

Generic Methodology for Verification and Validation (GM-VV) – Part 2: Processes, Information Artefacts and Roles

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ABSTRACT

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 a new recommended practice within the Simulation Interoperability Standards Organization (SISO), which is the result of a joint development effort with NATO. 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.

This paper is the second in a series of three papers that collectively describe and illustrate the complete GM-VV technical framework and its application. This second paper presents the processes, information artifacts and roles that constitute the GM-VV implementation and the associated tailoring framework.

1.0 INTRODUCTION

The GM-VV attains its generic quality from a three-part technical framework [1],[2],[3]: the conceptual, implementation and tailoring framework (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. The reader is referred to the first paper in this series of three papers on GM-VV, where this framework is discussed [4]. The implementation framework translates these concepts into a set of generic architectural templates 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. GM-VV provides a tailoring framework that utilizes these building blocks to develop and cost-efficiently apply such V&V application instantiations.

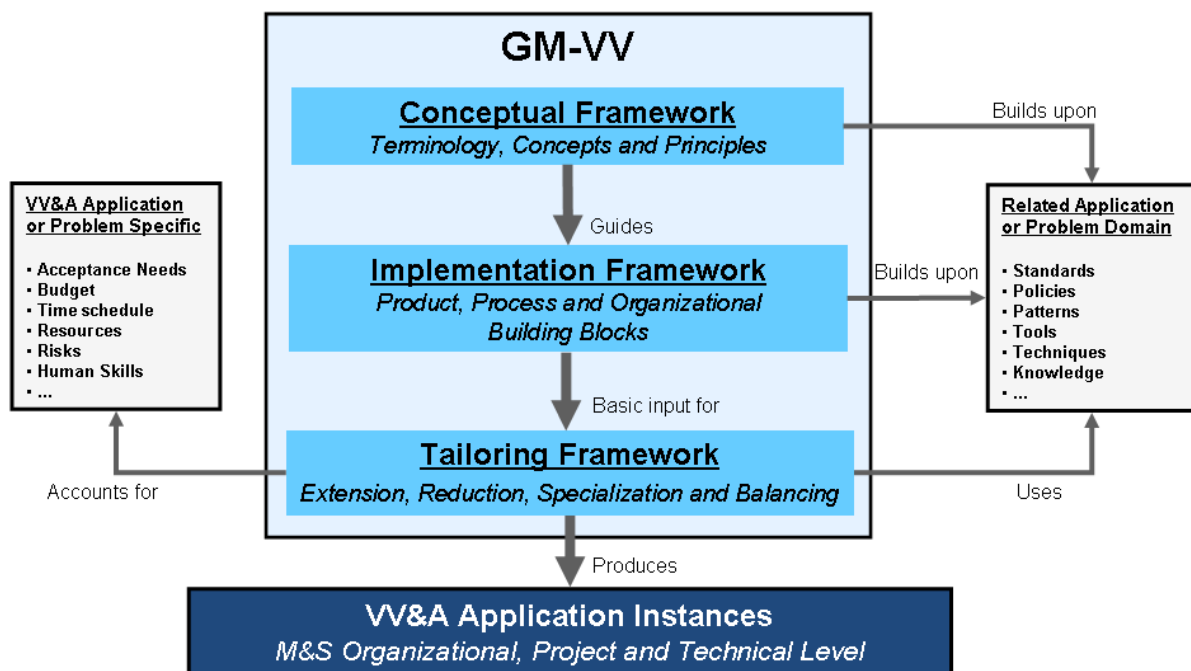


Figure 1: GM-VV Technical Framework Design and Operational Usage Concept.

This paper provides an overview of the purpose, relationship and application of the GM-VV implementation and tailoring frameworks (Chapter 2). Next the paper will discuss the processes, information artifacts and roles provided by the GM-VV implementation framework on three organizational levels: technical (Chapter 3), project (Chapter 4) and enterprise (Chapter 5).

General and specific tailoring considerations for developing concrete V&V solutions using these GM-VV implementation framework components are described in the final paper of this series [5]. This third paper focuses on the tailoring framework specifics to produce specific V&V solutions for various M&S organizations and projects.

