# WEAG THALES JP11.20 (REVVA) Results and Perspectives

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**ABSTRACT:** *Within the WEAG THALES Joint Program 11.20 "Common Framework for Verification, Validation, and Accreditation of Simulations" (nicknamed "REVVA") between Denmark, France, Italy, Sweden, and The Netherlands, a new customer-based and product-oriented VV&A methodology was developed. It includes: (1) The REVVA Generic Process, a stand-alone VV&A process, which can be easily linked to numerous types of model development processes; (2) The concepts of Target of Acceptance (ToA) and Target of Verification and Validation (ToVV), which put a strong emphasis on V&V requirements definition and traceability from the individual Items of Evidence acquired during V&V implementation up to the intended purpose of model use; (3) The explicit distinction between the properties "correctness" and "validity", which are inherent to a simulation model on the one hand, and the processes of "verification" and "validation" to reveal them on the other hand; (4) Hooks for the integration of methods for estimation of uncertainty introduced by the current inability to prove neither correctness nor validity; (5) A role model, which clearly distinguishes technical and managerial roles and parties from which the actors may come.*

*The follow-on project "REVVA2" shall formalize these former results and its own methodological basis. REVVA2 must also show its complementarities with other approaches such as the International Test Operations Procedure on V&V (WGE7.2) and the combined effort on HLA Federation VV&A by the NATO MSG019/TG016 and the SISO VV&A PDG. The ultimate objective of REVVA2 is the production of a set of documents that have to satisfy two kinds of goals: they have to be written in a style suitable for their submission to international standardization organizations, and need to be immediately applicable by VV&A practitioners. This paper, based on the Spring 05 SIW paper 041, outlines the results achieved by the first study and motivates future research and standardization directions.*

Keywords: WEAG THALES JP11.20, REVVA, Verification, Validation, Accreditation, REVVA Generic Process, Target of Acceptance, Target of Verification and Validation

## 1 Introduction

Modern simulation models tend to get more and more complex, thus becoming themselves complex systems, requiring a more formal engineering process, including validation of the model. Among the major deficiencies in the field of Verification, Validation and Accreditation (VV&A) of Simulation Models is the lack of an internationally accepted common methodological framework for VV&A. Today VV&A efforts are usually conducted differently in different organizations and different nations based on their own methods, processes and policies, with varying degrees of maturity. This heterogeneity does not only hinder the sharing and reuse of models and simulations between industrial or governmental bodies, but also may result in the rejection of a simulation model by a potential user unfamiliar with the used VV&A method.

With the objective to develop the basis for a common methodological framework for VV&A of simulation models and simulation results, the European REVVA project [1], (which already was presented in earlier papers, including [2] through [6]) was implemented from March 2003 through September 2004. The project was run under the auspices of the Western European Armament Group (WEAG) according to the THALES Memorandum of Understanding as Joint Program 11.20, which provides a mechanism for multinational defense research collaborations among Western European Union nations.

REVVA was funded by the Ministries of Defense of France (lead nation, ONERA), Denmark (UNI-C), Italy (DATAMAT), the Netherlands (TNO) and Sweden (FOI and FMV).

This paper summarizes the results of the REVVA project, gives an overview of its achievements, and outlines the objectives of the follow-on program "REVVA2". For reasons of brevity, however, the results are here only scratched at the surface. Those interested in more information concerning the REVVA methodology are referred to reports from [7] to [18]. Scientific and technical foundations, technical details, background information, and state of the art analysis the REVVA methodology is based on include [19] through [29]. In the follow-on project, REVVA2, the VV&A methodology will mature in such a manner that it can be submitted to an appropriate, internationally accepted standardization body.

The paper is organized as follows: Section 2 introduces and justifies the most important underlying assumptions, main objectives, and key concepts of the methodology. The REVVA methodology itself, addressing organizational, process- and product-oriented aspects, is presented in section 3. The paper proceeds with a presentation of REVVA2's objectives and challenges in section 4, and concludes with a summary of the REVVA vision in section 5.

# 2 Main Objectives, Underlying Assumptions, and Key Concepts

In this section the scope of the REVVA methodology is outlined. The three pillars of the methodology are introduced and the relationship between simulation model development and VV&A briefly discussed.

