The Generic Methodology for Verification and Validation (GM-VV) to Support Acceptance of Models, Simulations and Data

Customer

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EXECUTIVE SUMMARY

The Generic Methodology for Verification and Validation (GM-VV) to Support Acceptance of Models, Simulations and Data

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The Generic Methodology for Verification and Validation (GM-VV) development started in an international joint project of the Western European Armament Group (WEAG), called REVVA, and was continued within the NATO-MSG-073 task group. This cooperative effort of multiple nations (CAN, FRA, GER, NLD, SWE and TUR) aimed at delivering a standard and universal applicable framework for the verification and validation (V&V) of models, simulations and data, which will be shared between these nation's defence organizations. The GM-VV has been approved in 2013 as a standard guidance for V&V within the Simulation Interoperability Standards Organization (SISO).

In 2011 the Dutch Ministry of Defence initiated a project to develop a Dutch expertise centre for V&V of M&S in order to consolidate and capitalize their investments in the GM-VV. The objective was to obtain a permanent V&V service providing organization for the Dutch defence organization itself but also forother (inter)national M&S organizations outside the defence domain. This V&V expertise

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centre, called Q-tility, was launched in October 2012 and is powered by the Dutch National Aerospace Laboratory NLR and the Netherlands Organization for Applied Scientific Research TNO.

Description of work

Both the NLR and TNO have been the technical lead for the development of GM-VV within the NMSG-073, and Q-tility served as the Drafting Group Editor for all three volumes that comprise the GM-VV standard guidance within SISO:

Volume 1 – Introduction and overview: providing an introduction overview of the GM-VV conceptual, implementation and tailoring frameworks that constitute the methodology.

Volume 2 – Implementation Guide: providing the implementation framework components and detailed guidance on their application for V&V of models, simulations and serious-games.

Volume 3 – Reference manual: providing the underlying technical concepts and other referential background information on the development and application of the methodology.

This paper provides an introductory overview of the GM-VV basic principles, concepts, methodology components and their interrelationships. Furthermore, the paper focuses on how GM-VV may be tailored for a specific simulation application. This effort is illustrated with some results and lessons-learned from several research programs for the Dutch MoD.

Results and conclusions

Based on our case-studies, we conclude that the GM-VV standard guidance for V&V contains all the necessary high level ingredients for a rigorous approach to structuring, organizing and managing the V&V of M&S assets. As such, GM-VV provides a solid referential basis for the development of future M&S V&V methods, tools and techniques across all application domains. Applying the GM-VV tailoring framework resulted in practical V&V solutions for both presented case-studies. Some parts of both case-study results are re-usable for other V&V projects in the same domain. This reusable information and lessons-learned from this study should be compiled into a V&V life-cycle recommended practice guide that can be stored into a V&V Enterprise Memory.

Applicability

This paper applies to all who want to gain insight into the new SISO GM-VV recommended practice for the verification and validation of a model, simulation or serious-game.

The Generic Methodology for Verification and Validation (GM-VV) to Support Acceptance of Models, Simulations and Data

Z.C. Roza, J.M. Voogd[1] and D. Sebalj[2]

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Summary

The Generic Methodology for Verification and Validation (GM-VV) is a generic and comprehensive methodology for structuring, organizing and managing the verification and validation (V&V) of M&S assets. The GM-VV is an emerging recommended practice within the Simulation Interoperability Standards Organization (SISO). The GM-VV provides a technical framework to efficiently develop arguments to justify why M&S assets are acceptable or unacceptable for a specific intended use. This argumentation supports M&S stakeholders in their acceptance decision-making process regarding the development, application and reuse of such M&S assets. The GM-VV technical framework assures that during the execution of the V&V work the decisions, actions, information and evidence underlying such acceptance arguments will be traceable, reproducible, transparent and documented. Since GM-VV is generic (i.e. abstract) methodology it must be tailored to fit the specific V&V needs of an M&S organization, project or application domain. Therefore, V&V practitioners must incorporate specific V&V techniques within the generic architectural template offered by the GM-VV in order to properly assess the M&S assets under review.

The first part of this paper provides an introductory overview of the GM-VV basic principles, concepts, methodology components and their interrelationships. The second part of the paper focuses on how GM-VV may be tailored for a specific simulation application. This effort is illustrated with some results and lessons-learned from several technology demonstration programs of the Dutch MoD.

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Content

1 Introduction

Increasingly, models and simulations (M&S) are developed and deployed as enabling technology to support system analysis, design, test and evaluation, acquisition, training and education. Within safety critical domains it is imperative to perform systematic and robust verification and validation (V&V) to ensure that both the development and utilization of M&S technology is cost-effective, and provide credible results that do not pose unacceptable risks. For example, in civil flight crew training this is reflected by the flight simulator qualification standards and regulations that are imposed by various national aviation authorities. However, experience outside this specific area shows that V&V is often more of an afterthought than an integral part of any M&S development, employment and procurement policy. This is due to the fact that V&V for M&S is still a relatively new field of technology and practice, with many very divergent approaches. The V&V method that works best in a given situation depends on the individual needs and constraints of an M&S organization, project, application domain or technology. Therefore, there exist many different approaches to V&V that rely on a wide variety of V&V terms, concepts, products, processes, tools or techniques. In many cases the resulting proliferation restricts or even impedes the transition of V&V assets and results from one M&S organization, project, and technology or application domain to another. This context was the key driver behind the development of the Generic Methodology for Verification and Validation (GM-VV)[1,2,3] within the Simulation Interoperability Standards Organization (SISO).

The following V&V aspects guided the development of the GM-VV and are addressed by the methodology:

- The GM-VV shall provide common semantics and components for V&V that can be used unambiguously across and between different M&S organizations, projects, technology or application domains.
- The methodology scope shall encompass the V&V aspects of all artifacts within the M&S life-cycle, ranging from real world needs, through M&S development and usage, to supporting the acceptance decision.
- The methodology shall be suited for performing V&V activities concurrently to the M&S development process, as well as for post-hoc V&V of existing M&S assets, and it shall be applicable to a wide variety of M&S technologies and application domains.

- The methodology shall provide support for establishing V&V agreements between V&V user and supplier organizations. Such a V&V agreement covers all requirements and other arrangements placed on a V&V effort.
- The methodology shall be applicable not only on a technical level but also on a project and enterprise level to address managerial and organizational aspects of V&V efforts.
- The methodology shall be V&V client oriented and product-driven. For each V&V product an activity shall be defined to produce that product and for each activity a role shall be defined.
- The methodology shall be able to address various levels of organizational independence depending on the V&V client needs.
- The methodology shall facilitate the development of traceable, transparent and reproducible evidence-based arguments that underpin an acceptance recommendation. The methodology shall provide tailorable V&V products, activities and roles with respect to V&V needs, use risks and available resources to obtain a cost-effective V&V effort.

To accommodate the above mentioned V&V aspects, a reference model and architecture approach was used for the design of the methodology. This approach was applied in such a way that the GM-VV is not directly tied to any specific M&S application domain, standard, technology, organization or other distinctive M&S implementation details for V&V. As a result, the GM-VV comprises an abstract technical framework that consists of three parts that build upon existing V&V methods[4,5,6,7] and other related practices[7] (Figure 1). The conceptual framework provides unifying terminology, concepts and principles to facilitate communication, common understanding and execution of V&V within an M&S context (Section 0). The implementation framework translates these concepts into a set of generic architectural template and building blocks for the development of concrete and consistent V&V solutions supporting an individual M&S organization, project, and technology or application domain (Section 3). GM-VV provides a tailoring framework that utilizes these building blocks to develop and cost-efficiently apply such V&V application instantiations (Section 4).

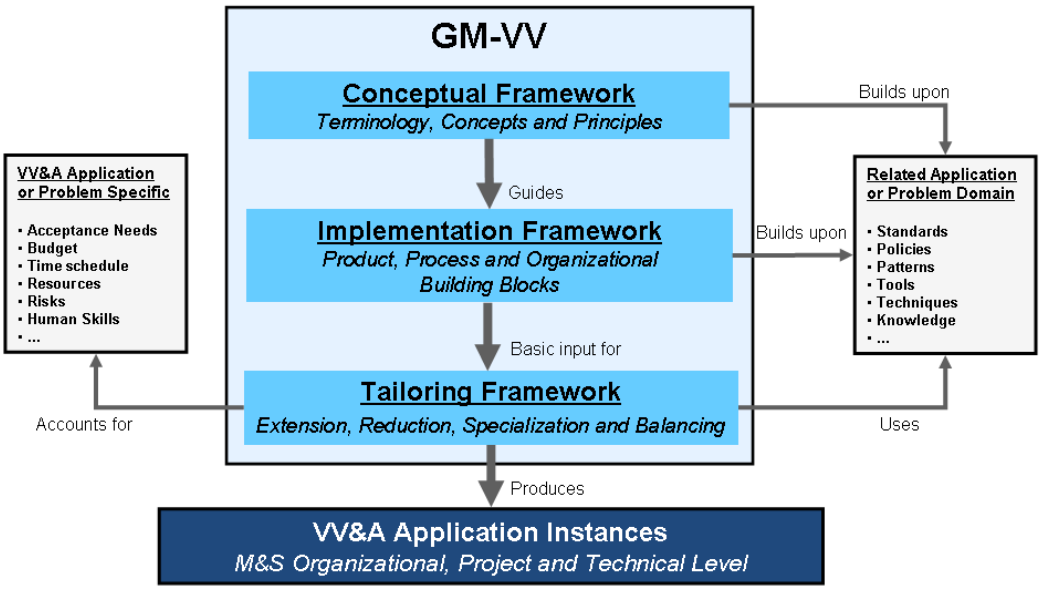

Figure 1 *GM-VV Technical Framework Design and Operational Usage Concept*

In Section 5 this tailoring of the GM-VV is illustrated with examples from two M&S case-studies. Lessons-learned from these case-studies are accumulated in Section 6 into several recommended practices regarding the application and tailoring the GM-VV for specific M&S projects and organizations. The paper ends with conclusions regarding the prospects and value of the GM-VV (Section 0).

