ISO CD/TR/DTR 20123:2023

ISO/TC 184/SC 4

Secretariat: ANSI

Date: 2023-03-0128

Automation systems and integration – — Industrial data –— Nuclear digital ecosystem specifications

WD/CD/DIS/FDIS stage

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This document was prepared by Technical Committee ISO/TC *184*, *Automation systems and integration*, Subcommittee SC 04 *Industrial data*.

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Introduction

~~At the meeting of ISO/TC 184/SC 4 held in Marina Del Ray, California, 2019-11-08 the following resolution was approved:~~

~~"The SC 4 Implementation Forum proposes the creation of an ad-hoc team with~~ The purpose ~~to create a draft NWI TR before the next ISO TC 184/SC 4 meeting. The purpose of the TR will be~~of this document is to bring all current knowledge together about standardization of information ~~of~~on nuclear installations in the nuclear industry.

~~The tasks of the ad-hoc team will be:~~

- ~~Define final purpose and scope of the NWI TR for a Nuclear Digital Ecosystem~~
- ~~Document the state of the art of standardization of information management of nuclear installations over their life cycle.~~
- ~~Do a survey among the nuclear stakeholders about their business cases and their interest to join the NWI TR project for the purpose to create a final standard for digital ecosystem.~~
- ~~Define the business case with use cases of developing and adopting such information standards.~~
- ~~Draft the NWI TR documentation before May 2020. "~~

~~The ad-hoc team is identified as ISO/TC 184/SC 4/AHG 02 (AHG 02) and has grown from the initial seven members to twenty, with representations from China, France, Netherlands, Japan, Republic of Korea, Sweden and United Kingdom. The team has met every two weeks from 2020-01-08. The information created in the course of these meeting is recorded in the AHG 02 section of ISO Documents and managed by the team.~~

This ~~Technical Report~~document provides orientations for how the concept of an industrial digital ecosystem ~~could~~can be realised for the nuclear industry, its installations and practices. These orientations are based on surveys of the state of the art for the adoption of digital methods and technology for the nuclear sectors by the participating members of ISO/TC 184/SC 4 ~~that are represented in AHG 02~~ and a review of the current state of the standards for the digital representation of engineering data that are the responsibility of ISO/TC 184/SC 4~~,~~ and international standards from other TCs/SCs from ISO, IEC, CEN and some de-facto international industry standards.

~~This report endeavours to make orientations~~The objective is to provide the nuclear industry with a common framework to address the intertwined aspects to manage digital information based on standards and related to nuclear facilities and materials.

The nuclear facilities are composed of all the physical structures, systems, and components: mining, fuel manufacturing, nuclear material transport, nuclear power plants (NPPs), reprocessing plants, waste management and disposal facilities.

This document aims to support operational processes in a nuclear ecosystem using digital tools to produce, manage and share information.

It is based on the experience and skills of ~~the AHG 02~~ experts with generic competencies in standards for industrial data, developed during the past years in the edition of standards for product modelling, plant modelling and construction modelling associated with some specific experience of some members in nuclear facilities lifecycle, the corresponding information and records management in the lifecycle.

This ~~report~~document will be updated when new technological advances become available, as many initiatives in the field of the "Industry of the future" are underway~~ –~~, the most relevant of which is the development of the digital twin~~. The experts of the AHG 02 are fully aware of these opportunities and are open to integrate~~ (DT). The corresponding outcomes can be integrated in a viable roadmap with steps to effectively guide ~~practicians~~practitioners of the nuclear ecosystem in implementing methodologies and technologies to make effective the benefit of the proposed standards.

This ~~DTR~~document does not ~~bring~~provide answers to all of the ~~answers~~issues but does raise questions and identifies barriers for successful implementation which will be addressed to create a digital ecosystem in the nuclear industry. It does provide a simple conceptual framework and a roadmap to guide the actors of the nuclear ecosystem.

