RISK-BASED TAILORING OF THE VERIFICATION, VALIDATION, AND ACCREDITATION/ACCEPTANCE PROCESSES

1.0 INTRODUCTION

1.1 Background

The idea for an exploratory team on Verification, Validation, and Accreditation (VV&A) of federations was first proposed during the 5th North Atlantic Treaty Organisation (NATO) Modelling and Simulation Group meeting in July 2000. Initial discussions over the Internet and during a meeting in September 2000 by interested parties at the Defense Modeling and Simulation Office in the United States made clear that sufficient interest and substance existed for the formation of a NATO Task Group (TG) on the subject of federation VV&A.

MSG-019/TG-016 was established in 2001 and met several times through 2005 in both the United States and Europe. MSG-019 carefully analyzed IEEE Std 1516.3™-2003 [1][1] to identify where VV&A contributions were needed, but were undefined. The Task Group also developed an initial model of the VV&A process to ensure the development of consistent VV&A guidance for federations.

In January 2005, the Simulation Interoperability Standards Organization (SISO) established the Verification, Validation, and Accreditation Overlay to the Federation Development and Execution Process (FEDEP) Product Development Group (PDG) to produce a VV&A Overlay to IEEE 1516.3™. At the same time, MSG-019 also had determined the need for such a standard and began contributing to the development as part of the SISO VV&A Overlay PDG. MSG-019 ensured the standard under development would meet NATO/Partners for Peace (PfP) specific needs.

MSG-019 completed its objectives by producing a draft recommended practice for the VV&A of federations [2]. MSG-019 reported its activities in the Research and Technology Organisation (RTO) Technical Report, Verification, Validation, and Accreditation (VV&A) of Federations (TR-MSG-019) [3] and closed in September 2006. MSG-019 made these recommendations:

- NATO should adopt the draft recommended practice as an interim Standardization Agreement (STANAG) until the IEEE standard is issued and then revise the STANAG to adopt the IEEE standard.
- MSG-054 (the follow-on study group) should:
  - Participate in the IEEE Std 1516.4™-2007 [4] balloting process;
  - Monitor on-going VV&A case study initiative and incorporate suggested improvements to the Overlay during the balloting process; and
  - Study the relationship between user risk, acceptance criteria, and tailoring of the VV&A process.
- NATO should consider adopting similar collaborative relationships with international standards bodies as appropriate.

In September 2006, the RTO approved the formation of MSG-054/TG-037, “An Overlay Standard for Verification, Validation, and Accreditation (VV&A) of Federations”, to formalize the draft recommended practice previously produced by MSG-019 as an international industry standard by participating in vetting the

[1] A list of References may be found in Section 5.

document through SISO's and the Institute of Electrical and Electronics Engineers Standards Association's (IEEE-SA) standards processes. The specific tasking assigned to MSG-054/TG-037 is discussed next in Section 1.2.

1.2 Tasking

The Terms of Reference [5] for MSG-054/TG-037 identified these specific activities to be performed:

- Complete development of a canonical VV&A process started by MSG-019;
- Identify a set of terms needed to adequately describe the elements of that process and choose consistent definitions for those terms;
- Apply the canonical VV&A process to define the activities, tasks, activity inputs and activity products of the FEDEP VV&A Overlay;
- Participate in the review, comment and balloting efforts of the SISO VV&A Overlay PDG that will make the VV&A Overlay an IEEE standard;
- Address such special topics as basic concepts and VV&A tailoring and provide sufficient guidance in these areas to practically implement the VV&A overlay;
- Develop qualifications that guide application of the VV&A Overlay standard to NATO/PfP-specific initiatives;
- Develop the standard adoption and qualification guidance recommendations for a final Technical Report; and
- Finalize the Technical Report.

1.3 Task Group Membership

Nations participating in the MSG-054/TG-037 were Canada, France, Germany, the United Kingdom, and the United States. The United States representative served as the chairperson.

1.4 Scope of Effort

The MSG-019 product defined a comprehensive set of VV&A activities, tasks, and products that overlay the phases of the FEDEP. As expected in an overlay, the product adopted the fundamental principles associated with the parent document including the concept of tailoring. The FEDEP specifically stated that the development and execution process was meant to be tailored for a specific application. The concept of tailoring was extended to VV&A by including a high level discussion regarding tailoring and its impact on planning for and implementing VV&A.