## 2.1 Main Objectives

The vision for the scope and focus of a VV&A methodology is founded on an attempt to answer the basic questions "why?" and "for whom?". Among existing VV&A methodological endeavors in science and defense convergence concerning the answers to the "why?" question can be observed, but the answers to the "for whom?" question vary significantly. These differences in the targeted audience have important consequences for the planning and implementation of VV&A activities. Differences exist, as well, in the identification of the "what", e.g. the VV&A products generated and/or used by VV&A activities.

In the context of REVVA, VV&A is considered as the set of methods, techniques and standards, which are used to determine and assess the justifiable confidence that may be put by the customer in the use of M&S products ("customer-oriented"). This assessment is a many facetted activity mainly dealing with the evaluation of the M&S products ("product-oriented"). It also identifies the source and impact of remaining uncertainties, to facilitate an overall assessment of the trustworthiness of an M&S product.

## 2.2 Three Pillars: Process, Product, and Organization

The above introduction to the scope of VV&A motivates the definition of the three pillars the REVVA methodology is based on: products, organizations and processes. These dimensions have to be explored for their impact on the resulting justifiable confidence as well as on their impact on the way of doing the actual work. The principles recommended for the implementation of a VV&A project are based on our 3-pillars model. The three pillars can be described as:

(1) *the organization*, which involves different groups with different, sometimes conflicting, interests. This pillar builds on identified *parties* and *roles* (see section 3.2);
(2) *the process*, which directs the flow of activities and products during VV&A. The *REVVA Generic Process*, which builds this pillar, is a stand-alone VV&A process which can be mapped to standard modeling processes via the M&S intermediate and final products made available for VV&A (see section 3.3); and
(3) *the products*, which document the findings of the VV&A effort. This pillar is mainly built out of *Items of Evidence*, which are the basic results of the application of V&V Techniques, the extensive documentation of the semi-formalized Acceptability Criteria and the rationale for their development (*Target of Acceptance*, ToA), and the documentation of the chosen V&V approach and the rationale behind it (*Target of Verification and Validation*). The basic results are integrated for the acceptance decision into an overall picture (see section 3.4).

This three-pillars model is the foundation of the REVVA methodology. The methodology captures the dependencies of and flow of information between the methodology components. It is expected that making these relationships explicit should be beneficial for the comprehensiveness, focus and balance of the VV&A project.

## 2.3 Key Concepts

- To keep the REVVA methodology as flexible as possible, only the developmental products (such as the Simulation Conceptual Model or model documentation) are used. It exclusively concentrates on available intermediate, final, or supplemental M&S products.
- Under the precondition that (dynamic) simulation is always about behavior, in accordance with not only

[25], the REVVA methodology exclusively concentrates on simulation model behavior, with the desired objective to demonstrate behavioral indistinguishableness (i.e., sufficient behavioral accuracy).

- The "intended purpose" statement itself usually is too vaguely defined for rigorous demonstration of objectives achievement [30]. In the REVVA Methodology acceptance or rejection is judged based on *Acceptability Criteria (AC)* addressing the behavior of the simulation model and its indistinguishableness from the behavior of the System of Interest are explicitly referred to as *Validation Criteria* which are a subset of AC. It is considered to be insufficient to just document the AC, but also the rationale for their derivation must be captured [13].
- A simulation model (or simulation result) *is* or *is not* factually valid and correct, regardless of how much time is explicitly spent on V&V. V&V facilitate the perception of the presence or absence of these properties. When making an acceptance decision for an M&S product, *uncertainty* is introduced because feasibility of a proof is an exception rather than the rule. With a lack of proof, there may be a discrepancy between the perceived validity and factual validity, and the perceived correctness and the factual correctness.

More on REVVA's underlying assumptions and key concepts can be found in condensed form in [2], and in detail in [8].

# 3 The REVVA Methodology

The methodology is based on the assumption that the VV&A activities are implemented by an organization or organizational sub-unit collectively named "VV&A Agent". This VV&A Agent should have, with respect to the M&S intended purpose, the adequate level of independence from the M&S customers and from the M&S suppliers, ranging from being an organizational sub-unit in the M&S supplier's organization to independence as defined in [31]. The VV&A organization has to be engineered both to satisfy this level of independence and to provide the personnel ("actors") fulfilling the tasks identified in the process view.

The VV&A process defines the logical and chronological flow of activities and products to facilitate the transition from the initial intended purpose, through a series of intermediate steps and products, to the final product, namely a report recommending/rejecting the use of the M&S product for the intended purpose. The process proposed here focus on the technical components of the M&S and VV&A products and activities.

