Chapter 4 – INTRODUCTION TO CONCEPTUAL MODELING: BEST-PRACTICE GUIDANCE

In the previous chapter, we addressed the conduct of MSG-058 and identified significant issues and strategies associated with the accomplishment of the Task Group's effort. In following chapters, we present exposition of best-practice guidance process and product finally developed and recommended to the conceptual modeling practitioner and stakeholder community for employment. In this Chapter 4, we establish the conditional determinations and findings upon which that operational best-practice is predicated. The discussion following addresses contextual issues of scope and enterprise context, and the appreciation of the stakeholder community whose wants, needs and collaborative participation are necessary for successful conceptual modeling. Foundational and pragmatic ideas related to specialized vocabulary, the complementary dyadic conceptions of representation spaces, and best-practice notational conventions are introduced in anticipation of the use of this terminology and these concepts in the formal prescriptive guidance to follow in Chapters 5 and 6. Finally, we comment on quality attributes of conceptual models in order to emphasize the necessity to verify and validate simulation conceptual models in much the same way as simulation artefacts themselves are verified and validated as a fundamental component of conceptual model quality management.

4.1 CONCEPTUAL MODELING OPERATIONAL SCOPE

While the scope of this guidance is nominally for NATO military modeling and simulation, the approach taken herein is to provide comprehensive guidance that can easily be adapted and tailored to individual enterprises and can be generalized to apply to alternative domains. Likewise, this guidance is intended to be general enough to serve as a foundation for subsequent establishment of industry standards for conceptual model development and life-cycle management activities.

Throughout MSG-058 deliberations, the Task Group found it convenient to keep in mind two contextual perspectives of conceptual modeling and conceptual models – both simple – each suggestive of the place of conceptual models and modeling in simulation life-cycle development paradigms. Such pictorial paradigms served to remind the Group at once of the intended scope of deliberation and of consequent best-practice guidance as well as the context of its analysis and work-products.

Consequently, it may be useful to consider a general case of conceptual modeling as shown in Figure 4-1, to illustrate that any conceptual model of interest may be of a particularly simple or complex domain or problem space, which can also benefit from these best-practices.

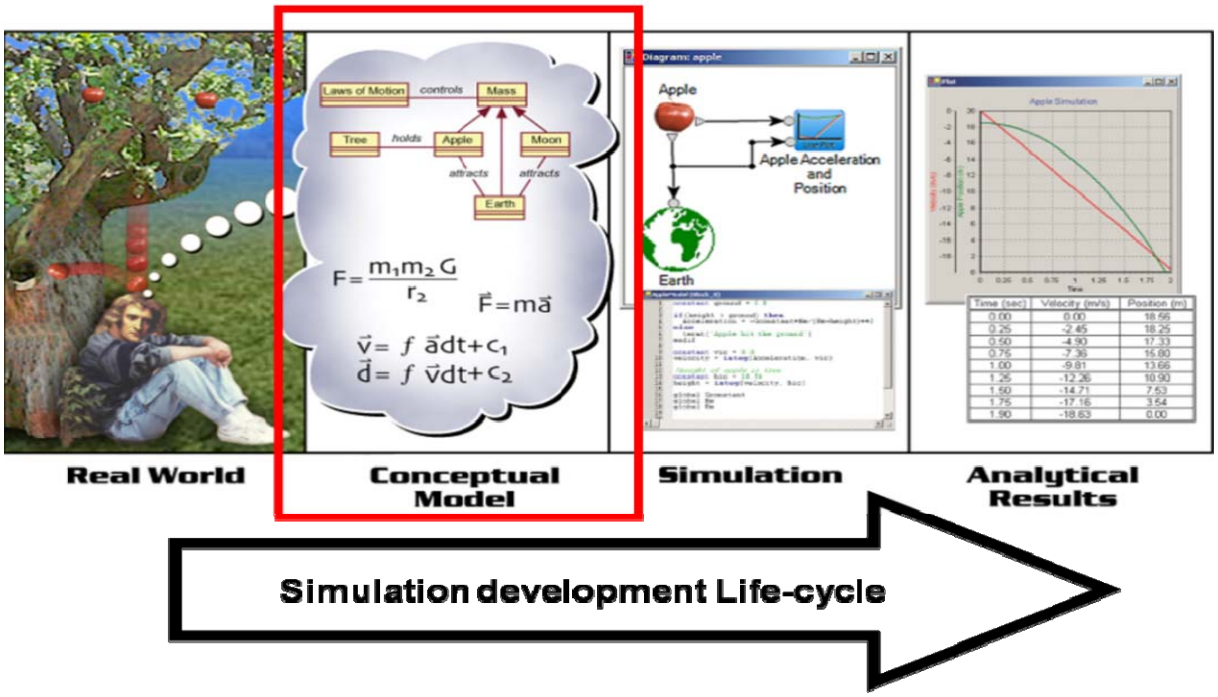

Figure 4-1: Conceptual Model Depicted as Intermediate Artefact Between Real-World or Mission Space Knowledge and Simulation Artefact and as Element in Progressive Simulation Life-Cycle Development Process.

While the application of this guidance is intended to be broad, the scope of this guidance is targeted to the conceptual model development process, and only provides limited best-practices pertaining to the rest of the conceptual model life cycle. And while the development of quality conceptual models enables other life-cycle characteristics such as interoperability and transformation, guidance to execute the additional stages is beyond the scope of this document. Figure 4-2 provides a context for the guidance provided here, as related to the larger conceptual model life cycle.