To consolidate this perspective, ~~the report~~this document has ~~been discussed with experts of ISO/TC 85 in~~ taken into account nuclear technology and ~~accordingly revised in order to take into account~~ the constraints on the nuclear industry. Developing a standardization framework for the nuclear industry could also be useful ~~also~~in order to face long standing issues met in conventional industries regarding information management.

Radioactivity structures all of the activities in the nuclear industry and strongly impacts the needs and the way of modelling facilities and of organising information to support the business processes.

Innovation and standardization will enable a nuclear digital ecosystem (NDE), which could be downsized for conventional industries with specific lighter requirements.

~~We are confident~~ This methodology offers the best ~~guarantees~~guarantee to meet the specific needs of a nuclear ecosystem and to reuse generic models, relationships, and standards already available or prepare their adaptation or extension for the future.

Automation systems and integration — Industrial data — Nuclear digital ecosystem specifications

1 Scope

This document provides:

— a review and summary of the adoption of digital methods and technology in the national nuclear sectors~~ of the participating members represented in ISO/TC 184/SC 4/Ad-Hoc Group 02,~~;

— a summary of the state of the art of some of the standards ~~from ISO/TC 184/SC 4, from other standards development and industrial professional organizations that support~~supporting the digital representation and interoperability of industrial data~~,~~;

— ~~orientations~~orientation on the use of these standards for model-based systems engineering (MBSE) in order to achieve a nuclear digital ecosystem~~,~~ (NDE);

— a high-level roadmap of the stages by which this ecosystem ~~could~~can be achieved, taking into account the maturity of the actors of the ecosystem, their relationships and the added value of using advanced standards.

NOTE The complete reports from the participating ~~members~~entities are presented in ~~Annexes A~~Annexes A to ~~F~~.F.

~~The objective is to provide the nuclear industry with a common framework to address the intertwined aspects to manage digital information based on standards and related to nuclear facilities and materials.~~

~~The nuclear facilities are composed of all the physical structures, systems, and components: mining, fuel manufacturing, nuclear material transport, nuclear power plants, reprocessing plants, waste management and disposal facilities.~~

~~The scope~~This document includes the following:

— the systems composing the nuclear facilities and their input, output, and other products resulting from interactions in the nuclear system or with its environment~~. It includes the material accounting and the corresponding international laws and requirements.~~;

— the material accounting and the corresponding requirements;

— waste management~~ is included in the scope.~~: all types of nuclear waste produced during processes and activities, and their properties ~~will be~~are considered for a seamless management of information in the whole value chain of the nuclear ecosystem.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

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

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

3.1.1
asset
item, thing or entity that has potential or actual value to an organization

[SOURCE: ISO/TS 18101:2019].]

3.1.2
information
knowledge concerning objects, such as facts, events, things, *processes* (3.1.13),(3.1.13), or ideas, including concepts, that within a certain context has a particular meaning

[SOURCE: ISO/IEC 2382:2015, 2121271, modified — Field of application and notes to entry have been removed.]]

[SOURCE: ISO 8000-2:2022, 3.2.1]

3.1.3
data
reinterpretable representation of *information* (3.1.2)(3.1.2) in a formalized manner suitable for communication, interpretation, or processing

[SOURCE: ISO/IEC 2382:2015, 2121272, modified — Notes to entry have been removed.]]

[SOURCE: ISO 8000-2:2022, 3.2.2]

3.1.4
data element
member of a *data set* (3.1.3)(3.1.5)

3.1.5
data set
logically meaningful group of data

[SOURCE: ISO/TS 18101-1:2019]

3.1.6
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 8000-2:20182022, 3.8.1, modified — Note 1 to entry has been modified.]

[SOURCE: ISO/TS 18101-1:2019]

3.1.7
digital ecosystem
distributed, adaptive, open, socio-technical system with properties of self-organisation, scalability and sustainability inspired from natural ecosystems

[SOURCE: ISO/TS 18101-1:2019]

3.1.8
digital representation
manner in which information is stored for interpretation by a machine

[SOURCE: ASME Y 14.47 – 2019]

3.1.9
domain
field of special knowledge, which can be further subdivided according to requirements to support a higher level of specialized detail

[SOURCE: ISO/TS 18101-1:2019]

3.1.10
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* ~~(3.1.7)~~(3.1.9) entities in a *digital ecosystem* ~~(3.1.5)~~(3.1.7) addressing lifecycle *asset* ~~(3.1.1)~~(3.1.1) management.

