NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE AND TECHNOLOGY ORGANIZATION

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STO TECHNICAL REPORT **TR-MSG-073**

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

(Méthodologie générale de vérification et de validation (GM-VV) visant à soutenir l'acceptation des modèles, simulations et données)

This Report documents the findings of the GM-VV Group 073 (MSG-073) / Task Group 043 (TG-043).

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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Table of Contents

List of Figures

List of Acronyms

ADSO	Australian Defence Simulation Office
AMSMP	Acquisition M&S Master Plan
AMSP-1	Allied M&S Publication n°1
ASSIST	Acquisition Streamlining and Standardization Information System
CAS	Credibility Assessment Scales
CMM	Capability Maturity Model
DID	Data Item Description
DoD	Department of Defence (US)
DOE	Department Of Energy (US)
DoN	Department of Navy
DVDT	DoD VV&A Documentation Tool
EDM	Engineering Data Management
FEDEP	Federation Development and Execution Process
FISG	Fidelity Implementation Study Group
FORM	First Order Reliability Method
FPI	Fast Probability Integration
GM-VV	Generic Methodology for Verification and Validation
GSN	Goal Structuring Networks
HLA	High Level Architecture
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
ISO/IEC	ISO International Electrotechnical Commission
ISV	Internal Security Verification
ITOP	International Test Operations Procedures
IV&V	Independent Verification and Validation
M&S	Modelling and Simulation
M&SCO	The United States DoD Modeling and Simulation Coordination Office
MSA	Modelling and Simulation Application
NAVAIR	Naval Air
NAVMSO	Navy Modeling and Simulation Management Office
NMSO	Navy Modeling and Simulation Office
NMSRR	Navy Modeling and Simulation Resource Repository
NMSSP	NATO M&S Standards Profile
PLM	Product Life cycle Management
RBA	Risk-based Accreditation
REVVA	Common Validation, Verification and Accreditation Framework for Simulation
RPG	Recommended Practices Guide

S&T	Science & Technology
SCS	Society for Computer Simulation
SEDEP	Synthetic Environment Development and Exploitation Process
SISO	Simulation Interoperability Standards Organisation
SIW	Simulation Interoperability Workshop
SME	Subject-Matter Expert
UK MoD	United Kingdom Ministry of Defence
VDT	VV&A Documentation Tool (US DoD)
VPMM	Validation Process Maturity Model
VV&A	Verification, Validation and Acceptance
VV&C	Verification, Validation and Certification
VVAMS	Verification, Validation and Acceptance of Model and Simulation
VVML	VV&A Markup Language
WEAG	Western European Armaments Group

Acknowledgements

NATO has developed a tradition of broad participation for international reporting of guidance and direction on issues fundamental to the Alliance. In keeping with this tradition, GM-VV is the result of that complex consultative process involving a large team of Subject-Matter Experts (SME) from all participating Nations, including other national SME directly involved in the Case Studies showing the benefits in using this generic methodology to increase the confidence in the results provided by M&S systems. Sincere gratitude for this support, consultation, and guidance is extended to all members of these participating teams.

It would be improper not to further extend our gratitude to all participating Nations of previous projects (REVVA1, REVVA2, and MEVAS) that initiated the effort to provide the GM-VV methodology.

We must also acknowledge not only the support of the NATO Modelling and Simulation Coordination Office (MSCO) but in particular its Head, LTC Francisco Gomez-Ramos, the Head of CSO (Collaboration Support Office), Dr. René Larose, the Technical Help Officer, LTC Adrian Voiculet and the MSCO Assistant, Ms. Illeana Ganz. Without their support, we would not have jumped at the offer to build MSG-073 and we are grateful.

SISO (the Simulation Interoperability Standards Organisation) was chosen as the preferred standardisation organisation for the REVVA methodology that was the main objective of REVVA2. According to SISO procedures a GM-VV (Generic Methodology for V&V) Study Group (SG) was established with the objective to provide a path into the creation of an internationally accepted VV&A standard. The follow-on Product Development Group (PDG) of SISO was tasked to make all the required steps to transform the REVVA outcomes into a generic SISO V&V guidance set of documents. We have to fully acknowledge all members of these groups for their efficient work, members of the GM-VV Volume 1 and Volume 2 ballot groups for their fruitful comments and suggestion and finally members of SISO both SAC (Standards Activity Committee) and EXCOM (Executive Committee) for their support.

Finally, many thanks to all (see Official Members of MSG-073) for the tremendous effort and for what we accomplished together to ensure the publication of the SISO GM-VV guidance documents.

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

(STO-TR-MSG-073)

Executive Summary

Purpose

The Generic Methodology for Verification and Validation (GM-VV) provides a generic framework to efficiently develop an argument to justify why identified models, simulations, underlying data, outcomes and capabilities are acceptable for deployment in the targeted (intended) operational context of use. The GM-VV has successfully completed the SISO standardization process through a GM-VV Product Development Group (PDG) in order to provide a fully accepted VV&A guidance document. In fact, NATO initiated the MSG-073 Task Group mainly to support the standardization process of GM-VV. One additional objective of this activity was to include the balloted SISO set of documents within the NATO M&S Standards Profile (NMSSP). One of the key activities to realize this MSG-073 objective is to gain practical experience in and where needed provide recommendations to refine the GM-VV through case studies.

Scope and Limitations

The scope of this V&V methodology is nominally for NATO M&S. However, the generic approach taken herein is to provide comprehensive guidance documents that can easily be adapted and tailored to other M&S enterprises. NATO and national defence establishments, M&S communities-of-practice are *de facto* enterprises in this spirit when the investment, development, maintenance, and use of M&S assets are concerned, and when V&V of simulations, models and data are critical to increase the confidence of the decision-makers in the results provided by their simulation systems. While the application of this V&V methodology is intended to be broad, its scope is targeted to M&S systems design, development and employment process.

Méthodologie générale de vérification et de validation (GM-VV) visant à soutenir l'acceptation des modèles, simulations et données

(STO-TR-MSG-073)

Synthèse

Objet

La méthodologie générale de vérification et de validation (GM-VV) fournit un cadre général au développement efficace d'une argumentation justifiant l'acceptabilité de modèles, simulations, données sous-jacentes, résultats et capacités identifiés, vis-à-vis du contexte opérationnel cible (prévu). La GM-VV a suivi avec succès le processus de normalisation de la SISO : elle est d'abord passée par un groupe de développement de produit GM-VV, qui a rédigé un document d'orientation entièrement agréé sur la vérification, la validation et l'accréditation (VV&A). En réalité, l'OTAN a principalement établi le groupe de travail MSG-073 pour prendre en charge le processus de normalisation de la GM-VV. Cette activité avait également pour but d'inclure le jeu de documents votés de la SISO au sein du profil des normes de M&S de l'OTAN (NMSSP). L'une des activités essentielles pour atteindre cet objectif du MSG-073 est d'engranger de l'expérience pratique là où elle est nécessaire pour fournir des recommandations en vue d'affiner la GM-VV par des études de cas.

Portée et limites

Cette méthodologie de vérification et validation (V&V) ne porte que sur la M&S de l'OTAN. Toutefois, l'approche générale adoptée ici consiste à fournir des documents d'orientation complets pouvant être facilement adaptés à d'autres entreprises de M&S. L'OTAN et les établissements de défense nationaux, réseau d'échange de pratiques, sont de fait des entreprises en ce sens lorsqu'il s'agit de l'investissement, du développement, de l'entretien et de l'utilisation des moyens de M&S et lorsque la V&V de simulations, modèles et données est essentielle pour renforcer la confiance qu'accordent les décideurs aux résultats fournis par leurs systèmes de simulation. Bien que l'application prévue de la présente méthodologie de V&V soit large, elle ne vise que la conception, le développement et le processus d'emploi de la M&S.

Chapter 1 – BACKGROUND OF THE MSG-073 EFFORT

Models and Simulations (M&S) are developed and employed as enabling technologies to support system analysis, design, test and evaluation, acquisition, training and instruction, and many more areas. Today, a wide variety of M&S assets are in use across an even wider range of different application and problem domains. M&S is usually applied when certain user needs cannot be achieved (e.g. risks, availability) with the actual system or otherwise are achieved more efficiently (e.g. costs, effectiveness) than with the actual system. However, in essence, all M&S assets provide some sort of abstract representation of systems (e.g. entity, phenomenon, process) that are based on different types of approximation. As such, M&S capabilities cannot fully replace the actual system and, more importantly, their usage introduces uncertainties. In combination with the increasing complexity of M&S assets being developed and employed, risks for failures, wrong usage, and misinterpretation of results are increasingly difficult to judge. Therefore, the benefits of using M&S always come at some cost, i.e. use risks. The key question then for M&S stakeholders (e.g. user, sponsor, developer) is to determine which M&S asset is acceptable for a particular intended use, and which is not. Verification and validation (V&V) are the processes that are typically used to support M&S stakeholders to determine and assure that an M&S asset is acceptable for the intended use. Hence, V&V provides information to be used in the acceptance decision process of M&S stakeholders, and associated practices such as M&S accreditation and certification.

The choice of which V&V method works best in a given situation depends on the individual needs and constraints of an M&S organization, project, application domain or technology. Moreover, V&V usually requires a complex mixture of various activities, methods, tools, techniques and application domain knowledge, which are often tightly coupled with the M&S development process. Therefore, many different approaches to V&V exist that rely on a wide variety of different V&V terms, concepts, products, processes, tools or techniques. In many cases, the resulting proliferation restricts or even works against the transition of V&V results from one M&S organization, project, and technology or application domain to another. Furthermore, history shows that V&V is often more of an afterthought than a built-in part of an M&S development, employment and procurement policy.

In 2002, a European consortium was created to address the VV&A issue under the Western European Armament Group (WEAG) umbrella: the REVVA1 (Reference project for VV&A) project was born. In its final composition (REVVA2), this consortium included five NATO Member/Partner Nations (Canada, Denmark, France, Netherlands and Sweden) with the task to complete the methodology and prepare for standardization.

The work of REVVA had its roots in both the UK/FR project MEVAS which was contracted under the Anglo French Defence Research Group (AFDRG No 11) cooperation and the International Test Operations Procedure (ITOP) Working Group of Experts (WGE 7.2).

MEVAS (Méthode d'Evaluation de Validation et d'Accréditation des Simulations) is the result of a Franco-British study devoted to the Verification, Validation & Accreditation (VV&A) of the synthetic environment. MEVAS was intended to facilitate the establishment of an organization and a process adapted to the development of a simulation. The methodology was presented in 2002 in the form of methodological guides (reference manual, operation manual) structured according to the identified relevant populations: developers, users and beneficiaries. The MEVAS work, among other things developed the three pillars concept, a concept being re-used in REVVA/GM-VV (see Chapter 5, GM-VV Implementation Framework Dimensions for a follow-up of this concept).

ITOP is a four-Nation initiative (DEU-FRA-GBR-USA) that focuses on standards for test operations, Part 7 focussing on simulation and V&V. ITOP WGE 7.2 intended to provide a standard template for uniform documentation in support of the exchange of V&V information among Nations. ITOP made extensive use of

V&V cases and the use of claims supported by arguments and evidence gathering, an approach that was also used as a baseline for REVVA and thus for GM-VV. The ITOP group produced an official release of their work as n°1-1-002, May 2004.

SISO (the Simulation Interoperability Standards Organization) was chosen as the preferred standardization organization for the REVVA methodology that was the main objective of REVVA2. According to SISO procedures a GM-VV (Generic Methodology for V&V) Study Group (SG) was established with the objective to provide a path into the creation of an internationally accepted VV&A standard. The follow-on Product Development Group (PDG) of SISO was tasked to make all the required steps to transform the REVVA outcomes into a generic SISO V&V guidance set of documents.

The purpose of the Generic Methodology for Verification and Validation (GM-VV) is to provide general applicable guidance for V&V that:

- Facilitates common understanding and communication of V&V within the M&S community;
- Is applicable to any phase of the M&S life-cycle (e.g. development, employment, and reuse);
- Is M&S stakeholders' acceptance decision-making process oriented;
- Is driven by the M&S stakeholders' needs and M&S use risks tolerances;
- Is scalable to fit any M&S scope, budget, resources and use-risks thresholds;
- Is applicable to a wide variety of M&S technologies and application domains;
- Will result in traceable, reproducible and transparent evidence-based acceptance arguments;
- Can be instantiated on enterprise, project or technical levels alike; and
- Facilitates reuse and interoperability of V&V outcomes, tools and techniques.

GM-VV is not aimed to replace the existing V&V approaches, methodologies, standards or policies of M&S organizations, technology and application domains; nor is GM-VV's intent to substitute common enterprise or project management practices prevalent within M&S client or supplier organizations. In addition, GM-VV is not intended to be prescriptive, in that it does not specify a single concrete or unique solution for all V&V applications. Rather, the GM-VV should be tailored to meet the needs of individual V&V applications.

MSG-073 at its inception in 2009 was based on the above outline. It was a follow-up on earlier efforts within NATO and the former US DoD DMSO (Defence Modeling and Simulation Office), which was renamed to US DoD M&SCO (Modeling and Simulation Coordination Office). Other US DoD V&V work was focussed on the development of IEEE 1278.4 (Recommended Practice for Distributed Interactive Simulation – VV&A) and IEEE 1516.4 (Recommended Practice for VV&A of a Federation – An overlay to the High Level Architecture Federation Development and Execution Process). IEEE 1516.4 was developed with support from NATO RTO Task Groups MSG-019 and MSG-054. Both the efforts IEEE 1278.4 and IEEE 1516.4 however are mainly focussed on the V&V of distributed simulations. On a national basis, the US DoD has also produced national guides/references that are well known from the international community [32] and have influenced the work of GM-VV [32],[33].