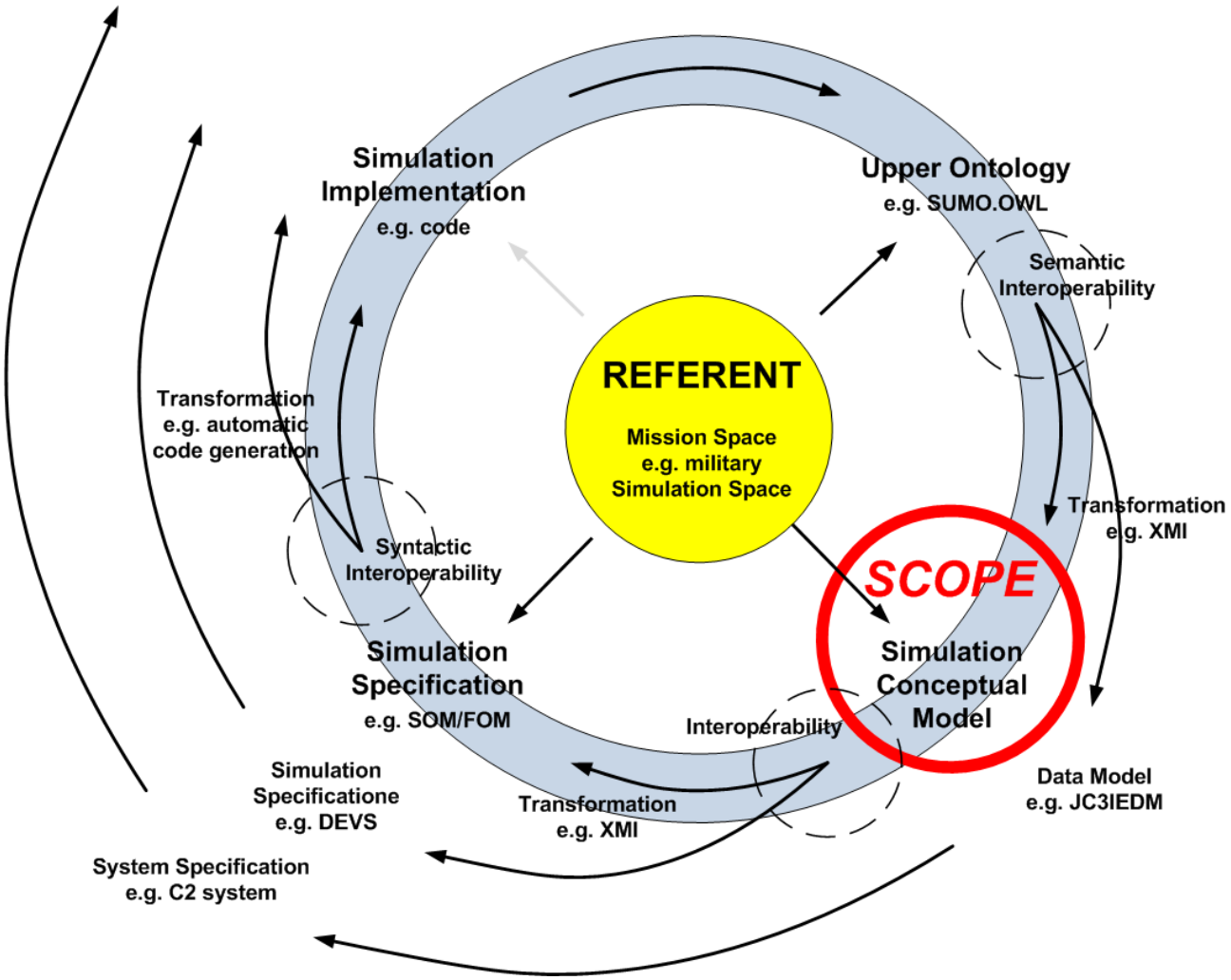

Figure 4-2: The Scope of Best-Practice Guidance in the Conceptual Model Life Cycle.

The approach for explication of this guidance is to discuss the role a conceptual model should have in the M&S development process, propose scope and terms of reference, expand and illustrate new and novel concepts, propose an analytical framework, define a thorough but tailorable process and associated products, and provide Process Activity and product descriptions for reference.

4.2 ENTERPRISE CONTEXT

One particularly significant component of the context of conceptual modeling is the institutional or business practice environment within which the modeling is performed and within which its value is expected to be realized. In the text that follows, we introduce the idea of enterprise context by discussing how modeling and simulation has evolved within the last decades. Next we define ‘enterprise’ and distinguish between ‘local’ operational contexts and enterprise contexts. Several implications that are entailed by enterprise-based conceptual modeling operations, including both:

- The influence of enterprise concepts-of-operations upon conceptual modeling process and the nature of conceptual models themselves; and
- The entailments of conceptual modeling and the use of conceptual model artefacts for the success of the enterprise environment, in which they are contained, will be described.

The very significant perspective of the control of quality of conceptual models over their life-cycle evolution – usually designated verification and validation of the conceptual model – are addressed in a following section in order to address in appropriate detail the specific place of conceptual model quality management in enterprise contexts.

4.2.1 Evolution of Operational Context

Modeling and simulation in general, and conceptual modeling in particular, are being conducted in different environments in recent decades than previously.

Heretofore, M&S (and conceptual modeling) were technical specialties that were conducted by individual staff, largely below the level of visibility of the organization-level management. Conceptual modeling was itself mostly a craft competency; and its conduct was private to the simulation developer or to the small Group of which he was a member. Conceptualization was a personal skill, seldom conducted at even Group level of visibility, and less often documented at all but instead manifest only implicitly in the simulation products produced by individuals or development Groups. Simulation development efforts were modest in size and scope or were organic within one or another user community. Simulations were seldom shared, re-used or operated in combination with other models or simulations; and there was little appetite or motivation for explicit, deliberate, public conceptual modeling practice and products.

More recently, M&S has become a significant component of operations within organizations. Consequently, M&S and their attendant conceptual modeling efforts have become both more expensive, and more critically valuable to the organizations within which they are conducted. Expectation of M&S re-use and interoperability, sensitivity to demonstrated M&S credibility through systematic verification and validation, and the persistence and pervasiveness of use of simulations within and beyond organizational boundaries have made deliberate, public, and accountable M&S practice in enterprise context the norm.

4.2.2 Enterprise Definition

For purposes of this discussion, the following definition is provided:

> ***Enterprise*** *n. – One or more organizations under common control. Generally refers to the broadest scope of organization and operational process relevant to the subject discussion rather than to individual components thereof.*

NATO and national defence establishment M&S communities-of-practice are *de facto* enterprises in this spirit when the investment, development, maintenance, and use of M&S assets are concerned. Naturally, the scope of any particular enterprise environment depends upon the circumstances and particularities of the M&S operation in question; but in most cases, questions of strategic investment in M&S policy, practice and implementation has as its scope the entire NATO community. The fundamental need for successful investment in modeling and simulation within NATO is well documented and broadly recognized. In addition, more than a few efforts have been conducted to assess the then-current state, prevalent need, and recognized gaps of

business practices for M&S, and the deliberate management of M&S investment to achieve necessary and sufficient state of mission capability. Such efforts have included: NATO M&S Conference [1] and Study Group [2] activity; initiatives by other national defence establishments [3]; efforts by professional societies to analyze the mechanisms of M&S cost-effectiveness [4][5][6][7][8]; and academic research efforts [9][10].

Enterprise-level M&S investment requires structure, persistence and common valuation for consistent execution. To paraphrase a quote [11] from the commercial environment:

> *Stand-alone M&S strategies don't work when DoD's enterprise-wide success depends on the collective value created across the organizations that influence the creation and delivery of value derived from investment in M&S. Knowing what to do requires understanding DoD's ecosystem and leadership's role in it.*

This admonition advances the fundamental premise that commercial businesses exist and thrive (or not) within the context of a business environment much larger than exists within the boundaries of an individual firm; and that to succeed, individual firms must learn to recognize and create value within 'the ecosystem' in which they exist. The article defined a 'business ecosystem' as that set of external organizations to which the success of your organization is closely tied, those for which critical dependencies exist. The key to maximizing value on an enterprise level is, as is implied by an 'ecosystem' viewpoint, understanding who shoulders the costs, and who potentially derives value from the allocation of resources to M&S.

4.2.3 Implications of Enterprise Context for Conceptual Modeling Practice

Enterprise level processes and products are required for all components of the M&S life cycle within the organization, but nowhere more than in the area of conceptual modeling.

From the perspective of enterprise operations, several implications follow for conceptual modeling practice. These influences must be reflected in recommended conceptual modeling best-practice, and constitute, in fact, a substantial set of the requirements for such practice. Among the several requirements driven by the expectation that conceptual models will inhabit an enterprise environment are the following:

- **Stakeholder Community** – Conceptual modeling will be conducted and its value recovered in a community or practice commensurate with the scope and diversity of the enterprise participants. Concepts invoked to develop, understand, share, and reuse conceptual model artefacts with confidence, and with reasonable expectation of accruing the benefits of shared investment require that all stakeholder roles be carefully defined and be appreciated as pertaining across the enterprise scope.

