Appendix 3 – VV&A COMPOSITE MODEL VERIFICATION RESULTS

Risk-Based Accreditation Methodology: an Ontology Implementation

(NATO MSG-054: "An Overlay Standard for VV&A of Federations")

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An international effort is currently under way towards developing a Risk-Based Accreditation (RBA) methodology for common VV&A frameworks for simulations and federations of simulations. Its goal is to better manage resources, to be able to account for risk and to support tailoring in the VV&A process. This work proposes an ontological implementation of the RBA methodology structure cleanly separating structure from data in order to promote coherent tailoring, to generate reliable documentation and to facilitate future methodology upgrades. A few detailed examples were implemented with the Web Ontology Language (OWL) [16] in order to demonstrate the basic implementation principles, however the RBA methodology is not yet finalized, and neither are the details of the individual RBA activities and tasks used for those examples.

1.0 INTRODUCTION

The Risk-Based Accreditation (RBA) methodology for common VV&A frameworks for simulations and federations of simulations is the result of an extensive international cooperation and convergence of efforts, as highlighted by DMSO [3], IEEE 1516.4 [4], NASA-STD-7009 [9], NATO MSG-054 [10], NDIA [2], REVVA [12], SISO [13], etc.

As its name implies, RBA is organized to identify and quantify various simulation risks (as well as resources) in order to optimize the VV&A process. Essential verifications and validations may thus be identified according to the importance of the corresponding risks and/or costs. Those parts of the VV&A process involving less risk are liable to be tailored out in order to keep a lid on costs while retaining an acceptable level of VV&A reliability.

The RBA methodology applies to the entire VV&A process, beginning with an Accreditation Plan in which the accreditation needs and resources are assessed in order to develop a suitable accreditation approach so as to determine optimal simulation acceptability criteria in light of the intended use and use risks. The V&V needs, risk, resources, schedule and cost resulting from this approach and criteria are then determined, and if appropriate, the thus determined VV&A procedure is carried out, ending with an Accreditation Decision with relevant supporting documents and evidence.

In other words, the goal of the RBA methodology is to devise and implement a VV&A approach which properly and efficiently determines the suitability (with respect to, e.g., cost, risk, utility, scheduling) of a model, simulation, or federation of simulations for the intended use, taking risk into account to optimize the efficiency and reliability of this determination and to adjust the complexity of the VV&A process in light of the available resources and constraints. In this context, risk refers in particular to the risk of using a simulation (i.e., use risk), but risks inherent to the development and VV&A process are also taken into account.

After a brief discussion in Part 2 of risk and its assessment in VV&A, Part 3 summarizes the current status of the international cooperation on the RBA methodology, Part 4 presents our implementation of RBA as an ontology and Part 5 concludes the presentation.

2.0 RISK IN VV&A OF SIMULATIONS

2.1 Different Types of Risk

"Risk is a measure of future uncertainties in achieving program performance goals and objectives within defined cost, schedule and performance constraints." [1]

Risks associated with simulation development and use can be categorized as development risks, operational risks, inherited risks, etc. [1],[5],[11]:

1) **Development Risks** (supported by program and developer managers) are related to the simulation development itself or to the modification of legacy simulations and typically relate to compromises made because the simulation does not exactly meet the needs of the intended application (e.g., inadequate representations, insufficient accuracy), or to potential problems in addressing the technical, scheduling, cost, or resourcing aspects, or to accreditation activities modifying these aspects during the course of development.
2) **Operational Risks** (supported by users and V&V practitioners, managed by accreditation agents) are risks arising from using simulation results that are incorrect and not believing simulation results that are correct, as well as risks arising from V&V activities when minimizing the effects (scheduling, budget, etc.) of potential failures and when producing the evidence of capability and credibility of M&S. Since the V&V activities are meant to provide evidence for the accreditation phase, ultimately the accreditation agent has to manage operational risk.
3) **Inherited Risks** (especially when reusing models, for instance in federations) are risks arising from effects carried forward from previous simulation development or usage, such as effects resulting from undocumented assumptions, limitations, and constraints, or errors and defects that were either undetected or considered insignificant in previous applications.

This list is not exhaustive. Other important risk categories relate for instance to the maintainability and reliability of the simulation.