[SOURCE: ISO/TS 18101-1:2019]

3.1.11
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, order to perform their specific tasks

Note 1 to entry: Examples of entities include devices, equipment, machines, people, processes, applications, computer firmware and application software units, data exchange *systems* ~~(3.1.12)~~(3.1.17) and enterprises.

Note 2 to entry: Examples of items include services information, material in standards, design documents and drawings, improvement projects, energy reduction programs, control activities, *asset* ~~(3.1.1)~~(3.1.1) 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/TS 18101-1:2019]

3.1.12
nuclear digital ecosystem
NDE
digital ecosystem ~~(3.5)~~(3.1.7) specialised for application to nuclear power facilities and related activities

Note 1 to entry: The objective is to provide principles, methodologies and technologies to enable sharing of shared resources across nuclear industry and beyond, and their specialization in each specific domain and discipline.

Note 2 to entry: There is a trend to name these shared resources "Commons"

3.1.13
process,noun
set of interrelated or interacting activities that use inputs to deliver an intended result

[SOURCE: ISO 9000:2015, 3.4.1, modified — Notes to entry have been removed.]

[SOURCE: ISO 8000-2:2022, 3.1.1]

3.1.14
property
A Property is a named measurable or observable attribute, quality or characteristic of a systemssystem

[SOURCE: Object Management Group. 2003. "Property." In SE Conceptual Model Semantic Dictionary (Draft 12_03-27-03). Available at http://syseng.omg.org/SE_Conceptual%20Model/Draft%2012/Concept%20Model%20Semantic%20Dictionary%2012th%20Draft%20Partitioned%203_27_03.xls] see https://www.sebokwiki.org/wiki/System_Property_(glossary)

3.1.15
reference data library
RDL
managed collection of reference data

[SOURCE: ISO 15926-1:2004]

3.1.16
requirement
need or expectation that is stated, generally implied or obligatory

[SOURCE: ISO 9000:2015, 3.6.4, modified — Notes to entry have been removed.]

[SOURCE: ISO 8000-2:2022, 3.1.2]17

3.1.13
system
combination of interacting elements organized to achieve one or more stated purposes

Note 1 to entry: A system is sometimes considered as a product or as the services it provides.

Note 2 to entry: In practice, the interpretation of its meaning is frequently clarified by the use of an associative noun, e.g.,. aircraft system. Alternatively, the word "system" is substituted simply by a context-dependent synonym, e.g.,. aircraft, though this potentially obscures a system principles perspective.

Note 3 to entry: A complete system includes all of the associated equipment, facilities, material, computer programs, firmware, technical documentation, services and personnel required for operations and support to the degree necessary for self-sufficient use in its intended environment.

Note 4 to entry: A system is also interacting with its environment.

[SOURCE: ISO/IEC/IEEE 15288:2015]

3.1.1418
system element
member of the combination of elements that constitutes a *system* (3.1.12)(3.1.17)

3.2 Abbreviated terms

AI
artificial intelligence

ALARA
As Low As Reasonably Achievable

BIM
Building Information Model (ISO 16739:2013)

CAD
Computer Aided Design

CAE
Computer Aided Engineering

CFIHOS
Capital Facilities Information Handover Specification

CNS
Convention on Nuclear Safety

DMS
Document Management System

EAM
enterprise asset management

EPC
engineering, procurement and construction

ERP
enterprise resource planning

ESPN
Equipment Sous Pression Nucléaire, Nuclear Pressure Equipment

FMEA
failure mode effects and criticality analysis

HVAC
heating, ventilation and air conditioning

IAEA
International Atomic Energy Agency

IFC
Industry Foundation Classes (ISO 16739:2013)

