Chapter 5 – CONCEPTUAL MODELING PROCESS GUIDANCE

Establishment and implementation of best-practices are critical to ensure that a sound and structured process is followed to produce conceptual models of sufficient quality, and to ensure that conceptual model products are robust and complete. It is particularly important to establish a homogeneous and common process for conceptual model development to enable a structured approach and to build a common vocabulary across the M&S community for the sake of collaboration and reuse.

Based on the research effort described above, and in order to meet the stated objectives of advancing the development of conceptual models beyond current practice, Chapters 5 and 6 (along with corresponding annexes) constitutes NATO Best-Practice Guidance, provided to enable the development of quality and re-useable conceptual models of military models and simulations.

5.1 PROCESS GUIDANCE INTRODUCTION

This chapter provides the MSG-058 Task Group's "Best-Practice Guidance Specification (BPGS)" for the "Conceptual Model Best-Practice Development Process" as indicated in Figure 3-4. This guidance includes descriptions of the Process Phases, Activities, and Activity-Flows required to ensure a quality conceptual model, and quality ancillary products. The products themselves will be described further in Chapter 6.

The desired process guideline is based on these desirable characteristics, which best-practices conceptual modeling process should contain, exhibit, or facilitate:

COMPLIANCE:

- Comply with policies.
- Conform to enterprise precepts and practices.
- Include identification of stakeholders' roles and responsibilities.
- Leverage available standards.
- Leverage systems engineering and information management best-practices.

SUFFICIENCY:

- Provide necessary activities to the conceptual model lifecycle.
- Contemplate multiple formalisms and views.
- Distinguish between Mission Space and Simulation (implementation) Space requirements and needs.
- Exhibit sufficient completeness for subsequent intended use.

'-ITILITIES' – this represents words that end in itilities, such as utilities, capabilities, etc.:

- Give developers flexibility to apply and tailor the process.
- Provide utility and efficiency.
- Allow sufficient expressiveness and flexibility.
- Foster reusability.
- Foster understanding.

QUALITY:

- Exhibit sufficient correctness for intended use.
- Produce quality documentation.
- Enable VV&A.

A five-phase development process is provided commensurate with these required characteristics. That process is shown in Figure 5-1, and its process elements are designated as follows:

- PP1 – Initiate Conceptual Model Development.
- PP2 – Define Conceptual Model Requirements and Knowledge Needs.
- PP3 – Acquire Conceptual Model Knowledge.
- PP4 – Design the Conceptual Model.
- PP5 – Build the Conceptual Model.

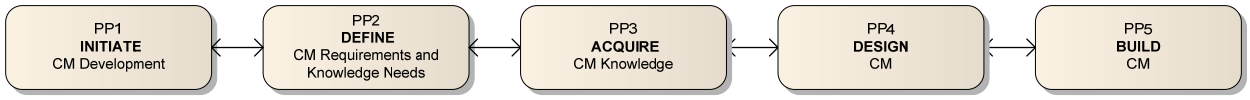

Figure 5-1: Conceptual Model Development Phases.

Each development phase is composed of a corresponding set of Process Activities. The complete collection of activities for the entire process is shown in Figure 5-2. Further guidance on the specific phases and activities is provided in the sections below, and technical descriptions of each Process Activity are provided in the text that follows and, systematically in Annex G.

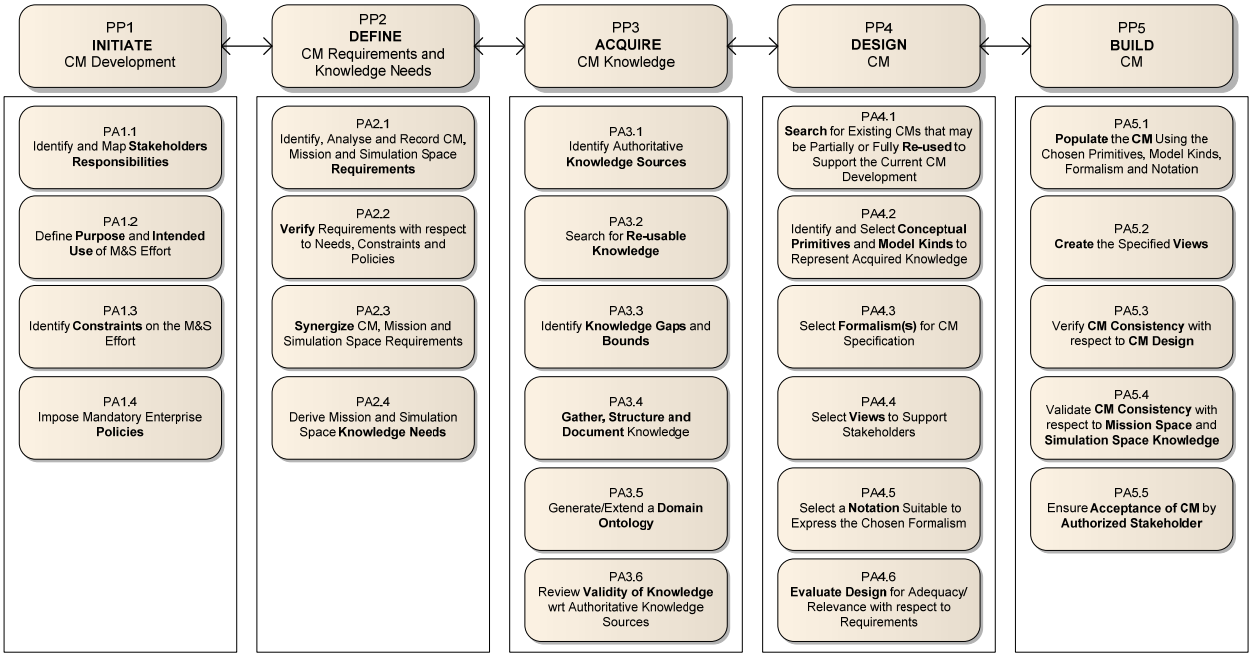

Figure 5-2: Conceptual Model Development Process Exhibiting Devolution of Process Phases to Process Activities.

It is important to note that these Process Phases and Activities need not be executed in the serial order implied by their enumerated listing; although, the ordinality of Process Activities associated with each Process Phase is considered to be logically suggestive. Pragmatically, many of the activities may be executed concurrently, in multiple iterations or out of numerical sequence, contingent such exigencies a team structure and availability of expertise, availability of information, election of spiral or other recursive implementation techniques, or, in fact, any of the circumstances that are the inevitable consequence of enterprise operational style or business practice. The only limitations to task activity sequencing is the necessity to satisfy entry conditions and exit conditions for each activity, as defined in the respective sections of Annex G.

Figure 5-3 illustrates such one such non-linear execution of the global process through the use of a state-transition diagram. In the example in the figure, S1…S13 indicate each state, and it can be seen that the sequence includes execution of multiple phases in parallel, and iterative passes through the process. These states may also involve execution of individual phased Process Activities in different or parallel order.

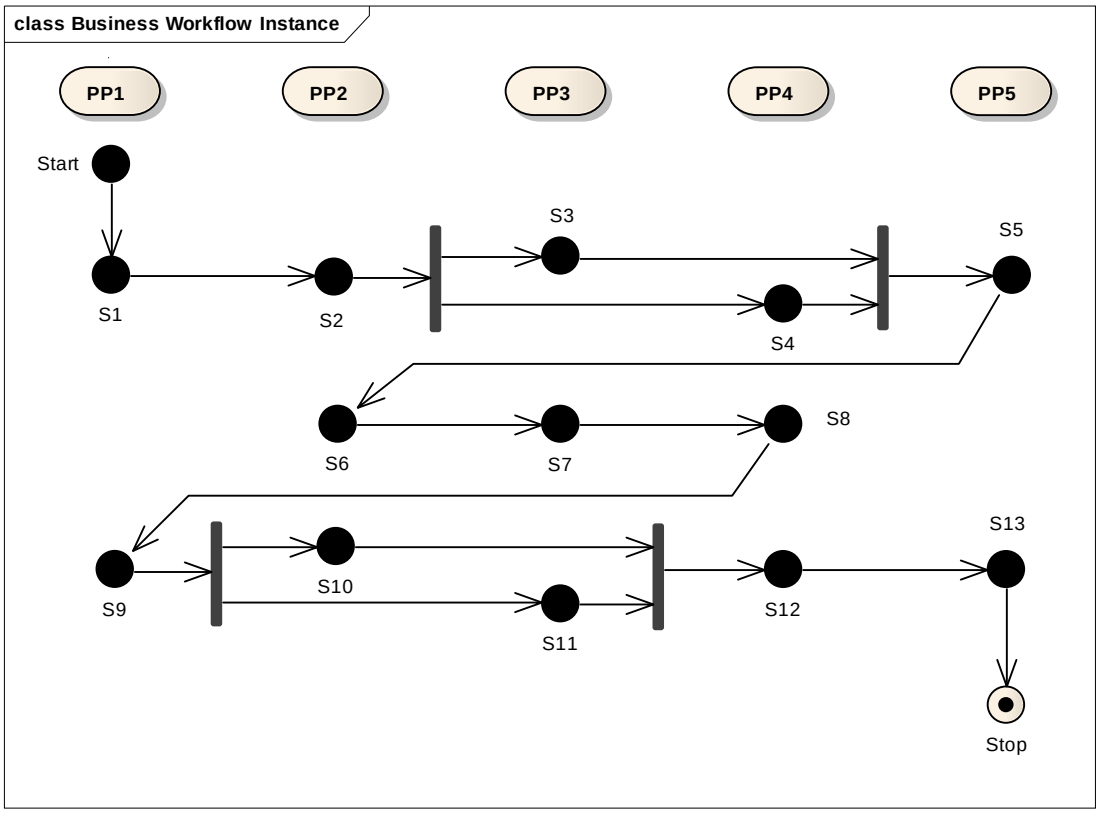

Figure 5-3: Example Conceptual Model Development Workflow.

