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Automation systems and integration — Oil and gas interoperability —

Part 1: Overview and fundamental principles

Systèmes d'automatisation et intégration — Interopérabilité entre les industries du pétrole et du gaz —

Partie 1: Vue d'ensemble et principes fondamentaux

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*.

This document provides an overview and outlines the fundamental principles of the ISO 18101 series. Future parts of the ISO 18101 series will be developed including sets of industry developed use cases, once the use cases have been documented using the Open Industrial Interoperability Ecosystem (OIIE) use case architecture and validated using the OIIE Oil and Gas Interoperability (OGI) Pilot, with the results captured in Technical Reports. These use cases will incrementally define industry prioritized elements of the secondary business process, which is the scope of the ISO 18101 series.

A list of all parts in the ISO 18101 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

It is difficult for the oil and gas industry, and other asset-intensive process industries, to adopt and adapt digital capabilities for many core business functions. For example:

— Why is it not possible for key industrial systems and applications to "plug and play" like consumer electronics do?

— Why is it so difficult and expensive to find, capture, manage and use the information that we need to:

  — engineer, design and build industrial plants, platforms and facilities?

  — operate and maintain industrial plants, platforms and facilities safely, reliably and profitably?

These issues significantly contribute to consistent patterns of major cost and schedule overruns in capital projects. They also lead to inefficient operations and maintenance spanning the entire life-cycle of the resulting plants, platforms and facilities. Clearly, this group of industries needs a better solutions model to help manage operational risks throughout the life-cycle of its plants, platforms and facilities.

Despite many improvements in individual business functions, the oil and gas industry (upstream, midstream and downstream) as well as other asset-intensive, process industries still struggle with many inefficient business practices. Many of these inefficiencies stem from how the entire industry and its primary participants are organized in 'silos'. This is particularly true for life-cycle asset management related business processes. These processes span many industry silos, crossing life-cycle phases, while including both intra and inter-enterprise activities. Meanwhile, participating systems, equipment, devices, materials, and services suppliers are also organized in their own industry sector silos. Despite many efforts to break these silos down, they are persistent and are often re-enforced by current industrial IM solutions, practices, and standards.

Digital business transformation is now being discussed as the solution for many of these issues. Unfortunately, this industry group lacks a pragmatic, supplier-neutral basis for achieving this objective and the sought-after business benefits in a timely manner.

The digital ecosystem concept was created for such purposes and has been successfully used in a variety of industry groups, but for the concept to succeed, it needs to be thoughtfully specialized to address included industry sectors, while achieving the largest practical scale. Other industry sectors such as banking, semiconductors, aerospace, consumer electronics and eCommerce have adopted this model using a combination of open standards and proprietary methods. Each industry has unique characteristics resulting in industry specific methods, with some basic common denominators such as the basic standards which define the internet and the World Wide Web.

The oil and gas industry shares many of the same engineering and work practices, while also using many of the same system (software and hardware), equipment and device classes as many other asset-intensive, process industries. This provides a mutually beneficial opportunity to share a supplier-neutral industrial digital ecosystem, where the scale of the aggregated market helps encourage its adoption. A successful industrial digital ecosystem needs to be supplier-neutral, because no single supplier has the scale and coverage to impose its will on the entire industry, including all its key participants.

While standards such as ISO 55000 specify good practices for all types of asset management, this document specifies how those good practices can be implemented using an industrial digital ecosystem. This document is intended to facilitate discussions between process industry decision-makers and the specialists who design, build and maintain the processes and systems that enable enterprises to function. The OIIE provides an example of the proposed, supplier-neutral industrial digital ecosystem. Key inter-enterprise relationships for the process industry digital ecosystem have been represented in Figure 1. It depicts the three-way relationship among Owner/Operators (O/O), Engineering, Procurement, Construction (EPC) organizations and Original Equipment Manufacturers (OEM), which forms the backbone of the secondary business process spanning the entire asset life-cycle.

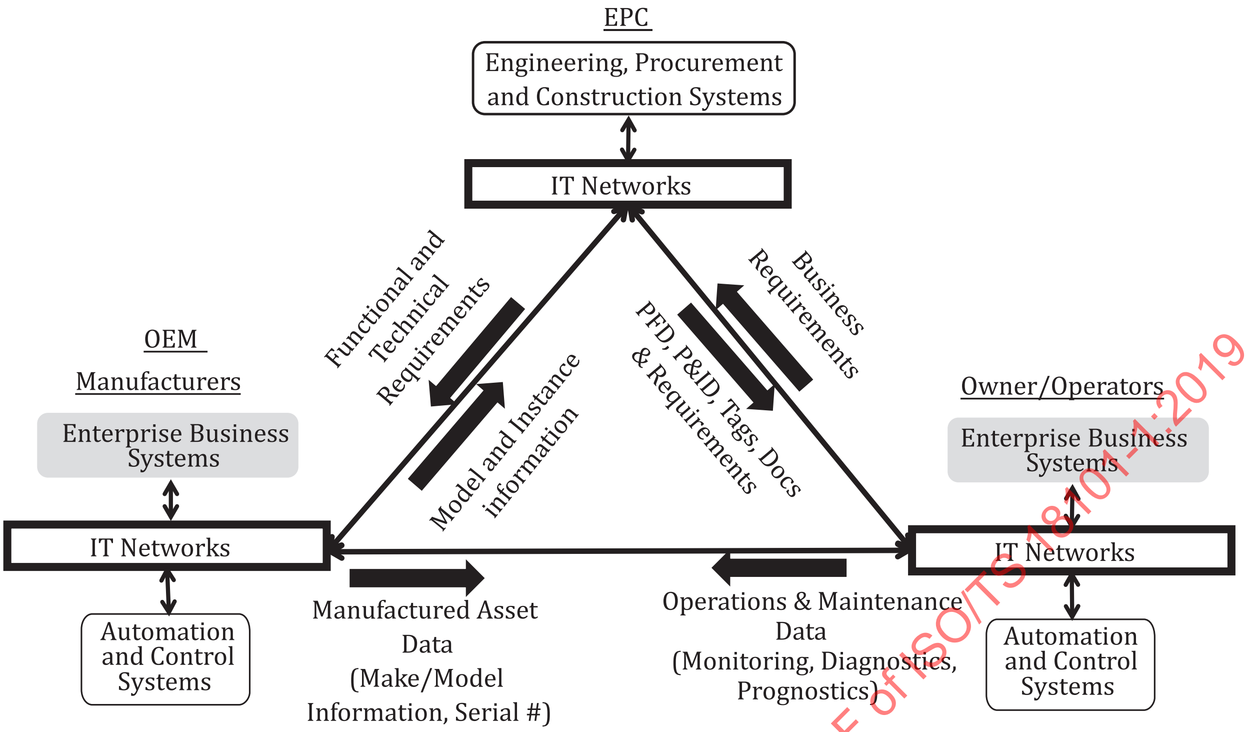


Figure 1 — OIIE inter-enterprise industrial digital ecosystem architecture

The secondary business process establishes and maintains operations capability. It spans both inter and intra-enterprise domains, based on requirements from the standard industry use cases, which are part of the portfolio of published, supplier-neutral standards and specifications which define the digital ecosystem. Using a portfolio of existing, well recognized standards, reduces risks associated with the creation of new standards. The OIIE/OGI Pilot is an interoperability test-bed and is implemented as an instance of the OIIE, which includes standard oil and gas asset classes and use cases, most of which are also applicable to other process industries.

This document identifies a portfolio of supplier-neutral IT and IM standards and specifications, including and driven by standardized industry use cases addressing life-cycle asset management. The included standards and specifications are validated to work with each other, properly supporting the standardized industry use cases, using the OIIE/OGI Pilot. Industry solutions are also validated to interoperate in the OIIE/OGI Pilot, based on the applicable standardized industry use cases, using the included standards and specifications in the specified manner. Three major phases of the OIIE/OGI Pilot have already been used to establish and validate the core methods and standards included in the OIIE. Results from new OIIE/OGI Pilot phases will be documented and published in Technical Reports, since they will be used to validate inclusions in future parts of the ISO 18101 series. This methodology provides a pragmatic, supplier-neutral basis for a digital ecosystem which meets major industry requirements for digital business transformation.

Industry implementation of the Technical Standard has the potential to substantially improve cost and risk management for the entire life-cycle of plants, platforms and facilities, following a pragmatic solutions process based largely on existing standards and widely accepted practices and methods.

Automation systems and integration — Oil and gas interoperability —

Part 1: Overview and fundamental principles

1 Scope

This document provides requirements, specifications and guidance for an architecture of a supplier-neutral industrial digital ecosystem. It includes a standardized connectivity and services architecture, and a standardized use case architecture with methods to specify atomically re-usable scenarios and events, which can be used to specify the characteristics of standardized industry use cases.

NOTE 1 Examples of standard industry use cases included in the secondary business process are included in Annex A along with standardized use case architecture.

This document gives:

— guidance for an architecture applicable to the oil and gas, petrochemical, power generation, public utilities and other asset-intensive industries;

— requirements for interoperability among systems of systems, systems (including hardware and software) and components included in the secondary business process of a plant, platform or facility at any given time;

— guidance on how these interoperability requirements are to be achieved and sustained in support of operations in the same plant, platform or facility;

— specifications enabling the specialization of a digital ecosystem concept for the requirements of the secondary business process in included industries;

— guidance to industry participants, including owner/operators and their product and services suppliers, to support their secondary business process requirements using products, which interoperate based on the specifications included in this document.

NOTE 2 This document is focused on interoperability requirements for systems which play roles in the secondary business process, including those in domains identified in Figure 7.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 15926-1:2004, *Industrial automation systems and integration — Integration of life-cycle data for process plants including oil and gas production facilities — Part 1: Overview and fundamental principles*

ISO 18435-1:2009, *Industrial automation systems and integration — Diagnostics, capability assessment and maintenance applications integration — Part 1: Overview and general requirements*

ISO/TS 8000-1:2011, *Data quality — Part 1: Overview*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
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 specified tasks

Note 1 to entry: Examples of entities include devices, equipment, machines, people, processes, applications, computer firmware and application software units, data exchange *systems* (3.2) and enterprises.

