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Systems and Software engineering — Methods and tools for model-based systems and software engineering

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee IST/15, Software and systems engineering.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Systems and Software engineering — Methods and tools for model-based systems and software engineering

Ingénierie du logiciel et des systèmes — Méthodes et outils pour l'ingénierie du logiciel et des systèmes basée sur des modèles

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Foreword

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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 and www.iec.ch/national-committees.

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Introduction

As systems grow in scale and complexity, some in the systems engineering community turn to model-based systems and software engineering (MBSSE) to, among other objectives, manage complexity, maintain consistency, and help ensure traceability during system development. With an MBSSE approach, the systems and software engineering activities rely on evolving models that serve as the main or major source of knowledge about the system-of-interest and its life cycle processes, which could be any entity subject to a system model such as a program, project, product, or company.

MBSSE benefits differ significantly from 'engineering with models', which has been a common practice among the engineering disciplines for decades and that is mainly based on independent discipline-specific models that, even if very useful for each discipline and system analysis contribution, do not provide an overall understanding of the architecture of the system sharable among stakeholders, e.g. computer-aided design (CAD) for mechanical engineering, aerodynamics models, control loop simulations. In addition, due to the diversity of approaches and terminologies (e.g. model-driven development or MDD), MBSSE usually falls within the context of a specific engineering discipline (e.g. MDD for the software engineering community).

MBSSE is the formalized application of modelling to support systems engineering or software engineering activities. Faced with the issues and challenges linked to the growing complexity of the systems to be developed, document-centric approaches are less and less suitable. The MBSSE approach makes it possible to develop logically consistent multi-view architecture description. These serve as a bridge to enable the traceable, verifiable and dynamic correlation of the system-of-interest and/or software-of-interest models cross multidiscipline and throughout its entire life cycle, and to drive the system and software engineering processes, activities and tasks at all levels of its hierarchy from system-of-systems to system element across multiple engineering disciplines and throughout all stages of its life cycle

From MBSSE perspective, other engineering disciplines (mechanical, thermal, electronic, electrical, etc.) are also considered.

Thus, a need exists to specify the considerations necessary for undertaking the application of MBSSE within an organization. An organization needs to address the considerations necessary for supporting the establishment of each project environment within its overall ecosystem, and the exchange of models between stakeholder organizations.

This document addresses MBSSE-related processes by categorizing them into four process groups:

— Plan MBSSE

— Build models

— Perform MBSSE

— Support models

Each process is defined in terms of purpose, inputs, outcomes, and supporting tasks. The task descriptions include tool and method guidance and the recommended capabilities needed to successfully implement them. The relationships among the four process groups in this document, the four process groups in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207, and the life cycle model and stages in ISO/IEC/IEEE 24748-1 are described in Annex A.

This document is intended to benefit those who acquire, supply, develop, operate, and maintain MBSSE tools and methods. It can be used by:

a) organizations that need to implement or build models – to understand, adopt, and enact the MBSSE processes, tools, and methods (it also helps to evaluate and select relevant tools and methods based on business- and user-related criteria);

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b) tool vendors who facilitate or leverage MBSSE practices – to provide a set of recommended tool capabilities for planning MBSSE, building models, MBSSE performance, and support.

Systems of systems are considered in this document to benefit from the same processes, methods and tool capabilities as any system.

The relationships between this document and other standards are described in Annex E.

NOTE 1 This document prescribes a way to engineer systems and software based on models thanks to a reference model and four process groups; however, other particular uses of models which are out of the scope of this document are used in "model engineering" in other ways: For example, in model-driven modernization [also called architecture-driven modernization (ADM) in object management group (OMG) terms], models are (automatically) generated from the existing code and artefacts of a running system in order to represent it and then build a new system in a different platform. Another usage scenario of models occurs in what is called "models@runtime" whereby the models are used to change the system and evolve with it; these are normally used in self-adaptive systems to achieve the required system self-adaptation features.

NOTE 2 The reference model does not take into account the system evolution (and that of its related models) as a fundamental phase of systems or software engineering in the maintenance and evolution of the system and its models.

NOTE 3 The design within the different domains, for example, mechanical, hydraulics, electrical, electronics, control algorithms, and software, has been performed using model-based techniques for decades. However, each domain uses specialized languages and tool chains for its modelling activities. The guideline to propose how the methods, modelling languages and tools apply in these domains is outside of the scope of this document. However, the interfaces of the engineering models and the system models are crucial and essential for applying MBSSE.

In this document, the following verbal forms are used:

— "shall" indicates a requirement;

— "should" indicates a recommendation;

— "may" indicates a permission;

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Systems and Software engineering — Methods and tools for model-based systems and software engineering

1 Scope

This document deals with the tool capabilities and methods for model-based systems and software engineering (MBSSE). This document:

— specifies a reference model for the overall structure and processes of MBSSE-specific processes, and describes how the components of the reference model fit together;

— specifies interrelationships between the components of the reference model;

— specifies MBSSE-specific processes for model-based systems and software engineering; the processes are described in terms of purpose, inputs, outcomes and tasks;

— specifies methods to support the defined tasks of each process;

— specifies tool capabilities to automate or semi-automate tasks or methods.

This document does not bring any additional life cycle processes for system and software but specifies an MBSSE reference model considered as activities, not only from the life cycle perspectives of systems engineering problem solving and the system-of-interest evolution, but also from the cognitive perspectives of modelling and model management, which can sustain and facilitate the system and software life cycle processes during digital transformation and in the digital age.

The processes defined in this document are applicable for a single project, as well as for an organization performing multiple projects or an enterprise. These processes are applicable for managing and performing the systems and software engineering activities based on models within any stage in the life cycle of a system-of-interest.

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, IEC, and IEEE 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 http://www.electropedia.org

— IEEE Standards Dictionary Online: available at http://dictionary.ieee.org

NOTE For additional terms and definitions in the field of systems and software engineering, see ISO/IEC/IEEE 24765, which is published periodically as a “snapshot” of the SEVOCAB (Systems and Software Engineering Vocabulary) database and is publicly accessible at computer.org/sevocab.

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3.1.1
analytical model
model (3.1.15) that describes mathematical relationships, such as differential equations that support quantifiable analysis about the *system* (3.1.35) parameters

Note 1 to entry: Analytical models can be further classified into dynamic and *static models* (3.1.34).