It is worth noting here that Nations other than the contributing Nations have followed the REVVA efforts. Nations which have already implemented an M&S policy in with direct references to REVVA (and GM-VV) are Germany and Australia. The countries currently participating in MSG-073 are also working on the implementation of GM-VV in their own organizations.

Chapter 2 – OBJECTIVE OF THE MSG-073 EFFORT

In 2009, the NMSG originated a Task Group (MSG-073) to support the development of a set of guidance documents on a generic methodology to verify and validate models, simulations and data which can be used in the future by NATO to support its M&S requirements. The major objective of the MSG-073 TG was to create a follow-on process for finalizing the standardization work on the GM-VV methodology. According to the Technical Activity Proposal (TAP) and Terms of Reference (TOR) charter, enclosed as Annex A, the MSG-073 TG was responsible and engaged in specific activities with the following objectives:

- To finalize the work on the VV&A document set (this task started under the European REVVA consortium banner and is now under development by the SISO GM-VV PDG);
- To guide the proposed document set through the formal SISO standardization process;
- To participate in the review, commenting and balloting efforts needed for creation of a new SISO standard;
- To assemble confidence in and fine-tune the methodology on the basis of 'real' case studies; and
- To provide education and training based on a documentation set for dissemination.

Other objectives were to include the balloted SISO products within the NATO M&S Standards Profile (NMSSP), AMSP-01, and to produce a Final Technical Report. The work of the Task Group has built on former technical VV&A activities:

- Former NMSG TGs (MSG-019 and MSG-054);
- Previous work on VV&A under the International Test Operations Procedures (ITOP) organization;
- Past work on the previous SISO Study Group on generic Methodology for V&V (GM V&V); and
- Activity of the GM-VV SISO Product Development Group (PDG).

The TG has worked together with the SISO GM V&V PDG and was in direct support to the Drafting Group of the PDG. More specifically the TG has been in charge of supervising the PDG activities to guarantee that NATO and Member/Partner Nation's needs were addressed in the PDG. Moreover SISO PDGs are widely open to other communities of interest such as transport, medicine, etc., and not only targeted to military or security purposes.

Chapter 3 – MSG-073 PROGRAM OF WORK

The effort described in this Chapter constitutes the program-of-work executed by the Task Group MSG-073, which mainly resulted in the publication of three documents:

- **GM-VV Vol. 1**: "Introduction and Overview", a SISO guidance product that provides an overall description of the methodology. It presents the core concepts of the methodology as well as how its architecture binds them together to establish the foundations of a tailorable implementation.
- **GM-VV Vol. 2**: "Implementation Guide", a SISO guidance product that extends Volume 1 by providing guidance on how to apply the methodology. It unfolds the methodology's architecture by elaborating on the processes, products, interactions among the roles, and how to tailor the methodology.
- **GM-VV Vol. 3**: "Reference Manual", a SISO reference document that describes the foundations of the concepts, their dependencies and rationale. This document is meant to be referenced whenever a deeper technical understanding of the methodology is required.

According to SISO, Volume 1 and 2 are "guidance products" officially balloted according to the SISO Balloted Products Development and Support Process (reference SISO-ADM-003-2011, 14 November 2011). Volume 3 is a SISO "reference product" that is not balloted but officially approved by main SISO committees.

3.1 INTRODUCTION

Both SISO GM-VV PDG and MSG-073 efforts are strongly inter-related. MSG-073 members were key contributors to the elaboration of SISO-published documents as either documents editors or PDG leaders (see Section 3.2.3). For this reason, many artefacts composing this TG Final Report are also parts of the SISO GM-VV documents. SISO documents are freely available but are copyrighted. For this reason, all parts of SISO documents that are reproduced within this final report with the agreement of the SISO Board of Directors in compliancy with the technical cooperation agreement signed between SISO and the RTO/ NMSG in 2007. The agreement letter of the SISO BoD chairman is reproduced in Annex B.

3.2 GENERAL DISCUSSION OF EFFORT ELEMENTS

3.2.1 Calendar of Meeting Activities

During its life, the Task Group met 15 times:

- April 2009, in the NATO R&T Agency (Neuilly, FRA);
- September 2009, in University of Central Florida (Orlando, USA);
- January 2010, in DGA (Bourges, FRA);
- March 2010, in University of Central Florida (Orlando, USA);
- September 2010, in University of Central Florida (Orlando, USA);
- February 2011, in University of Bundeswehr Munchen (Neubiberg, DEU);
- June 2011, during the Euro SIW (The Hague, NLD);
- September 2011, in University of Central Florida (Orlando, USA);
- February 2012, in FMV (Stockholm, SWE);

- June 2012, in ONERA (Toulouse, FRA);
- September 2012, in University of Central Florida (Orlando, USA);
- March 2013, in NLR, (Amsterdam, NLD);
- June 2013, in NATO STO CSO (Neuilly, FRA);
- September 2013, in University of Central Florida (Orlando, USA); and
- November 2013, in NATO STO CSO (Neuilly, FRA).

Many meetings were organized in the US, despite the fact that this Nation was not part of this technical activity, for organisational reasons: all these meetings were co-located with SISO workshops (SIWs).

3.2.2 Task Group Work-Product Generation

All products of the Task Group are linked with the TG objectives. In addition to the three SISO documents published as official SISO documents but freely available to the M&S community, other products relate to the TG objectives as expressed in the Terms of Reference of the MSG-073 technical activity:

- To finalize the work on a VV&A document set under development by the SISO GM-V&V Product Development Group;
- To guide the proposed document set through the formal SISO standardization process;
- To participate in the review, comment and balloting efforts for these new SISO standards;
- To assemble confidence in and fine-tune the methodology on the basis of 'real' case studies; and
- To provide education and training based on a documentation set for dissemination.

Objectives 1 to 3 correspond to the supporting activity of the SISO GM-VV PDG (see Section 3.2.3) that has resulted in the three SISO documents.

Objective 4: Chapter 7 describes case studies as known at the time of completion of this report.

Objective 5 has been achieved with the production of three tutorials at different levels:

- One high-level presentation of the methodology (half-an-hour introduction) dedicated to managers and M&S policy-level individuals;
- Introductory Tutorial (1 hour to 90 minutes): this tutorial was prepared by NLD and has already been introduced in some non-NATO events such as SISO Workshops, ITEC and I/ITSEC conferences; and
- A 2-day tutorial initially developed by France for the education and training of GM-VV users. This longer tutorial is the foundation for a STO Lecture Series.

3.2.3 Coordination with SISO GM-VV PDG

According to its TOR, MSG-073 had to support the SISO Product Development Group that has the mission to develop and ballot the GM-VV documents. The MSG-073 acted has a "management group" for the SISO GM-VV PDG.

MSG-073 provided the chair, one co-vice-chair and the secretary of the PDG. Main members of the GM-VV Drafting Group (DG) including both DG Editors were members of the MSG-073 TG. Nearly all MSG-073 members are also members of the SISO PDG: this ensured that concepts developed by the MSG-073 TG were well taken into account in the SISO PDG production, while MSG-073 members were voting within the SISO PDG when decisions had to be taken.

3.3 CONCLUSION

As far as the Task Group can judge, it has completed its initial 5 objectives. In addition, MSG-073 dealt with specifications of supporting tools that was not explicitly expressed in its TOR.

Concerning the SISO activity, the support to GM-VV standardization is a permanent future activity and a Task Group has a limited life-time. The NMSG should decide what specific actions they should initiate to support this future effort.

A Product Support Group (PSG) was instantiated by SISO in December 2013. In accordance with SISO regulations, a PSG serves as the central point for interpretation of product language, providing help desk support, and accepting, developing, and maintaining problem and change reports to support future product revisions.

Chapter 4 – GM-VV CONCEPTUAL FRAMEWORK[1]

4.1 INTRODUCTION

The GM-VV provides a technical framework that focuses on M&S V&V practices. Though interrelated, acceptance decision processes and associated practices such as M&S accreditation and certification are outside the scope of the methodology.

GM-VV attains its generic quality from a technical framework that consists of three sub-parts: the conceptual, implementation and tailoring framework (Figure 4-1). This framework is rooted in established international standards and other related practices. The conceptual framework provides the terminology, concepts and principles to facilitate communication and a common understanding and execution of V&V within an M&S context. The implementation framework translates these concepts and principles into a set of generic building blocks to develop consistent V&V solutions for 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 instances. As such, the GM-VV provides a high-level framework for developing concrete V&V solutions and conducting V&V, into which lower-level practices (e.g. tools, techniques, tasks, acceptability criteria, documentation templates) native to each individual M&S organization, project, and technology or application domain can easily be integrated.

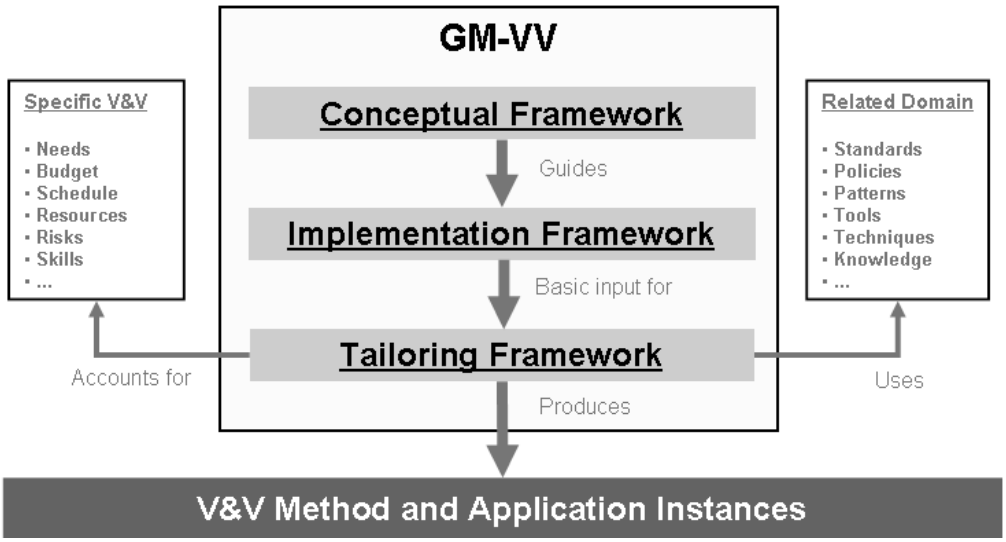

Figure 4-1: GM-VV Technical Framework Design and Operational Use Concept.

4.2 GM-VV CONCEPTUAL FRAMEWORK

This framework provides fundamental and general applicable terminology, semantics, concepts and principles for V&V. The purpose of the framework is to facilitate communication, understanding and implementation of V&V across and between different M&S contexts (e.g. organizations, application domains, standards, technologies). The framework is the foundation upon which the GM-VV implementation framework rests.

[1] Parts of this chapter are taken from SISO-GUIDE-001.1-2012, "GM-VV Vol.1: Introduction and Overview" (Copyright 2012 by Simulation Interoperability Standards Organization – SISO) [1].

4.2.1 Links to System Engineering

Within the GM-VV, M&S systems are considered to be Systems-of-Systems (SoS) that have a life-cycle and are subject to system engineering practices. Moreover, models and simulations are considered to be part of a larger system in which they are used. From this perspective, M&S is a systems engineering specialization. Verification and Validation (V&V) are an intrinsic part of the systems engineering process [23],[27],[28], [29]. Therefore, the GM-VV considers the V&V of M&S as a specialization of systems engineering V&V. Hence, the GM-VV can be integrated with, complement or extend the V&V processes within such existing systems engineering methodologies or standards.

4.2.2 M&S-Based Problem Solving Approach

The basic premise of the GM-VV is that models and simulations are always developed and employed to fulfil the specific needs of their end users (e.g. trainers, analysts, decision-makers). Modeling and simulation is thus considered to be a problem solving process that transforms a simple statement of an end user's need into an M&S-based solution for the problem implied in the need. The GM-VV assumes that V&V always takes place within such larger context. This context is abstracted by means of defining four interrelated worlds (Figure 4-2). Together, these four worlds define a generic life-cycle and process view of M&S-based problem solving. A view that serves as a common basis, in which V&V for M&S (e.g. concepts, principles, processes, products, techniques) can be understood, developed or applied.