2.2 Example of Risk Assessment

In order to objectively manage risk and establish risk-based priorities for VV&A according to the RBA methodology, it is essential not only to be able to identify all or most of the risks in the preliminary phase, but also to be able to (preferably quantitatively) compare the different risks with one another by using an established measure of risk (e.g., mathematical expectation of loss) due to an event, for instance as follows [5]:

(Measure of Risk due to an event) = (impact level) x (probability of occurrence)

In ordinary management decisions, "impact level" often is the estimated monetary cost of the average loss resulting from this risk, expressed either as a numerical value or as belonging to a predetermined range of values identified by a label (such as "high", "medium", "low"). Depending on the domain of use and goals of the simulation, other methods of determining risk may be more appropriate, for instance:

- The “impact level” may instead be a quantitative measure of potential loss of life or a measure of mission failure.
- The “probability of occurrence” of the event may be unknown or only subjective, in which case broad ranges of probability (such as “high”, “medium”, “low”) are often used.

A detailed discussion of the various methods for determining the different types of risk in M&S is beyond the scope of this presentation; for more details, please refer to the appended literature resources on risk definition, risk types and risk assessment.

3.0 RBA METHODOLOGY STRUCTURE

3.1 RBA Methodology Activity Sequence

The RBA methodology consists of three major successive phases which are represented by the three columns of Table A3-1. The first phase, during which Activities 1, 2 and 3 are meant to be carried out in sequence, is meant to efficiently and coherently plan and prepare the actual VV&A effort as such, which is subsequently conducted in Phase 2 (V&V process as per Activity 4) and Phase 3 (Accreditation/acceptance decision process as per Activity 5).

Table A3-1: RBA Methodology Activity Overview (bullets refer to sub-activities) [10].

Prerequisite to V&V Process	V&V Process	Accreditation Decision
Activity 1 **Plan Accreditation Effort**: • Assess the Accreditation Needs • Develop the Accreditation Approach • Identify the Accreditation Resources • Build the Accreditation Schedule • Estimate the Accreditation Costs • Prepare the Accreditation Plan • Execute and Evolve the Accreditation Plan	**Activity 4:** **Collect Validation Evidence**: • Plan the V&V Effort • Apply Relevant Historical Information • Verify and Validate the Simulation Conceptual Model • Perform Supplemental Verification • Apply the Verification Products to Validation • Verify and Validate the Data and Knowledge Sets • Validate the Simulation Results • Integrate the Validation Evidence	**Activity 5:** **Recommendations for Use:** • Analyze the Validation Evidence • Develop the Recommendations for Use • Prepare the Accreditation Report and Accreditation Support Package • Support the Official Decision to Accredit
Activity 2 **Characterize Simulation's Use:** • Collect the User Needs • Verify the Requirements/ Objectives • Document the Intended Use • Assess the Use Risks • Define the Conditions of Expected Use • Develop the Acceptability Criteria		
Activity 3 **Construct Validation Referent:** • Identify Practical Referent Information Sources • Collect the Applicable Referent Information • Assemble the Validation Referent • Collect the Validation Evidence		

The RBA methodology is therefore just an overlay on traditional VV&A methodology permitting a more rational determination of acceptability criteria and more efficient planning of VV&A while taking risk and real-world constraints into account, at the expense of a few additional preparatory steps, essentially consisting of Activities 1, 2, and 3. The additional resource expenditure required by these additional preparatory steps is offset by better risk and resource control in the overall process, a more pragmatic and resource-effective VV&A process and more useful and relevant acceptability criteria yielding a more trustworthy accreditation.

Particulars of the individual Activities 1 – 5 are likely to change and have been specified in Table A3-1 only as a rough guide providing a more specific understanding of the overall philosophy of the RBA methodology and its influence on VV&A.

3.1.1 Prerequisite to the V&V Process: "Activities 1, 2 and 3"

Activities 1, 2 and 3 are instrumental in planning the entire VV&A process and its scope.

Specifically, Activity 1 (Accreditation Plan):

- Decides the scope of the accreditation effort;
- Influences the entire V&V effort concerning V&V approach, resources, schedule, costs, V&V Plan;
- Establishes priorities for the V&V effort; and
- Identifies required information to guide the accreditation assessment.

Activity 2 focuses on the use risks assessment and on the process of defining suitable acceptability criteria in light of those risks, the constraints and the intended uses. Acceptability refers to the decision to apply a simulation to an intended use, i.e., this defines on which basis the accreditation decision will have to be taken.