IIoT
Industrial Internet of Things

IVV
Integration, Verification and Validation

LOTAR
Long Term Archiving

LTKR

Long Term Knowledge Retention

MR
Micro Reactor

NIST
National Institute of Standards and Technology, USA

NPP
Nuclear Power Plant

O&M
Operation and Maintenance

OO
Owner and Operator

PLM
Product Lifecycle Management
plant lifecycle management

PWR
Pressurized Water Reactor

RDL
Reference Data Library

SMR
Small Modular Reactor

SOP
Standard Operating Procedures

SSC
Structure System Component

SSoT
Single Source of Truth

WANO
World Association of Nuclear Operators

4 About the nuclear industry

The

AI	artificial intelligence
ALARA	as low as reasonably achievable
ANN	artificial neural network
APR	advanced pattern recognition
BIM	building information model (see ISO 16739-1)
BWR	boiling water reactor
CAD	computer aided design

CAE	computer aided engineering
CDE	common data environment
CDF	core damage frequency
CFIHOS	Capital Facilities Information Handover Specification
CM	configuration management
CNS	Convention on Nuclear Safety
DMS	document management system
DT	digital twin
EAM	enterprise asset management
EPC	engineering, procurement and construction
ERP	enterprise resource planning
eSOMS	electronic shift operations management system
ESPN	nuclear pressure equipment (equipement sous pression nucléaire)
FAIR	findable, accessible, interoperable end reusable
HLW	high-level waste
HVAC	heating, ventilation and air conditioning
ISDC	International Structure for Decommissioning Costs (ISDC) of the OECD
IAEA	International Atomic Energy Agency
IFC	industry foundation classes (see ISO 16739-1)
IIoT	industrial internet of things
IVV	integration, verification and validation
K-PIM	knowledge-centric plant information model
LD	linked data
LLW	low-level waste
LOTAR	long term archiving
LTKR	long term knowledge retention
MBSE	model-based systems engineering
MR	micro reactor
NIST	National Institute of Standards and Technology (USA)
NLP	natural language processing
NPP	nuclear power plant
NRC	Nuclear Regulatory Commission (USA)
O&M	operation and maintenance
OECD	Organisation for Economic Co-operation and Development
OO	owner and operator
O&M	operations and maintenance
PIM	plant information model

PLM	product lifecycle management plant lifecycle management
PWR	pressurized water reactor
RDF	resource description framework
RDL	reference data library
SMR	small modular reactor
SNF	spent nuclear fuel
SSC	structure system component
SSoT	single source of truth
SW	semantic web
WANO	World Association of Nuclear Operators
WBS	work breakdown structure

4 Overview of the nuclear industry

4.1 Nuclear fuel cycle

The nuclear industry can be analyzedanalysed starting with the fuel cycle [1],.[1] and includes all activities from the uranium mining, fuel fabrication, construction of the nuclear installations, operation and maintenanceO&M of the nuclear installations, decommissioning, fuel reprocessing, waste management and waste disposal.

Whilst reprocessing of nuclear fuel is possible, with facilities to manage the valuable material and the waste produced during the whole fuel cycle, which prefigures a circular economy, it is currently not regularly practiced in a large fraction of the world's nuclear power plantNPP fleet.

An integrated management of the data produced during all the fuel cycle and in all the facilities involved in this cycle will bring a clear added value.

The lack of interoperability of data along this cycle is conservatively estimated from 1 % to 3 % of the cost of investment of all of these facilities [2]..[2] At an international level, this represents tens of billions of Euros. Data interoperability and traceability is moreover a regulatory requirement for the nuclear industry.

With the extended use of digital tools at every step of the cycle, it is of the utmost importance that standards support the interoperability of data which must be accessible for reuse for time spans of more than 100 years.

Sharing a global understanding of the situation of the nuclear industry as a system of systems is key.

Systems engineering combined with Model Based Systems EngineeringMBSE in a digital environment offer the best available framework of a global understanding.