3.1.2
asset
item, thing, or entity that has potential, or actual value to an organization

Note 1 to entry: Assets can be classified from different perspectives, such as tangible assets, intangible assets; moveable assets, immoveable assets. Intangible assets can be classified into digital assets and non-digital intangible assets.

Note 2 to entry: Cognitive assets refer to intangible assets generated by an organization in the course of its operations. Data, information, knowledge, wisdom, and modelling assets are all belong to cognitive assets..

[SOURCE: ISO/IEC 19770-1:2017, 3.1, modified — The original three notes to entry have been replaced by two new notes to entry.]

3.1.3
capability
ability to do something useful under a particular set of conditions

Note 1 to entry: Generally, different kinds of capabilities exist: organizational capability, *system* (3.1.35) capability, and operational capability. Organizational capabilities relate through the work practices that are adopted by the organizations. New systems (with new or enhanced system capabilities) are developed to enhance enterprise operational capability in response to *stakeholders'* (3.1.32) *concerns* (3.1.5) about a problem situation. Operational capabilities provide operational services that are enabled by system capabilities. These system capabilities are inherent in the system that is conceived, developed, created, and/or operated by an enterprise. Enterprise SE concentrates its efforts on maximizing operational value for various stakeholders, some of whom can be interested in the improvement of some problem situation.

3.1.4
concept of operations
verbal and graphic statement, in broad outline, of an organization's assumptions or intent in regard to an operation or series of operations of new, modified, or existing organizational *systems* (3.1.35)

Note 1 to entry: The concept of operations frequently is embodied in long-range strategic plans and annual operational plans. In the latter case, the concept of operations in the plan covers a series of connected operations to be carried out simultaneously or in succession to achieve an organizational performance objective. See also *operational concept* (3.1.24).

Note 2 to entry: The concept of operations provides the basis for bounding the operating space, system capabilities, interfaces, and operating environment.

[SOURCE: ISO/IEC/IEEE 15288:2023, 3.9]

3.1.5
concern
matter of interest or importance to a *stakeholder* (3.1.32)

EXAMPLE Affordability, agility, availability, dependability, flexibility, maintainability, *reliability* (3.1.27), *resilience* (3.1.28), usability and viability are examples of concerns. Survivability, depletion, degradation, loss, obsolescence are examples of concerns. The PESTEL mnemonic is a reminder of possible areas of concern: political, economic, social, technological, environmental, and legal.

[SOURCE: ISO/IEC/IEEE 42020:2019, 3.8]

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3.1.6
descriptive model
model (3.1.15) that shows an interconnected set of *model elements* (3.1.19) which represent key *system* (3.1.35) aspects including its structure, behaviour, parametric, and requirements

Note 1 to entry: Descriptive models are complementary to analysis and design models of a system.

3.1.7
discipline-specific model
representation of a *system* (3.1.35), or system elements from the perspective of a discipline addressing domain-specific *concerns* (3.1.5) where the *model elements* (3.1.19) come from a specific discipline

3.1.8
maturity
degree to which a *system* (3.1.35), product, or component meets needs for *reliability* (3.1.27) under normal operation

Note 1 to entry: The degree of maturity of a system, product or component can be associated with trust in, and good knowledge of, the behaviour of the system.

Note 2 to entry: The system, product or component is considered immature if there are still flaws or missing parts that prevent users from benefitting from the item. The item is considered mature if there are no flaws or missing parts that prevent users from benefitting from the item.

[SOURCE: ISO/IEC 25010:2011, 4.2.5.1, modified — The original note to entry has been replaced by two new notes to entry.]

3.1.9
maturity level
degree of achievement to which all goals have been attained

3.1.10
measure of effectiveness
MOE
operational measure of success that is closely related to the achievement of the operational objective being evaluated in the intended operational environment under a specified set of conditions

[SOURCE: ISO/IEC/IEEE 24748-4:2016, 4.7]

3.1.11
measure of performance
MOP
engineering parameter that provides critical performance requirements to satisfy a *measure of effectiveness (MOE)* (3.1.10)

Note 1 to entry: An MOP typically characterizes physical or functional attributes relating to the *system* (3.1.35) operation.

[SOURCE: ISO/IEC/IEEE 24748-4:2016, 4.8]

3.1.12
meta-model
special kind of model that specifies the abstract syntax of a modelling language

Note 1 to entry: The typical role of a meta-model is to define the semantics for how *model elements* (3.1.19) in a *model* (3.1.15) get instantiated. A model typically contains model elements. These are created by instantiating model elements from a meta-model (i.e. meta-model elements).

[SOURCE: ISO/IEC 19506:2012 Clause 4]

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3.1.13
mission
important operational job or duty assigned to a *resource* (3.1.29) or a group of resources or certain groups of people

Note 1 to entry: A resource can be a human resource or a technical resource including *systems* (3.1.35) and products.

3.1.14
mode
definition of the expected behaviour of the *system* (3.1.35) (or of its actors, or of its components) in situations foreseen at design time

Note 1 to entry: Each mode is mainly characterized by the expected functional content of the system in this mode. A mode can reflect various concepts, such as:

— *phases* (3.1.25) of a *mission* (3.1.13) or of a flight for example (taxiing, taking-off, cruising, landing, etc.);

— specific required functioning of the system under certain conditions (connected, autonomous, etc.);

— specific conditions where the system is used; test, training, maintenance, etc.

The transition from one mode to another is in general the result of a decision, such as a change in the way the system operates, in order to adapt to new needs, or new contexts; it is therefore conditioned by the choices of the system, its users, or of external actors.

3.1.15
model
abstract representation of an entity or collection of entities that provides the ability to portray, understand or predict the properties or characteristics of the entity or collection under conditions or situations of interest

Note 1 to entry: A model can use a formalism that could be based on mathematical or scientific principles and concepts. A model can be generated using an established meta-model. Meta-models are often used to facilitate development of accurate, complete, consistent and understandable models.

Note 2 to entry: A model can be used to construct or express architecture views of the entity. *Descriptive models* (3.1.6) and analytic models are two kinds of models. A model should be governed by a model kind in accordance with ISO/IEC/IEEE 42010.