2 GM-VV Conceptual Framework

The GM-VV conceptual framework provides fundamental and general applicable terminology, semantics, concepts and principles for V&V. The framework aims to facilitate communication, understanding and implementation of V&V across and between different M&S contexts. The conceptual framework is the fundament upon which the GM-VV implementation framework rests.

2.1 Landscaping the V&V World

The basic premise of GM-VV is that models and simulations are always developed and employed to help fulfill the specific needs of their stakeholders (e.g. trainers, analysts, and decision makers). GM-VV uses a four-world view to structure this larger context (Figure 2). Together, these four worlds define a generic M&S life-cycle and process view. When this

process is properly followed the M&S-based solution that is transferred to the real world for operational usage should fulfill the original needs.

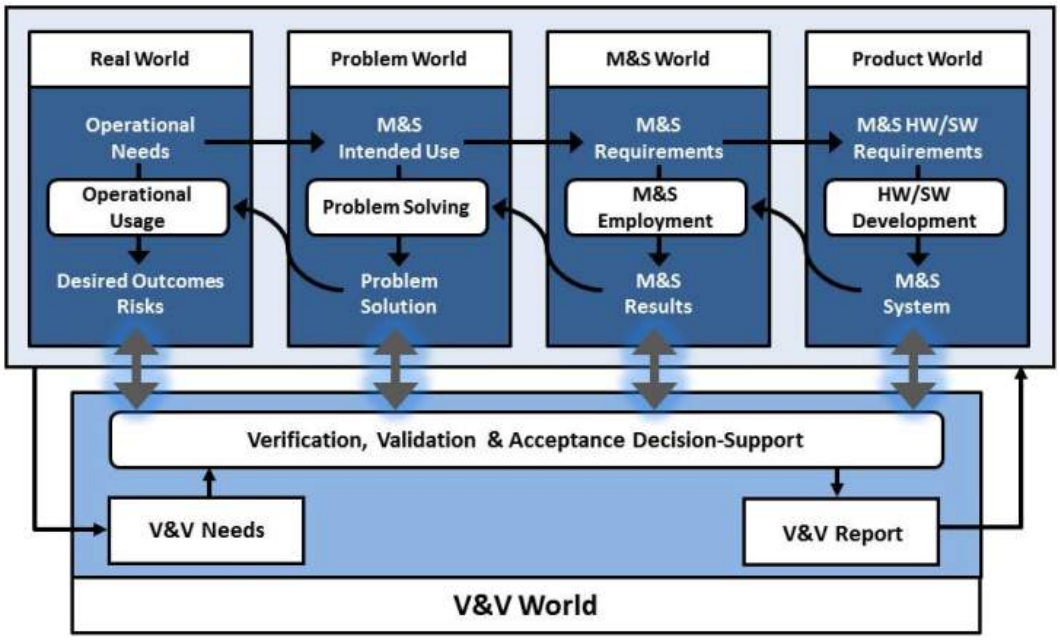

Figure 2 *GM-VV Worlds View*

Within the four world context, stakeholders (e.g. developers, managers and authorities) exist who are responsible for making acceptance decisions on the use of M&S systems, its results or any intermediate products. Such stakeholders are referred in the GM-VV as the *V&V User/Sponsor* (Section 3.3.). The inherent problem is that it is not possible to demonstrate with absolute certainty that such M&S assets will meet the needs *prior* to its actual use. Consequently, there is a probability that the M&S-based solution will not meet user needs and hence, it poses a risk. An M&S asset is *acceptable* when the responsible stakeholder has sufficient confidence in the success of the asset without posing unacceptable risks (e.g. costs, liabilities). The objective of verification and validation, as defined by GM-VV, is to collect, generate, and maintain a body of evidence. This accumulated evidence is then applied to build an argument to support acceptance decision-making processes. *Validation* in GM-VV is referred to as the process to ensure that the right M&S assets is built or procured for the intended use (i.e. M&S validity). To ensure that the M&S asset at delivery can be demonstrated to be valid, it is necessary that the M&S asset is built and employed in the right manner. *Verification* is therefore referred to in GM-VV as the process to ensure that the evolving M&S asset is built right (i.e. M&S correctness).

V&V is a specific M&S problem domain that is known within GM-VV as the V&V World (Figure 2). The V&V world groups the products, processes and organizational aspects necessary to develop a suitable acceptance recommendation for the responsible stakeholder in one of the other four worlds. This recommendation included in a *V&V Report* is the key deliverable of a V&V effort and contains evidence-based arguments regarding the acceptability of an M&S system or result. The V&V effort is driven by the *V&V Needs* that are traceable to the stakeholders acceptance decision needs (e.g. budget, responsibilities, risks, liabilities). V&V effort rigor depends on these needs; can span the whole or specific M&S phase of the four worlds; or can focus on one or multiple (intermediate) M&S assets. A V&V effort can thus be a post-hoc, concurrent, iterative, recursive or even a recurrent effort when legacy M&S assets are updated or reused for a different intended-use.

2.2 Acceptability Criteria Satisfaction and Evidential Quality

The V&V objective is to develop an acceptance recommendation that convincingly shows why an M&S asset is acceptable or not acceptable for the stakeholder. This objective is articulated in GM-VV as an *acceptance goal*. This goal is conceptually accomplished in GM-VV by means of five high-level activities. First, define a set of concrete and assessable *acceptability criteria* for the M&S asset. Second, collect or generate relevant evidence to demonstrate the satisfaction of the acceptability criteria. Third, assess the evidential quality of this demonstration. Fourth, based on the outcomes of the previous three steps develop arguments underlying claims whether or not the M&S asset is acceptable for its intended use (i.e. *acceptance claim*). Finally, compile all previous information into an acceptance recommendation for the stakeholder

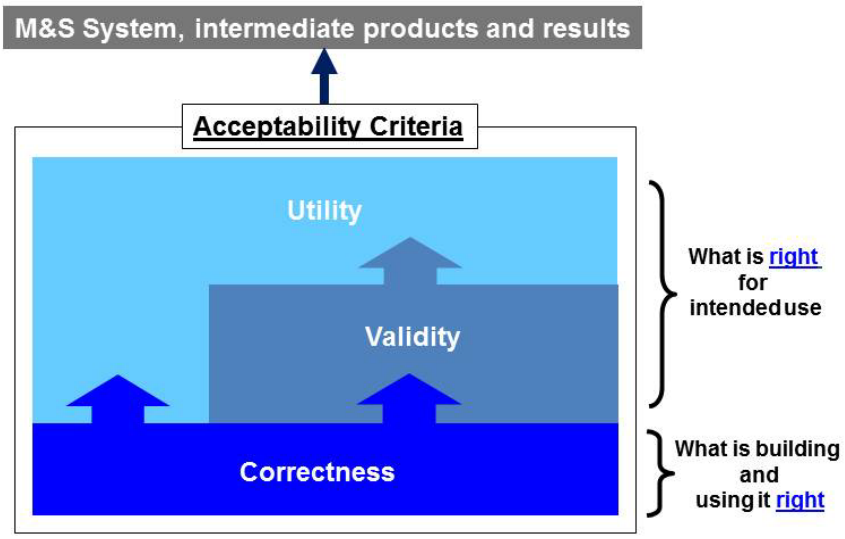

Figure 3 *Acceptability Criteria*

As depicted in Figure 3, GM-VV defines three major M&S asset property areas for which acceptability criteria can be defined. Here *utility* refers to the usefulness of the M&S asset in solving the needs from the real world. *Utility* properties could comprise sub-types such as M&S asset value, cost and use risks. *Validity* properties refer to the degree of realism (i.e. fidelity) of the system of interest that is replicated by the M&S asset [9]. The validity significantly determines the utility of an M&S asset. *Correctness* properties refer to the extent to which the M&S asset implementation and usage conforms to its specifications (e.g. conceptual model, design); and is free of design, development and employment defects (e.g. semantic errors, syntactic errors, numerical errors, user errors). M&S asset correctness impacts its utility and validity.

To be able to make a well informed acceptance decision, also the evidential strength of an acceptance claim must be known. The latter determines the level of trust that can be placed on such claim, and directly relates to the stakeholders tolerance of use risk. For this purpose, the GM-VV identifies V&V quality properties that refer to how well the V&V effort is performed (e.g. rigor) with regard to developing the acceptability criteria, collecting evidence, and assessing to what extent the M&S assets satisfy the acceptability criteria. Examples of V&V quality properties are the completeness, consistency and relevance of the acceptability criteria. In the process of collecting and assessing evidence, V&V quality properties may include: knowledge and data uncertainties, skill level of V&V personnel, reliability and repeatability of V&V techniques, relevance and justification for any assumption made in this whole effort.