Note 2 to entry: Examples of items include *services* (3.7), information, material in standards, design documents and drawings, improvement projects, energy reduction programs, control activities, *asset* (3.5) description and ideas.

Note 3 to entry: In this context, entities provide items to, and accept items from, other entities, and they use the items exchanged in this way to enable them to operate effectively together.

[SOURCE: ISO 18435-1:2009, 3.12, modified — The word “respective” has been replaced with “specified”, Notes 1 and 2 to entry have been modified and Note 3 to entry has been added.]

3.2
system
combination of interacting software and hardware elements organized to achieve one or more stated purposes

Note 1 to entry: Since a system is composed of *system elements* (3.3), a system can include hardware, software (embedded and applications), data, humans, processes, procedures, facilities, materials, and other naturally occurring entities (e.g. water, organisms, minerals), or any combination.

Note 2 to entry: Industrial application software is included in industrial systems.

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.46, modified — The words “software and hardware” have been added and Notes to entry have been modified.]

3.3
system element
member of a set of elements that constitutes a *system* (3.2)

EXAMPLE Hardware, software, data, humans, processes (e.g. processes for providing *service* (3.7) to users), procedures (e.g. operator instructions), facilities, materials, and other naturally occurring entities (e.g. water, organisms, minerals), or any combination.

Note 1 to entry: A system element is a discrete part of a system that can be implemented, instructed or used to fulfil specified requirements.

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.47, modified — The words "(e.g. water, organisms, minerals)" have been added to the Example and the words “instructed or used” have been added to Note 1 to entry.]

3.4
system of systems
system-of-interest whose elements are themselves *systems* (3.2)

Note 1 to entry: Systems of systems typically entail large-scale inter-disciplinary problems with multiple, heterogeneous, distributed systems.

Note 2 to entry: In ISO/IEC/IEEE 15288:2015, 4.1.48, a system-of-interest is defined as a system whose life cycle is under consideration in the context of this document.

[SOURCE: ISO/IEC/IEEE 24765:2017, 3.4111, modified — The second definition has been removed and Notes to entry have been added.]

3.5
asset
item, thing or entity that has potential or actual value to an organization

[SOURCE: ISO 55000:2014, 3.2.1, modified — Notes to entry have been removed.]

3.6
capital project
long-term, capital-intensive investment project

3.7
service
repeatable business activity that has a specified outcome

Note 1 to entry: The service is self-contained, may be composed of other services and is a "black box" to consumers of the service.

Note 2 to entry: Examples of business activities include: check customer credit, provide weather data, consolidate drilling reports, maintenance work order.

[SOURCE: ISO/IEC TR 30102:2012, 2.1.17, modified — The words "logical representation of a set of repeatable activities that has specified outcomes" in the first half of the original definition have been replaced with "repeatable business activity that has a specified outcome", the content of the original Note 1 to entry has been replaced with the content of the second half of the original term and Note 2 to entry has been added.]

3.8
data set
logically meaningful group of data

[SOURCE: ISO 8000-2:2018, 3.2.4, modified — The word "grouping" has been replaced with "group".]

3.9
digital twin
digital asset (3.10) on which *services* (3.7) can be performed that provide value to an organization

Note 1 to entry: The descriptions comprising the digital twin can include properties of the described asset, *IIOT* (3.24) collected data, simulated or real behaviour patterns, processes that use it, software that operates on it, and other types of information.

Note 2 to entry: The services can include simulation, analytics such as diagnostics or prognostics, recording of provenance and service history.

EXAMPLE A digital model of an aircraft that allows crew training in a simulator; a stream of vibration readings that allows analysis of bearing wear; maintenance records that enable certification checks or total operation time computation.

3.10
digital asset
data set (3.8) describing an *asset* (3.5) that is not necessarily physical

EXAMPLE Digital assets describing non-physical assets include technical specifications, software, algorithms.

3.11
domain
field of special knowledge, which can be further subdivided according to requirements to support a higher level of specialized detail

3.12
reference architecture
IT architecture specialized for the requirements of a particular *domain* (3.11)

EXAMPLE PERA (Purdue Enterprise Reference Architecture) is a reference architecture that can model the enterprise in multiple layers and multiple stages of the architectural life cycle. Initially, PERA was part of the PERA methodology, which consisted of three main building blocks (Purdue Enterprise Reference Architecture; Purdue Reference Model; Purdue implementation procedures manual).

3.13
information model
formal model of a bounded set of facts, concepts or instructions to meet a specified requirement

Note 1 to entry: In this context, the description of *domain* (3.11) entities in a *digital ecosystem* (3.26) addressing lifecycle *asset* (3.5) management.

3.14
reference data
domain (3.11) and sector standardized *data sets* (3.8) that help define the set of values to be used to populate other data sets

3.15
industry standard datasheet
ISD
industry developed, supplier neutral specification for equipment and device classes

Note 1 to entry: The industry standard datasheet includes functional requirements, model and instance level details needed for industry digital transformation.

3.16
industry standard datasheet definition
ISDD
meta data required to enable machine interpretability of all attributes on *industry standard datasheets* (3.15)

3.17
reference data library
RDL
managed collection of *reference data* (3.14)

[SOURCE: ISO 15926-1:2004, 3.1.19]

3.18
supplier catalogue
list of goods and *services* (3.7) provided by an organization to its clients that conform to a specification defined by a supplier

3.19
data quality
degree to which a set of inherent characteristics of data fulfils requirements

Note 1 to entry: Examples of requirements for quality data also include data integrity, *data validation* (3.22), *data portability* (3.23), data synchronization and the data provenance record.

[SOURCE: ISO 8000-2:2018, 3.8.1, modified — Note 1 to entry has been modified.]

3.20
primary business process
process defining principal operations of an enterprise

3.21
secondary business process
process establishing and maintaining operations capability

3.22
data validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled

[SOURCE: ISO 8000-2:2018, 3.8.6]

3.23
data portability
ability to easily transfer data from one *system* (3.2) to another without being required to re-enter data

Note 1 to entry: The need to manually, find, re-read, re-interpret and re-enter data is one of the main factors which increase industry costs and risks, while also decreasing *data quality* (3.19). Digital Business Transformation eliminates this redundant work, simultaneously reducing costs and risks while increasing data quality.

3.24
Industrial Internet of Things
IIOT
global infrastructure for the information society, enabling advanced *services* (3.7) by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies

Note 1 to entry: The Industrial Internet of Things (IIOT) is used to identify the industrial specializations of the Internet of Things (IOT).

[SOURCE: ISO/IEC 38505-1:2017, 3.6, modified — The original Notes to entry have been removed and a new Note 1 to entry has been added.]

3.25
plant to business stack
P2B stack
vertical data/information axis from sensor to enterprise *systems* (3.2)

3.26
digital ecosystem
distributed, adaptive, open socio-technical *system* (3.2) with properties of self-organisation, scalability and sustainability inspired from natural ecosystems

3.27
asset-intensive industry
industry requiring a significant amount of large-scale industrial equipment to operate

4 Abbreviated terms

ADID	Application Domain Integration Diagram
API	Application Programming Interface
CCOM	Common Conceptual Object Model
CMMS	Computerized Maintenance Management System
EAM	Enterprise Asset Management
EPC	Engineering, Procurement, Construction

ERP	Enterprise Resource Planning
HSE	Health and Safety Executive
IM	Information Management
ISBM	Information Service Bus Model
IT	Information Technology
ITB	Invitation to Bid
MSM	Message Service Model
OEM	Original Equipment Manufacturers
OGI	Oil and Gas Interoperability
OIIE	Open Industrial Interoperability Ecosystem
O&M	Operations and Maintenance
OpenO&M	Open Operations and Maintenance
O/O	Owner/Operators
PERA	Purdue Enterprise Reference Architecture
RSPL	Recommended Spare Parts List
SPIL	Spare Parts Interchange List
SPIR	Spares Parts Interchange Record

5 Overview and general requirements

5.1 Secondary business process

Industry activities can be modelled using multiple axes approaches, where the primary business process concerns itself with the core operations of a given industry group. In the oil and gas industry, this primary business process usually features raw material inputs, which are taken through a conversion process resulting, in desired outputs. The upstream, midstream and downstream sectors of the oil and gas industry, as well as other asset-intensive process industries, can all be modelled in this fashion, although midstream generally provides no conversion process other than transport.

This document focuses on the secondary business process which supports the primary business process as is depicted in Figure 2. The secondary business process is shown in more detail in Figure 3. It includes capital project activities (engineering, design, procurement, and construction), followed by the handing over and maintenance of the associated plants, platforms, and facilities (collectively referred to as facilities in the oil and gas industry). Inefficiencies in capital projects often result in large cost and schedule overruns in capital projects, while also greatly increasing costs and reducing operational efficiencies over the asset life-cycle. Frustrated operators and maintenance personnel then spend too much time struggling with sub-optimal implementations of various operations and maintenance systems. In many cases, they are forced to and re-enter information into their systems, when this information should have been efficiently captured find as machine interpretable information during the capital project phase, then handed over and automatically provisioned into their systems.