Note 3 to entry: A reference model can be used to capture a general case that is used as the basis for creating special case models for particular conditions or situations. A reference model can be used to encourage and enforce uniformity of architectures and architecture elements.

Note 4 to entry: The model can be an architecture model, architecture entity model, concept model or reference model, as the case may be.

Note 5 to entry: A physical model is a concrete representation that is distinguished from the mathematical and logical models, both of which are more abstract representations of the *system* (3.1.35). The abstract model can be further classified as descriptive (similar to logical) or analytical (similar to mathematical).

Note 6 to entry: (modelling and simulation) An approximation, representation, or idealization of selected aspects of the structure, behaviour, operation, or other characteristics of a real-world process, concept, or system. Models can have other models as components (Authoritative Dictionary of IEEE Standards Terms).

Note 7 to entry: An example of classification of models and relationships in MBSSE is given (see Annex C).

[SOURCE: ISO/IEC/IEEE 42020:2019, 3.13, modified — notes 5, 6 and 7 to entry have been added.]

3.1.16
model-based systems and software engineering
MBSSE
formalized applications of modelling to support *systems* (3.1.35) and software engineering

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3.1.17
model baseline
immutable set of *model configuration items* (3.1.18) with their associated versions and variants

3.1.18
model configuration item
MCI
logical part of the *model* (3.1.15) that is maintained in a controlled fashion, having a trackable revision history

— Model (what is developed within a particular project)

— Each main package under the model root

— Catalogues which can be reusable as Libraries (e.g. Functions, Services, Measurements)

Note 1 to entry: A model as well as any *model element* (3.1.19) and its references can be part of a MCI. A MCI can be defined in different granularities, from a set of model elements, to the entire model. MCIs are managed to maintain the integrity of the models.

3.1.19
model element
atomic (elementary) item that represents an individual component, action, *state* (3.1.33), message, property, relationship, or another item that describes the composition, characteristics, or behaviour of a *system* (3.1.35)

3.1.20
model element library
set or catalogue of non-modifiable *model elements* (3.1.19) usable within any project, packaged in a single artefact

3.1.21
model pattern
general, reusable *model* (3.1.15) or model part that can be used as a solution to a commonly occurring problem within a given context in *system* (3.1.35) or software design

3.1.22
model repository
means to store different *models* (3.1.15) at different levels of abstraction and to facilitate understanding and cooperation between *stakeholders* (3.1.32) and practitioners at different levels

[SOURCE: Adapted from TOGAF 9.2 (The Open Group Architecture Framework)]

3.1.23
ontology
logical structure of the terms used to describe a domain of knowledge, including both the definitions of the applicable terms and their relationships

[SOURCE: ISO/IEC/IEEE 24765:2017, 3.2691]

3.1.24
operational concept
verbal and graphic statement of an organization's assumptions or intent in regard to an operation or series of operations of a specific *system* (3.1.35) or a related set of specific new, existing or modified systems

Note 1 to entry: The operational concept is designed to give an overall picture of the operations using one or more specific systems, or set of related systems, in the organization's operational environment from the users' and operators' perspectives. See also *concept of operations* (3.1.4).

Note 2 to entry: The operational concept is about systems, while a concept of operations typically refers to organizations.

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[SOURCE: ISO/IEC/IEEE 15288:2023, 3.23]

3.1.25
phase
period of time in the life cycle during which activities are performed that enable achievement of objectives for that phase

[SOURCE: ISO/IEC/IEEE 42020:2019, 3.15]

3.1.26
reference framework
structure for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment

Note 1 to entry: A reference framework provides a common backplane for consistency, collaboration, sharing, and reuse.

[SOURCE: ISO/IEC 20013:2020, 3.5, modified — The domain "<e-Portfolio>" has been removed; the original note to entry has been replaced by a new one.]

3.1.27
reliability
ability of the *system* (3.1.35) or the component to perform its required functions under stated conditions for a specified period of time.

3.1.28
resilience
ability of the *system* (3.1.35) to deliver required *capability* (3.1.3) in the face of adversity

3.1.29
resource
entity that is utilized or consumed during the execution of a process

EXAMPLE Diverse entities such as funding, personnel, facilities, capital equipment, tools, and utilities such as power, water, fuel and communication infrastructures.

[SOURCE: ISO/IEC/IEEE 12207:2017, modified — "asset" has been replaced by "entity"; note 1 to entry has been removed.]

3.1.30
safety
avoidance of injury or harm through the use or misuse of the *system* (3.1.35)

3.1.31
security
ability of the *system* (3.1.35) to withstand an attack, whether it is an intrusion, interference, or theft

3.1.32
stakeholder
role, position, individual or organization or classes thereof, having an interest, right, share, claim in an entity or its possession of characteristics that meets their needs and expectations

EXAMPLE End users, operators, acquirers, owners, suppliers, architects, developers, builders, maintainers, regulators, taxpayers, certifying agencies, and markets

Note 1 to entry: Some stakeholders can have interests that oppose each other, or oppose the *system* (3.1.35).

[SOURCE: ISO/IEC/IEEE 42020:2019, modified — "or classes thereof" has been added; "a right, share, claim or other interest" has been changed to "an interest, right, share, claim"; "architecture entity" and "architecture" have been replaced by "entity" and "possession of characteristics" respectively: "reflects" has been replaced by "meets"; EXAMPLE and note 1 to entry have been added.]

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3.1.33
state
condition that characterizes a *system* (3.1.35), system element, function, or other entity at a point in time

[SOURCE: ISO/IEC/IEEE 29148:2018, 3.1.30, modified — "the behaviour of a function, subfunction or element" has been replaced by "a system, system element, function, or other entity"; note 1 to entry has been removed.]

3.1.34
static model
analytical model (3.1.1) of a *system* (3.1.35) in which there is no change

EXAMPLE A scale model of a bridge, studied for its appearance rather than for its performance under varying loads.

[SOURCE: The Authoritative Dictionary of IEEE Standards Terms]

3.1.35
system
arrangement of parts or elements that together exhibit a stated behaviour or meaning that the individual constituents do not

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.