- **Process Consistency, Commonality and Tailorability** – Processes comprising the conceptual model best-practice must be appropriate for execution in a NATO-diverse constituency. Best-practice process elements must be sufficiently consistent that participation in conceptual modeling can be extended across any sub-set of the NATO M&S community. Practice commonality must have a similar domain in order that suitable common ground exist from which NATO M&S constituents may fully appreciate both how conceptual models were achieved and what their contents are, once produced. Conceptual modeling processes and products must, nevertheless, be sufficiently tailorable so that they can be socialized by any particular sub-set of the enterprise to which they will particularly pertain – and they must be sufficiently tailorable as to admit the specific referent subject matter, conceptual constructs, and representational schemas as may be elected by one or another sub-set of the stakeholder community.

- **Product Consistency** – Conceptual model product consistency must be sufficient that the library of conceptual models deployed and used within the NATO M&S enterprise are at least evidently

interpretable among stakeholders, and preferably interoperable (to within similarity of mission- and simulation-space referents) across the enterprise. While complete interoperability and exhaustive re-usability are not likely to occur even under the most auspicious circumstances, and while it is certain that no degree of product 'best-practice' results could guarantee such consistency; any element of the prescribed practice that can be established with a view to improving product consistency should be adopted.

- **Product Quality** – Conceptual model product quality across the enterprise is relevant from two complimentary perspectives. On the one hand, consistent quality resulting from the subject guidance is directly correlated to the value of the return on investment in conceptual modeling itself. On the other hand, sufficient and auditably documented product quality across conceptual models will influence greatly both the likelihood of use of the conceptual modeling best-practice guidance and the re-use, sharing, and recovery of utility of the pursuant models themselves.

4.2.4 Consequences of Conceptual Modeling for Enterprise Mission

The use of simulation in military applications such as analysis, acquisition, training and decision support requires that the simulations are fit for use. V&V can be applied to evaluate if this fitness for use is achieved. The quality of the end-product (i.e., the simulation) is, however, largely dependent on the quality of the intermediate products. To be more specific, a large portion of the problems with the end-product come from a poor understanding of the customer's situation which leads to a low quality of the requirements. Explicitly building a conceptual model is one of the ways to improve the quality of the end-product by allowing for a good starting point for its development. In order for the conceptual model to be able to really improve the overall quality, the quality of the conceptual model itself must be sufficiently high. Building the conceptual model is *the* step in simulation development in which the actual modeling takes place. Therefore validation (determining whether the abstractions taken during the modeling are allowed) of the conceptual model against the stakeholders' purpose is important for the simulation's fitness for purpose.

From a project management point of view, the conceptual model is the last step in simulation development where correcting errors, such as having erroneously left out important parts that should be represented in the end-product, is still relatively easy, quick and cheap. If simulation design and implementation starts, correcting mistakes quickly becomes much more costly. Therefore V&V of the conceptual model is an important form of risk mitigation.

The amount of resources put into the V&V effort must be related to the risk (financial risk, loss of lives, etc.) of using a faulty end-product because a faulty conceptual model was used for its development. If almost no consequences exist of using a faulty conceptual model then the V&V effort may be low. If, however, a substantial risk is present, and using M&S results for military application usually has, the V&V effort must be accordingly.

For an enterprise it is advantageous to re-use as much of previous efforts as possible. This means that conceptual models from previous projects should be available for re-use, but it also means that V&V results should be available. One important way of achieving this is to use a set of enterprise-mandated processes and product formats. Then a common approach across projects can be achieved. On enterprise level, a V&V methodology must be chosen that supports this reuse in the sense that the V&V data of previous efforts should be (partially) re-usable.

4.3 CONCEPTUAL MODELING ENTERPRISE STAKEHOLDERS

Stakeholders can be defined as people being affected by a process or product. In this sense conceptual modeling and conceptual models have a number of stakeholders – each with different responsibilities, concerns and interests. They will typically also have different backgrounds and consequentially different perspectives, and therefore often use different "languages" or terminology.

4.3.1 The Importance of Identifying Stakeholders

Explicit identification of stakeholders of the conceptual modeling endeavor will help each stakeholder understand his role in a larger context. It will make him aware of the roles of other stakeholders and thus facilitating necessary communication between stakeholders.

4.3.2 Main Categories of Stakeholders

The primary stakeholder targeted by this guidance is the developer of conceptual models. There are however several other types of stakeholders. These can be referred to by many names. For our purpose we will use the following main categories:

- **Sponsor**: This is a person or organization that sees a need for modeling and simulation in the solving of a problem such as specifying an operational requirement or analyzing a capability. The sponsor will typically initiate and fund a modeling and simulation activity.
- **Producer**: This is a person or organization that will endeavor to satisfy the sponsor's need. The supplier will undertake activities such as project management and development of the conceptual model. This will typically include subject-matter experts providing mission space knowledge and knowledge engineers eliciting, structuring and documenting knowledge.
- **Consumer**: This is a person or organization that will put the conceptual model to use in order to implement an executable model to satisfy the sponsor's needs. The users of the simulation model may also be conceptual model consumers, as they will profit from understanding mission domain concepts and their relationships.

In an organization where conceptual model development is a recurring activity, it will, in the long run, pay to employ a repository containing results from past development efforts. In this approach is chosen, there will be need for a:

- **Custodian**: This is the person or organization that ensures that the repository is maintained and policies adhered to.

In order to ensure the quality of the conceptual model, it is recommended to implement a verification and validation process. This will be carried out by an:

- **Evaluator**: The person/organization that validates the conceptual models.

4.3.3 Use Case Description of a Conceptual Model Development Process

Figure 4-3 shows a high level view of the activities and stakeholders typically involved during a conceptual model development process.