During the balloting rounds, there were a significant number of comments that related to the defined tailoring section. Although there was general recognition of the critical nature of the tailoring function, several of the balloting comments identified the need for additional, detailed guidance on how and when to tailor the verification and validation processes. The SISO VV&A PDG Drafting Group intended that additional, more detailed guidance products would be developed to address key concepts such as tailoring. Tailoring VV&A to address a specific intended use is driven by the risk associated with the use of the federation results and resource constraints such as available information, budget, skills, and time. Quantifying risk and the tolerance for those risks are factors that drive tailoring decisions. Developing a tailoring approach is predicated on an understanding of the relationship and impacts of tailoring and risk.

Section 2 describes the results of the IEEE-SA standards process that resulted in an approved international industry standard. Section 3 describes the V&V Composite Model which was developed as guidance for tailoring VV&A processes.

2.0 IEEE STD 1516.4™-2007

The SISO VV&A PDG conducted the first round of review and comment of the MSG-019 product from March 31 to May 15, 2006, and a total of 214 comments were received. The SISO VV&A PDG Drafting Group and MSG-054/TG-037 met June 5-9, 2006 in Ottawa, Ontario, Canada, to review and finalize resolutions for non-editorial type comments. A SISO VV&A PDG teleconference was conducted on June 28, 2006 to vote on the resolutions of the comments. The vote was conducted in accordance with the PDG's voting rules. One comment that was unresolved during the teleconference was resolved via an electronic vote for which the polling feature of the SISO VV&A PDG discussion forum was used.

A second round of comments by the SISO VV&A PDG was conducted from August 4 to September 4, 2006. An additional non-editorial type 22 comments were addressed by the SISO VV&A PDG at its meeting on September 14, 2006 held in conjunction with the 2006 Fall Simulation Interoperability Workshop. As a result of voting conducted in accordance with the PDG's voting rules, two comments were withdrawn by the submitter and 20 resolutions were approved. The PDG also voted to recommend the SISO Standards Activity Committee approve the proposed standard for entry into the IEEE-SA standards process.

A Project Authorization Request was submitted to the IEEE-SA Standards Board to begin that organization's standards process. On December 6, 2006 the IEEE-SA Standards Board approved the project "P1516.4 – Verification, Validation, and Accreditation of a Federation, an Overlay to the High Level Architecture Federation Development and Execution Process." Both SISO and IEEE distributed messages announcing the project and inviting members to join the ballot pool in January 2007.

There were 55 individuals who joined the Sponsor Ballot that was conducted from April 17 through May 17, 2006. The Sponsor Ballot achieved a 93.6% (44/47 responders) approval rate. Table 1 summarizes how the votes were distributed according to the IEEE-SA classification codes.

Table 1: Sponsor Ballot Voter Summary.

Classification	Affirmative	Negative	Abstain	Unreturned	Total
Academic	5	0	0	0	5
General Interest	11	0	3	2	16
Government/Military	12	0	1	0	13
Producer	5	1	1	0	7
User	11	2	0	1	14
Totals	**44**	**3**	**5**	**3**	**55**

A total of 80 comments were received. All comments were addressed and negative comments were adjudicated directly with the submitter. A revised version of draft P1516.4 was produced and a message announcing the

recirculation ballot was distributed on June 26, 2007. The recirculation ballot ended on July 6, 2007 with no new comments received.

As a result of the recirculation ballot, one negative vote was changed to affirmative. The document achieved a 96% (45/47 respondents) affirmative vote. Table 2 summarizes the results of the recirculation ballot.

Table 2: Recirculation Ballot Voter Summary.

Classification	Affirmative	Negative	Abstain	Unreturned	Total
Academic	5	0	0	0	5
General Interest	11	0	3	2	16
Government/Military	12	0	1	0	13
Producer	5	1	1	0	7
User	12	1	0	1	14
Totals	**45**	**2**	**5**	**3**	**55**

As a result of MSG-054/TG-037 efforts, IEEE Std 1516.4™-2007 [4] was approved by the IEEE-SA Standards Board in September 2007 and was published as an international industry standard in December 2007.

3.0 DESCRIPTION OF V&V COMPOSITE MODEL

3.1 Approach to VV&A Tailoring

Enabling the tailoring of VV&A processes begins with describing the range of phases, activities, and tasks that possibly could be performed when implementing VV&A processes. The efforts of MSG-054/TG-037 resulted in the description of the phases, activities, and tasks for the Verification and Validation (V&V) processes only. The phases, activities, and tasks for the accreditation process were not completed as a result of these efforts.