Activity 3 identifies, collects and assembles the validation referent, against which the simulation will be measured and evaluated.

3.1.2 V&V Process: "Activity 4"

Activity 4 corresponds to the V&V steps of traditional VV&A, but according to RBA these are defined by the results and outcomes of Activities 1, 2 and 3, and may be tailored according to these outcomes, thus taking risks and resource availability into account. The primary purpose of performing V&V, as in traditional VV&A, continues to be the collection of evidence indicating that the simulation is properly implemented and valid for its intended use.

3.1.3 Accreditation Decision: "Activity 5"

Activity 5 results in an Accreditation Decision with supporting documents, based on the evidence from Activity 4 according to the acceptability (acceptance) criteria defined in Activity 2 (in the light of risks and resource availability). As in traditional VV&A, the accreditation decision is a formal decision authorizing the application of the simulation for its intended use; it may include recommendations for limitations of use.

3.2 Detailed Tailorable RBA Methodology Examples

The RBA methodology as proposed in NATO MSG-054 is presented in the form of an Excel sheet having the format shown in Tables A3-2 – A3-5. It is structured using the following categories of items, or fields, which will be individually discussed below:

1) Description of activities and tasks of each activity (this includes the use risks assessment activity and its influences);
2) Information required, information sources and information interrelations;
3) Information produced by each activity and task; and
4) Tailoring guidance.

3.2.1 Description of Activities and Tasks

Each "Activity" corresponds to the performance of a specific function in the RBA methodology and normally includes a sequence of several "Tasks". These "Tasks" are assigned pieces of work which, unless tailored out, all need to be finished in order to complete the activity to which they belong. Each "Task" requires information from various sources (for instance from previous completed tasks) and provides information for documentation purposes and/or for use in subsequent tasks.

Table A3-2 and Table A3-3 reproduce a fragment of this Excel sheet corresponding to Task 4.1.1.1 of Activity 4.1.1 corresponding to Activity 4. Although the numbering scheme is likely to change as this work progresses, this example concretely shows that the RBA methodology must be implemented as a (tailorable) sequence of "Activities".

Table A3-2: Activity 4.1.1 "Develop the V&V Approach" Description.

Activity No.	Activity Title	Activity Description
Activity 4	Collect the Validation Evidence	The primary purpose of performing V&V is to collect evidence indicating that the simulation is valid for intended use.
Activity 4.1.1 (This activity corresponds to Activity 4)	Develop the V&V Approach	This activity selects the specific activities and tasks that will be performed as part of the V&V approach

Table A3-3: Tasks (4.1.1.1 – 4.1.1.5) Description of "Activity 4.1.1".

Task No.	Task Description
Task 4.1.1.1	Determine the V&V activities and tasks that could be performed
Task 4.1.1.2	Select level of validation process maturity
Task 4.1.1.3	Candidate V&V techniques
Task 4.1.1.4	Candidate tool needed to support V&V
Task 4.1.1.5	Estimate complexity of each of the V&V tasks to be performed

3.2.2 Information Sources and Interrelations

In order to perform a task, information may be required from one or more information sources. These belong to two categories: "internal information sources" and "external information sources" defined as follows:

1) Internal information sources correspond to activities and tasks: Information produced by each activity and task is mostly provided to other subsequent activities or tasks as information input required for carrying out these other tasks. The fields for internal information sources are therefore referring to an activity or task by the name and/or number of that activity or task providing the information.

2) External information sources are entities such as Sponsor, Developers, Users, VV&A Team, Test and Evaluation Team, etc. They are expected to provide appropriate information such as V&V personnel list, simulation configuration, management history, documentation from prior VV&A or testing activities, etc.

RBA guidance from open literature and standards information from standards organizations are also required.

Table A3-4 is an example description of Task 4.1.1.1 (which corresponds to Activity 4.1.1), listing the information inputs and outputs of this task.

Table A3-4: Detailed Description of "Task 4.1.1.1".

Task No.	Task Description	Information Required	Information Source	Information Produced
Task 4.1.1.1 (This task corresponds to Activity 4.1.1)	Analyze the Accreditation Plan, the acceptability criteria and the RBA guidance to determine the V&V activities and tasks that could be performed	Accreditation Plan	Activity 1.6	Candidate V&V activities and tasks
		Acceptability Criteria	Activity 2.6	
		Use Risk Assessment Report	Activity 2.4	
		RBA Guidance	Open Literature	

3.2.3 Information Produced by Each RBA Activity and Task

Information produced by each RBA activity and task must be documented in a report for documentation and traceability purposes.

