

## GM-VV Part 3 – Implementation Guidance for M&S Projects and Organizations

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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 last in a series of three papers that collectively describe and illustrate the complete GM-VV technical framework and its application. This third paper presents the tailoring framework and implementation guidance for the GM-VV towards M&S projects and organizations. This is illustrated with examples and lessons-learned from the establishment of the Dutch V&V expertise center Q-tility and the V&V case-studies conducted by this organization.*

### **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 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. The reader is referred to the second paper in this series of three papers on GM-VV, where this framework is discussed [5]. GM-VV provides a tailoring framework that utilizes these building blocks to develop and cost-efficiently apply such V&V application instantiations.

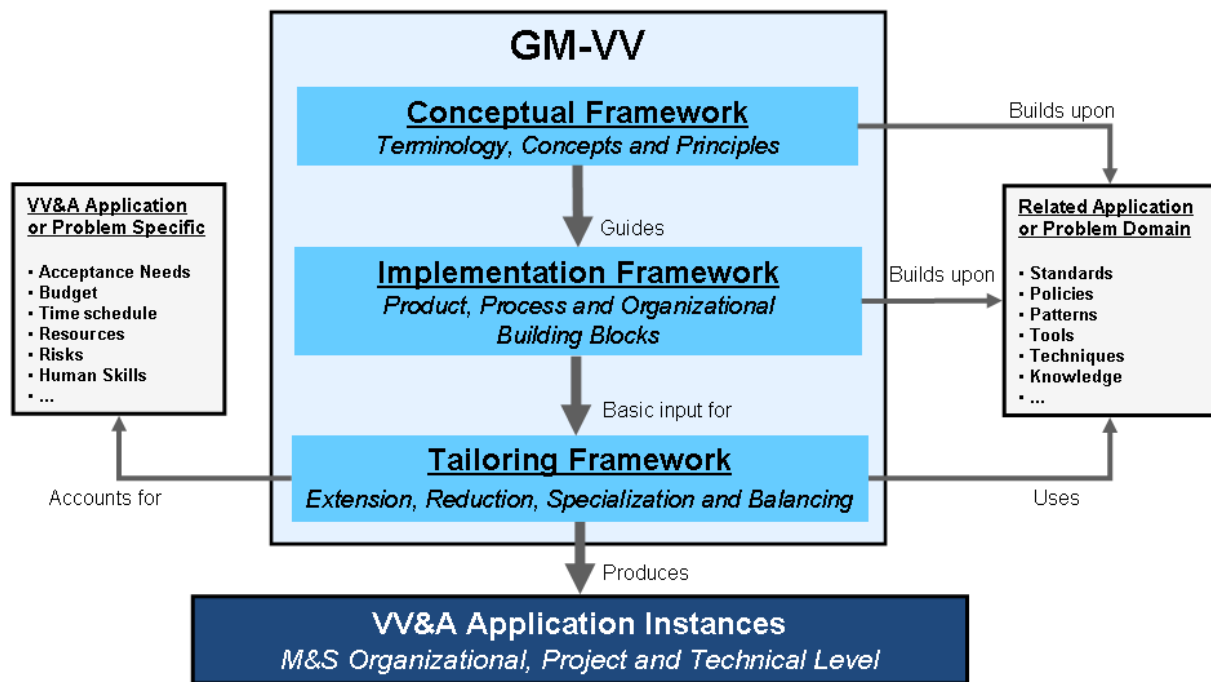
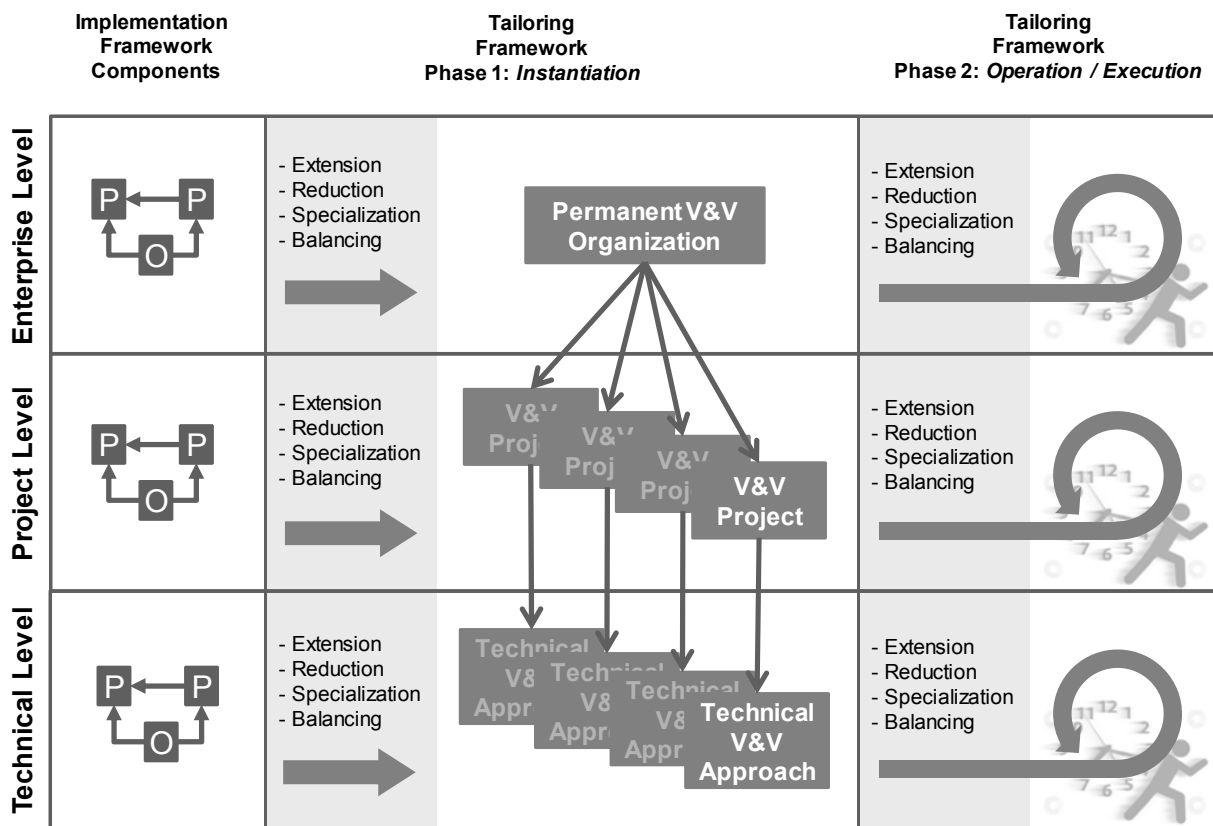