The V&V Composite Model (see Appendix 1) describes the components of the processes (i.e., phases, activities, and tasks) from which to select to match the risk and resource constraints of the V&V efforts while still adhering to relevant policies, standards, and guidance. The V&V Composite Model is a superset of the possible activities and the context in which those activities can be tailored into working V&V processes.

Several assumptions underlie the construction of the V&V Composite Model:

- The V&V Composite Model is a general model representing V&V processes.
- The audience for the V&V Composite Model are stakeholders in the V&V processes.
- Accreditation refers to the process used to arrive at an acceptability decision based on an assessment of evidence collected by implementing V&V processes.
- Acceptability refers to the decision to apply an M&S for an intended use.
- Acceptability criteria adequately describe the M&S capabilities needed to support an intended use.

- The primary purpose for implementing V&V processes is to collect evidence to support applying M&S results for an intended use.
- Risk refers to the risk of using an M&S (i.e., use risk).

The paper included as Appendix 2, *"Decomposing the VV&A Processes to Support Their Tailoring"* (08S-SIW-066) was presented at the 2008 Spring Simulation Interoperability Workshop sponsored by the Simulation Interoperability Standards Organization in Providence, Rhode Island, USA, on April 14-18, 2008 [6]. Authored by the United States, the paper describes the components of the V&V Composite Model phases, activities, and tasks. Since 2008, the V&V Composite Model has been updated and revised, but the paper still serves as a good source of background information. Additionally, information from the paper was adapted for inclusion in Sections 3.2 and 3.3.

3.2 Components of Tailoring Guidance

Using risk as an effective tailoring mechanism for VV&A processes depends on understanding the factors that drive the risk as well as the VV&A activities and tasks that can and should be implemented to address the use risks. The V&V Composite Model (see Appendix 1) describes one perspective of the activities and tasks that constitute the V&V processes for M&S upon which to found risk-based VV&A tailoring.

The V&V Composite Model generalizes the guidance provided in IEEE Std 1516.4™-2007 [4] to apply to M&S beyond just federations, and extends that guidance to consider the broad range of possible sources of validation evidence. This model of the V&V processes defines the tasks that may be tailored to best suit the limits of acceptable use risk and optimize the resources available for VV&A.

As the complexity of the M&S and the associated V&V processes increase while budgets and schedules decrease, it is likely that not all V&V activities and tasks will be able to be performed. Additionally, when V&V is performed on legacy M&S, legacy developmental products may not be available to review, analyze, and test. To avoid becoming overwhelmed by the tasks described, to utilize resources efficiently, and to mitigate risk effectively, tailoring of the V&V processes is needed. Tailoring guidance helps determine the activities required for different V&V implementations.

Tailoring guidance is embedded within the descriptions of the activities in the V&V Composite Model. This guidance helps the V&V practitioner determine what tasks to omit and to understand the corresponding risk.

3.3 Overview of the V&V Composite Model

The V&V Composite Model comprises phases, activities, and tasks that decompose the general V&V processes. The highest levels are phases and there are eight phases in the V&V Composite Model:

- **PHASE 1: Plan the V&V Effort.** The V&V processes are planned to address the acceptability criteria (developed during planning for accreditation) and the requirements for using the M&S. The V&V practitioner executes and evolves the V&V Plan throughout the V&V effort. This includes monitoring the V&V effort and adjusting the V&V Plan to better reflect any new information gained while executing the V&V processes. The V&V Plan should be approved by the individual responsible for ensuring the V&V processes are implemented.
- **PHASE 2: Apply Relevant Historical Information.** When a legacy M&S is to be applied for the same or a similar intended use for which it has been previously accredited, considerable historical information

may exist upon which to base the new accreditation decision. In those instances, it is possible the entire V&V effort could focus upon the collection and analysis of historical information. When a legacy M&S is changed, when the simuland changes, or when the intended use changes, historical information may contribute to identifying the gaps in the additional V&V evidence that will be needed. Applying historical information begins by determining how closely the prior intended uses match the current intended use to determine what part of the history is relevant to the current problem. Historical information can come from prior V&V and testing activities, the records of prior uses, and the developer's accounts of the M&S capabilities and limitations. The V&V practitioner should analyze the relevant historical record to identify the factors that may constrain use. Then a coherent picture of the M&S capabilities and limitations based upon the historical evidence can be assembled. If results validation will be performed, the V&V practitioner can use the historical evidence to identify possible output sampling areas to improve its efficiency.