## 3.1 Terminology

The definitions for Verification and Validation recalled here in order to give the feeling of the road explored by REVVA introduce an important distinction among properties of products (i.e., correctness and validity) and the way to perceive these properties, the processes and their constraints (which introduces some relativism).

Correctness: The property of a simulation model to comply with formal rules and bodies of reference information for its content and representation, and for the transformation into another representation.

Validity: The property of a simulation model to have, within a specific experimental frame, a behavior which is indistinguishable from the behavior of the System of Interest.

Verification: The process which is used to construct, under a set of time, cost, skills, and organizational constraints a justified belief about model correctness.

Validation: The process which is used to construct, under a set of time, cost, skills, and organizational constraints a justified belief about model validity.

This separation between properties and processes stresses that currently V&V cannot guarantee absolute correctness and validity.

## 3.2 Parties and Roles

To implement the pillar "organization", the REVVA methodology identifies *roles* and *parties*. A *role* is characterized by the skills required to accomplish a particular task or set of tasks, and the responsibilities that are taken. Also groups with different interests, including those who are going to acquire a simulation model or simulation results (and are likely to pay for it), and those who deliver the requested M&S product, are distinguished. These interest groups are called *parties*.

### 3.2.1 Parties

A party is assumed to be an organization or organizational unit. With the situation that somebody provides a simulation model or simulation results, which will be used by somebody else, there exists a "customer-supplier relationship":

- *Customer*: A customer is an organization or organizational unit which plans to use or is using an M&S product (such as a simulation model, simulation results, or data) developed by the supplier.

- *Supplier*: The supplier is an organization or organizational unit which provides the M&S product to the customer.

A relationship of trust between the customer and the supplier is desirable, but it must be always kept in mind that the supplier is trying to sell something to the customer, with all its implications. Thus, the REVVA Methodology introduces the

- *3rd Party VV&A Agent:* The 3rd Party VV&A Agent is an organization or organizational unit external of the customer and the supplier parties. Its degree of independence is assessed based on managerial, technical, and financial factors.
- *Acceptance Authority*: The Acceptance Authority is an organization or organizational unit external of both the customer and the supplier parties, officially entitled to accept M&S products, and trusted by the customer. Its degree of independence is assessed based on managerial, technical, and financial factors.

The roles introduced in section 3.2.2 are played by actors from the above parties. The decision, which party an actor comes from, must be made carefully and deliberately.

### 3.2.2 The Roles

The assignment of tasks to persons or individuals who are a member of a party (management of human resources) should be based on an agreement of the parties involved. In the following, roles interacting with and responsibilities within the VV&A process are identified [7]. Each role is outlined by

- the required knowledge and skill to complete the assigned tasks,
- the authority given and responsibility taken in the process, and
- its interaction with other roles.

A role does not determine, whether it is played by one actor, or shared by several actors, which even might come from different parties. However, particular roles require a sufficient distance between the individuals or teams performing them, while others are likely to be played by the same, single individual. *VV&A core roles* are directly involved in the VV&A endeavor by using, planning, conducting, evaluating, or assessing the substantial VV&A work.

- The *Contextual User* defines the contextual objective. It is assumed that the Contextual User always is in the customer party.
- The *Acceptance Leader* is a user representative (trusted by the Contextual User), who is responsible for the assessment of the M&S product.
- The *V&V Leader* knows approaches to V&V, techniques, and tools. This role is responsible for developing an appropriate V&V approach to substantiate the AC with the information about System of Interest and simulation model available.
- The *V&V Executioners* is a composite of roles including Simulation Model Operators, System Analysts & Subject Matter Experts, M&S Experts, and HW/SW Engineers. It consists of a number of actors playing several roles that actually implement the analysis and test activities required to provide the Items of Evidence specified by the V&V Leader.

*Affected roles* take advantage of the REVVA methodology, but are not directly involved in the technical planning and implementation of VV&A. Often they are decision makers outside of the process and are responsible for the smooth organizational flow of the VV&A effort, such as the M&S Sponsor, M&S Project Manger, and VV&A Project Manager.