3.2.4 Tailoring Guidance

The RBA process, like the resulting VV&A process, is tailorable.

"A general approach to VV&A tailoring is the selection and modification of VV&A activities to meet the needs of the intended use within the risk, resource and implementation constraints of the program and the simulation users and processes as follows:

1) Begin with a composite model that defines the entire spectrum of VV&A activities and tasks that could be done;
2) Select and modify the components of that model to best satisfy the risk and resource constraints of the simulation program; and
3) Assemble the selected components into a consistent process that satisfies the use risk goals of the simulation program while still adhering to the policies, standards or guidelines that may be relevant to the intended use." [17]

Since the individual activities and tasks rely on information produced by previously executed activities or tasks, ensuring a "consistent process" when an activity or task is tailored out requires identifying how this affects the remaining activities and tasks, either providing alternative information sources to those tasks depending on the tailored one, or tailoring them out as well. The corresponding instructions, taking only the first level of those cascading dependencies into account, are currently documented for some tailorable activities and tasks as "Activity Tailoring Guidance" and "Task Tailoring Guidance" (see Table A3-5).

Table A3-5: Task 4.4.1.3, Task 4.4.1.4 and Task 4.4.1.5 Descriptions.

Task No.	Information Required	Information Source	Information Produced	Task Tailoring Guidance
Task 4.4.1.3	Developer's verification products	Task 4.4.1.2	Simulation capabilities and limitations implied by the Developer's verification products	This task only needs to be performed if the Developer has supplied the products that its verification activities have produced
	Simulation configuration management history	Task 4.4.1.1		
	Acceptability Criteria Report	Activity 2.6		
Task 4.4.1.4		Task 4.4.1.2	Gaps and inconsistencies in the Developer's verification products	If the Developer has produced no verification products then the set of gaps consists of all of the acceptability criteria
		Task 4.4.1.3		
		Task 4.4.1.1		
		Activity 2.6		
Task 4.4.1.5		Task 4.4.1.3	Estimated coverage of the Developer's verification products	If the Developer has produced no verification products then the coverage of those products is none
		Task 4.4.1.4		
		Activity 2.6		

4.0 RBA METHODOLOGY ONTOLOGY STRUCTURE

4.1 Overview

Implementing the RBA methodology as a knowledge base, using an appropriate ontology (formal specification for a community of agents of the concepts and relationships forming the methodology) would make possible its automated use by agents in an intelligent network. In particular, an ontology facilitates the implementation of a reasoning mechanism in order to support tailoring processes of the RBA methodology.

The use of an ontology clearly separating structure from data and documentation in order to implement the RBA methodology guarantees a greater flexibility and upgradeability in case of RBA methodology changes or updates (this is particularly important so long as RBA is not finalized).

Furthermore, ontology representation tools [14]] and available search, navigation, visualization and reasoning support ontology tools [15] seem particularly suited to provide the documentation and exhaustive justifications of tailoring in a clear graphical manner as needed for VV&A.

(1) **Conceptualization:**

The RBA ontology modeling pattern is based on two corresponding, mirror image sub-ontologies named "Structure Description" and "Documentation (Data Description)" on Figure A3-1 below. The former consists of activities, tasks and their interrelations (information required and sources). The latter, as its name implies, consists of activity and task reports.