Figure 1: GM-VV Technical Framework Design and Operational Usage Concept.

The GM-VV implementation framework defines three organizational levels: enterprise, project and technical. This paper provides the general guidance for tailoring the processes, information artifacts and roles of the GM-VV implementation framework (Chapter 2). Next the implementation of the enterprise level is illustrated and lessons-learned provided based on the experience of Q-tility (Chapter 3). The implementation of the project and technical levels is exemplified using a V&V case study which is presented in Chapter 4. The implementation details of the project level and technical level are given in Chapter 5 and 6. Finally, some discussions and conclusions are presented in Chapter 7.

## 2.0 GENERAL IMPLEMENTATION GUIDANCE

The GM-VV implementation framework provides a set of generic reusable components for the triplet of processes, information artifacts and roles. These components are grouped into three interrelated organizational levels (i.e., enterprise, project and technical) where V&V of M&S can be considered as depicted in Figure 2.



**Figure 2: 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),
- A M&S/V&V supplier delivering V&V products or services (e.g., standards, processes),
- A M&S/V&V project (e.g., time, budget, scale, complexity, risk, resources).

As depicted in Figure 2, 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). For this purpose four tailoring approaches can be used: 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.

The next three sections give general tailoring considerations for instantiating each organizational level of the GM-VV implementation framework. This enables GM-VV users to determine whether they should instantiate each level and in what manner they should do so.

## **2.1 Tailoring Considerations for Instantiating the Technical Level**

The technical-level components of the GM-VV implementation framework are typically the components that all users of the GM-VV should instantiate. This technical level provides a generic template for a structured execution of technical V&V activities and tasks. In this template technical-oriented V&V practices, tools and techniques native to each individual M&S organization, project, and technology or application domain should be integrated. Among others such technical-oriented V&V practices, tools and techniques include:

- Informal, Formal, Static, and Dynamic V&V techniques to be used,
- Risk analysis techniques and methods,
- Argumentation structure formats, techniques and methods,
- Referent development techniques and methods,
- Domain specific or standard acceptability criteria,
- Domain specific or standard V&V documentation templates,
- Experimental design techniques and methods (DOE),
- Information management and configuration tools.

A more detailed discussion of such technical V&V methods and techniques is beyond the scope of this papers. The interested reader can find references on such technical-oriented V&V methods and techniques in GM-VV Vol. 3 or in another LS123 paper [14]. The types of technically-oriented practices, tools and techniques selected and when they should be applied during the V&V of an M&S system, is an outcome of the run-time execution of a technical V&V approach. Such a technical V&V approach is thus a tailored instance of the generic life-cycle for structuring the technical V&V work of the GM-VV implementation framework. A technical V&V approach describes which technical V&V activities and tasks are executed and how they map onto the M&S system life-cycle phases or (work) products. It typically scopes the V&V technical work, structures the technical V&V activities and tasks to be performed in a logical order. Furthermore it identifies the technical standards to be used, the V&V design techniques to be applied and the associated completion criteria. The technical V&V approach depends strongly on the M&S application and problem domain, the M&S organization and project context in which the V&V is executed, and more importantly on the V&V needs of the V&V client. This means that the GM-VV technical level components must be tailored by specialization, reduction and extension to gain a suitable and matching technical V&V approach for the M&S system under consideration.

A structured V&V engineering life-cycle is obtained if the technical V&V approach has been instantiated correctly. This helps to assure that during the execution of the V&V work; the decisions, actions and information will be traceable, reproducible, transparent and documented. This is accomplished by a tailored (e.g., by specialization and extension) implementation of the V&V Argumentation Structure. How such decisions are made during the execution of this technical V&V approach depends on the V&V project context and involves the GM-VV tailoring approaches, in particular balancing.

