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Industrial automation systems and integration — Diagnostics, capability assessment and maintenance applications integration —

Part 1: Overview and general requirements

Systèmes d'automatisation industrielle et intégration — Diagnostics, évaluation des moyens et intégration des applications de maintenance —

Partie 1: Vue d'ensemble et exigences générales

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18435-1 was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Architecture, communications and integration frameworks*.

ISO 18435 consists of the following parts, under the general title *Industrial automation systems and integration — Diagnostics, capability assessment and maintenance applications integration*:

— *Part 1: Overview and general requirements*

The following parts are under preparation:

— *Part 2: Descriptions and definitions of application domain matrix elements*

— *Part 3: Applications integration description method*

Introduction

0.1 General

ISO 18435 defines a set of integration methods intended to be used when integrating diagnostics, capability assessment, and maintenance applications with the applications in production, control, and other manufacturing operations.

ISO 18435 describes application integration models and common application interoperability requirements. These application integration models are intended to:

a) provide diagnostics, capability assessment, and maintenance applications' integration reference architecture for manufacturing assets, such as equipment, automation devices, and software units;

b) enable integration of diagnostics, capability assessment, and maintenance applications with other applications;

c) provide for a system view context in dealing with asset management lifecycles.

Application integration models are intended to guide users of industry specifications or standards when integrating diagnostics, capability assessment, and maintenance applications with production and control applications. These integration models define elements and rules to help identify and select interfaces described in the interoperability templates. These interoperability templates are used to reference interoperability profiles based on international standards that are required for integrating the applications within and at different levels of an enterprise's functional and resource hierarchies.

The intended users of ISO 18435 are developers of industrial automation applications, especially those that design, implement, deploy, commission, and operate the required systems which integrate diagnostics, capability assessment, control, production, and maintenance applications.

0.2 Asset operation and maintenance lifecycle management integration framework

The main focus of ISO 18435 is to describe the integration requirements that manufacturing assets and resources need to meet in order to support the operation and maintenance phase within a manufacturing system's lifecycle (see Figure 1).

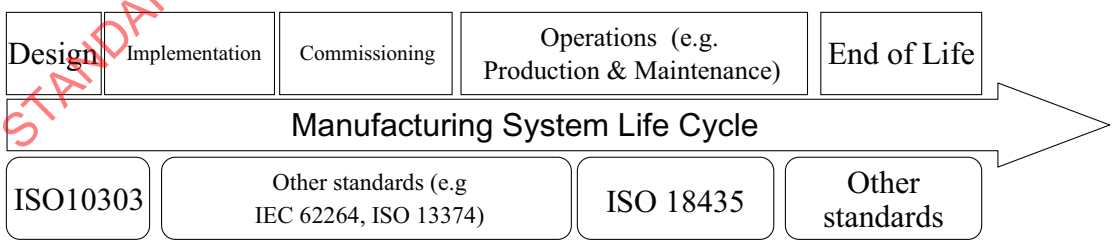


Figure 1 — Scope of ISO 18435 in the lifecycle of a manufacturing system

In Figure 2, the diagnostics and maintenance related activities are shown in a framework, where several combinations of these activities, as distinguished in scope by the ovals, provide effective mechanisms for adapting maintenance strategies to various changes in manufacturing operations, such as changes in production requirements, changes in operational conditions and environment, and changes to continuously improve manufacturing assets during their lifecycle.

For example, the first combination of activities deals with the operational phase of maintenance task execution, which consists of maintenance task planning, involving asset inspection, monitoring and diagnostics, followed by treatment or repair if needed, and ends in the evaluation of maintenance results. These activities are mainly concerned with controlling routine maintenance tasks.

The second combination of activities focuses on maintenance strategy planning that involves the selection of an approach for performing maintenance appropriate to each asset with options such as breakdown maintenance (BM), time-based maintenance (TBM) and condition-based maintenance (CBM). The maintenance strategies can be improved based on diagnostic capability assessment and maintenance histories.

The third combination of activities includes manufacturing asset design improvement driven by inputs from maintenance strategy planning. The design improvements drive maintenance strategy planning. This third cycle seeks to minimize maintenance costs or reduce maintenance effort and time through asset improvement.

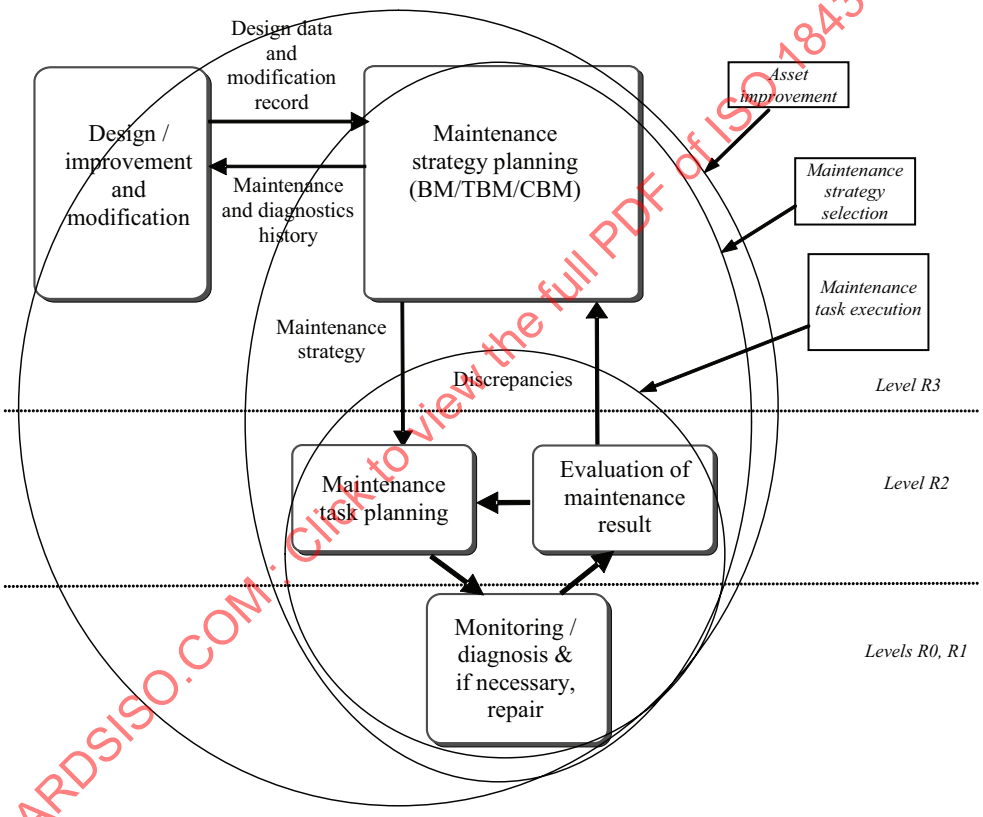


Figure 2 — Framework for maintenance management of manufacturing assets

Although condition-based maintenance (CBM) can be regarded as an advanced strategy, it is not always the most cost-effective method. When failures of machines or components are not critical, the breakdown maintenance (BM) approach is preferable. When the remaining useful life of machines or components can be estimated, time-based maintenance (TBM) is preferred.