2.0 GM-VV IMPLEMENTATION AND TAILORING FRAMEWORK OVERVIEW

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 provides a generic architectural template for developing structured and well-organized V&V solutions for specific M&S organizations, projects, and technologies or application domains. As such, the GM-VV implementation framework provides the reusable components arranged in a generic design pattern that underpins concrete V&V solutions. This generic design pattern consists of three component categories: product, process and organization (Figure 2). 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 [4] are addressed by one or more V&V products, being the V&V report and possibly other intermediate V&V information artifacts (i.e. 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

one or more organizational roles (e.g., persons, organization or organizational unit) that are 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.

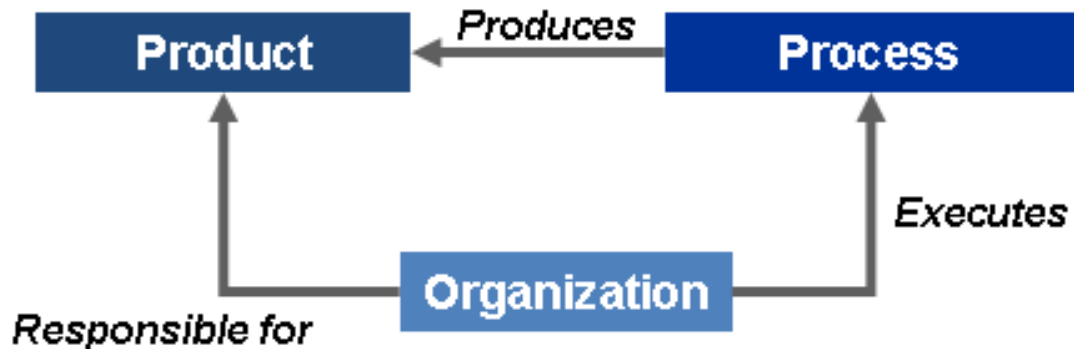


Figure 2: GM-VV Implementation Framework Component Categories.

The aforementioned building components are a cost-efficient means of developing and applying specific V&V solutions using the four basic tailoring approaches of the GM-VV tailoring framework, namely:

- 1) *Tailoring by Extension*: adaptation of the implementation framework 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.
- 2) *Tailoring by Reduction*: adaptation of the implementation framework 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.
- 3) *Tailoring by Specialization*: adaptation of the implementation framework by modifying domain specific V&V methods, techniques and data that are unique for a V&V project, organization or application.
- 4) *Tailoring by Balancing*: adaptation of the implementation framework by fitting a suitable cost-benefit-ratio towards an acceptance recommendation. The level of acceptable M&S use risk should drive the rigor and resources employed for V&V. Therefore, in this approach one tries to balance V&V project resource variables (e.g., time schedule, budget, V&V personnel skills and infrastructure) with aspects such as:
 - M&S use-risk tolerances and thresholds;
 - Criticality and scope of the acceptance decision;
 - Scale and complexity of the M&S system; and
 - Information security.

The GM-VV implementation framework provides a consistent and coherent set of generic reusable components for each of the categories depicted in Figure 2. These components are grouped into three interrelated organizational levels where V&V of M&S can be considered (Figure 3). In here *the technical level* comprises a set of technical components that together constitute a generic engineering life-cycle template for structuring the technical V&V work necessary to develop and deliver an acceptance recommendation (i.e., the technical activities performed, the information artifacts produced and the roles fulfilled). To develop a quality (e.g., timely, accurate and relevant) acceptance recommendation, the technical V&V work should be executed in a well-controlled and organized manner. Therefore, the GM-VV

recommends performing the technical V&V work as part of a managed project. *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 technical V&V work. When a V&V supplier establishes, directs and supports the execution of multiple V&V projects and delivery of V&V products, the GM-VV recommends establishing a permanent V&V business environment. Such a permanent V&V organization helps to improve the quality, reduce costs and lead time of these V&V projects and products. *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.