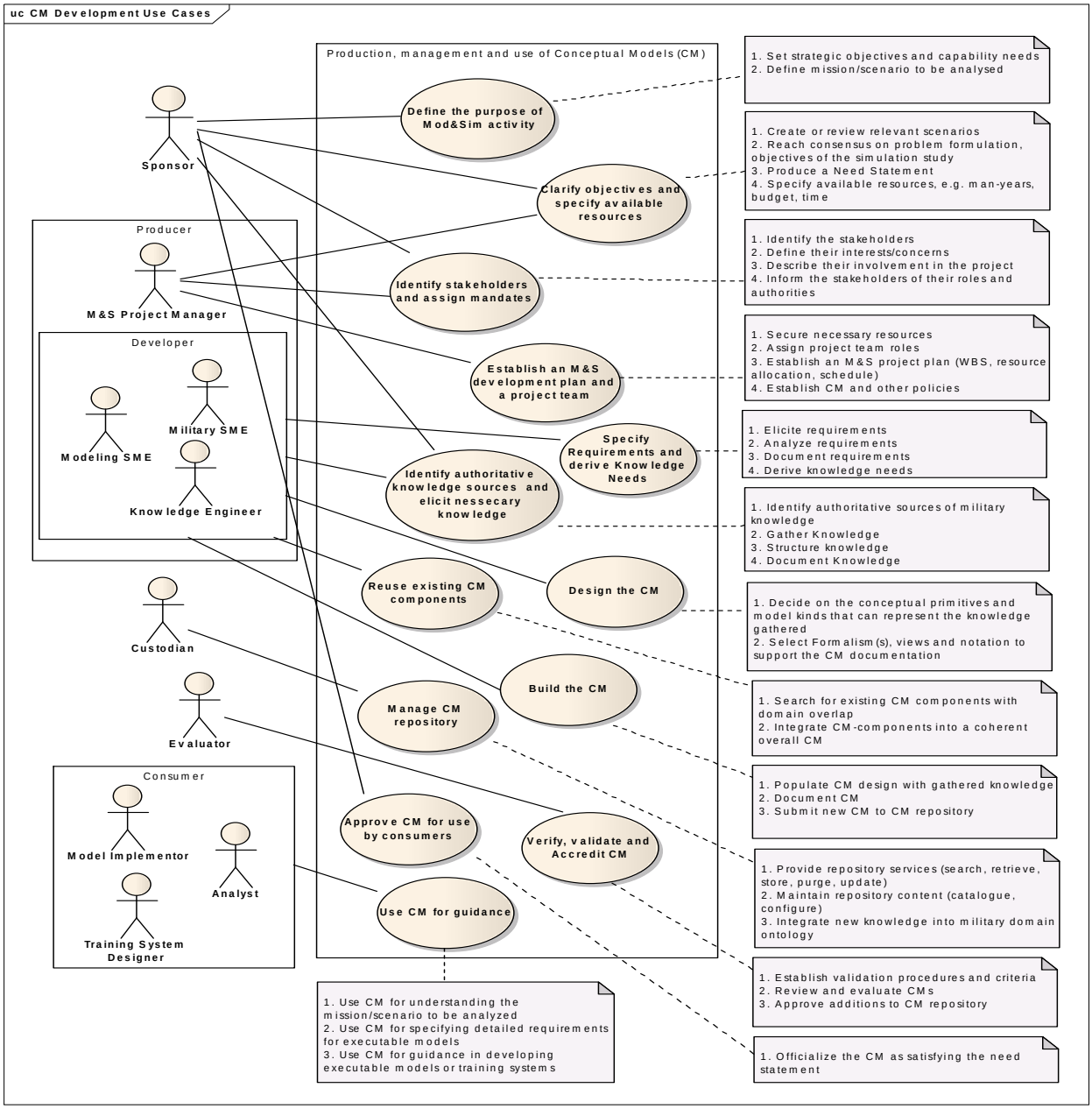

Figure 4-3: High Level Use Case Diagram Illustrating the Main Actors and Interactions During a Conceptual Model Development Process.

4.3.4 Stakeholders Responsibilities

Some of the main concerns of the different stakeholders in the process of conceptual model development and use are summarized in Table 4-1.

Table 4-1: Stakeholders' Concerns.

Stakeholder	Responsibility
Sponsor	• Analysis of combat outcome, system performance, system alternative trade-offs, etc. • Cost-effective training. • Credibility of analysis results. • Making sure the conceptual model represents necessary and sufficient relevant information about operational issues and mission context of interest (correct scope). • Decision-making based on analysis products (introducing a new tactic, procuring a new system, etc.). • Cost of modeling and simulation.
Producer (M&S Project Manager)	• Effective use of allocated resources (e.g., ensuring reuse when appropriate). • Unambiguous communication with customer.
Producer (Knowledge Engineer)	• Understanding of operational issues and mission context. • Translation of operational issues and mission context into a conceptual model. • Unambiguous communication with SMEs and implementers.
Producer (M&S Subject-Matter Expert, Military Subject-Matter Expert)	• Understanding operational issues and mission context. • Provide technical and military know-how at appropriate level of detail.
Consumer (Model Implementer)	• Understanding operational issues and mission context. • Implementation of simulation model. • Verification of simulation model compliance with conceptual model.
Consumer (Analyst)	• Understanding operational issues and mission context. • Producing relevant analysis products.
Consumer (Training System Developer)	• Understanding operational issues and mission context. • Producing adequate training environment.
Custodian	• Provide services for effective reuse of available knowledge and conceptual model components.
Evaluator	• Ensuring validity of conceptual model and compliance with requirements.

4.4 CONCEPTUAL MODEL ATTRIBUTES AND DEFINITIONS

Conceptual modeling has often been practiced as an art form or implied activity in M&S development processes. There was has been little formal structure or definition, and no consistent approach to applying various standards or formalism in previous practice. Conceptual modeling has been defined in several ways in literature, of which copious evidence is provided in Annex K – Bibliography. Most of these definitions are compatible, overlapping, or complimentary, but taken as a whole; they produce considerable ambiguity in regards to the scope of the conceptual modeling process and products. Further, consideration of conceptual modeling in the Military M&S context puts additional constraints and implications on the set of applicable definitions.

4.4.1 Scoping Definitions

Since it is difficult to write a definition of conceptual modeling that is not self-referential, and while Annex J – Lexicon provided a glossary of relevant terms; the following definitions will be used for the purposes of this guidance document:

- A *referent* is a set of fictive or existing systems, entities, phenomena, or processes subjected to modeling and simulation, which a user may want to consider in the context of their own objectives or interest.
- A *model* is a simplified/abstracted representation of a part of reality or a potential reality. It is a physical, mathematical, or otherwise logical representation of a referent of interest.
- A *simulation* is the implementation of a model over time.
- A *concept* is an abstract idea or a mental symbol, typically associated with a corresponding representation in language or symbology, that denotes all of the objects in a given category or class of entities, interactions, phenomena, or relationships between them.
- A conceptual model is a model that abstractly represents a referent.
- An *M&S* conceptual model is a conceptual model intended for realizing a simulation capability.
- A *military M&S* conceptual model is an M&S conceptual model within the military domain.

The relationship between these terms is further illustrated in Table 4-2.

Table 4-2: Relationships Between Defined Terms.

Term	Definition			
	Subject	**Attribute**	**Relationship**	**Object**
Concept	Abstraction	Generalized	Characterizes	Referent
Model	Description	Simplified Explicit	Represents	Referent
Conceptual Model	Model	Abstract	Represents	Referent
Military Conceptual Model	Conceptual Model		Represents	Military Referent
Simulation Conceptual Model	Conceptual Model		Represents Referent in	Simulation
Military-simulation Conceptual Model	Conceptual Model		Represents Military Referent in	Simulation

These basic terms define the content of the conceptual model, which is the set of information that is the collection of abstractions of the represented referents. But it is also necessary to consider the nature of the conceptual model in terms of the characteristics, the composition, and the context of the conceptual model in the relationship of the Conceptual Model Space to the Mission Space and Simulation Space must be defined.

4.4.2 Conceptual Model Characteristics

Any conceptual model will have characteristics of the following categories: Quality Characteristics, Utility Characteristics, Formality Characteristics, and Abstractness Characteristics. Figure 4-4 provides an illustrative list of characteristics in these categories, but is not intended to be exhaustive in its illustration.