Balancing approaches are needed during technical V&V activities since it is practically impossible to verify or validate an entire M&S system in any project. Exhaustive verification and validation (i.e., 100% coverage of all aspects) of an M&S system exists only in theory; requiring infinite time and V&V resources. In practice, there is always a limited time and budget available for a V&V project. Moreover, there is always the pressure on the M&S system development to provide the needed capabilities (i.e., functionality) on time and usually more capabilities (i.e., nice-to-have features). In practice this means that the original time and budget allocated for performing V&V is often reduced by such M&S system development requests and constraints. This requires continuously balancing the time schedule, budget and resources available for V&V against what should and could be verified or validated throughout the life-time of a V&V project.

Risk-based techniques and methods are practical means of balancing. Risk-based V&V centers the verification and validation around the 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 item. A risk-based approach responds to these M&S use risks as follows:

- Target technical V&V activities: allocating V&V effort and selecting V&V techniques based on the level of risk of each identified risk item; matching the rigor and extensiveness of V&V techniques to the level of risks.
- Sequencing of technical V&V activities: prioritizing 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 throughout the life-time of the V&V project, V&V activities and techniques can be reduced in reverse-risk priority order, starting with least important ones.
- Reporting of technical V&V results: reporting V&V results in terms of residual M&S use risks (e.g., V&V solutions executed, not executed, executed with limitations or omitted).
- When applying a risk-based approach, V&V project managers 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.

Risk-based approaches have proven to be very effective for V&V of software, hardware and M&S systems alike, and are therefore recommended by GM-VV [14].

## **2.2 Tailoring Considerations for Instantiating the Project Level**

The GM-VV concept of a V&V project can be viewed as a unique process comprised of coordinated and controlled activities that address: technical V&V work planning in terms of cost, timescales and milestones; measuring and checking progress against this planning; and selecting and taking corrective actions when needed. The project level of the GM-VV implementation framework provides the components to implement this V&V project concept. It is inevitable that the project-level components provided by GM-VV do not directly match the way V&V is organized and managed in specific M&S organization or project. Nevertheless, these aspects are important for assuring the quality (e.g., timely, accurate and relevant) of the V&V products, and thus such aspects should be considered and addressed by all V&V suppliers; independent of whether the V&V is performed by an external organization, a separate business unit in the M&S organization or solely from within the M&S development project. Therefore, the concept of a managed V&V project can be instantiated by tailoring the GM-VV project-level components as either a separate V&V project or as a sub-project or work package of a larger M&S project. This constitutes a generic organizational scheme to organize and manage the technical V&V work.

Independent V&V (IV&V) requires V&V projects that have the highest level of independence [4]. In that case the V&V project organization and team are fully separated from the M&S development project. Such V&V projects are executed by a V&V supplier outside the own M&S organization. A less strict level of independence can be achieved by having a dedicated V&V supplier organization unit inside the own M&S organization. In this case the V&V project manager and his or her team have a V&V project budget which is separate from the M&S development budget, and reports to the higher enterprise management of the own M&S organization. In the case of a V&V sub-project, the V&V project manager and team usually work on the same level with the M&S development project manager and team under the direction of an overall M&S program/project manager. When the V&V is executed as a V&V work package in M&S project, the V&V team is usually integrated within the M&S development project, and there is no separate V&V project



manager or project plan. The V&V project manager role is assumed by the M&S project manager itself. In that case there is no independence.

Whether the V&V work should be executed as a separate project, a sub-project or a work package depends on the V&V client organization, what level of independence the V&V client requires and the scale of the M&S project. For instance, if the M&S supplier organization is the V&V client, conducts V&V on various projects and has high quality standards (e.g., for customer satisfaction and marketing perspective), a separate V&V project is recommended for the technical V&V work. In cases where customers of M&S systems do not require a high-level of V&V independence, a V&V sub-project or work-package within a larger M&S project is recommended. When a dedicated V&V organization is contracted, a separate V&V project or sub-project within a larger M&S project is the most obvious option. A separate V&V (sub) project is in particular the best option when the V&V client is a different organization than the M&S supplier, and wants a fully independent V&V of the M&S system it acquires. All are forms of tailoring the V&V project level by specialization.

For large, complex or safety-critical M&S projects, usually multiple levels of V&V independence are required for the M&S system, meaning that the V&V team is a mix of permanent, temporary, internal and external personnel. Hence, having a separate V&V project, with a separate V&V manager and project plan from the M&S development project is then highly recommended to organize and manage the technical work properly. Good alignment, cooperation and communication should be maintained between both the V&V and M&S project to assure the right quality (i.e., fit for purpose) M&S system is delivered. In smaller M&S organizations or projects, where everybody contributes to every activity it is harder to differentiate the technical V&V work and roles from those of the M&S development. Hence, it is easier and cheaper to embed V&V as a work package inside the M&S project. In general, higher levels of independence or outsourcing to external V&V organizations comes with higher organizational (i.e., managerial) effort and costs but on the other hand when done correctly provide more effective V&V. Therefore, the decision to setup and manage the technical V&V work as a separate project, sub-project or work packages should involve a careful analysis of the balance between aspects such as the project risks, scale of the M&S project or organization, cost, time and other resources required. This is a form of tailoring by balancing.