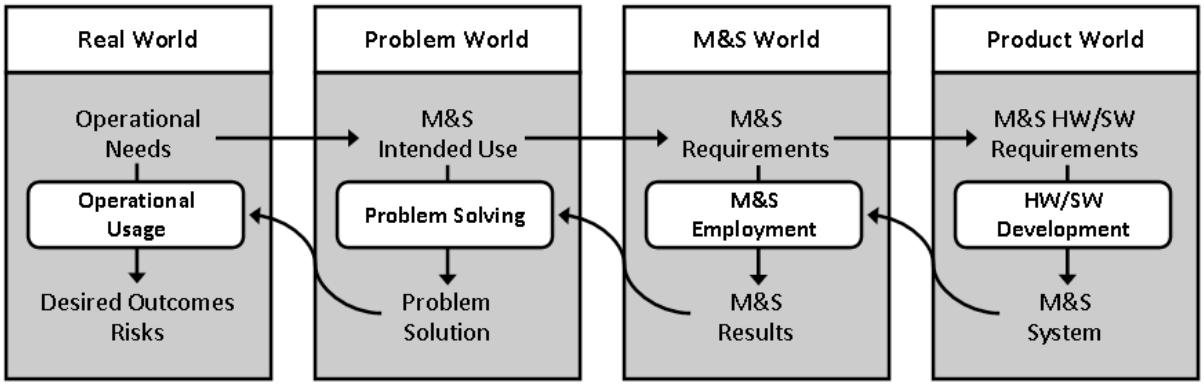

Figure 4-2: Four Worlds View of M&S-Based Problem Solving.

In the four-world's view of M&S-based problem solving, Real World operational needs are translated into an M&S intended use statement in the Problem World. In the M&S World this M&S intended use serves as the basis from which the M&S requirements are set for an M&S System. The M&S system is developed within the Product World, which involves setting low-level requirements for each element in the M&S system. M&S employment in the M&S World comprises well-controlled operation of the M&S system. The M&S results that come from the M&S system operation (i.e. simulation execution) are used in the problem solving process within the problem world. Finally, the M&S-based solution (e.g. new product, trained person, and analysis report) is transferred to the real world where it is exploited in the operational environment. When this M&S problem solving process is properly executed, the resulting solution should satisfy the originally identified needs with a minimal level of (use) risk in the Real World.

The M&S system, M&S requirements, M&S results and other development artifacts (e.g. conceptual model, software design, code) are thus always directed toward contributing to and satisfying the Real World operational needs. The degree of success of such M&S in satisfying these needs depends on how well they are specified, designed, developed, integrated, tested, used, and supported. These M&S activities require the contribution of individuals or organizations that have a vested interest in the success of the M&S asset,

either directly or indirectly. An individual or organization with such interest is referred to in GM-VV as a stakeholder. Stakeholders can play one or more roles in each of the four worlds such as M&S user/sponsor, supplier, project manager, software developer, operator, customer or Subject-Matter Expert (SME). Depending upon their role, stakeholders may hold different responsibilities in the M&S life-cycle processes, activities or tasks.

Notice that the four-world view is not intended to be prescriptive or to replace alternative, more detailed M&S life-cycle and process implementations (e.g. FEDEP [8], DSEEP [7] that are required or used by organizations. Such concrete implementations can be considered as tailored instances of this abstract four-world view.

4.2.3 V&V Problem Solving Approach

Within the four-world context, stakeholders exist who are responsible for making acceptance decisions on the use of M&S. Within the GM-VV, these stakeholders are referred as V&V User/Sponsor. In this context, the V&V User/Sponsor could be an M&S User/Sponsor, Accreditation Authority or any other domain specific role that uses the outcomes of the V&V. V&V Users/Sponsors face the problem of having to make a judgment on the development and suitability of the M&S system or results for an intended use. The key issue here is that it is not possible to demonstrate with absolute certainty that the M&S system or results will meet the Real World needs prior to its actual use. Consequently, there is always a probability that the M&S-based solution is not successful when used (i.e. fails). Such a failure would result in an undesirable impact (i.e. a risk) on the operational environment. Therefore, an M&S system or result is only acceptable to the V&V User/Sponsor if he or she has sufficient confidence that the use of an M&S system or result satisfies the Real World needs without posing unacceptable risks (e.g. costs, liabilities). This M&S acceptability is something relative to different V&V Users/Sponsors: what is acceptable to one V&V User/Sponsor may not be acceptable for another. The V&V User/Sponsor's decision-making process therefore requires appropriate evidence-based arguments to justify his or her acceptance decision.

The basic premise of GM-VV is that V&V are performed to collect, generate, maintain and reason with a body of evidence in support of the V&V Users/Sponsors acceptance decision-making process. Here, validation is referred to as the process that establishes the V&V User/Sponsor's confidence as to whether or not they have built or procured the right M&S system or result for the intended use (i.e. M&S validity). In other words "Did we build the right M&S system?" To ensure that the M&S system or results at delivery can be demonstrated to be valid, it is necessary to ensure that the M&S system is built and employed in the right manner. Here verification is referred to as the process of establishing V&V User/ Sponsors confidence in whether the evolving M&S system or result is built right (i.e. M&S correctness). In other words "Did we build the M&S system right?" The GM-VV considers V&V as a specific problem domain of M&S with its own needs, objectives and issues. This domain is referred to as the V&V World (Figure 4-3).

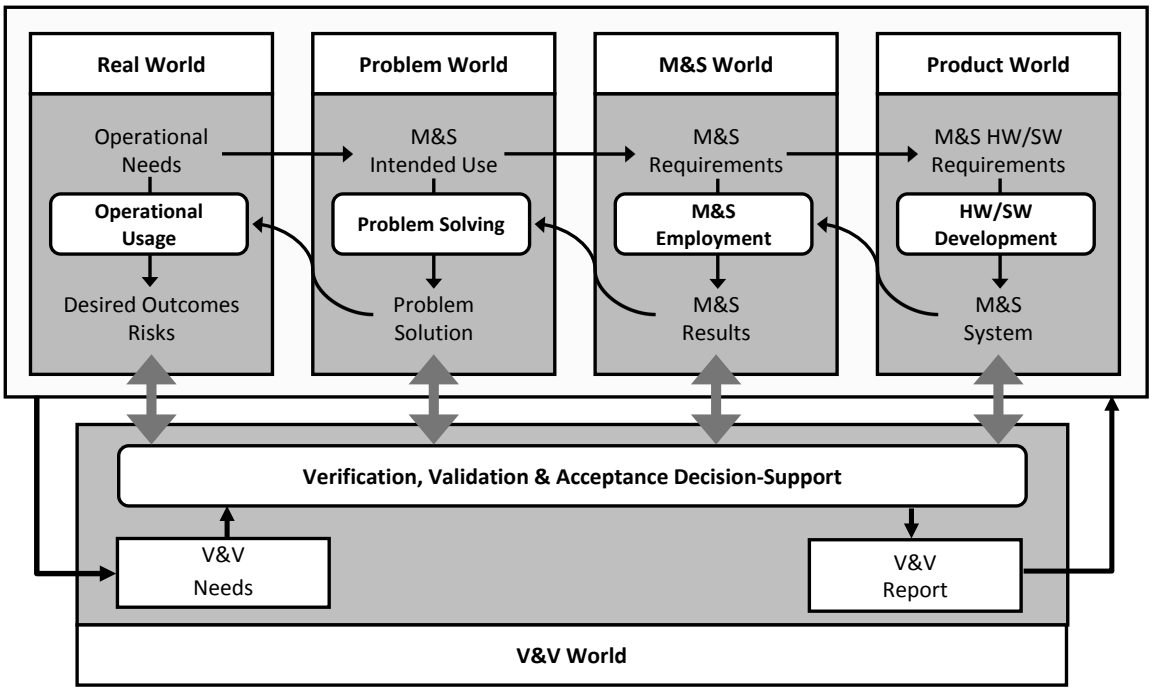

Figure 4-3: V&V World and Four-World Interfacing.

The V&V world groups the products, processes and organizational aspects that are needed to develop an acceptance recommendation that can be used by the V&V User/Sponsor in his or her acceptance decision procedure(s). 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 results. Here the GM-VV premise is that the acceptance decision itself is always the responsibility of the V&V User/Sponsor and decision procedure(s) may involve trade-off aspects beyond the V&V effort scope.

The development of an acceptance recommendation in the V&V world is driven by the V&V needs that are traceable to the V&V User/Sponsor's acceptance decision or procedure(s) needs (e.g. budget, responsibilities, risks, liabilities). Therefore, the extent, rigor and timeframe of a V&V effort depend on these needs. Depending on these needs, the V&V effort could span the whole or specific M&S life-cycle phase of the four worlds; could focus on one specific or multiple (intermediate) M&S products; and should match the development paradigm that was used (e.g. waterfall, spiral). Each case may require a separate acceptance recommendation with its own scope and development timeline. Moreover, the way the V&V effort interacts with the four M&S-based problem worlds also varies from case to case. These mutual dependencies are depicted in Figure 4-3 with bi-directional arrows that interface the V&V world with each of the four M&S-based problem solving worlds. Two classical types of V&V that can be identified based on the time frame of their execution are [23],[24],[25],[26]:

- **Post-Hoc V&V**: V&V conducted in retrospect on an M&S system after development or on M&S results after M&S system employment; and
- **Concurrent V&V**: V&V conducted in prospective throughout the whole M&S life-cycle to manage and improve the quality of newly developed M&S systems or results.

The GM-VV supports both V&V time frames but is not limited to these distinct types. A V&V effort can be post-hoc, concurrent, iterative, recursive or even be a recurrent effort in the case where legacy M&S products are updated or reused for a different intended-use.

4.2.4 Acceptance Recommendation, Acceptability Criteria and Evidential Quality

The objective of a V&V effort is to develop evidence upon which an acceptance recommendation is based. This V&V objective is articulated as an acceptance goal. This high-level goal should be translated into a set of concrete and assessable acceptability criteria for the M&S system or result(s). Relevant and convincing evidence should then be collected or generated to assess the satisfaction of these criteria. When it is convincingly demonstrated to what extent the M&S system or result(s) does or does not satisfy all these acceptability criteria, a claim can be made on whether or not the M&S system or result(s) is acceptable for its intended use (i.e. acceptance claim).

GM-VV identifies four types of M&S properties for which acceptability criteria could be set (Figure 4-4):

- **Utility**: This property refers to the extent to which the M&S system or result(s) is useful in solving the M&S user/sponsor's needs. Utility properties could comprise sub-types such as M&S value (e.g. measures of effectiveness, measures of performance), cost (e.g. money, time) and use risks (e.g. impact, ramifications);
- **Validity**: This property refers to the extent to which the M&S system's representation corresponds to the simulated simuland (i.e. system of interest) from the perspective of the intended use. The level of validity impacts the utility; and
- **Correctness**: This property refers to the extent to which the M&S system implementation conforms to its specifications (e.g. conceptual model, design specification); and is free of design and development defects (e.g. semantic errors, syntactic errors, numerical errors, user errors). The level of correctness impacts both validity and utility.
- **V&V Quality**: This property refers 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 satisfy the acceptability criteria (e.g. evidential value, strength).

  Typical examples of V&V quality properties are the completeness, consistency, unambiguous and relevance of the acceptability criteria or their supporting items of evidence. In the process of collecting or generating evidence, quality properties could comprise independence of applied V&V techniques or persons, knowledge gaps and uncertainties of referent data for the simuland [22], skill level of V&V personnel, and reliability and repeatability of V&V techniques. Relevance and warrants for any assumption made in a V&V effort could also be addressed in the form of quality properties.

These four types of M&S properties include but not limited to capability, accuracy, usability and fidelity [17],[18]. To make an acceptance decision, the V&V User/Sponsor needs to know whether the M&S system or results are (un)acceptable, as well as the evidential value of this acceptance claim (i.e. strength). The required evidential strength to establish sufficient trust in such a claim depends on the use risks and the V&V User/Sponsor responsibilities (i.e. liability). The convincing force that can be placed on such a claim depends on the quality of the whole V&V effort. For this purpose, the GM-VV identifies quality properties that can be associated with identifying and defining the acceptability criteria; and developing convincing evidence for demonstrating their satisfaction (Figure 4-4).

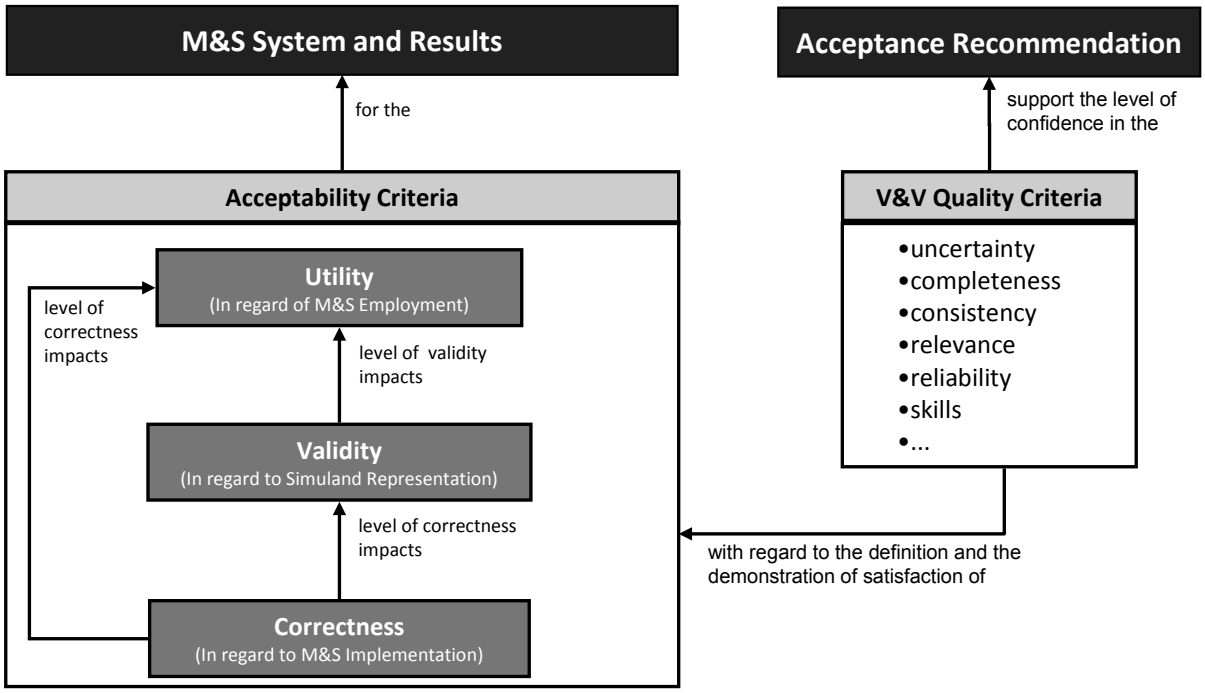

Figure 4-4: Utility, Validity, Correctness and V&V Quality Criteria Relationships.