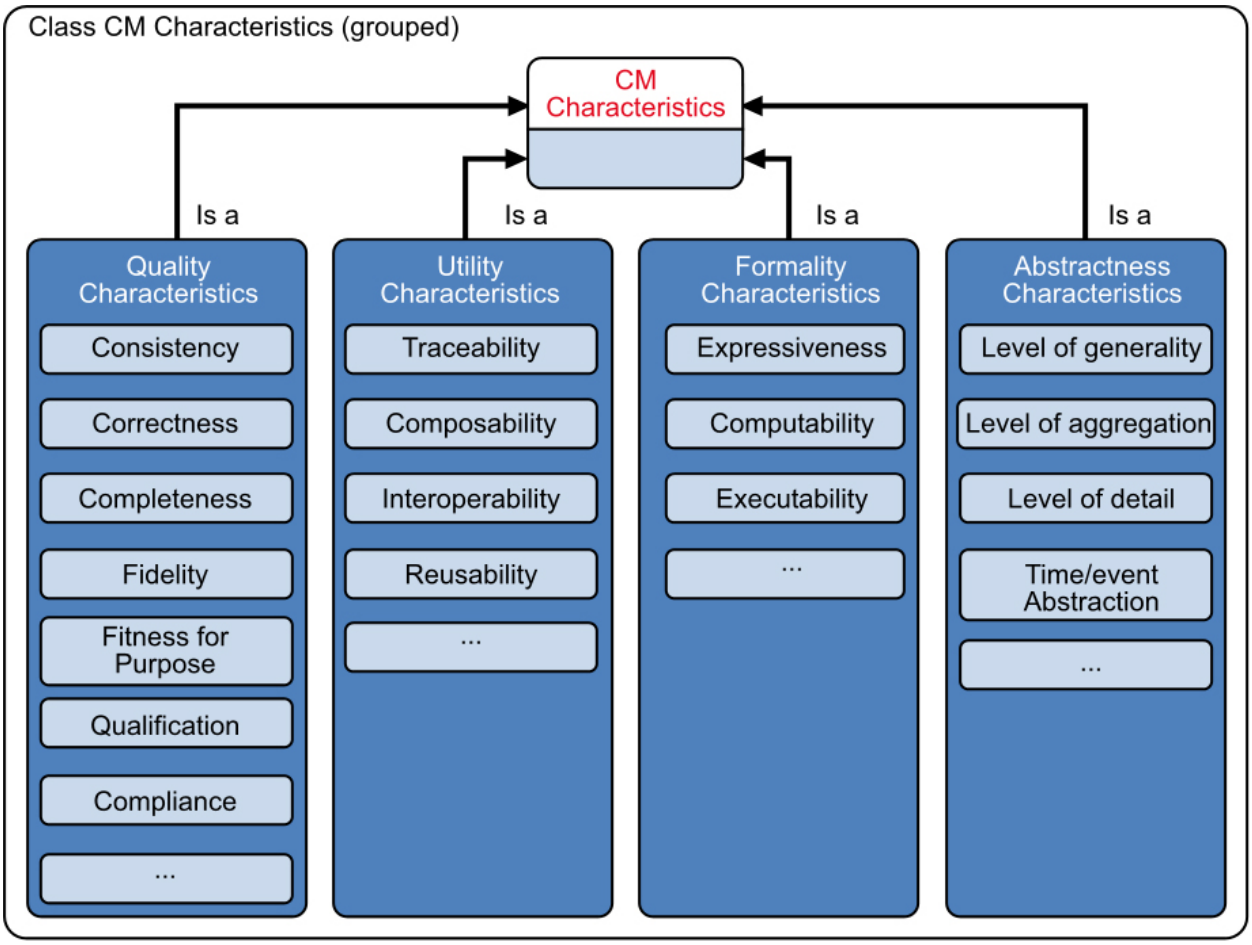

Figure 4-4: Conceptual Model Characteristics.

A practical set of definitions for these illustrative characteristics may be found in the Lexicon to this document. Definitions of the four categories are as follows:

- *Quality* is a totality of features and characteristics of a conceptual model that bear on its ability to satisfy stated or implied needs. It measures how "good" a conceptual model might be for various purposes.
- *Utility* is the property of the relative satisfaction gained by the use of a system expressed in terms of a value and cost. It measures the kinds of purposes for which the conceptual model might provide value.
- *Formality* is compliance with formal or conventional rules.
- *Abstractness* relates to the way the conceptual model abstracts or symbolizes the referent.

These characteristics are inherent to the conceptual model, and are not necessarily explicitly defined, measured, or in some cases even known. But it is this set of characteristics that will determine the use of the conceptual model by the Stakeholders, the re-use of the conceptual model by future Stakeholders, and the V&V Status throughout the conceptual model development and life cycle.

4.4.3 Conceptual Model

Most importantly, the conceptual model has content. And this content is composed, structured, and viewed as shown in Figure 4-5. This figure shows that a conceptual model is composed of Model Kinds, which are similarly composed of Conceptual Primitives. Model kinds use Formalism, and Conceptual Primitives are specified by that Formalism. Notation supports the Formalism and realizes Views, and the Views allow the conceptual model to be presented in appropriate manners to respective Stakeholders.

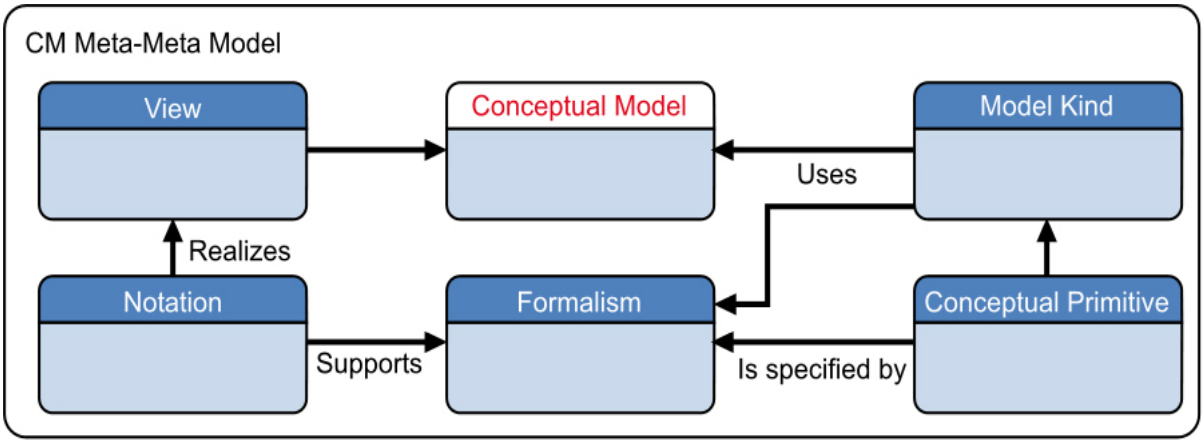

Figure 4-5: Conceptual Model Composition.

These composition terms have standard definitions, per Webster:

- *Primitive* – "an elemental component from which higher-order composites may be composed. Commonly applied to conceptual model constructs".
- *Model Kind* – "a type or alternative classes of models".
- *Formalism* – "the practice or the doctrine of strict adherence to prescribed or external forms".
- *Notation* – "a system of characters, symbols, or abbreviated expressions used in an art or science or in mathematics or logic to express technical facts or quantities".
- *View* – Explication of a subject model-kind instance created using one or another selected notation.

The following are illustrative lists of these composition elements. These lists are not intended to be exhaustive in their illustration.

- Example Primitives: Entity, object, signal, time, event, attribute, message, state, etc.
- Example Model Kinds: Dynamic, static, state machine, structural, behavioral, agent, object-based, process-based, Meta data, entity relation, activity, composition, generalization, collaboration, event trace, sequence, etc.
- Example Formalisms and Suitable Notations: Unified Modeling Language (UML), Conceptual Modeling Language (CML), System Modeling Language (SysML), Integration Definition for Function Modeling (IDEF0), Base Object Models (BOM), BOM++, Conceptual Graphs, Mind Maps, and Business Process Modeling Notation (BPMN).
- Example Views: Class diagram, activity diagram, swim lanes, state diagram, operational view, etc.

A more detailed discussion of the composition of the conceptual model, in terms of the design process, will be given in Chapter 6.

