITU), and deepen international standards cooperation in the smart manufacturing field.