The defined acceptability criteria, the collected evidence and assessment of the satisfaction of these criteria are the basis for developing the arguments underlying the acceptance claim. This acceptance claim provides the V&V User/Sponsor with a recommendation regarding the acceptability of the M&S system or result for the intended use. In practice, an acceptance recommendation is not necessarily just a yes or no claim, in the sense that an M&S system or results can be accepted only if it meets all of the acceptability criteria and cannot be accepted if it does not. Meeting all the acceptability criteria means the claim can be made that the M&S system or result should be accepted to support the intended use without limitations. In case not all acceptability criteria are met, alternative weaker acceptance claims with underlying arguments can be constructed. Such alternative acceptance claims could, for example, provide recommendations regarding conditions or restrictions under which the M&S system or result can still be used (i.e. limit the domain of use); or on modifications that, when implemented, will lead to an unconditionally acceptable M&S system or results for the intended use. Another rationale for alternative acceptance claims is when convincing or sufficient evidence is lacking (e.g. access to data prohibited, or referent system unavailable for testing). In any case, an acceptance recommendation always requires well-structured supporting arguments and evidence for the V&V User/Sponsor to make the right acceptance decision. Depending on the identified M&S use risk, the V&V User/Sponsor can also decide not to take any actions when not all acceptability criteria are met by the M&S system. In that case, the V&V User/Sponsor simply accepts the risks associated with the M&S system use.

4.2.5 V&V Argumentation Approach: Structured Reasoning with Arguments

Developing an acceptance recommendation that meets the V&V User/Sponsor needs usually involves the identification and definition of many interdependent acceptability criteria, particularly for large-scale and complex M&S systems or for M&S-based solutions used in safety–critical, real-world environments. Demonstrating the satisfaction of acceptability criteria requires evidence. Collecting the appropriate evidence is not always simple and straight-forward, or even not always possible due to various practical constraints (e.g. safety, security, costs, schedule). In many cases, the collected evidence comprises a large set of individual items or pieces of evidence that may be provided in different forms or formats, and may originate

from various sources (e.g. historical, experimental data, SME opinion). Moreover, the strength of each item of evidence may vary and the total set of collected evidence may even contain contradicting items of evidence (i.e. counter evidence). The quality of this effort determines the value of an acceptance recommendation for the V&V User/Sponsor. Therefore, the arguments underlying an acceptance recommendation should be developed in a structured manner using a format where the reasoning is traceable, reproducible and explicit. Alternative approaches to implement such reasoning exist and may be incorporated within the GM-VV technical framework to tailor it the specific needs of an M&S organization or domain. An example of such an approach is the V&V goal-claim network approach (Figure 4-5) as developed by the WEAG REVVA consortium and the NATO NSMG-073 Task Group. A V&V goal-claim network is an information and argumentation structure rooted in both goal-oriented requirements engineering and claim-argument-evidence safety engineering principles.

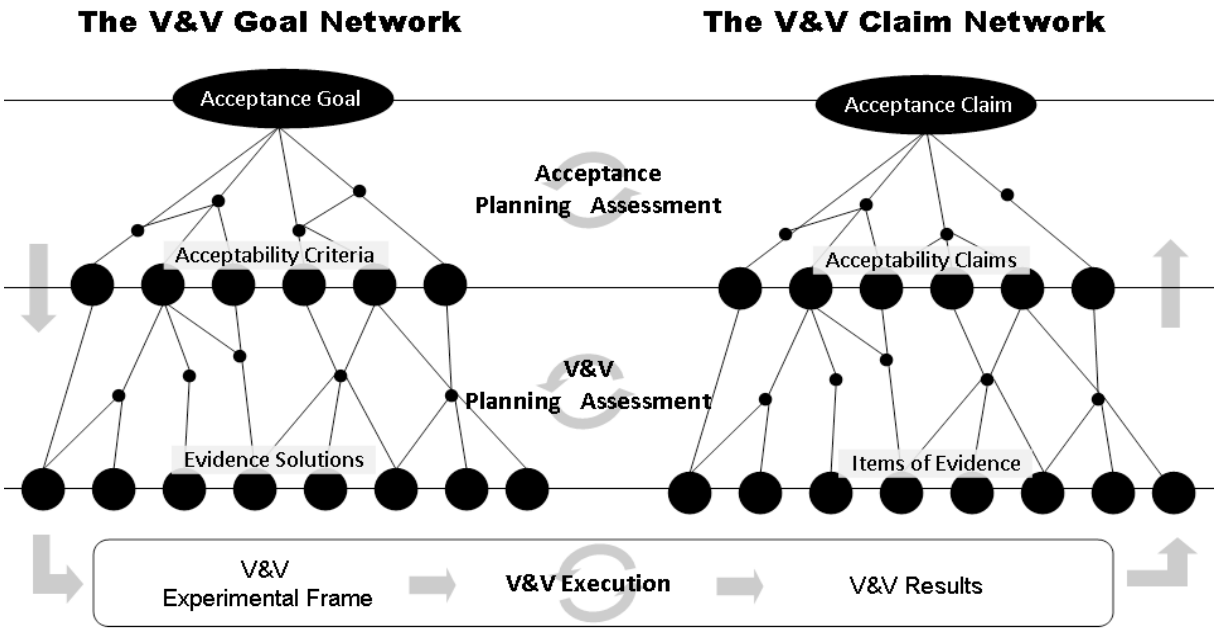

Figure 4-5: V&V Goal – Claim Network.

Figure 4-5 provides an abstract illustration of a V&V goal-claim network. The left part of the goal-claim network is used to derive the acceptability criteria from the acceptance goal; and deriving solutions for collecting evidence to demonstrate that the M&S asset satisfies these criteria as indicated by the top-down arrows (Figure 4-5). The acceptance goal reflects the V&V needs and scope (e.g. simuland, intended use). Evidence solutions include the specification of tests/experiments, referent for the simuland (e.g. expected results, observed real data), 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 system and its results. When implemented, the experimental frame produces the actual V&V results. After a quality assessment (e.g. for errors, reliability, strength), these results can be used as the items of evidence in the right part of the goal-claim network. These items of evidence support the arguments that underpin the acceptability claims. An acceptability claim states whether a related acceptability criterion has been met or not.

Acceptability claims provide the arguments for assessing whether or to what extent the M&S system and its results are acceptable for the intended use. This assessment, as indicated by the bottom-up arrows (Figure 4-5), results in an acceptance claim inside the V&V goal-claim network. As such a V&V goal-claim network encapsulates structures and consolidates all underlying evidence and argumentation necessary

for developing an appropriate and defensible acceptance recommendation. The circular arrows in Figure 4-5 represent the iterative nature of developing a V&V goal-claim network during planning, execution and assessment phases of a V&V effort.

4.2.6 V&V Organizational and Management Approach

In order to facilitate efficient and high quality V&V, the V&V effort inside the V&V world should be executed in a controlled and organized way. The basic premise of the GM-VV is that the acceptance recommendation for an M&S asset is developed and delivered by means of a managed project. Moreover, GM-VV assumes that V&V is conducted by a person, a team of people or a dedicated organization with assigned responsibilities, obligations and functions. Therefore, GM-VV identifies three organizational levels at which V&V efforts can be considered. In order of the lowest to the highest organizational level these levels are:

- **Technical Level**: Concerns the engineering aspects of a V&V effort that are necessary to develop and deliver an acceptance recommendation;
- **Project Level**: Concerns the managerial aspects related to the proper execution of the technical actions of a V&V effort; and
- **Enterprise Level**: Concerns the strategic and enabling aspects to establish, direct and support the execution or business environment for V&V efforts.

The core GM-VV concept on the V&V project level is the concept of a managed project. A V&V project can be viewed as a unique process comprised of coordinated and controlled activities that address: V&V effort planning in terms like cost, timescales and milestones; measuring and checking progress against this planning; and selecting and taking corrective actions when needed. A V&V project could be a separate project alongside the M&S project of which the M&S asset is part, or be an integral part of this M&S project itself (e.g. sub-project, work package). A separate V&V project is particularly relevant in the case when a level of independence must be established between the M&S development and V&V team/organization. On the V&V project level, GM-VV also provides derived concepts such as a V&V plan and report to manage the technical V&V work.

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 life-cycle 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. GM-VV defines two types of enterprise entities:

- **V&V Client**: The person or organization that acquires V&V products or services; and
- **V&V Supplier**: The person or organization that develops and delivers V&V products or services.

A V&V agreement is arranged between a V&V client and V&V supplier to provide products and/or services that meet the V&V client's needs. Both these V&V entities could be organizations (e.g. companies) separate from the organization that develops or acquires M&S or it could be different units (e.g. department, division, group) within a single M&S supplier or client organization. Typically, a separate V&V supplier is an organization that has the provision of independent V&V products and services to external V&V clients as its core business. Though depending on their business model, an M&S supplier or client organization could have their own V&V supplier entity that may provide V&V services and products to internal and external V&V clients alike.

4.2.7 V&V Levels of Independence: Acceptance, Certification and Accreditation

An independent V&V (IV&V) authority is often described as an organization or a person that is employed to conduct V&V, independent of the developer's team or organization. The need for IV&V is mostly driven by:

- Risks and liabilities taken by the V&V User/Sponsor's acceptance decision;
- Level of trust the V&V User/Sponsor has in the M&S developer;
- Authoritative policies and regulations that may demand independent V&V for the M&S intended use; and
- Lack of specialist skills, tools and techniques by user, sponsor or developer to perform V&V.

In this context, the terms "certification" and "accreditation" are often used. Certification is the process of providing a written guarantee that a (M&S) system is acceptable for operational use [4]. Accreditation has two connotations. Accreditation is the official certification that a (M&S) system is acceptable for use for a specific purpose, as used by the US DoD. This meaning of the term of accreditation is the one that is part of the commonly used acronym, VV&A, which stands for Verification, Validation and Accreditation. This acronym has a specific meaning within the US DoD M&S and decision-maker community, since it integrates V&V effort within their formal acceptance decision process.

In practice however, it is highly incumbent upon the V&V User/Sponsor acceptance decision needs and complexity of the M&S system as to which parts and to what extent V&V should be conducted in an independent manner. Therefore, the GM-VV adopts a sliding scale of independence for V&V, which can be selected accordingly to match the V&V needs. The justification and selection of a proper level of independence is supported within GM-VV through the use of the V&V argumentation network. Within this sliding scale for independent V&V, certification and accreditation can be located in the right part of the scale (Figure 4-6).

Figure 4-6: Levels of Independent V&V.

4.2.8 V&V Information and Knowledge Management

V&V of M&S is an information and knowledge intensive effort. In particular, during the V&V of large-scale, distributed or complex M&S applications, care must be taken to preserve or reuse information and knowledge. Therefore, GM-VV applies the memory concept on both the V&V project and enterprise levels. A memory is viewed as a combination of an information and knowledge repository and a community of

practice. The repository is a physical place where information, knowledge objects, and artifacts are stored. The community of practice is composed of the people who interact with those objects to learn, understand context and make decisions.

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. V&V is often an iterative and recurrent process linked to an M&S system's life-cycle, hence V&V products for an M&S system may have different configurations. Therefore, a V&V project memory may also retain records on possible different V&V product configurations. The V&V enterprise memory retains the total body of information and knowledge from past and current V&V projects to sustain and support the cost-effective execution of future V&V projects. Such reusable information could be, for example, M&S technology or domain specific recommended practices, acceptability criteria, V&V goal-claim network design patterns, V&V tools and techniques, or policies and standards. On a more strategic level, a V&V enterprise memory could retain information and knowledge on V&V project costs and maturity as well.

Chapter 5 – GM-VV IMPLEMENTATION FRAMEWORK[1]

5.1 INTRODUCTION

The GM-VV implementation framework translates the GM-VV basic concepts of Chapter 4 into a set of generic V&V building blocks (i.e. components). These may be used to develop a tailored V&V solution that fits the V&V needs of any particular M&S organization, project, application, and technology or problem domain. The implementation framework has three interrelated dimensions: product, process and organization (Figure 5-1). The underlying principle of this framework 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, those 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. Individual needs will drive which V&V products are required.