4.5 CONCEPTUAL MODEL PERSPECTIVES AND COMPOSITION

Conceptual Model of a Simulation is predicated for the purposes of this effort as the conceptual model of the Mission Space (i.e., that which is represented within the simulation during its execution) integrated with the conceptual model of Simulation Space (i.e., encompassing the design and implementation of the simulation artefact itself). Consequently, it is important to differentiate between aspects of the conceptual model space, the Mission Space of the referent world, and the Simulation Space where the simulation itself resides. Each of these Spaces will impact the design of the conceptual model in its own fashion.

Figure 4-6 shows the nature of these three spaces, and how they interact through the requirements and design of the conceptual model. Following are examples of requirements which might be applied to the conceptual model components relevant to the two spaces and the composite conceptual model itself.

- Example from conceptual model composite space: The conceptual model shall be machine-readable.
- Example from Mission Space: The conceptual model shall represent World War II trench warfare.
- Example from Simulation (Implementation) Space: The conceptual model shall be at a level of abstraction allowing real-time execution at 1000 Hz on a commercial desktop platform.

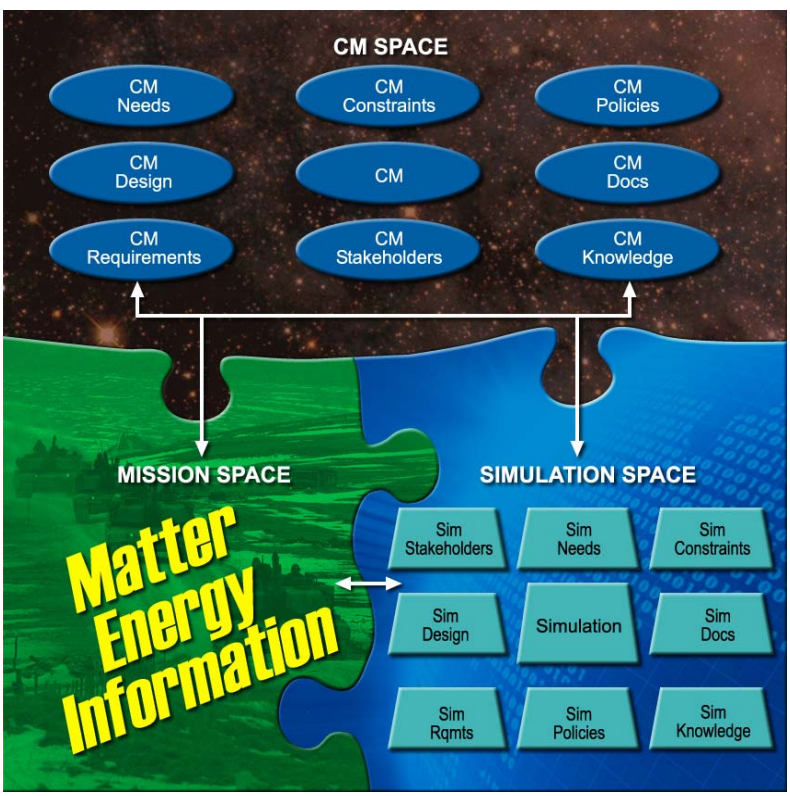

Figure 4-6: Mission Space and Simulation Implementation Spaces Indicated as Disjoint, but Highly Integrated 'Worlds' Whose Natures are to be Included in the Entire M&S Conceptual Model.

Also see Annex I – Conceptual Model Examples.

The diagrams of Figure 4-6 and Figure 4-7 illustrate the notions of the disjoint representation and simulation implementation spaces and their composition into the fully articulated conceptual model artefact.

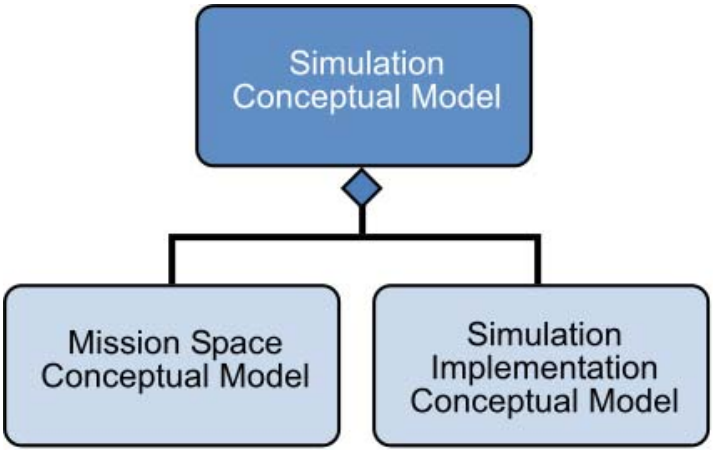

Figure 4-7: Simple Indication of Composition of the Simulation Conceptual Model from Mission Space and Simulation Implementation Space Components.

Typically, the conceptual model is thought to only represent the Mission Space. Although it is often said that the ideal conceptual model is "implementation independent", thus "Simulation Space independent", such is rarely ever the case. Even if the conceptual model does not explicitly mention an implementation, and may be highly portable from one Simulation Space to the next, the original Simulation Space to which the conceptual model was designed will have influenced the structure and content of the conceptual model, sometimes in significant ways. This is also true of the Conceptual Model Space influences, such as Conceptual Model Stakeholders and Policies.

It is, in fact, the frequency of conflation of mission and simulation implementation spaces, and the occurrence of unanticipated pejorative consequences that has motivated the Task Group to adopt this particular partition convention. By making the partition explicit, the degree of machine independence and the artificial implementation of mission space representations by means of undesirably static implementation techniques are believed to be better appreciated and controlled.

4.6 BEST-PRACTICE SPECIFICATION NOTATION

One of the practical determinations and findings of the Task Group related to representational notations whereby specifications of best-practice and resulting conceptual models could be mad manifest; and, whereby the conceptual model itself may be captured, published, archived, retrieved, understood, modified, and maintained in a systematic and deliberate manner without corrupting the semantic content of the model itself. It was abundantly clear from the Team's investigations of current practice and available standards that myriad notational schema were available. It was further determined by the Group that the use of any of any one notational form in expressing best-practice or the requirement for use of any such single form by conceptual model practitioners in executing the recommended best-practice would be found to be technically and socially impractical, however desirable and fit-for-purpose it might seem.

Notwithstanding this determination, it was clear that the Team needed a provisional or 'nominal' notation for expressing its guidance; and that the conceptual modeling practitioner would be obliged to select some one specific documentary notational schema in executing the recommended best-practice. In the later case, the Group resolved that practitioners should (could) elect any formulation consistent with the representational capacity required to express their particular conceptual model and commensurate with the norms and requirements of the enterprise environment in which they worked. Naturally, selection from among common standard notations and specification languages is strongly recommended in any case. In the former case, the Group was particularly sensitive to its own use of notational artifice for two reasons. On the one hand, any notation employed herein to specify conceptual modeling process or conceptual model structure and semantic content must be sufficiently expressive and ecumenical so that the best-practice guidance communicated thereby might be clearly intelligible. On the other hand, the Group was anxious not to imply by its own selection and use of notational schema, that our particular choice of schema was particularly preferred for use by practitioners – let alone a required element of the recommended best-practice.

Therefore, the group strove to use the most simple and self-evident notation within the document, and to reserve the best-practice guidance itself to vernacular English in Chapters 5 and 6 and in tabular prescription in annexes tabular prescriptive guidance in Annexes G and H for process and product respectively. The fundamental activity-on-node with control-on-arrow notation with which this guidance is modestly introduced in Chapter 6 for process particularly together with an expression of the degree to which this notational convention is practically a 'least common denominator' of several common representational forms, is indicated in the figures following.