The eventual acceptance recommendation comprises acceptance claims along with the supporting arguments and underlying evidence. An acceptance recommendation is not necessarily just a yes or no claim. Meeting all the acceptability criteria means the claim can be made that the M&S asset should be accepted for the intended use without limitations. If all acceptability criteria are not met, alternative weaker acceptance claims with supporting arguments and evidence can be constructed. Such alternative acceptance claims could, for example, provide recommendations regarding conditions or restrictions under which the M&S asset can still be used; or on modifications that, when implemented, will lead to an unconditional acceptance for the intended use.

2.3 V&V Argumentation Approach

Evidence and arguments underlying an acceptance recommendation should be developed in a structured manner using a format where the reasoning is transparent, traceable and reproducible. GM-VV supports this by means of a V&V argumentation approach. This

approach can be implemented in various manners. One implementation is a V&V goal-claim network developed by the REVVA projects [10,11]. Such a network provides an information and argumentation structure rooted in both goal-oriented requirements engineering and claim-argument-evidence safety engineering principles (Figure 4).

The left side of a V&V goal-claim network is used to derive the acceptability criteria from the acceptance goal; and design solutions for collecting evidence to demonstrate that the M&S asset satisfies these criteria. Evidence solutions include the specification of tests/experiments, referent information, and methods for comparing and evaluating the test/experimental results against the referent. Collectively, they specify the design of the V&V experimental frame used to assess the M&S assets. The V&V experimental frame produces the actual V&V results that serve as the items of evidence for the right side of the goal-claim network. These items of evidence support the arguments that underpin the claims on whether or not a related acceptability criterion has been met. These acceptability claims provide the arguments for assessing to what extent the M&S asset are acceptable. This assessment eventually results in an acceptance claim for the M&S asset. The V&V goal-claim network encapsulates, manages and consolidates all underlying evidence and arguments necessary for developing an appropriate and justifiable acceptance recommendation. At the end of the V&V effort the resulting V&V Goal-Claim Network can be used to make an assessment on whether the overall V&V effort is of sufficient quality given the real world risk. This assessment must accompany the Acceptance Recommendation. Since for example insufficient resources (e.g. budget, time, skilled people, access to facilities, real world referent data) for the V&V effort may have lead to weak Acceptance Recommendations for the V&V User/Sponsor risk tolerances.

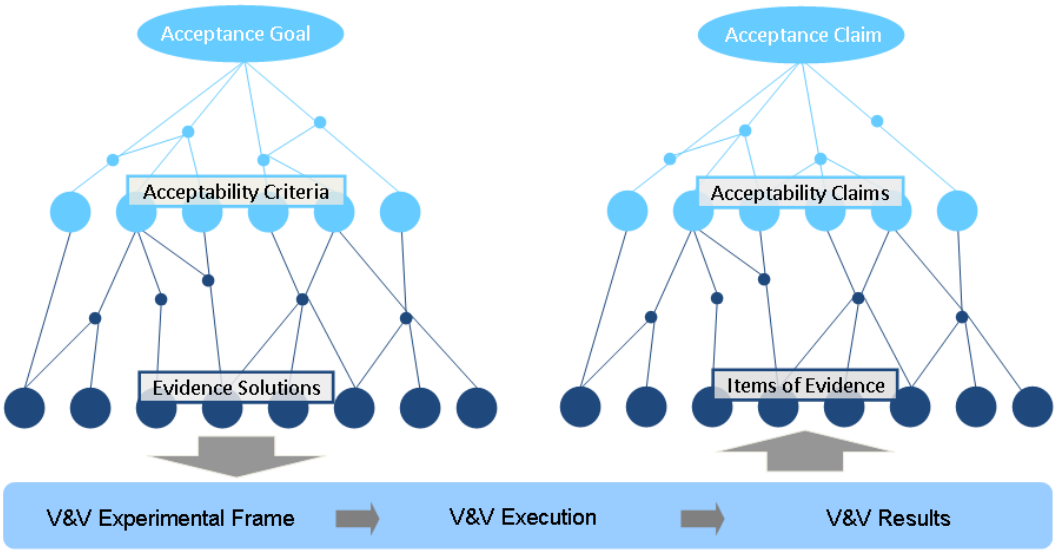

Figure 4 *V&V Goal-Claim Network Implementation*

2.4 V&V Management and Organizational Aspects

To facilitate V&V efficiency and quality, the V&V effort, as presented in the previous two paragraphs, should be executed in an organized way inside the V&V world. Therefore, GM-VV identifies three organizational levels where V&V efforts can be considered.

The first is the V&V technical level, which concerns all technical aspects of a V&V effort necessary to develop and deliver an acceptance recommendation for an M&S asset. Among others, such technical aspects comprise establishing a referent, the design of experiments (DOE), and the selection of application or domain specific V&V tools and techniques [9,4].

The second level is the V&V project level, which concerns all managerial aspects related to the proper application of all the technical aspects of a V&V effort. The *V&V Project* is a managed project, which addresses V&V planning in terms of cost, schedule and milestones. It aids in checking the V&V progress against this planning, and selecting corrective actions when needed. This V&V project could be a separate project alongside the M&S project of which the M&S asset is part of, or be an integral part of this M&S project itself (e.g. subproject, work package). A separate V&V project is relevant in the case where a level of independence must be established between the M&S development team and the V&V team (i.e. independent V&V).

The third level is the V&V enterprise level. This level defines an organizational structure, the *V&V Enterprise*, which establishes, directs and enables the execution environment for V&V projects (i.e. permanent V&V organization). At the enterprise level GM-VV distinguishes between *V&V Client* and *Supplier* entities (e.g. organizational unit and company). A V&V Client entity is an organization that acquires V&V services and products. The aforementioned *V&V User/Sponsor* is a role inside this entity (Section 3.3.). A V&V Supplier entity is an organization that provides V&V services and products. Within the V&V supplier various roles can be identified such as the *V&V Leader* and *V&V Implementer* (Chapter 3). A single person inside such an organization can fulfil one or more of these roles. The V&V effort carried out by the V&V Supplier is based on a *V&V Agreement* between the V&V Client and Supplier.

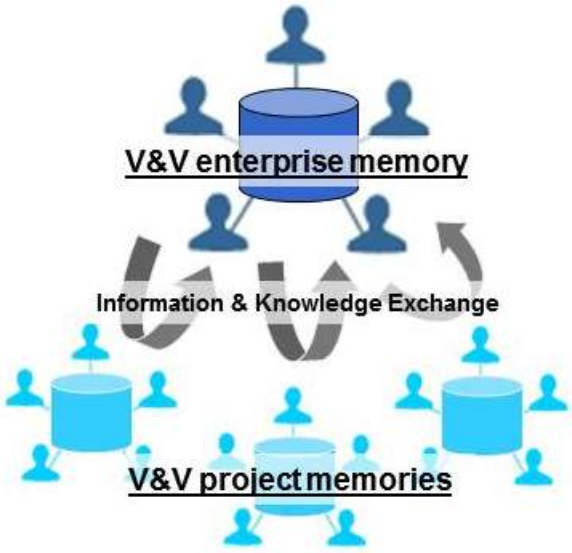

Figure 5 *V&V Memory Concept*

GM-VV applies the memory concept (Figure 5) to the V&V project and enterprise levels. A memory combines an information and knowledge repository and a community of practice (i.e. human resources). The *V&V Project Memory* provides the means to manage information and knowledge produced and used during the life-time of an individual V&V project. The *V&V Enterprise Memory* retains information from past and current V&V projects to support the cost-effective execution of future V&V projects. Examples of such information include M&S technology or domain specific recommended practices, acceptability criteria, V&V goal-claim network design patterns, V&V tools and techniques

3 GM-VV Implementation Framework

The GM-VV conceptual framework comprises a fundamental and common applicable set of terminology, semantics, concepts and principles for the V&V of M&S. They are independent of specific organizations, application domains, standards, technologies, implementations or other concrete details. This framework enables the development of different less abstract (i.e. reference) and specific (i.e. concrete) implementations for V&V of M&S, but all build on common and consistent foundation. The GM-VV implementation framework is such a reference implementation for V&V of M&S assets. Therefore, its purpose is to provide a generic architectural template for developing *structured* and *well-organized* V&V solutions for a specific individual M&S organization, project, and technology or application domain. As such, the GM-VV implementation framework provides the generic design patterns and reusable building blocks (i.e. components) to underpin such concrete V&V solutions. Extension,

reduction, specialization and balancing are the four basic tailoring approaches within the GM-VV tailoring framework (Section 4.). These tailoring approaches are applied to the generic templates and building blocks of the GM-VV implementation framework to develop and cost-efficiently utilize specific V&V application instances.

3.1 Structural Design and Application

The GM-VV implementation framework comprises two major generic design patterns. The first pattern comprises three interrelated implementation dimensions: product, process and organization (Figure 6). The underlying principle of this pattern is that the V&V Needs of the V&V User/Sponsor in the M&S four-world view are addressed by one or more V&V products, being the V&V Report and possibly other custom V&V products the V&V User/Sponsor may need. These V&V products in general require intermediate products (i.e. information artifacts) and associated processes to produce them. The V&V processes are executed by a corresponding V&V organization that is responsible for the development and delivery of the V&V products. In general the V&V effort should result in a V&V Report to be delivered to the customer containing one or more of the information artifacts.