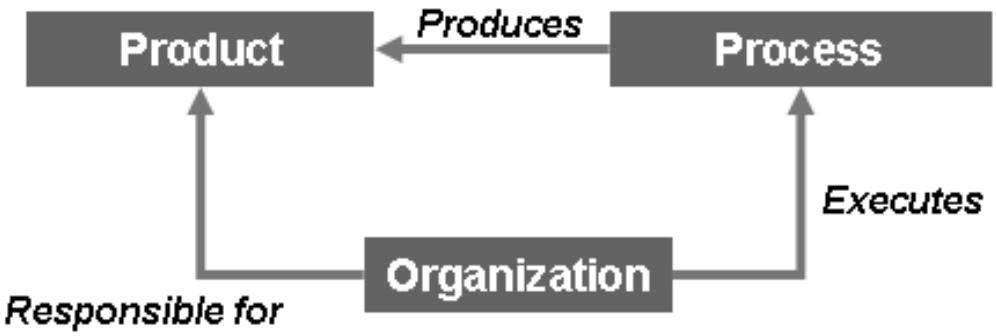

Figure 5-1: GM-VV Implementation Framework Dimensions.

As indicated in Figure 5-1, the GM-VV implementation framework consists of three key dimensions:

- **Products**: The information artifacts that may be delivered, developed or used throughout a V&V effort. These artifacts can have multiple instances, representational and documentation formats. Examples of such tailored documentation formats are the US DoD accreditation plan and report templates, and the V&V plan and report templates.
- **Processes**: The set of activities and tasks that comprise V&V execution as well as those management tasks that increase the efficiency and effectiveness of the V&V effort. These activities and tasks are inspired by the IEEE standard system life-cycle processes model [6] and can be carried out recursively, concurrently, and iteratively.
- **Organization**: The roles played either by people or by organizations in the V&V effort. The roles are defined in terms of responsibilities and obligations. Depending on the M&S organization, project and application domain needs; several roles could be played by separate organizations, separate people in one organization or by a single person.

[1] Parts of this chapter are taken from SISO-GUIDE-001.1-2012, "GM-VV Vol. 1: Introduction and Overview" (Copyright 2012 by Simulation Interoperability Standards Organization – SISO) [1].

The V&V effort culminates in a V&V report that is comprised of the information generated throughout the execution of the V&V and acceptance decision-support process. The following sub-sections provide an overview of the information artifacts, activities and roles that are implemented or produced during this execution. They are ordered according to the GM-VV technical, project and enterprise levels. In this volume only high level descriptions are provided. Detailed descriptions of all components can be found in Vol. 2 [2].

It is important to re-emphasize the tailorable nature of the methodology. GM-VV provides all the elementary information artifacts, activities, tasks and roles to address the most common technical, project and enterprise level aspects of a V&V effort. Depending on the M&S project and organizational needs one could choose not to implement all GM-VV components or one could choose to adjust them accordingly. This is particularly relevant for M&S organizations that already have some project and enterprise level components in place, and only require technical level V&V (intermediate) products, processes and roles to conduct their V&V effort.

5.2 TECHNICAL LEVEL GM-VV INFORMATION ARTIFACTS, ACTIVITIES AND ROLES

This sub-section describes the technical activities performed, the artifacts produced and the roles that are filled during the execution of the V&V effort. These lists are not all inclusive and may be tailored to reflect the needs and constraints of a specific V&V project.

5.2.1 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.
- **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 [9].)
- **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.

5.2.2 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. This process can include the following activities:
  - Verify M&S requirements;
  - Collect, analyze and apply relevant M&S system historical information;
  - Verify and validate the conceptual model;
  - Perform verification on the M&S system design and/or implementation;
  - Verify and validate the data and knowledge sets; and
  - Validate the M&S results.
- **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 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 artifacts into the V&V Report and delivering it to the V&V User/Sponsor, and archiving the information artifacts in appropriate repositories.

5.2.3 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 SMEs, M&S developers and test engineers.

5.3 PROJECT LEVEL GM-VV INFORMATION ARTIFACTS, ACTIVITIES AND ROLES

This sub-section describes the managerial activities performed at project level, the artifacts produced and the accompanying organizational structure. The project level provides a supporting environment that can enhance the effectiveness and efficiency of the technical V&V work. This includes a V&V project memory that facilitates the management and maintenance of the total body of V&V information artifacts produced during a V&V project. These lists are not all inclusive and may be tailored to reflect the needs and constraints of a specific V&V project.

5.3.1 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.

5.3.2 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 parties and roles 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.

5.3.3 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.

5.4 ENTERPRISE LEVEL GM-VV INFORMATION ARTIFACTS, ACTIVITIES AND ROLES

This subsection describes the managerial activities performed at the enterprise level, the artifacts produced and the accompanying organizational structure. The enterprise level provides a supporting environment that can establish a V&V effort and can enhance its effectiveness and efficiency. This includes a V&V enterprise memory that facilitates the management 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 that executes V&V projects.

5.4.1 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).

5.4.2 Enterprise Level Processes

- **Agreement Management**: Establishes and manages the V&V agreement between V&V client and the 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 product(s) meets the enterprise entity quality standards and achieves V&V User/Sponsor satisfaction.

5.4.3 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 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 client side.

Chapter 6 – GM-VV TAILORING PRINCIPLES[1]

6.1 OVERVIEW

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

- **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.
- **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.
- **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.
- **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 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, with V&V project resource variables (e.g. time schedule, budget, V&V personnel skills and infrastructure).

The GM-VV implementation framework provides a set of generic reusable components for each of the categories depicted in Figure 6-1. These components are grouped into three interrelated organizational levels (i.e. enterprise, project and technical) where V&V of M&S.

[1] Parts of this chapter are taken from SISO-GUIDE-001.1-2012, "GM-VV Vol.1: Introduction and Overview" (Copyright 2012 by Simulation Interoperability Standards Organization – SISO) [1] and "GM-VV Vol. 2: Implementation Guide" [2].

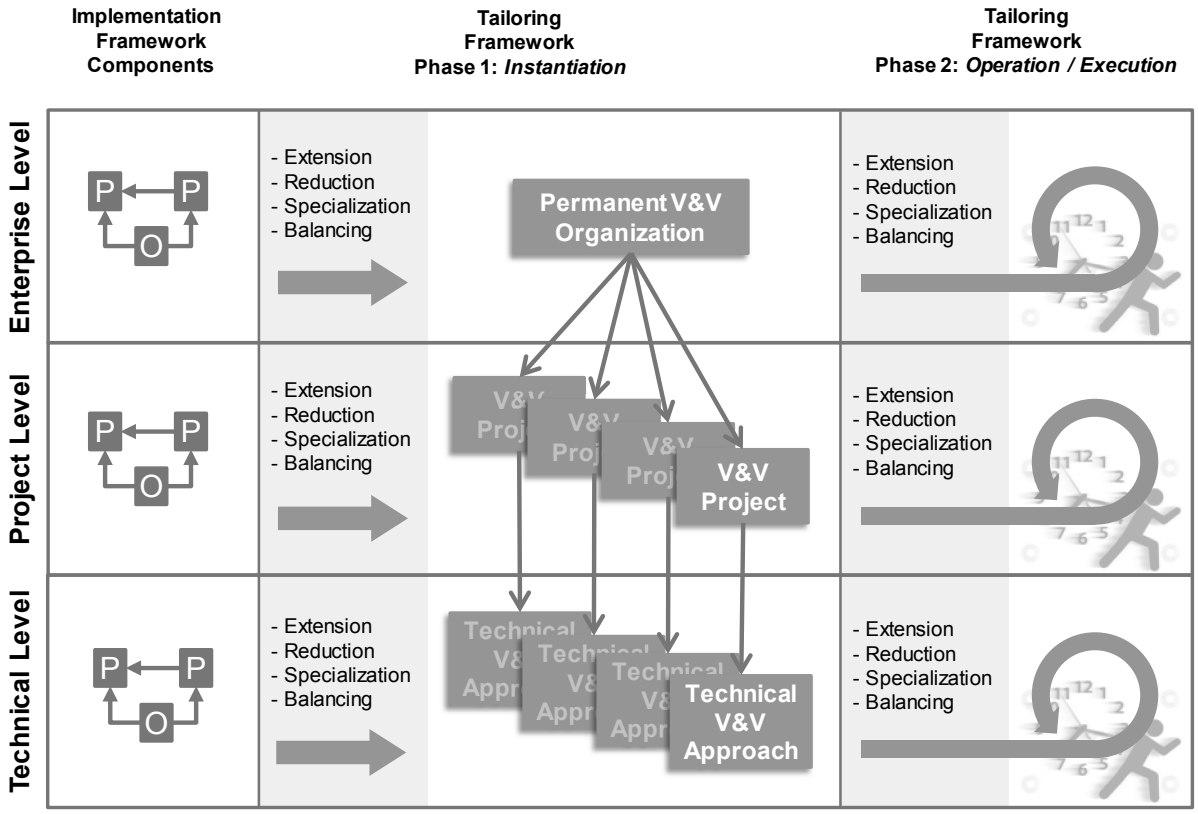

Figure 6-1: GM-VV Implementation and Tailoring Framework Application Overview.

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.

NOTE: The GM-VV implementation framework solely focuses on the V&V supplier perspective. The V&V client and its V&V User/Sponsor role are only identified to describe the involvement in and interaction with the V&V supplier.

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); and
- A M&S/V&V project (e.g. time, budget, scale, complexity, risk, resources).

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 [1].

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 to prioritize the acceptability criteria, allocate specific V&V techniques and tools based on V&V User/Sponsor 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 (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.

6.2 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; and
- Experimental design techniques and methods (DOE), Information management and configuration tools.

A more detailed discussion of such technical V&V practices, tools and techniques is beyond the scope of this document. The interested reader can find references on such technical-oriented V&V practices, tools and techniques in GM-VV Vol. 3 [3]. 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 which is the practical implementation of the GM-VV evidence based and structured reasoning concept introduced in GM-VV Vol. 1 [1]. 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 [18]; 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 [34],[35],[36]. However, it is beyond the scope of this guidance document to give a complete overview of risk-based techniques and methods. The interested reader is referred to the GM-VV Vol. 3 for references on this topic [3]. It must also be noted that a pure risk-based approach to V&V can leave blind spots [34].

6.3 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 [1]. 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 (see GM-VV Vol. 1 for more details on IV&V [1]). 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 a 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 [SISO-REF-039-2013]. 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.

6.4 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.

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 stand-alone 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.

Chapter 7 – CASE STUDIES

7.1 INTRODUCTION

For demonstration and validation of the GM-VV in itself, several possible case studies were identified and evaluated. Two case studies were selected: a relatively small scoped one and a more complex one. Both cases were instrumental and proofed to be vital for the on-going development of the methodology. The cases are briefly introduced in this chapter with the intention to provide insight in the domain and the verification and validation efforts.

All activities were bounded by, as in any real-world case, availability of resources (time, budget, etc.). The first case was identified as the "Flashing lights" case, when the Dutch government instantiated research experiment of handling traffic on a highway at an incident location. The second case was identified as "Heavy weather ship handling". In this second case, the Royal Netherlands Navy started an R&D experiment to investigate the effects of motion on human performance of 'officers of the watch'.

The following paragraphs provide a short impression of both cases. The referred reports provide more in depth details on the technicalities of the problem domain and findings in applying the GM-VV methodology. The overall final conclusion is that the theoretical model of GM-VV is actually performing according to expectation, but future work is needed to address techniques and tools to effectively support further acceptance by the community and implementation.

Notice that the case studies were designed with the primary objective to test the GM-VV. The outcomes of the cases with regard to the simulations being studied as such must therefore be seen as a useful by-product. However where possible, case studies were sought that provided synergetic effects. This was achieved in Case Study 2 where a running experiment was extended by a cooperative effort from the V&V team. In this way, not only was the value of the Heavy Weather experiment enhanced, but to a large extent it also transformed the V&V case study into a real V&V case.

7.2 CASE STUDY 1 "FLASHING LIGHTS"

The "Flashing Lights" case was the first case to test-drive the GM-VV methodology. This case comprised a recently executed test and evaluation study for Dutch Ministry of Transport, Public Works and Water Management. For this study, the Netherlands Organisation for Applied Scientific Research TNO driving simulator was used as a testbed for the investigation of the effects of a new traffic accident signalling strategy.

The workshop sessions of the "Flashing Lights" case were conducted by a team consisting of GM-VV experts from MSG-073 countries while working together with TNO driving simulator experts and the M&S customer representatives. The findings of this case study were published and presented in a Final Report [42] to the NMSG, published in 2010, and secondly presented in a paper [43] and presentation of the SISO Simulation Interoperability Workshop held in Spring 2010.

7.2.1 Real-World Problem: Reduction of Traffic Jams

Within the densely populated country of the Netherlands, traffic jams are becoming an ever more serious problem with significant economic consequences. The Dutch Traffic Information Centre estimated the total cost of traffic jams (in the Netherlands) in 2007 at over a billion Euros. Nowadays, traffic jams are increasing in length, frequency and duration. Traffic density in the Netherlands is so high that when accidents happen on one of the main highways, even other parts of the highway infrastructure is severely implicated. There is strong need in the Netherlands for short-term solutions to reduce traffic jams and

improve the efficiency of the current Dutch high way system. For this purpose, the implementing body of the Dutch Ministry of Transport, Public Works and Water Management, called Rijkswaterstaat (RWS) initiated the FileProof research program. This program focuses on research into 60 possible counter measures for traffic jams that can be implemented fairly quickly into the Dutch highway system.