[SOURCE: ISO/IEC/IEEE 15288:2023, 3.46]

3.1.36
system element
discrete part of a *system* (3.1.35) that can be implemented to fulfil specified requirements

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

[SOURCE: ISO/IEC/IEEE 15288:2023, 3.47]

3.1.37
system-of-interest
system (3.1.35) whose life cycle is under consideration

[SOURCE: ISO/IEC/IEEE 15288:2023, 3.48, modified — The abbreviated term "SoI" has been removed.]

3.1.38
technology map
outline of required and anticipated changes in technologies, with expected dates, which will enable achievement or transformation of a *system* (3.1.35)

[SOURCE: ISO/IEC 26560:2019, 3.6, modified — "product or product family" has been replaced by "system".]

3.1.39
use case
description of the behavioural requirements of a *system* (3.1.35) and its interaction with a user

[SOURCE: ISO/IEC/IEEE 26515:2018, 3.15, modified — Note 1 to entry has been removed.]

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3.1.40
viewpoint
set of conventions for the creation, interpretation and use of a *model* (3.1.15) view to frame one or more *concerns* (3.1.5)

[SOURCE: ISO/IEC/IEEE 42010:2022, 3.8, modified — The term has been changed from "architecture viewpoint" to "viewpoint"; "an architecture view" has been replaced by "a model view"; notes to entry have been removed.]

3.2 Abbreviated terms

BOM	bill of material
BPMN	business process model and notation
CI	configuration item
CIR	configuration item record
COTS	commercial-off-the-shelf
CPU	central processing unit
CRUD	create, read, update, and delete
CSA	configuration status accounting
CV	curriculum vitae
DBMS	database management systems
DIKW	data information knowledge wisdom
FAST	function analysis system technique
FFBD	functional flow block diagram
FMEA	failure mode and effects analysis
FTA	fault tree analysis
HFE	human factors engineering
HLA	high level architecture
ICD	interface control document
ILS	integrated logistics support
IPR	intellectual property rights
IV and V	integration verification and validation
KSA	knowledge, skills and abilities
MBSA	model-based safety assessment
MBSSE	model-based systems and software engineering
MCI	model configuration item

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MDD	model-driven design
MOE	measure of effectiveness
MOP	measure of performance
OOSEM	object oriented systems engineering method
OPM	object-process methodology
PBS	product breakdown structure
RAMT	reliability availability maintainability testability
SBS	system breakdown structure
SE	systems engineering
SSE	systems and software engineering
SysML	systems modelling language
UML	unified modelling language

4 Conformance

4.1 Intended usage

The requirements in this document are contained in Clauses 5, 6, 7, 8 and 9. This document provides requirements for a number of processes, tasks, methods and tool capabilities for MBSSE suitable for usage during the system and software engineering processes, activities and tasks at all levels of its hierarchy from system-of-systems to system element and throughout all stages of its life cycle. It is recognized that particular projects or organizations may not need to use all of the processes provided by this document. Therefore, implementation of this document typically involves selecting and declaring a set of processes suitable to the organization or project. There are two ways that an implementation can be claimed to conform to the provisions of this document – full conformance and tailored conformance.

There are two criteria for claiming full conformance. Achieving either criterion suffices for conformance, although the chosen criterion (or criteria) shall be stated in the claim. Claiming "full conformance to tasks" asserts that all of the requirements of the tasks, methods and tool capabilities of the declared set of processes are achieved. Alternatively, claiming "full conformance to outcomes" asserts that all of the required outcomes of the declared set of processes are achieved. Full conformance to outcomes permits greater freedom in the implementation of conforming processes and can be useful for implementing processes to be used in the context of an innovative life cycle model.

NOTE 1 Options for conformance are provided for needed flexibility in the application of this document. Each process has a set of objectives (phrased as "outcomes") and a set of tasks, methods and tool capabilities that represent one way to achieve the objectives.

NOTE 2 Users who implement the tasks, methods and tool capabilities of the declared set of processes can assert full conformance to tasks of the selected processes. Some users, however, can have innovative process variants that achieve the objectives (i.e. the outcomes) of the declared set of processes without implementing all of the tasks, methods and tool capabilities. These users can assert full conformance to the outcomes of the declared set of processes. The two criteria – conformance to task and conformance to outcome – are necessarily not equivalent since specific performance of tasks, methods and tool capabilities can require, in some cases, a higher level of capability than just the achievement of outcomes.

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NOTE 3 When this document is used to help develop an agreement between an acquirer and a supplier, clauses of this document can be selected for incorporation in the agreement with or without modification. In this case, it is more appropriate for the acquirer and supplier to claim compliance with the agreement than conformance with this document.

4.2 Full conformance

4.2.1 Full conformance to outcomes

A claim of full conformance declares the set of processes for which conformance is claimed. Full conformance to outcomes is achieved by demonstrating that all of the outcomes of the declared set of processes have been achieved. In this situation, the provisions for tasks, methods and tool capabilities of the declared set of processes are guidance rather than requirements, regardless of the verb form that is used in the provision.

One intended use of this document is to facilitate process assessment and improvement. For this purpose, the objectives of each process are written in the form of 'outcomes' compatible with the provisions of ISO/IEC 33002. That standard provides for the assessment of the processes of this document, providing a basis for improvement. Users intending process assessment and improvement may use the process outcomes written in this document as the "process reference model" required by ISO/IEC 33002.

4.2.2 Full conformance to tasks

A claim of full conformance declares the set of processes for which conformance is claimed. Full conformance to tasks is achieved by demonstrating that all of the requirements of the tasks, methods and tool capabilities of the declared set of processes have been achieved. In this situation, the provisions for the outcomes of the declared set of processes are guidance rather than requirements, regardless of the verb form that is used in the provision.

NOTE A claim of full conformance to tasks can be appropriate in contractual situations where an acquirer or a regulator requires detailed understanding of the suppliers' processes.

4.3 Tailored conformance

When this document is used as a basis for establishing a set of processes that do not qualify for full conformance, the clauses of this document are selected or modified. The tailored text, for which tailored conformance is claimed, is declared. Tailored conformance is achieved by demonstrating that the outcomes, tasks, methods and tool capabilities, as tailored, have been achieved.

5 MBSSE reference model

5.1 Overview

The MBSSE reference model, as shown in Figure 1, specifies MBSSE processes structured into four process groups:

— plan MBSSE;

— build Models;

— perform MBSSE;

— support Models.