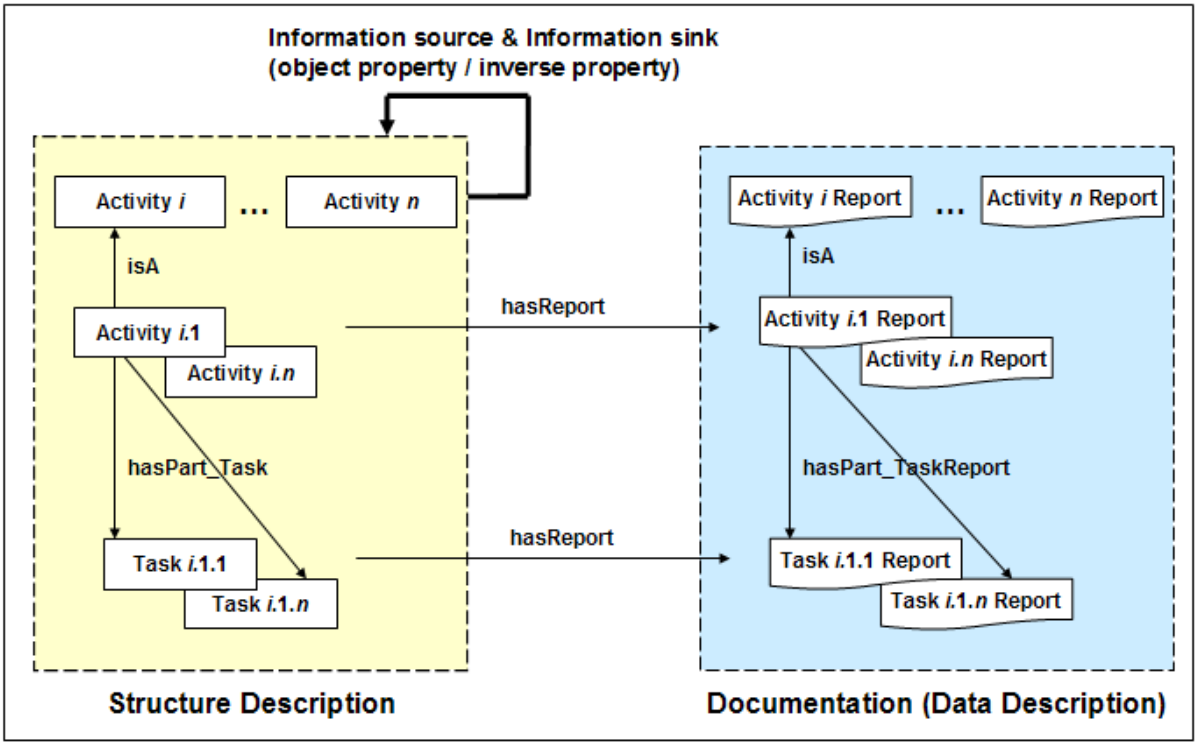

Figure A3-1: Overview of the RBA Methodology Ontology Structure.

(2) **Formalization:**

The RBA methodology was formalized as an OWL ontology [16], using Protégé version 3.4 as ontology editor [14], and using the essential OWL language features as follows (see Figure A3-2):

- Classes;
- Object properties / Inverse properties (the latter being especially useful in particular for the property information source/sink, thus permitting easy forward/backward navigation through the ontology for rapidly evaluating the consequences of RBA/VV&A tailoring);
- Data type properties; and
- Instances.

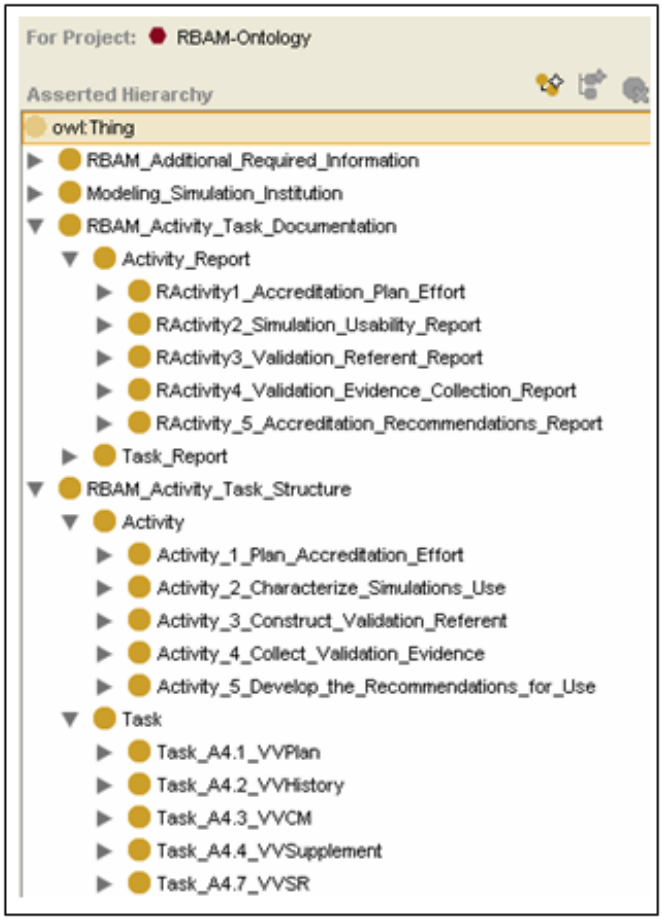

Figure A3-2: OWL Formalization: Overview of the RBA Methodology Ontology.