For Post-Hoc V&V projects the V&V is conducted in retrospect on an M&S legacy system after development or application. This is not the most efficient form of V&V. Post-Hoc V&V projects are often seen within organizations that reuse or acquire M&S systems (e.g., modified off the shelf, commercial off the shelf) from an external M&S supplier. In such case the acquiring organization usually wants an independent V&V to assure that the reused or acquired M&S system will fit the intended-use. V&V is then best executed as a separate V&V project by an external third-party V&V supplier. Since in this case the M&S supplier and the V&V supplier are separate entities, some alignment, cooperation and communication between them should be established. This is to ensure that the V&V supplier can access the M&S system itself and associated information (e.g., conceptual model, design specifications and test data), and address any M&S supplier intellectual property rights and security issues that may apply.

It must be stressed that the GM-VV project-level organizational pattern and components are not intended as a substitute for standard project management and organization practices; instead they contain complementary V&V project-level aspects that should be used in conjunction with standard practices. Therefore, the GM-VV project-level components are not all inclusive and should be tailored to reflect the needs, objectives and constraints of an M&S project or M&S/V&V organization. For example in the case where the V&V effort is established as a standalone V&V project, all GM-VV project-level components may have to be implemented from scratch in order to organize and manage the V&V project. An M&S organization that already has similar processes in place, may only adapt these to meet the specific managerial needs of the M&S project. These are forms of tailoring the GM-VV by reduction, extension and specialization.

A prerequisite for instantiating the project-level components and successfully executing a V&V project is that technical V&V work is also executed in a structured manner. If no such approaches exist yet within the

M&S project or organization, this should be first developed. For developing a structured technical V&V approach, instantiation of the GM-VV technical-level components is recommended.

### **2.3 Tailoring Considerations for Instantiating the Enterprise Level**

A permanent organization for supplying V&V services and products can be implemented as an autonomous company or as an organizational unit part of a larger company. The first type of V&V suppliers are companies who have as their core business the delivery of V&V products (e.g., V&V reports, services, expertise and tools) to M&S developer, user or regulation organizations (i.e., external V&V clients). The latter types of V&V suppliers are M&S developer, user or regulation organizations that have their own internal V&V organization unit to support their own M&S projects (i.e., internal V&V clients); and possibly also as an additional business for external V&V clients. It is not necessary for all V&V suppliers to establish a permanent V&V organization. V&V products can be delivered using project-based approach on a case by case basis. However, if the V&V supplier executes V&V projects and delivers V&V products on a regular basis to one or more V&V clients it can become more cost-effective to set up a permanent organization for V&V. A V&V supplier should consider this option when there is:

- Increasing V&V efforts and costs,
- Quality reduction in V&V projects and products,
- Lack of internal V&V standards, policies and guidance,
- Lack of internal coordination of V&V projects and products,
- Insufficient reuse of prior knowledge, tools, techniques, facilities and lessons-learned,
- Lack of experienced V&V personnel or reduction of their knowledge and skills,
- Insufficient means to enhance V&V project and product quality,
- Confusion regarding V&V project responsibilities, and,
- Lack of V&V assessment objectivity and independence.

To determine if a permanent V&V organization is indeed worth the investment requires a cost benefit analysis between the resources required to setup, manage and maintain a permanent V&V organization, and resulting benefits such as improved V&V quality, cost savings and lead-time reduction. This determination must also consider the V&V supplier organization's own objectives, the problem and application domain in which it operates, and the V&V clients it serves. These are forms of tailoring the GM-VV by balancing.

For a V&V supplier that has determined that a permanent V&V organization is a viable solution, Chapter 8 provides the generic components (products, process and roles) to help setup, manage and maintain such a V&V enterprise organization. One must remember that there is neither a fixed set of requirements or rules to do so nor an ideal one size-fit-all blue print for the implementation of a permanent V&V organization. Therefore, the GM-VV enterprise-level components may not all be required and should be tailored to reflect the needs, objectives and constraints of a specific V&V supplier. For example in the case where a permanent V&V supplier is established as a new standalone company, it may have to implement all enterprise-level components from scratch. For an existing company that wants to establish permanent V&V supplier within its own organization may already have similar enterprise products, processes and organizational roles in place and may only adapt these to meet the specific needs of this internal V&V unit. These are forms of tailoring the GM-VV by reduction, extension and specialization.

A prerequisite for instantiating the enterprise-level components and to successfully sustain a permanent V&V organization is that V&V projects are executed in a structured manner on both project organizational and technical level. If no such approaches or methods exist yet within the V&V supplier, they should be first

developed. For developing a new structured V&V approach or method it is recommended to instantiate the GM-VV project and technical-level components.

### **3.0 ENTERPRISE LEVEL IMPLEMENTATION: Q-TILITY**

The core GM-VV concept on the V&V enterprise level is the concept of an enterprise entity. A V&V enterprise entity can be viewed as an organization that: establishes the processes and lifecycle models to be used by V&V projects; initiates or defers V&V projects; provides resources required (e.g., financial, human, equipment); retains reusable knowledge and information from current V&V projects; and leverages such knowledge and information from previous V&V projects. The V&V enterprise provides the environment in which V&V projects are conducted.