### 3.2.3 Choosing Actors

Table 1: Actors, Roles, and Independence

| | **Acceptance Leader** | **V&V Leader** | **V&V Executioners** |
|---|---|---|---|
| **DV&V** | Not explicitly assigned | Supplier | Supplier |
| **IA** | Customer or 3rd Party VV&A Agent | Supplier | Supplier |
| **IV&V** | Customer or 3rd Party VV&A Agent | 3rd Party VV&A Agent | 3rd Party VV&A Agent |

Whether an actor or group of actors is appropriate to play a particular role depends on organizational aspects, including the desired degree of independence and required transfer of information, and on her/his educational background and experience. The assumption here is that if technical activities should be shared, responsibilities on both the customer side and the supplier side have to be clearly identified to prevent conflicts of interests. In accordance to [31] the REVVA methodology distinguishes:

- Dependent V&V (DV&V): The V&V is conducted by the M&S supplier according to the customer's V&V requirements (i.e., the actors for V&V Leader and V&V Executioners are members of the supplier party), and accepted "as is" by the customer.
- Independent Assessment (IA): The V&V work is conducted by the M&S supplier, but is assessed by an independent Acceptance Leader (from and independent 3rd Party) trusted by the customer,

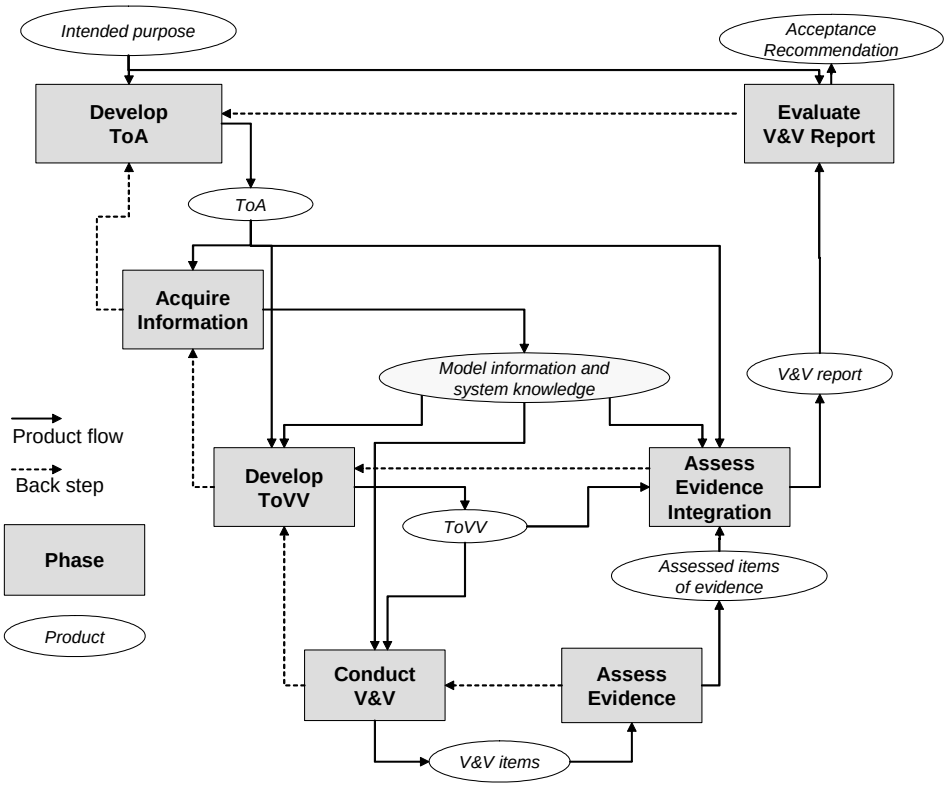


Figure 1: The REVVA Generic Process

- Independent V&V (IV&V): V&V activities are planned and conducted independently from both the supplier and the customer by the independent 3rd Party VV&A Agent.

Table 1 gives an overview over cost-effective assignment of actors to roles, considering independence from the customer's perspective.

### 3.3 The REVVA Generic Process

The REVVA Generic Process implements the pillar "process" and supplies the pillar "product" of the REVVA methodology. As shown in Figure 1, it supports product-oriented VV&A during or after model development (e.g., as required for reuse for another related intended purpose), and can be used as guidance for planning a VV&A effort. The "V-Form" for the process representation was deliberately chosen, mirroring the preparation for V&V and the execution of the V&V activities on the left trunk ("\") of the "V", against the evaluation and the integration of the V&V results for the purpose of assessment on the right trunk ("/") of the "V".

#### 3.3.1 Phases and Products

Each phase description contains a summary of activities, lists the input and output products, and points out the involved roles and their type of involvement. The REVVA Generic Process is no waterfall process, but iterative, which means that especially those products close to the bottom of the "V" become available in several versions. More detailed description is found in [30].