- **PHASE 3: Verify and Validate the Conceptual Model.** The conceptual model serves as a bridge between the requirements for developing an M&S and the M&S design, providing the developer's interpretation of the requirements. The conceptual model is the documented theoretical approach to the design of the M&S. The conceptual model describes what the M&S is expected to do, to be, and what data and other elements are needed for a successful outcome. The V&V practitioner begins by characterizing its coverage of the intended use and inferring the M&S capabilities from the information that the conceptual model contains. Conceptual model verification involves checking it for internal consistency problems. After that, the V&V practitioner can evaluate the conceptual model against the acceptability criteria to determine its validity. The objective of performing conceptual model validation is to demonstrate that the M&S functional elements accurately and completely represent the M&S requirements and to identify where assumptions, limitations, or architectural structure impact the intended M&S use. If available, the V&V practitioner should also verify and, if needed, validate the use scenarios.

- **PHASE 4: Perform Supplemental Verification.** How much the V&V practitioner contributes to development product verification depends largely upon the verification activities performed and documented by the developer of the M&S. The V&V practitioner begins the supplemental verification by collecting the developer's development products and determining how much additional verification is needed to achieve the desired confidence. The types of verification tasks that can be performed depend largely upon the development products available. The verification and validation activities performed and documented by the developer against the requirements for building the M&S can be used to support the M&S validation activities performed by the V&V practitioner. The V&V practitioner should leverage as much of the developer's verification and validation evidence as possible and only perform what supplemental verification is needed to increase the confidence in and bolster the validation evidence.

- **PHASE 5: Apply The Verification Products to Validation.** During this phase, the V&V practitioner applies the collected verification information to develop evidence on the M&S validity, adds to the information to support the accreditation recommendations, estimates the coverage and uncertainties in the development product verification evidence, and employs the verification evidence to identify factors that may constrain use and candidate output sampling areas.

- **PHASE 6: Verify and Validate the Data and Knowledge Sets.** V&V is performed on both the M&S and data used by the M&S. This phase focuses upon the data used to build the M&S, the data used as input into the M&S, and the data output by the M&S. Data and knowledge sets are distinguished by definition. Knowledge is a class of data that incorporates a knowledge representation scheme

(e.g., production rules, semantic network), while data are representations of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means. Data and knowledge set V&V should be performed because of their independence from the M&S and because the M&S relies upon those sets to produce its output. The phase begins by identifying their sources and the pedigrees of those sources because in many cases the organizations responsible for producing the data differ from the organizations that either develop or use the M&S. The credibility of those data-producing organizations often weighs heavily in determining the credibility of the data itself. After establishing the pedigrees of the data and knowledge, the V&V practitioner should verify the internal consistency of the data sets; verify any transformations used to make the data accessible and meaningful to the M&S (e.g., units transformations, coordinate transformations) then validate the completeness and correctness of the data sets against the acceptability criteria. The data validation information can then be used to identify output sampling guidance and factors that may constrain M&S use.

- **PHASE 7: Validate the M&S Results.** During this phase, the V&V practitioner reviews, analyzes, and tests the M&S. Tests are run to produce output; the output is analyzed to determine capabilities; and the capabilities are reviewed against the acceptability criteria to infer validity. The V&V practitioner uses the developer's test results to tailor the results validation effort, if those results are available. Design of experiments techniques are applied to build the test cases used to sample the M&S output. The V&V practitioner executes the test cases, collects the output, analyzes the output, and documents an integrated description of the M&S capabilities and limitations from the collected V&V evidence.

- **PHASE 8: Integrate the V&V Evidence.** The preceding phases produce the evidence that this phase integrates into a description of the M&S validity to support the accreditation recommendations. The V&V practitioner examines the evidence produced by the preceding activities, forms a consistent picture of the M&S validity and estimates the confidence in that determination. The V&V practitioner identifies the factors that may constrain use and combines those constraints with the assessments of the M&S completeness and correctness for the intended use. Then, the V&V practitioner assembles the results of this integration with the evidence produced by the prior V&V activities into the V&V Report. The information in the V&V Report should present the evidence upon which an accreditation assessment can be made to base the accreditation recommendations. This phase may include any post-execution follow-up and archival activities.

Figure 1 identifies the activities that compose each of the eight phases. Each activity includes a description, as well as possible tailoring guidance, notes, and assumptions. Each activity is decomposed into tasks. Each task includes a description, information required to perform the task, the source of that information, and the information produced by the task. The V&V Composite Model assumes that once a product is created, it is available for all subsequent activities; even though the product might not be identified as information that is required to perform the task.