To consolidate the significant R&D investments to develop the state-of-the-art V&V knowledge and technology, and to make the know-how available for application in the whole NL MoD organization and other M&S market segments, the NL MoD set the objective to realize a V&V expertise center based on the GM-VV enterprise level definition. The NLR and TNO were tasked to conduct a project, financed by the NL Ministry of Economic Affairs, Agriculture and Innovation, to establish this V&V expertise centre in 2012. The result of this effort is named “Q-tility” [10].

#### **3.1 Q-tility**

Q-tility is a premier cooperation of NLR and TNO specializing in verification and validation solutions for models, simulations and serious-games. Both partners are well established independent R&D organizations in the area of M&S. Q-tility’s strength is the unique combination of this extensive V&V knowledge with deep application domain specific knowledge of both parent organizations. This allows Q-tility to perform independent and objective V&V in virtually all problem and application domains. Many M&S professionals and organizations have gained valuable and directly applicable V&V knowledge through Q-tility’s real-life experience that allowed them to grow their M&S business professionally and successfully.

#### **3.2 Services**

Q-tility provides complete verification and validation services for M&S projects, either for clients that acquire, develop, or use M&S products. These V&V services are based on a V&V life-cycle model which is based on the GM-VV and involves management, planning, design, implementation, execution, results analysis and reporting for any level of V&V in a client’s M&S project. Since the V&V life-cycle model is scalable and tailorable, Q-tility is able to provide V&V services that always meets the clients budget, time-frame and business needs. Instead of doing the V&V work for clients, it is also possible to assist them to do V&V themselves by coordinating and setting-up V&V activities and teams, and transitioning these into the client organization. Moreover, Q-tility provides hands-on training courses that help clients to increase the V&V competence level of their M&S personnel, novice or expert alike. Q-tility also offers customized consultancy services that help solve V&V challenges and provide the advice, research and development tools to make a client’s M&S business successful. Q-tility offers clients the possibility of quick-scans, in short engagements, to help introduce or decided on V&V inside their M&S project or organization, effectively and efficiently.

The GM-VV defines a number of products, processes and roles on the enterprise level. After considerable tailoring Q-tility was implemented as described briefly below.

#### **3.3 Enterprise Level Information Artifacts**

According to the GM-VV one information artifact is defined: the **V&V Agreement**. This is 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). Q-tility has developed a standard template that can be filled in and tailored to reflect all elements to define a project to be executed by Q-tility for a client.

Besides this V&V Agreement, Q-tility has developed other products and tools related to V&V Information and Knowledge Management and running a V&V enterprise. Collectively these are stored in the Enterprise Memory. This storage facility is currently implemented simply as a directory structure in an on-line content and document management system. It contains a number of items necessary for the operations of Q-tility:

- Templates for all other GM-VV information artifacts,
- Knowledge base with lessons learned information on how to best execute processes and tasks,
- Catalog with application and domain specific knowledge obtained from executing V&V projects,
- Information on V&V techniques and risk & uncertainty analysis techniques,
- Acceptance criteria metrics,
- Node definitions and patterns to build argumentation networks,
- Tools for executing V&V tasks such as building argumentation networks,
- Flyers showcasing Q-tility's approach and finished projects.

Additionally a web-site [10] was built attract potential customers and to provide them information on Q-tility's approach to V&V projects, experience and contact information.

### 3.4 Enterprise Level Processes

The GM-VV defines a number of enterprise level processes:

**Agreement Management;** establishes and manages the V&V agreement between V&V client and the supplier entity.

Agreements between Q-tility and the client are tailor made for each project. The agreements are managed by close cooperation with this client.

**Life Cycle Model Management;** defines, maintains and ensures availability of V&V life-cycle models suitable for carrying out any V&V project.

The basic life cycle model is based on the GM-VV. However, since the GM-VV is capable of being tailored towards other V&V approaches [8] Q-tility is able to execute a broad range of life-cycle models as may be needed for specific projects.

**Project Portfolio Management;** initiates and sustains necessary, sufficient and suitable V&V projects in order to meet the strategic V&V supplier entity objectives.

Q-tility currently has two business developers to acquire projects. Currently the focus is on the acquisition of NL MoD projects, but the application of V&V in other domains, e.g. medical M&S, and international projects are planned.

**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.

Q-tility can rely on many years of experience in the V&V of models, simulations and serious-games. Since the mid-nineties the founders of Q-tility have applied V&V solutions in many national and international M&S projects within the aerospace, maritime, defence, safety and security domain. As described above, Q-tility is a cooperation between two R&D organizations with a total number of

personnel of about 5000. Q-tility's strength is the unique combination of an extensive V&V knowledge with deep application domain specific knowledge of both parent organizations. This allows Q-tility to perform independent and objective V&V in virtually all problem and application domains. Additional subject matter experts can be obtained via contacts with companies and universities with specialized knowledge and experience in V&V or application domains.

**Quality Management;** ensures that the delivered V&V product(s) meets the enterprise entity quality standards and achieves V&V User/Sponsor satisfaction.

Since the GM-VV is only recently accepted as a recommended practice much emphasis is on the expansion of experience and consolidation of lessons learned on the application of the GM-VV. Q-tility continually keeps an eye on new developments that can improve the effectiveness and efficiency of V&V project execution.

