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**Automation systems and integration - Integration model of
discrete manufacturing enterprise data space**

自动化系统与集成 离散制造企业数据空间集成模型

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Table of Contents

1 Scope	1
2 Normative references	1
3 Terms, definitions and abbreviations	1
4 Data space model of the discrete manufacturing enterprise	3
4.1 Overall model	3
4.2 Business domain	4
4.3 Modality domain	4
4.4 User domain	4
4.5 Data life cycle domain	4
5 Cross-domain integration model of the research and design business domain	5
5.1 Core businesses of the research and design domain and their data entity models	5
5.2 Cross-domain integration model of the research and design domain	9
6 Cross-domain integration model of the production and manufacturing business domain	11
6.1 Core businesses of the production domain and their data entity models	11
6.2 Cross-domain integration model of the production domain	20
7 Cross-domain integration model of the operations management business domain	22
7.1 Core businesses of the operations management domain and their data entity models	22
7.2 Cross-domain integration model of the operations management domain	27
8 Cross-domain integration model of the operation and maintenance service business domain	29
8.1 Core businesses of the service domain and their data entity models	29
8.2 Cross-domain integration model of the service domain	35
9 Requirements for trusted data circulation across business domains	37
9.1 General	37
9.2 Data generation	37
9.3 Data processing	37
9.4 Data publication	37
9.5 Data exchange	38
9.6 Data transmission	38
9.7 Data storage	38
9.8 Data use	38

9.9 Data destruction	38
Bibliography	39

3 Terms, definitions and abbreviations

A data space is defined as a set of data with the features of multiple data subjects, multiple sources of generation, multiple heterogeneous types, multiple physical distributions and multiple ownership relations, forming a logical data body with internal correlation and dynamic evolution that serves the application needs of enterprises, data consumers and other users. A manufacturing enterprise data space is the data space formed by the data produced in the main business areas of a manufacturing enterprise, such as product research and design, production and manufacturing, operations management and operation and maintenance service.

Data integration is defined as bringing together, logically or physically, data of different origin, format, character and nature so as to provide the enterprise with data sharing. A model is a representation or description of an entity or a system that describes only those aspects held relevant to its purpose. An information model is the organizational form and framework that defines, describes and relates the information resources of a given manufacturing enterprise, and an information object is one information body of a business domain of the manufacturing enterprise; a note adds that an information object describes an entity, general, real or abstract, that can be conceptualized as a whole.

A data entity model is the formal description of the concrete instances of a class of data objects. An attribute is data describing the nature and features of an entity, an attribute element is a basic element composing an attribute and is its basic unit, and an attribute set is a set of one or more attributes that can exist alone as a node and forms the structured element of the attribute description of the enterprise data space information model.

Further terms taken over from other standards are product, defined as the output expected by the enterprise or a by-product of a process, with a note that it may be an intermediate, final or finished product; production, the function or action that converts raw material or semi-finished goods into finished goods; procedure, work or a task containing one or more operating units and normally to be completed at one location; plan, the controlled analysis and design of process sequence, resource requirements and process management needed to reach a given operation; product data, information about a product expressed in a formalized way suitable for communication, interpretation or processing by people or computers; and manufacturing resources, any equipment, tool or means used by the enterprise to make products or provide services.

A trusted data circulation system is defined as distributed key data infrastructure built on the existing information network for data sharing, circulation and application, which through

systematic technical arrangements ensures the confirmation, performance and maintenance of digital contracts in cross-domain data circulation and resolves the security and trust problems between data providers, data users and other subjects. The related term for the contract itself is printed in the document as digital contract, defined as a machine-readable and machine-executable electronic contract reached between the data provider and the data user before circulation, which provides the ability to set circulation conditions and configure control policies and which governs the data during use according to those policies.

The abbreviations listed are BOM for bill of material, CAD for computer aided design, CAE for computer aided engineering, HDFS for Hadoop distributed file system, HTML for hypertext markup language, ID for identity, JSON for JavaScript object notation, WBS for work breakdown structure and XML for extensible markup language.

4 Data space model of the discrete manufacturing enterprise

4.1 The data space of the discrete manufacturing enterprise describes the composition and relations of the space from several dimensions, namely the business domain, the modality domain, the user domain and the data life cycle domain, shown in Figure 1. The four dimensions describe the model respectively from the angle of the enterprise business activities that generate the data, of the functions and operations applied to the data over its whole life cycle, of the classification of data by modality, and of the roles of the several kinds of user.

4.2 The business domain is composed of the main business activities of the manufacturing enterprise and the data they generate, chiefly the data produced in the four stages of product research and design, production and manufacturing, operations management, and operation and maintenance service. The research and design domain covers the product design data models generated by the design activities; the production and manufacturing domain covers the data models relating to people, machines, materials, methods and environment in production, machining and assembly; the operations management domain covers the data models of the management and decision activities of production, supply, sales, personnel, finance and materials; and the service domain covers the data models of customer service, operation and maintenance activities on the products of the enterprise.

4.3 The modality domain describes the classification by modality of the data involved in those business activities, in three classes: structured data, semi-structured data and unstructured data. Structured data is represented and stored chiefly by the relational data model, in the form of two-dimensional structured tables. Semi-structured data is represented and stored chiefly by the key-value mapping model, its format not being fixed, the formats used being XML and JSON. Unstructured data has no fixed data structure model and includes office documents of every format, text, pictures, HTML, reports of all kinds, images and audio or video information; it is represented and stored chiefly by a

distributed file model such as HDFS.

4.4 The user domain is composed of the user subjects that interact with the data in those business activities, including designers, process engineers, engineers, production line workers, dispatchers, quality inspectors, production supervisors, supply chain supervisors, sales supervisors, customer service staff and operation and maintenance supervisors. These roles are both the producers of the data of their own business domain and the users of the data in the related business applications.

4.5 In cross-domain circulation the full life cycle of the data generated in the business domains comprises eight stages: data generation, data processing, data publication, data exchange, data transmission, data storage, data use and data destruction. A trusted data circulation system should be set up to safeguard trusted cross-domain circulation through those eight stages. To keep the data and the systems trustworthy, the generation stage should ensure the trustworthiness of the source of the data, including equipment, people and processes; the processing stage should use trustworthy algorithms and programs so that integrity and accuracy are not damaged; the publication stage should ensure authenticity and integrity and avoid the release of erroneous or misleading information; the exchange stage should use secure and trusted exchange methods and protocols; the transmission stage should use reliable transmission methods and protocols; the storage stage should use trustworthy storage methods and devices; the use stage should ensure that only authorized users can access and use the data; and the destruction stage should follow the established procedure so that the data cannot be maliciously exploited.

5 Cross-domain integration model of the research and design business domain

5.1.1 The core businesses of the research and design domain that bear on cross-domain integration are requirement analysis management, product and process design management, and simulation and verification management, shown in Figure 2. Requirement analysis management manages the design requirements of the design activity and serves as the basis of product and process design, covering among others the product requirement specification, the product function specification, the functional breakdown, the performance index specification, the requirement bill of material and specialist design knowledge, and involving requirement survey and requirement analysis staff. Product and process design management manages the design process, covering among others conceptual design, product structure CAD design, the internal and external structure design of components, the work breakdown structure of the product, variant design, standard part design, product library design and the generation of the process, design and manufacturing bills of material, and involving product designers and process designers. Simulation and verification management manages the quality checking of the design models, covering among others CAE simulation, operating condition simulation, process simulation,