It is significant to note that the process specification is organized and presented in order to provide the greatest possible discretion to the conceptual modeling execution agent, while encouraging elements that have been determined to comprise best-practice. In that spirit:

- These defined Process Phases and Activities are provided as best-practices in conceptual model development.
- This process may be tailored as needed by the developer.
- The Process Activities may be executed in any sequence allowed by the entry and exit criteria.

5.2 CONCEPTUAL MODEL PROCESS DESCRIPTION

In the sections that follow, discussion of conceptual modeling Process Phases and their component Process Activities are provided. The intention of the text is to provide a plausible explanation and rationale of the entire effort expected to be necessary and sufficient for the creation and management of military simulation conceptual models. Information is provided that is deemed:

- Useful to the practitioner in understanding motivation for particular process components;
- Constructively prescriptive in conducting conceptual modeling;
- Effective in elaborating on special circumstances likely to apply to such execution;

- Liberating to the practitioner in specializing the subject guidance contingent particular circumstances following from enterprise and task peculiarities; and
- Prescriptive of intentions for resulting work-products.

This account is provided as a complimentary and consistent form of guidance which, when taken together with the systematically tabular guidance specification contained in Annex G, is considered necessary and sufficient to inform best-practices.

5.2.1 Process Phase 1 Guidance – Initiate Conceptual Model Development

The conceptual model development activity in this phase is to identify, collect, and document initial needs, constraints, and policies that are most often described in terms of the underlying simulation, and to identify stakeholders and map them to their roles and responsibilities. This phase is critical to the translation of simulation needs, mandates, and constraints into those for the conceptual model itself.

Since it is highly unusual for conceptual models to be developed for their own sakes, rather than in the context of one or more M&S initiatives, the initiation process is often seen as external to the conceptual model process. Yet most senior stakeholders in the enterprise make their greatest conceptual model development contributions at this time. Historically these contributions rarely have been documented within the conceptual model itself, which has often resulted in limited conceptual model reusability or sub-optimum representation due to assumed constraints and mandates that dictate the form and content of the conceptual model.

For example:

> *A Joint Forces Commander recognizes the need to provide transportable helicopter simulators in the field to reduce the number of flight hours required for mission training. He develops an M&S need statement to address the problem, and an Acquisition Executive decides to fund the development of the simulators to meet the need. Due to the urgency of the problem, the Acquisition Executive allocates twenty million dollars to do the development in the nine remaining months of the current year, and tasks an Army Program Office to execute the mission. The Army Program Manager knows that to execute within time and budget, he will not be able to develop a validated flight model, and will have to use a surrogate, which will limit the value of the training in the near-term. He decides to direct the development of a composable architecture so that he can drop in a validated flight model at a later date. He also is constrained to develop the simulators using existing tools and using mandated software development practices. He articulates this to his Group, who are now prepared to develop the conceptual model for the simulation effort.*

In this example, conceptual model development began long before the development Group received their direction, in terms of the constraints, policies, and mandates limiting the simulation development effort. As mentioned above, an ideal conceptual model is said to be implementation independent. And a conceptual model can certainly be developed to support the example above, without specifying application constraints. But even if the conceptual model does not explicitly reference these constraints, those constraints will still bind and shape it, and as will be shown in the next process steps, the conceptual model requirements definition and knowledge acquisition will be highly impacted by the decisions made by the senior stakeholders.

Therefore, in order to translate and document the impacts of the M&S development effort to the conceptual model, the following Process Activities must take place:

- PA1.1 – Identify and Map Stakeholder Responsibilities.
- PA1.2 – Define Purpose and Intended Use of M&S effort.
- PA1.3 – Identify Constraints on the M&S effort.
- PA1.4 – Impose Mandatory Enterprise Policies.

The relationships among these Process Activities and with their products are shown in Figure 5-4.

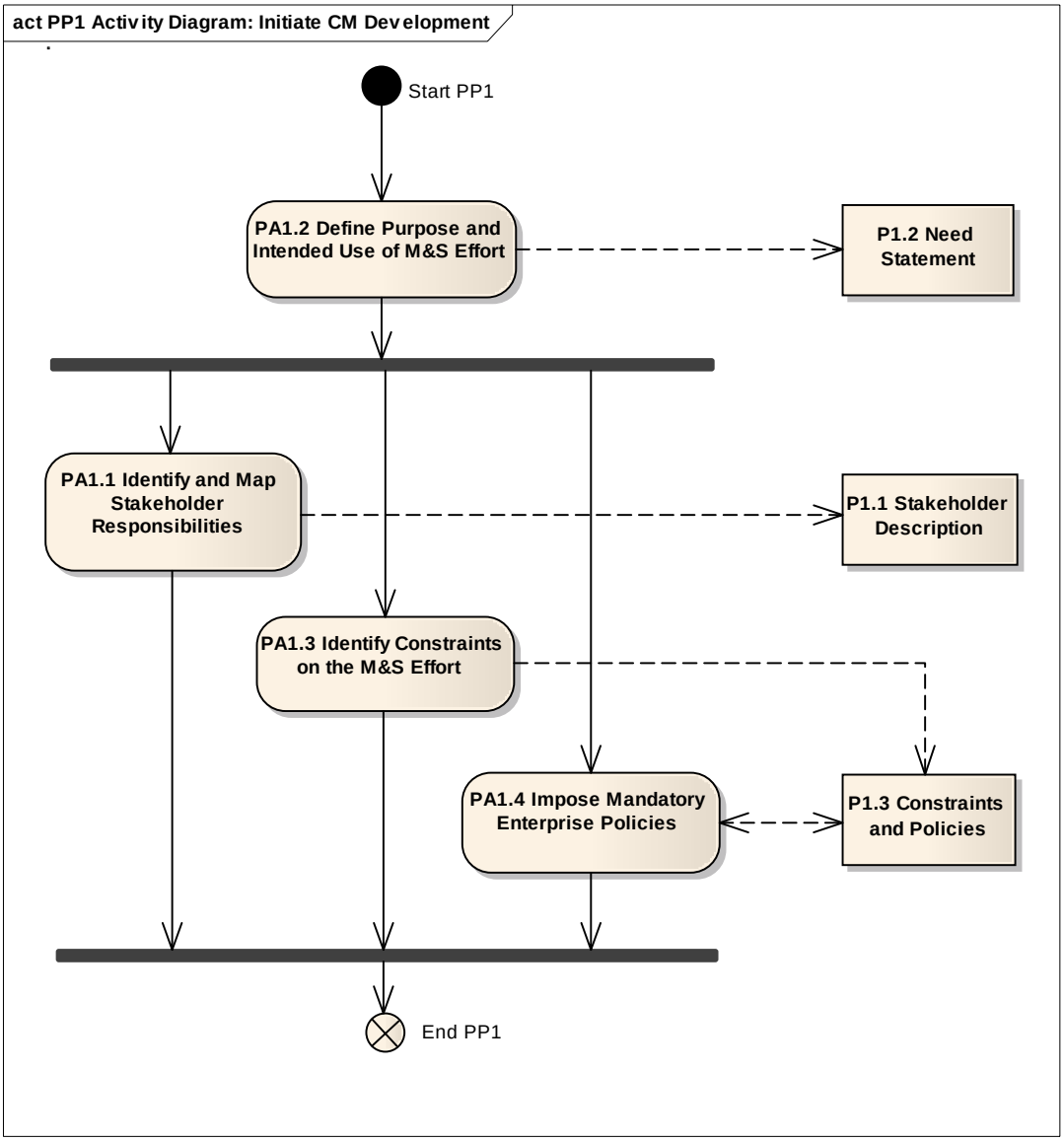

Figure 5-4: Process Phase 1 (PP1) Activity Diagram.