One of these possible counter measures is the directive "Flashing Lights Off on Accident Site". However, before implementing this directive RWS wants to be sure that the directive successfully reduces traffic jams around accident sites (both day and night) and do not impose unacceptable risks for the safety of rescue workers on site. One possible way to solve this problem statement is to implement a new directive for emergency services and workers at incident sites. If these objectives can be assured then the directive is considered to be an acceptable solution.

The question about the validity of the simulator supported experiment results, i.e. M&S results, still remained open. A minimal confidence level is required on the validity of the experiments to support the claim that, whatever the outcome, the results are indeed acceptable to make a valid conclusion. This depends both on the collected evidence of driving simulator itself and how the simulator has been utilized in the experimental set-up.

7.2.2 Product World: Driving Simulator

The TNO driving simulator is a six Degree Of Freedom (6DOF) moving base simulator, which has proven to be an acceptable research tool for investigating human driver behaviour in many other projects. However, the Flashing lights scope has never been investigated before, hence were never simulated in the simulator. Therefore, TNO did conduct a feasibility study to determine how flashing lights can be simulated as convincingly realistic as possible. The solution TNO finally implemented comprised a flashing light model and environmental light effects in the 3D image generator software of the visual system. This visual set-up has been combined with an additional projector to simulate environmental light conditions inside the mock-up (compensating for screen projection artifacts). The 3D images of the flashing lights and the live mock-up light conditions were synchronized. However proving the possibility to simulate flashing lights in the existing driving simulator doesn't directly imply the simulator to be acceptable for the testing and evaluating the new flashing lights directive. Acceptable in this sense means that the driving simulator should be realistic enough to induce effects on human driving behaviour due to flashing lights that are similar or sufficiently similar to the one of a human in the real-world environment under the same conditions.

Figure 7-1: The TNO Driving Simulator.

7.2.3 First Conclusions

As this experiment was the first real attempt to apply the GM-VV methodology, the findings while applying theory in practice were meticulously recorded and used for later evaluation. As a result of this exercise the present set of GM-VV documents went through a major restructuring process which finally led to a change in the Product Nomination for a SISO Standard. This process also led to a reduced document set as duplications between documents were removed. It was also found that more case studies were necessary to

fully fine tune the methodology for practical application in a wider community and support by automated tools is a mandatory pre-requisite.

7.3 CASE STUDY 2 "HEAVY WEATHER SHIP HANDLING"

The second case study was chosen and designed around a mutual understanding on the value of a VV&A effort for the design and outcomes of an M&S-based experiment for the Royal Dutch Navy. The team that designed the experiment covered specialists from the human factors domain through simulation engineers from various organisations involved and the VV&A experts. For this experiment a full motion research simulator, called DESDEMONA, was equipped and prepared to facilitate the conditions required by the experiment.

The proposition of the acceptance goal, the GM-VV wording of the actual answer to the main question, was formulated as:

> "*The results of the experiment are useful in the determination of the significance of physical motion in simulation of high sea state for training and doctrine evaluation*".

This proposition ultimately needs to be demonstrated with evidence collected while preparing for the experiment (verification and validation of the model used) and running the experiment itself (verification and validation of the experiment).

The outcomes of this case study were publicized as a paper [44] and several presentations in the SISO Simulation Interoperability Workshop and the I/ITSEC and ITEC conference[1].

7.3.1 Real-World Problem: Training Heavy Weather

In order to be able to operate effectively and safely, the Royal Dutch Navy needs well educated and trained personnel and appropriate doctrine. Currently no specific training for Heavy Weather Ship Handling (HWSH) is available. Learning to handle ships in heavy weather is learned on the job in real-world situations under guidance of experienced officers. The navy has a lot of practical experience in these real-world situations, but training and doctrine evaluation in a land-based simulation would be safer, cost effective and time saving. Currently the navy uses a Full Mission Bridge Simulator (FMBS) in educational programs, but that simulator is fixed based. In a fixed-based simulator many of the necessary procedures can be practiced, but how well can one perform the same procedures during real world heavy weather situations?

The Defence Materiel Organisation (DMO) is responsible for all materiel within the defence organization: from procurement and major maintenance to disposal. The DMO now faces the question that if the navy wants to offer HWSH as part of their educational program and as a doctrine evaluation aid, is the FMBS sufficient? Part of that question deals with the issue of whether a motion base is necessary for a HWSH simulator?

[1] 2011 Euro SIW, 2011 Fall SIW, 2011 I/ITSEC, 2012 ITEC.

Figure 7-2: Handling Ships in Heavy Weather.

7.3.2 Product World: Heavy Weather Simulator

To answer the question of DMO, TNO designed an experiment to determine training effects due to motion simulation via an in-simulator comparison approach. In this experimental design two groups of test subjects were used, one that is trained with motion and one without motion. All test subjects followed the same test sequence consisting of a habituation period followed by a pre-test, the training and a post-test. Both groups did the habitation and testing in the simulator with motion simulation. The scenario consisted of a number of tasks that also during heavy weather may still need to be performed (following a ship, changing course, making a 180 turn.) During the experiment subjective, Subject-Matter Expert (SME), and objective measurements were taken to assess the test subject task performance.

Figure 7-3: The Full Motion Research Simulator DESDEMONA.

Based on the experimental design a Conceptual Model (CM) for the M&S environment has been constructed in cooperation with all parties together with DMO and navy officers with relevant experience. The CM encompasses the ship, its environment, other traffic and tasks to be executed by the ship's crew. The mine hunter was chosen for this experiment because of the size of the ship: heavy weather has a large impact on the ship's motion and handling. A more practical reason is that a simulation model of the ship dynamics is available. In Desdemona only one person can be seated. It was chosen to use the officer of the watch as test subject, but place them in the position of the helmsman. The simulated sea state is 4-6 in blue water environment.

7.3.3 First Conclusions

Based on the case-study as executed, one can conclude that the GM-VV contains all necessary high level ingredients for a rigorous approach to VV&A. This abstract methodology, however, needs to instantiated and the instantiated VV&A method needs tailoring in order to fit to the needs of the VV&A project at hand. Tailoring has been applied in several ways: during instantiation elements are added or removed from the default GM-VV and during the execution of the processes specialization has been applied. One of the main technical products, the V&V Goal-Claim Network, is built with a continuous tailoring by balancing results, risks, cost and time. Defining the V&V Experimental Frame also required extensive balancing. The GM-VV tailoring principles worked well and resulted in a practical application of the abstractly defined GM-VV.

Some parts of the results of the case-study may be re-usable for other VV&A projects dealing with VV&A of training simulation or experimentation. Examples are the specialization of the processes and parts of the VV&A Goal-Claim Network. Besides finishing the case-study, reusable information and lessons-learned from this study have been used to improve the GM-VV implementation guide (Vol. 2).

7.4 CONCLUSIONS AND RECOMMENDATIONS

Both case studies brought up a number of methodological issues, textual issues related to the documents, as well as certain overall concerns about the GM-VV document set available at time of execution. These findings were addressed in new releases of the document set before the SISO balloting took/takes place in 2012. One issue that needs to be addressed is the lack of domain specific automatic tool support (i.e. case tool). The execution of a V&V process creates large amounts of data that needs to be collected, structured and maintained in the course of the process. The relations between the data need to be recorded and such a task needs automated tool support that is currently missing in the field (see Chapter 8). Using simple office applications as is often done is more error prone and simply not doable for larger project.

Chapter 8 – NATIONAL ACHIEVEMENTS BY USE OF GM-VV

8.1 EXPERIENCES FROM APPLYING GM-VV IN GERMANY

8.1.1 Preface

The following three case studies summarize some experiences gained from application of some essential concepts of GM-VV in different simulation projects. All three projects have been initiated by institutions of the German Armed Forces acting as project sponsor and as user. In each case, companies specialized in the respective field (szenaris GmbH, ESG GmbH) had been contracted for the design and development of the simulation models, and an independent institution (ITIS) was assigned to develop V&V plans, to support M&S documentation, and to support V&V-activities in cooperation with sponsor and developers. In two of these projects virtual simulations were implemented as training platforms while in the third project a constructive simulation environment had to be developed.

8.1.2 Case Study: Usability and Efficiency of the Proposed Documentation and Tailoring Concepts (as Part of the Project "Pioneers Ribbon/Floating Bridge")

In context of the development of a team training simulator for coordinating actions that have to be taken to assemble different parts of a ribbon/floating bridge for crossing a river, major experiences have been gained from application of a project and model documentation process according to national guidelines adapted to GM-VV requirements. According to general process, product, role and tailoring guidelines, the project was processed cooperatively by a team including representatives of the project sponsor (BWB), M&S developers (szenaris GmbH), and an independent V&V-agent (ITIS). While the M&S developers were designing and implementing the simulation model according to the sponsor needs, they had to provide process and model documentation for each model development phase in accordance with these guidelines. In this case study, ITIS provided guideline coaching and evaluated the quality of model documentation in form and content.

Activities which had to be performed regarding GM-VV and adapted national guidelines:

- Coaching the application of the process and documentation guideline;
- Supporting the tailoring of M&S process and documentation activities;
- Sample application of V&V techniques for quality control and for effort or cost estimation of V&V-activities and documentation; and
- Gathering feedback from sponsor and developers regarding the general documentation structures and guideline concept.

Major findings and lessons learned:

- Basically, the proposed documentation structures and guideline was perceived as time-consuming but also as beneficial by the M&S developer. After this cause study, the company decided to apply this guideline in other projects on its own initiative.
- Standardized formalization languages, methods, and tools are indispensable for model documentation.
- IPR and know-how protection has been seen as a critical issue related to model documentation and (independent) model V&V.
- Costs and efforts for model documentation and model V&V should be calculated as early as possible along with tailoring decisions. As total project budget, as well as quality assurance, will significantly depend on tailoring decisions, these should be accepted and well documented by all contributing parties.

Figure 8-1: Pioneers Ribbon/Floating Bridge.

8.1.3 Case Study: Efforts, Efficiency and Effectiveness of Performing V&V-Activities (as Part of the Project "Robot Movement Simulator")

While the first case study was focused on the aspects like usability, efforts for and efficiency of the proposed documentation guideline and tailoring concept, the goal of this case study was to investigate acceptance, feasibility and involved efforts/costs for development and application of a V&V-plan in the context of the robot simulator project. For budgetary reason, the scope of this case study was limited, or tailored to a sub-set of the model development phases, and to three of thirteen pre-defined application scenarios.

Major activities performed in context of this case study were:

- Supporting the required model documentation (e.g. regarding completeness, consistency);
- Development of a V&V-plan as a result of static tailoring based on the project requirements as well as based on case study budget and in cooperation with sponsor, developer and V&V-agent;
- Cooperative decisions regarding additional dynamic tailoring actions (together with the sponsor and the developer);
- Execution of V&V activities and documentation of V&V results according to the V&V plan; and
- Sample application of different V&V techniques to investigate their effectiveness.

Major findings and lessons learned are:

- Time and efforts required for the initial application of the documentation guideline is extremely high (especially for the M&S developer who rarely documents their work). However, once such a guideline is properly introduced to the M&S development team, documentation time/costs for further projects can be significantly reduced.

- A documentation guideline and structures in the form of flexible, “living” guidelines and documents would increase efficiency. Consequently, two studies for development of electronic guidelines were initiated and conducted.
- The “V&V Triangle” concept can be applied for process management tasks (such as planning, organizing, and monitoring the V&V effort) as well as for technical tasks (like analyzing, evaluating, reviewing, and testing model elements).
- Both static tailoring (at the beginning of an M&S project) and dynamic tailoring (adaptation during the M&S development process) are indispensable.
- Regarding IPR and know-how protection, the following concept was proposed:

  1) The independent V&V agent specifies detailed V&V requirements, examination criteria and measures and contents of V&V reports for model work products subject of V&V;

  2) An internal inspector on the M&S developer side (e.g. from the quality assurance department) performs the specified examination according to the V&V requirements, and documents the V&V process and its results; and

  3) The V&V agent evaluates correctness and validity of the model, simulation and data based on the created examination protocol of the internal inspector.

Figure 8-2: Robot Movement Simulator.

8.1.4 Case Study: V&V of Safety-Critical Constructive Simulation Model (as Part of the Project “Guidelines for Platoon Commanders”)

Goal of this simulation project was to be able to analyze different guideline options for platoon Commanders, how to lead his or her platoon in different and safety-critical scenarios. One of the project requirements

defined a limited time frame for simulation model development and availability of the requested simulation results. Beside this time limitation, quality of the modeling process and its results should be evaluated through V&V. Therefore, as a case study, ITIS as an independent V&V agent was assigned to guide or support some V&V activities concurrently with simulation model development.

Figure 8-3: Platoon Commanders.

Major activities performed by the V&V agent included:

- Supporting the preparation of the model documents especially checking completeness and consistency);
- Tailoring of M&S activities and documentation (in cooperation with the project sponsor and the M&S developer);
- Preparation of the V&V plan (in cooperation with the project sponsor and the M&S developer);
- Selecting V&V techniques and conducting V&V activities according to the V&V plan; and
- Documentation and demonstration of the V&V results.