Standards to support interoperability of the nuclear ecosystem are numerous and various and concern plants, products, buildings, material, fuel, waste and the environment. The governance of these standards is mademanaged locally by subject matter experts to support specific needs of the actors.

4.2 Nuclear power plant (NPP) safety leadership and management

Safety is a critical issue in the nuclear industry, and the prime public concern asof the 1986 Chernobyl accident and the 2011 Fukushima I accident would confirm their worst fears. confirmed the concerns. This is reflected in IAEA CNS (Convention on Nuclear Safety, 9th Feb 2015):[73]:

— New ~~nuclear power plants~~NPPs are to be designed, sited, and constructed, consistent with the objective of preventing accidents in the commissioning and operation and, should an accident occur, mitigating possible releases of radionuclides causing long-term off-site contamination and avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions.

— Comprehensive and systematic safety assessments are to be carried out periodically and regularly for existing installations throughout their lifetime to identify safety improvements that are oriented to meet the above objective. Reasonably practicable or achievable safety improvements are to be implemented in a timely manner.

— National requirements and regulations for addressing this objective throughout the lifetime of ~~nuclear power plants~~NPPs are to consider the relevant IAEA Safety Standards and, as appropriate, other good practices as identified inter alia in the Review Meetings of the CNS.

Safety in this clause focuses on key radiation-related aspects of NPP O&M safety, namely nuclear safety, radiation protection and radioactive waste management. Safety data is essential for safety management.

When considering safety in relation to nuclear facilities there are a number of different domains to be considered (both nuclear industry specific and general) including: nuclear safety supervision according to regulations and operation license documents, change management of safety justification basis for the license extension (e.g. change of safety related SSCs, change of operating limits and conditions~~, etc.)~~). Nuclear safety inspection requires the recording data of NPP operation ~~LCO (~~Limiting Condition for Operation (LCO), periodic test data related to safety, parameters of safety system and the defect reporting data~~, etc~~.

Radiation protection~~–~~: the goal of NPP radiation protection is to ensure that O&M personnel are exposed to doses below the limits, and to maintain the radiation at reasonable and feasible levels, and to protect the public ~~people~~ and the environment. The main work of radiation protection includes radiation work management, radiation dose control, radiation pollution control, radioactive material control, radiation monitoring ~~and so on~~, all of which require ~~data of RWP (~~Radiation Work Permit~~),~~ (RWP) data, ALARA, radiographic testing permit, individual dose record, personnel RP (radiation protection) certificate~~, etc~~.

Radioactive waste management~~–~~: The principles of radioactive waste management are radioactive waste minimization and radioactive ~~effluents~~effluent optimization. Radioactive waste management requires continuous monitoring data of the effluents, and the sampling analysis data~~, etc~~.

~~'~~Safety leadership and ~~Management'~~management requires the involvement and active participation of all parties and ~~will take benefit of~~benefits from a system engineering approach. The ISO 8000 ~~Data Quality~~series is an important standard ~~to help~~which helps to improve NPP safety data quality.

IAEA has provided a series of safety standards as well as international cooperation to ensure that high safety performance ~~would be~~is attained~~–~~. All countries with operating ~~NPP to~~NPPs report on the implementation of their obligations under CNS for international peer review. WANO also has programs to help improve safety.

Digital technology has been implemented to help improve NPP safety, as NPP safety management is still largely paper-based~~ now~~. In China, blockchain technology is used for personal exposure data management. In France, a unique collaborative 'ESPN digital' platform centralizes safety ~~requirements~~requirement management for all stakeholders. In the Pallas project in the Netherlands blockchain principles are adopted by means of attaching a digital signature to each digital statement in the project repository ~~(Common Data Environment)~~[common data environment (CDE)] which defines meta data ~~like~~such as provenance, access rights, confidentiality, and when applicable, the replace chain (history) of each statement (as per ISO/TS 15926-11~~ ed2).~~).

A few data interoperability barriers ~~are hindering~~hinder NPP safety, for example, the lack of an international standard for the safety classification of equipment, as shown in ~~the following table~~Table 1.