The rest of this document describes tasks, methods and tools in terms of the process groups and MBSSE-specific processes defined in the reference model. Annex D describes the key roles of model-based systems and software engineering.

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The MBSSE reference model divides each process group into MBSSE-specific process and describes each process in terms of the following attributes:

— name of the process;

— purpose of the process;

— inputs to produce outcomes;

— process outcomes;

— tasks to achieve the outcomes;

— method and tool capabilities for performing tasks effectively and efficiently.

Method capability shall be understood as an ability to implement tasks in a systematic or established fashion.

The method in this document:

— reduces time and effort when conducting impact analyses and trade studies;

— implements administrative and support task that is quite different from modelling methods.

NOTE See ISO/IEC/IEEE 24774 for further guidance on specification for process description.

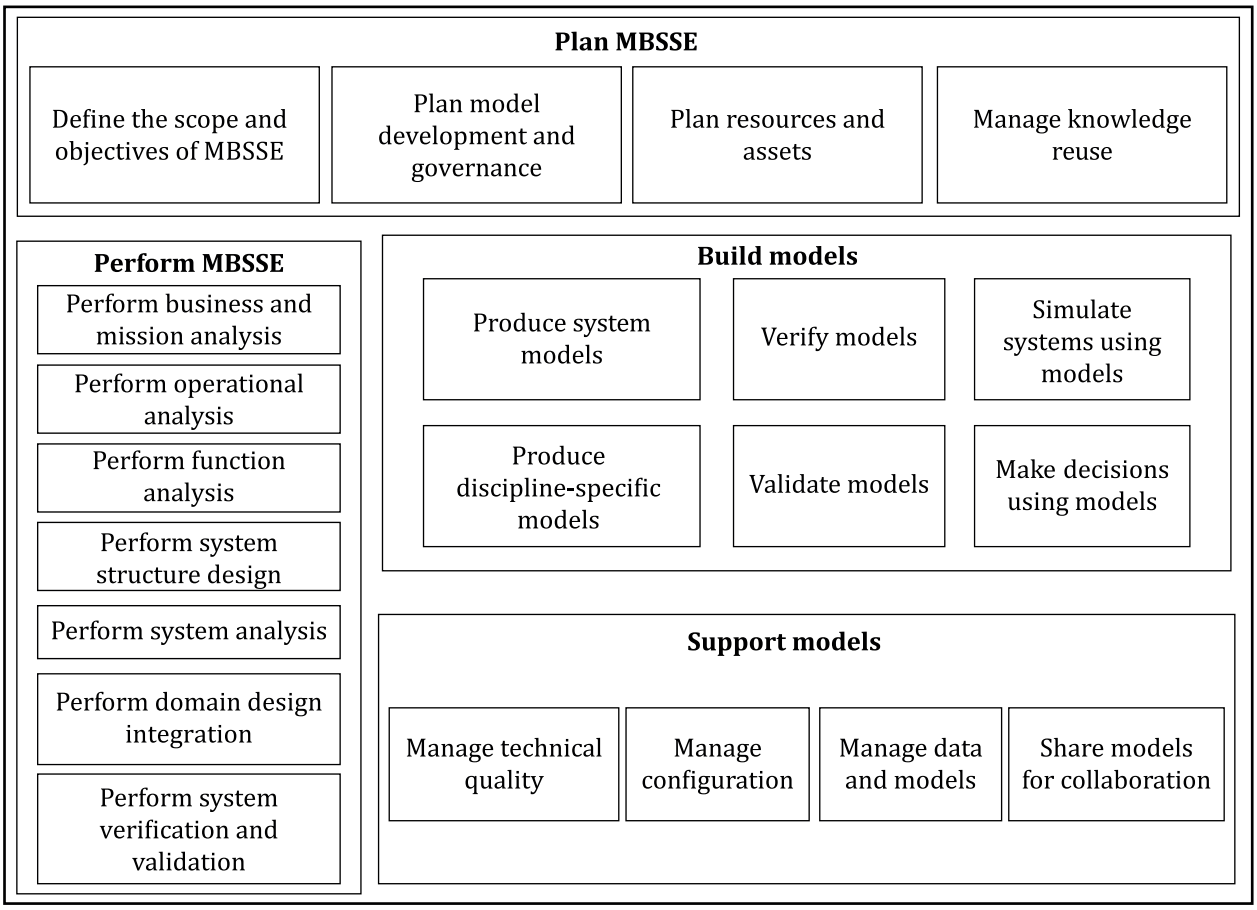

Figure 1 — MBSSE Reference model

The first group, "Plan MBSSE" identifies processes required as prerequisites for modelling. Any MBSSE deployment shall go through these processes. "Plan MBSSE" processes are performed at the beginning

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of the systems and software modelling life cycle. The scope and objectives help select systems and software engineering concerns to be addressed.

The "Plan MBSSE" process group identifies processes dedicated to the model development organization that may be considered necessary for each specific modelling project or either independent of any specific modelling effort (e.g. plan model development and governance, or plan resources and assets) and in this case, the associated tasks are non-recurring, or not necessary for each project.

The other two main process groups, "Build models" and "Support models" apply to any specific MBSSE process defined in the "Perform MBSSE" group. "Build Models" processes are core-modelling processes and help ensure consistency in the model repository. "Support models" processes deal with technical data and are performed during the whole life cycle.

The "Perform MBSSE" processes included in the MBSSE management plan should include the systems engineering (SE) concerns identified during the "Plan MBSSE" processes. These processes specify which kind of models are to be produced and use all the other processes described within three main process groups.

This MBSSE reference model aims to support iterative workflows, enabling several iterations between the processes of different groups, to progressively reach adequate MBSSE definition according to defined objectives and strategy.

The relationships among these process groups are presented by Figure 2.