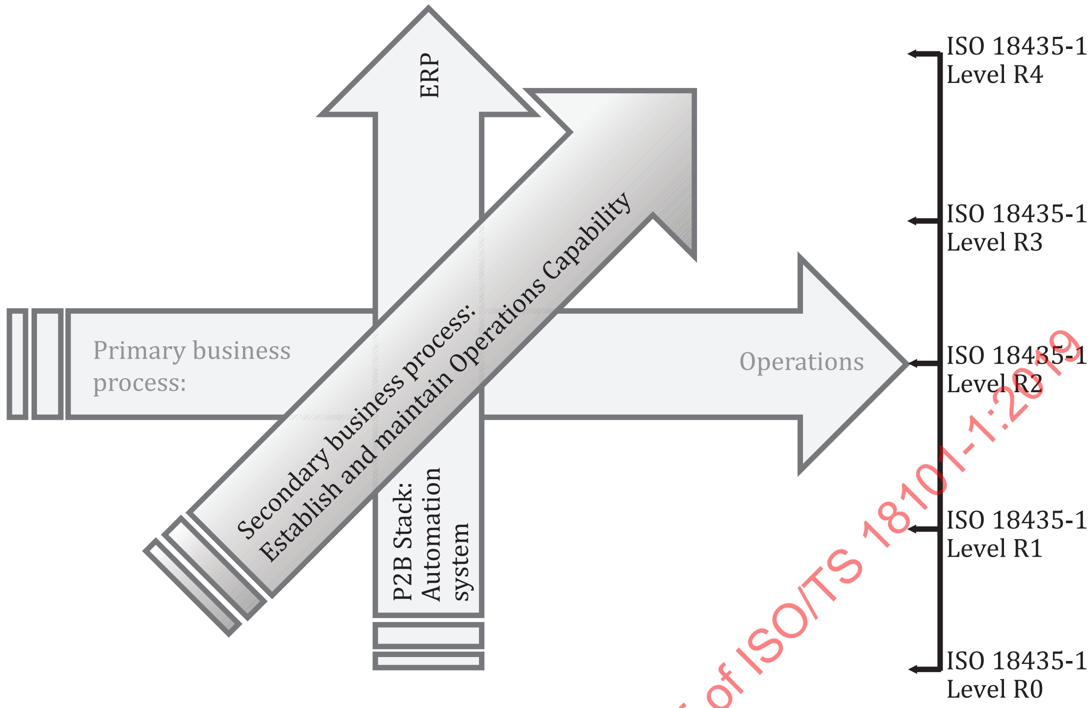


Figure 2 — Focus on secondary business process

The interrelationships between the primary and secondary business processes and the plant to business (P2B) stack is illustrated in Figure 2. This three-axis model is a way of visualizing these key relationships.

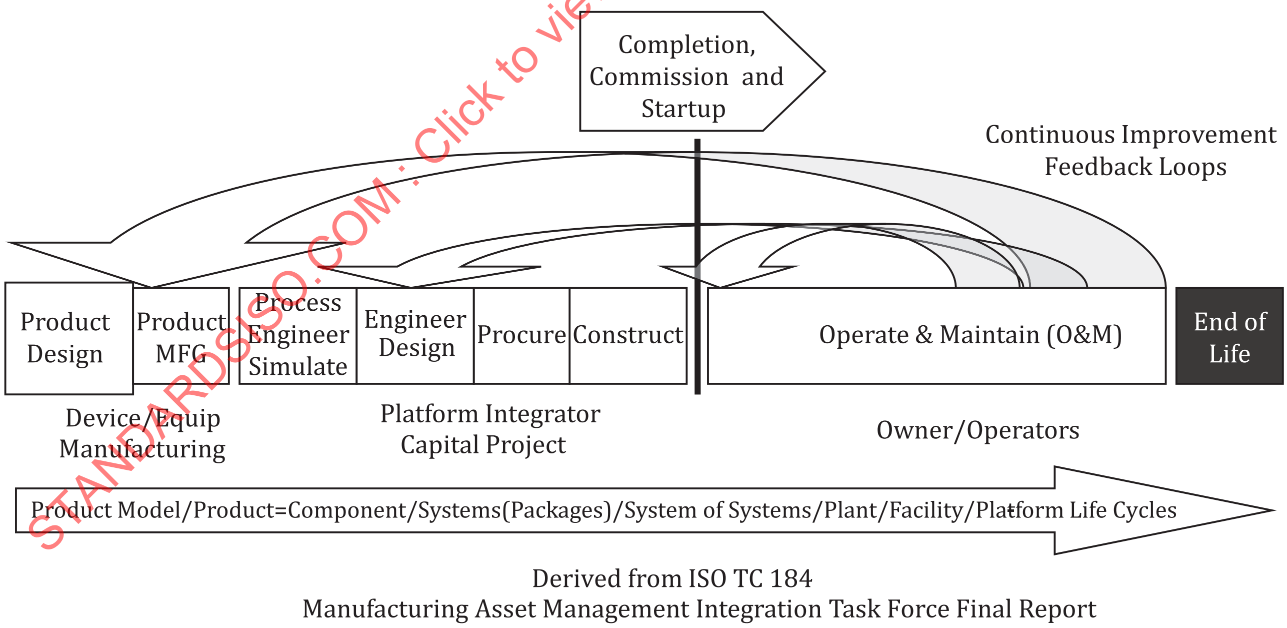


Figure 3 — Secondary business process — Asset life-cycle integrated view

While capital projects now seek to build and handover a digital representation of the physical assets, known as the digital twin, processes for doing this and associated data quality vary greatly, and the results are often not properly synchronized with the physical assets, nor maintained in synchronization. Collectively, these factors significantly increase a variety of operational and enterprise risks and costs impacting the entire life-cycle of plants, platforms, and facilities. While capital project managers have historically been resistant to managing more data which can help operators and maintainers, since it can increase their own costs, true digitalization of the secondary business process will require much more data than is being managed today. The key is finding pragmatic ways to shift most of the management of this much larger amount of data from individual enterprises and project teams to the entire industry. At that point, individual project costs can be reduced, and risk managed, while everyone involved in the entire asset life-cycle can leverage all the machine interpretable information they need.

EXAMPLE 1 A set of loading data is usually specified by the O/O (in the project specifications) as being required to be "exchanged in an electronic format", however, this format is usually not clearly defined and machine interpretable. Data included or embedded in documents are frequently difficult to extract, transform and load into the target systems and the focus is on a limited set of Enterprise Resource Planning (ERP) oriented master data. At the time the contracts are placed with the EPC, the ERP and/or the Computerized Maintenance Management System (CMMS) or Enterprise Asset Management (EAM) system and many other target systems are often not known. There is also a lack of standardization in load data requirements spanning all these systems, particularly when trying to add the other details needed for true industry digitalization. As the project proceeds, other project deliverables generally take precedence for remaining resources, time and budget and what is ultimately delivered is usually limited to the minimum requirements for loading and commissioning the ERP system, often based on sub-optimal practices and methods. Collectively, this inefficient process increases costs, errors, and risks, both during a given project and during the entire life-cycle of the associated plant, platform or facility, where the lack of readily available, complete, accurate, machine interpretable information is paid for over and again. If there are no fixed user requirements before placing an order of EPC project and requesting the EPC to deliver the solution, the load data is delivered in a sub-optimal manner.

EXAMPLE 2 Typically, material requirements are extracted from Spare Parts Interchange Lists (SPIL), sometimes referred to as Spares Parts Interchange Records (SPIR) or Recommended Spare Parts Lists (RSPL). These lists are supplied to the O/O at handover via the EPC and originate from the OEM. These documents have many drawbacks: they are not extractable; contain only a brief description of the product, often just a noun; they take no account of the equipment criticality; they take no account of the O/O maintenance capability, or their spares and repair strategy, such as repair or replace. Extracting this data to create material master records is costly, involves many man days and results in poor data quality. There is a paradigm shift using new technology and international standards such as ISO/TS 8000-1. The traditional process of the buyer creating templates to describe an item that fulfils a fit, form, or function as a method of identifying substitutable goods or services, is being replaced with the importing of supplier catalogue items created using specifications defined by the supplier in a computer interpretable format, based on ISO 8000 requirements. This new process reduces the cost of handling such data, thus increasing the quality of the data, and importantly, establishing the provenance of the data.

EXAMPLE 3 The Plant Information Management System contains a wide range of information describing the details of a given plant, generally from an operations point of view. It forms part of the interface between physical assets installed, automation and control systems and ERP oriented systems and should be based on a digital twin including as-built information. Information associated with many aspects of the Purdue Reference Architecture is collected, compiled and represented in an organized manner. The Plant Information Management System is built in parallel during the engineering, design, procurement, and construction process. There are often requirements for information that is not available when it is needed, but the design and implementation of the Plant Information Management System continues with many associated inefficiencies. Many subsequent efforts are then required to find, cleans, correlate, validate and load data in the associated applications and systems, adding substantial time, cost and risk to the project and to future operations and maintenance. The use cases to be included in future parts of the ISO 18101 series will show how to capture the digital information at the most appropriate time, then maintain it and re-use it.

EXAMPLE 4 Currently, there is a constant tension in capital projects between those who want to spend more time and money to identify, capture and manage all known requirements at a very high level of detail and those who are concerned this adds too much cost to the project and/or unnecessarily slow the project. Most of this problem is due to the way the industry continues to manage data and information, where each enterprise or even each project team is forced to do substantial work to find, manage and use data and information in a consistent and quality-controlled manner. Forced to manage identified costs and resources, managers usually try to minimize the details to be managed, but all too often, this means nobody is managing these other details. Overlooked issues in those details then result in significant cost, schedule and quality issues.

EXAMPLE 5 Over the last 100 years (or more in the case of some process industry equipment), major industry associations have worked on behalf of industry to create supplier-neutral Industry Standard Datasheets (ISD). ISDs are extremely useful because they provide coverage for all the known properties over the entire life-cycle of major equipment and device classes, and the functional roles which they play in processes and systems. The challenge has been to find a way to use them in a machine interpretable manner. They are broadly referenced on an international basis but are used somewhat inconsistently. Industry Standard Datasheet Definitions are created via a semi-automated process, capturing the information from ISDs, then binding them to the engineering units of measure. The ISDDs are published in an information model that is part of the MIMOSA Common Conceptual Object Model, which is easily associated with processes, systems, models and serialized components. ISDDs are version managed and can be incrementally updated to follow updates in the ISDs they are associated with, in cooperation with the organizations publishing the ISDs. Individual O/Os can then specify which versions of which ISDDs they wish to be used to support their own industrial digital ecosystem, including their supplier chain partners. This provides a pragmatic risk managed way of using existing, well respected specifications to support industry digital business transformation.