Major findings and lessons learned have been:

- The generic tailoring concept of GM-VV was applied and has confirmed its usability as a general framework. In total, applying static and dynamic tailoring actions according to the project requirements and constraints, 8 versions of the V&V plan were developed. The first version was prepared based on static tailoring, all the others were results of dynamic tailoring needs.

- Because of some vague Sponsor Need specifications and a large number of uncertainties (e.g. as an extensive involvement of Subject-Matter Experts (SMEs) was indispensable), the focus of V&V was directed towards an evaluation of the Structured Problem Description (SPD) and the Conceptual Model (CM) development. As a consequence of V&V of work products and documentation of these two development phases, and based on intensive discussions between the V&V agent, developer and sponsor, 9 versions of SPD and 10 versions of CM had to be developed.
- A combination of different V&V techniques (e.g. combination of Inspections, Face Validation, and Visualization/Animation in this case study) was very useful and demonstrated to be very effective.

Time and efforts required for execution of V&V techniques and interpretation of V&V results has to be calculated at the begin of a project (static tailoring based on project constraints and requirements). Experience showed that just time scheduling requirements and availabilities of team members (roles), has to be considered as a limiting factor for processing certain V&V activities. This experience indicated the need for dynamic tailoring actions.

8.2 EXPERIENCES FROM APPLYING GM-VV IN SWEDEN

8.2.1 Case Study: Air-to-Air Missile

This case study is based on [37] reporting on a case where the GM-VV has been tested within the Swedish Defence Research Agency (FOI) on an unclassified model of a generic air-to-air missile. The intended use of this missile model was training of fighter pilots in Beyond-Visual-Range (BVR) scenarios, thus aimed at being *Suitable for Air Combat Training*.

The exercise involved a team of M&S developers using requirements specifications on this generic model coming from project sponsor organizations such as the Swedish Armed Forces and industrial partners. The GM-VV has been used to refine and elaborate on these requirements specifications to derive an acceptance recommendation for the intended use of the model. Three top requirements on the model have been selected to test and apply the GM-VV (Figure 8-4):

- **Sufficient Realism**: Choices of physical modelling in terms of structure and sub models reflecting the vital components of a BVR missile.
- **Sufficient Transparency**: Information regarding the interaction between the missile and all surrounding objects (target, environment, etc.) to be displayed to the pilot during flight but also for post mission review.
- **Be Executable in a Simulator**: Use of MERLIN, a component based simulation framework for soft real-time simulations of weapon platforms, to run the missile model.

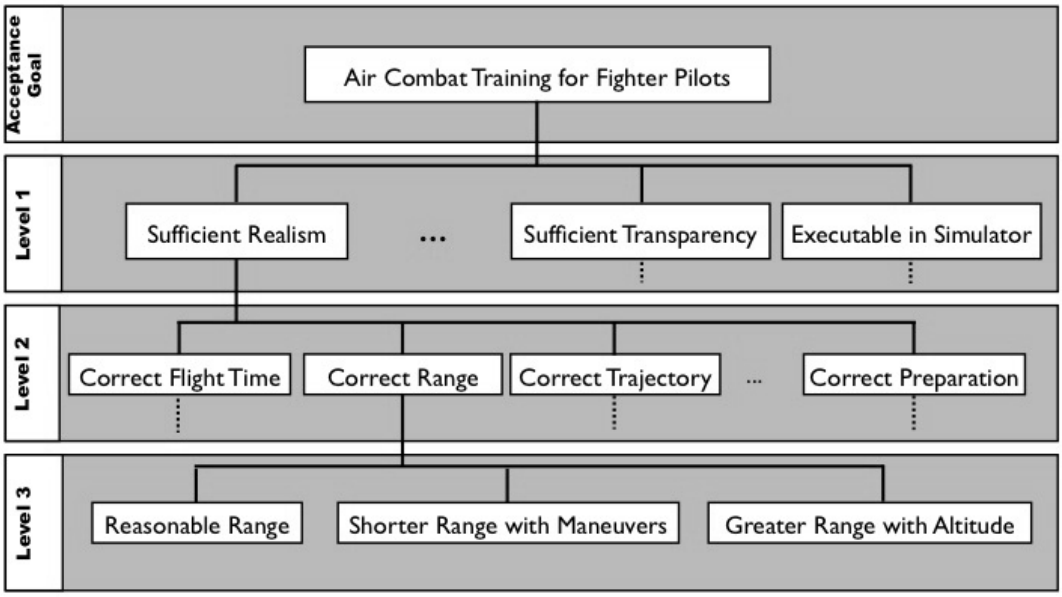

Figure 8-4: Requirements Breakdown for the Air-to-Air Missile Model.

Objectives of the exercise regarding the GM-VV:

- Test the applicability of the methodology;
- Coach the application of the GM-VV process;
- Support the development of the Goal-Claim Networks;
- Support the tailoring of M&S process and documentation activities; and
- Gather feedback from M&S developers regarding utility and benefits of using the GM-VV, highlighting particular aspects of the methodology being more relevant/useful as well as ones that are less relevant/useful that need be improved.

Major findings and lessons learned:

- GM-VV is a promising method for the validation of missile models, and should also be suitable for other applications. A strength of the method is the clear link to the application and targets with the model.
- With a structured V&V methodology created, a documented and transparent chain of evidence between the declared objective of the model and the assertion that the model lives up to the goal.
- The importance of a thorough requirements definition and formulation of the intended use of the model has been clarified in the work. In the reported example it has been found that a simpler model of the missile, could have had fulfilled the use area so as described herein.
- The work carried out has also further demonstrated the utility of a close dialogue between V&V implementers, M&S developers and users.

8.3 EXPERIENCES FROM APPLYING GM-VV IN THE NETHERLANDS

8.3.1 Case Study: Distributed Air Operation Mission Training Environment

This example is based on [38] and [39]. In order to be able to operate effectively and safely, the Royal Netherlands Air-Force (RNLAF) Air Operation Control Station (AOCS) needs fighter controllers that are

familiarized with F-16 cockpit operations. Until recently, fighter controllers were trained for this purpose by several familiarization flights in the RNAF F-16B dual-seat aircraft. For economic reasons, the RNLAF has phased out all its F-16B aircraft. Therefore, AOCS has to find alternatives to continue this type of fighter controller training. A simulation-based training system could provide the fighter controller a cost-effective and safe learning environment in which fighter controllers can experience F-16 flight operations in realistic mission scenarios. To support the concept development and specification phase of such future simulation training environment, a prototype was developed by the Dutch National Aerospace Laboratory NLR. This prototype integrates NLR's four existing fixed-based F-16 flight simulators, a constructive simulation that provides computer generated air threats, and two real-life and NATO classified fighter controller working stations (MASE) into a single distributed air operation mission training environment. Interoperability between all simulation assets was accomplished through DIS.

A V&V study was requested to assess the utility and validity of this training simulation concept and its underlying technology for intended use of AOCS. Based on the acceptance recommendations of this V&V study AOCS would take decisions regarding the acquisition process of a new alternative training environment (e.g. go/no-go decision for an M&S system or M&S requirements refinements). The GM-VV is the recommended standard for V&V within the Dutch MoD. Therefore this methodology was selected for this study. Since AOCS didn't have the GM-VV knowledge and expertise they contracted (i.e. through the GM-VV recommended V&V agreement) the Dutch V&V service supplier organization Q-tility to perform the V&V. As a V&V User/Sponsor AOCS was actively involved in the V&V work (e.g. review of the V&V argumentation structure, V&V plan approval and SME provision in the V&V execution phase) and was kept up to date on the V&V progress by Q-tility though regular V&V progress reports.

Figure 8-5: Distributed Air Operation Mission Training Environment Architecture.

Objectives of the exercise regarding the GM-VV:

- Evaluate the utility of the GM-VV project and technical level components for the V&V of (LVC) distributed simulation applications;
- Establish a tailored instance of GM-VV in the form of a reusable V&V life-cycle model by applying the GM-VV tailoring framework Phase 1: instantiation [2];
- Evaluate and refine the yEd tool for V&V argumentation structure and standard office tools (e.g. MS-Word, MS-Excel, MS-Project and MS-Sharepoint) to support the GM-VV process activities, document and manage the GM-VV information artifacts; and

- Develop an initial basis for a M&S risk-analysis and reporting approach that could be applied as future concrete technique for "tailoring by balancing" in the GM-VV tailoring framework Phase 2: optimization [2].

Major findings and lessons learned:

- The GM-VV project and technical level components showed sufficient utility for a satisfactory V&V of this (LVC) distributed simulation application.
- The yEd tool and the standard office application based GM-VV support tools showed to be effective and efficient for this V&V study.
- The V&V of the classified simulation application MASE required additional V&V planning, time and resources to complete the V&V study compared to the non-classified simulation applications. Furthermore, V&V configuration and information management process required more attention, effort and more formal implementation.

8.3.2 Case Study: Public Order Management Serious Game

This example is based on [40]. TNO examined how Commanders can learn to maintain public order in their area of operations. Serious gaming proves to be an effective and efficient learning tool. Q-tility has performed an explorative V&V study to the added value of a demonstrator Public Order Management (POM) serious game. The study results show its added value as well as extensions to the current game.

One of the POM game users is the Royal Netherlands Marechaussee (KMar). The game can potentially be used for a number of training objectives. With V&V the KMar instructors want to find for what objectives the game is already suited, and what needs to be adapted in order for the game to have utility for the full set of training objectives.

The added value of Q-tility V&V approach is that it takes more than just the technical game aspects into account: they also examine and give advice on the required personnel, effective and efficient use of a game in combination with other available training methods and even gaming relevant policies that can enhance the added value of the game.

Figure 8-6: Public Order Management Serious Game.

Objectives of the exercise regarding the GM-VV:

- The KMar trainers and various subject matter experts hired by Q-tility derived the acceptance criteria from the main goal: the game must ensure that training objectives are achieved more efficiently and effectively;
- Further define templates for GM-VV documents;
- The V&V tests consisted of two full training sessions, 4 days in total, in which KMar personnel used the POM game as they intend to use; and
- V&V techniques included interviews, observations, 360° assessment, and hardware/software inspections.

Major findings and lessons learned:

- The V&V results 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 KMar has started implementing changes to allow for efficient and effective use of the POM game.

Chapter 9 – GM-VV NEEDS FOR TOOLS

9.1 OVERVIEW, CURRENT SITUATION AND RECOMMENDATIONS

The case studies represented in the previous paragraph identified a need for dedicated tools that will support performing VV&A activities. Several issues need to be supported; predominantly the large amount of data being collected and maintained during a V&V activity is driving this requirement. The other issue to cover is to be able to enforce a well-structured and formalized approach in data collection. The subsequent need to provide an infrastructure to document, maintain, re-asses and support version control the evidence as well as the process of building the V&V argumentation was recognized at a very early stage of the project. First efforts in this field were made within REVVA1 in 2002, which generated a list of available tools that might support the V&V process. The conclusion after completion of this effort was that hardly any tools existed, a situation that unfortunately hasn't much improved since.

The US DoD MS&CO, the successor of US DoD DMSO, recently developed a standard document template form (Military Standard 3022 [30]). These templates prescribe a common documentation format. This standard contains a set of four documents that subsequently cover the Accreditation Plan, the V&V Plan, the V&V Report, and the Accreditation Report. The US Navy M&S Office (NMSO) developed a DoD VV&A Documentation Tool (DVDT) to automate the set of MIL-STD-3022 templates.

MSG-073 product GM-VV is based on readily available standard engineering approaches however differs in terms of collecting evidence and providing proof of a sound simulation solution with regard to the 'intended use'. The requirement for automated V&V support is driven by V&V specific needs which led to investigating approaches within the security and safety world. These communities have to deal with the same problem as the V&V community in dealing with risk. The Goal Structured Notation (GSN) and Claim Argument Evidence (CAE) structures utilized in these communities seems to have a close fit the VV&A needs. One company, Adelard, developed the Assurance and Safety Case Environment (ASCEtm), in which the needed formalism is, however, lacking. Similar approaches are being under development within the academic world, however with little success so far. In daily practice standard MS Office products are generally used for documentation of V&V activities. Requirements management tools like DOORS or RequisitePro may have been used as an alternative.

VV&A for simulations recently has become more prominently visible. To make a real breakthrough, however, the V&V process needs more efficient tools to proof its real value. Being supported by better and more automated tools would surely help to make VV&A not only more efficient and effective but also lower the financial threshold for investing in V&V activities. NATO should therefore invest in the promotion of VV&A and challenge industry to invest in V&V support by respective CASE-tools.

Chapter 10 – CONCLUSIONS AND RECOMMENDATIONS

The MSG-073 has successfully completed its TOR as it was approved in 2009. The GM-VV series of standards is the first standardization effort completed in SISO with the support of the NMSG.

This final report is only shortly describing the methodology: the description provided is better described in the 3 SISO documents. Information reproduced from these documents has SISO copyrights: SISO kindly granted permission to reproduce a part of them for this report. Obviously all NATO members and partners are freely allowed to download the 3 documents from the SISO website (http://www.sisostds.org). This standardization effort was the main part of the activities of MSG-073 and it was hopefully completed in November 2013. The GM-VV description was already included in the current version of the NATO M&S Standards Profile [31] and has been recently updated for the publication of a new version (Version C).

