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# Industrial automation systems — Requirements for enterprise-reference architectures and methodologies

*Systèmes d'automatisation industrielle — Prescriptions pour architectures de référence entreprise et méthodologies*



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# Foreword

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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 International Standard ISO 15704 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 15704 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC 5, *Architecture, communications and integration frameworks*. In preparing this document, substantive contributions were received from groups involved with enterprise-reference architectures such as the Purdue Enterprise-Reference Architecture (PERA), the Graphes et Résultats et Activités Interreliés GRAI Integrated Methodology (GRAI GIM), the Computer Integrated Manufacturing Open System Architecture (CIMOSA), and the Generalised Enterprise-Reference Architecture and Methodology (GERAM).



Annexes A and B of this International Standard are for information only. Annex A is based on version 1.6.2 of GERAM developed by the IFIP/IFAC Task Force on Architectures for Enterprise Integration who granted permission for its inclusion in ISO 15704.

# 0 Introduction

## 0.1 Rationale for enterprise-reference architectures and methodologies

Industrial enterprises create and modify manufacturing and business operations to improve performance in local and global markets. In the operational phase, they deploy a variety of resources such as people, information systems, and automated machinery. Individually and collectively these resources provide the functional capabilities required to expedite business processes and their constituent activities. The inter-working of resources needs to be organised and targeted to accomplish the mission. This requires suitable business rules and organisational structures to enable the enterprise to provide products and services to its customers in conformance with agreed upon criteria.

Enterprises operate under uncertain market and environmental conditions so that enterprise engineering may need to be ongoing. It follows that enterprise personnel have a variety of roles to play in the conception and ongoing development of the mission, business rules, business processes, organisational structures, and supporting resources and services. Because of the high levels of complexity involved in enterprise engineering, invariably it is necessary to deploy means of assessing, structuring, coordinating and supporting these engineering activities.

Enterprise-reference architectures underpinned by reference methodologies provide generally applicable means of organising and coordinating engineering projects. By adopting, and as required adapting, a reference methodology and architecture, enterprise personnel can cooperate in progressing enterprise-engineering projects, improving the enterprise and utilisation of resources. By adopting a reference methodology, architecture, and a supporting tool set, it becomes practical for personnel to reuse explicit enterprise designs and models to achieve enterprise engineering on an ongoing basis to realise further improvements in enterprise operation.



Therefore, a vital need is an enterprise engineering and integration reference base providing methodologies and supporting technologies that can realistically treat the problem of enterprise integration.



The work of the IFAC/IFIP (International Federation of Automatic Control/ International Federation for Information Processing) Task Force on Architectures for Enterprise Integration and of many other similar organisations around the world have recently focused their work on this problem in hopes of achieving the generic solution needed. Their work has shown that such a reference base can be devised, and must be underpinned by an enterprise-reference architecture that:

a) can model the whole life history of an enterprise-integration project from its initial concept through definition, functional design or specification, detailed design, physical implementation or construction, operation to decommissioning or obsolescence;

b) encompasses the people, processes, and equipment involved in performing, managing, and controlling the enterprise mission.

It is important to note that enterprise-reference architectures deal with the structural arrangement (organisation) of the development and implementation of a project or programme such as an enterprise-integration or other enterprise-development programme. In contrast to these enterprise-reference architectures, system architectures deal with the structural arrangement (design) of a system; for example, the computer-control-system part of an overall enterprise-integration system.

The IFAC/IFIP Task Force on Architectures for Enterprise Integration has developed the definition of a complete, generalised enterprise-reference architecture and methodology and has called it GERAM, described in annex A. GERAM will be used as the example reference for the requirements set forth in this document.

### 0.2 Key principles of enterprise integration

Several concepts that describe the nature of enterprise-reference architectures and methodologies have emerged from the studies of the IFAC/IFIP Task Force on Architectures for Enterprise Integration that can greatly simplify, integrate, and extend the work of enterprise engineering. This work has led to the development of GERAM, which is capable of supporting those who plan, design, and implement complex enterprise-integration projects.

Key principles of an enterprise-reference architecture are described below to provide a basis for the requirements of clause 4.

#### 0.2.1 Applicability to any enterprise

The early work in CIM (computer-integrated manufacturing) and enterprise integration was confined largely to the field of discrete-parts manufacturing, and to computers and information handling. However, the basic principles involved in enterprise integration apply to any enterprise, regardless of its size and mission or any other such attributes involved and to all aspects of the enterprise. In addition, it has been a mistake to confine the integration discussions to information and control systems alone. Often there are problems within the mission system, manufacturing or other customer product and service operations, or in the associated human and organisational area whose solution would greatly ease the overall system problem, that is, a total solution must involve information, culture, and mission.