4.2 Concept "Activity"

The class "Activity" has sub-classes (linked by "isA" relations) of subordinated activities. Each class "Activity" has object and data type properties, for instance as shown in Figure A3-3.

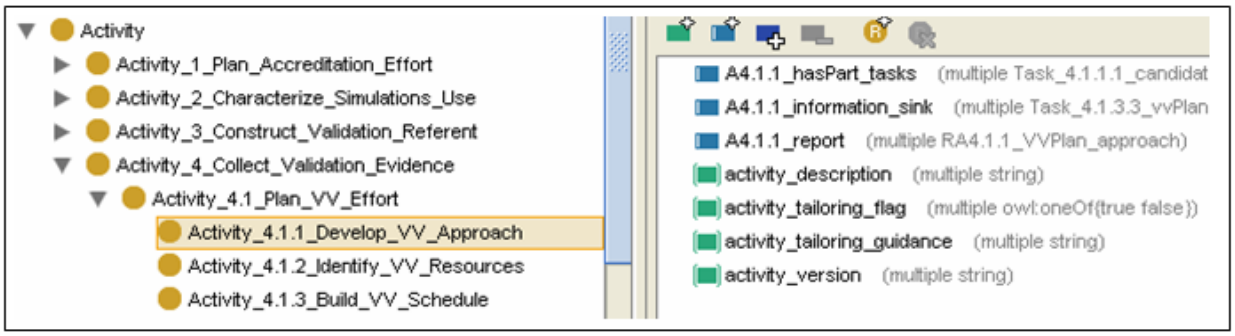

Figure A3-3: OWL Formalization: Class "Activity", its Sub-Classes and Properties of Class "Activity 4.1.1".

4.3 Concept "Task"

The class "Task" has sub-classes (linked by "isA" relations) of subordinated tasks. Each class "Task" has object and data type properties for instance:

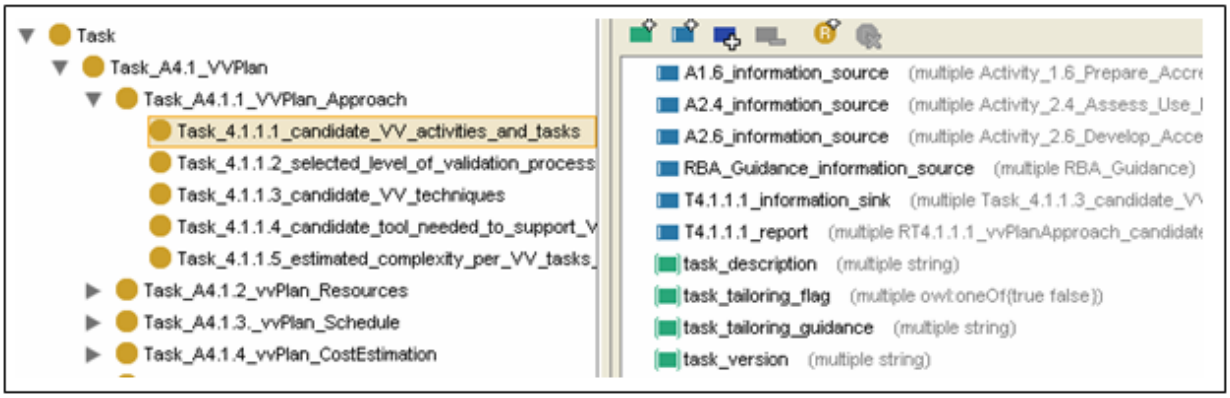

Figure A3-4: OWL Formalization: Class "Task", its Sub-Classes and Properties of Class "Task 4.1.1.1".

4.4 Concepts "Activity" and its "Tasks"

The relations (composition) between each class "Activity" and its corresponding tasks (class "Task") are defined by "hasPart" relations.