A fundamental issue has been the lack of standardized, reliable methods for specifying and managing the required information exchanges and services shared between participants and the various associated systems (including software applications) used by each of them who are engaged in the asset life-cycle. This includes a process for coordinating the application of systems (including software applications) updates in conjunction with applying industry RDL updates to an Enterprise RDL updates. A related problem is modelling and capturing all the information exchanges and associated information changes in the normal course of an efficient, standardized work process, which is also flexible enough to allow the required levels of specialization.

Part of the challenge is due to a highly complex EPC supply chain and the complex nature of the different systems used by them. It consists of multiple EPC and OEM firms using multiple Engineering, Simulation, Design, Procurement and Construction Management tools in parallel or over time. This is compounded by the wide variety of systems (and software applications) used by the various O/Os involved in process industries, as many of these different systems require detailed, high-quality information provisioning to deliver their intended business value.

While it is possible to build or buy proprietary, hub-oriented software, the different scopes and complexity of the interrelated systems interactions increase the cost while decreasing the adaptability and quality of such tools. Outsourcing the effort to discover and manage all the permutations provides some short-term relief, but without the power of standardization, the task can be overwhelming for the supplier. Other participants then suffer from problems associated with lock-in and high switching costs.

There is also a lack of maturity in the engineering reference standards models. No single standard has broad, in-depth support for capturing all the requirements addressed. The industry should progress from the current model based on insufficient individual standards to the portfolio approach. Industry needs to leverage a combination of external reference data libraries and published standards for format, content, and services, thus adequately addressing the interoperability requirements for process industries.

The level of standardization specified in this document addresses all these key issues, enabling commercial software to be adapted to meet the prioritized requirements for industrial business digitalization.

Digital business transformation has the potential to restructure how the industry works, such that significantly greater amounts of detailed information are standardized and quality managed by the entire industry at the lowest practical aggregate costs. The aim is that individual project teams are able to leverage larger volumes of detailed machine interpretable information, providing required levels of detail to lock down most key project specifications with far less remaining ambiguity, and that semantic reasoners are able to validate much more of the detail needed for each project stage, providing the opportunity to dramatically improve cost, quality and risk management, both for the capital project and for the delivered plants, platforms and facilities over their entire useful life. This document provides high-level guidance for how industry can accelerate the process for this needed transformation, using existing supplier-neutral standards and specifications. Future parts of the ISO 18101 series will provide further levels of detail organized around industry use cases.

5.2 Systems of systems interoperability

A broad group of the inefficiencies in both the primary and secondary business processes is a direct result of Industrial IT not yet adopting a fundamental principle of the industrial revolution; interoperability. Traditional systems integration techniques artificially constrain the quality of the interactions between people, process, and systems.

To address this issue, the systems engineering community has helped develop systems of systems modelling techniques, which enable the industrial model for interoperability. This technique includes methods for sharing both information and services between the systems elements, systems, and systems of systems.

Systems of systems interoperability improves both the quality and sustainability of such interactions, while also reducing direct integration costs, as no traditional systems integration layers need to be developed or sustained by individual organizations. When systems of systems interoperability are entirely based on published, supplier-neutral standards, the cost savings and improved quality are efficiently shared by the entire group of participating industries, creating the basis for a cross-industry, supplier-neutral, industrial digital ecosystem. While this document focuses on the secondary business process, that process also establishes the basis for systems of systems interoperability in the primary business process of industry participants.

Figure 4 shows the systems connectivity and services architecture based on the systems of systems modelling techniques.

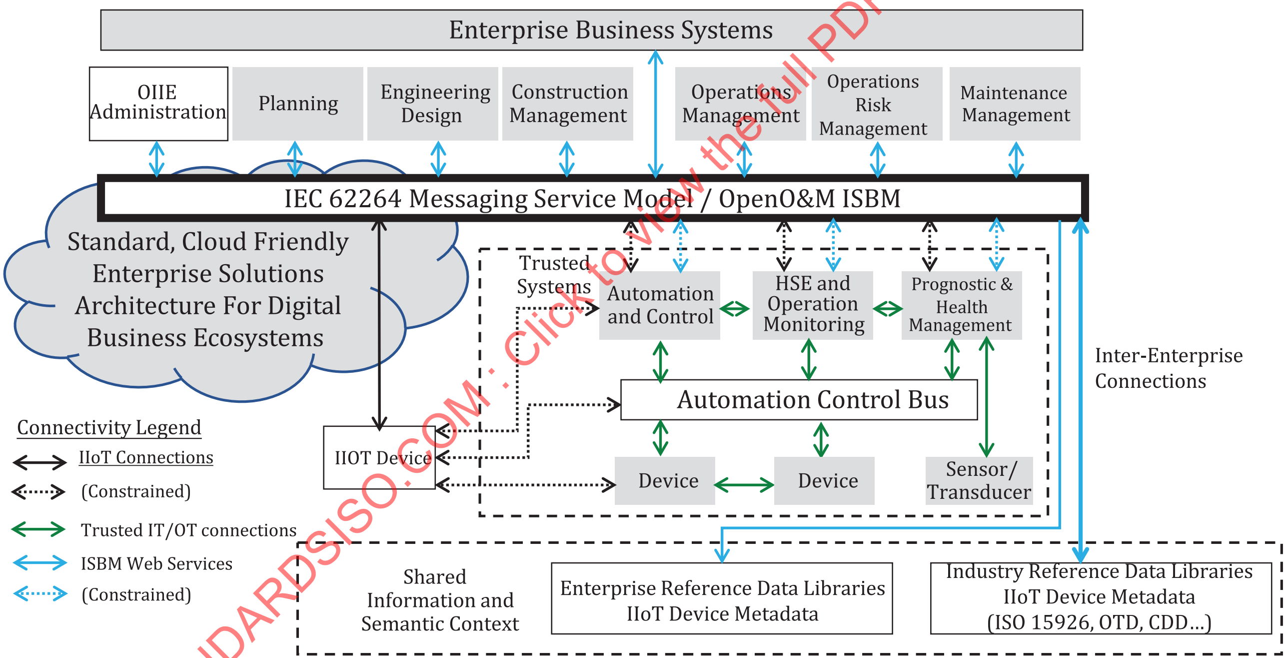


Figure 4 — OIIE Intra-Enterprise Industrial Digital Ecosystem Architecture

NOTE Figure 4 provides a simplified view of the connectivity and services included in the OIIE intra-enterprise architecture. Reference information is persisted in a variety of industry technologies including Relational Databases, Object Databases and RDF Triple Stores, while the associated information is exchanged using a variety of standard protocols, information models, data formats and languages including SOAP, REST, XML, JSON, SQL, SPARQL. The included technologies will continue to change over time as is determined by industry requirements and the evolution of technology.

This standard industrial digital ecosystem architecture includes Enterprise Business Systems, Operations Management Systems, Automation and Control Systems, Engineering Systems, and also contains a standardized basis for shared Information and Semantic Context. It follows the levels traditionally identified in the Purdue Reference Architecture, ISO 18435-1 and IEC 62264, while also including the flexibility and adaptability needed for IIOT, cloud platforms, and digital ecosystems. It also features a standard information services architecture specified by the IEC 62264 Message Service Model (MSM) and the OpenO&M Information Service Bus Model (ISBM) specification which provides both intra and inter-enterprise services required for the digital ecosystem. The architecture also leverages a group of other internet-oriented standards developed by the World Wide Web Consortium (W3C), including basic requirements for web services and modelling. Systems of the included classes interoperate for specified use cases based on standard adaptors, which can be developed and supported on a commercial basis.

5.3 Industrial digital ecosystem architecture

5.3.1 Overview

The life cycle phases incorporate information and requirements from different sources, starting from conceptualization and planning phases throughout the final disposition of the assets at the end of life. The information model view is managed by different parts of the organization and stakeholders depending on each life cycle phase. Information flowing to succeeding phases are filtered or added to by different organizational stakeholders.

An industrial digital ecosystem architecture employs system-of-systems interoperability (see Figure 5). The foundation is standards. The selection of standards is based on their capability to meet the industry-specified requirements, as well as levels of industry adoption and community engagement. An industrial digital ecosystem architecture enables interoperability between Enterprise Business Systems, Engineering Systems, and Automation and Control Systems.