Each Process Activity is described below, and is further specified in Annex G.

5.2.1.1 PA1.1 – Identify and Map Stakeholder Responsibilities

A conceptual model primarily exists for the benefit of its stakeholders. Stakeholders must be identified to support the conceptual model development process: to support requirements development and knowledge acquisition, and to impact the design and build of the conceptual model. Stakeholders and their roles must be known before views can be determined. Stakeholder perspectives will drive terminology and will impact the selection of models and relationships.

This Process Activity involves three kinds of things: Lists of actual points of contact, by name or office; identification of relevant stakeholder roles as described in Section 4.3; and a mapping of the points of contact to the roles.

Points of contact may be generated from lists, employee roles, organizational charts, personnel databases, referrals, resumes, biographies, contract labor categories, or any other programmatic or administrative means.

Roles must be defined by analysis of the PA1.2 defined purpose and intended use of the M&S effort to the stakeholder classes described above, tailored to the particular application.

Mapping of the two will most likely involve M to N mapping, given that many individuals or offices can often have multiple roles in a particular conceptual model development, and many roles include multiple people for any realistically sized effort.

In the example above, the points of contact “Joint Forces Commander” and “Acquisition Executive” might map to “Sponsor”, and “Army Program Manager” would likely map to the stakeholder role of “Producer”.

This activity produces the P1.1 – Stakeholder Descriptions, which are used to derive conceptual model requirements and conceptual model knowledge needs.

5.2.1.2 PA1.2 – Define Purpose and Intended Use of M&S Effort

This Process Activity may begin upon stated or implied intent to develop a model, simulation, or conceptual model. This intent may come in the form of task orders, mission needs statements, user requirement documents, requests for proposal, statements of work, formal or informal directives, test agreements, oral or written orders, or any combination of like manners of communication.

The purpose of this activity is to compile all these M&S source documents and implied intents into a single set, to deconflict the elements of the set, and to provide this reconciled, definitive description of intent to the conceptual model developers, written in terms of descriptions of needs for the conceptual model.

It may be possible that multiple references to intent cannot be reconciled, as in the example above, where the Joint Forces Commander wants to train pilots but the Army Program Manager is not providing a validated flight model. In that case, even these potentially conflicting or mutually exclusive intents must be documented and highlighted, as they will likely drive complexity into the conceptual model, as the Army Program Manager’s decision to develop a composable architecture surely would have done.

This activity produces the P1.2 – Intended Use Statement, which is used to derive conceptual model requirements and conceptual model knowledge needs.

5.2.1.3 PA1.3 – Identify Constraints on the M&S Effort

As in the example, time and resources can constrain the conceptual model design, as can the intended use itself. These M&S constraints in turn constrain the conceptual model development, and impact the reusability and implementation independence.

And as in PA1.2, information pools such as documented resource constraints, senior stakeholder preferences and requirements, planning/budgeting management limitations, legacy M&S preferences and availability, data availability, enterprise preferences, and such, must be collected, integrated, and de-conflicted into a self-consistent set of descriptions of M&S constraints.

This activity, combined with PA1.4, is necessary to produce P1.3 – Constraints and Policies, which is used to derive conceptual model requirements and conceptual model knowledge needs.

5.2.1.4 PA1.4 – Impose Mandatory Enterprise Policies

In this Process Activity, developers collect information from enterprise standard operating procedures, industry and government standards, enterprise executive mandates, law, agency regulations, agency directives, written policy, implied enterprise mandates, and other references relating to Enterprise Policy Mandates. This data must be collected, integrated, and de-conflicted into a self-consistent set of descriptions of policies.

Examples of enterprise mandates include the US Department of Defense mandate to use High Level Architecture (HLA), some industries standardizing on UML, or even a small business's decision to use a proprietary software tool for competitive advantage. This activity is where the enterprise has tailored the intended use and constraints to its own interests, and that tailoring gets reflected in the initial state of the conceptual model.

This activity, combined with PA1.3, is necessary to produce P1.3 – Constraints and Policies, which is used to derive conceptual model requirements and conceptual model knowledge needs.

Listed below are the points of emphasis:

- The INITIATE phase of conceptual model development is a critical and often overlooked set of activities that must be understood and documented.
- These activities are necessary to document stakeholder roles, conceptual model requirements, policies, and mandates.
- This phase sets the initial state of the conceptual model.
- In mature enterprises, much of this initial state is quite repeatable from one conceptual model activity to the next, and might generate documents that are highly reusable in subsequent efforts.

5.2.2 Process Phase 2 Guidance – Define Conceptual Model Requirements and Knowledge Needs

Overview of Process Activities and Products – The second Process Phase in the conceptual model development process consists of four Process Activities in a simple sequence as shown in Figure 5-5. This Process Phase takes two input products (P1.2 – Need Statement and P1.3 – Constraints and Policies) and produces two output products (P2.1 – Conceptual Model Requirement Specification and P2.2 – Conceptual Model Knowledge

Acquisition Needs). A preliminary product is used to record requirements during the Process Phase execution before they have been synergized and verified.

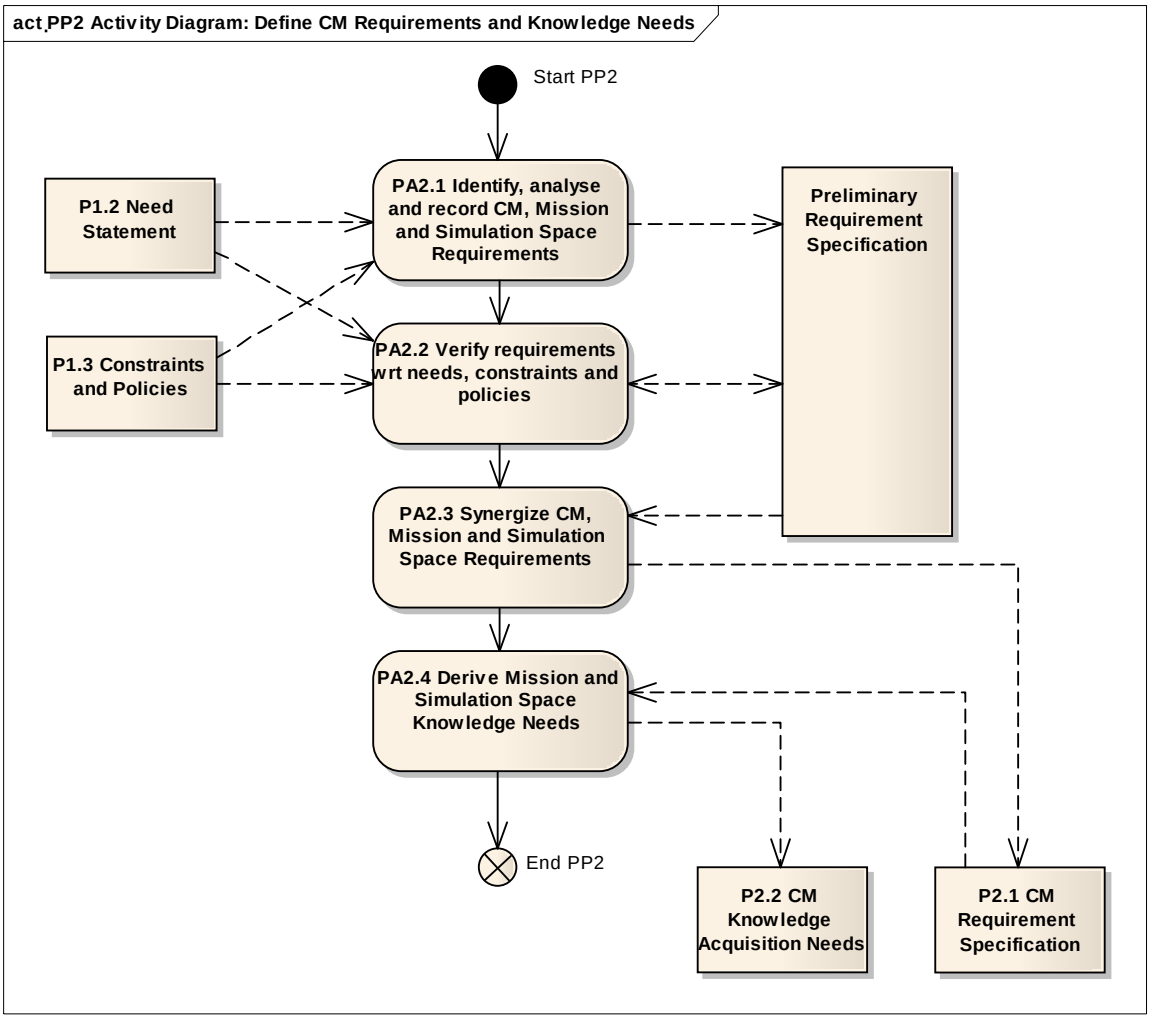

Figure 5-5: Process Phase 2: Define Conceptual Model Requirements and Knowledge Needs.