### **3.5 Enterprise Level Roles**

The GM-VV defines two roles on enterprise level:

**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 supplier side.

The founders of Q-tility have more than a decade of experience and strongly lead Q-tility with the most recent V&V methodologies, techniques and tools. Moreover, Q-tility's principles stood at the basis of the GM-VV and contributed to others.

**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 client side.

The V&V projects for the NL MoD have been executed with a fixed project manager on the MoD side who was involved in the development of the GM-VV from the beginning and is thus very experienced in managing the customer side of the V&V agreements.

### **3.6 Lessons Learned**

Many lessons were learned during the project to establish Q-tility. A large portion of these were related to setting up an organization, in the case of Q-tility a cooperation between two existing research organizations, and how to run that organization as a business. This e.g. included writing an extensive business plan. Another important point is to prepare material to effectively communicate the offered services and experience to potential customers.

A major lesson learned during the execution of the V&V studies was the need for a V&V life-cycle model based on GM-VV but incorporating the practical experiences. This new life cycle model is compatible with the GM-VV and is further presented in the paper on the other V&V study [6].

## **4.0 V&V CASE STUDY DESCRIPTIONS**

Two V&V studies were performed during the project to establish Q-tility. One case concerned the concept for a simulation for F16 familiarization of AOCS personnel. This V&V study is the topic of another paper [6]. Here we focus on the other V&V study: the implementation of the GM-VV project and technical levels for the V&V of the Public Order Management Serious Game. Below the V&V study background is briefly described, a more extensive description can be found in [7]. In urban operations, military commanders have to take into account the civilians present in the operation area. This is why Public Order Management (POM) is an important subject of their training.

#### 4.1 V&V of the POM Serious Game

In the Netherlands, the National Training and Knowledge Centre of the Royal Netherlands Marechaussee (military police) is responsible for POM commander training. Until 2011, this training mainly consisted of classroom-based planning exercises and field training. Field research shows that it is hard to make the training sufficiently effective and efficient [13]. Therefore the Royal Netherlands Military Police and TNO initiated the development of a dedicated POM training system for commander staff, this became the POM serious game. This system includes simulations of own POM units (formations, stances and dress) and crowds (movements, formations and aggression). Virtual Battlespace (VBS2) provides the system's simulation engine. As VBS2 [12] is not meant primarily for staff training nor for crowd control, a fair amount of functionality had to be added.



Figure 3: Public Order Management Serious Game.

During development, multiple trials were organized with students from the NL school for Public Order Management. The final trials were meant to evaluate the utility and validity of the new training system. These V&V sessions were executed by Q-tility and revealed that the new training system creates a valuable learning experience for the staff of a full POM platoon. It provided a challenging urban setting, where the trained staff could focus on the four key POM competences (tactics violence management, command and control, situational decision making, and communication), without the logistic burden of having the full platoon and several crowds on site. It also indicated extensions to the current game for further improvement.

Summarized, the major findings have been: The Acceptance Recommendation confirmed many of the strengths and weaknesses of the game. The added value of V&V is that now sufficient – and independently obtained – data is available to back up these claims. The POM game developers also appreciated the independent view on the usefulness of the game to prevent tunnel vision in the development team. Immediately after the V&V tests the Royal Netherlands Marechaussee has started implementing changes to allow for efficient and effective use of the POM game.

## 5.0 IMPLEMENTATION OF THE GM-VV PROJECT LEVEL

This chapter describes the implementation of the GM-VV project level for the POM serious game V&V study.

At the moment of execution of the V&V study the enterprise level was not in place yet since this study was part of the project to establish Q-tility. Therefore the enterprise level agreement management process was executed at the start of the project instead of before its start. The V&V agreement that was set up for the V&V project for the POM serious game specified the purpose, scope, requirements and constraints that guided the implementation of the V&V project.

The purpose for the Royal Netherlands Military Police was to evaluate what the current version of the POM serious game was capable of now with respect to their training needs and what short and mid term enhancement would increase the effectiveness and efficiency of the use of the game. It was also requested to keep a log of all additional ideas that may become implemented at some point in the future. The scope specified both the scope of the V&V work as well as the M&S System and its use. The V&V effort was to encompass all of the four worlds, see [4]. The specification of the deliverables reflected the purpose of the V&V effort and that the deliverables should be in the form of presentations and discussions. The timeframe and financial budget were dictated by the project to establish Q-tility and the availability of personnel and students NL school for Public Order Management. Other sections in the V&V agreement specified a.o. the required independence of the V&V effort and information handling.

After tailoring the project level was implemented as described briefly below.

### **5.1 Project Level Information Artifacts**

The GM-VV defines two artifacts on project level:

**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.

A more or less standard project management Project Plan was used during the project. No V&V specific elements were used.

**V&V Project Status Report;** an account or record to provide information on the conduct of the V&V project, its status and issues.

During the V&V study the status reports were mostly orally presented during meetings or via email.

### **5.2 Project Level Processes**

The GM-VV defines a number of project level processes:

**Project Planning;** produces, maintains and communicates an effective V&V project plan.

At the start of the V&V project a plan was made and regularly kept up to date during the project. Especially the time planning provided some challenges because of the limited availability of the stakeholders from the NL school for Public Order Management.