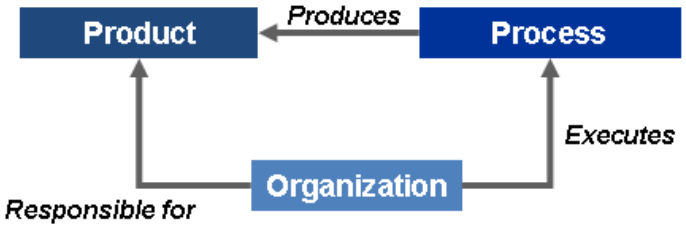

Figure 6 *GM-VV Implementation Framework Dimensions*

The GM-VV implementation framework provides a consistent and coherent set of generic reusable building blocks (i.e. components) for each of these dimensions (Section 3.2., 3.3. and 3.4.). These components are grouped into three interrelated organizational levels where V&V of M&S can be considered (Figure 7), as discussed in Section 2.4. In here the technical level comprises a set of technical components that together constitute a generic engineering life-cycle template for structuring the low-level technical V&V work necessary to develop and deliver an acceptance recommendation (e.g. the acceptance criteria developed, V&V techniques applied, the evidence produced and the assessment of the evidence). The project level of the GM-VV implementation framework provides a set of project-oriented components that together constitute a generic project structure template for organizing and managing the low-level technical V&V work (e.g. V&V project staffing, plans and reports). The enterprise

level of the GM-VV implementation framework provides a set of enterprise-oriented components that together constitute a generic enterprise level organization (i.e. a line organization) template for establishing and operating a permanent V&V organization.

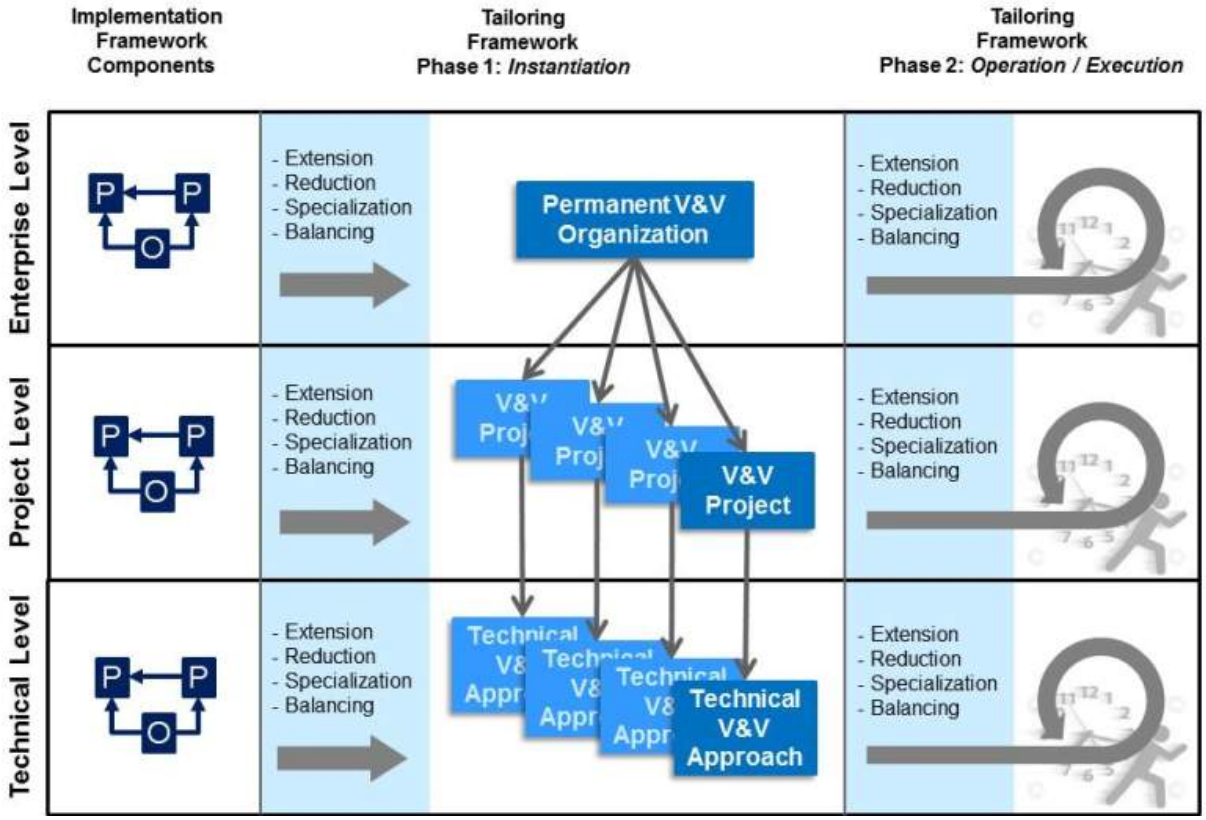

Figure 7 *GM-VV Implementation Framework Levels and Tailoring Application Overview*

Figure 7 depicts the two phases of tailoring the implementation framework. In the *first* phase the implementation framework components are utilized to establish concrete V&V solutions on one or more of the three organizational levels (i.e. a permanent V&V organization, V&V project or technical V&V approach). The four tailoring framework approaches, namely, extension, reduction, specialization and balancing should be applied (Section 4.). Successful application of this first tailoring phase results in a V&V solution conforming to the GM-VV architectural templates (i.e. in a structure and organizational manner) and matches the V&V needs of an M&S project or organization.

In the second phase these same tailoring approaches are applied throughout the operational life-time (i.e. permanent organization or project) or execution (i.e. technical approach) of each V&V solution. This type of tailoring comprises run-time optimization of the instantiated V&V processes at all three organizational levels. At a technical level this could

imply the application of a risk-based V&V approach, such as the MURM[12], to prioritize the acceptability criteria, and allocate specific V&V techniques and tools based on V&V User/Sponsor risk tolerance levels (Section 4.2.). On the project level this could be the alignment of technical V&V activities with the progress of the M&S system's life-cycle phases, balance and allocate the available V&V resources to each phase M&S life-cycle or (work) products. On the enterprise level this could mean balancing the cost-risk of new investments in training of personnel or V&V tool infrastructure development against a future V&V project order intake volume.

3.2 Technical level GM-VV information artifacts, activities and roles

This level describes the low-level technical activities performed, the artifacts produced and the roles that are filled during the execution of a V&V Project (Figure 8). The technical level processes are executed from the project level (Section 3.2.). It is the Project Planning process from this project level that starts and controls their execution. The technical work is started with the V&V Requirements Definition process that takes the V&V Agreement as input and prepares the ground for the other technical processes. These lists are not all inclusive and should be tailored to reflect the needs and constraints of a specific V&V Project.

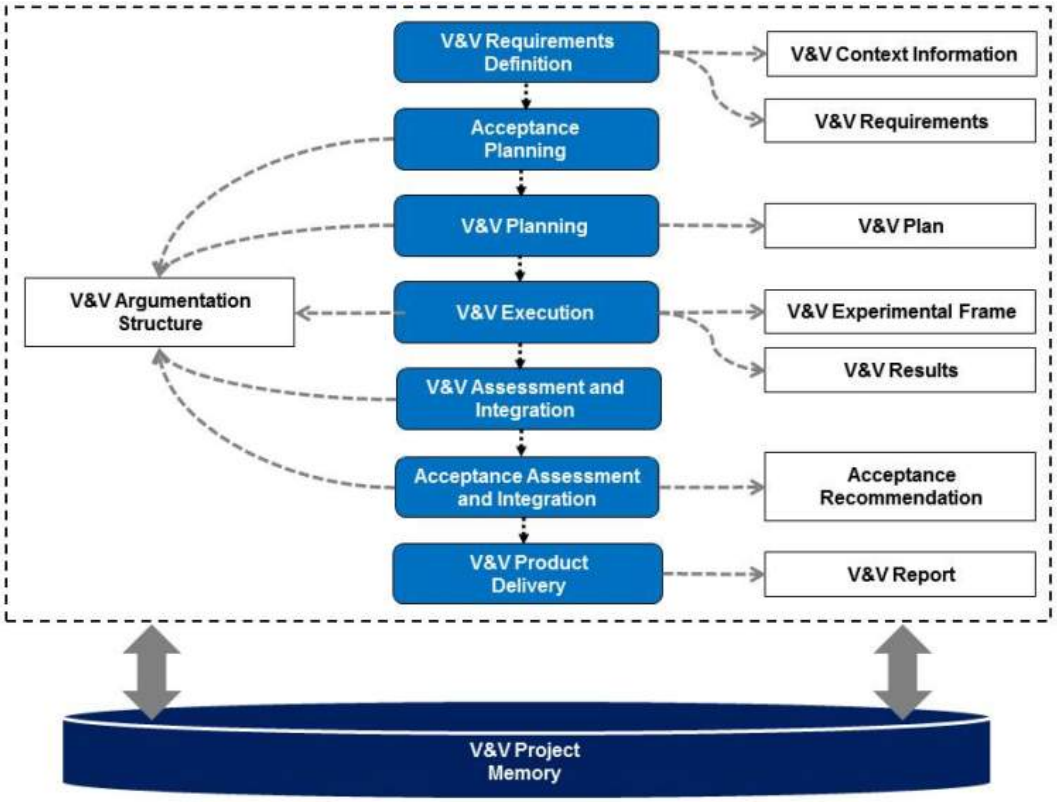

Figure 8 *GM-VV Technical Level Product and Process Components Overview*

Technical level Information artifacts

- V&V Requirements; requirements placed on the V&V project deliverables and execution, including constraints. Note these are not the M&S requirements for the M&S system.
- V&V Context Information; M&S information needed prior to or during the V&V project. It captures information regarding the M&S problem solving life-cycle and process such as the M&S system requirements, intended use and risks (i.e. the four worlds).
- V&V Plan; specifies the V&V execution process, tasks and experimental frame to be implemented as well as the associated resources.
- V&V Experimental Frame; a set of experiments, tests and conditions used to observe and experiment with the M&S system to obtain V&V results.
- V&V Results; the collection of data items produced by applying a V&V experimental frame to an M&S system.
- V&V Argumentation Structure; captures the derivation of acceptability criteria from the acceptance goal, and the derivation of the V&V experimental frame specification from the acceptability criteria. It provides the rationale for these derivations. It integrates the V&V results into items of evidence, and provides argumentation for the acceptability claims underlying the acceptance recommendation. (Possible implementations could be a V&V goal-claim network [11] or a traceability matrix[4 5 6]).
- Acceptance Recommendation; an account or record containing the recommendations on the acceptability of the M&S system for the intended use. This acceptance recommendation integrates descriptions of all the information artifacts.
- V&V Report; accumulates and documents the information generated throughout the V&V effort, along with information on how the V&V effort has been performed.

