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Automation systems and integration — Collaboration environment requirements of simulation on different manufacturing platforms —

Part 1: Reference model and process

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Foreword

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This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Interoperability, integration, and architectures for enterprise systems and automation applications*.

A list of all parts in the ISO 21175 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

Open, sharing and self-organization on demand among group enterprises or small and medium-sized enterprises (SMEs) of manufacturing in the product full life cycle is the trend for the future which calls for deep collaboration within or among enterprises especially simulation-oriented model collaboration. At present, collaboration within or among enterprises has developed from simple information-based collaboration, drawing based collaboration, 3D model-based collaboration to simulation-oriented model collaboration. Simulation-oriented model collaboration can support global enterprises, virtual enterprises in industrial cluster and integrated product teams within enterprise to carry out joint innovation, complex product research and development, virtual fabricate/test/operation/maintenance and other activities in the product full life cycle, which is of great significance to innovate products and improve their time (to market), quality, cost, and service, etc.[1]

Nowadays, an expanding trend about all kinds of simulation-oriented model collaboration related activities in the functional hierarchy of manufacturing systems can be observed. In the activities of business planning and logistics, simulation-oriented model collaboration among different enterprise stakeholders is needed to improve plant production scheduling, operational management, etc. In the activities of manufacturing operations management, simulation-oriented model collaboration among different enterprise or department stakeholders is needed to improve dispatching production, detailed production scheduling, etc. In the activities of batch control, continuous control and discrete control, simulation-oriented model collaboration among different department stakeholders is still needed to improve prediction and optimization.

In particular, with the deepening applications of technologies in the manufacturing system such as model based system engineering, model engineering, cyber-physical system, digital twin, cognition and decision intelligence (based on the deep reinforcement learning especially)[2][3][4] which increase the requirements of simulation-oriented model collaboration upon different manufacturing platforms. First, the development scope of the simulation has expanded from the traditional Local Area Network to the global Internet. Second, the deployment place of the simulation has expanded from the traditional desktop to the pervasive terminal. Meanwhile, the operation form of the simulation has expanded from the traditional off-line small-scale sequential verification to the on-line large-scale parallel analysis on demand.

The prerequisite for simulation-oriented model collaboration is simulation interoperability which now is covered by several existing standards or specifications supporting distributed interactive simulation system like Discrete Event System Specification (DEVS)[5][6], Distributed Interactive Simulation (DIS)[7], High Level Architecture (HLA)[8], Test and Training Enabling Architecture (TENA)[9], Functional Mock-up Interface (FMI)/System Structure and Parameterization (SSP)[10][11][12][13], Distributed Co-Simulation Protocol (DCP)[14] and FIWARE[15]. The Distributed Simulation Engineering and Execution Process (DSEEP) standard[16] describes the different development steps of a distributed interactive simulation system which is independent of any distributed interactive simulation architecture like HLA or DIS. However, there are no formal standards existing for a kind of environment where all kinds of stakeholders involved in the joint simulation project could improve collaboration to enable on-demand simulation at any time and any place upon different manufacturing platforms with different infrastructures, operating systems, simulation middleware. The common problems that exist in the current implementation of joint simulation projects include requesting the infrastructure device by phone, integrating the software / model offline, and running the simulation system manually, which bring great inconvenience to the projects. Therefore, a new standard required for shielding distribution and heterogeneity of them to enable service-oriented share-use, integration and collaboration, by providing the semantic and pragmatic guarantee plus the general and neutral interface definition.

This document specifies the reference model (including collaboration environment meta-model and collaboration environment interface) and the reference process (including joint simulation project analysing, joint simulation project realizing with the steps of business and system describing, software collaboration implementing and infrastructure collaboration supporting) of the collaborative modeling and simulation environment to promote the solution formulation of joint simulation projects.

The annexes provide additional information. Annex A introduces the functional hierarchy defined in IEC 62264-1[17] and its relationship with this document. Annex B shows an example of using collaborative modelling and simulation environment in a joint simulation project. Annex C illustrates the legend of OPM used in this document.

Automation systems and integration — Collaboration environment requirements of simulation on different manufacturing platforms —

Part 1: Reference model and process

1 Scope

This document specifies a reference model and process for Collaborative Modeling and Simulation Environment (CMSE), which establishes a general framework of CMSE to provide guidance for implementation of joint simulation projects. The CMSE which is based on the reference process and the reference model including neutral interfaces and meta-models can enable service-oriented share-use of the infrastructure, integration of the software and collaboration of the business to improve collaboration among all kinds of stakeholders involved in a joint simulation project which needs on-demand simulation at any time and any place upon different manufacturing platforms owned by different enterprises or by different departments within an enterprise.