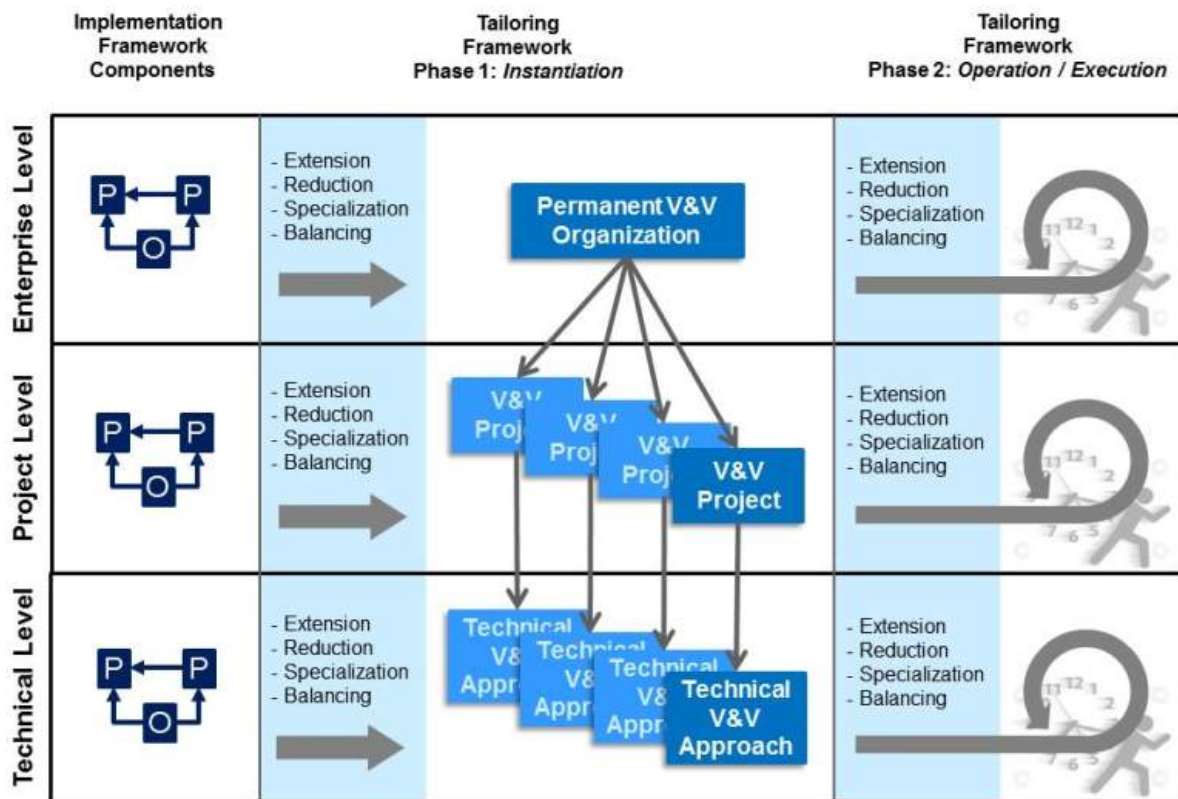


Figure 3: GM-VV Implementation and Tailoring Framework Application Overview.

The purpose of the GM-VV tailoring framework is to customize the GM-VV implementation framework components (i.e., products, processes, organizational 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),
- An M&S/V&V supplier delivering V&V products or services (e.g., standards, processes), and
- An M&S/V&V project (e.g., time, budget, scale, complexity, risk, resources).

As depicted in Figure 3, this tailoring is accomplished in two phases. In the *first* phase of the GM-VV tailoring framework, the implementation framework components are utilized to establish concrete V&V solution instances on one or more of the three organizational levels (i.e., a V&V enterprise, V&V project or technical V&V approach). The GM-VV recognizes that a particular M&S organization, project, technology or problem domain may not need all three organizational levels or all components nor even use them directly

as-is. Therefore, the GM-VV implementation framework organizational levels and components are selected, combined and modified accordingly, to obtain a tailored V&V solution. For instance an M&S organization may already have an M&S project and enterprise level in place, and only require technical level V&V (intermediate) products, processes and roles to conduct their technical V&V work. Successful application of the first phase of the tailoring framework results in a modified or new V&V solution instance conforming to the GM-VV architectural templates (i.e., in a structure and organizational manner). The aforementioned tailoring approaches should be used for this purpose: extension, reduction, specialization and balancing [5].

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 instance. 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 or PRISMA method [6],[7], to prioritize the acceptability criteria, allocate specific V&V techniques and methods based on V&V User/Sponsor use risk tolerance levels. 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, and balancing the available V&V resources over each M&S life-cycle phase or 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.

3.0 GM-VV TECHNICAL LEVEL PROCESSES, INFORMATION ARTIFACTS AND ROLES

This chapter provides detailed implementation guidance for instantiating the technical level of the GM-VV. The technical level comprises the technical processes to perform the technical V&V work (Figure 4). The technical-level processes are executed from the project level (Chapter 4). It is the Project Planning process from this project level that starts and controls their execution.