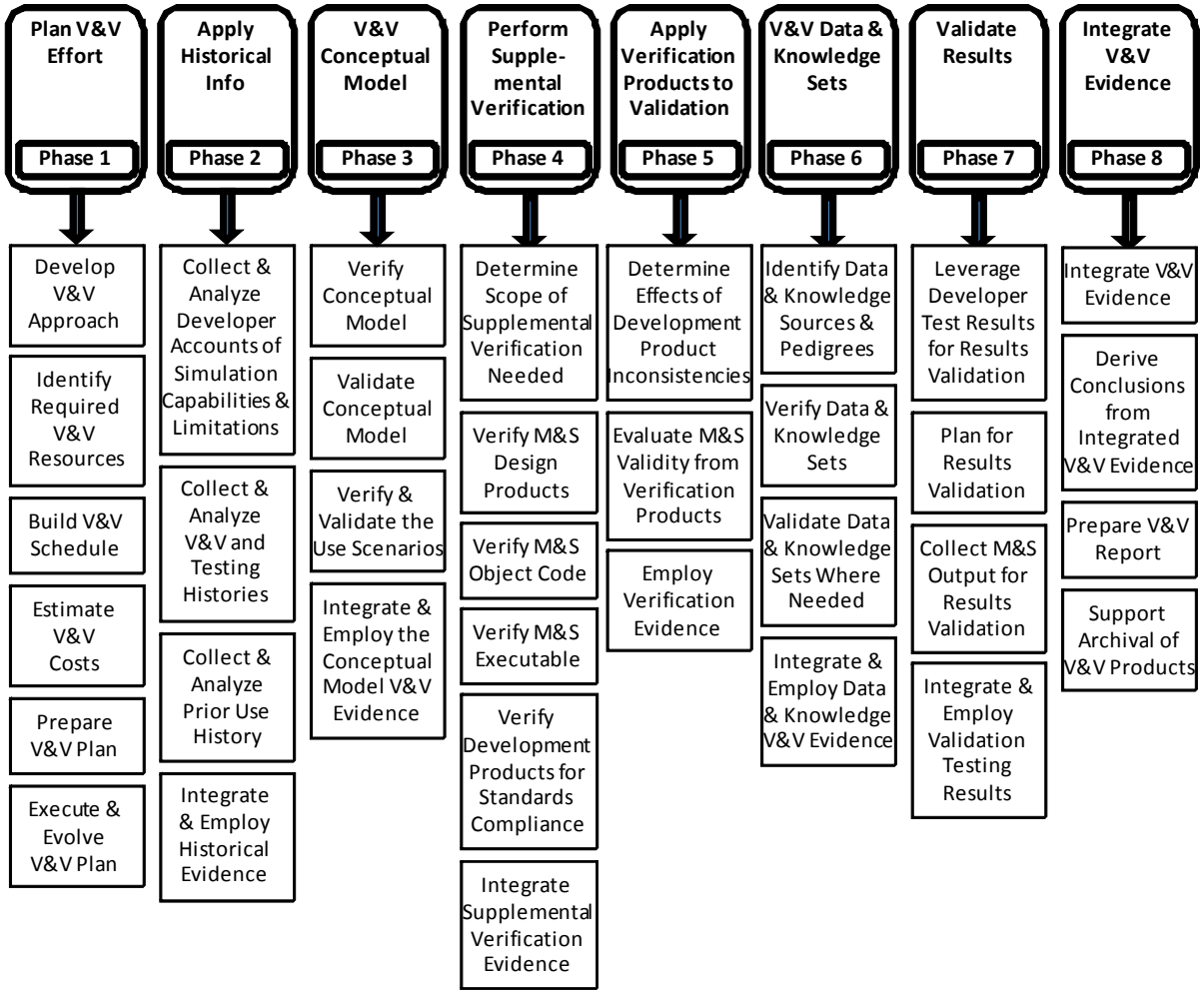

Figure 1: Activities Associated with Each V&V Composite Model Phase.

Although many of the activities and tasks in Figure 1 might appear sequential, the intention is not to restrict the implementation to any specific approach (e.g., waterfall, spiral, evolutionary). Rather, the diagram is meant to highlight the general activities from which V&V processes can be tailored to meet the needs of the M&S application based upon the intended use.