5.2.2.1 PA2.1 – Identify, Analyze and Record Conceptual Model, Mission and Simulation Space Requirements

Process Activity 2.1 refers to requirements grouped into three "Spaces": Conceptual Model Space, Mission Space and Simulation Space. The concepts of these "Spaces" are explained in Chapter 4, Section 4.1 Scope and Definitions and an example are presented in Annex I.

This Process Activity refines the need statement by detailing the implications of the needs in a more explicit set of requirements. It can be described as a kind of translation process from qualitative and informal statements in the "language" of the client (needs) to more quantified and precise statements of content and attributes of the required conceptual model (requirements).

Analyzing the requirements is a process of reviewing and evaluating the requirements to ensure that they are complete, consistent and correct.

Typical requirements originating from the conceptual model space may include:

- The views needed of the conceptual model by different stakeholders.
- The level of formality needed by stakeholders.
- Mandatory tools, documentation formats, notations, etc.
- Mandated conceptual model characteristics.
- What policy to follow to validate the conceptual model.
- What acceptance criteria to apply in validation.

In order to prepare the acceptance of the results of the V&V effort by the stakeholders used in PA5.5 (Ensure Acceptance of Conceptual Model by Authorized Stakeholder), it must be determined what information the stakeholders require for their acceptance decision-making process.

Typical requirements originating from the mission space may include:

- Definition of what parts of the mission space to be included in the conceptual model (Scope).
- Questions to be answered by the modeling and simulation effort (Critical Operational Issues (COIs)).
- Level of realism and detail needed in order to address the COIs (Abstractness characteristics).
- How the degree of satisfaction of operational issues are to be measured (Measures of effectiveness).

Typical requirements originating from the simulation space may include:

- Intended use of the model (e.g., training, feasibility study, trade-off studies, performance analysis).
- Implementation strategy and choice of fundamental technology.
- Explicit performance constraints (e.g., real-time requirements, Monte Carlo simulation requirements).
- Requirement to interface with existing software, hardware equipment or human operators.

5.2.2.2 PA2.2 – Verify Requirements with Respect to Needs, Constraints and Policies

Process Activity 2.2 shall ensure that the requirement specification satisfies important quality criteria. As `described in Section 4.7 V&V, an AF is built during the V&V work. For the first part of the AF a goal-oriented approach is taken. Starting with the top goal, criteria are derived in a hierarchical fashion. A part of those criteria deal with the requirements of the conceptual model space, the mission space and the simulation space. The requirements are to be verified against the criteria in that part of the AF.

Typical quality criteria are:

- **Completeness**: All needs, constraints and policies are covered by one or more requirements.
- **Traceability**: Every requirement statement can be referred to a corresponding need, constraint or policy statement.
- **Correctness**: All needs, constraints and policies have been interpreted as the sponsor intended.
- **Un-ambiguity**: The requirement is given a form that avoids misinterpretation.

Other possible criteria are consistency, adequacy, measurability, pertinence, feasibility, comprehensibility and good structuring.

Completeness ensures that all requirements implicit in the need statement and applicable constraints and policies are accounted for. Traceability ensures that no requirement that is *not* implied by these inputs has found its way into the requirement specification product. That is, there should be no element of invention at this stage. The requirement specification shall simply be an accurate reflection of preceding products.

The process of verifying the requirements may however reveal inconsistencies, inaccuracies or omissions in the input products. It is therefore a good opportunity to clarify and adjust Phase 1 products before weaknesses are propagated to downstream Process Phases.

5.2.2.3 PA2.3 – Synergize Conceptual Model, Mission and Simulation Space Requirements

Conceptual model space, mission space and simulation space requirements may in some cases be incompatible. There may therefore be a need for harmonizing any conflicting requirements. This is taken care of in Process Activity 2.3.

5.2.2.4 PA2.4 – Derive Mission and Simulation Space Knowledge Needs

Process Activity 2.4 shall produce a description of the knowledge needed by the developers of the conceptual model. These needs must be based on the conceptual model requirement specification and should identify relevant knowledge:

- Used by military personnel in the execution of their profession (tactics, techniques and procedures).
- About the scientific basis for military technology.
- About construction and performance of military technology.
- About simulation methods and technologies.

Note that only the knowledge *needs* are described at this stage, not the knowledge itself (which is the task of Process Phase 3). It is important to be careful in limiting the knowledge needs to what is strictly necessary for the conceptual model to be constructed. It is easy to be carried away by the wealth of information available and making the knowledge acquisition task more onerous than necessary.

Some aspects that should be considered when deriving knowledge needs are:

- The entities and behaviours that must be described by the model.
- The granularity or level of detailed needed in describing the phenomena to be modelled.
- Which simplifying assumptions can be allowed and what causal relationships must be included in the model.

When assessing these aspects the knowledge needed must finally be dictated by what questions the model is supposed to answer, that is the purpose of the model.

For example:

> *A simulation model shall be used to evaluate the effectiveness of flare countermeasures against infrared homing anti-ship missiles. In such a setting we may need the following type of knowledge:*

- *Missile flight trajectory, agility and speed.*
- *Missile seeker sensitivity, field of view and tracking ability.*
- *Missile seeker countermeasure discrimination ability.*
- *Countermeasure blooming profile, intensity and duration.*
- *Countermeasure alternative tactics for deployment.*
- *Ship IR signature.*
- *Ship maneuverability.*
- *Ship alternative maneuvering tactics.*
- *Environmental conditions influencing background IR radiation.*
- *Environmental conditions influencing IR radiation propagation.*
- *Environmental conditions influencing flare movement.*

Listed below are the points of emphasis:

- Bring any hidden assumptions into the open by spelling them out explicitly in the form of requirements and so reduce room for alternative interpretations.
- The knowledge acquisition needs should be limited to what is strictly needed.
- Leverage earlier requirements and knowledge specifications.

5.2.3 Process Phase 3 Guidance – Acquire Conceptual Model Knowledge

The Phase 3 in the NATO conceptual modeling process, called "Acquire Conceptual Model Knowledge", will begin by taking the two products generated in Phase 2, which are P2.1 – Conceptual Model Requirement Specification and P2.2 – Conceptual Model Knowledge Acquisition Needs, as input. These inputs will be used to identify the authoritative knowledge sources for a particular piece of knowledge. Thus Phase 3 is where the knowledge required for description of a certain mission space will be acquired. This phase will, after gathering, structuring and documenting and review the validity of that acquired knowledge with respect to the authoritative knowledge sources, produce a product called P3.1 – Validated Knowledge. This product will serve as the foundation for designing and building the final conceptual model.

Given that a conceptual model repository already exists, this phase will begin by looking for reusable knowledge that may already be in the conceptual model repository and can be completely or partially usable for this new need. If not, the lack of knowledge is identified, along with the gaps that must be filled. But before that knowledge can be acquired the authoritative knowledge sources should be identified. After that, the required knowledge will be gathered, structured, and documented, and finally analyzed for necessity and sufficiency. After that, enough knowledge should exist to either generate a Domain Ontology for this particular mission space or to extend the existing Domain Ontology. The last activity in this phase will be to review the validity of the acquired knowledge with respect to the authoritative knowledge sources.

The third phase in the conceptual model development process consists of six Process Activities as shown in Figure 5-6.