This document can not only be applied to manufacturing enterprises but also be applied to other kinds of enterprises. It is intended for use by stakeholders who are concerned with developing and deploying solutions of the joint simulation project based on information and communication technology. It focuses on simulation activities related cross-platform simulation collaboration capability supporting business planning and logistics, manufacturing operations management and production control within or among enterprises, which can cover the levels from 2 to 4 of the functional hierarchy of manufacturing systems in IEC 62264-3[27].

This document specifies the following:

— the general framework of CMSE;

— the methodology of the joint simulation project analysis and realization by CMSE.

This document does not relate to the simulation irrelevant collaboration environment, and does not specify the specific approach to implement CMSE in the solution formulation of joint simulation projects.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

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

3.1
simulation
use of a similar or equivalent system to imitate a real system, so that it behaves like or appears to be the real system

[SOURCE: ISO 16781:2021,[18] 3.1.9]

3.2
simulation collaboration
process of two or more participants of a simulation activity working together to complete a simulation task

Note 1 to entry: Collaboration is the process of two or more people, entities or organizations working together to complete a task or achieve a goal. Simulation collaboration includes three aspects: collaborative modeling, collaborative simulation and collaborative evaluation.

[SOURCE: IEEE 1730-2022[19]]

3.3
platform
combination of an operating system and hardware that makes up the operating environment in which a program runs

Note 1 to entry: The platform includes infrastructure, operating system, simulation middleware which are depending on a simulation activity.

[SOURCE: ISO/IEC/IEEE 26513:2017,[20] 3.30]

3.4
collaboration environment
kind of software system which enables service-oriented share-use, integration and collaboration upon different manufacturing platforms, by providing the semantic and pragmatic guarantee plus the general and neutral interface definition, based on the interoperability of the manufacturing platforms

Note 1 to entry: Interoperability defined in ISO/TS 15926-8 is about ability of different types of computers, networks, operating systems, and applications to work together effectively, without prior communication, in order to exchange information in a useful and meaningful manner.

4 Abbreviated terms

DIS	distributed interactive simulation
HLA	high level architecture
TENA	test and training enabling architecture
CMSE	collaborative modeling and simulation environment
DEVS	discrete event system specification
SES	system entity structure
OPM	object process methodology
OPD	object process diagram
OPL	object process language
M&S	modeling and simulation
FMI	functional mock-up interface

DCP distributed co-simulation protocol

DSEEP distributed simulation engineering and execution process

5 Conformance

In order to claim conformity with this document, any particular CMSE in the solution formulation of joint simulation projects shall be able to be positioned within the general framework defined in this document. This positioning shall consist of joint simulation project analysing and joint simulation project realizing which includes the business and system describing, software collaboration implementing and infrastructure collaboration supporting.

This document conforms with ISO 19450, which was established following the realization that the next generation of standards needs to be not only machine-readable, but also executable, so they can be tested and validated for completeness, coherence, and consistence, both within each standard and across related standards.

6 General framework of CMSE

The general framework of CMSE proposed in this document includes “collaborative modeling and simulation environment reference model and process enabling”, which is the main process of this document.

Figure 1 is the OPM (ISO 19450) system diagram (SD) of the system specified in this document. This process fully utilizes the simulation environment reference model and process to promote the solution formulation of the joint simulation project, as specified in this document.

The joint simulation project can be changed by the process “collaborative modeling and simulation environment reference model and process enabling” from rigid to flexible. The cross-platform simulation collaboration capability of joint simulation project can be improved from low to high by the process. The simulation collaboration reference model and process which support the process exhibit cross-platform simulation collaboration capability of joint simulation project at state “high”. And simulation stakeholder group handles “collaborative modeling and simulation environment reference model and process enabling” and participates in the joint simulation project. The joint simulation project encapsulates or selects simulation services which response to collaborative environment interface.