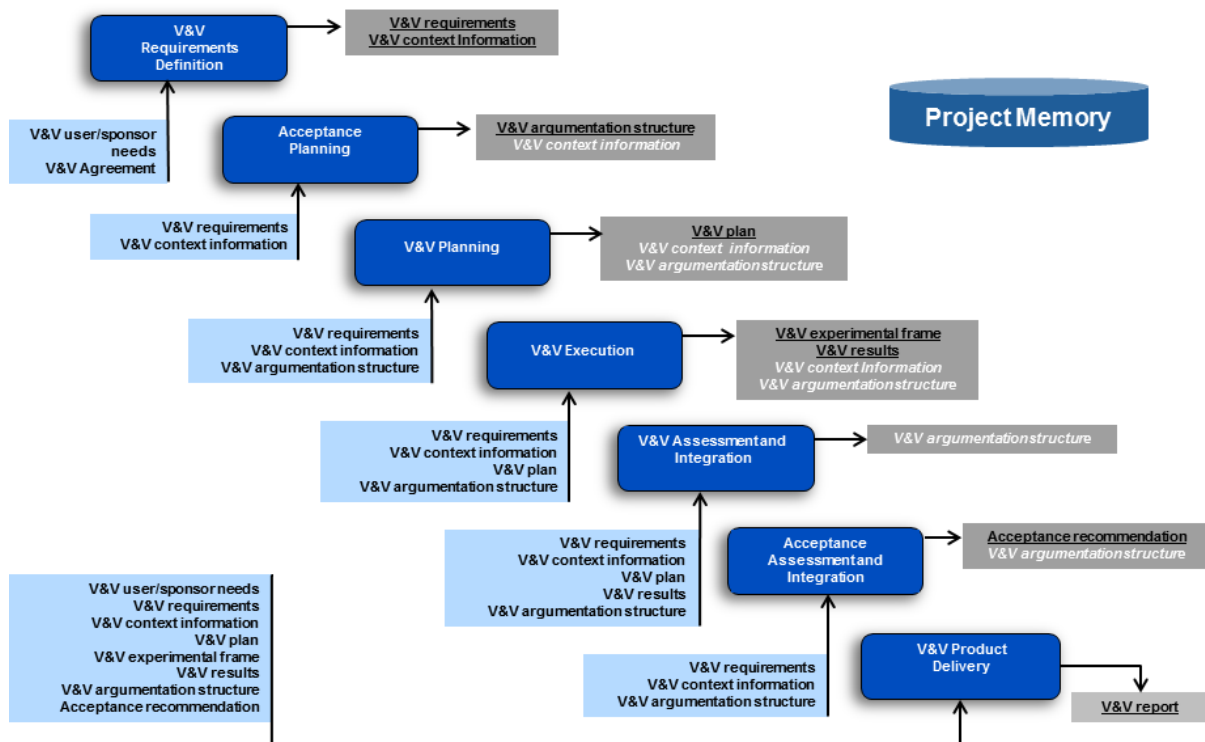


Figure 4: GM-VV Technical Level Product and Process Components Overview.

The technical work begins with the V&V Requirements Definition process. It takes the V&V User/Sponsor needs as expressed by the V&V Agreement as input and sets the groundwork for the other technical processes. The V&V Requirements and Context Information from this process are used as input for the Acceptance Planning process which delivers the acceptability criteria for the M&S system along with the first part of the V&V Argumentation Structure. In the V&V Planning Process a specification for a V&V experimental frame is derived from the acceptability criteria, and a V&V Plan is developed. The V&V Execution process implements and executes the specified V&V experimental frame according to this V&V plan. In the V&V Assessment and Integration process the V&V results from the V&V Execution process, are assessed and integrated into acceptability claims regarding whether or not the M&S system satisfies the acceptability criteria. Next, the Acceptance Assessment and Integration process assesses and integrates the acceptability claims into claims regarding to what extent the M&S system is acceptable for the intended use (i.e., the Acceptance Recommendation). This process also develops the complete V&V Argumentation Structure underlying this Acceptance Recommendation. Finally, in the V&V Product Delivery process, the V&V Report is compiled and delivered to the V&V client.

Instantiation and use of a V&V Project Memory on the technical level is recommended. (See also Chapter 4). A V&V project memory provides the means to manage both project and technical level information produced and used during the life-time of an individual V&V project. A V&V project memory provides technical support by keeping track of historical data, such in case of consecutive V&V information artefact configurations and versions.