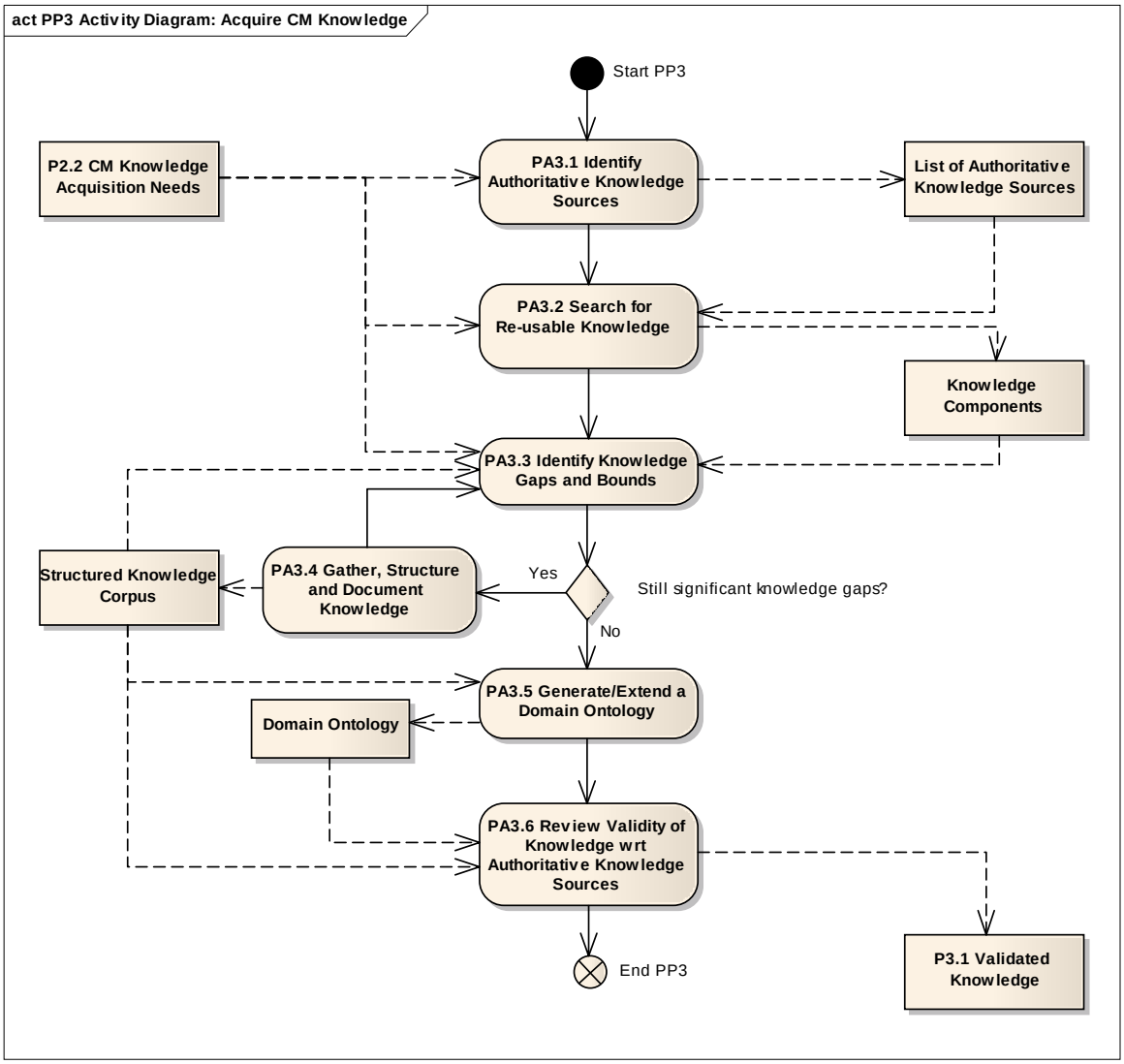

Figure 5-6: Process Phase 3 Activity Diagram: Acquire Conceptual Model Knowledge.

5.2.3.1 PA3.1 – Identify Authoritative Knowledge Sources

This activity is about identifying authoritative knowledge sources to fetch correct and authoritative information that describes a certain domain. Knowledge Acquisition (KA) belongs to the initial phases of almost any kind of system development process. There is no specific methodology for identifying appropriate sources for KA but the important issue here is to rely only on authoritative knowledge sources, those authorised by some organisation/authority beforehand (who this person or agency should be is beyond the scope of this report). These sources can be anything from books, web information, papers, regulations documents, pictures, maps, and case studies, but perhaps most important of all interviews with SMEs. Having a deeper understanding of the problem domain and (preferably) having experience of the particular area are necessary qualities for success.

5.2.3.2 PA3.2 – Search for the Reusable Knowledge in the Conceptual Model Repository

A successful result of this activity requires that good work is done in previous phases to identify the purpose, need, and requirements that are posed on the acquired information. This list of needs and requirements will be the foundation for building the necessary queries to the conceptual model repository. Keep in mind that several qualitative properties are critically important to search and find either the reusable knowledge component (part of a conceptual model) or a complete conceptual model fulfilling a specific need. One is to try to model knowledge in smaller components that makes reusability easier. The other property is to have a degree of formalisation and semantic description that makes it possible to compose smaller components for building the needed conceptual model. The third is to have good Meta data addressing artefacts in the Conceptual Model Repository; this makes it possible to easily find the knowledge which corresponds to the need.

5.2.3.3 PA3.3 – Identify Knowledge Gaps and Bounds

This activity concerns whether the knowledge retrieved from an existing conceptual model repository is in accordance with the requirements; here the reusability of already gathered conceptual models or components will be examined to see if they can be used for the new purpose. The outcome aids in identifying what is missing. This activity will be considered only if the result of the previous activity (search for the reusable knowledge in the conceptual model repository) has been that the knowledge components have been found that only partly fulfils the need. These are then compared with the requirements to make certain that either the set of requirements are fulfilled or alternately, if knowledge corresponding to a specific requirement is missing, further knowledge acquisition will be taken care of in the next activity.

5.2.3.4 PA3.4 – Gather, Structure and Document Knowledge

Information sources for military activities can be anything from instructions, books, military doctrines, military scenarios, and case studies to military experts, Subject-Matter Experts, etc. However, the information that is needed for a certain purpose is often not documented anywhere and is only available through SMEs. Since there is no easy way to access this knowledge and it is often expensive to gather, recount, and store. This activity is about gathering, structuring and documenting this important knowledge. Certain military knowledge is often not documented anywhere and is only available through SMEs. The art of gathering this information from SMEs is usually called *Knowledge Elicitation (KE)* and is considered to be one of the greatest challenges of KA. Another challenge is to capture and obtain tacit knowledge – things that the expert does routinely, without much thought and considered obvious by the expert. The more knowledge an expert possesses, more is often considered obvious and it is usually more difficult for him to recount what they know.

5.2.3.5 PA3.5 – Generate/Extend a Domain Ontology

The previous activity has captured and documented new knowledge about a certain military activity that did not already exist in the conceptual model repository. It means new knowledge most likely will introduce new military concepts, properties, relations, and constraints which should be stored in some kind of knowledge base for future use and reuse. This activity covers structuring, tagging, and storing the gathered information either as new domain ontology or as an extension to an existing one.

5.2.3.6 PA3.6 – Review Validity of Knowledge with Respect to the Authoritative Knowledge Sources

This activity is about evaluation of the validity of acquired knowledge with respect to authoritative knowledge sources. This occurs by examining whether the result of the knowledge acquisition phase is acceptable to the owner of the mission space (the SME). It is about checking with the experts, whose realities have been

captured and documented, to see if the documented knowledge is correct and completely represents the activity. This is preferably performed by a VV&A agent.

A challenge of knowledge acquisition is that it often begins with the gathering of information from descriptions about a certain domain, through books, papers, tutorials, etc. All stored information is static while reality is dynamic and in constant change, which, if nothing is done, results in information that has been correctly gathered, but over time, becomes out-dated. Another challenge may appear when several experts have to be involved, where each expert might use different terminology or emphasize different things. A method for solving this can be to have one expert write something and then use a system of peer-review to iteratively refine the data. However a good methodology for keeping the generated conceptual models updated over time is required.

5.2.4 Process Phase 4 Guidance – Design Conceptual Model

The objective of this phase is to translate the conceptual model requirements into a conceptual model design preparing to build the actual conceptual model.

The conceptual model design explicitly trades off and balances conflicting requirements, such as the stakeholders understanding and involvement in the simulation development process and enterprise mandated policies.

It may seem artificial to explicitly separate the design and the building. However, a conscious conceptual model design makes the producers aware of their own bias relative to the stakeholders' bias.

The conceptual model design is basically a top-down selection of conceptual primitives, model kinds, views, formalisms and notations. The selection can be influenced by the bottom-up choice of reusing existing conceptual model artefacts. The design must be submitted to an evaluation against the conceptual model requirements for typical quality criteria like completeness and fitness for purpose.

The conceptual model design is divided in six activities:

- PA4.1 – Search for Existing Conceptual Models that May be Partially or Fully Re-Used to Support the Current Conceptual Model Development.
- PA4.2 – Identify and Select Conceptual Primitives and Model Kinds to Represent Acquired Knowledge.
- PA4.3 – Select Formalism(s) for Conceptual Model Specification.
- PA4.4 – Select Views to Support Stakeholders.
- PA4.5 – Select a Notation Suitable to Express the Chosen Formalism.
- PA4.6 – Evaluate Design for Adequacy/Relevance with Respect to Requirements.

As shown in Figure 5-7, conceptual primitives, model kinds, formalisms, views and notations are implicitly entangled, but they are artificially separated to make the producers aware of the interrelation of design choices and their consequences on meeting the stakeholders' expectations and the conceptual model characteristics requirements. This separation is necessary to be intentionally selective on the conceptual model design options. It is an investment against the risk of uninformed use of conceptual model components.