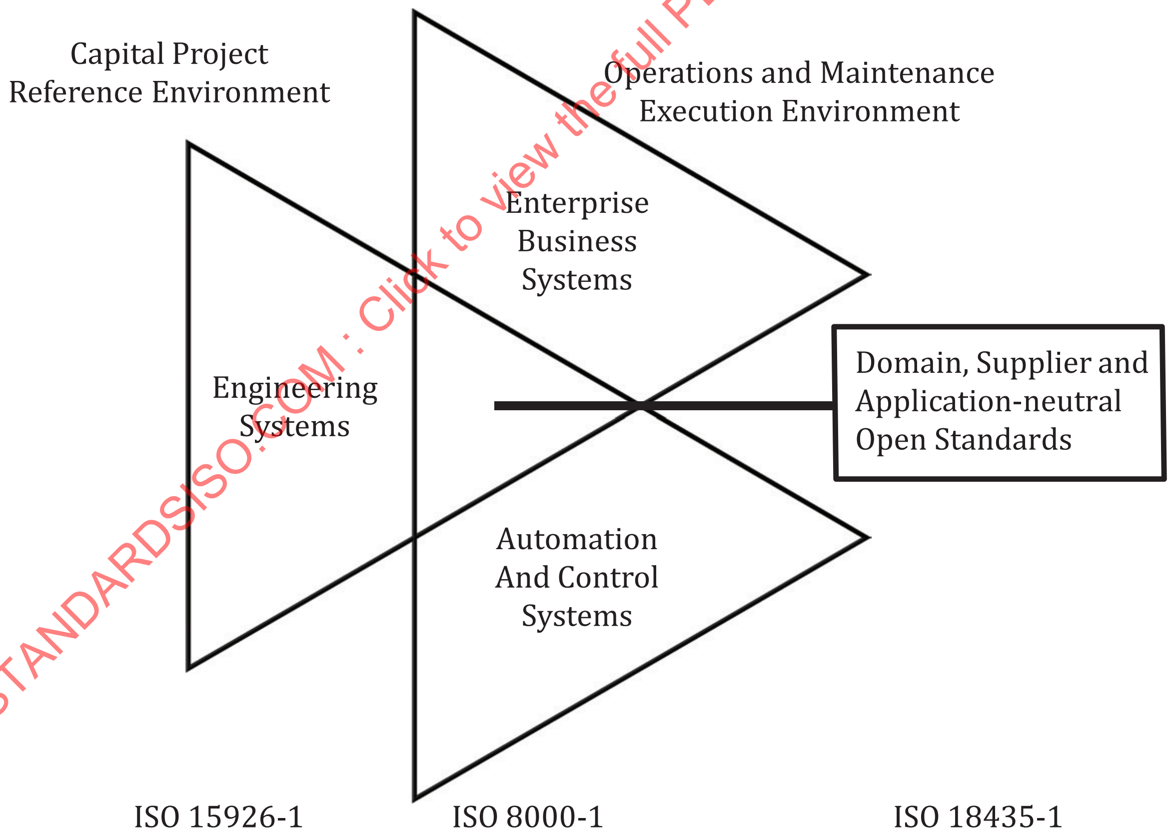


Figure 5 — Industrial digital ecosystem architecture

ISO 18435-1 and the associated Purdue Reference Architecture provide interoperability requirements that are fundamental for systems and applications used to operate and maintain plants, platforms, and facilities. These requirements include key aspects of industrial digital ecosystems architecture, which supports the data sets that are specified, aggregated and validated by EPCs and OEMs working on behalf of the owner/operator, then loaded into various owner/operator systems and applications.

For this reason, EPCs and OEMs should play a critical role in information management and data quality. High quality in these areas is essential to prevent poor data from being imported into the Owner/ Operator systems, to avoid problems when starting up the plant, platform, and facility.

ISO 15926-1 provides a mechanism by which consistent representation of engineering information can be drawn from diverse international and national standards including reference data. ISO 15926-1 can be used in conjunction with other standards for industrial data including other reference data libraries and ISO/TS 8000-1. ISO/TS 8000-1 can also be used in conjunction with other reference data libraries, parts libraries and data dictionaries based on international/ industry standards.

Systems and applications participating in the industrial digital ecosystem specified by this document shall follow these key principles:

a) information and data shall be defined and processed in neutral and uniform ways to make cost reductions possible for both individual enterprises and the entire industrial digital ecosystem;

b) all information and data shall be portable and computer interpretable, following principles specified by ISO/TS 8000-1:2011;

c) each information and data element shall be defined in a data dictionary or a reference data library;

d) all information elements shall be identified using standardized concept identifiers;

e) lifecycle information shall comply with the fundamental principles specified in ISO 15926-1:2004, Clause 5;

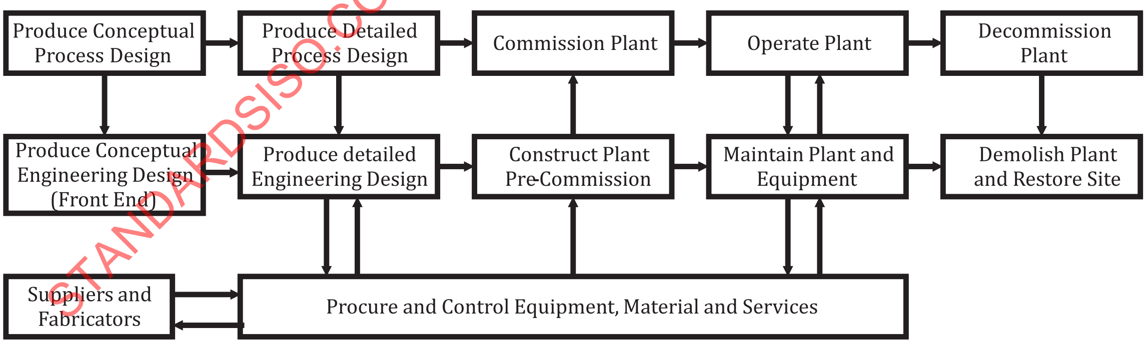
f) information models shall use existing reference data libraries, parts libraries and data dictionaries based on international/industry standards;

g) interoperability requirements for intra-enterprise and inter-enterprise activities in the secondary business process which are included in this document, shall be represented using an Application Domain Integration Diagram (ADID), as defined in ISO 18435-1 and depicted in Figure 7;

h) use case architecture as described in Annex A.

5.3.2 Engineering Systems

Activities involved in capital project and operations and maintenance are illustrated in Figure 6.



NOTE Image source: ISO 15926-1:2004, Figure 1.

Figure 6 — Activity model

In the capital project, both physical and digital assets related to the life-cycle of production facilities are created, used, modified and archived by many different organizations throughout the life-cycle. The purpose of the ISO 15926 series standard is to facilitate the integration of information to support the lifecycle activities and processes of production facilities. Figure 6 illustrates the main activities and data flows.

The top row is focused on functional engineering and it depicts key activities associated with the life-cycle of a process plant, platform or facility, starting with process engineering and including the processes for commissioning, operations and decommissioning in the order of their occurrence.

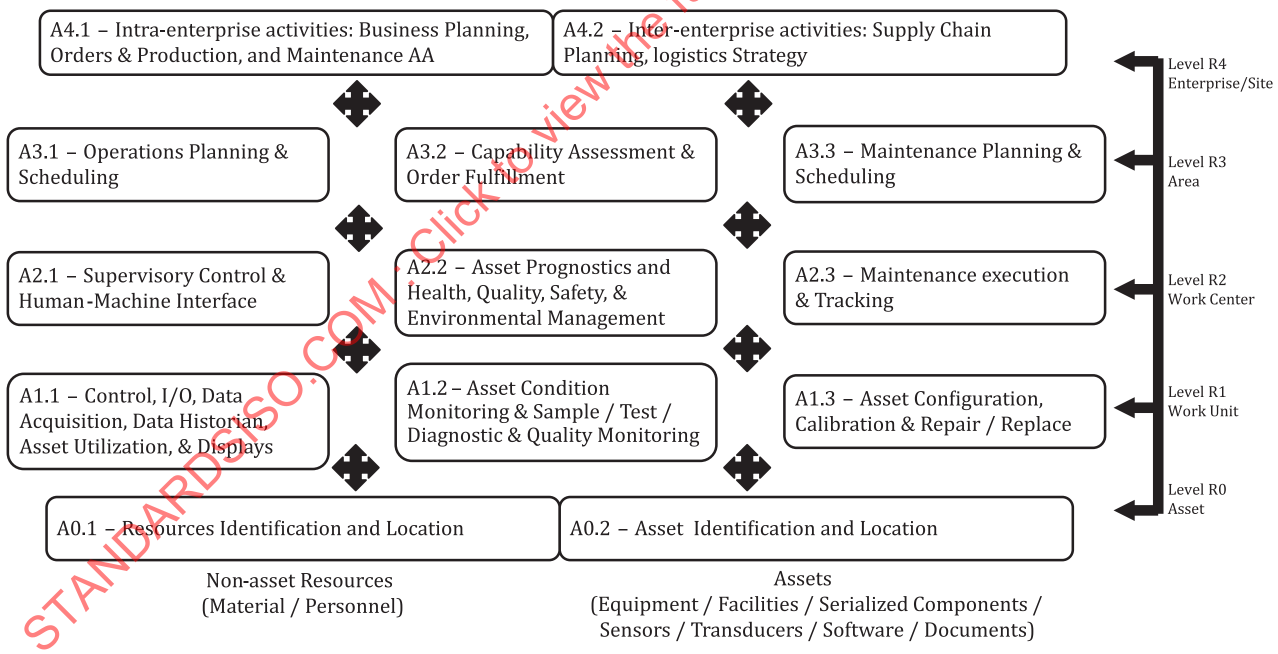
The middle row is physical engineering focused, and it shows key activities causing changes in physical aspects of a plant, platform or facility, from design, through construction, then its maintenance, followed by its physical demolition and site reclamation.

The bottom row depicts logistically oriented activities (including interactions with suppliers and fabricators) to procure and manage equipment (and devices), material and services. Models and engineered/fabricated assets as well as spare parts and general materials are determined through these activities.

Each of the above activities produces digital artefacts which are mapped to each other.

5.3.3 Enterprise Business Systems and Automation and Control Systems

Enterprise Business Systems and Automation and Control Systems are all included in various levels in the Purdue Reference Architecture and IEC 62264. Included applications and systems can be classified using the matrix notation shown in Figure 7. In the ADID, the crosses were intentionally drawn not touching the boxes representing the domains, as an indication that applications and systems in any domain can communicate directly with an application or system in any other domain using the matrix notation. This anticipated the development of cloud architectures, where the domains can be seen to float in an IT/OT cloud, rather than being locked into rigid locations, but where the standard functional decomposition is still an important interoperability enabler. This concept can be implemented in a cloud, traditional industrial IT and OT architecture, or a combination of both, as technology evolves.



NOTE Image source: ISO 18435-1:2009, Figure 5.

Figure 7 — Application Domain Integration Diagram (ADID)

5.3.4 Data Quality and Architecture

ISO/TS 8000-1 introduces the basic principles of data quality and provides the frameworks for improving data quality for specific kinds of data. ISO/TS 8000-1 also defines which characteristics of data are relevant to data quality, specifies requirements applicable to those characteristics and provides guidelines for improving data quality. These principles are expanded in other parts of the ISO 8000 series of standards. ISO 8000 applies to all the stages of the data life cycle.