*Develop ToA (phase 1):* Based on the intended purpose of model use, a detailed set of AC is developed in such a manner that meeting the AC implies fitness for purpose, i.e., the AC must be sufficient and – for the sake of efficiency – necessary. All AC and the rationale for their derivation are recorded as the "Target of Acceptance" (ToA). AC should be prioritized.

*Target of Acceptance (product):* The Target of Acceptance (ToA) contains a precise specification of the AC and the rationale for their derivation from the intended purpose, and documents "what needs to be demonstrated" during the V&V effort. On top of a refinement hierarchy stands the vague intended purpose, which is – based on an explicitly stated argument – refined into a set of sub-objectives (SO), which again is decomposed, until AC related to the M&S product's correctness and validity can be derived directly from the lowest sub-objective. An abstract ToA is shown in Figure 2.

*Acquire Information (phase 2):* Under consideration of the intended purpose of model use and the detailed AC (documented in the ToA), knowledge about the System of

Interest, its structure and behavior, its subsystems and their structure and behavior, or related systems (in related work this body of real world knowledge is referred to as "referent") is collected and filed.

*Model information and system knowledge (product):* This information will be used as foundation of the approach to demonstrate the model's correctness and validity. The product identifies all sources of information and knowledge and all bodies of information and knowledge that are available or will become available during the V&V effort.

*Develop ToVV (phase 3):*For each Acceptability Criterion a rationale is developed, which points out how with the information at hand and the available technical means it can be demonstrated that the Acceptability Criterion is met or missed. To substantiate that the Acceptability Criterion is met becomes a *V&V Objective*. Developing the ToVV usually includes the decomposition of a V&V Objective into more easily assessable V&V sub-objectives.

*Target of Verification and Validation (product):* The Target of V&V (ToVV) documents the approach taken to the substantiation of the AC. It elaborates on the "how to demonstrate that the AC are met or missed", identifies the Items of Evidence required to substantiate the AC contained in the ToA, and documents the rationale for the necessity and sufficiency of these Items of Evidence. In Figure 2 an abstract ToVV is shown and its connection to the ToA revealed.

*Conduct V&V (phase 4):* V&V is conducted to provide the V&V items identified as required by the ToVV. If, due to, e.g., missing or insufficient information about the model, missing knowledge about the System of Interest, or unavailability of the required tools, a particular Item of Evidence cannot be acquired, or if an elementary V&V objective is demonstrated to be failed, a step back to "Develop ToVV" is made.

*V&V items (product):* Each test result, analysis report, or proof outcome is documented as V&V Item, which as a set, constitute the "atomic building blocks" of V&V. A V&V Item consists of some piece of information about the Simulation Model, the evaluation objective, reference information, an evaluation technique, and the evaluation result. V&V Items have different probative forces, depending on the method or technique used for their creation, and the reference information or knowledge used

*Assess Evidence (phase 5):* The key issue of this phase is to assess the probative force of the V&V items, to accept the individual V&V items as Items of Evidence, or to reject them. The *probative force* of each individual Item of Evidence is assessed based on the repeatability of the associated V&V activity. Criteria for the assessment of the probative force of an Item of Evidence add objectivity to this currently subjective procedure.

*Items of Evidence (product):* The Items of Evidence document the individual executions of single V&V techniques and their outcomes, as conducted or acquired by the V&V Executioners. The assessed Item of Evidence includes (in addition to the information contained in the V&V item from which the Item of Evidence originates) the assessment statement, and a judgment of its probative force.

*Assess Evidence Integration (phase 6):* A single Item of Evidence will usually not allow the conclusion that a particular Acceptability Criterion is met, but several Items of Evidence are assembled according to the (most recent version of the) ToVV. The key issue of this phase is to build and accept or reject the rationale of supporting the AC with the available Items of Evidence. Under reconsideration of the ToA, the assembly of the evidence is reviewed and it is judged how sufficiently the evidence substantiates that the AC are passed (convincing force). The convincing force of the V&V sub-objectives hierarchy as documented in the ToVV is an expression of the preciseness and coverage of the AC.

*V&V report (product):* The gathered or otherwise created Items of Evidence assembled and integrated by the V&V Leader to substantiate the AC in the ToA according to the most recent version of the ToVV, build the substance of the V&V report. The V&V report links the rationale why the referenced Items of Evidence substantiate the claim that the AC are met with the Items of Evidence made available, and how meeting the AC indicates fitness for purpose. Figure 2 shows the integrated picture which allows to trace the individual items of evidence back to the intended purpose statement.