One objective of the MSG-073 was the dissemination of the GM-VV concepts and methodology: it has been achieved by numerous papers, talks and tutorials that were given by MSG-073 members during diverse conferences (including NATO Symposia), SISO workshops and important M&S events like the ITEC and IITSEC. References on recent GM-VV publications may be found in the list of references of this final report. This tutoring activity will be complemented by a Lecture Series that will take place in 2014 (MSG-123). Members of the MSG-073 and contributing nations realize that this effort has to be maintained and they are ready to continue the effort under adequate formats such as workshops, specialist team meetings, etc.

As the V&V activity is complex and painful, there are still a lot of aspects to be explored or improved. Then the MSG-073 Nations will propose a new NMSG activity on the risk identification and management in using M&S systems. NATO Nations and Partners are invited to participate in this new NMSG activity.

The GM-VV may appear as very theoretical but the methodology was developed and matured using experiences. Some use cases are reported in this report. More details could be found in references of published documents. One of the outputs of past experiences was the need for developing specific tools to support the use of GM-VV: people are using existing tools, which are more or less fitted to the activity, but there is a real need to develop better adapted tools. Despite this was not listed as an objective of MSG-073, this question was treated by the group without any success. Establishing specification for GM-VV tooling does not appear difficult but it was not done for a lack of resources during the MSG-073 time life.

Nations are invited to report on future uses they will have on GM-VV taking profit of future NMSG activities. Experience will allow the methodology to evolve and improve. Concerning the standardization aspect, standards are not built one time and forever. Then there is a need to monitor uses of the methodology, lessons learned from future uses to identify needed update to the first version of the GM-VV. Support for the set of GM-VV documents will be done via SISO. A SISO Product Support Group (PSG) has been established in 2013 for the GM-VV. It is recommended that nations mandate representatives to the SISO PSG to ensure that the methodology stay up-to-date and evolve according to the state-of-the-art.

Chapter 11 – REFERENCES

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Annex A – TAP/TOR

TECHNICAL ACTIVITY PROPOSAL (TAP)

ACTIVITY	**Task Group**	**Generic Methodology for Verification and Validation of Models, Simulations and Data**											TBA	
Activity REF. Number	**MSG-073/RTG-043**												04/2009 (IS)	
PRINCIPAL MILITARY REQUIREMENTS		1	2	3	4	5				UU			03/2012	
MILITARY FUNCTIONS		1	4	9	10	11	12	13	14				(9)	(9) (9)
PANEL AND COORDINATION		MSG											(11)	
LOCATION AND DATES		Multiple											P-I	
PUBLICATION DATA		EN and TR						2012		150				
KEYWORDS	M&S	Data					VV&A			Interoperability				
Re-use														

BACKGROUND AND JUSTIFICATION (RELEVANCE TO NATO)

The general issue of Verification and Validation (V&V) and Acceptance (VV&A) of Models, Simulations, and Data has been addressed in many working groups inside and outside NATO. While there is a general consensus on the importance of this topic, there are few international standards on VV&A. With the start of important NATO training projects like the ACT Snow Leopard, Nations will have the opportunity of contributing to the supporting simulation systems. The application of M&S, such as within the training domain, brings an inherent risk associated with the danger of using erroneous or unsuitable models and simulation results. Verification and Validation (V&V) of models and simulations are intended to ensure that only correct and suitable results are used thereby facilitating risk management. There is a need to agree on a generic methodology to validate models, simulations and data to be used in future NATO and national projects. A neutral and consensus-agreed VV&A guidance document shall be proposed to NATO.

OBJECTIVE(S)

- To finalize the work on a VV&A document set under development by the SISO GM-VV Product Development Group.
- To guide the proposed document set through the formal SISO standardization process.
- To participate in the review, comment and balloting efforts for these new SISO standards.
- To assemble confidence in and fine-tune the methodology on the basis of 'real' case studies.
- To provide education and training based on a documentation set for dissemination.

TOPICS TO BE COVERED

Main outputs of the TG will be finalized under 3 SISO "guidance" documents: the "Handbook": a user's manual, the "Reference manual"; which will document the underlying concepts of the methodology, and the "Recommended Practice Guide" which provides specific guidance with regards to the selection and use of techniques.

DELIVERABLE AND/OR END PRODUCT

The final technical report published under a RTO reference will be a short introduction to the 3 SISO guidance documents and recommendations for their specific use in NATO.

TECHNICAL TEAM LEADER AND LEAD NATION

France will chair the Task Group.

NATIONS WILLING TO PARTICIPATE

Participating Nations include Canada, Denmark, France, Netherlands, and Sweden. Other NATO and Partner Nations are kindly invited to join the Task Group.

NATIONAL AND/OR NATO RESOURCES NEEDED

Input to and participation in the meetings including travel funds (1 – 2 specialists per Nation/NATO body).

RTA RESOURCES NEEDED (E.G. CONSULTANT FUNDING)

Electronic publication. One practical case for experimentation of the methodology could be proposed the last year of this activity.

TERMS OF REFERENCE (TOR)

ORIGIN

Background

The general issue of Verification and Validation (V&V) and Acceptance[1] (VV&A) of Models, Simulations, and Data has been addressed in many working groups. While there is a general consensus on the importance of this topic, there are few international standards on VV&A and they are targeted on simulation interoperability within distributed systems of simulation (federations), and related to both DIS and HLA standards (IEEE 1278.4 and 1516.4). NATO has been supportive to the IEEE HLA VV&A efforts under two Task Groups (MSG-019 and MSG-054).

VV&A of Models and Simulation (M&S) composing distributed systems are supported by national processes, methodology and tools (like the US VV&A Recommended Practice Guidance, RPG), but there is clearly a lack of **internationally recognized** standards on this general topic. As early as 2002, an European consortium was created to address this issue under the Western European Armament Group (WEAG) umbrella: the REVVA (Reference project for VV&A) project was born. In its final composition, this consortium was composed from 5 NATO Member/Partner Nations (Canada, Denmark, France, Netherlands and Sweden) and has started a standardization effort in the context of SISO (the Simulation Interoperability Standards Organization). Unfortunately the REVVA contract ends in 2008 and the consortium will have to be disbanded before the standardization effort is finalized as WEAG is no longer existing as a parent organization.

Since all Nations contributing to the REVVA efforts are represented in the NATO M&S Group (NMSG) it seemed natural that the NMSG take the lead on supervising the corresponding V&V effort currently under process in SISO. This will be the opportunity to welcome additional nations to support this effort. This is also clearly in consistency with the NMSG standardization mission and its cooperation with SISO.

Justification (Relevance to NATO)

Credibility and validity are critical to the effective and appropriate use of models and simulations (M&S) whether used independently or combined in federations. First VV&A efforts were the responsibility of former TGs of the NMSG with a well-targeted focus on federation of simulations. With the start of important NATO training projects like Snow Leopard, Nations have the opportunity of contributing to the supporting simulation systems. There is a need to agree on a generic methodology to validate models, simulations and data to be used in future NATO and national projects. A neutral and consensus-agreed guidance document shall be proposed to NATO.

Military Benefits

Increasingly, M&S is being exploited as an enabling technology to support tactical, operational and strategic objectives within the military domain. The use of M&S provides those within the military domain with a powerful and resource-efficient capability for:

- Training and education;
- Mission analysis and rehearsal;
- Decision support (such as exploration of doctrinal alternatives);

[1] **Acceptance** is the decision to use a simulation for a specific purpose and the term **Accreditation** is the official certification that a model or simulation is acceptable for use for a specific purpose.

- Capability management;
- Investigation of leading-edge technologies; and
- Effective support to the acquisition process.

The application of M&S, such as within the training domain, brings an inherent risk associated with the danger of using erroneous or unsuitable models and simulation results. Verification and Validation (V&V) of models and simulations are intended to ensure that only correct and suitable results are used thereby facilitating risk management.

Lots of military decisions could be based on M&S results. One of the aims of the V&V methodology is to structure the argumentation which will permit the military authorities to take decisions based on a more credible evaluation of the risks involved.

The non-direct benefits concern every phase of the design and development processes of military systems and weapons by armament companies and their customers.

OBJECTIVES

Area of Research and Scope

The proposed Task Group will build on former technical activities:

- Former NMSG TGs (MSG-019 and MSG-054);
- Previous work on VV&A under the International Test Operations Procedures (ITOP) organization;
- Past work on the previous GM-VV SISO Study Group on generic Methodology for V&V (GM-VV); and
- Current activity of the current GM-VV SISO Product Development Group (PDG).

The TG will act with the GM-VV PDG and will be in direct support to the Drafting Group of the PDG. More specifically the TG will be in charge of supervising the PDG activities to guarantee that NATO and Member/Partner Nation's needs are addressed in the PDG. Moreover SISO PDGs are widely open to other communities of interest such as transport, medicine, etc., and not only targeted to military or security purposes.

Specific Activities to be Performed by the TG

The major objective of this TG is to create a follow-on process for finalizing the standardization work on generic VV&A for models and simulations. The TG will be responsible and engaged in specific activities with the following objectives:

- To finalize the work on the VV&A document set (this task started under the European REVVA consortium banner and is now under development by the SISO GM-VV PDG);
- To guide the proposed document set through the formal SISO standardization process;
- To participate in the review, commenting and balloting efforts needed for creation of a new SISO standard;
- To assemble confidence in and fine-tune the methodology on the basis of 'real' case studies; and
- To provide education and training based on a documentation set for dissemination.

Other objectives to be fulfilled cover the inclusion of the SISO balloted products within the NATO M&S Standards Profile (NMSSP) and to produce a final Technical Report. Through case studies the methodology will be refined in the course of this TG, while at the same time providing material for dissemination and training.

Products

Main outputs of the TG will be published under SISO references according to the Technical Cooperation Agreement between NATO and SISO:

- The "**Handbook**", which will be a User's Manual that safely guides its users through the VV&A effort and clarifies their responsibilities by explaining how to apply the methodology in practice; it describes the activities to perform and the products to produce, the interactions taking place among those involved, the flow of products, and how to tailor the methodology to the specific needs of the M&S project.
- The "**Reference Manual**", which will document the underlying concepts of the methodology, including the foundations of the chosen terminology, the explanation of the dependencies between activities and products, their meaning for the VV&A endeavor, and the rationale for their execution and creation; the Reference Manual is referred to whenever a deeper understanding of the methodology is required. The Reference Manual will provide all the handles needed for future development of supportive case-tools and repositories.
- The "**Recommended Practice Guide**", which will be a recommended practices document that provides specific guidance with regards to the selection and use of techniques and tools in support of the user manual (the Handbook); it will include domain specific case studies thereby illustrating the application and tailoring of the methodology.)

The first and the third document will be "officially balloted" SISO "guidance products"; the second one will be a SISO "reference document" in support of the two other ones.

The final technical report published under an RTO reference will be a short introduction to the SISO documents.

Overall Duration

This TG should be established for the full life-cycle of the SISO GM V&V PDG and no longer than 3 years.

RESOURCES

Membership

Participating Nations are initially France (lead Nation), Canada, Denmark, Netherlands and Sweden. All NMSG Nations are invited to join.

Anticipated Meeting Schedule

The TG is expected to meet face-to-face 2 – 3 times a year (1 – 3 day meetings). It will use teleconferencing as far as possible. Face-to-face meetings could be organized during or in conjunction of SISO workshops and other international events either in North America or in Europe.

National and/or NATO Resources Needed

Input to and participation in the meetings including travel funds (1 – 2 specialists per Nation).

SECURITY CLASSIFICATION LEVELS

Unclassified/ Unlimited.

PARTICIPATION BY PARTNER NATIONS

Partner Nations are invited to participate.

LIAISON

ACT, NIAG, NC3A, SISO, US M&S CO.

Annex B – SISO COPYRIGHT PERMISSION

From: Martin ADELANTADO (NATO MSG-073 Chairman) ONERA-MiP/DTIM
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France
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To: Mr. David DRAKE,
SISO Board of Directors Chair

Dear David,

As you know the NATO NMSG-073 task Group on « GM-VV: Generic Methodology for Verification and Validation » is supporting the process of SISO standardization of this methodology since 3 years. Recently, the PDG meeting held in Orlando on Thursday 29 March 2012 has approved the balloting resolutions proposed by the GM-VV PDG Drafting Group chaired by Manfred Roza (NLR – NLD). The balloted document is entitled « GM-VV Vol.1: Introduction and Overview » referenced by SISO-GUIDE-001.1-2012.

As Chairman of the NATO NMSG-073 and in agreement with Jean-Louis IGARZA, GM-VV PDG Chairman, I am writing you to request permission to include parts of the document «SISO-GUIDE-001.1-2012 » in the NMSG-073 Task Group Final Report. I believe that SISO is currently the holder of the copyright. If you do not currently hold the rights, please provide me with any information that can help me contact the proper rights holder. Otherwise, your permission confirms that you hold the right to grant this permission.

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Sincerely,

Martin Adelantado

19 April 2012

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14. Abstract

Work on V&V of models, simulations and data was initiated in 2002 through several projects such as REVVA1, REVVA2 and MEVAS. MSG-073 Task Group was a follow-up on earlier efforts within NATO and the former US DoD DMSO (Defence Modeling and Simulation Office), which was renamed to US DoD M&SCO (Modeling and Simulation Coordination Office). The objective of MSG-073 was to provide a path into the creation of an internationally accepted VV&A standard, GM-VV (Generic Methodology for V&V) through the SISO (Simulation Interoperability Standards Organisation). 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 the GM-VV is a 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.

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