Technical level processes

- V&V Requirements Definition; defines the V&V requirements and the associated V&V context information for the V&V project based on the V&V User/Sponsor needs.
- Acceptance Planning; transforms the V&V requirements and context information into associated acceptability criteria for the M&S system.

- V&V Planning; transforms the acceptability criteria into the V&V Experimental Frame specification and the V&V plan.
- V&V Execution; implements and executes the V&V Experimental Frame according to the V&V plan to produce V&V Results; integrates them into items of evidence for the M&S system.
- V&V Assessment and Integration; assesses and integrates the items of evidence into acceptability claims regarding whether or not the M&S system satisfies the acceptability criteria.
- Acceptance Assessment and Integration; assesses and integrates the acceptability claims into a claims regarding to what extend the M&S system is acceptable for the intended use i.e. acceptance recommendations.
- V&V Product Delivery; packaging the information artifacts into the V&V Report and delivering it to the V&V User/Sponsor, and archiving the information artifacts in appropriate repositories.

Technical level roles

- Acceptance Leader; responsible for specifying the acceptability criteria, assessing the acceptability claims and constructing the acceptance recommendations.
- V&V Leader; responsible for developing the V&V plan, assessing and integrating the V&V results into items of evidence, and constructing the acceptability claims.
- V&V Implementer; responsible for implementing the V&V experimental frame and generating V&V results. Examples of V&V implementers are SME, M&S developers and test engineers.

3.3 Project level GM-VV information artifacts, activities and roles

This level describes the supporting project environment activities performed, artifacts produced, and roles involved that can enhance the effectiveness and efficiency of the low-level technical V&V work (Figure 9). This includes a V&V Project Memory that facilitates the management and maintenance of the total body of V&V information artifacts produced during the lifetime of a V&V Project. A V&V project is instantiated once the V&V Agreement at enterprise level has been signed (Section 3.3.) by starting the Project Planning process. From the Project Planning process, the other project level processes (left side of Figure 9) and the technical level processes are started (right side of Figure 9). These lists are not all inclusive and should be tailored to reflect the needs and constraints of a specific V&V Project.

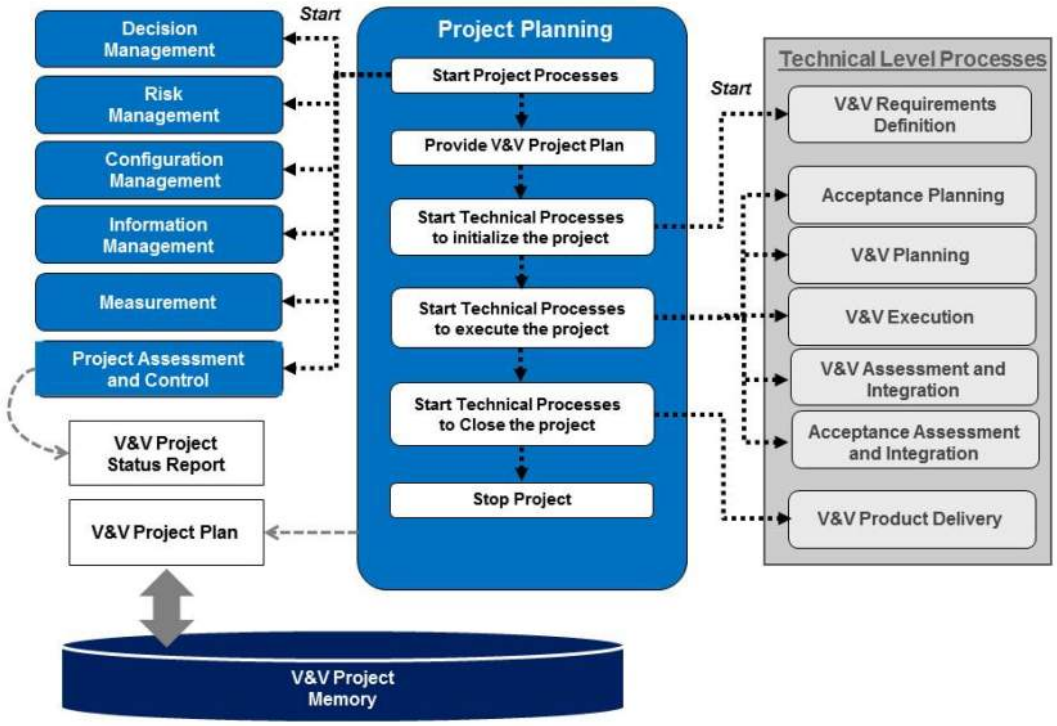

Figure 9 *GM-VV Project Level Product and Process Components Overview*

Project level information artifacts

- V&V Project Plan; a coherent arrangement of activities and tasks to guide both the V&V project execution and control. Can incorporate or reference the technical level V&V plan.
- V&V Project Status Report; an account or record to provide information on the conduct of the V&V project, its status and issues.

Project level processes

- Project Planning; produces, maintains and communicates an effective V&V project plan.
- Project Assessment and Control; reports on the V&V project status and supports V&V project plan execution to ensure that the schedule, costs, deliverables and objectives specified in a V&V agreement are met.
- Decision Management; provides information to determine the most beneficial course of action for the V&V project where alternatives exist.
- Risk Management; provides information to identify, analyze, monitor and manage V&V project risks continuously.

- Configuration Management; defines the mechanism to establish and maintain the integrity of all project deliverables, associated intermediate products, and information during the V&V project execution.
- Information Management; supports appropriate information exchange among all involved in the V&V project execution.
- Measurement; collects, analyzes, and reports data related to the overall V&V project, its performance and the quality of its deliverables.

Project level role

- V&V Project Manager; responsible for managing the V&V project to assure that the V&V report and possibly other custom V&V product(s) are developed and delivered according to the V&V agreement.

3.4 Enterprise level GM-VV information artifacts, activities and roles

This level describes the enterprise environment activities performed, artifacts produced, and roles involved that establish a permanent V&V Supplier organization (Figure 10). Such permanent V&V organization (i.e. line organization) can enhance the effectiveness and efficiency of V&V projects. This includes a V&V Enterprise Memory that facilitates the management, reuse and maintenance of the total body of V&V information artifacts, knowledge and products required to sustain the delivery of V&V products by a V&V Supplier for any M&S project. These lists are not all inclusive and may be tailored to reflect the needs and constraints of a specific enterprise or company that executes V&V Projects.

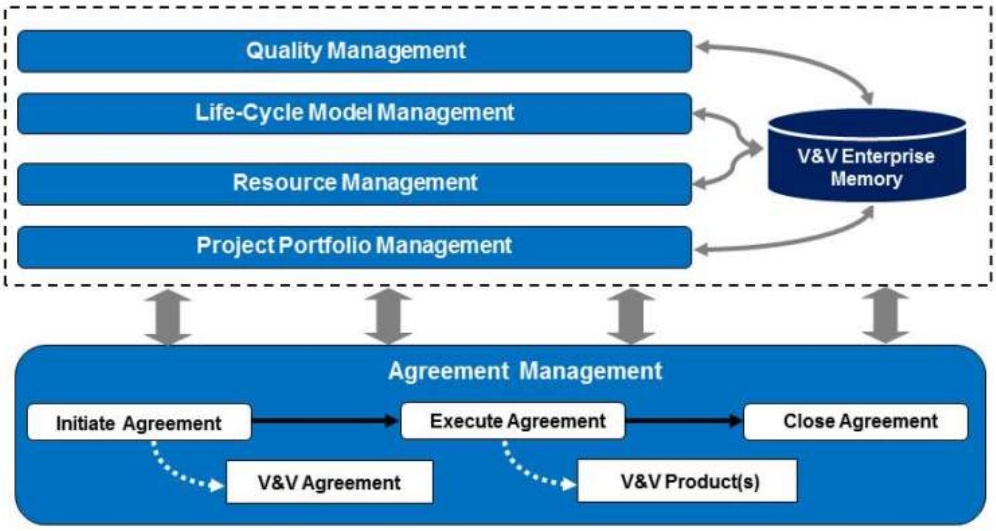

Figure 10 *GM-VV Enterprise Level Product and Process Components Overview*

Enterprise level information artifacts

- V&V Agreement; a contract, statement of work or any type of agreement between a V&V client entity and a V&V supplier entity for the delivery of a V&V product(s).