3.4 Verification of the V&V Composite Model

The Web Ontology Language (OWL) [7] was used to create a partial ontological implementation of the Risk-based VV&A methodology structure to verify its composition and relationships. In the future, a complete ontological implementation could serve as a tool to promote coherent tailoring, to generate reliable documentation, and to facilitate future methodology upgrades. A few detailed examples were implemented using OWL to demonstrate the basic implementation principles; however the RBA methodology is not yet finalized, and neither are the details of the relationships of the individual activities and tasks. The MSG-054 German representative developed a paper that describes the results of this effort (Appendix 3).

Three conclusions were reached based on the work thus far to verify the V&V Composite Model:

1) The implementation of the RBA methodology as an OWL ontology is feasible without making any compromise and appears to promise a greater flexibility and upgradeability than more conventional approaches while preserving the fundamental advantages of the RBA methodology.
2) It will allow, with some additional work, a seamless integration in comprehensive ontology-based modeling and simulation tool platforms.
3) Ontological tools implementing reasoning mechanisms potentially can track tailoring effects throughout the RBA sequence of activities and tasks; additional work might reveal whether sufficient quality assurance guarantees can be provided in this manner for deeper, more customized tailoring approaches. Further work might also consider using such tools to visualize tailoring effects in a user friendly manner in order to facilitate tailoring decisions and to explore the relationships between risk constellations and the tailoring strategies most appropriate for them.

4.0 CONCLUSIONS AND RECOMMENDATIONS

MSG-054/TG-037 succeeded in its task to institutionalize VV&A processes overlaid upon the federation development and execution process with the publication of IEEE Std 1516.4™-2007 [4] in December 2007. As an international commercial standard, IEEE Std 1516.4™-2007 is available for application by government, industry, and academia worldwide.

IEEE Std 1516.4™-2007 focused on VV&A processes for federations and purposely did not address the VV&A processes associated with the individual federates (e.g., federation managers, data collectors, live systems, M&S, viewers, etc.). Because information from the VV&A processes conducted on federates is used by the federation, it is important that the federate level information be complete, credible, and accessible. Therefore, MSG-054/TG-037 leveraged the IEEE Std 1516.4™-2007 concepts to develop a composite model of the V&V processes that could be applied to federation and federate level M&S, as well as to M&S that were not distributed. MSG-054/TG-037 accomplishments further extended to the development of guidance for tailoring the VV&A processes.

MSG-054/TG-037 was successful in producing a draft composite model of the V&V processes but was unable to complete work on the accreditation/acceptance processes due to the availability of resources to the various members. Additionally, while the members of MSG-054/TG-037 were able conduct some level of vetting of the V&V Composite Model within their national M&S communities, the model would benefit from more extensive vetting.

MSG-054/TG-037 leveraged NATO STANAG 4603 [8] and IEEE Std 1516.3™-2003 [1] in the development of IEEE Std 1516.4™-2007 [4] and the V&V Composite Model. The group found that leveraging established standards ensured consistency and understanding of basic VV&A concepts across products.

MSG-054/TG-037 feels it made progress in providing detailed descriptions of how to conduct V&V processes, but the work is not complete.

Based on these conclusions, MSG-054/TG-037 makes the following recommendations:

- NATO should process and ratify IEEE Std 1516.4™-2007, *IEEE Recommended Practice for Verification, Validation, and Accreditation of a Federation – An Overlay to the High Level Architecture Federation Development and Execution Process*, as a NATO Standardization Agreement.

- NATO should continue the decompose the accreditation/acceptance aspects of the V&V Composite Model necessary to evolve it into a complete VV&A Composite model. Enhancements include:
  - Update the V&V activities and tasks by including more information in Activity Tailoring Guidance, Activity Notes, and Activity Assumptions.
  - Incorporate accreditation/acceptance activities and tasks.
  - Revise based on comments received from reviews.
  - Add phase descriptions.
  - Map the completed VV&A Composite Model to IEEE Std 1516.4™-2007.
- Member Nations should each to continue vetting the composite model within their M&S communities.
- NATO should complete the effort to create an ontological implementation of the completed VV&A Composite Model to verify its consistency, completeness, and correctness.
- NATO should continue participation in the Simulation Interoperability Standards Organization and lead the effort to process the VV&A Composite Model as a standard once it is completed and fully vetted.

5.0 REFERENCES

[1] IEEE Std 1516.3™-2003, IEEE Recommended Practice for High Level Architecture (HLA) Federation Development and Execution Process (FEDEP), 2003.

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