*Evaluate V&V Report (phase 7):* Based on the probative force of the evidence, the convincing force of the ToVV, and the selection of AC as motivated in the ToA (all documented in the V&V report), the residual uncertainty associated with the statement that the M&S product actually is fit for its intended purpose is estimated.

The degree of residual uncertainty needs to be identified for each Acceptability Criterion and each relevant set of AC individually. While for particular AC a high degree of uncertainty is acceptable (criteria which may be missed without serious consequences), for others only very low uncertainty is acceptable (criteria whose failure will have serious impact). To prepare a responsible acceptance or rejection decision, an upper bound for this residual uncertainty is estimated.

*Acceptance Recommendation (product):* The final recommendation whether to accept or reject the M&S prod-

uct for its intended use, considering the uncertainty that is left even after V&V was successfully conducted, is documented in form of the acceptance recommendation. The acceptance recommendation confirms that the acceptability for the intended purpose is demonstrated by the Items of Evidence gathered to substantiate the AC, and states a reasonable degree of confidence in this confirmation. However, the achieved level of uncertainty, regardless how low, must never imply that the results of the use of the M&S product can be blindly transferred to the real world.

### 3.4 Transparent and Traceable V&V Approach

The Target of Acceptance [13] and the Target of Verification and Validation implement together with the Items of Evidence the "products" pillar. The integrated structure of ToA, ToVV, and Items of Evidence holds all information required for an informed acceptance decision. The basic structure of the ToA stems from the hierarchical way the objectives are elicited, yielding a directed acyclic graph rather than a tree: It can happen that two V&V objectives both need the same sub-objective. The objectives that are refined must have an additional piece of information associated with them. This extra information is the argumentation on why the sub objectives together are necessary and sufficient to constitute their parent objective. This argumentation is named the "Decomposition argument", which is the glue in the hierarchical structure of the ToA.

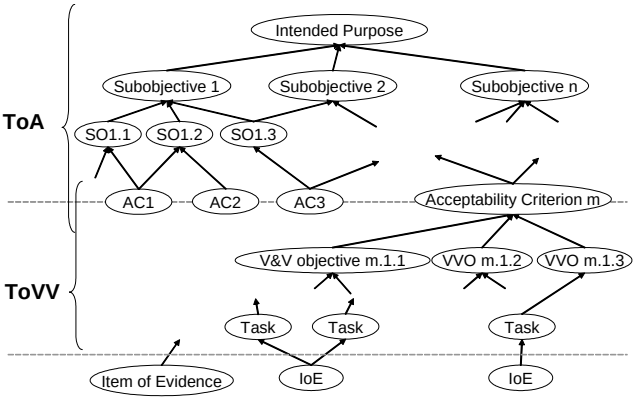


Figure 2: ToA and ToVV with items of evidence attached

The ToVV documents the approach how to substantiate the AC with the available model information, the available system knowledge, a choice of V&V techniques, and a suite of tools at hand.

## 4 REVVA2 Objectives and Challenges

The REVVA2 project is supposed to start in summer '05 and will run under the EUROPA MoU. At the current planning stage, REVVA2 includes partners coming France (leading the project), Denmark, The Netherlands, and Sweden. In addition, MoD interest was declared by Germany and Canada. UK industry plans to participate with own funding. The project will run for three years.

### 4.1 REVVA2 Objectives

The REVVA played an important role in the exploratory analysis of the VV&A problem statement and problem understanding. REVVA2 shall formalize these former results and its own technology basis. REVVA2 must also show its complementarities with other approaches (e.g. the integrated SISO VV&A PDG / NATO MSG019/TG016, and the ITOP WGE 7.2). REVVA2 then must organize all these contributions into a workable VV&A methodology. The ultimate objective of REVVA2 is the production of a complete VV&A methodology contained in a set of documents that have to satisfy two kinds of goals. They have:

- to be written in a style suitable for their submission to international standardization organizations,
- to be of immediate applicability by VV&A practitioners.

These documents shall consistently and exhaustively cover the methodological foundations of M&S VV&A, providing:.

- A **User's manual**, which safely guides its users through the VV&A effort and clarifies their responsibilities by explaining how to apply the methodology in practice. It describes, e.g., 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.
- A **Reference manual** documenting 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.