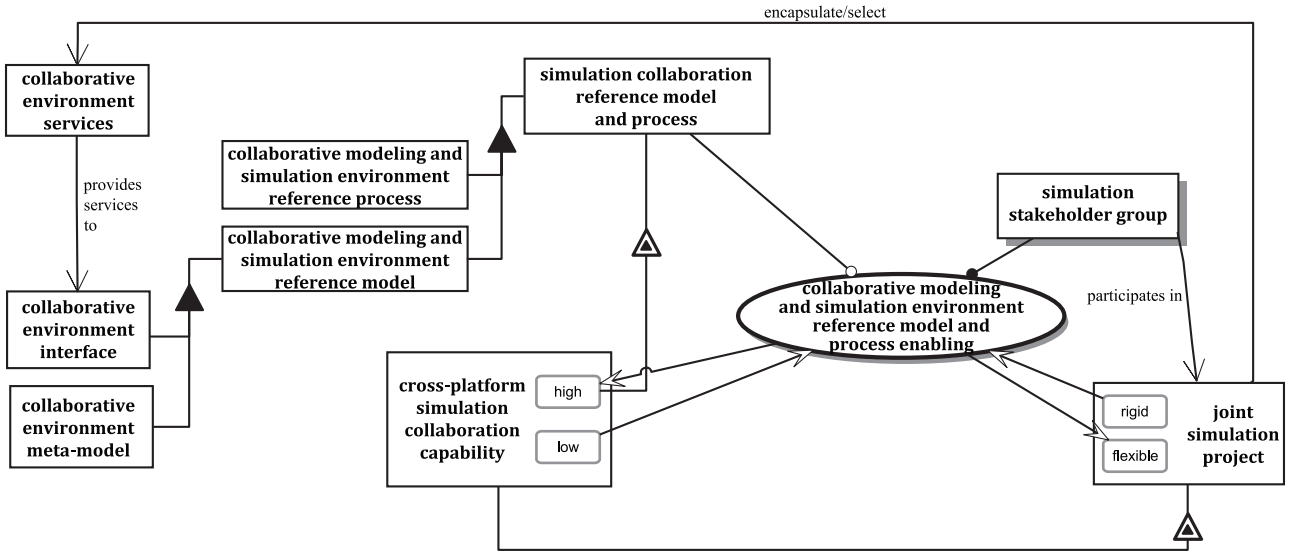

Figure 1 — OPM (ISO 19450) top-level system diagram of CMSE

The OPL corresponding to Figure 1 is as follows:

1. Cross-platform simulation collaboration capability of joint simulation project can be high or low.

2. Joint simulation project can be flexible or rigid.
3. Simulation stakeholder group participates in joint simulation project.
4. Simulation collaboration reference model and process consists of collaborative modeling and simulation environment reference model and collaborative modeling and simulation environment reference process.
5. Collaborative modeling and simulation environment reference model consists of collaborative environment interface and collaborative environment meta-model.
6. Joint simulation project exhibits cross-platform simulation collaboration capability.
7. Simulation collaboration reference model and process exhibits cross-platform simulation collaboration capability of joint simulation project with value high.
8. Joint simulation project encapsulate/select collaborative environment services.
9. Collaborative environment services provide services to collaborative environment interface.
10. Collaborative modeling and simulation environment reference model and process enabling changes cross-platform simulation collaboration capability of joint simulation project from low to high.
11. Collaborative modeling and simulation environment reference model and process enabling changes joint simulation project from rigid to flexible.
12. Simulation stakeholder group handles collaborative modeling and simulation environment reference model and process enabling.
13. Collaborative modeling and simulation environment reference model and process enabling requires simulation collaboration reference model and process.
14. Collaborative modeling and simulation environment reference model and process enabling yields M&S objectives and project goals.

In Figure 2, “collaborative modeling and simulation environment reference model and process enabling” is in-zoomed in the OPD. This diagram shows that the “collaborative modeling and simulation environment reference model and process enabling” has four sub-processes: “project goals deciding”, “modeling and simulation (M&S) objectives deciding”, “joint simulation project analysing” and “joint simulation project realizing”. “project goals deciding” yields “project goals”, which can be expressed at levels 2-4 of the IEC 62264-1 functional hierarchy (see Annex A). “M&S objectives deciding” uses the project goals to develop a set of M&S objectives, or measures of effectiveness, used to drive the M&S experiment. “joint simulation project analysing” requires M&S objectives and yields “structured task list”. The last sub-process “joint simulation project realizing” gets the structured task list and turns the joint simulation project from flexible to rigid. Meanwhile, it also turns the cross-platform simulation collaboration capability to state high. The structured task list directs the joint simulation project.