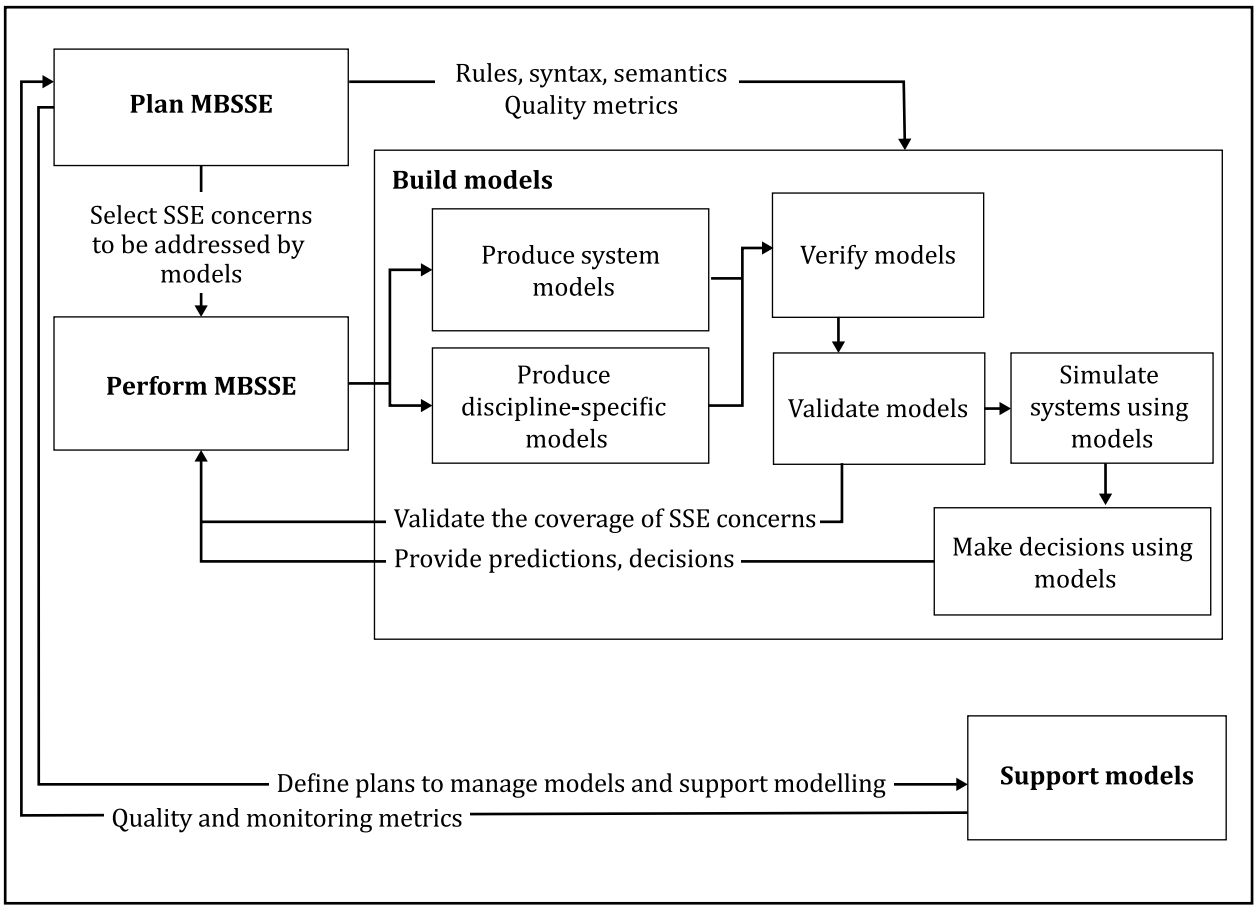

Figure 2 — The relationships among MBSSE process groups and build models processes

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5.2 Build models processes and data-information-knowledge-wisdom (DIKW)

The primary objective is building useful models in an effective and collaborative way. The core modelling activities can be put in perspective through the lenses of the data-information-knowledge-wisdom (DIKW) (See Reference [39]) pyramid:

— producing models makes system engineering data useful by transforming them to shareable information and knowledge;

— verifying and validating models increases the confidence and the accuracy of the knowledge gained;

— analysing and simulating systems using models allows us to predict the future correctly, not only by detecting and understanding patterns but also deeply comprehending the "why" behind those patterns.

The relationships among the build models processes and the data-information-knowledge-wisdom pyramid are presented by the Figure 3;

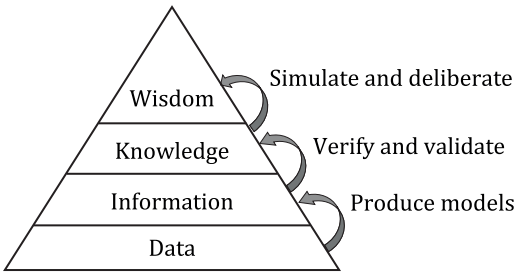

Figure 3 — Build models processes and data-information-knowledge-wisdom (DIKW) pyramid

Figure A.2 provides an example of a cognition dimension based on the DIKW pyramid.

6 Plan MBSSE

6.1 General

The plan MBSSE process group gathers MBSSE-enabling prerequisites, contributing to the effectiveness and efficiency of the approach both within the project and at the enterprise level. It encompasses assessing and scoping, planning, and technical management (setting up the MBSSE approach) along with resources, knowledge, and knowledge management activities (for the mid-term and long-term perspectives).

As the MBSSE management plan has to be provided, for practical reasons, it may be included and described in the systems engineering management plan instead of producing a separate MBSSE management plan.

Plan MBSSE includes the following processes and the tools and methods that support them:

— define the scope and objectives of MBSSE;

— plan model development and governance;

— plan resources and assets;

— manage knowledge reuse.

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6.2 Define the scope and objectives of MBSSE

6.2.1 Principal constituents

6.2.1.1 Purpose

This process defines the scope and objectives of MBSSE and is expected to increase the value added by performing MBSSE. Tasks included in this process identify system or software engineering concerns to be addressed and the depth and breadth of models to be produced.

NOTE 1 It is important to decide on the objectives and on the scope of modelling: the granularity, where to stop, the interoperability constraints, the synchronization with the other MBSSE models or other MBSA and the expected sequences of (re)synchronization.

NOTE 2 The MBSA approach is defined as abstracting a physical model into a formal model consisting of the failure behaviour of the system and its' components. The main physical model can be extended or an exclusive failure model can be used.