Enterprise level processes

- Agreement Management; initiates, executes and closes the V&V agreement between V&V Client and the V&V Supplier entity.
- Life Cycle Model Management; defines, maintains and ensures availability of V&V life-cycle models suitable for carrying out any V&V Project.
- Project Portfolio Management; initiates and sustains necessary, sufficient and suitable V&V projects in order to meet the strategic V&V Supplier entity objectives.
- Resource Management; ensures that necessary resources are provided for carrying out V&V projects and that skills, competencies, and infrastructure are maintained, consistent with the enterprise entity needs.
- Quality Management; ensures that the delivered V&V products meets the enterprise entity quality standards and achieves V&V User/Sponsor satisfaction.

Enterprise level roles

- V&V Enterprise Manager; responsible for managing the environment in which V&V projects are conducted. This role contributes to the arrangement of a V&V agreement from the V&V Supplier side.
- V&V User/Sponsor; responsible for specifying the V&V requirements and endorsing the delivered V&V product(s). This role contributes to the arrangement of a V&V Agreement from the V&V Client side.

4 GM-VV Tailoring Framework

The GM-VV is intended as a generic, high-level implementation framework for V&V, which should be tailored or "customized" for each individual M&S organization, project or application domain (Figure 7). The basic premise of the GM-VV tailoring concept is that the GM-VV implementation framework components should first be cast into a tangible V&V solution fit for an organization or application domain, and secondly this instance should be optimized for a V&V organization or project life-time (Section 3.1). The objective of this

tailoring is to adapt the GM-VV implementation framework products, processes and organization roles to satisfy the specific requirements and constraints of:

- An organization that is employing the GM-VV (e.g. company policies, standards),
- A domain in which the GM-VV is employed (e.g. standards, regulations, technologies),
- A V&V Supplier entity delivering V&V products or services (e.g. standards, processes),
- A V&V Project (e.g. time, budget, scope, complexity, risk, available resources).

4.1 Tailoring Approaches

The GM-VV tailoring framework applies four basic tailoring approaches:

- Tailoring by Extension: adaptation by adding custom V&V products, processes, activities, tasks and roles. For example, a V&V Client organization or application domain may require additional custom artifacts not foreseen by the GM-VV.
- Tailoring by Reduction: adaptation by deleting products, processes, activities, tasks and roles due to constraints such as inaccessibility of data and information protected by intellectual property rights, security or technical restrictions.
- Tailoring by Specialization: adaptation by adding or using domain specific V&V methods, techniques and data that are unique for a V&V project, organization or application.
- Tailoring by balancing: adaptation by fitting a suitable cost-benefit-ratio for the available V&V project time and budget towards an acceptance recommendation. The level of acceptable M&S use risk should drive the rigor and resources employed for V&V.

Tailoring by these four approaches should be performed in accordance with the three dimension design of the GM-VV implementation framework (Figure 6), to obtain a consistent and coherent V&V solution. For example, for each new or specialized product a corresponding process (activities, tasks) and an organization (roles) need to be defined. The result of a successful implementation of the GM-VV tailoring framework is a modified or new V&V method instance according to the GM-VV. This consists of concrete V&V organization, products and processes, which should achieve the V&V needs of an M&S organization, project, technology or application domain.

The power of GM-VV's implementation framework is that it allows for tailoring concrete V&V solutions (Figure 11). The GM-VV framework allows other V&V recommended practices and standards to be compared and understood. Moreover, it enables the integration and usage of such practices within the GM-VV framework. For example, the literature shows that the V&V standard specially designed for distributed simulations using the HLA can be considered a tailored V&V method instance of the GM-VV framework[13]13.

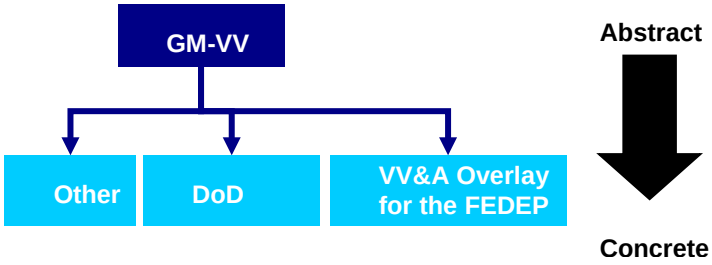

Figure 11 *Other V&V standards as concrete V&V method instances of the GM-VV*

4.2 Tailoring by Balancing and Risk-Based V&V Approaches

GM-VV stresses the importance of balancing approaches while performing technical V&V activities since, in any project, it is impossible to verify or validate the entire M&S system. Exhaustive verification and validation (i.e. 100% coverage of all aspects) of an M&S system is something purely theoretical [9]; requiring infinite time and V&V resources. In practice, there is always a limited time and budget available for a V&V project. In reality the original time and budget allocated for performing V&V is often squeezed by M&S system life-cycle aspects (e.g. on time delivery). This requires continuous balancing of time, budget and resources available for V&V against what should and could be verified or validation throughout the V&V project life-time.

Risk-based techniques and methods are effective, practical means of balancing [4 11 16]. Risk-based V&V centers verification and validation around M&S use risks. M&S use risks are the risks directly related to usage of the M&S system and what the impact could be if the M&S system isn't (completely) fit for the intended use. Risk-based V&V identifies and analyzes the M&S use risks, and aims at addressing these risks by guiding the technical V&V activities towards the level of risk of each identified risk items. A risk-based approach responds to these M&S use risks as follows:

- *Target technical V&V activities*: allocate V&V effort and select V&V techniques based on the level of risk of each identified risk item; match the rigor and extensiveness of V&V techniques to the level of risks.
- *Sequencing of technical V&V activities*: prioritize the risk items, starting with verifying and validating the most important M&S use risk items first and work down to the less important ones.
- *Reduction of technical V&V activities*: if the initial time, budget and resources are limited or are reduced during the life-time of the V&V project, V&V activities and evidence solutions (Section 3.2.) can be deleted in reverse order, starting with least risky ones.
- *Reporting of technical V&V results*: report V&V results in terms of residual M&S use risks (e.g. V&V solutions executed, not executed, executed with limitations or skipped).

When applying a risk-based approach, one should ensure that the risk-based V&V activities and techniques recommended by the M&S use-risk assessment corresponds to the overall V&V project organization and plan (Section 3.3.).

The remainder of this paper will provide an illustration and guidance on performing V&V using the GM-VV tailoring framework.

5 GM-VV Application Illustrations

Currently two case-studies have been completed for the Dutch MoD and these will be used to illustrate the tailoring and application of GM-VV towards a specific M&S application [14,15] [16]. The results of these case studies will be discussed on a high-level for brevity reasons since the general approach of tailoring the GM-VV towards an M&S application is the topic of this paper, rather than the detailed V&V results of a specific M&S application

5.1 Case-Study Backgrounds

The first case-study comprised the V&V of an upgrade to the TNO research driving simulator (Figure 12). This full-motion simulator is used for human driver behavior studies. This simulator was upgraded with a new visual model that simulated the flashing lights of emergency service vehicles. The upgrade facilitated a research project for the implementing body of the Dutch Ministry of Transport, Public Works and Water Management (RWS). The objective of this research project was to investigate the effects of a new flashing-light directive for emergency service vehicles at a crash site. The aim was to reduce traffic jams while

ensuring the safety of emergency rescue workers. Human test subjects were exposed to several crash site scenarios with different flashing-light configurations to observe how the drivers adapted their speed, stayed in their lanes and smoothly passed the crash site. The outcome of this simulator study would be used by RWS to make a decision on enforcing a new flashing-lights directive at real crash sites.

Figure 12. *TNO Driving Simulator (left) and the Desdemona Motion Simulator (right)*

The second case-study comprised the concurrent V&V of a full-motion heavy weather ship handling research simulator for the Royal Netherlands Navy. This simulator was developed to research the added value of a motion platform in a possible new simulator based heavy weather ship handling education program and for doctrine evaluation. Heavy weather ship handling skills are currently acquired “on the job” during the final stages of training when students go out to sea under guidance of experienced officers. The navy has a great deal of practical experience in these real world situations, but training and doctrine evaluation in a simulator would make training safer, more cost effective and save time. The navy uses a full mission bridge simulator for their educational programs; however this simulator is on a fixed based and not used to train heavy weather ship handling. If the Navy decides to procure such a simulator the results of this research will be used during acquisition to decide on whether to procure a fixed or motion-base. The research simulator and the related scientific experiments were built and conducted by TNO, Desdemona Ltd and MARIN[16].

For this case study the project level and the technical level of GM-VV were instantiated. Some cooperation between the M&S project (the above described experiment) and the V&V project (the V&V case study) was possible: the M&S project benefitted from the concurrent V&V work because they were made aware of the important aspects early in the project; the V&V work benefitted because some of the experts of the M&S project could provide criteria and data.

5.2 GM-VV Instantiation Process Illustrations

In both case studies the GM-VV instantiation began with identifying the V&V user/sponsor. In practice, the user/sponsor role proved to be two separate roles. The person who sponsored the V&V effort was in both cases the person in the Dutch MoD who initiated the V&V knowledge and service centre program. The user of the V&V effort outcome (i.e. acceptance recommendation) was in both cases a single decision maker. For the RWS, the user's objective was to obtain a decisive acceptance recommendation based on the validity of the upgraded driving simulator. The Navy's was to determine the added value of a motion base for a heavy weather ship handling simulator.