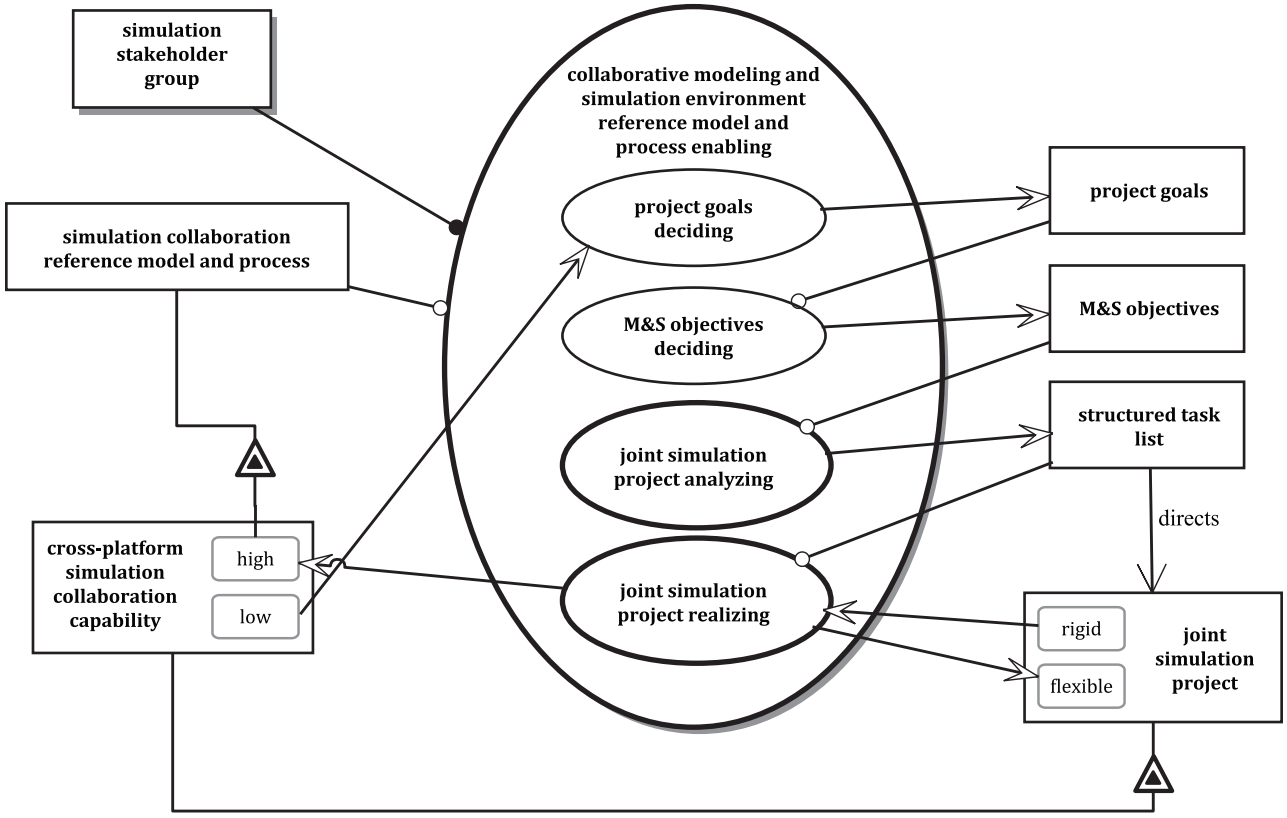

Figure 2 — SD1: The main process in Figure 1 in-zoomed, exposing four sub-processes

The OPL corresponding to Figure 2 is as follows:

1. Collaborative modeling and simulation environment reference model and process enabling from SD zooms in SD1 into project goals deciding, M&S objectives deciding, joint simulation project analysing, and joint simulation project realizing, which occur in that time sequence.
2. Cross-platform simulation collaboration capability of joint simulation project can be high or low.
3. Joint simulation project can be flexible or rigid.
4. Structured task list directs joint simulation project.
5. Joint simulation project exhibits cross-platform simulation collaboration capability.
6. Simulation collaboration reference model and process exhibits cross-platform simulation collaboration capability of joint simulation project with value high.
7. Simulation stakeholder group handles collaborative modeling and simulation environment reference model and process enabling.
8. Collaborative modeling and simulation environment reference model and process enabling requires simulation collaboration reference model and process.
9. Joint simulation project analysing requires M&S objectives.
10. Joint simulation project analysing yields structured task list.
11. Joint simulation project realizing changes joint simulation project from rigid to flexible.
12. Joint simulation project realizing requires structured task list.
13. Joint simulation project realizing changes cross-platform simulation collaboration capability of joint simulation project to state high.