ISO/TS 8000-1 states that the following principles of data quality are fundamental in the ISO 8000 series:

— data quality involves data being fit for purpose, i.e. the decision it is used in;

— data quality involves having the right data, in the right place, at the right time;

— data quality involves meeting agreed customer data requirements.

ISO/TS 8000-1 introduces the basic ISO 8000 data architecture. The basic data architecture model published in ISO/TS 8000-1 (see Figure 8) establishes the following:

— data includes information about data provenance, data accuracy, and data completeness;

— data is coded using concepts in a data dictionary;

— data conforms to a data specification;

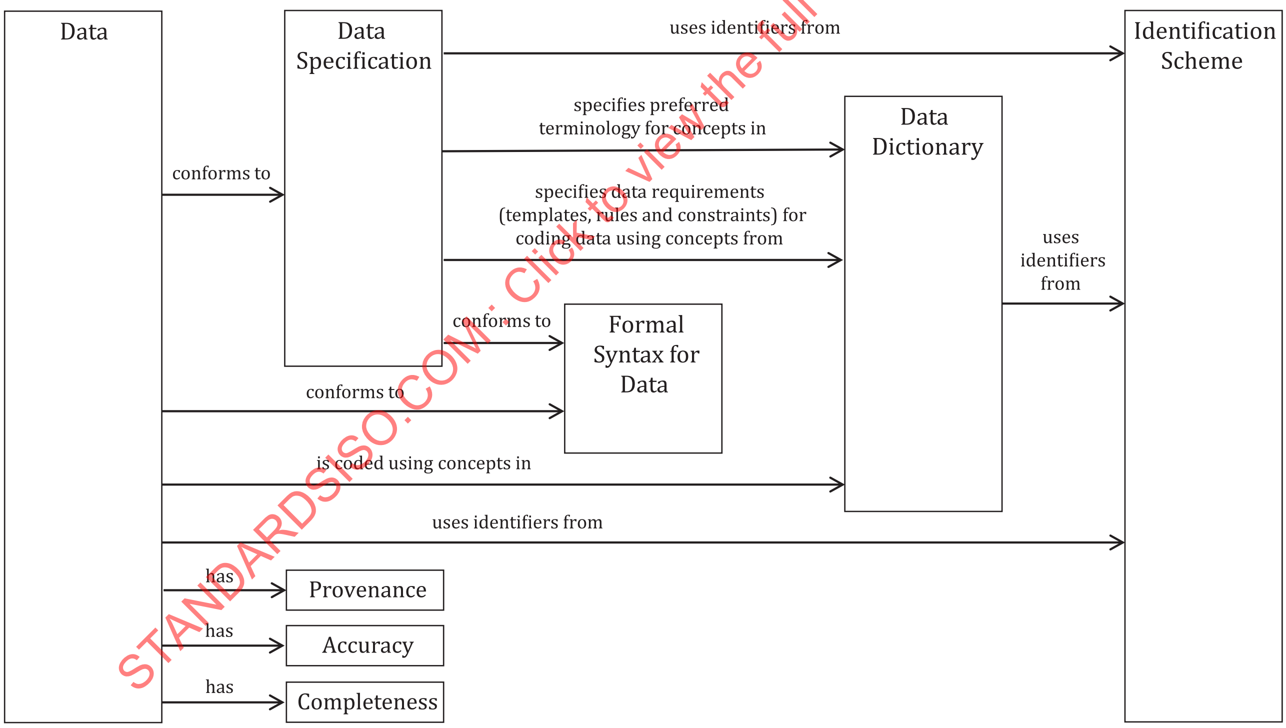
— data conforms to a formal syntax;

— a data specification specifies data requirements for coding data using concepts from a data dictionary;

— a data specification specifies preferred terminology for concepts in a data dictionary;

— a data specification specifies the use of formal syntax;

— data, data specifications, and data dictionaries use identifiers from an identification scheme.



NOTE Adapted from ISO/TS 8000-1:2011, Figure 1.

Figure 8 — ISO 8000 data architecture

5.4 Inter-enterprise user stories

The OIIE inter-enterprise industrial digital ecosystem architecture in Figure 1 illustrates some common interactions between enterprises, where interoperability is useful. A common user story including these interactions is provided below.

An Owner/Operator (O/O) is a plant, platform, and facility owner, who is also usually an operator, though they may outsource that business function to a third party. They wish to build a plant, platform, and facility so that they can engage in their primary business process.

An O/O sends out basic business requirements to one or more Engineering Procurement Construction (EPC) firms to perform and complete engineering, design and construction resulting in the new plant, platform or facility. An O/O normally outsources most of these activities, but where these are handled internally, the EPC functionality can still be modelled in a very similar manner.

An EPC firm uses functional requirements generated from the engineering and design activity to engage in a dialog with an Original Equipment Manufacturer (OEM), where the OEM is asked for information about its equipment and device models which meet or exceed the identified requirements. Once a selection of appropriate models has taken place, an EPC procures the number of instances of selected models which have been identified by the design process.

The O/O negotiates with the OEM to determine what information they will exchange with each other to enable the O/O to better meet their business objectives with the support of the OEM. This is frequently done in advance of any specific project and usually involves reciprocal non-disclosure agreements. The OEM is then able to provide the information which the O/O needs to properly install, operate and maintain instances of their equipment and devices. The OEM may also gain rights to interact with O/O systems, so they can better support the O/O business operations, by monitoring their equipment and devices, then using diagnostics and prognostics.

EXAMPLE 1 EPC Selection: An O/O decides to build a new refinery. All initially identified requirements are put together in terms of the Invitation to Bid (ITB) document. Qualified EPCs are welcomed to the bidding. After a selection process, the O/O awards the nominated Primary EPC a contract to deliver the facility, including information needed to operate and maintain it.

— An EPC goes through the applicable processes to be included in a bid.

— An EPC often works as part of a team with several other EPC firms. In this case, a Primary EPC is usually identified for each major set of work to be done.

— An EPC receives high-level requirements to execute the capital project.

— An EPC provides functional engineering and associated design detail requirements back to O/O based on high-level requirements received from O/O.

— The EPC sends a subset of detailed requirements to OEMs which are applicable to their products, so they can perform additional detail design and manufacture the equipment or devices.

— An EPC or an OEM or systems integrator working on behalf of the EPC assembles equipment and devices (components) into systems (functional packages).

— An EPC then integrates the individual systems into systems of systems to build up the plant, platform, and facility.

EXAMPLE 2 EPC and OEM Interaction: A nominated OEM receives detailed requirements information from an EPC working on behalf of an O/O.

— OEMs receive requirements from the EPC and based on them, the OEMs provide make/model information of the equipment and devices they manufacture.

— OEMs and fabricators also provide project specific manufactured assets, as well as those for which they have standard models.

— Once a purchase order is issued, the OEM uses the requirements information to manufacture, assemble, mass customize (when required) and supply components (equipment or devices),

— The OEM can integrate equipment and devices into a system (sometimes called a functional package). They can also have a systems integrator do this work on their behalf.

— They also hand over associated model and serial number information (complying with a specification included in the purchasing agreement) to the EPC or directly to the O/O depending on the contract.

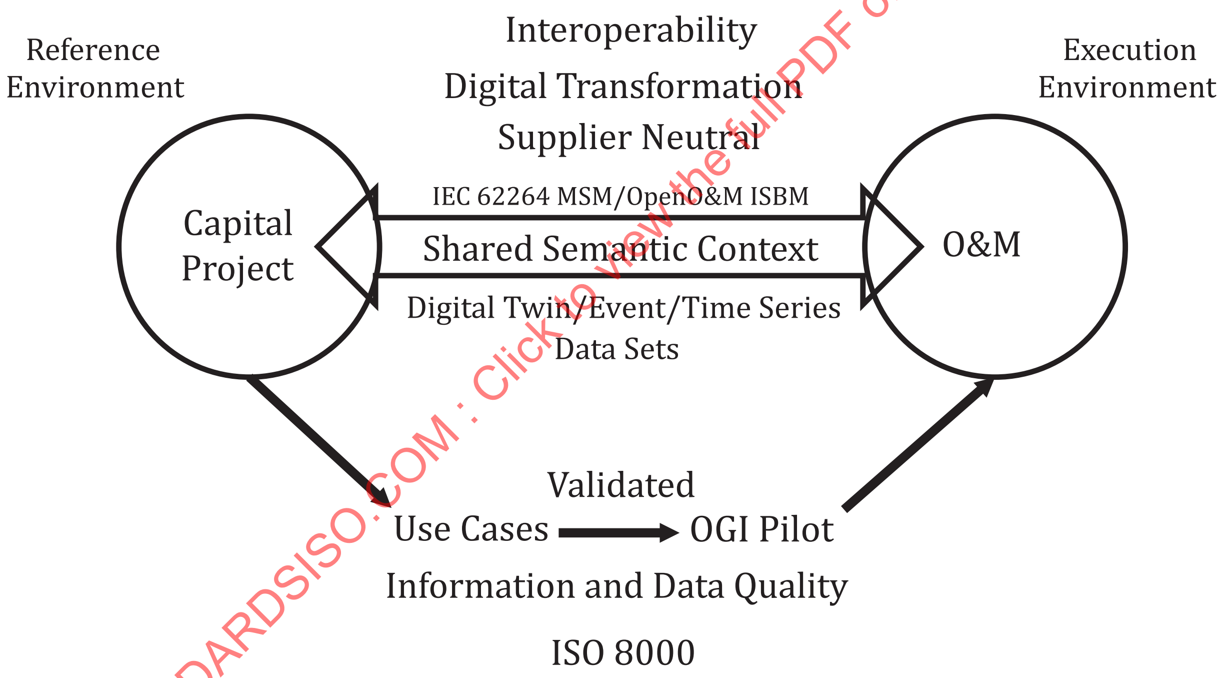
6 Compliance and conformance

Systems and applications in compliance with this document shall conform with 5.3.1.