Activity_4.1.1_Develop_VV_Approach		
A4.1.1_hasPart_tasks	Instance*	Task_4.1.1.1_candidate_VV_activities_and_tasks
		Task_4.1.1.2_selected_level_of_validation_process_maturity
		Task_4.1.1.5_estimated_complexity_per_VV_tasks_to_be_performed
		Task_4.1.1.4_candidate_tool_needed_to_support_VV
		Task_4.1.1.3_candidate_VV_techniques

Figure A3-5: Ontology Visualization: Class "Activity 4.1.1" and Object Property "A4.1.1_hasPart_ tasks" (see also Figure A3-3).

4.5 Concepts "Information Source" and "Information Sink"

An "Information Source" denotes an activity or task which provides information to the current activity or task. An "Information Sink" denotes an activity or task which may need information from the current activity or task. The interrelations of information between (activity or task) and (activity or task) are defined by "_information source" as object property and "_information sink" as its inverse property, in order to permit navigation. This is crucial for tailoring needs.

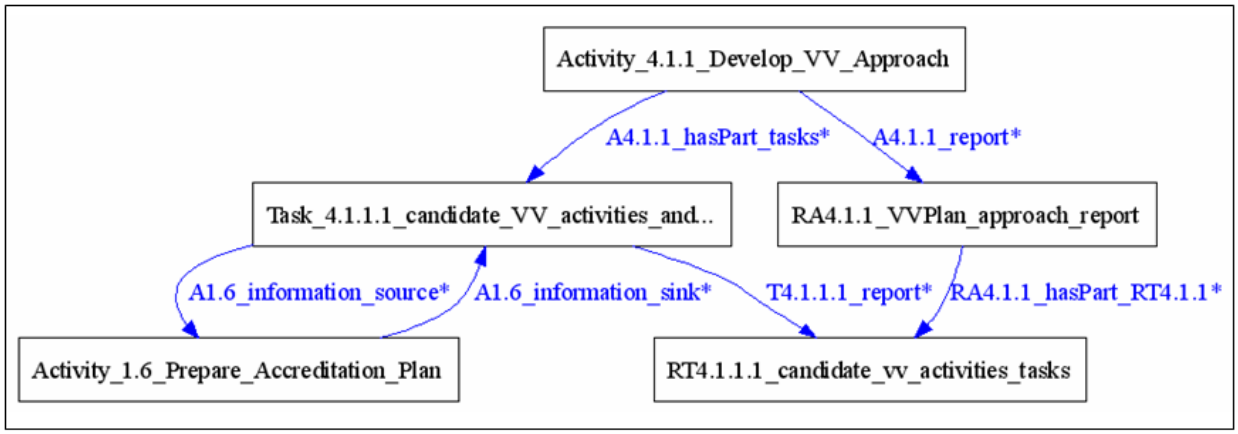

Figure A3-6: Ontology Visualization: Class "Task 4.1.1.1", "Activity 1.6" and Properties "A1.6 Information Source/Sink" (see also Figure A3-4).

4.6 Concept "Information Produced"

The concept "Information produced" is defined as the property "_report" which links to the class "Activity_Report" or "Task _Report". This concept provides concrete documentation for traceability, model management, RBA and VV&A purposes.

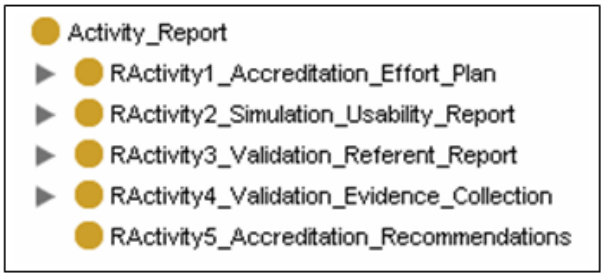

Figure A3-7: OWL Formalization: Class "Activity Report" and its Sub-Classes (see also Figure A3-6).

4.7 Concepts "Activity Tailoring Guidance" and "Task Tailoring Guidance"

The actual implementation of tailoring concepts remains outside of the scope of this work; however the example of Table A3-5 and Figure A3-8 describes how the concept "Tailoring Guidance" may be formalized for Task 4.4.1.4 using the "information_source" object property. Specifically, if Task 4.4.1.4 is tailored out then the information source to Task 4.4.1.5 is retrieved from Task 4.4.1.3 and Activity 2.6 only; the "Task Tailoring Guidance" of Task 4.4.1.4, retrieved by tracing the properties "information_source", specifies which information is to be used, namely the default value defined by "Set of gaps consists of all of the acceptability criteria" (instead of the information "Gaps and inconsistencies in the Developer's verification products" which would have been produced by Task_4.4.1.4). Thus in the event of tailoring the appropriate information can be retrieved from the previous information sources by tracing the "information_source" object property. Alternatively, in situations where the use of default values in the tailoring process is deemed likely to produce

inaccurate or misleading information, it may be desirable to cause the execution of the system to stop with a warning to the user that tailoring is not appropriate in this case.