The reference architecture can be extended to cover all possible types of enterprise by considering manufacturing as a type of customer service, providing concept, development, design, modification, production, and supply of goods to the customer. Thus the mission-execution area of the architecture would represent the customer service rendered by any enterprise even if that service involved the supply of information-type products to the customer.



#### 0.2.2 Enterprise identification and mission definition

No enterprise can exist in the long term without a business or mission, that is, it must produce products or services desired by its customers. It usually produces these products or services in competition with other enterprises. Therefore the enterprise identification and mission definition are essential parts of any enterprise-integration project.



#### 0.2.3 Separation of mission-fulfillment functions from mission-control functions

There are only two basic classes of functions involved in operating any enterprise. These are described below.

a) One class comprises functions involved in fulfilling the mission, i.e. operating the processes that produce the product or service. In the manufacturing plant these would include all material and energy transformation tasks and the movement and storage of materials, energy, goods-in-process, and products; and services.

b) The other class comprises functions involved that manage and control the mission-fulfillment to achieve the desired economic or other gains that assure the viability or continued successful existence of the enterprise. These include the collection, storage, and use (transformations) of information to control the business processes, that is, to develop and apply necessary changes to the business processes to achieve and maintain their desired operation. Control includes all planning, scheduling, control, data management, and related functions.

### 0.2.4 Identification of process structures

Enterprise operation consists of many transformations of material, energy, and information that can be categorised into two distinct classes: one for information transformations and the other for material and energy transformations. These transformations will be carried out by many separate activities that can be executed both concurrently and sequentially to constitute processes of an equivalent class. Processes of both classes interface with each other in those activities that request and report status, and in those activities that deliver operational commands. In combination these transformations define the total functionality of the enterprise being considered.

### 0.2.5 Identification of process contents

For many technical, economic, and social reasons, humans are involved in the implementation and execution of many business processes of all types in both classes mentioned in 0.2.4. Other processes may be automated or mechanised. There are only three classes of implemented tasks or business processes, which are as follows:

a) information and control activities that can be automated by computers or other control devices;

b) mission activities that can be automated by the mission-fulfillment equipment;

c) activities carried out by humans, whether of the information and control or mission-fulfillment class.

It is desirable to have a simple way of showing where and how the human fits in the enterprise and how the distribution of functions between humans and machines is accomplished.

### 0.2.6 Recognition of enterprise life-cycle phases



All enterprises, of whatever type, follow a life cycle from their initial concept in the mind of an entrepreneur through a series of stages comprising their development, design, construction, operation and maintenance, refurbishment or obsolescence, and final disposal.



Not only does this life cycle apply to the enterprise but also to the enterprise products as well. Carried further, one enterprise can be the product of another. For example, a construction enterprise could build a manufacturing plant (enterprise) as its product. The manufacturing plant would then produce its own product, such as an automobile. The automobile also has its own life cycle that goes through similar steps to those discussed here (see 0.2.1).

A particular distinction can be made between those life-cycle phases which are concerned with the creation and modification of enterprise entities (its development, design, construction, etc.) and their use (operation). This distinction enables the orderly move (release) from the engineering environment to the operation environment, providing for validation, testing and release of engineering results prior to operation.

### 0.2.7 Evolutionary approach to enterprise integration

The integration of all of the informational and customer-product and service functions of an enterprise may be a part of a master plan. The actual implementation of such integration may be broken up into a series of co-ordinated projects that are within the financial, physical, and technical capabilities of the enterprise. These projects can be carried out individually or collectively, as these resources allow, as long as the master plan is followed.

### 0.2.8 Modularity

Because of the massive nature of all enterprise integration projects, modularity should be enforced whenever possible. Thus it would be helpful if all activities were defined in a modular fashion, along with their required interconnections, so they may later be interchanged with other activities that carry out similar functions but in a different manner should this be desirable. Likewise, these replacement activities would also be best implemented in a modular fashion, permitting their later substitution by still other different methods of carrying out the same function. The choice of these implementation methods can be governed by independent design and optimisation techniques as long as the activity specifications are honoured.

Provided the modular implementation just stated is used, the interconnections between these modules can be considered interfaces. If these interfaces are specified and implemented using company, industry, national and/or internationally agreed upon standards, the interchange and substitution noted above will be greatly facilitated.

## 0.3 Aim and benefits of deploying enterprise-reference architectures and methodologies

An enterprise-reference architecture with its associated methodologie and related enterprise-engineering technologies that fulfill the requirements of this standard will enable an enterprise-integration-planning team to determine and develop a course of action that is complete, accurate, properly oriented to future business developments, and carried out with the minimum of resources, personnel, and capital. That is, to:

a) describe the tasks required;

b) define the necessary quantity of information;

c) specify relationships among humans, processes, and equipment in the integration considered;

d) address management concerns;

e) address relevant economic, cultural, and technological factors;

f) detail the extent of computer-support required;

g) support process-oriented modelling that can model the whole life history of an enterprise.