7 OGI concept map

This document takes an open specification approach to enabling the required levels of industrial interoperability for an industrial digital ecosystem, providing specifications for a standardized enterprise solutions architecture, identical instances of which are configurable to meet the needs of individual enterprises. Systems and applications adaptors, as well as ecosystem administration components, can then be built, maintained and licensed as either open source or commercial off the shelf solutions, following the same specifications. Participating enterprises then share many of the same standards for both intra- and inter-enterprise interoperability.

The industrial digital ecosystem strategy is shown in Figure 9 works for both the oil and gas industry and many other industries which share similar Capital project and O&M methods, while using similar classes of equipment and devices. It includes the Owner/Operators, OEMs, EPCs who all benefit from this cross-industry methodology, as industry supply chains are highly interrelated in ways now being discussed as part of Industrie 4.0 and similar initiatives. Industrial software suppliers also gain from this cross-industry approach, while it eliminates the "lock-in" to proprietary platforms and applications, which was traditionally linked to high switching costs for industry participants.



NOTE In this document, Industrie 4.0 is used instead of Industry 4.0.

Figure 9 — OGI major concepts

Annex A
(normative)

IT/OT Cloud and Standardized Use Case Architecture

A.1 Application domains in the IT/OT cloud

Figure A.1 provides a cloud-oriented view of the ADID defined in ISO 18435-1. The use case architecture depicted in Figure A.2 shall be used to define industry use cases that are piloted before they are included in future parts of the ISO 18101 series. These use cases will be focused on specifying key, standardized interactions in the secondary business process, where process industry O/Os have identified their desire to be as standardized as possible. Both intra-enterprise and inter-enterprise use cases will be included and will model interactions between systems associated with domains identified in the ADID, using the matrix notation.

NOTE A partial list of such use cases to be piloted and then included in future parts of the ISO 18101 series are included as examples at the end of this annex. The partial list includes use cases being included in the current phase of the OIIE/OGI Pilot.

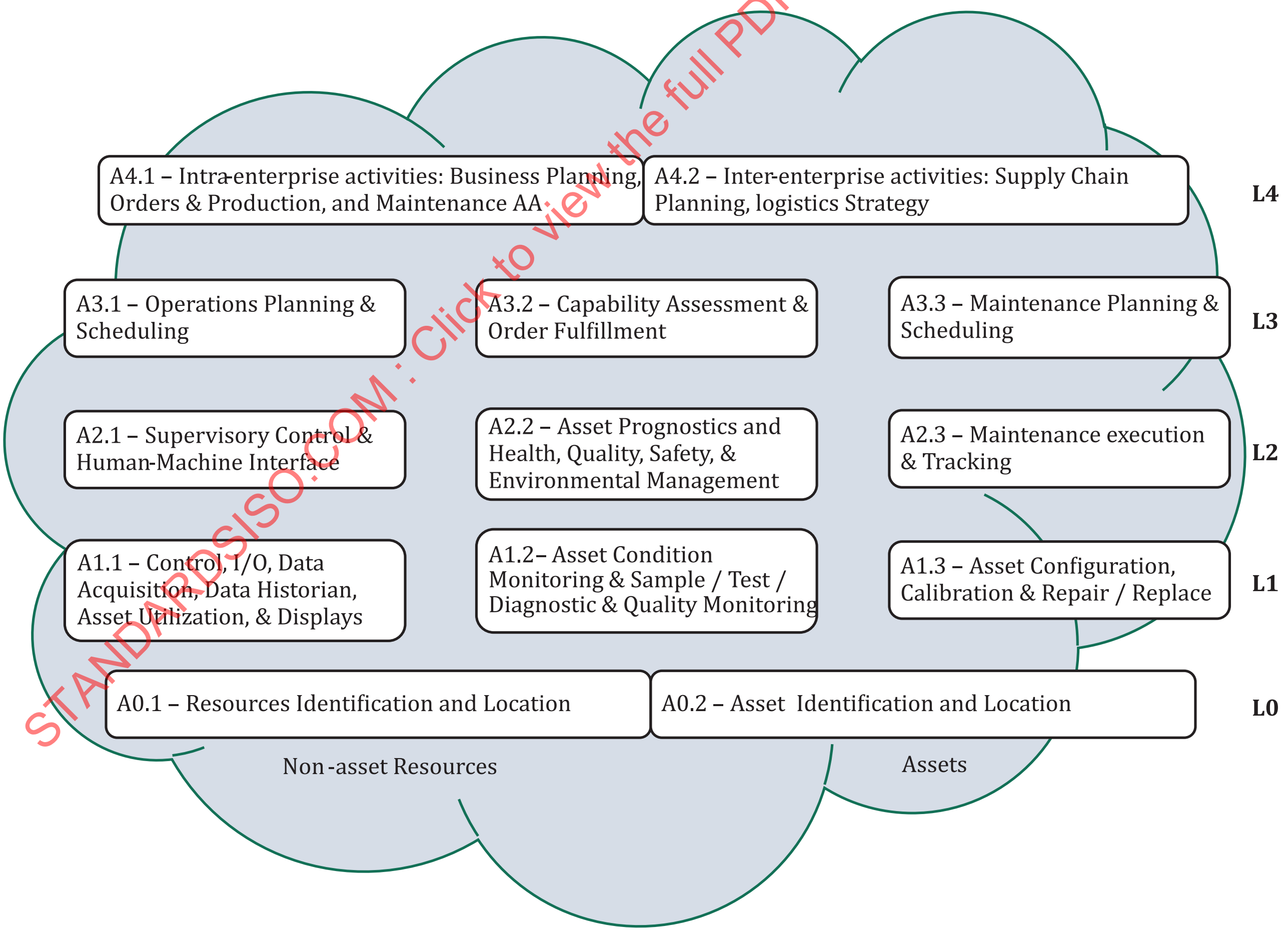


Figure A.1 — Application domains in the IT/OT cloud

A.2 OIIE use case architecture

The OIIE *Use Case Architecture* defines a standardized breakdown of Use Cases into smaller reusable parts, as well as a top-level overview of a Use Case or group of connected Use Cases. This breakdown forms a 3+1 level architecture, totalling 4 main components: *Use Cases*, *Scenarios*, *Events*, and *User Stories*. Each of the first two components decompose into the next, i.e. Use Cases decompose into Scenarios and Scenarios decompose into Events, while the fourth, User Stories, forms the "+1" as they can cross the other layers to illustrate specific events or whole use cases as required to achieve their purpose. An overview of the Use Case Architecture is shown in Figure A.2.

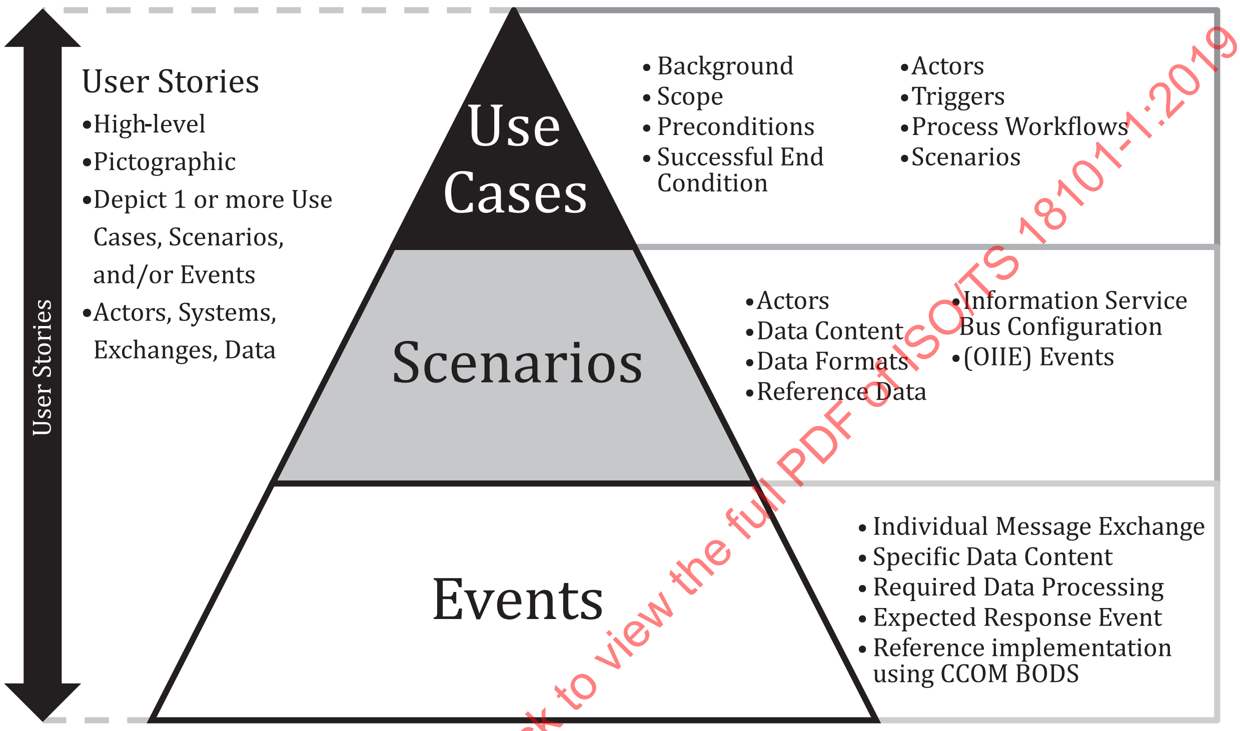


Figure A.2 — OIIE use case architecture overview

A.3 Use cases

A Use Case provides a general description of interactions to achieve an (interoperability) goal within a specified scope and background context. The description includes the actors (systems or people) that are interacting, any preconditions and triggering events/conditions/use cases, the success case, a main success workflow (and possibly other workflows, e.g. exception flows, as required), and the Scenarios that are necessary to perform those workflows.