ISO 18435 addresses the first cycle of maintenance task execution and the integration of maintenance applications with the other manufacturing applications, especially in the case of condition-based maintenance. The following are examples of integration issues concerning aspects of quality, cost and delivery:

a) quality aspect: conditions of manufacturing assets, kept by the maintenance tasks, used in product quality assurance;

b) cost aspect: trade off between maintenance cost and production loss due to malfunction, unsafe condition and inefficiency of assets;

c) delivery (time) aspect – coordinating maintenance schedule with production schedule.

0.3 Approach

In ISO 18435, the definitions and concepts in other international standards, such as IEC 62264, ISO 15745, and ISO 13374, are used to describe the functions and interfaces that gather information about the process, equipment, operators, and materials and other manufacturing assets and convey the information to various diagnostics and maintenance sub-systems in order to perform asset management. The information exchanges are denoted by a set of schemas that describe the conveyed information and the usage of the required interoperability interfaces.

In particular, reference is made to applicable concepts and definitions provided in ISO 15745, ISO 13374, IEC 61499, IEC 61131, IEC 62264, IEC 61915, ISO/IEC 15459-1, MIMOSA OSA-CBM and MIMOSA OSA-EAI.

0.4 Intended benefits

In a manufacturing enterprise, an appropriately integrated asset management system can provide critical information to improve the productivity of the manufacturing assets deployed. Ideally, effective and timely asset maintenance enables these assets to provide the services required by the production system.

In the past, the information about the process, equipment, operator and material that is already provided by many industrial automation systems and control devices, was not fully utilized in the manufacturing process. Today, with increasing use of digital signal processing in these devices, the available information can now be more effectively analyzed closer to the manufacturing process and used in the diagnostics, capability assessment, control, and maintenance applications. In addition, some of this information can be extracted via interfaces already present in the control system, without adding additional sensors to the manufacturing process. This increased information access capability needs to be presented in a standardized form to other analysis tools that diagnose process, material and equipment problems via well-defined interfaces.

Other benefits that can be gained are as follows:

a) end users can facilitate the specification and procurement of open, integrated and safe systems by referencing pre-defined diagnostics and maintenance application interoperability profiles;

b) system integrators can reduce the time to develop diagnostics and maintenance solutions by using generic tools based on ISO 18435;

c) suppliers of diagnostics and maintenance products and services can provide and develop new offerings using generic tools based on ISO 18435;

d) system aspects of safety management can be improved with an easy access to critical information.

Integration increases the likelihood of the system to realize process optimization per the performance and capacity targets of the application and the business requirements, such as, cost, safety, security, and environmental compatibility.

The application integration models and interoperability schemas can provide equipment and field device suppliers, system integrators, and application designers a means to assess the suitability of diagnostic and maintenance components when integrating the required condition monitoring, maintenance scheduling and asset management systems with other manufacturing applications.

0.5 Relationship to other parts of ISO 18435

The different parts of ISO 18435 are briefly described in Table 1 and illustrated in Figure 3.

In Figure 3, the focuses of the various parts of ISO 18435 are shown as dotted-line areas that bound specific portions of the UML class diagram representing the integration model for an application and between applications.

Table 1 — Outline of ISO 18435

Part	Description
ISO 18435-1	Overview of the integration approach and the application integration model elements, their relationships and a description of general requirements in terms of selected industry application scenarios.
ISO 18435-2[a]	Descriptions and definitions of application domain matrix elements and application interaction matrix elements which represent the application-to-application integration requirements.
ISO 18435-3[a]	Applications integration description method in terms of interoperability profile templates.
[a] Under preparation.	

This part of ISO 18435 provides an overview of the elements and the rules of a method to describe a manufacturing application's integration requirements. The elements include the key aspects when integrating a manufacturing application with other applications and the relationships of these key aspects. The rules include the information exchanges to support interoperability within an application and between applications.

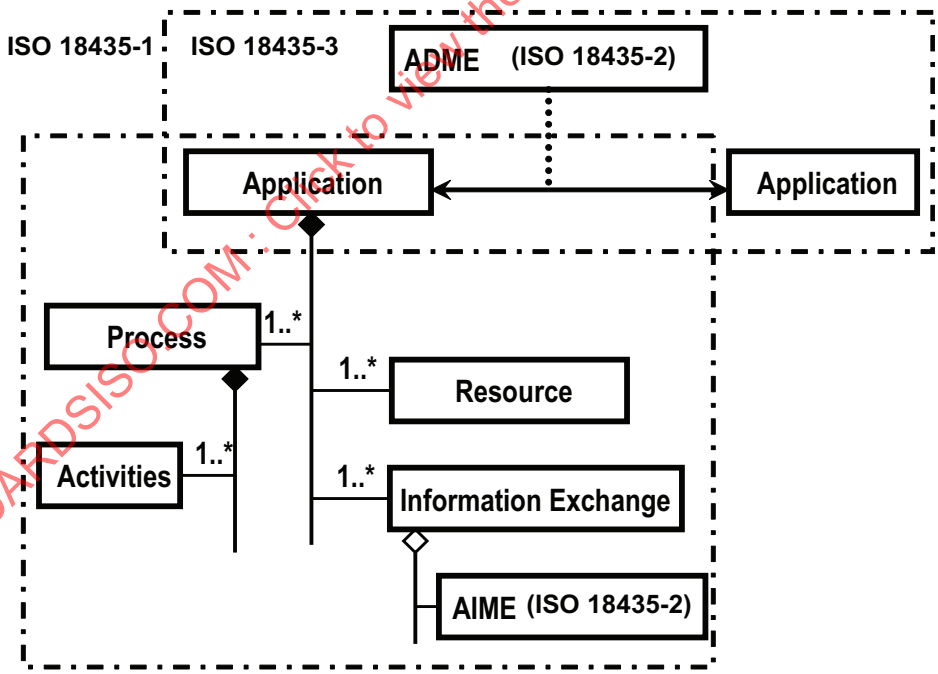


Figure 3 — Relationships within ISO 18435

ISO 18435-2 will provide the detailed definitions of the Application Interaction Matrix Element (AIME) and Application Domain Matrix Element (ADME) structures and their relationships. In particular, the steps for constructing an ADME from a set of AIMEs will be described.