Next the GM-VV generic M&S life-cycle and process view was used as the start point of the tailoring process to create a V&V method that fits the needs of both the V&V user and sponsor (Figure 2). In both cases the GM-VV M&S life-cycle view helped to scope and focus the V&V effort. It provided the major input for the V&V requirements specification and V&V context. The driving simulator case-study focused on the flashing-lights upgrade of the M&S system. The ship handling simulator case-study focused on the utility of a motion system based on the M&S Results. In order to build an acceptance recommendation for the use of these M&S Results, the V&V activities not only focused on the 'M&S System' (i.e. Desdemona simulator soft/hardware) but also on the "M&S Employment" including the experiment's execution, the choice of measurements, and how they were performed.

It is beyond the scope of this paper to present in detail how the methodology was tailored. What follows are only high level examples of how the GM-VV tailoring principles were employed for the two case-studies:

5.2.1 Tailoring the Organization Dimension

The V&V effort on the driving simulator was an instance of a post-hoc V&V project. An independent V&V team was assembled according to the V&V user needs. The ship simulator V&V was conducted concurrently with the simulator development and employment. However, since the M&S project team had no a-priori interest in a particular experimental outcome it was decided by the V&V user that independent V&V was not necessary. This meant that M&S project team members could be part of the V&V project team as well. For both case-studies all V&V technical and project level roles were instantiated to create the V&V team. The V&V project team was managed by one of the authors who did not participate in the activities of the M&S project team. However, in both case-studies the enterprise level role was not instantiated because no V&V enterprise existed. This is an example of tailoring by reduction.

For both cases tailoring of the organization was mainly applied to the subject matter experts (SME) employed by the V&V Leader in the construction of the V&V Goal-Claim Network and the execution of the V&V experimental frame. For the ship simulator case-study the role of V&V implementer could be assigned to SMEs of all parties involved, depending on the acceptance criterion at hand. Due to the wide spectrum of available SMEs, resource limitations and the level of risk, no external V&V implementers were involved. For the driving simulator, the independence requirement mandated external V&V implementer involvement. These are both examples of tailoring by balancing.

5.2.2 Tailoring the Product Dimension

In both cases the V&V user focused on an overall acceptance recommendation, including evidence for a number of specific questions where he expected to be faced with task critical conditions. For efficiency reasons the V&V users and V&V project manager collectively decided to document the results in one single document containing most of the technical products defined by the GM-VV. This is a form of tailoring by specialization.

For both case-studies, the V&V Goal-Claim Network was constructed using the ASCE tool. Both V&V Goal-Claim Networks were built iteratively and used extensively in discussions with SMEs and other stakeholders. However, for the final report, only an overview of the most important findings relevant for the V&V users remained in the delivered recommendation report.

5.2.3 Tailoring the Process Dimension

The most important input for tailoring the processes was that the V&V project had to be executed post-hoc for the driving simulator case-study and concurrently for the ship simulator case-study. This is a form of tailoring by specialization. The driving simulator V&V project had to produce results in just four weeks and only utilized information and evidence that was readily available. The ship simulator V&V project was allotted six months which allowed for many interactions with the M&S project team.

- Process Tailoring by Reduction: Some reduction tailoring was applied: not all processes, activities or tasks defined by the GM-VV were executed. For example, since no enterprise organization was involved, all activities related to enterprise management were omitted in both case-studies. This is consistent with the abstract framework of the methodology.
- Process Tailoring by Specialization: The V&V goal-claim network for the driving simulator was constructed during several face-to-face meetings with SMEs. While for the ship simulator case-study, the network development process was partly

executed during M&S project meetings where it was possible for the V&V team to interact with the navy experts. In other words, during the ship simulator case-study many process activities and tasks were executed in a way typical of concurrent V&V in an experimental setting involving human test subjects in order to determine learning effects.

- Process Tailoring by Balancing: During the development of the V&V Goal-Claim Network a decision needs to be made on whether or not to continue decomposition of each identified goal in smaller sub-goals. Factors included in such a decision are:
- Availability of test methods to obtain evidence (e.g. measurements, literature study, SME opinion)
- Costs (budget, time, needed expertise, etc.) to execute the available test methods
- Expected strength or convincing force of the obtained evidence from the test methods

For both case-studies the overall optimization by balancing resulted in a thorough study of the M&S system.

5.3 V&V Goal-Claim Network Illustrations

The V&V Goal-Claim Network is one possible implementation of the GM-VV argumentation approach (Figure 4). The balancing concept was extensively applied during the development of the V&V goal-claim network. Since the scope and budget differed significantly between the V&V case-studies, there is a significant difference in size and complexity of the V&V goal-claim network structures.

5.3.1 V&V Goal Network

The V&V Goal-Claim Network starts with the acceptance goal. This goal is to be understood within a certain explicitly given context. This top goal should encompass the complete V&V needs of the V&V user/sponsor (Figure 13; a goal is depicted as a rectangle, the context as an oval) and is therefore usually a vague high level statement. Therefore, no test method (a circle in Figure 13) to obtain evidence is available. This problem is tackled by defining sub-goals via a decomposition strategy (a parallelogram in Figure 13). Via a number of decompositions one arrives at the acceptability criteria.

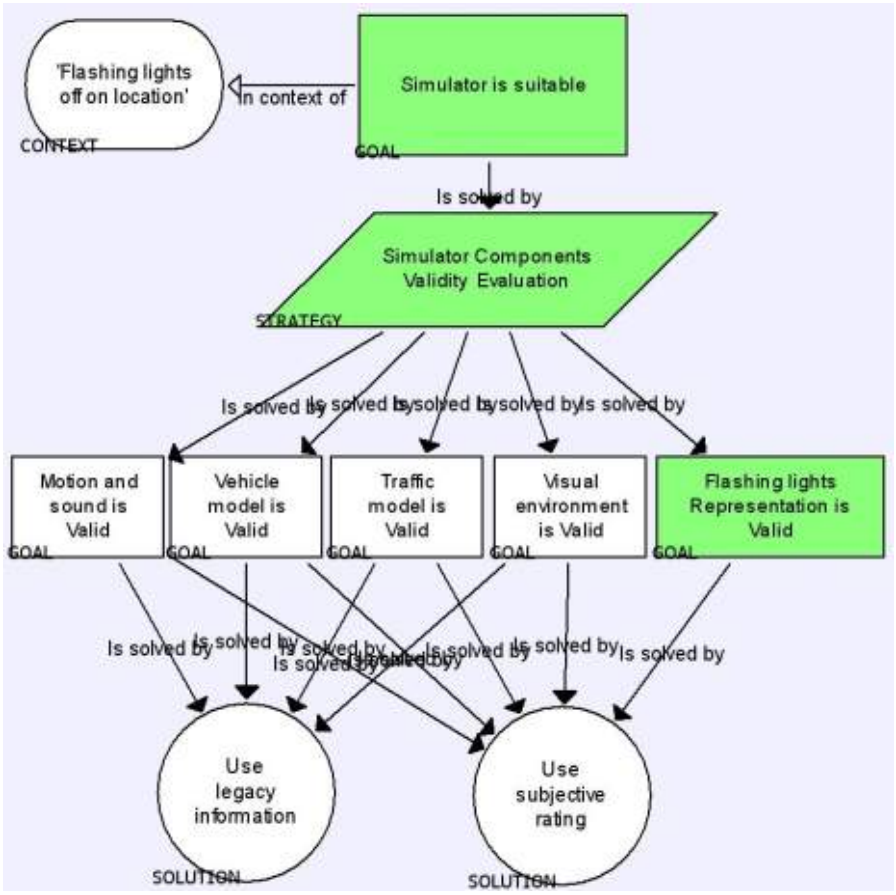

Figure 13. *V&V Goal Network Top (Sub)Part of the Driving Simulator Case-Study*

For the ship simulator case-study two main groups of acceptability criteria were deduced: the experiment must be executed correctly and the experiment must deliver valid results. The assessment of the experimental correctness consisted of the evaluation of acceptance criteria on, amongst others: the qualification level of the test-subjects, the usage of both an experiment and a control group, the number test-subjects, experimental phases, test-subjects and time allotted to each experimental phase. The assessment of experimental validity consisted of the evaluation of acceptance criteria on three main subjects, each with a number of sub-criteria: simulator validity, operational task validity, and human factors related measurement methods utility. Examples of human factors measurement related acceptability criteria are the Transfer Effectiveness Ratio and Training Cost Ratio[15]. Defining acceptability criteria for such a utility property means defining compliance rules in terms of acceptable margins, for example: 0.8 < Transfer Effectiveness Ratio < 1. Another example, the acceptance criterion for sufficient simulator validity has been further developed via decomposition into smaller sub-criteria for the: motion platform hardware and motion filter, ship and wave dynamics simulation model, visual system out of the window representations, sound systems

for wave and ship slamming sounds, and the ship-bridge mock-up configuration. This branch in the V&V goal network is presented in Figure 10 to give an impression of its size and level of complexity.

5.3.2 V&V Experimental Frame

The V&V experimental frame specification is the union of the evidence solutions: the leaf nodes (circles) on each branch of the V&V Goal Network (Figures 13 and 14). For the V&V experimental frame a number of different test methods for obtaining V&V results can be defined. For the heavy weather ship simulator the following test methods were applied:

- Inspection is suitable in cases where an unambiguous acceptance criterion (e.g. that some instrument must be present) is easy to check. The cost of inspection is usually low and the residual uncertainty zero (it either is or is not present).
- Measurement has been used to assess many physical observables of the visual, motion and sound systems. Furthermore, measurements where also used to assess human factor such as task performance and workload.
- Reuse of existing V&V results and other historical evidence for ship motion model, from validation and test reports, was used to assess the sufficiency of its level of validity for this specific ship simulator.
- SME opinion was used for many acceptance criteria. For example the perceived realism of the simulated ship motion during the given environmental conditions was assessed in this way.