**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.

This process was not executed explicitly. The V&V Project Manager managed the project states and communicated with the V&V project team or the NL MoD project manager when needed.

**Decision Management;** provides information to determine the most beneficial course of action for the V&V project where alternatives exist.

This process was not executed explicitly. If problems occurred a decision was made by consulting members of the overall project to establish Q-tility and the project manager from the NL MoD.

**Risk Management;** provides information to identify, analyze, monitor and manage V&V project risks continuously.

This process was not executed explicitly, although V&V project risks were of course identified, analyzed, monitored and managed.

**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.

This process was not executed explicitly. Configuration management was mainly implemented as naming all files consistently and putting them in the correct directory and having separate files tagged with dates for each update.

**Information Management;** supports appropriate information exchange among all parties and roles involved in the V&V project execution.

The Project Memory that was used during the V&V Project was defined here. For the V&V study it was simply implemented as a directory structure on one of the parent organization's data storages.

**Measurement;** collects, analyzes, and reports data related to the overall V&V project, its performance and the quality of its deliverables.

This process was not executed explicitly, although measurements on the V&V project were of course made.

### 5.3 Project Level Role

The GM-VV defines one role on project level:

**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.

For the V&V study the V&V Project Manager is one of the founders of Q-tility.

### 5.4 Lessons Learned

Although this V&V study was a serious V&V project that delivered useful results to the client, it was also meant to result in material for demonstration purposes and papers such as this one, but also to collect lessons learned for future use by Q-tility. Below are some of the lessons learned on the GM-VV project level. Some of those are quite common in nature, others are more GM-VV specific.

At the start of the project it became clear that it was going to be difficult to set up meetings due to busy schedules of the client's personnel. This cause some difficulties in time planning. The start of the technical work kept on delaying, while the project end was fixed. In addition to the busy schedules a further complication that became apparent during the first few meetings with the client was that the trials would need a considerable number of trainees of the NL school for POM. Getting them together would again pose a time planning problem.

The timing problem could be solved for this V&V study because the developers of the POM serious game were available within TNO and they were very much aware of the clients M&S needs and of the set-up for the trials. So, while the NL school for POM started getting personnel and trainees for the trial, some of the technical work could already start. The technical level tasks that could begin were collecting context information, asking SMEs for topics that are very likely to be tested and starting building a goal network.

Potentially a conflict of interest was present and thus the independence of the V&V work had to be addressed. For this V&V study the client had a good relation with the developers and encouraged the use of



the developers in the V&V study. No issues were observed during the V&V project, but this use of developers for the V&V work is a mixed blessing and always needs to be considered carefully in future projects.

In practice many of the project and technical level processes were executed in parallel and some of them were not explicitly executed, but nevertheless the important tasks were done anyway.

It is important for the V&V project to obtain the client's V&V Needs & Objectives as early as possible. If this depends on a single person from the client side with a busy schedule this may be difficult. It is then advised to try to get a group of client personnel that can serve as V&V User/Sponsor; in that way it is easier to get the needed information. On the other hand, the M&S User/Sponsor group should not have differences in opinion about the V&V Needs and Objectives. If that is the case, try to appoint one person who is the most often available and who can represent the group.

## **6.0 IMPLEMENTATION OF THE GM-VV TECHNICAL LEVEL**

The technical level of the GM-VV is what most will consider as the core of the V&V effort. It concerns the engineering aspects that are necessary to develop and deliver an acceptance recommendation. After tailoring the technical level was implemented as described briefly below.

### **6.1 Technical Level Information Artifacts**

The GM-VV defines a number of technical level information artifacts:

**V&V Requirements;** requirements placed on the V&V project deliverables and execution, including constraints.

For the POM serious game V&V study the requirements and constraints as stated in the V&V Agreement were used and adhered to.

**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.

The POM serious game was developed by TNO on the basis of VBS2. Therefore detailed documentation and the developers themselves were available to provide information on the M&S System. The user of the POM serious game provided documentation on their POM training and information on the operational reality in which public order management is executed.

**V&V Plan;** specifies the V&V execution process, tasks and experimental frame to be implemented as well as the associated resources.

No separate V&V Plan was made. Most of the information was available either in the Project Plan or in the document detailing that part of the V&V Experimental Frame on trials at the NL school for Public Order Management. Also the V&V Argumentation Structure was used to keep track of what tasks were still needed to complete the argumentation.

**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.

The V&V Argumentation Structure contained nodes that specify details of the required tests. Tests included interviews, observations, 360° assessment, and hardware/software inspections.

Besides the above mentioned document for the actual trials with the NL school for POM, no specific V&V Experimental Frame documents were produced.

**V&V Results;** the collection of data items produced by applying a V&V experimental frame to an M&S system.

The data that was collected consisted of: interviews of which the audio was recorded and summaries of those interview, various sets of questionnaires which were filled in by trainers, trainees and observers, photos of the experimental set-up, and many notes on various topics made by the observers of the experiment.

**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.

The V&V Argumentation structure was implemented based on the set of network nodes defined by Q-tility. In its final version contained almost a thousand nodes. Such large networks require tools to manage and analyze. For this V&V study the yEd tool [11] customized for Q-tility V&V work was used. Building and maintaining such a large network requires a significant effort and experience with the tooling is needed.