6.2.1.2 Inputs

The following inputs should be available to perform the 'Define the scope and objectives of MBSSE' process:

a) stakeholder needs, requirements, concerns and expectations, and expected model usage;

b) models of interest; that will need to be created and that already exist such as the model library(ies);

c) system and software requirements related to specific topics (e.g. functional, non-functional, integration, development, production, procurement, costs, delays, logistics, knowledge, skills and abilities (KSA), etc.) into which the MBSSE helps gain insight;

d) quality and modelling life cycle monitoring objectives (expected measures and indicators, expected periodicity);

e) overall strategic goals of the entity (program, project, product, company);

f) business data model (meta model) to assess the candidate modelling methods and tools;

g) available MBSSE methodologies; some parts of a methodology can be used as applicable to the MBSSE context and expectations;

h) available modelling languages, with their applicable domains;

i) available modelling tools for supporting:

   1) MBSSE methodology and modelling conventions;

   2) interoperability with other engineering tools (e.g. for requirements management, traceability, and so on) and environments.

6.2.1.3 Outcomes

The following outcomes shall be achieved as a result of the successful implementation of the 'define the scope and objective of MBSSE' process.

a) Knowledge on the context of the system-of-interest, and current MBSSE capability of the project realizing system (e.g. stakeholders KSA for model understanding, production and review) is characterized.

b) MBSSE objectives and strategies are established.

c) Domain ontologies, required perspectives, required models and views and their levels are defined.

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d) Quality and modelling life cycle monitoring objectives and strategies are established.

NOTE Knowledge can be understood (including but not limited to) as a set of quantifiable items such as constraints list, capability descriptions, data fidelity descriptions, model metrics, etc.

6.2.1.4 Tasks

The organization shall implement the following tasks with respect to the 'define the scope and objectives of MBSSE' process.

— Establish MBSSE goals and measures for the successful achievement of the entity level (program, project, product, company) goals.

— Specify the key elements of the MBSSE approach to define the most suitable MBSSE enablers to achieve the defined goals.

6.2.2 Establish MBSSE goals and measures

The goal of this task is to define and measure the MBSSE goals and strategies contributing to the successful achievement of the goals of a program or project or the organization.

a) A method supporting this task should contain the following capabilities:

   1) assessing the current MBSSE capability within the entity (program, project, product, company): this assessment has an effect in some MBSSE goals;

   2) defining collaboratively the MBSSE Objectives, progress measures, strategies, key drivers and perspectives;

   3) defining the target usages and types of users or consumers (i.e. knowledge sharing, communication, semi-formal or formal description, artefacts generation, etc.).

b) Management tool capabilities should support establishing MBSSE management goals by allowing the user to do the following:

   1) assess and report current MBSSE capability;

   2) access MBSSE goals and the program or project or organizational level plans;

   3) communicate the MBSSE management goals and strategies with key stakeholders by supporting channels and implemented mechanisms.

6.2.3 Specify the key elements of the MBSSE approach

This task defines the key elements of the MBSSE approach adapted to the context and goals.

a) The method should provide the following capabilities to define the key elements:

   1) establishing and maintaining the MBSSE concepts and ontologies;

   2) defining the languages (e.g. usage of domain-specific languages or universal languages);

   3) defining the usage of meta-models (e.g. fixed or evolving);

   4) identifying and analysing the risks mitigation means;

   5) establishing that the model structure conforms to an appropriate ontology according to the target usages and users; model structure is defined in terms of parts such as sections, perspectives, layers, abstraction layers, sub-models;

   6) setting the expected level of representativeness of each model;

   7) defining model integration, verification and consistency strategies;

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8) identifying the different analyses and simulations that are to be conducted with those models;

9) defining the key drivers for MBSSE to tailor or define the detailed activities.

b) Tool capabilities should support defining key elements for MBSSE goals by allowing the user to do the following:

1) share the MBSSE concepts, ontologies, languages, meta-models with the relevant organization units and participants;

2) access MBSSE key element related artefacts produced during MBSSE governance;

3) share risk sources;

4) accumulate historical data for capturing risks;

5) identify potential risks and opportunities associated with key elements.

6.3 Plan model development and governance

6.3.1 Principal constituents

6.3.1.1 Purpose

The purpose of this process is to develop an MBSSE model strategy, schedules and procedures for model building, model reviewing, model use, MBSSE risk mitigation, MBSSE benefit tracking and MBSSE governance to achieve the intended benefits.

The model strategy identifies the modelling need according to engineering defined goals: which models, model layers, viewpoints, model interactions are necessary for who.

NOTE The outcomes of this process can be captured in a development or management plan for MBSSE.

6.3.1.2 Inputs

The following inputs should be available to the 'plan model development and governance' process:

a) context, goals and measures as well as key elements of the MBSSE approach;

b) stakeholders expectations, needs, requirements and concerns of the modelling life cycle;

c) risk tolerance for stakeholders, which influences the risk mitigation efforts;

d) quality and life cycle monitoring objectives.

6.3.1.3 Outcomes

The following outcomes shall be achieved as a result of the successful implementation of the 'plan model development and governance' process.

a) Model development objectives and strategy are defined.

b) Cost estimates associated with the model development and governance activities.

c) MBSSE activities, risks, inventory, and associated analysis and mitigation means (e.g. KSA, tooling, over or under modelling) are defined.

d) MBSSE risks, issues and changes management and corrective process definition are defined.

e) Model life cycles are defined.

f) A model development schedule tied to program development milestones is defined.

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g) Reviews roadmap is defined.

h) MBSSE guidance is available:

1) methodological - describing the methodology to be applied and providing guidance and rules;

NOTE 1 This methodological guide can also state the justifications of the methodology choice, and of its potential customization.

2) modelling -describing the formalism to be applied, modelling guidance and rules;

NOTE 2 This modelling guide can also state the justifications of the formalism choice, and of its potential customization or profiling.

3) tooling - identifying the modelling tool supporting the defined MBSSE methodology and formalism.

i) Implementations of model verification (i.e. the correctness and completeness of model content), for the target tools and formalisms are established.

j) Implementations of expected model conformance indicators, metrics and success criteria evaluation means, against identified methodological rules, modelling rules and patterns are established.

k) Implementations of expected MBSSE activities progress indicators and metrics are established.

l) MBSSE trainings to disseminate methodology, modelling guidance and tool usage within the teams are managed.

m) Required performance/capability of model development and governance is defined.

n) Improvement either on the established model development and governance goals or on its achievement is performed.

NOTE As an entity evolves over time to include or eliminate common infrastructure services, leased services or other capabilities and functions; the MBSSE planning processes accommodate periodic changes to a management plan.