14. M&S objectives deciding requires project goals.
15. M&S objectives deciding yields M&S objectives.
16. Project goals deciding changes cross-platform simulation collaboration capability of joint simulation project from state low.
17. Project goals deciding yields project goals.

7 Joint simulation project analysing

The “joint simulation project analysing” is in-zoomed in the OPD in Figure 3. This process, which requires M&S objectives, involves four sub-processes which include “participant identifying”, “structure analysing”, “behaviour analysing” and “model construction analysing”. The description of each sub-process and related objects is expressed in the OPL in Figure 3. The sub-process “participant identifying” yields participants list while the sub-process “structure analysing” obtains objects list. The “behaviour analysing” requires objects list and produces process list. The last sub-process “model construction analysing” requires both objects list and process list and yields model list. participants list, objects list, process list and model list are the parts of structured task list.

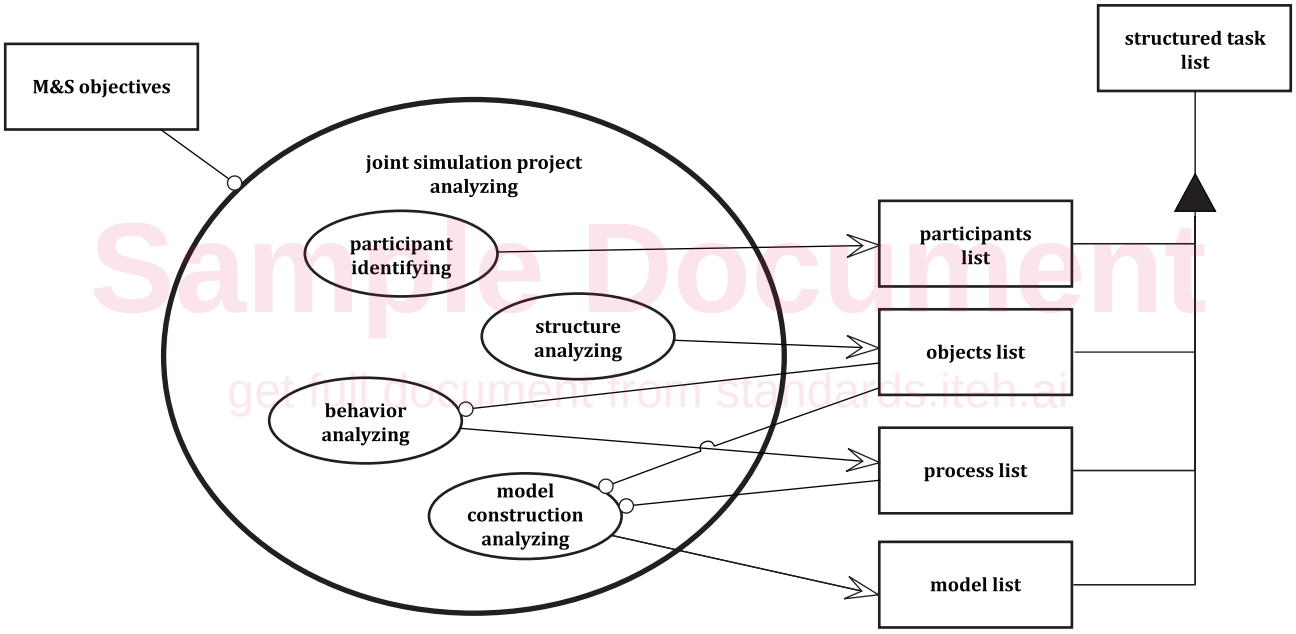

Figure 3 — SD1.1: Joint simulation project analysing in-zoomed

The OPL corresponding to Figure 3 is as follows:

1. Joint simulation project analysing from SD1 zooms in SD1.1 into participant identifying, structure analysing, behaviour analysing, and model construction analysing, which occur in that time sequence.
2. Structure task list consists of model list, objects list, participants list, and process list.
3. Joint simulation project analysing requires M&S objectives.
4. Participant identifying yields participants list.
5. Structure analysing yields objects list.
6. Model construction analysing requires objects list and process list.
7. Model construction analysing yields model list.
8. Behaviour analysing requires objects list.