## 0.4 Benefits of this standard

The enterprise-reference architecture and methodology requirements in this standard will allow a specific enterprise-reference architecture and methodology to be checked for completeness with respect to its current and future purpose. This standard will help guide their development.

This benefit will be most relevant to any group charged with improving an enterprise infrastructure or its processes. Such a group will find it necessary to either select or create a reference architecture of its own with a terminology that pertains specifically to the company, industry, and culture involved. This standard will help guide that selection or creation.

# Industrial automation systems — Requirements for enterprise-reference architectures and methodologies

## 1 Scope

This International Standard defines the requirements for enterprise-reference architectures and methodologies, as well as the requirements that such architectures and methodologies must satisfy to be considered a complete enterprise reference architecture and methodologies.

The scope of these enterprise-reference architectures and methodologies covers those constituents deemed necessary to carry out all types of enterprise creation projects as well as any incremental change projects required by the enterprise throughout the whole life of the enterprise, including

a) enterprise creation,

b) major enterprise restructuring efforts, and

c) incremental changes affecting only parts of the enterprise-life cycle.

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.



ISO 14258, *Industrial automation systems — Concepts and rules for enterprise models*.



ISO 14258, *Industrial automation systems — Concepts and rules for enterprise models: Technical Corrigendum 1*.

## 3 Terms and definitions

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

**3.1**
**activity**
all or part of functionality

NOTE Enterprise activity consists of elementary tasks performed in the enterprise that consume inputs and allocate time and resources to produce outputs.

**3.2**
**architecture**
a description (model) of the basic arrangement and connectivity of parts of a system (either a physical or a conceptual object or entity)

NOTE There are two, and only two, types of architectures that deal with enterprise integration. These are:

a) system architectures (sometimes referred to as "type 1" architectures) that that deal with the design of a system, e.g. the computer control system part of an overall enterprise integration system;

b) enterprise-reference projects (sometimes referred to as "type 2" architectures) that deal with the organisation of the development and implementation of a project such as an enterprise integration or other enterprise development programme.

**3.3**
**attribute**
a piece of information stating a property of an entity

NOTE An attribute models an intrinsic property of something, for example, the geometry of a part, the condition of a tool, or the qualifications of a worker.

**3.4**
**behaviour**
how the whole or part of the system acts and reacts

**3.5**
**business process**
a partially ordered set of enterprise activities that can be executed to realise a given objective of an enterprise or a part of an enterprise to achieve some desired end-result

**3.6**
**enterprise**
one or more organisations sharing a definite mission, goals, and objectives to offer an output such as a product or service

NOTE This term includes related concepts such as extended enterprise or virtual enterprise.

**3.7**
**enterprise engineering**
the discipline applied in carrying out any efforts to establish, modify, or reorganise any enterprise



**3.8**
**enterprise model**
a representation of what an enterprise intends to accomplish and how it operates



NOTE An enterprise model, which is used to improve the effectiveness and efficiency of the enterprise, identifies the basic elements and their decomposition to any necessary degree. It also specifies the information, resources and organisational requirements of these elements, and provides the information needed to define the requirements for integrated information systems.

**3.9**
**framework**
a structural diagram that relates the component parts of a conceptual entity to each other

NOTE Neither the structure involved nor the relationship of the parts to each other have a life cycle or time relationship in contrast to the enterprise-reference ("type 2") architecture.

**3.10**
**genericity**
the extent to which a concept is generic

**3.11**
**life cycle**
the finite set of generic phases and steps a system may go through over its entire life history

**3.12**
**life history**
the actual sequence of steps a system has gone through during its lifetime

**3.13**
**master plan**
the documentation of the major engineering and operations planning effort carried out prior to any large enterprise integration or other systems engineering project

NOTE The master plan is based on management goals for the project and uses functional and economic analysis techniques for the preliminary engineering of the project to achieve an initial design specification and prove economic feasibility.

**3. 14**
**methodology**
a set of instructions (provided through text, computer programs, tools, etc.) that is a step-by-step aid to the user

NOTE In carrying out needed aspects of the life cycle of the entity integration project, the methodology prescribes or describes the processes of enterprise engineering and integration. A methodology may take account of any involved social, political and economic aspects.

**3.15**
**mission**
that activity in which an enterprise engages to fulfil the customer product or service function for which it was established; the mechanism by which an enterprise achieves its goals and objectives

**3.16**
**model**
an abstract representation of reality in any form (including mathematical, physical, symbolic, graphical, or descriptive form) to present a certain aspect of that reality for answering the questions studied



NOTE A model can be used to describe the enterprise activities or the different phases of the life cycle of the enterprise (see 3.8).