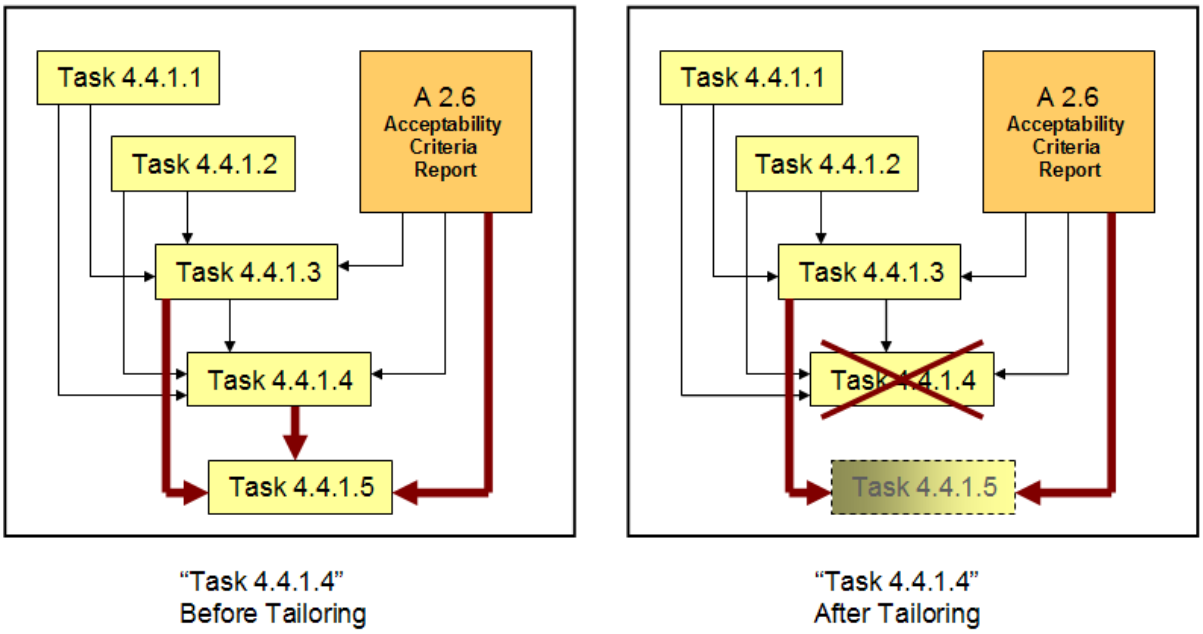

Figure A3-8: "Task 4.4.1.4" Before and After Tailoring (arrows represent the properties "information_source"). Information sources to "Task 4.4.1.5" are "Task 4.4.1.3" and "Activity 2.6" only after "Task 4.4.1.4" is tailored out.

An ontological approach makes it easier to obtain a complete picture of these cascading dependencies and their consequences beyond the first level.

The bulk of the remaining tailorable tasks is not discussed because its tailoring guidance is trivially implementable (this task need not be performed / only needs to be performed if some obvious condition) and does not require any tracing.

5.0 CONCLUSION

The implementation of the RBA methodology as an OWL ontology is feasible without making any compromise, and appears to promise a greater flexibility and upgradeability than more conventional approaches while preserving the fundamental advantages of the RBA methodology.

It will allow, with some additional work, a seamless integration in comprehensive ontology based modeling and simulation tool platforms under development at ITIS such as "Model Management System" [7] (including the "Leitfaden für Modelldokumentation" (Guidelines for model documentation) [6], and VV&A model documentation [8].

Ontological tools implementing reasoning mechanisms potentially can track tailoring effects throughout the RBA/VV&A sequence of activities and tasks: additional work might reveal whether sufficient quality assurance guarantees can be provided in this manner for deeper, more customized tailoring approaches. Further work

might also consider using such tools to visualize tailoring effects in a user friendly manner in order to facilitate tailoring decisions and to explore the relationships between risk constellations and the tailoring strategies most appropriate for them.

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