Execution of the technical process in the sequence described above (Figure 4) is recommended. However, like all GM-VV processes, the technical processes can be carried out recursively, concurrently, and iteratively. This depends on the M&S project life-cycle type (e.g., sequential, incremental, iterative, or spiral) and associated processes upon which the V&V project should be mapped and aligned. This mapping and alignment of processes is done from the Project Planning process.

In the next subsections a summary overview of the GM-VV technical level processes, information artifacts and roles are given. The complete description and template information structures are described in detail in GM-VV Vol 2 [2].

3.1 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 extent the M&S system is acceptable for the intended use i.e. acceptance recommendations.
- **V&V Product Delivery**; packaging the information artefacts into the V&V Report and delivering it to the V&V User/Sponsor, and archiving the information artefacts in appropriate repositories.

3.2 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 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 artefacts.
- **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.

3.3 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.

4.0 GM-VV PROJECT LEVEL PROCESSES, INFORMATION ARTIFACTS AND ROLES

The project level is instantiated by the enterprise-level Agreement Management process as soon as the V&V Agreement has been signed (Chapter 5). Before actually signing the V&V Agreement, some project and technical-level tasks may have already been performed to obtain information necessary to develop a feasible V&V agreement. At the end of the Initiate Agreement activity of the Agreement Management process, the V&V Agreement is made and the Project Planning process is started. From the Project Planning process, the other project-level processes and the technical-level processes are started (Figure 5).

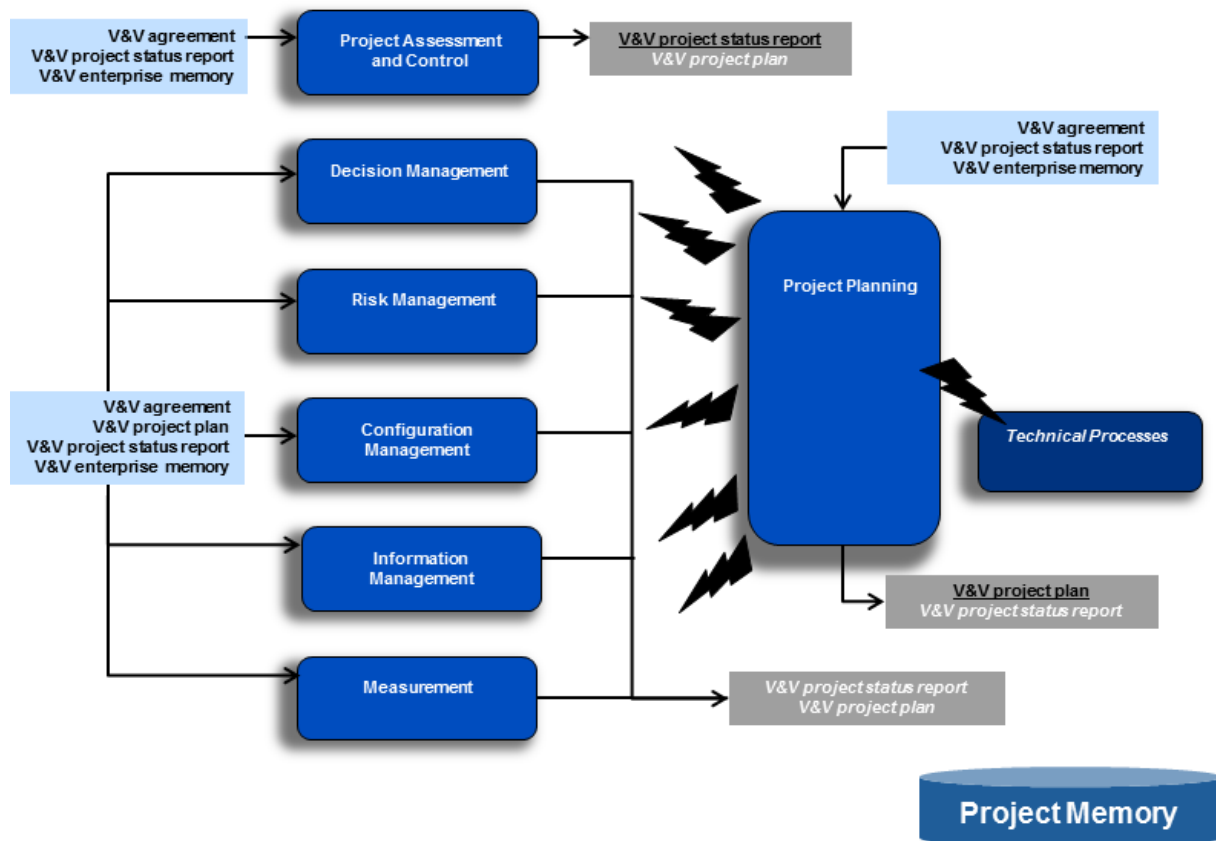


Figure 5: GM-VV Project Level Product and Process Components Overview.