**Acceptance Recommendation;** an account or record containing the recommendations on the acceptability of the M&S system for the intended use.

The acceptance recommendation was made in the form of several documents. A PowerPoint document detailing all observed V&V aspects was presented and discussed during a meeting with the client. Also a document with proposed changes for the short and mid term, and possible future additions was made.

**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.

All information produced during the V&V study was first stored in the Project Memory and later in the Enterprise Memory. Additionally a document was made with lessons learned for each of the executed processes.

## 6.2 Technical Level Processes

The following technical level processes are defined by the GM-VV:

**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.

Besides the subject matter experts from the client, which all had a busy schedule, it was possible for this V&V study to use the developers of the POM serious game who were aware of the client's context and needs.

**Acceptance Planning;** transforms the V&V requirements and context information into associated acceptability criteria for the M&S system.

The stakeholders from the NL school for Public Order Management together with the developers of the POM serious game derived the acceptability criteria based on the top goal that the POM serious game had to be useful to the Royal Netherlands Marechaussee.

**V&V Planning;** transforms the acceptability criteria into the V&V Experimental Frame specification and the V&V plan.

For each acceptability criterion a test was defined that, when executed, should result in evidence suitable for determining with sufficient convincing force whether a criterion was met.

**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.

A large number of the tests were combined in a set of trials at the NL school for Public Order Management, while others were executed via interviews and studying the context information. The trials consisted of four days in which two different groups of trainees used the POM serious game for its training purposes.

**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.

In consultation with mostly training experts the obtained evidence was assessed and integrated. Not all obtained evidence had the desired level of convincing force due to the low number of trainees which were visible in the statistics of the results. Since additional trials were not possible the observations made during the trials and the experience of the experts was used in the integration of the evidence. These problems were also mentioned in the Acceptance Recommendation towards the client.

**Acceptance Assessment and Integration;** assesses and integrates the acceptability claims into claims regarding to what extent the M&S system is acceptable for the intended use (i.e., acceptance recommendations).

The obtained claims from the V&V Assessment and Integration process were matched with the Acceptability criteria in the argumentation structure. At places where a claim fell short compared to the corresponding acceptability criterion a recommendation was made for further improvement of the POM serious game.

**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.

As requested by the client the V&V Report was in the form of a presentation with discussion and in the form of a document with possibilities for adaptations in the short and mid term, and a list of ideas that may be implemented in the (far) future.

### **6.3 Technical Level Roles**

The following roles are defined by the GM-VV:

**Acceptance Leader;** responsible for specifying the acceptability criteria, assessing the acceptability claims and constructing the acceptance recommendations.

This role was implemented by the V&V Project Manager.

**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.

This role was implemented by the V&V Project Manager.

**V&V Implementer;** responsible for implementing the V&V experimental frame and generating V&V results.

A number of V&V Implementers were employed during the V&V study. These roles were executed by the V&V Project Manager, Subject Matter Experts that were e.g. used as observers during the trials, the developers of the POM serious game and various operators that were necessary for the execution of the training.

## 6.4 Lessons Learned

Many detailed lessons learned on methods and techniques were obtained during the execution of the V&V study. Some more general lessons learned are summarized below.

The trials needed for a large part of the implementation of the V&V Experimental Frame consisted of two full training sessions with different groups of trainees, 4 days in total, in which NL school for POM personnel used the POM game as they intend to use it in the future. It was difficult to get the needed 24 trainees and it was decided to use operational personnel from both the Marechaussee and the police force.

Since this was the first time that the actual operators of the NL school for POM were used some hick-ups due to inexperience was encountered during the trials. However more experienced operators of the developers of the POM serious game were present to help out. This is really necessary because the obtained evidence need to be obtained (when possible) in a way as the M&S System is going to be used in real training sessions.

Building the goal-claim network took quite some effort. Because of its size tools and learning to work with those tools became necessary. After some trials with tools it was decided to use yEd [11] and customize it for use in Q-tility. This mainly meant defining a node-set and a set of indicators for e.g. progress, priority levels and met/un-met goals.

During the building of the goal network it was found that it is very difficult to foresee all relevant aspects in advance of the actual trials. Therefore it is recommended to build the goal network up to some level of detail, then execute a first trail, elaborate on the goal network and then perform a second trial. This approach was named explorative V&V.

From this and the other [6] V&V study general applicable and domain knowledge was obtained that will help building the argumentation network for future V&V studies.

## 7.0 DISCUSSION AND CONCLUSIONS

This V&V study showed that the GM-VV provides good guidance and set of reference products and process to effectively set up an V&V enterprise layer and conduct V&V Projects.

Establishing a GM-VV enterprise level entity needs a considerable amount of work. The GM-VV itself does not provide guidance on e.g. writing a business case or implementing a V&V Enterprise Memory. Also instantiating a concrete V&V life-cycle through its tailoring framework took some experience. This implementing and tailoring is not a trivial and straight-forward activity, and has a steep learning curve for those not familiar with the GM-VV approach. However, our current V&V projects show that this initial investment effort pays back through reuse of the created material. Furthermore, the efficiency of our current active V&V projects is further enhanced by the better V&V guidelines, methods, techniques and metrics that resulted from the lessons-learned from the instantiations of the project and technical levels for the V&V studies.

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