ISO 18435-3 will define a recommended method to describe the interoperability and integration requirements between applications in two or more manufacturing domains within a manufacturing enterprise. The focus will be on the production operations and maintenance operations domains.

Industrial automation systems and integration — Diagnostics, capability assessment and maintenance applications integration —

Part 1:
Overview and general requirements

1 Scope

This part of ISO 18435 defines an integration modelling method and its use to integrate diagnostics, capability assessment, prognostics and maintenance applications with production and control applications. The integration of other application aspects, such as security, is outside the scope of ISO 18435.

NOTE 1 Other parts of ISO 18435 will define the activity domain matrix elements and the detailed integration methods between applications in the application domain integration diagram.

NOTE 2 It is recognized that security is an important aspect of many applications; however, security will not be addressed in ISO 18435.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62264-1, *Enterprise-control system integration — Part 1: Models and terminology*

IEC 62264-2, *Enterprise-control system integration — Part 2: Object model attributes*

IEC 62264-3, *Enterprise-control system integration — Part 3: Activity models of manufacturing operations management*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
activity
set of actions performed by a set of actors

NOTE An activity can also be performed by the actors' agents.

3.2
application
ordered set of processes, performed by a set of resources, coordinated by a set of interactions intended to accomplish a definite objective

3.3
behaviour
observable activities of a component via its effect on its environment and/or through its measurable attributes

3.4
capability assessment
evaluation of the ability or capacity of a manufacturing asset to provide a resource to the system

3.5
component
〈resource〉 part of a system that plays a particular role, by providing some or all of a system's functions when performing a task

3.6
control application
type of manufacturing application that monitors availability and identifies the conditions of manufacturing assets and provides other applications with such information in order to accomplish a manufacturing production objective

3.7
diagnostics application
type of manufacturing application that monitors and checks the continued availability of manufacturing assets, and notifies the other manufacturing applications of any conditions or constraints on such availability

3.8
data historian
capability of a system to collect operating information of that system

3.9
integration
system condition or activity to realize the condition in which components of a system are organized to collaborate, coordinate and interoperate while exchanging items, as needed, to perform a system's task

3.10
interaction
transaction involving multiple resources to accomplish some part of a system's function

EXAMPLE Examples include coordination, collaboration, cooperation, unwitting assistance, witting non-interference, and even competition.

3.11
interface
set of services and related service mechanisms, available via a logical or physical access point, provided by a resource, in order to transfer or exchange information, material, energy, and other manufacturing aspects

NOTE ISO/IEC 10746-2:1996, 8.4, defines "interface" as "an abstraction of the behaviour of an object that consists of a subset of the interactions of that object together with a set of constraints on when they may occur".

3.12
interoperability
capability of two or more entities to exchange items in accordance with a set of rules and mechanisms implemented by an interface in each entity, in order to perform their respective tasks

NOTE 1 Examples of entities include devices, equipment, machines, people, processes, applications, software units, systems and enterprises.

NOTE 2 Examples of items include information, material, energy, control, assets and ideas.

3.13
maintenance application
type of manufacturing application that manages the reconfiguration, removal, replacement or repair of the manufacturing assets, and notifies the other manufacturing applications of such activities

3.14
manufacturing application
set of manufacturing processes, related resources and information exchange involved in the manufacture of a product or the provision of a service

3.15
manufacturing asset
tangible, uniquely identified system with a defined role in the manufacturing process

NOTE Manufacturing assets include structural, mechanical, electrical, electronics and software components, but they do not include human resources, process materials, financial assets and in-process materials.

3.16
manufacturing process
set of processes in manufacturing involving a flow and/or transformation of material, information, energy, control, or any other element in a manufacturing area

3.17
manufacturing resource
physical or logical entity that enables a manufacturing process

NOTE Manufacturing resources include (but are not limited to) manufacturing assets such as equipment, machinery, software, automation units, control devices, instrumentation, tooling, and other resources, e.g. operators, materials, fuels and the physical plant wherein the resources are deployed.

3.18
path
association established between functional units for conveying information

3.19
process
temporal or logical ordering of a set of activities, events, or tasks performed under a set of conditions

3.20
production segment
sequence of process segments and product segments

NOTE See IEC 62264-2.

3.21
resource
entity used to accomplish a task

3.22
role
set of characteristics that distinguish a resource's ability to exhibit a set of required behaviours

3.23
system
set of resources that jointly accomplishes one or more functions of an application's process

NOTE The set of resources can be, for example, software, hardware or personnel.

3.24
task
set of actions intended to accomplish a set of functions

3.25
transaction
exchange of an entity at an interface using a service defined by the resource

4 Abbreviated terms

ADID Application Domain Integration Diagram

ADME Application Domain Matrix Element

AIME Application Interaction Matrix Element

AIRD Application Integration Relationship Diagram

ERP Enterprise Resource Planning

UID Unique ID (of asset for its entire lifetime)

UML Unified Modelling Language

XML eXtensible Mark-up Language

5 Integration and interoperability of applications

5.1 Requirements for integration of applications

The requirements for the integration of applications shall be described in terms of:

a) generic interoperability templates that enumerate an application's resource interfaces and the constraints on those interfaces;

b) specific interoperability profiles for integration across target applications.

As shown in the use case diagram in Figure 4, the manufacturing applications addressed by the integration model described in ISO 18435 reside either within a single domain or in different domains. Inter-domain integration involves at least two applications each residing in a different domain. Intra-domain integration involves two or more applications that reside within the same domain.

The integration requirements for applications in both intra-domain and inter-domain cases shall include the provisions to support the interoperability of these applications. ISO 18435 defines a description method to capture these integration requirements for both cases in the form of interoperability profiles and templates.