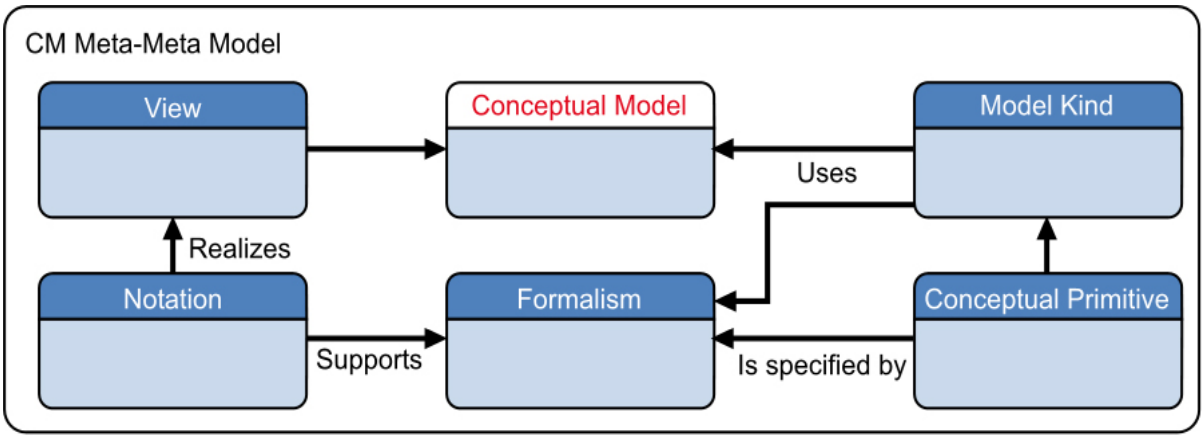

Figure 5-7: Conceptual Model Components.

The activity diagram in Figure 5-8 shows how the activities are interrelated.

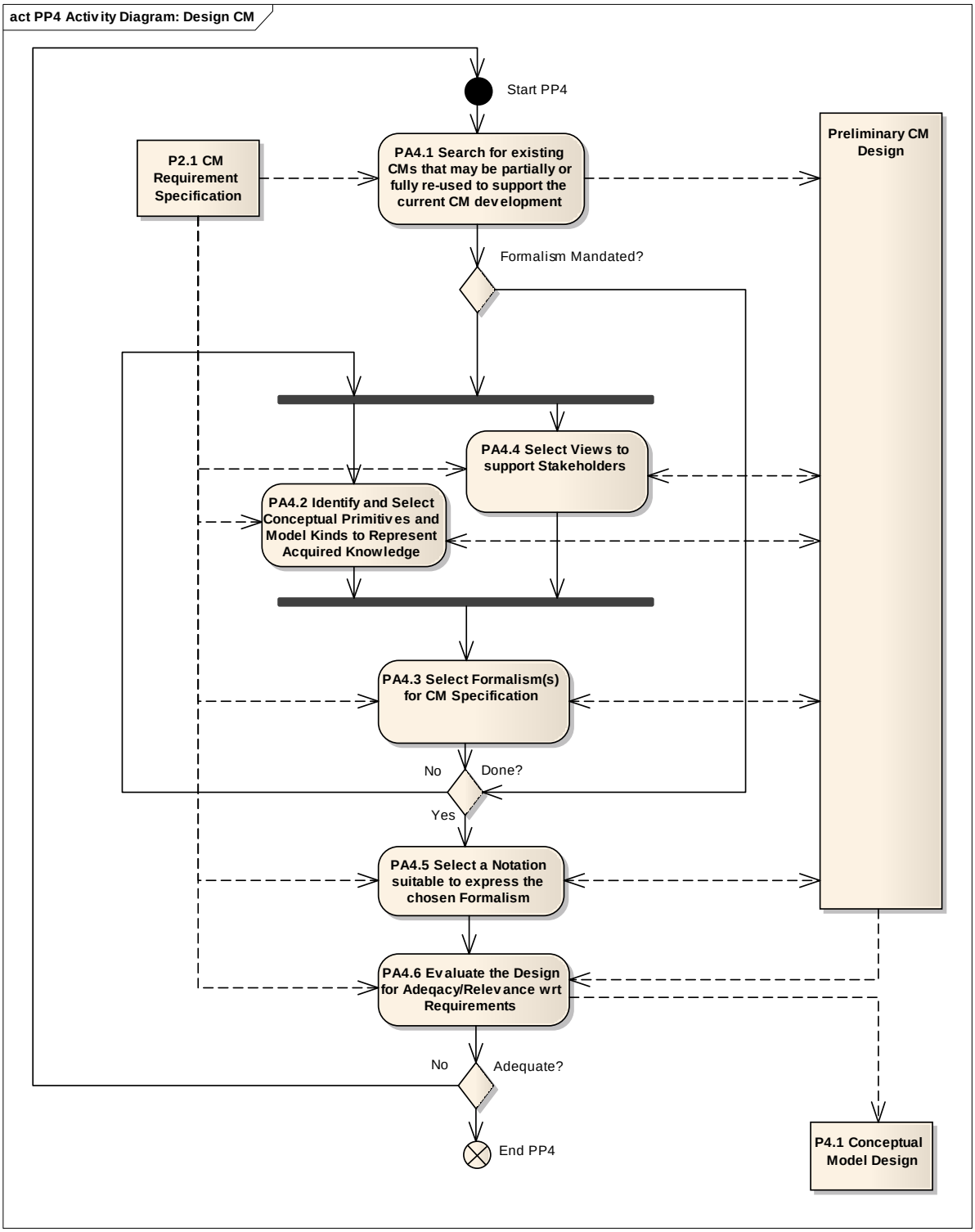

Figure 5-8: Process Phase 4 (PP4) Activity Diagram.

There is no mandatory order in PA4.1 to PA4.5. They all input to the preliminary design for evaluation in PA4.6 and for acceptance by the stakeholders as the Product 4.1 – Conceptual Model Design. Several preliminary design and evaluation cycles are usually required to finally pass the evaluation. Experience will allow passing the evaluation with fewer cycles.

Annex I presents several examples of different conceptual model designs. The example in Annex I, Section I.5 specifically emphasizes on the iterative conceptual model design process.

5.2.4.1 PA4.1 – Search for Existing Conceptual Models that May be Partially or Fully Re-Used to Support the Current Conceptual Modeling Development

In this Process Activity, the producer of the conceptual model is searching for existing partial conceptual models with the intention of reusing it for the conceptual model design. Typical search criteria are driven by mandated enterprise policies, the obligation for stakeholder's involvement and relevant common practice. Even if the producer cannot find an appropriate conceptual model design that suits all of these criteria, a conceptual model design that has been used successfully might be a good starting point. Future iterations are likely to refine search criteria and hint of other existing designs.

Motivations for reusing conceptual model designs are to avoid discussions that have been settled in the past and endorse common practice within a relevant community.

5.2.4.2 PA4.2 – Identify and Select Conceptual Primitives and Model Kinds to Represent Acquired Knowledge

In this Process Activity, the producers select suitable conceptual primitives that will capture the knowledge elements and the model kinds that will organize the conceptual primitives.

The producers do not need to know the exact knowledge content to be modelled, but need to have a rough idea of the domain area and the type of knowledge. For example, decision support knowledge may require action-related conceptual primitives while system knowledge may require function-related ones.

The producers need to analyze the conceptual model characteristic requirements from P2.1 – Conceptual Model Requirement Specification to derive the implications on conceptual primitives and model kinds.

The producers need to know about the conceptual primitive and model kind options either from the literature or from experience. There is a critical need to further develop the body of knowledge necessary to categorize the conceptual primitives and model kinds in terms their implications on conceptual model characteristics on the other conceptual model components. For example, it would be useful to understand how characteristics such as expressiveness, computability or level of detail influence the choice of conceptual primitives and model kinds.

Each time the conceptual primitives and model kinds are updated; they influence other conceptual model components, the existing conceptual model artefact and its Meta data, including its characteristics and its validation status. Conversely each time other conceptual model components and requirements change, the conceptual primitives and model kinds will be influenced.

5.2.4.3 PA4.3 – Select Formalism(s) for Conceptual Model Specification

In this Process Activity, one or more formalisms are selected to be enforced in the build phase. A formalism is the constraint of form over content. A formalism can be more or less formal. The formality is the amount of constraints imposed on the form. Informal representations such as loose or structured natural language would not be considered as a conceptual model (e.g., glossaries, dictionaries, thesaurus, and hierarchies). A formal representation imposes an artificially defined formalism. A more formal formalism clearly defines concepts with semantics, theorems and proofs that enable inferences. A higher level of formality fosters some conceptual model characteristics such as consistency, interoperability, reusability, computability and executability.

Several formalisms may be required to bridge the gap between different stakeholders. For example, decision-makers, simulation end-users, simulation developers and machines may feel more comfortable to retrieve meaningful and valuable input from a particular paradigm or a particular level of formality. The conceptual model design is meant to cope with contradictory requirements such as expressiveness for human understandability (e.g., Mind Map or UML) and computability or executability for machine readability (e.g., Web Ontology Language (OWL)).