Figure 4-8 illustrates the simplified baseline graphical representation for indication of activities and their relationships with other entities in the conceptual modeling practice process Used by the Task Group in following explication.

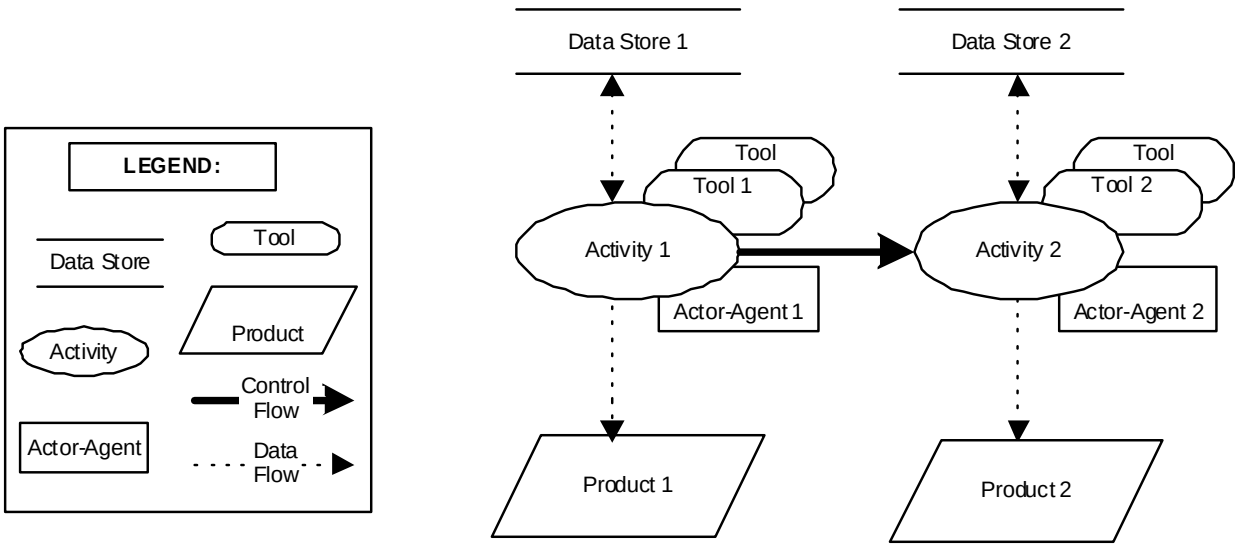

Figure 4-8: Simplified Process Graphical Notation Used in Expressing Conceptual Modeling Best-Practice Process.

Figure 4-9 indicates alternative canonical views with information-preserving transform operations are possible, facilitating use of CASE-supported native representations and guaranteed information sharing.

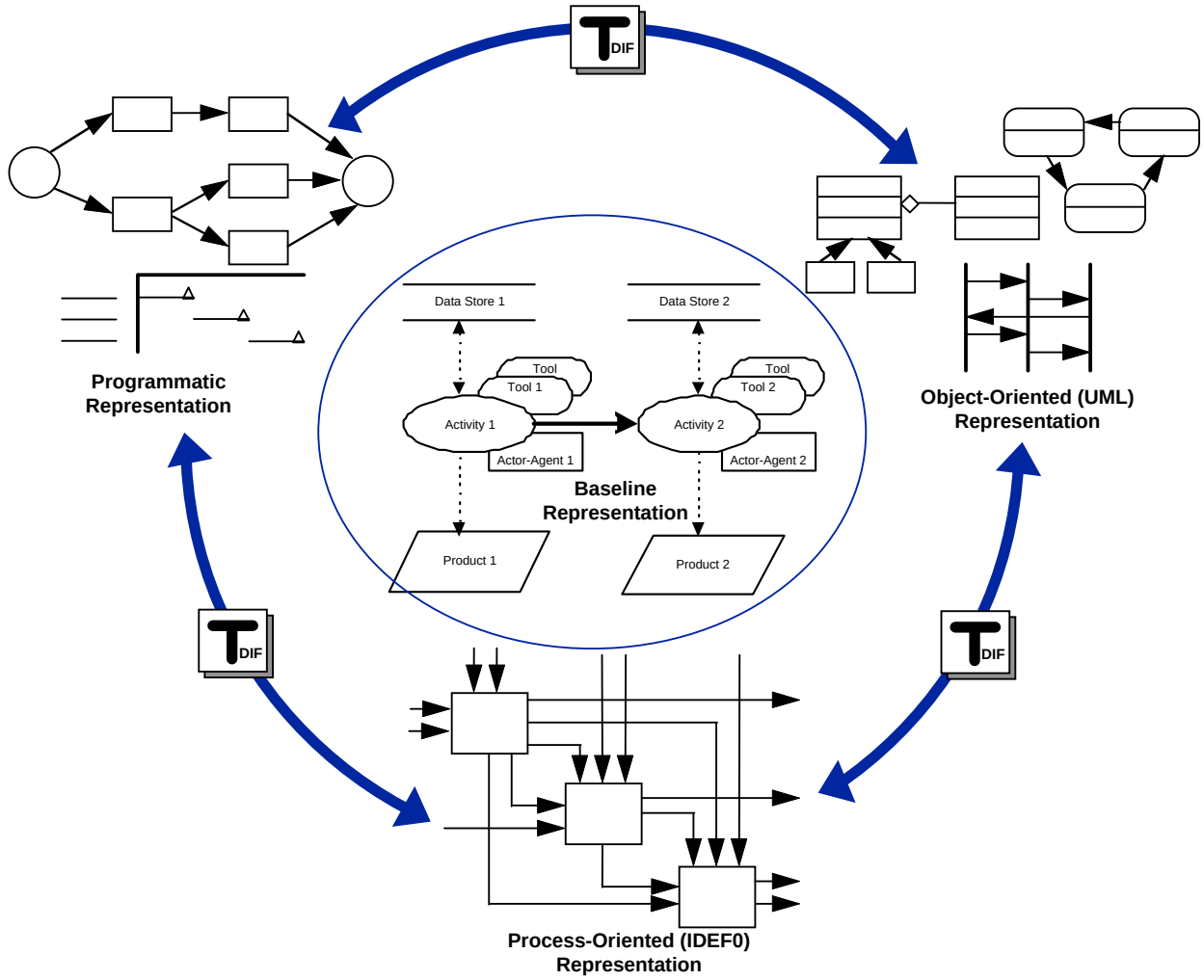

Figure 4-9: Notional Illustration of Relationship of Simplified Process Specification Graphical Notation in Context of Other Canonical and More Powerful Notations.

4.7 CONCEPTUAL MODEL QUALITY (VERIFICATION AND VALIDATION)

In this section some aspects that are relevant for understanding the role of V&V of a conceptual model in the project context are described. Although the complete product life cycle is not described in this report, some aspects of this larger setting may still be useful for a complete understanding. An enterprise that decides to explicitly make a conceptual model clearly has the desire to deliver quality products. Just making a conceptual model, however, is not sufficient for achieving quality. The quality of the conceptual model (and other intermediate products) must be sufficient to allow the development of a quality end-product. V&V helps in determining the quality of the final product and must be applied throughout the whole of the development, and thus also to the conceptual model. V&V of the whole development can be a large undertaking. Here we describe the V&V work with the focus on conceptual model and as if the rest of the V&V work is non-existent. It is important, however, to understand that the result of V&V of a conceptual model is only a part of the overall V&V effort.