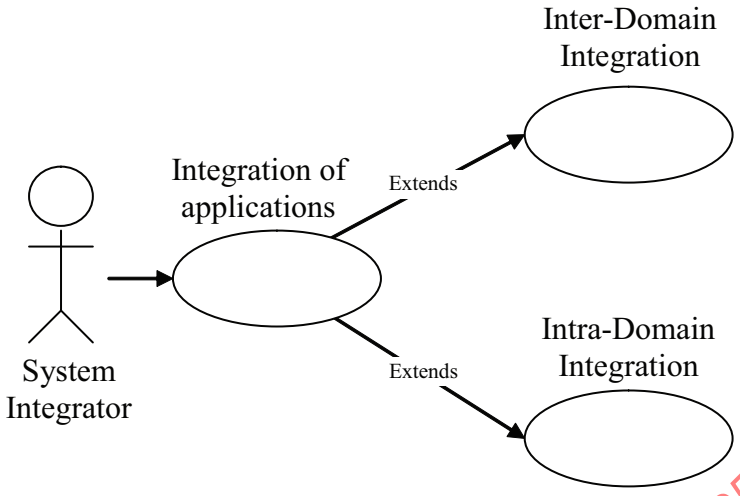


Figure 4 — Applications integration requirements

5.2 Requirements for integration models

An integration model for integrating applications shall describe the following:

a) a set of applications to be integrated, including the distinguishing aspects of these specific target applications;

b) a set of domains formed by these applications within an application domain integration diagram of a manufacturing enterprise;

c) a set of interoperability interfaces, provided by the applications' resources and used in the information exchanges among the applications.

5.3 Criteria for interoperability and integration

Two or more entities shall be considered to interoperate in the following cases:

a) when they exchange information;

b) when the information is exchanged in accordance with a set of rules and mechanisms;

c) when they have a common understanding of the information.

Two or more entities shall be considered integrated in the following cases:

— when each one has a distinguishable structure, behaviour, or boundary;

— when the behaviour is perceived to be accomplished by the integrated entities and not by an individual entity;

— when the entities collaborate, coordinate, and interoperate as needed to perform tasks.

NOTE Entities can be applications, resources, or processes.

These criteria are further elaborated in 5.5 and 5.6.

5.4 Application domains

5.4.1 General

In an enterprise, each manufacturing application uses resources that participate in particular roles to perform specific tasks to accomplish the enterprise's mission. The applications initiate information exchange with other applications using interfaces that are provided by the resources.

The applications in an enterprise can be distinguished in terms of the processes, the sequence of activities in the processes, the tasks that are scheduled and performed during the activities, the specific functions and the required resources used when performing the tasks.

As defined in IEC 62264, the applications in an enterprise shall be distinguished to be resident at some level in a hierarchy of concurrently running applications. Each level in a hierarchy is distinguished by the types of functions performed, the types of resources involved in the tasks, the types of activities and processes conducted, the types of information produced and consumed by the functions, as well as the information structures exchanged with the other levels in the hierarchy.

Within each level, one or more applications categorized to provide the same generic type of function can form a distinct set of applications. In ISO 18435, each distinct function set shall be called a manufacturing application domain. Each application domain shall be modelled to consist of one or more applications that can satisfy a set of interoperability requirements associated with the specific domain.

When each integrated application in a domain satisfies the domain's specific set of interoperability requirements, then the domain shall be referred to as an integrated domain.

5.4.2 Categories of application domains

In ISO 18435, the categories of application domains of interest are enumerated below and shall be represented using an Application Domain Integration Diagram (ADID), as shown in Figure 5.

Some of the application domains at Level R3 of an enterprise hierarchy are as defined in IEC 62264.

a) Production and control applications in application domains D3.1, D2.1, and D1.1

   1) D3.1: Operations planning and scheduling

   2) D2.1: Supervisory control and HMI

   3) D1.1: Control, I/O, operational data historian and panel display

b) Capability assessment, prognostics and diagnostics applications in application domains D3.2, D2.2, and D1.2

   1) D3.2: Capability assessment and decision support

   2) D2.2: Asset prognostics and health, product quality, safety and environmental management

   3) D1.2: Asset utilization, condition monitoring and quality monitoring

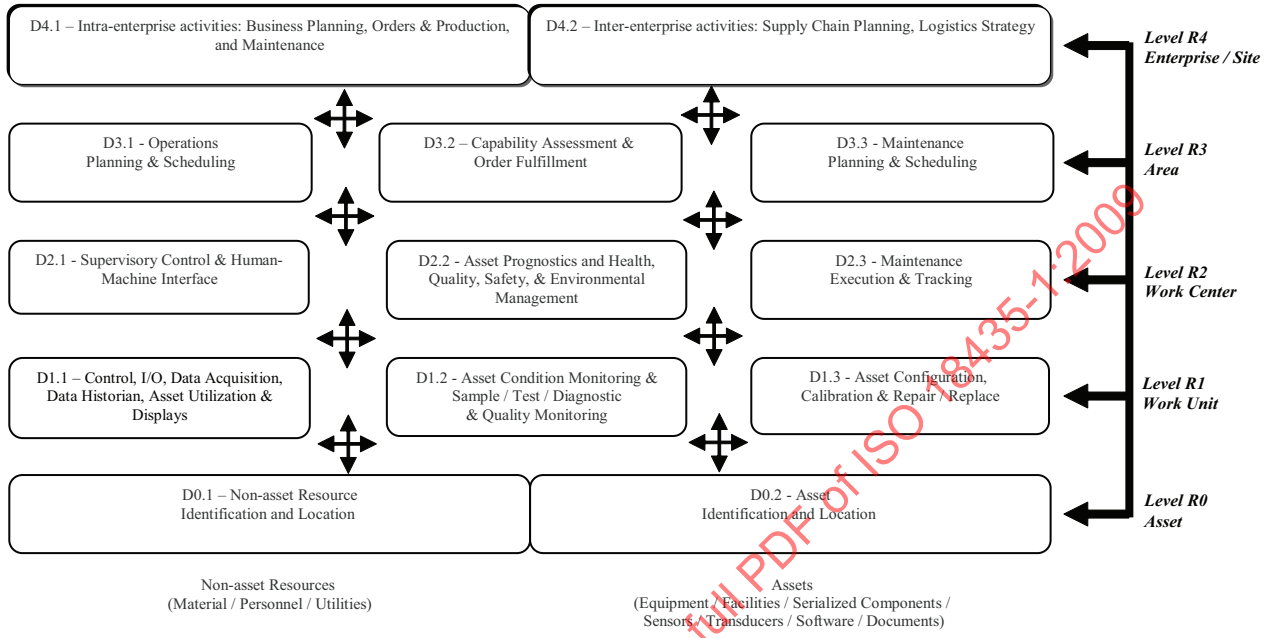
c) Maintenance, configuration, and repair applications in application domains D3.3, D2.3, and D1.3

   1) D3.3: Maintenance planning and scheduling

   2) D2.3: Maintenance work order management and tracking

   3) D1.3: Asset configuration, calibration, repair, and replace

EXAMPLE Application domain D1.2 can be considered as a single application that monitors the condition of manufacturing assets and performs diagnostics to determine if the asset is still able to perform its task. The resources assigned to perform the application's task need to support the required interoperability interfaces in order to act as an integrated system.