The formalisms are carefully chosen according to the policies, the characteristics and the stakeholders' requirements from P2.1 – Conceptual Model Requirement Specification. In an iterative and incremental design process, the choice of formalism is driven by and influences the other conceptual model components, the existing conceptual model artefact and its Meta data, including its characteristics and its validation status.

The producers need to know about the formalism options either from the literature or from experience. There is a critical need to further develop the body of knowledge necessary to categorize the formalisms in terms their implications on conceptual model characteristics and on the other conceptual model components.

5.2.4.4 PA4.4 – Select Views to Support Stakeholders

In this Process Activity, views are selected to fit the purpose of the different stakeholders. Views are the graphical user interfaces of the conceptual model. When selecting views, the producers are always biased by their own way of "seeing" the problem. It is of utmost importance to make an elective choice of views that support the stakeholders' requirements.

A complete conceptual model design generally includes multiple views. For example, Department of Defense Architecture Framework (DoDAF)/NATO Architecture Framework (NAF) includes an Operational, System and Technical views. UML offers Design, Process, Component, Deployment, Use Case views.

A view can be represented by several model kinds. For example, the UML Process view represents dynamic aspects using State, Activity, Sequence and Collaboration diagrams.

Although views are prescribed by P2.1 – Conceptual Model Requirement Specification, many other latent views can emerge from available conceptual primitives and model kinds if a stakeholder requires it. In an iterative and incremental design process, the stakeholders' representation requirements and the views can evolve as the conceptual model is being built.

The producers need to know about the view options either from the literature or from experience. There is a critical need to further develop the body of knowledge necessary to determine which views are appropriate fit which stakeholders' representation requirements and which conceptual primitives and model kinds make meaningful views.

If formalisms have been selected in the preliminary conceptual model design, they may impact on the discretionary specification of views. There may be more than one way of presenting a view and a specific formalism may impose specifications on the view.

5.2.4.5 PA4.5 – Select a Notation Suitable to Express the Chosen Formalism

In this Process Activity, suitable notations are elected to express the formalisms, the conceptual primitives, the model kinds and the views selected in the preliminary conceptual model design. The choice is driven by P2.1 – Conceptual Model Requirement Specification. For example, in Annex I, Section I.2, the Use Case view was expressed using a custom pictogram notation instead of the UML notation to meet an expressiveness requirement. Introducing the UML notation to non-initiated decision-makers could have added an overhead if not a misunderstanding.

The producers need to know about the notation options either from the literature or from experience. There is a critical need to develop the body of knowledge necessary to explicitly categorize the notations in terms of supported formalisms, conceptual primitives, model kinds, and views.

In an iterative and incremental design process, the selected notations need to be adapted when the requirements and the conceptual model design change.

5.2.4.6 PA4.6 – Evaluate Design for Adequacy/Relevance with Respect to Requirements

In this Process Activity, the stakeholders verify whether the conceptual model design meets the criteria that are manifest in the conceptual model requirements. Their criteria are also part of the V&V argumentation framework. Typical topics that must be specified and transformed into criteria are whether all views needed by the stakeholders are available and for each view whether the chosen formalism is capable of expressing the conceptual model. For example, there must be one or more model kinds that present and completely cover the user's view. There must also be one or more views that present and completely cover the designer's view.

Listed below are the points of emphasis:

- It is not necessary to wait until the requirements are perfect before starting to design the conceptual model and it is not forbidden to start building the actual conceptual model to express the intent as the effort progresses in order to help progressing through the requirements. This conceptual modeling guidance supports the creative process of evolving a conceptual model. Trying to express in building a preliminary conceptual model is part of the iterative design.
- The conceptual model design always starts with an informal mean to express ideas. It evolves each time the mean induces ambiguity or constrains what needs to be expressed. The evolution is from less formal to more formal. The process of evolving a conceptual model design is essential to the stakeholders self and mutual understanding. The conceptual model design process is a learning process; the process of becoming aware of self and others' understanding, bias and expectations. There is more to it than just what is recorded in the actual conceptual model artefact. The journey serves as much as the end destination.
- It is important to be intentionally selective on the conceptual model components (conceptual primitives, model kinds, views, formalisms, and notations) to reduce the risk of uninformed use of components.
- The producers have the discretionary choice of conceptual model components, but they also have the responsibility to justify their choice.

- Because the conceptual model components are tightly entangled, this five-unknown system of equations can only be solved iteratively until the requirements are all satisfied and the design is reconciled in a coherent conceptual model component combination. It is advised to select conceptual model components and try building a preliminary conceptual model. If the design becomes too constraining, it is time to redesign toward another level of conceptual model characteristics.
- Specific modeling tools are helpful to design coherent conceptual model component combinations. It is not rare that the tool influences the design choices, which may affect the conceptual model characteristics.
- It is important to remind that although the coherence of the conceptual model component combination is a necessary condition, the conceptual model design must be driven by the requirements, mostly stakeholders' representation requirements and conceptual model characteristics requirements.
- It is important to document which requirements cannot be met within the constraints of the design and to update the effective conceptual model characteristics accordingly in the conceptual model Meta data.
- It is not rare to feel the need to invent new conceptual model components when encountering expressiveness limitations. This is why general modeling languages allow creating profiles (e.g., UML, SysML) and common standards emerge from specific communities. It is useful to look at related community conceptual models, as a reference since they are likely to suit similar needs. It is not wrong to invent new conceptual model components when nothing satisfying already exists. It would be useful to develop the body of knowledge to determine the common design patterns (appropriate conceptual model component combinations) typically used by the M&S community.

5.2.5 Process Phase 5 Guidance – Build Conceptual Model

The Conceptual model development Process Phase described here is the final stage of the five-step process and entails the completion of the subject conceptual model by means of its compilation and qualification for its intended use.

The components of Phase 5 (PP5) Process Activities, their inputs, and resulting products are indicated in diagram of Figure 5-9 below.

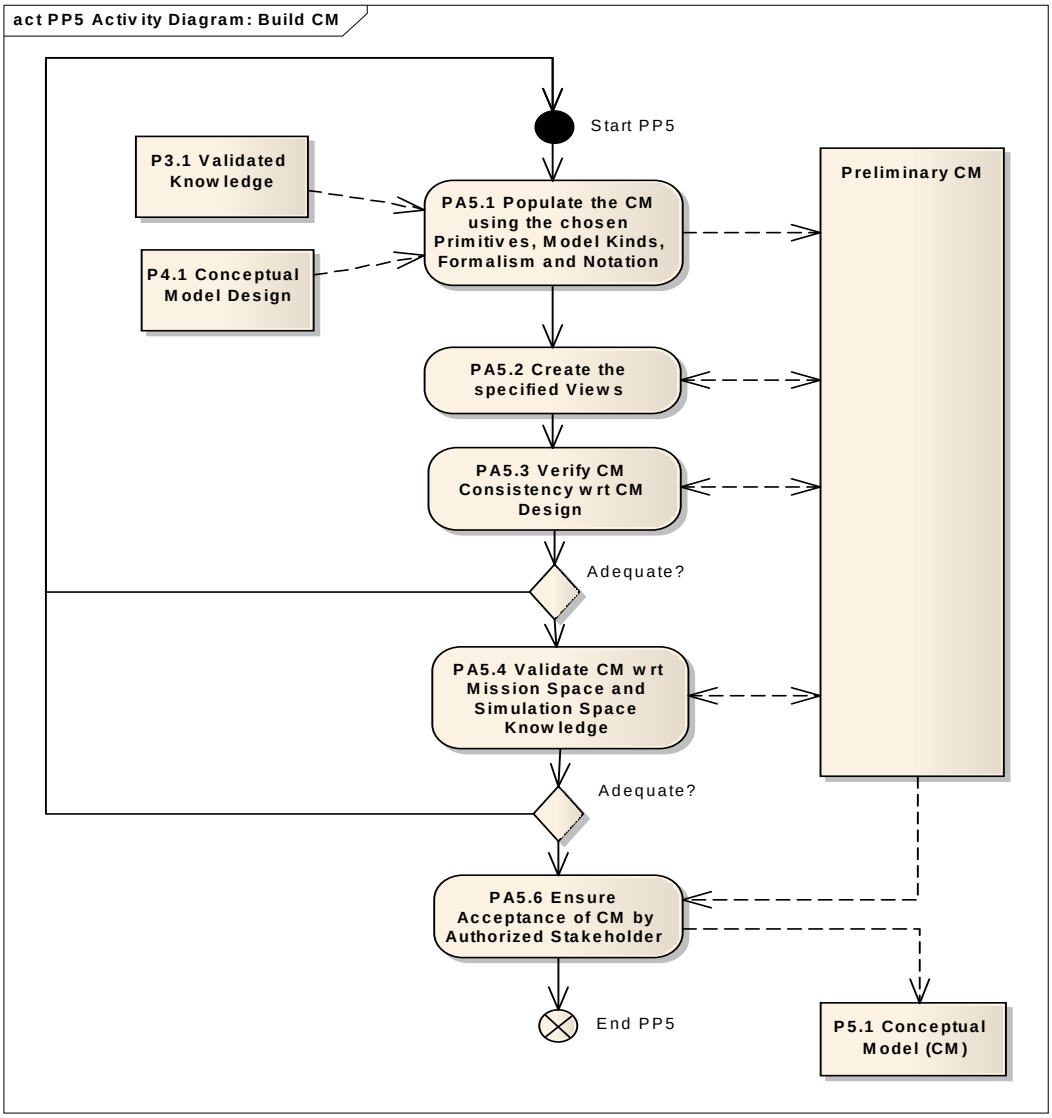

Figure 5-9: PP5 Activity Diagram: Build Conceptual Model Indicating Process Activities, Process Flow, and Artefact Generation.