**3.17**
**organisation**
the structure of an enterprise and the distribution of responsibilities and authorities in the enterprise

**3.18**
**resource**
an enterprise entity that provides some or all of the capabilities required by the execution of an enterprise activity and/or business process

**3.19**
**structure**
the definition of the relationships among the components of an organization

**3.20**
**system**
a collection of real-world items organised for a given purpose

NOTE A system is characterised by its structure and its behaviour.

# 4 Requirements for enterprise-reference architectures and methodologies

## 4.1 Applicability and coverage of enterprise-entity types

### 4.1.1 Generality

Enterprise-reference architectures and methodologies shall be capable of assisting and structuring the description, development, operation, and organisation of any conceivable enterprise entity, system, organisation, product, process, and their supporting technology. There may be reference architectures that cover a sub-set and therefore are confined to a specific class or type of enterprise or systems (such as discrete parts manufacturing, process industries, and information systems). However, the area covered by these reference architectures and methodologies shall be clearly identified.

The methodology associated with a reference architecture shall provide the necessary guidelines and management techniques for the initiation and pursuit of a project or program of development and operation of an enterprise or entity. Such a methodology may or may not be model-based. That is, the enterprise engineering process may or may not result in a specific enterprise model.

Enterprise-reference architectures and methodologies need not be based on any one single methodology and its accompanying architecture or framework. There are potentially many different methodologies and/or frameworks that might be used for it. The primary consideration shall be applicability and capability in relation to these requirements.

Enterprise-reference architectures and methodologies shall identify concepts and components as described in 4.2 and 4.3.

### 4.1.2 Enterprise design



Enterprise-reference architectures and methodologies shall identify the activities needed to manage, conceive/define, describe, design, implement, maintain, and decommission any enterprise entity. See 3.2.3 and 3.4 of ISO 14258.



### 4.1.3 Enterprise operation

Enterprise-reference architectures and methodologies shall identify the activities needed to use the results of enterprise engineering in the operation itself. Such use may include model-based decision support and model-driven operation monitoring and control.

## 4.2 Concepts

### 4.2.1 General

The enterprise-reference architectures and methodologies shall address the role of humans, the description of processes (function and behaviour) and the representation of all supporting technologies throughout the life cycle of the enterprise.

### 4.2.2 Human oriented

Enterprise-reference architectures and methodologies shall exhibit the capability to represent human aspects, such as organisational and operational roles, capabilities, skills, know-how, competencies, responsibilities, authorisation, and relations to the organisation.

### 4.2.3 Process oriented

Enterprise-reference architectures and methodologies shall exhibit the capability to represent the enterprise operation. Such representations shall cover both the functionality and behaviour of the operation. The representations shall recognise the life cycle and life-history concepts of enterprise-entity types and shall support process-oriented operations.

### 4.2.4 Technology oriented

Enterprise-reference architectures and methodologies shall exhibit the capability of representing all technologies employed in the enterprise operation.

NOTE Such representation of 4.2.2, 4.2.3, and 4.2.4 shall provide for integration-technology infrastructures used to support enterprise engineering and operation of business processes, models of enterprise resource (information technology, manufacturing technology, office automation and others), facility layout models, information-system models, communication-system models and logistics models.

### 4.2.5 Mission-fulfillment oriented

Enterprise-reference architectures and methodologies shall exhibit the capability to represent any process and its constituent activities involved in performing the established mission of the enterprise in terms of providing the enterprise products and services to its customers.

### 4.2.6 Mission-control oriented

Enterprise-reference architectures and methodologies shall exhibit the capability to represent any process and its constituent activities of the accomplishment of the management and control of the established mission of the enterprise according to the criteria established by enterprise management.



### 4.2.7 Framework for enterprise modeling

Enterprise-reference architectures and methodologies that are model-based shall exhibit the capability to model entities within the conceptual space defined by the dimensions of life cycle, genericity, and modelling views.



NOTE These dimensions are discussed further in ISO 14258.

### 4.2.8 Life cycle

Enterprise-reference architectures and methodologies shall identify and represent the life-cycle phases that are pertinent during the life of any enterprise entity.

NOTE Life-cycle phases encompass all activities from inception to decommissioning (or end of life) of the enterprise entity which might be characterised. There is no presumption that these phases are necessarily sequential.

### 4.2.9 Life history

An enterprise-reference architecture and methodology shall be capable of representing the life history of any enterprise entity; that is, the representation in time of activities carried out on any enterprise entity.

NOTE Using the life-cycle concept of 4.2.8, the user can identify these activities as life-cycle-activity types while the life history allows the same user to identify the corresponding time element. This demonstrates the iterative nature of the life-cycle concept compared with the time sequence of life history. These iterations identify different change processes required on the operational processes and/or the product or customer services.