NOTE 1 This figure only includes domains which are significantly related to operation and maintenance integration, such as production control, maintenance, and capability management.

NOTE 2 The arrows between and across levels indicate that transactions can occur between any levels and any columns (e.g. D1.1 can communicate to D3.2).

NOTE 3 Domains are related to the reference levels. An implementation can have all reference domains, some can have less. It is advisable that any implementation map back to these application reference domains. Any application domain on this picture can interact with any other application domain. An implementation defines the interfaces exposed by the associated applications with reference to these application domains.

Figure 5 — Application Domain Integration Diagram (ADID)

5.4.3 Operations planning and scheduling (D3.1)

Applications in Domain D3.1 shall correspond to production operations planning and scheduling based upon production commitments issued by the business applications in the application domains D4.1 and D4.2. The D3.1 applications shall be modelled to have information exchanges with the applications which can be in the following application domains: D2.1, D3.2, D3.3 and D2.2. Examples of specific information exchanges are described in Annex A.

5.4.4 Supervisory control and HMI (D2.1)

Applications in domain D2.1 shall correspond to supervisory control and operator interface functions that enable production requirements to be converted to control system task planning and scheduling. These functions also monitor the status of control system execution and provide displays and operator interfaces to enable supervisory personnel and applications to monitor and to intervene in the process being controlled. The D2.1 applications shall be modelled to have information exchanges with the applications which can be in the following application domains: D3.1, D3.2, D2.2, D2.3, D1.1 and D1.2. Examples of specific information exchanges are described in Annex A.

5.4.5 Control, I/O, operational data historian and panel display (D1.1)

Applications in application domain D1.1 shall correspond to closed loop control and the operation of input / output devices that interface with the plant floor processes, equipment, machinery and personnel. These applications shall include but may not be limited to the following:

a) plant floor data archiving and access to historical data access;

b) recording which assets were used with a specific lot of material;

c) track the production line and assets' productivity and downtime due to quality problems, changeovers, equipment failure, fail-safe position, preventive maintenance, etc.;

d) process and equipment control;

e) process and equipment data acquisition.

The D1.1 applications shall be modelled to have information exchanges with the applications which can be in the following application domains: D2.1, D2.2, D1.2, D1.3, D0.1 and D0.2. Examples of specific information exchanges are described in Annex A.

NOTE By altering the control or configuration of an asset subject to new constraints (e.g. energy, lifetime, and throughput), the utilization of the asset could be improved or changed. Panel displays allow operators to view the operating state of the equipment and provide control engineers with the ability to change the operational capability of the asset.

5.4.6 Capability assessment and decision support (D3.2)

Applications in application domain D3.2 shall correspond to evaluations of current and future manufacturing operations capabilities within the manufacturing enterprise. These applications shall also include, but not be limited to, the following:

a) forecasts of capabilities needed for a particular production segment based on projected production levels;

b) projected probability of success and impact assessment (environmental, safety, and financial) for an entire production facility or line over time based upon future demands and regulatory constraints;

c) recommend resource commitments to support manufacturing operations based on other information, such as:

   1) production output and quality level over time;

   2) direct/indirect costs, scrap output, environmental risk, safety risk, unexpected downtime risk;

   3) shift and seasonal factors.

The D3.2 applications shall be modelled to have information exchanges with the applications which can be in the following application domains: D3.1, D3.3, D4.1, D4.2, D2.1, D2.2, and D2.3. Examples of specific information exchanges are described in Annex A.

5.4.7 Asset prognostics and health, product quality, safety and environmental management (D2.2)

Applications in application domain D2.2 shall correspond to asset prognostics and asset health assessment that estimate an asset's remaining useful life and, consequently, when to perform the next major maintenance action. These applications shall also include, but not be limited to, the following:

a) prognostics using other intelligent agents (e.g. ISO 13374 agent) to determine the current health of an asset based upon diagnoses of abnormal states (e.g. ISO 13374 Health Assessment functions);

b) synthesis of complex data and events (alarms, operating changes, etc.) to develop operations and maintenance advisories and schedule modifications;

c) predicting an asset's future health grade and diagnostic faults with an associated probability;

d) estimating impact of asset health on product quality, safety levels and environmental compliance.

The D2.2 applications shall be modelled to have information exchanges with the applications which can be in the following application domains: D3.1, D3.2, D3.3, D4.1, D4.2, D2.1, and D2.3. Examples of specific information exchanges are described in Annex A.

5.4.8 Asset utilization, condition monitoring and quality monitoring (D1.2)

Applications in application domain D1.2 shall correspond to asset condition monitoring and diagnostics that acquire and convert plant floor data (e.g. the ISO 13374 Data Acquisition block) into specific descriptors (features) of interest. These applications shall also include, but not be limited to, the following:

a) use of signal processing algorithms to extract specific descriptors of interest (e.g. the ISO 13374 Data Monitoring block);

b) comparison of these descriptors against expected baseline profile values or condition monitoring limits to trigger certain output of enumerated state indicators (e.g. level low, level normal, level high, “alert”, “alarm”, etc);

c) generating condition monitoring alerts based on defined condition monitoring limits or baselines (e.g. the ISO 13374 State Detection block);

d) generating asset utilization assessments based on operational context, sensitive to current operational state or operational environment;

e) performing sampling and testing of equipment and process machinery similar to those done with laboratory information management systems;

f) performing embedded diagnostic applications that return fault codes if abnormal conditions in the asset are detected.

The D1.2 applications shall be modelled to have information exchanges with the applications which can be in the following application domains: D1.1, D1.3, D2.1, D2.2, D2.3, D0.1, and D0.2. Examples of specific information exchanges are described in Annex A.