6.3.1.4 Tasks

The organization shall implement the following tasks with respect to the 'plan model development and governance' process.

— Define the MBSSE deployment procedure.

— Define the MBSSE life cycle flow; this task defines a high-level vision of the life cycle of the models and the development strategy of these models.

— Define the MBSSE methodology to be applied or tailored as appropriate with justification.

— Specify how to manage and control the modelling life cycle process, which identifies key elements, procedures, tools and parameters for assessing the effectiveness of the model management activities and its results. Improvements are identified and their possibilities are validated regarding the management of models activities and its results.

— Document the MBSSE management plan; this task creates and shares the plans.

— Improve model development and governance process continuously.

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6.3.2 Define MBSSE deployment procedure

The goal of this task is to tailor and define MBSSE deployment procedures and to share the defined procedures with key stakeholders.

a) The method should support this task with the following capabilities:

   1) defining MBSSE activities planning (including allocation to resources);

   2) identifying the collaborative engineering interactions with other potential engineering phase, other concurrent engineering activities (e.g. requirements management, change management, version management, integration verification validation management, risk management, safety, security), previous and next engineering phase;

   3) maintaining the consistency of the interfaces with other development tools (e.g. specific engineering disciplines tools);

   4) specifying the constraints due to the runtime platform(s), access and control of access, replication and synchronization, performance (i.e. response times), availability, and backup/recovery; see 8.4.3;

   5) maintaining the consistency of the MBSSE management plan with other potential engineering discipline plans, and systems engineering management plans to facilitate collaborative engineering;

   6) defining monitoring, measuring, and controlling the effectiveness of the MBSSE activities and the associated risks management.

b) Tool capabilities should support defining key procedures for MBSSE management goals by allowing the user to do the following:

   1) access the existing procedures for MBSSE management;

   2) share key procedures with relevant key stakeholders;

   3) integrate and calibrate procedures;

   4) document the defined procedures electronically.

6.3.3 Define the MBSSE life cycle flow

The goal of this task is to define a high-level vision of the life cycle of the models and the development strategy of these models.

This strategic planning:

— should be detailed along the MBSSE life cycle flow;

— serves as an input to the choice of MBSSE methods and formalisms.

a) The method should support the definition of the MBSSE life cycle flow goals with the following capabilities:

   1) defining which models are produced at each stage or phase, and how models are enhanced and updated after creation in successive states and phases;

   2) managing the dependencies between the models produced at different stages of the development;

   3) defining the required maturity of models at each stage of development: the information they are required to carry and the information not required at that time;

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4) defining the competency profiles of the resources needed (human, enablers) to bring the models to the required maturity stage;

5) defining the training, or other development opportunities, to raise the modelling KSA to the required level;

6) defining the maturity milestones of the models;

7) defining the model acquisition milestones (when developed by suppliers).

b) Tool capabilities should support documenting the MBSSE life cycle flow goals by allowing the user to do the following:

1) access a vision of the life cycle of the models and the development strategy;

2) communicate the high-level vision and goals with key stakeholders;

3) share the MBSSE life cycle status and models maturity level with relevant participants.

6.3.4 Define the MBSSE methodology

The goal of this task is to define or tailor the MBSSE methodology.

The MBSSE methodology includes the formalisms to be used for modelling and the tool capabilities.

a) The method should support defining the MBSSE methodology with the following capabilities:

1) defining the key concepts, the traceability between key concepts, the process for modelling those key concepts in order to accomplish stakeholder objectives, and the inputs and outputs of each process;

2) defining the MBSSE methodology, preferably from a set of available candidate methodologies, potentially to be tailored according to the MBSSE context;

3) defining the MBSSE formalism from a set of available candidate formalisms, potentially to be customized or profiled according to the identified methodology and the MBSSE context;

4) documenting and sharing the MBSSE methodological and modelling guides;

5) preparing and delivering the associated training.

b) Tool capabilities should support documenting the MBSSE methodology goals by allowing the user to do the following:

1) access defined MBSSE methodology and its goals;

2) allow customization or profiling according to the MBSSE methodology;

3) help ensure the accuracy and configuration of the information;

4) verify the model meets rules for that diagram type;

5) execute models to ensure they have no logic errors.

6.3.5 Specify how to manage and control the modelling life cycle process

The goal of this task is to prepare means for managing and controlling the modelling life cycle process.

a) The method should support specifying how to manage and control the modelling life cycle process goals with the relevant following capabilities:

1) defining the MBSSE reviews roadmap;

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2) defining the quality and life cycle monitoring elements (i.e. indicators, dashboards, etc.) according to the MBSSE objective;

3) configuring the potential monitoring and reporting tools of the MBSSE model development environment accordingly;

4) configuring the potential change management tools of the MBSSE model development environment, according to the MBSSE domain specificities (i.e. models artefacts types, defect types, etc.);

5) implementing for the target tools and formalisms the model verification and consistency checking rules as specified in the MBSSE modelling guide;

6) implementing the extraction or collection procedures for the expected model conformance and indicators, metrics and success criteria;

7) implementing the extraction or collection procedures for the expected MBSSE activities progress indicators and metrics;

8) institutionalizing sizing parameters and related efforts for the MBSSE activities;

9) proposing potential MBSSE process improvements;

10) periodically producing the quality and life cycle monitoring elements as defined in the MBSSE management plan.

b) Tool capabilities should support specifying how to manage and control the modelling life cycle process goals by allowing the user to do the following:

1) manage the configuration of the information provided by the models and other data elements (see Clause 8 for more details);

2) access historical data related to monitoring and controlling other processes;

3) specify key elements, procedures, tools and parameters using document standards.

6.3.6 Document the MBSSE management plan

The goal of this task is to document the MBSSE management plan, which is initiated during the 'defining scope and objectives of MBSSE' process.

a) The method should support documenting the MBSSE management plan goals with the following capabilities:

1) documenting and sharing the MBSSE management plan;

2) identifying and managing the model development risks and issues;

3) planning model development significant development achievements (e.g. schedule and milestones) for progress monitoring.

b) Tool capabilities should support documenting the MBSSE management plan goals by allowing the user to do the following:

1) write the MBSSE management plan or generate from the repository;

2) review and approve the MBSSE management plan.

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