The activities inside the Project Planning process are shown in Figure 5, but the activities for the other processes are not shown for brevity of the figure. All other project level processes necessary to effectively and efficiently execute a V&V project are started from Project Planning process. Also the technical level processes are started from the Project Planning process. All project level processes are typically executed concurrently and therefore no particular time order is supposed for their execution during the life-time of a V&V project.

The V&V Project Memory should be instantiated on the project level. A V&V project memory provides the means to manage both project and technical level information produced and used during the life-time of an individual V&V project. V&V is a process aligned with an M&S system’s life-cycle that could be iterative or incremental; hence the V&V information artefacts for an M&S system may have different configurations and versions as well. Therefore, a V&V project memory also supports keeping track of possible different V&V information artefact configurations and versions.

The V&V Project Manager has the responsibility for the execution of the V&V project by means of the project level processes, and the underlying technical level processes and deliverables (Chapter 4). During the V&V project life-time, the V&V Project Manager serves as the V&V supplier principle Point Of Contact (POC) for the V&V client. He or she uses V&V Project Status Reports to inform the V&V User/Sponsor or other V&V client appointed stakeholders on a regular basis about the progress of the V&V project. When necessary a V&V Project Status Report is provided to the V&V User/Sponsor to resolve urgent issues, problems and risk contingencies that impact the outcome of the project. These activities should be performed in accordance with the V&V Agreement on status reporting to the V&V client. The V&V Project Manager also uses V&V Project Status Reports to inform his V&V team members (e.g., Acceptance Leader, V&V

Leader and V&V implementer) and V&V supplier management (e.g., V&V Enterprise Manager) in order to make internal decisions and steer the direction of the V&V project execution.

In the next subsections a summary overview of the GM-VV project level processes, information artefacts and roles are given. The complete description and template information structures are described in detail in GM-VV Vol 2 [2].

4.1 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, analyses, and reports data related to the overall V&V project, its performance and the quality of its deliverables.

4.2 Project Level Information Artefacts

- **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.

4.3 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.

5.0 GM-VV ENTERPRISE LEVEL PROCESSES, INFORMATION ARTIFACTS AND ROLES

The enterprise level helps to establish and operate a permanent V&V organization. Such a permanent V&V organization provides the V&V supplier's business environment to establish, direct and support the execution of multiple V&V projects and delivery of V&V products. More importantly, it provides the V&V supplier with an enterprise-level organization (i.e., line organization) to sustain and improve the quality, reduce costs and lead time of these V&V projects and products. An example of such a permanent V&V organization is the Dutch V&V expertise center, Q-tility [8], which was established in October 2012 by the National Aerospace Laboratory NLR and TNO Defence, Safety and Security organization.

A prerequisite for instantiating the enterprise-level components and to successfully realize a permanent V&V organization is that V&V projects are executed in a structured manner, both on a project organizational and technical level (Chapter 3 and 4). Such structured V&V approaches or methods should be used as the basis to establish V&V life-cycle models that can be applied across multiple V&V projects. To develop and maintain V&V life-cycle models a life-cycle model management process should be instantiated on enterprise level. Together with an instantiation of a quality management process this will help to reduce V&V project initiation costs, enhance and assure the quality of the V&V services and products delivered by the V&V supplier (Figure 6).