5.4.9 Maintenance planning and scheduling (D3.3)

Applications in application domain D3.3 shall correspond to maintenance operations planning and scheduling based upon production commitments issued by application domain D3.1 applications. The D3.3 applications then generate detailed maintenance plans for application domain D2.3 applications.

The D3.3 applications shall be modelled to have information exchanges with the applications which can be in the following application domains: D3.2, D3.1, D2.1, D2.2, D2.3, D4.1, and D4.2. Examples of specific information exchanges are described in Annex A.

5.4.10 Maintenance work order management and tracking (D2.3)

Applications in application domain D2.3 shall correspond to maintenance work execution and work order tracking applications. These applications accept maintenance operations schedules and condition-based maintenance work requests to create and track work orders throughout their lifecycle.

The D2.3 applications shall be modelled to have information exchanges with the applications which can be in the following application domains: D2.2, D2.1, D3.2, D3.3, D1.2, and D1.3. Examples of specific information exchanges are described in Annex A.

5.4.11 Asset configuration, calibration, repair and replace (D1.3)

Applications in application domain D1.3 shall correspond to configuration of serialized asset components, including asset component tracking. These applications shall also include, but not be limited to, the following:

a) managing asset lifecycle usage, calibration, repair, and replacement activities on all serialized components (including field devices and instrumentation) directly or via a portable field instrument;

b) controlling and recording such activities in response to a work order request;

c) detecting abnormal state profiles and providing indication to other asset management applications.

The D1.3 applications shall be modelled to have information exchanges with the applications which can be in the following application domains: D0.1, D0.2, D1.2, D1.1, D2.1, D2.2, and D2.3. Examples of specific information exchanges are described in Annex A.

5.4.12 Intra-enterprise and inter-enterprise activities (D4.1 and D4.2)

Applications in the application domain D4.1 shall be modelled to correspond to business planning, human resources, orders and production. Application domain D4.2 shall be modelled to correspond to applications that assist suppliers and buyers with supply chain management functions and assist the enterprise in business planning, financial management, customer relationship management, and logistic applications.

NOTE Level 4 applications are sometimes called Enterprise Resource Planning (ERP) systems. These applications are intended to help enterprise management through better sharing of information and communication across the organization and locations of an enterprise.

The D4 applications shall be modelled to have information exchanges with the applications which can be in the following application domains: D3.1, D3.2, and D3.3. Examples of specific information exchanges are described in Annex A.

5.4.13 Resource registry services (D0.1 and D0.2)

Applications associated with the application domain A0 shall correspond to identifying and locating:

a) asset resources, including, but not limited to, equipment, machinery, devices, instruments, tools, software units, containers, networks, facilities, and other reusable assets;

b) non-asset resources, including, but not limited to, raw materials, fuels, reagents, catalysts, lubricants, packaging, processing fluids, and other consumable assets.

These applications shall also involve, but are not limited to, the following:

— coordinating lifecycle management of similar asset bases across multiple, geographically separated sites to exploit the knowledge and practices developed at individual sites;

— supporting a common asset registry scheme across multiple enterprises, using standardized universal identifiers (e.g. ISO/IEC 15459) for resources and tracking the resources from deployment-to-disposal.

In ISO 18435, a uniquely defined identifier (UID) shall be used to distinguish an asset.

NOTE The definition of a UID, the method and means of assigning a UID to an asset, and the method and means of recognizing a UID of an asset are not within the scope of ISO 18435; however, the definition, methods and means are expected to be based on non-proprietary, publicly-available specifications.

Annex B describes a method of organizing and using a collection of UIDs that represent a group of manufacturing assets that are being handled by diagnostics, maintenance and related asset management applications.

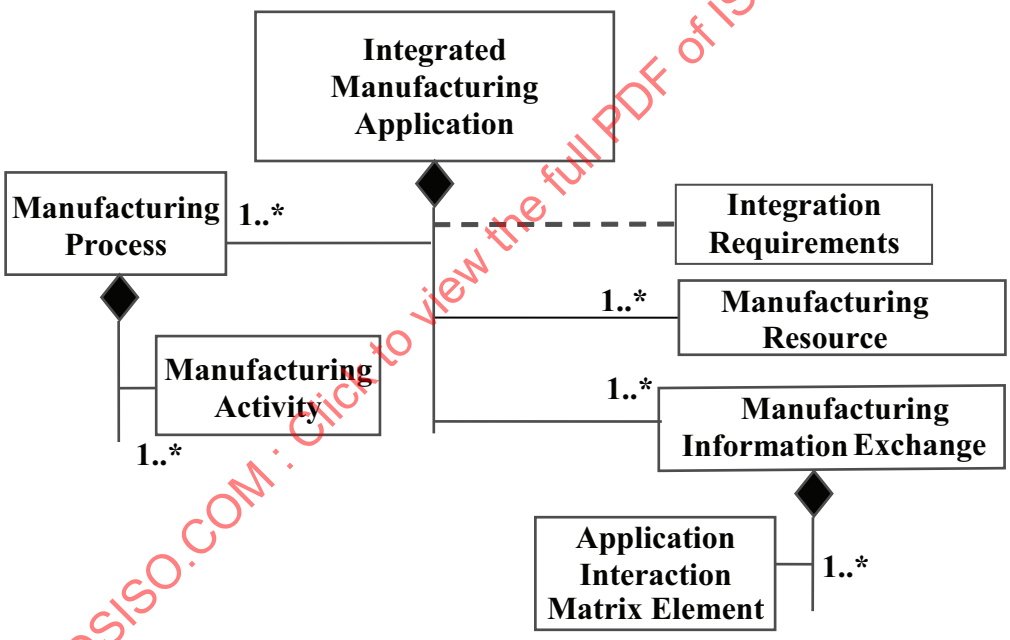
5.5 Integration within an application

5.5.1 Application interoperability model

As defined in ISO 15745, the key interoperability elements of an application consist of its processes, resources and information exchanges (see Figure 6).

Integration within an application shall be described in terms of the integration of the processes and the resources of an application. Each manufacturing process in a manufacturing application shall be modelled to consist of a set of activities, where each activity shall employ a set of component manufacturing resources and each resource shall participate in a specific role in the activities organized by the process. In performing its role in a given activity, each resource shall provide a set of interoperability interfaces to support the information exchanges conducted. To support all the information exchanges of all the manufacturing processes in a manufacturing application, each and every manufacturing resource component in a system shall provide a particular set of interfaces appropriate for the interacting processes.