The last nodes of the goal network, specifying the V&V Experimental Frame, also incorporates a discussion on how to interpret the V&V Results in order to judge if they can be used as items of evidence in the V&V Claim Network. One important aspect for this judgment is the level of residual uncertainty of each V&V result. A test method based on a single SME opinion has more residual uncertainty than a test method that is based on a measurement. This is an example of a quality criterion for the V&V effort.

5.3.3 V&V Claim Network

For both case-studies the V&V Claim Network proved to be a mirror image of the V&V Goal Network (the green bottom half of Figure 14). The reason for this is that the V&V user only required a “yes / no” acceptance recommendation. In such cases the V&V Goal Network can be used as a direct blue print to construct the V&V Claim Network. The collected V&V result indicates whether each acceptability criterion is met or not. In a case where the evidence shows that one or more acceptability criteria are not met (red blocks in Figure 14), the impact of that failure must be assessed against the satisfaction of the high-level goals in the V&V goal

network. Inference based arguments must then be constructed to make a claim on whether or not a single failure aggregates into the failure of a higher level goal.

To illustrate this evidence-argument-claim mechanism the next example from the heavy weather ship simulator cases is considered. The example concerns the controls available to the test-subject. In the real navy vessel a small steering wheel is used in much the same way as in a car (turning clockwise makes the ship go to the right). In the simulator mock-up, however, a handle was available. It had been implemented as a miniature tiller: pushing the tiller to the left makes the rudder go to the left, steering the ship to the right. This caused some initial confusion in several test subjects. One might say that the V&V Results indicate that the acceptability criterion on the validity of the controls in the simulator mock-up was not met. However, the V&V Results on the experimental correctness, and more specifically the habituation period (the time the test subjects have to familiarize themselves with the simulator), indicate that the habituation period was sufficiently long for the test subjects to get accustomed to the unintuitive steering controls. Therefore, overall one piece of pro and one piece of counter evidence is found. Finally, it was inferred with the help of a SME that the simulator steering introduces no problem for the experimental outcome. Hence it can be claimed that the simulator mock-up is valid.

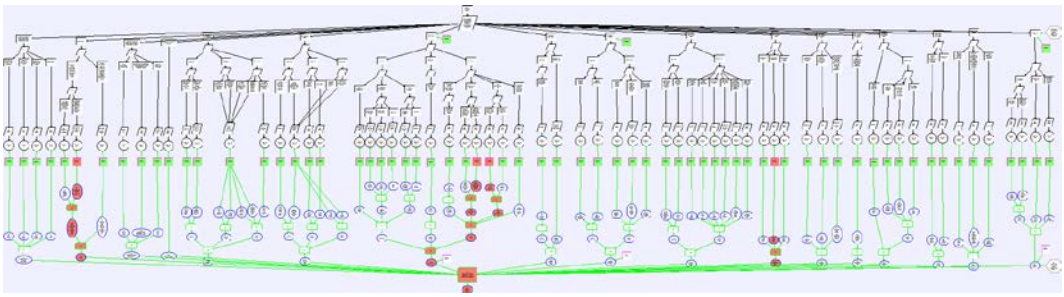

Figure 14. *V&V Goal Network and its Claim Network Mirror (green) of the Ship Simulator Case-Study (Deliberately made unreadable for confidentiality reasons)*

6 GM-VV Application and Tailoring Guidance

The emerging GM-VV standard is defined in a document set of three closely interrelated volumes. Volume one is the introductory document which should be read by everyone who intends to apply the GM-VV within an M&S organization or project[1]. This document is the portal document for volume two which contains all the implementation framework details along with detailed guidance on applying and tailoring the GM-VV[2]. The third volume provides

all reference information on GM-VV and other related V&V background information relevant for use with GM-VV framework[3].

Based on the GM-VV case-studies executed to date, we recommend the following general practices for an effective and efficient application of the GM-VV for an M&S organization or project:

- Always begin by determining at which level (i.e. technical, project enterprise or a combination thereof) the GM-VV must be applied. Determine how the V&V effort fits on the chosen levels and omit all unnecessary GM-VV implementation framework elements. If possible re-use any pre-existing elements e.g. if the V&V effort is part of a larger M&S project, some elements, such as project planning, may not need to be instantiated for V&V.
- Involve the V&V User/Sponsor as much as possible. Try to stabilize and agree on the V&V Requirement Specification and V&V Goal Network as early as possible because, due to the size of the goal-claim network, late changes prove to be very time and resource consuming.
- Stop disaggregating the V&V Goal Network into sub-goals as soon as convincing evidence can be obtained. Unnecessary disaggregation of goals into fine-grain detailed goals makes the V&V Goal Network content more difficult to understand. This could easily cause over-specification and it makes the effort more expensive than necessary.
- Select appropriate tools to manage the large quantities of information, as well as check the completeness, consistency and correctness of the V&V Goal-Claim Networks. This contributes to the quality and efficiency of the V&V effort. Argumentation Interchange Format compliant languages (e.g. GSN, CAE) and tools are suitable for this purpose.
- Where appropriate, use standard domain techniques/methods for selecting appropriate evidence solutions.
- For evidence solutions balance the expected convincing force with costs (e.g. time, money, required expertise) for an efficient V&V effort.
- When GM-VV is used on a regular basis inside an M&S organization, implement a V&V Enterprise Memory to consolidate reusable V&V knowledge and enhance the V&V return on investment. For this purpose develop tailored domain or organization specific V&V recommended practices, identify and document recurring goal and claim network patterns, and, develop libraries of reusable domain specific acceptability criteria and evidence solutions (e.g. techniques, tests, referent data).

7 Conclusions and Future Work

Based on our case-studies, we conclude that the emerging GM-VV recommended practices contain all the necessary high level ingredients for a rigorous approach to structuring, organizing and managing the verification and validation (V&V) of M&S assets. As such, GM-VV provides a solid referential basis for the development of future M&S V&V methods, tools and techniques across all application domains. Applying the GM-VV tailoring framework resulted in practical V&V solutions for both presented case-studies. Some parts of both case-study results are re-usable for other V&V projects in the same domain. This reusable information and lessons-learned from this study should be compiled into a recommended practice guide that can be stored into a V&V Enterprise Memory.

8 References

1. SISO, *"GM-VV Vol. 1:Introduction and Overview"*, SISO-GUIDE-001.1-2012, June, 2012
2. SISO, *"GM-VV Vol. 2: Implementation Guide"*, SISO-GUIDE-001.2-2012-DRAFT-, July 2012
3. SISO, *"GM-VV Vol. 3: Reference Manual"*, SISO-REF-039.3-2011-DRAFT, July 2012
4. US DoD, DMSO, *"Recommended Practice for VV&A",* Build 3.0, 2006
5. UK MoD, *"A Generic Process for the Verification & Validation of Modeling and Simulation & Synthetic Environments Systems"*, DEF STAN 03-44 Issue 2, 31 March 2008
6. Australian DoD, DSO, *"Simulation Verification, Validation and Accreditation Guide"*, Canberra, 2005
7. IEEE 1516.4-2007, "Recommended Practices for Verification, Validation and Accreditation of a Federation – An Overlay to the HLA FEDEP", December 2007
8. IEEE 15288, *"Systems and Software Engineering – System Life-Cycle Processes",* January 2008
9. Roza Z.C., *"Simulation Fidelity Theory and Practice: a unified approach to defining, specifying and measuring realism of simulations"*, Delft University Press Science. December, 2004
10. Roza M, J. Jacquart, C. Giannoulis. Common Reference Framework for Validation, Verification and Accreditation for Simulation, REVVA-2 Reference Manual. Report: Europa 111-104. March 2009
11. Jacquart J., J. Voogd J., D. Brade, C. Yi, WEAG THALES JP11.20 (REVVA-1) Results and Perspectives. 2005 European Simulation Interoperability Workshop, June 2005, Paper 021.
12. Risk-Based Methodology for Verification, Validation and Accreditation (VV&A): The M&S Use Risk Methodology (MURM), Johns Hopkins University Applied Physics Laboratory Report, NSAD-R-2011-011, April 2011
13. Roza M, J. Voogd, "The GM-VV: It's Relationship to the VV&A Overlay for the FEDEP" *SISO Fall Simulation Interoperability Workshop 2011*, 11F-SIW-019
14. Emmerik van M., M. Roza, J. Voogd, "GM-VV Illustrated: An Educational Example from the Human Driving Behavior Research Domain", *SISO European Simulation Interoperability Workshop 2011*, 11E-SIW-03
15. Roza M. J. Voogd, M. van Emmerik, A. van Lier, "Generic Methodology for Verification and Validation for Training Simulations", *Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC)*, Orlando, 2010, Paper 10008
16. Voogd J., M. Roza, A. van Lier, "The GM-VV Tailored for a Naval Ship-Handling Training Simulation", *SISO European Simulation Interoperability Workshop 2011*, 11E-SIW-03
17. Willmott S., et al., *"AIF: Argumentation Interchange Format Strawman Model"*, Version 0.8, 16th December, 2005

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