4.7.1 Context of Conceptual Model V&V Effort

The V&V work consists of a number of activities that are described in the activities in this guidance. These V&V activities do not all need to be completely finished before a next activity can be started: they may partly be executed in parallel. Process Activities can also be executed iteratively.

The V&V work starts with agreement on a number of elements such as: who performs the V&V work, what resources (time, money, etc.) are available for V&V, and how the results of the V&V work are used. See also the V&V elements in the "Meta data" product in the V&V elements in the "Information Pool" of Annex H, Table H-5. The amount of available resources for V&V must be related to the risk (financial, loss of lives, etc.) of using a faulty end-product because a faulty conceptual model was used for its development. If almost no consequences exist of using a faulty conceptual model, then the V&V effort may be low. If, however, a substantial risk is present, and using M&S results for military application usually has, the V&V effort must be accordingly. The applied V&V methodology should be tailorable such that it delivers the best possible V&V given the risk and available resources.

4.7.2 Quality Attributes Relevant to Conceptual Model V&V

Three properties must be shown during the V&V work: utility, validity and correctness:

- Utility
  - Assesses the effectiveness and efficiency of the conceptual model in solving the problem statement. Evaluation metrics for utility comprises three areas: value or benefits (measures of effectiveness, measures of performance, etc.), costs (money, time, etc.) and use risks (impact, probability, etc.).
- Validity
  - Assesses the level of agreement of the conceptual model behavioral representation with that of the simuland. Validity metrics are also used to assess the consequences any behavioral discrepancies on the utility of the M&S system.
- Correctness
  - Assesses whether the conceptual model implementation is free of error and of sufficient precision. Correctness metrics are also used to assess the consequences of implementation discrepancies on both the validity and utility of the conceptual model.

4.7.3 Sufficiency Criteria for Conceptual Model V&V

In order for the conceptual model to have utility it must help improve the quality of the end-product within with resources that are in balance with the risk. Building the conceptual model is the step in simulation development in which the actual Modeling takes place. Therefore validation (determining whether the abstractions taken during the Modeling are allowed) of the conceptual model against the stakeholders' purpose is important for the simulation's fitness for purpose. In order to serve its purpose the constructed conceptual model must also be correctly implemented such that its representation is useful and leads to a correct transformation of purpose, via requirements to design and implementation.

A conceptual model that has been V&V-ed with positive results increases the chances of a high quality end-product and can serve as part of a referent for the V&V of that final product. For conceptual models no formal acceptance process (accreditation) is available, it must however be acceptable for the stakeholders (users, developers, etc.) that use the conceptual model in the development process. This must be achieved in two

ways. First, the acceptance criteria must be derived from the stakeholders' purpose, and, second, the format in which the results of the V&V effort are delivered must be suited for their purpose.

4.7.4 V&V Compliance Framework

It is important that the V&V effort results in a compliance network linking stakeholders' goals via a set of evidences to justifiable claims.

Figure 4-10: The V&V Argumentation Framework (AF) Consists of the Goal Network, Evidence and the Claim Network.

The goal network is used in a top down fashion for reasoning about the decomposition of a top-level objective into smaller goals and, finally, into a set of definitions of tests to generate evidence. Therefore goal networks can be used for planning purposes. V&V goal networks are closely related to and overlap with goal-oriented requirements engineering.

Claim network structures work in the opposite way. A claim network structure aggregates evidence collected in a certain context into sub-claims, and these sub-claims into a single justified top-level claim on the subject of interested. This aggregation is done by means of logical arguments.

The rationale for using both a goal network and a claim network stems from the fact that in practice decomposition and re-composition do not mirror each other for various practical reasons like time, cost and availability of equipment to gather the appropriate evidence.

After completion of the claim network, and thus also the goal network and evidence collection, the results must be communicated to the stakeholders. The results are an acceptance recommendation in the format best suited for the stakeholders' purpose with the V&V results. Since there is no formal acceptance process for conceptual models, the result is not an accredited conceptual model but a recommendation on acceptance.

If all is well the top claim shows that the top goal is justified. For all M&S related products, and indeed possibly all products, the top goal is of the same form: the system must provide utility for the given purpose. Therefore the top goal of the Goal Network is a utility goal. In case of conceptual models the following top goal is proposed:

The Conceptual Model provides utility for the improvement of the quality of the end-product.

This top goal must be decomposed into smaller goals. At first these are likely to be more specific utility goals. At some point the utility goals can be expressed either into criteria for which tests can be devised or into smaller goals that deal with validity and correctness. The validity goals express criteria on the abstractions from reality that are made in the conceptual model since the phase in which the conceptual model is build is

the modeling phase. Only those abstractions are allowed that will result in a model that – given its purpose and the way it is used in the final product – result in a behaviour that is indistinguishable from the equivalent behaviour in the real world. The correctness goals state criteria on how the conceptual model is build, expressed in formalism and used in the rest of the development process. The conceptual model must for example be understandable for all relevant stakeholders and be specified without errors in formalisms that are appropriate.

Some of these criteria will be independent of the specific topic and formalisms, but many criteria, and especially those in the validity goals, will be highly dependent on the stakeholder's purpose with the final product. Inspiration for criteria can be found in standards on software quality, namely [ISO/IEC 9126], papers on conceptual model quality such as [Lindland] [Pace] [Teeuw], SMEs and domain specific knowledge that may be available from previous quality evaluation efforts. A good overview of quality frameworks specific for conceptual models is given by [Moody].

4.8 REFERENCES

[1] Gordon, S., Waite, W., Öhlund, G. and Björk, Å., *Review and Update of Findings from Economics of Simulation Study Groups*, Paper 21, NATO Modeling and Simulation Group Symposium, Warsaw, Poland, October 2005 (Paper presented at the RTO NMSG Symposium on "The Effectiveness of Modeling and Simulation – From Anecdotal to Substantive Evidence", held in Warsaw, Poland, 13-14 October 2005).

[2] *The Cost Effectiveness of Modeling and Simulation (M&S) MSG-031 Final Report – Draft*. NATO MSWG, 2008.

[3] Department of National Defence, Canada, *The Joint Simulation and Modeling for Analysis, Requirements, Training, and Support (SMARTS) Initiative: A Vision for enabling Strategy 2020.*

[4] Waite, W.F., *Proposal for Establishment of a Technical CHAPTER within the Society for Computer Simulation (SCS) on "The Economics of Modeling and Simulation"*, 2000.

[5] Waite, W.F., *Terms of Reference (TOR) Revised for the SISO Task Group on The Economics of Simulation*, 2001.

[6] Waite, W.F., Tutorial: *Economics of M&S: Change-Agents or Martyrs for Innovation.* I/ITSEC 05, Sponsored by NTSA, 2005.

[7] Erlandson, M. and Gordon, S., *Economics of Simulation Data Compilation Work Group*, 1995.

[8] Gordon, D.S., *Review and Update of Findings From Economics of Simulation Study Groups*, Waite, B., Editor, NMSG-035/RSY-005, 2005.

[9] Nesselrode, M.C., *Developing a Repeatable and Reliable Methodology to Determine Return-on-Investment*, Old Dominion University, 2008.

[10] Ostwalt, Ivar, *et al*., *Calculating Return on Investment for U.S. Department of Defense Modeling and Simulation*, in Defense Acquisition Research Journal, Vol. 18, No. 2, April 2011.

[11] Iansiti, M. and Levin, R., *Strategy as Ecology*, in Harvard Business Review, March 2004.