The interoperability elements and their relationships are illustrated in the Application Integration Relationship Diagram (AIRD).



NOTE The presentation in this figure does not preclude processes within processes or applications within applications.

Figure 6 — Application Integration Relationship Diagram (AIRD)

In ISO 18435 the focus is on the information exchange requirements within the “Integration Requirements” association class in Figure 6. The “Integration Requirements” association class shall contain the conditions that determine whether the interfaces provided by the manufacturing resources can support the required information exchanges.

In Figure 6, each manufacturing process shall be associated with a set of manufacturing resources that may be depleted or reused after the process is completed. When each manufacturing process proceeds from start to finish, a series of information exchanges shall be associated with those manufacturing resources. The series of information exchanges shall be modelled in terms of resources acting as information producers and information consumers, and where the exchanges occur via properly configured interfaces.

5.5.2 Interoperability and integration of resources in an application

Using the criteria established in 5.3, two or more application resources interoperate in order to perform their respective tasks via an interface in each interacting resource. Each information exchange between resources may be associated with a type of interface that is configured and deployed in each participating resource.

Using the criteria established in 5.3, two or more resources associated with each process are integrated to exhibit a structure, behaviour, or boundary as required by the application.

NOTE 1 Typical interface types are sensor interfaces for physical signal acquisition, human-machine interfaces for operator commands and displays, network interfaces for devices, etc. To support the required exchanges, each interface supports a set of required services, where each service offers a certain grade and a specific quality of service.

NOTE 2 The interfaces that enable the interoperability of the resources are configured to support the information flow characteristics, such as, quantities, qualities, sources, destinations, and information exchange rates. The information flows among the resources involve data types, meanings, structures, sequences of exchanges and timing of exchanges that are handled by a set of software and hardware interfaces.

NOTE 3 Each information flow can be modelled as a detailed UML sequence diagram showing the resources involved, the information exchanged among these resources, and each exchange's time-related properties (e.g. initiation, ordering, synchronization, completion).

NOTE 4 The integrated process is enabled by the combined behaviour of the resources and coordinated by the order and timing of the information exchanges.

5.5.3 Interoperability and integration of processes in an application

In ISO 18435, the criteria established in 5.3, requires that the integration of two or more processes in an application be enabled by the interoperability of these processes and the use of the associated integrated resources.

All the interfaces required to support the information exchanges between the processes in an application shall be represented in a resource-to-resource table for the application. If N is the total number of resources in the application, the table shall be represented as an $N \times N$ matrix, where each element in the matrix shall enumerate the information exchange requirement between any two resources in an application.

The AIME is a method for ensuring the compliance of 5.3. When the completed AIMEs for an application can be specified, then the processes shall be considered integrated. An AIME should be defined in terms of an ISO 15745 application interoperability profile.

5.6 Integration within a domain

5.6.1 Interoperability and integration of applications in a domain

In ISO 18435, the criteria established in 5.3 requires that the integration of two or more applications in a domain be enabled by the interoperability of these applications and the use of the associated integrated processes as supported by the combined set of integrated resources.

A subset of these integrated resources shall provide the following types of interoperable information exchange interfaces:

a) resource with process;

b) process with application;

c) application with domain.

The full set of interfaces for an integrated application may differ from the set of interfaces of another integrated application. However, any two applications in a particular domain shall support a common set of interface types to enable the information exchanges between them. The set of AIMEs corresponding to an integrated application may also differ partly from the set of AIMEs for another integrated application in a particular domain.

All the interfaces required to support the information exchanges between the applications in a domain shall be represented in an application-to-application table for the domain. If K is the total number of applications in a domain, the table shall be represented as a $K \times K$ matrix, where each element in the matrix shall enumerate the information exchange requirement between any two applications in the domain.

The ADME is a method for ensuring the compliance of 5.2. When the completed ADMEs for a domain can be specified, then the applications shall be considered integrated. An ADME should be defined in terms of an ISO 15745 application interoperability profile.

5.6.2 Overview of Matrix Elements

In ISO 18435, only the ADMEs for the applications in the maintenance and repair domain, in the control and production domain, and in the diagnostics and capability assessment domain shall be considered.

ISO 18435-2 will provide a detailed definition of an AIME (Application Interaction Matrix Element) and ADME (Application Domain Matrix Element). Each element will enumerate the information exchanges between two interacting entities (see Figure 7).

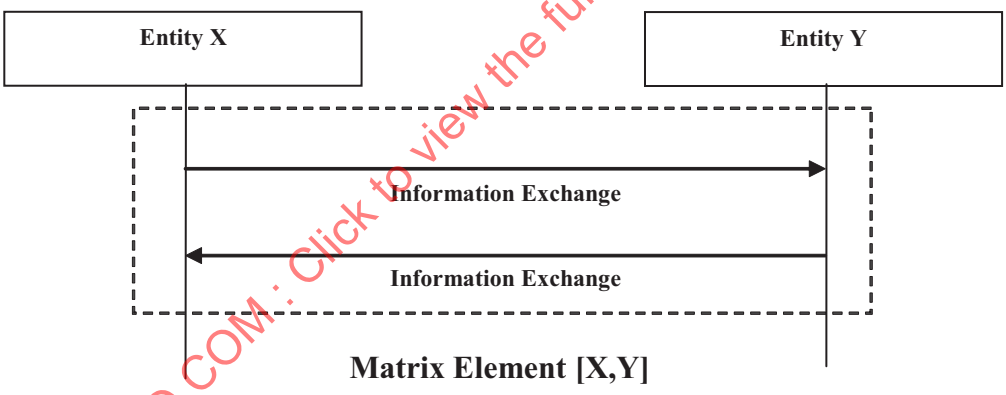


Figure 7 — Matrix element

NOTE 1 An ADME for any two integrated applications is related to a set of AIMEs that are associated with resources belonging to different applications.

NOTE 2 The required interfaces to support the AIMEs between the resources of an application can also support the AIMEs between the resources of different applications.

The information exchanges between entities will be described using a path description method. A set of path descriptions shall be represented by an AIME or ADME. This description method distinguishes the source entity, the destination entity, as well as the other attributes of the exchange, such as:

a) the frequency and the latency of the exchange;

b) the criticality of the exchange;

c) the type of exchange;

d) any constraints on the exchange, such as:

   1) asynchronous,

   2) synchronous,

   3) blocking;

e) interface type.