Depending primarily on the results of proceeding activities including work-products (i.e., P3.1 – Validated Knowledge and P4.1 – Conceptual Model Design), and resulting in a single work-product result (i.e., P5.1 – Conceptual Model); Phase 5 consists of five (5) Process Activities (PA5.1 through PA5.5) whose contextual circumstances, execution, and consequent results together with inter process flows will be elaborated in the commentary that follows and in detailed formal specification in Annex G, Tables G-23 through G-28.

Some guidance relevant to the entire PP5 – Conceptual Model development phase includes the following elements considered prudent for any such product build effort:

- Confirm entrance criteria are satisfied and that all necessary resources are likely to be available in time.
- Establish Group composition, roles and responsibilities.

- Establish expectations for the execution of all Process Activity elements. Plan effort and manage to resources, schedule, and product deliverables.
- Confirm exit criteria with conceptual model product customer/user.

5.2.5.1 PA5.1 – Populate the Conceptual Model Using the Chosen Primitives, Model Kinds, Formalism, and Notation

Several considerations relevant to the execution of PA5.1 relate to: input assets, preparation for effort execution, conduct of the activity itself, and the nature of resulting effort.

Overall program management agent for conceptual model effort is presumed to provide:

- A full specification of characteristics of an acceptable conceptual model product; and
- A complete set of validated knowledge of both the mission space and the simulation space.

Nevertheless, conceptual model build Task Group should be prepared to communicate liberally with Process Phase 3 and 4 execution agents to request clarification of information provided in work-products P3.1 and P4.1 and to request additional information determined necessary to complete the model specification as build population proceeds.

In preparation for formal task activity, anticipation of circumstances likely to arise during the effort is prudent. Building of a conceptual model entails a variety of determinations that may not be fully prescribed by design guidance but which are likely to affect the efficiency and quality of conceptual model product. In each of these cases, provisional determinations by the conceptual model build Group are recommended.

Build strategy refers to the election of style of operation by the Group, election of alternative design options not otherwise bound by requirements, and establishing such stylistic conventions as may facilitate cooperation and efficiency of the Group. Build versions may be spiral so that a succession of products is generated progressively converging on the desired result. Alternatively, parallelization techniques such as partitioning the mission space, allocating model constructs (i.e., primitives or model kinds) to Group members of the group may be convenient.

Election of alternative options for Primitives, Model kinds, Formalisms and Notation which may persist, consistent with P4.1 – Conceptual Model Design specified constraints may be necessary. These determinations and such style conventions to be shared across the Group should be established by consensus before significant build composition effort is begun. Checking the implications of such determinations during first spiral reviews will reassure the Group of the wisdom of its choices.

Prefatory interpretation of sufficiency criteria for the expected product, cast in terms of easily observable and confirmable product characteristics and evidently correlated to requirements specification elements will provide insurance against shortfalls in product quality in areas such as detail and completeness (scope, entities, entity-attribute and entity-relationships) as specified.

Selection and prompt access to sufficient tools is prerequisite to start of work. Selection of such tools should be made carefully with consideration for:

- Familiarity and competence of Task Group;
- Power to meet conceptual design capture and specification; and
- Facility to generate views and published data products acceptable to customer user stakeholders.

Finally, establishment of Product Document management process and information storage and retrieval sufficient to contain the evolving conceptual model work-product, control of its authoritative configuration and containing commentary on tactical decisions – just as is prudent for requirements or code management under other circumstances.

During execution, conduct of Group reviews of work progress, product convergence according to build strategies, and product quality should compliment normal program reviews and control mechanisms. Cultivation of consistency of vision across the conceptual model build Group is a powerful mechanism to maintain consistency of product, and collaboration among Group members.

Work-product capture in tool consistent with Model Design guidance in form suitable for use as publication or transmission of database as Product P5.1. For this purpose, preliminary coordination with Stakeholder recipient is prudent.

5.2.5.2 PA5.2 – Create the Specified Views

Assuming the requirements for conceptual model design are satisfied, and tools that sufficiently articulate and powerful, the generation, capture, and publication into document or database archive under configurable control should be straightforward. In order not to be disappointed in this expectation, view generation should be included in product reviews during PA5.1.

5.2.5.3 PA5.3 – Verify Conceptual Model Consistency with Respect to Conceptual Model Design

The practice of system, software, or simulation verification is of course too extensive in its scope and detail and too myriad in its alternative strategies, tactics and techniques to be specified here. With respect to the range of options available for verification of the preliminary conceptual model, the most important considerations are consistency, and sufficiency – otherwise wide discretion is allowed to the conceptual model build group commensurate with ‘good practice’ contingent that such process as is elected is declared and documented together with the results of its execution.

Sufficiency of verification consists in a complete, documented, persistent, and traceable confirmation that all the attributes required by the conceptual model design of P4.1 are present in the subject conceptual model. Naturally deliberate and professional requirements management beginning with conceptual model design and proceeding through the process of model build is desired in avoiding (or, alternatively in detecting) such errors of omission.

Consistency in verification entails that attributes of the Conceptual Model are in fact self-consistent (presumably in accordance with Conceptual Model Design) and that, in particular, no pathological attributes of the Conceptual Model not addressed in the Design are present that will interfere with the acceptability of the conceptual model in supporting its intended use and in meeting the need for which it was conceived and created. Such errors of commission are more difficult to identify without a consistent representational schema in the design, conscientious attention to build discipline, and thorough testing and customer use. Execution or inspection of the conceptual model in representation of use cases that may have been used in its design as well as with such *cases that were not used in its design* will likely be helpful.

5.2.5.4 PA5.4 – Validate Conceptual Model with Respect to Mission Space and Simulation Space Knowledge

See above, recognizing the distinction between verification and validation, and interpreting the above in relation to the appropriate referent – that is, Validated Knowledge of Product P3.1.

5.2.5.5 PA5.5 – Ensure Acceptance of Conceptual Model by Authorized Stakeholder

Whereas verification and validation are technical determinations of goodness of fit or similarity between artefact (here a conceptual model) and one or another referent (here design requirements, and Validated Knowledge respectively); accreditation is an administrative decision regarding the degree to which an asset (here the conceptual model) is acceptable for its intended use. On this account, accreditation processes entail articulate collaboration between the accreditation agent stakeholder and the proponent of the asset in question. Several considerations pertain to this circumstance.

First of all, unambiguous identification and acquiescence of the identity of the accreditation agent is necessary. If the authoritative accreditation agent (or agents) is not clearly identified, due, for instance, to the relatively large number of agents with a significant 'stake' in the conceptual model, an inefficient decision process is to be expected at best. Note that multiple accreditation agents for alternative intended uses are not uncommon for either simulations or conceptual models.

Clarity of agreement on intended uses and re-confirmation of accreditation exit criteria in advance of the accreditation application is prudent if only to remove inconsistency between acceptability of the conceptual model asset due to migration or evolution of the use or changes in staff appointees.

It is incumbent upon the conceptual model build agent to have designed and execute factory acceptance tests and if desired user delivery tests whose results have been suitably documented, interpreted and reported in anticipation of the preparation of submission of accreditation request. Coordination of accreditation reviews; support of the accreditation decision process itself; documentation of the consequences and its delivery with the completed Product P5.1 prepared in compliance with associated guidance completes PA5.5, PP5 and conceptual model development.

5.3 CONCEPTUAL MODELING PROCESS CONCLUSION

In preceding text, a linearized account of recommended best-practice guidance for conceptual model development and management process is provided. That account is intended to be interpreted together with the more terse but systematic specification provided in Annex G as constituting recommended best-practice conceptual modeling process. Every effort was made by the Task Group to produce necessary and sufficient guidance; in forms that are comprehensible, consistent, and sufficient for guidance of practice throughout the conceptual modeling process and practically; while leveraging the minimal sufficient binding on the conceptual modeling practitioner in favor of allowing liberal elective of style, an convention commensurate with the challenge of the effort and the cultural, technical and business practice constraints of the enterprise environment in which effort is effected.