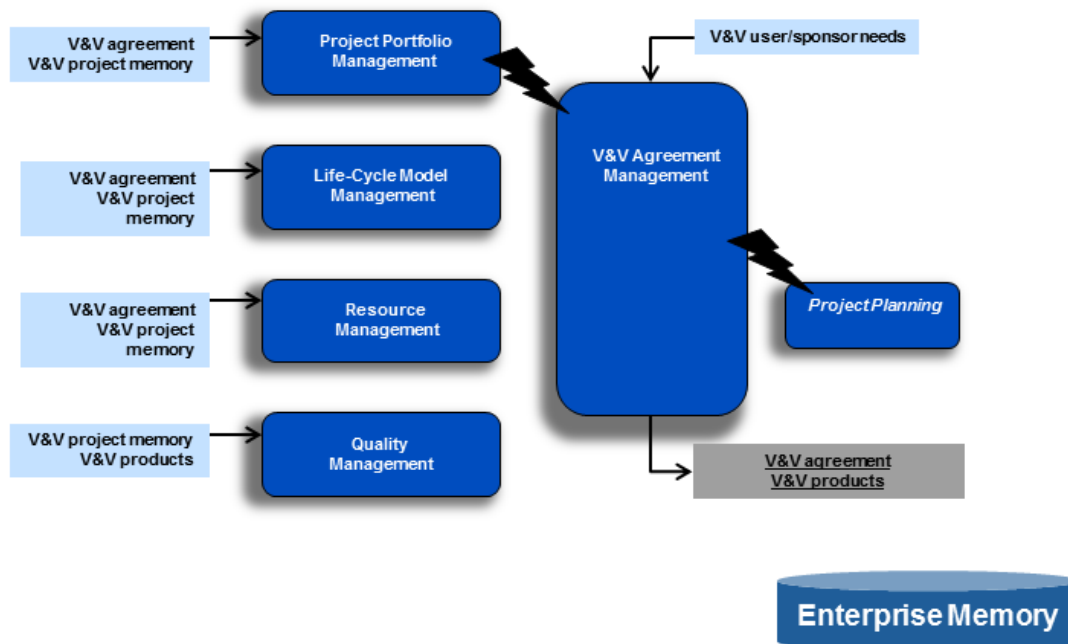


Figure 6: GM-VV Enterprise Level Product and Process Components Overview.

To sustain the delivery of good quality V&V products by a V&V supplier the availability of sufficient V&V professionals (e.g., V&V project managers, V&V leaders and V&V implementers) and adequate infrastructure (e.g., V&V tools, techniques and templates) is required. Therefore, a permanent V&V organization should implement a Resource Management process to assure that the right personnel and infrastructure is available for the current and future V&V projects. A profitable permanent V&V organization requires a continuous flow of adequate V&V projects. To acquire V&V projects and to sustain a stable flow of V&V projects that meet the strategic V&V business objectives, a permanent V&V supplier organization should implement a Project-Portfolio Management process. If in the Project-Portfolio process a business opportunity for a V&V project is identified, the V&V supplier will have to begin a process to initiate, execute and close the V&V Agreement with the potential V&V client. For this purpose a permanent V&V supplier organization should implement a common V&V Agreement Management process. Multiple V&V Agreement Management processes could be invoked by the V&V supplier overtime, either in parallel or sequential to each other. From within the V&V Agreement Management process the V&V project organization is established (Chapter 4) and the technical V&V work is executed (Chapter 3). The Quality, Life-cycle, Resource and Project-portfolio processes are the processes that support the V&V Agreement Management process instances.

A V&V Enterprise Memory should be implemented within a permanent V&V supplier organization. Such a V&V Enterprise Memory facilitates the management and maintenance of the total body of V&V information artifacts, knowledge, resources, life-cycle models and products required to sustain the delivery of V&V

products by a V&V supplier. All V&V enterprise level processes should share their information through the V&V Enterprise Memory (Figure 6). The V&V enterprise manager is responsible for managing the aforementioned permanent V&V supplier, including the V&V projects that are conducted by the V&V supplier. Since all GM-VV project and technical level roles are part of a permanent V&V supplier organization, these roles contribute to or are involved in one or more of the V&V enterprise level processes.

In the next subsections a summary overview of the GM-VV enterprise level processes, information artefacts and roles are given. The complete description and template information structures are described in detail in GM-VV Vol 2 [2].

5.1 Enterprise Level Processes

- **V&V 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.

5.2 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).

5.3 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 (client);** 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.

6.0 CONCLUSION

This paper presented the GM-VV implementation framework architecture and constituent components. Furthermore, it's relation with the tailoring framework has been explained. The components presented in this paper are based upon and discussed in much more detail in the original GM-VV Vol 2., and the original papers of the author and other members of the GM-VV product development group. The interested reader is referred to these documents as listed in the reference section.

7.0 REFERENCES

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