Examples of an ADME's attributes include:

— source application name;

— source application identifier;

— target application name;

— target application identifier;

— application registration authority;

— application message description;

— application message identifier;

— application domain name;

— application domain identifier.

6 Integration among domains

6.1 Interoperability and integration between applications in different domains

Information exchanges between two applications in different domains shall also be represented in terms of an ADME. The applications may be in different domains at the same hierarchy level or in different domains at different hierarchy levels of the enterprise in accordance with the ADID.

The structure of an ADME for two applications in different domains is similar to an ADME for two applications within the same domain. If L is the number of applications in one domain and M is the number of applications in another domain, the complete matrix with $L \times M$ elements will contain the set of ADMEs that describes the interoperability requirements for the applications.

6.2 Applications in different domains at the same level in a hierarchy

When two applications reside in different domains but within the same level in an enterprise application hierarchy, the set of ADMEs describing the interoperability requirements will involve the types of resources that have similar information handling capabilities. The information exchange between these resources associated with the different domains form AIMEs that span across application and extend across domains.

The integration of applications resident in different domains shall be described in terms of ADMEs that span across domains. The interoperability interfaces that will support the AIMEs and the ADMEs shall be common to the domains at the same level.

6.3 Applications in different domains at different levels in a hierarchy

When the applications in different domains are resident at different levels in an enterprise hierarchy, the set of ADMEs describing the interoperability requirements will involve types of resources that have different information handling capabilities. The information exchanges between these resources associated with different domains at different levels will form AIMEs and ADMEs that require a set of interoperability interfaces which can enable resources at different levels to cooperate, collaborate and coordinate the performance of their combined tasks.

6.4 Integration requirements across application scenarios

Several application scenarios from various industries will be provided in ISO 18435-3. These scenarios illustrate the combined intra-level and inter-level interactions among the application domains.

These scenarios are not intended to be comprehensive, but are provided as examples on how to use definitions of the ADID, the AIRD, the AIME, the ADME and the interoperability profile definitions of ISO 15745 to describe integration requirements.

6.5 Integration requirements in terms of interoperability templates

ISO 18435-3 will define the templates used to represent the integration requirements of the various applications participating in any given scenario.

7 Conformance and compliance

7.1 Conformance aspects

Conformance to this part of ISO 18435 shall be stated by implementation providers in accordance with the following guidelines:

a) a conformance statement shall declare which clauses in this part of ISO 18435 are referenced in a particular implementation;

b) when several clauses in this part of ISO 18435 need to be implemented as a group, this set of clauses shall be referenced as a group in a particular implementation;

c) certain diagrams in this part of ISO 18435 that have been constructed following UML conventions shall be part of a conformance statement, as needed.

7.2 Compliance aspects

Compliance to this part of ISO 18435 shall be stated by specification providers in accordance with the following guidelines:

a) the purpose of a compliance statement shall be to declare which clauses in this part of ISO 18435 are referenced in a particular specification;

b) when several clauses in this part of ISO 18435 need to be referenced as a group, this set of clauses shall be referenced as a group in a particular specification;

c) certain diagrams in this part of ISO 18435 that have been constructed following UML conventions shall be part of a compliance statement, as needed.

Annex A
(informative)

Application domain matrix

A.1 Overview and properties

Following the integration model described in this part of ISO 18435, the integration of applications within an application domain shall be modelled in terms of a set of ADMEs.

These information exchanges shall be considered to also occur between applications in different application domains that may be at different levels in the application hierarchy.

In particular, a set of information exchanges between two applications can be represented as an ADME. A set of ADMEs is used to describe the integration of several applications in different domains to realize a particular industry application scenario.

The 13 application domain categories in Figure 5 can be used to form a generic 13×13 matrix where the rows and columns correspond to the application domains and the entries in the table correspond to the inter-domain matrix elements.

Table A.1 — Application domain matrix

		To (column)												
		D0.1	**D0.2**	**D1.1**	**D1.2**	**D1.3**	**D2.1**	**D2.2**	**D2.3**	**D3.1**	**D3.2**	**D3.3**	**D4.1**	**D4.2**
From (row)	**D0.1**													
	D0.2													
	D1.1													
	D1.2													
	D1.3													
	D2.1													
	D2.2													
	D2.3													
	D3.1													
	D3.2													
	D3.3													
	D4.1													
	D4.2													

For example, the matrix element designated as “From D2.2 To D3.2” represents the information exchanged by an application resident in domain D2.2 with another application resident in domain D3.2.

A.2 Examples of exchanged information items among domains

Tables A.2 to A.11 show groups of ADMEs organized by domain levels in the enterprise, in accordance with the ADID. The domain identifiers follow the notation of Figure 5. Each example includes a set of information items exchanged between the applications resident in the domains.

Table A.2 — Items exchanged between Level D0.1 and Level 1, 2, 3 domains

		To	
		D0.1	**D1.1, D1.2, D1.3, D2.1, D2.2, D2.3, D3.1, D3.2, D3.3**
From	**D0.1**	—	Unified registry of non-asset resources (material, personnel, utilities)
	D1.1, D1.2, D1.3, D2.1, D2.2, D2.3, D3.1, D3.2, D3.3	Registry updates of non-asset resources, of material, of personnel	—

Table A.3 — Items exchanged between Level D0.2 and Level 1, 2, 3 domains

		To	
		D0.2	**D1.1, D1.2, D1.3, D2.1, D2.2, D2.3, D3.1, D3.2, D3.3**
From	**D0.2**	—	Unified registry of assets (equipment, facilities, serialized components)
	D1.1, D1.2, D1.3, D2.1, D2.2, D2.3, D3.1, D3.2, D3.3	Registry updates of assets (equipment, facilities, serialized components)	—

Table A.4 — Items exchanged between domains at Level 1

		To		
		D1.1	**D1.2**	**D1.3**
From	**D1.1**	—	— Digitized sensor output data with timestamp and quality — Test outputs — Operational events	— Desired calibration and configuration data to monitor and/or archive — Desired instrumentation and field device alarms/event to monitor and/or archive — Asset utilization information
	D1.2	Desired sensor monitoring locations and monitoring frequency, tests to review, operational events to monitor at a given frequency	—	Abnormal state detection data based on normal and abnormal calibration profiles
	D1.3	— Calibration/configuration data — Instrumentation and field device alarms/event data	— Calibration/configuration data — Instrumentation and field device alarms/event data	—