A.4 Scenarios

A Scenario provides a specific description of a group of events that achieves an interaction detailing data and configuration requirements; multiple scenarios can be required to achieve the goal of a use case and the same scenario can be reused by the same or in multiple use cases. Items included in the description of a Scenario are: the actors involved in the interaction (usually systems only, if a person is specified it indicates a device that the person is using); the data content in general terms; required data format(s); the use of particular reference data libraries or items to ensure interoperability for the Scenario; any required configuration of the Information Service Bus (e.g. channel/topic configuration); any other infrastructure requirements (support systems that are required, etc.); and the Events required to achieve the Scenario.

A.5 Events

An Event describes an individual message exchange between systems, detailing data and processing requirements. This includes specific data content (in contrast to the general description of the Scenarios), any processing requirements placed on the recipient (e.g. if a flag is set to true, then behave in a certain way), and any expected response event such as a confirmation or a query result.

Events are still abstract in that they can be realized in multiple ways to support various mechanisms for exchange while adhering to the data and other requirements. Each Event is provided with a reference implementation. This allows events to be reused in different contexts and to support future exchange mechanisms. Moreover, remaining partially abstract allows Events to represent different types of event (note, lowercase 'e') where necessary.

A.6 User stories

A User Story provides a high-level graphical representation of interactions and events defined by one or more use cases and/or scenarios. They are designed to provide a business level overview of interactions and Use Cases across any level of the architecture (as necessary) using a simple graphical notation. The notation differentiates people, systems, and data/documents and connects them using arrows to illustrate interactions. A User Story consists of a number of *frames*, each frame illustrates a small portion of the Story and can be connected to preceding frames in various ways to illustrate continuity and/or use of data from a previous frame.

EXAMPLE A user story can illustrate the various events and interactions (including person-to-person, system-to-system, person-to-system, business-to-business, etc.) involved in a series of related use cases such as the triggering of a maintenance event based on condition data which leads to the removal of asset and the installation of a new asset. User stories can simply describe a logical sequence of related use cases, rather than following a trail of 'triggering events' defined in the use cases.

A.7 Use case data model

Figure A.3 illustrates an OIEE use case data model.

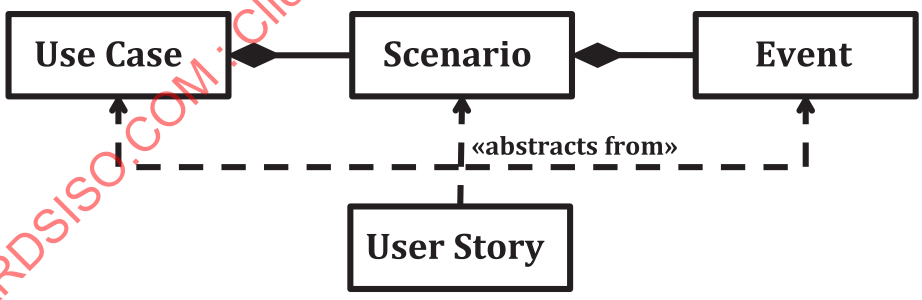


Figure A.3 — OIEE use case data model

EXAMPLE A list of industry use cases being included in the current phase of the OIIE/OGI Pilot is included immediately below. This list is incrementally expanded using the piloting process.

— Greenfield request for information and response.

— Capital project installation of assets (serialized equipment and devices).

— Event-driven handover of as-built information.

— Condition based maintenance on installed device or equipment.

— Remove and replace installed device or equipment.

— Brownfield request for information and response.

Annex B
(informative)

OGI activity model

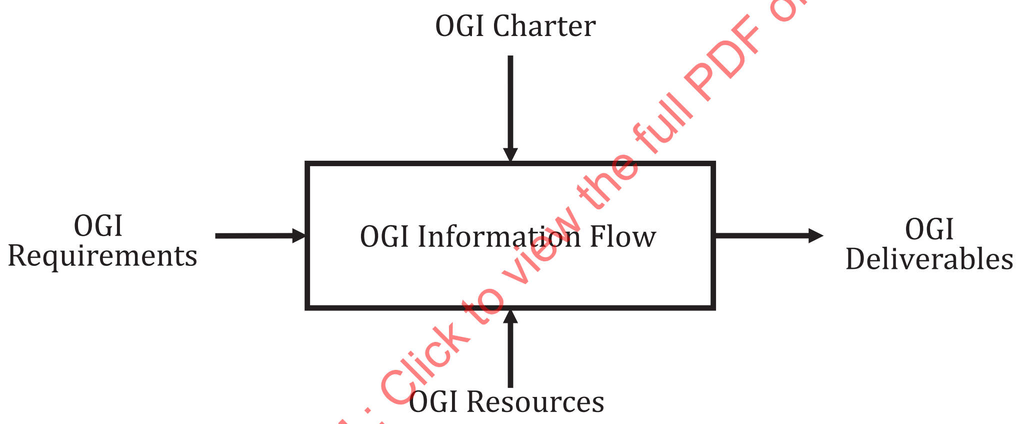
Different EPC processes have their own models. One instance of such models is shown in Figure B.1. It is a part of the OGI framework, which is realized by the general framework concept for development and management of the digital assets as depicted in Figure B.1:

— OGI charter: legal, regulatory and societal constraints;

— OGI requirements: e.g. facility requirements, operational performance and facility operational cost (and regulatory requirements can apply);

— OGI deliverables: e.g. physical asset (facility) and digital asset (information);

— OGI resources: disciple engineers and tools reference data libraries versus supplier catalogues and repositories.



Purpose: to manage OGI Information Flow
Viewpoint: The System to system Integration Team

Figure B.1 — Manage OGI information flow

Standardized reference data libraries support the development of the structured digital assets used in the physical assets of the facilities. The decomposition of the phases provides further detail to describe different views for function and information dependent upon the use cases.

NOTE Almost all the engineering products currently use parts and materials prepared according to a defined set of standards. Use of standard parts generally reduces the cost and simplifies the maintenance of the product. For each designed product, investigation of applicable standards, codes, specs and technical regulations are essential. They are generally defined in a contract and accompany the document. The market size, price, and often the legal sale of a product can depend on the satisfaction of proper engineering standards.

Figure B.2 is the further breakdown of A0.

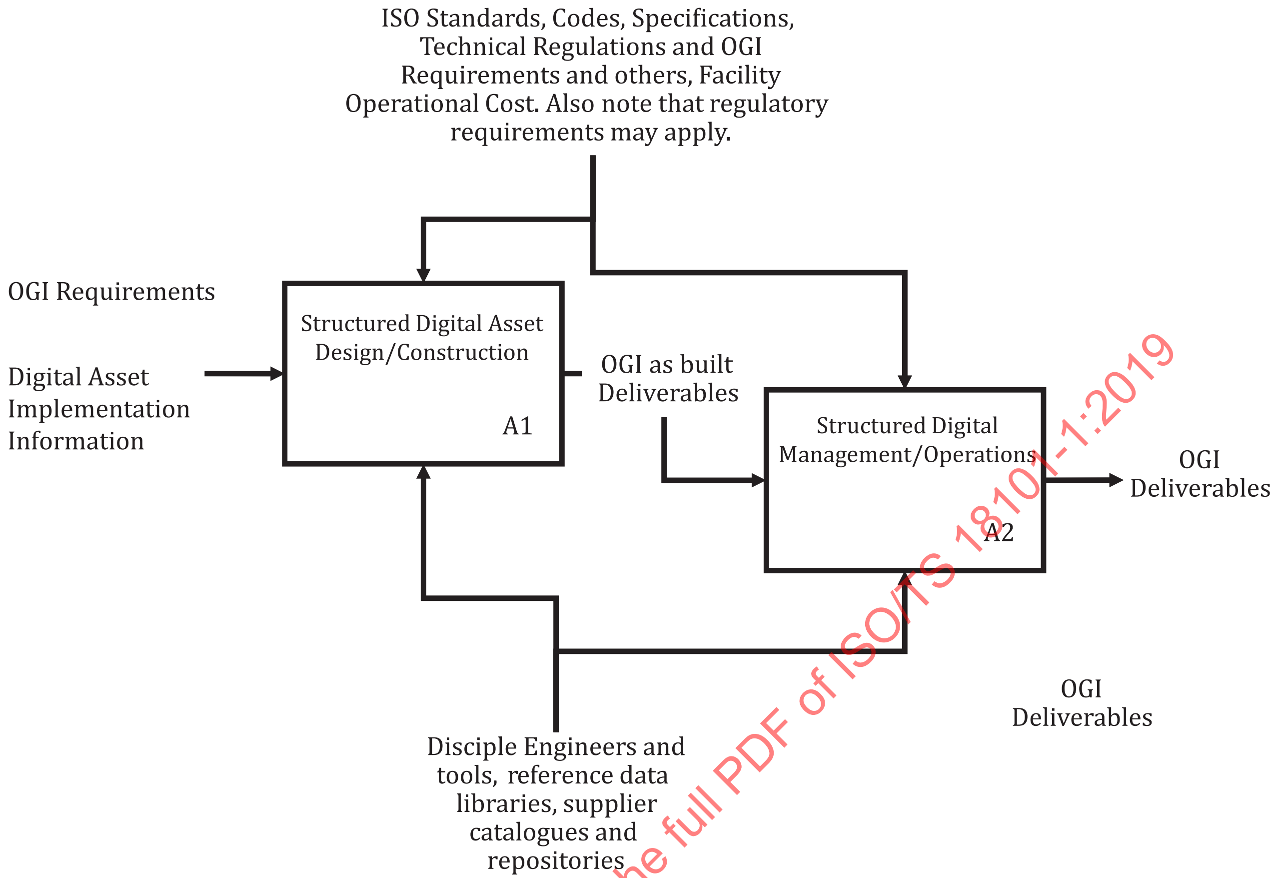


Figure B.2 — Development and management of the digital assets

Figure B.3 represents the further breakdown of A1 where A15 is created to represent Completion/Commissioning/Start-up.