As a complement to the user's manual, specific guidance documents will be produced at different levels of generality. At the highest level it is proposed to produce a document compiling the "**recommended practices**" which will guide in the selection and use of techniques and tools related to the support of the User's Manual method's components.

At lower level, guidance documents for selected **application domains** will be produced (e.g. for Training and Education, for SBA, etc). To facilitate the development of meaningful guidance documents, intermediate goals and

the ways to achieve them have been identified. These goals include:

- To establish clear, unambiguous and commonly accepted terms and definitions;
- To improve, formalize, and finalize the basic concepts developed in JP11.20, including the product, organization, and process descriptions;
- To clarify the relation between VV&A (e.g. VV&A levels and residual uncertainties) and M&S product acceptance by the customer;
- To formally define the VV&A specialized (tailored) products and processes related to important application domains;
- To identify the techniques for evaluation of the confidence in M&S products, V&V results, clearly separated from techniques for software quality assurance and independent from the development process.

### 4.2 Conceptual and technical challenges

The analysis of the state-of-the-art and the previous work and outcomes of REVVA are such that it has been considered as mandatory to explore the topics identified here below. Achievements on these topics provide the ground to build the theory, the procedure, and the pragmatics of a VV&A methodology. The topics that deserve more work are structured in fundamental concepts and techniques and tools.

#### 4.2.1 Fundamentals concepts

The state-of-the-art in both M&S and VV&A, as shown within JP11.20, led to some issues being identified as major sources of errors or problems. The work accomplished within JP11.20 consisted of reviewing the terminology, investigation of the factors impacting VV&A concepts, reviewing the V&V techniques, and also in providing a first draft of the methodology, based on an organization, a process, and products.

A set of areas will be explored, which will permit the creation of formal definitions, requirements and specifications on these VV&A concepts:

- Requirements on M&S products and processes: Most of the existing VV&A methodologies rely on a very informal definition of what they must have as inputs coming from M&S (products, process and data) in order to implement their own activities on solid grounds. This requirements specification of M&S products and processes must be done without interfering too much with the M&S developer's freedom to select their preferred development methodology. M&S developers and V&V agents should use a repository for their information exchange needs. This repository should be specified to take into account the very specific aspects of M&S uses.
- Formalization of VV&A products and processes: This point is a formal corollary of the previous one and a favorable consequence. It is only because inputs are formalized that it is possible to formalize outputs and procedures. The benefits of formalization are well known and accepted in critical domains for their ability to complement human judgment and also to decrease developments costs.
- VV&A techniques: This research topic has to deal with the understanding and support of many items in conjunction. Topics that have not been exploited in sufficient depth in other national or international VV&A research programs include argumentation theory, decision making, uncertainty, and quality evaluation.
- Cost models: This is certainly a very long-term applied research topic. It needs both (simple) theoretical models, support techniques and, mainly and primarily, data on experiments to substantiate and play with these models. Few publications are specifically devoted to this topic. It is our intent to build on work published by Lewis [32] and Kilikauskas [33], and approaches coming from economical sciences.
- Tailoring and adaptation: Tailoring instances of a VV&A methodology are needed by practitioners and necessary to keep the additional effort for VV&A as low as possible. The VV&A methodology kernels are generic and designed for "worst case" exhaustive V&V. VV&A practitioners could take into account the specificities of application domains to make them more efficient. This needs experiment capitalization and more work on taxonomies targeted to the VV&A needs related to application domains.
- Capitalization and repository: This topic is not M&S or VV&A specific for its most basic requirements. VV&A activities suggest however some advanced requirements on knowledge management: logical vs. chronological management, inconsistencies management, management of non-monotonic updates … etc. This topic must be also related to the specifications of roles in an organizational context larger than M&S and VV&A.

#### 4.2.2 Techniques and Tools Exploration

The JP11.20 outcome on techniques and tools was essentially an identification of sources, a review and a classification. The goal in REVVA2 should be to identify the set of techniques which will permit the effective support of the methodology and to suggest improvements of existing tools or new developments based on the VV&A requirements. The identification of a list of fundamental topics for research has been used to suggest some specific zoom on state-of-the-art of techniques and their corresponding tool support, such as:

- the identification and the support of V&V requirements (V&V problem statement and then V&V requirements),
- the creation, maintenance, and version control of the V&V plan, with specific target objects, as, e.g., the Target of Acceptance and the Target of V&V,
- the collection, organization and qualification of V&V items of evidence: trial data generated by M&S developers or by V&V agents have to be managed (audit, record) and technically exercised (e.g., trial data becomes evidence which substantiates that an acceptability criterion is met, at some level of trust, after a specific work),
- support and maintenance of the argumentation: A specific set of techniques and tools must be defined to support the required level of expressiveness allocated to argumentation production and maintenance,
- V&V in support of decision making: The composition of pieces of evidence and arguments must lead to a proposal of VV&A agents to an accreditation authority, if existing, or to customers. The type of document generated and the kind of help for decision making have to be identified as they have impact on processes and resources,
- formal foundations for V&V tools development: The state-of-the-art in military M&S and VV&A about the use of formal techniques is not as matured as in many other critical areas. Embedded real time systems, security, or VLSI integrated circuit development are examples of application areas, where the use of formal techniques has produced a dramatic increase of productivity of developers and V&V teams. The use of formal techniques may be explored in M&S and VV&A on selected critical areas,
- guidance for choosing and selecting V&V tools: This type of recommended practices guide has to be supported by (simple) tools which are capitalizing the pragmatic knowledge of VV&A, and mostly the compilation of taxonomies,
- audit trail of processes: This area is in direct relation with the advanced requirements expressed about repositories management. Actual processes (chaotic, non-monotonic behavior) must be captured at a (pre)defined level of granularity and following some policies. This need must be supported and the requirements for tools must be derived.

### 4.3 Relationships with Other VV&A Initiatives

The "Combined Convention on International VV&A Standardization Endeavors" (CConVV&A) [33] had permitted to clarify the relationships among the proposals coming from the NATO, SISO, ITOP, and REVVA. A global scheme describing these relationships will be a part of the CConVV&A final report. This scheme creates the opportunity during REVVA2 of fruitful co-operation with the other study groups, and even to share some work on common topics with:

- ITOP on the Claim-Argument-Evidence structure and more generally on V&V report templates, on risks and levels, and on uncertainty,
- NATO/SISO on tailoring the REVVA process to a specific technology base (HLA and the FEDEP), and on the support techniques, and
- NATO, SISO and ITOP on common case studies applying the methodology.

The various working group terminologies and taxonomies have to be reviewed, as well as the contributions coming from the art and science of M&S. The contribution about the terminology is essential to clarify the foundations of the methodology. For example, existing definitions for the words "verification" and "validation" show limitations, drawbacks or biases. The core VV&A terminology will be defined in co-operation with the other VV&A groups in order to build common and stable foundations for the methodology.

The contribution about the taxonomies is essential to the actual and efficient application of the methodology. Taxonomies are very important preliminary products of guidance documents.

## 5 Summary

This paper gives an overview over the VV&A methodology developed within the WEAG THALES JP11.20 "A Common Framework for the Verification, Validation, and Accreditation of Simulations" (nickname "REVVA"). The REVVA methodology is built on a set of underlying assumptions and concepts, including (1) a clear demarcation of M&S VV&A from problem formulation and HW/SW development, (2) the need for the definition of a VV&A organization, a VV&A process, and VV&A products within the methodology, (3) the desire to minimally constrain M&S development by VV&A, but to increase the quality of the M&S product, (4) the justification for exclusively behavior oriented validation, (5) the indispensable prerequisite of clearly defined Acceptability Criteria, (6) the distinction between formal accreditation and informal acceptance for use, which also should be done deliberately, and (7) the inherent uncertainty associated with an acceptance decision. The presented building blocks of the REVVA methodology include (1) parties, roles, and guidance on how to assign actors, who are members of those parties, to roles in an efficient manner, (2) the REVVA Generic Process, which is a seven-phased stand-alone VV&A process, and (3) the products Target of Acceptance (ToA), Target of Verification and Validation (ToVV), Items of Evidence (IoE), and their integration into a combined ToA-ToVV-IoE structure.

Although the work conducted during REVVA stabilizes numerous aspects of VV&A, the methodology is not yet complete. Open issues include the further investigation of the comprehensive integration of the methodology components (organization, products and process); the impact of this integration on the argumentation framework and on the evaluation of remaining uncertainties; a specific work on the tailoring of the methodology; and specific technical zooms on the support of the argumentation framework by formal techniques. Those open issues will be addressed in the REVVA follow-on program, which is arranged under the Western European Armament Group's EUROPA memorandum of understanding, and is expected to start in summer '05.

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